Student Manual
MODULE 1a ADMINISTRATION

TERMINAL OBJECTIVE

At the conclusion of this portion the Student shall have received all information regarding course administration and operational requirements for successful completion

ENABLING OBJECTIVES

- Students shall receive an introduction to all Instructors and support staff
- Students shall receive instructions on starting times and attendance requirements for successful completion of the course
- Students shall receive information and the necessary paperwork to complete all administrative processes required for successful completion including

  1. Reimbursement paperwork if applicable
  2. Access to course critiques
  3. Testing procedures
  4. Paperwork and process for injuries
- Students shall receive a review of the information they were sent to pre-study prior to arrival at the course
- Students shall receive an overview of the criteria for successful completion of the course
- Students shall receive an overview of the Student manual and its contents
- Students shall be broken into six person squads for operational periods. Multiple squads shall be assigned to a division for rotation periods
- Students shall have the opportunity to introduce themselves if applicable
- Students shall receive a schedule of events and rotation times, course agenda and locations of specific events.

Administrative matters

A. Welcome and introduction of Instructors
B. Starting times, attendance requirements
C. Rotations and squad/division assignments
D. Contact numbers for emergencies
E. Site rules (sponsor)
F. Reimbursement and paperwork requirements
G. Transportation issues
H. Social activities

Course Overview and Requirements

A. Each Student has been selected for attendance based on their position within the rescue component of the task force

B. This course is designed to provide you with the information and skills you need to successfully complete the knowledge, skills and abilities for certification as a Structural Collapse Technician.

C. There are specific requirements that must be met by each Student in order to obtain a certificate of completion and the course curriculum:

   1. Show up on time, work as a team member, and remain safe.
   2. Successfully complete all practical station rotations
   3. Successfully demonstrate all skills as outlined on the practical skills check lists
   4. Obtain a passing score of 80% on the comprehensive written exam.
   5. Successfully participate in and complete the Field Exercise.

D. Each Student is continually evaluated during classroom and didactic sessions. Instructor observations coupled with specific passing criteria are all taken into account in evaluating a Student's success.

E. There are certain pre-requisites that each Student must have met prior to entry into the course. These skills are necessary to complete many of the scenarios you will undertake. Each Student will be expected to perform skills, which are pre-requisites. Pre-requisites are outlined in NFPA 1670 Training and Operations for Technical Rescue. Students shall have successfully completed

   1. Confined space awareness, operations and technician
   2. Trench rescue awareness, operations and technician
   3. Structural collapse awareness and operations
   4. Vehicle and machinery awareness, operations and technician
   5. Rope rescue awareness, operations and technician
   6. Water rescue awareness
   7. Hazmat operations

F. Each Student should have already received prior to the course information to study before arrival. These include:

   1. Task Force Rescue Operations
   2. Task Force Safety
   3. Search Capabilities
   4. Base of Operations set up
   5. Tool lab list

STUDENT MANUAL

A. Each manual has been set up to provide you with the information you need to successfully complete this course

B. Review the following sections of the manual
- 1a. Admin and Introduction
- 1b. Safety
- 1c. Structural engineering systems
- 1d. Tool lecture and tool labs
- 2a & b. Shoring Basics & Shoring Construction
- 3, Breaching, Breaking, Burning and Cutting
- 4. Lifting and rigging
- 5 Field exercise
- Instructor evaluation forms
- Appendix, A, B & C

C. Student critiques

1. Each Student shall be evaluated on practical and didactic skills
2. All evaluations are based on Knowledge, Skills and Abilities required to successfully function as a FEMA Rescue Specialist

SAFETY ISSUES

A. Safety is the responsibility of the individual, the team and the lead Instructor. Practice safety at all times

IF AT ANYTIME A STUDENT, INSTRUCTOR OR SAFETY OFFICER SEES AN IMMINENT SAFETY HAZARD WHICH MAY RESULT IN INJURY THE COMMAND SHALL BE STOP!

B. Safety officers will be on site and have the authority to shut down any operations.

C. Any injury, no matter how minor shall be reported to the lead Instructor for the module.

SAFETY ISSUES (continued)

D. Students and Instructors will wear all necessary personal protective gear during all evolutions, including but not limited to

1. Helmet
2. Wrap around eye protection
3. Long pants and long sleeves
4. Steel toed boots
5. Leather work gloves
6. Hearing protection (when applicable)
7. Respiratory protection (where applicable)
8. Knee and elbow protection (where applicable)
9. Dust masks (at least 10) or half face APR
10. Web gear, canteens, high energy snacks
11. Knife
12. Flashlight
13. Foul weather gear
14. Dry change of clothes
15. Hat
16. USACE Shoring Operations Guide (SOG) Disasterengineer.org
17. FEMA Rescue Operations Guide (when available in 2007)
18. Carpenters apron, speed square, framing hammer (20-24 0z.), tape measure (16' – 24'), pencil, lumber crayon, utility knife

E. Students should not eat or drink on site without assuring proper hygiene is addressed. Handy wipes or other hand washing must occur prior to eating.

F. No smoking on site, smoking areas to be designated

G. Students and Team Leaders should assure everyone stays hydrated.

H. Students should always be aware of their surroundings including the following:

1. The potential for tool movement and reaction
2. The potential for concrete or steel movement
3. Keeping hands and feet from pinch points
4. Communicating with squad personnel to assure operations are understood
5. Shifting or moving overhead loads
6. Flammable materials and products
7. Vehicular and heavy equipment movement on site
8. Electrical safety
9. Personal and team members fatigue

CONCLUSION

A. Questions?

B. If you find yourself with any questions or concerns please address them with your Lead Instructor.

STUDENT MANUAL
MODULE 1B SAFETY AND SECURITY

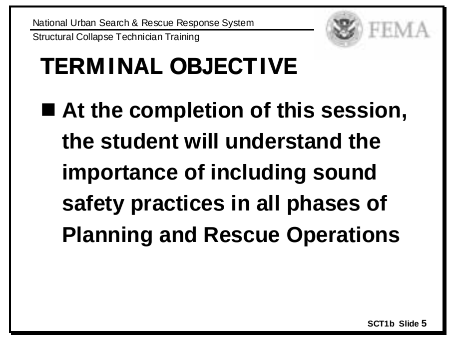
Module Purpose

This module is intended to provide a review of all the safety issues that confront US&R Teams during an incident, and to provide the guidelines that can help reduce these risks

Terminal Objectives

In this introductory section the Terminal Objectives are as follows:

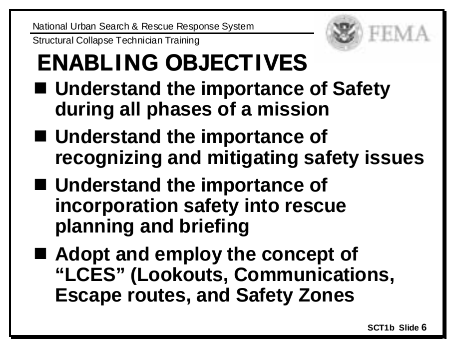
The student will understand the importance of including sound safety practices in all phases of the planning and rescue operations.

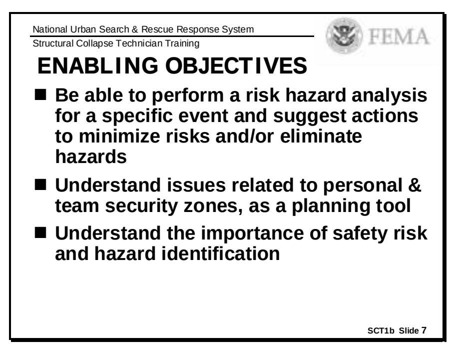


Enabling Objectives

At the conclusion of this module, the student will:

- Understand the importance of safety during all phases of a mission
- Understand the importance of recognizing and mitigating safety hazards
- Understand the importance of incorporating safety into rescue planning and briefing
- Adopt and employ the concept of "LCES" (Lookouts, Communications, Escape routes, and Safe zones)
- Be able to perform a risk hazard analysis for a specific event and suggest actions to minimize risks and/or eliminate hazards
- Understand issues related to personal and team security zones, as a planning tool.
- Understand the importance of safety risk and hazard identification





Introduction

Search and rescue is one of the most dangerous types of emergency response activities that can be performed. It exposes the team members to many hazards for which they have little training and virtually no experience to combat. The application of the most current SAR techniques and safe methods of operation are vital to the accomplishment of that mission. Hence the reason for this course.

- Safety is a very situation dependent issue.
- Safety is most importantly an attitude. That attitude needs to be have very Positive about Safety. It becomes a balance between accomplishing the task in the shortest possible time and minimizing the risk associated with the task.
- The most effective path is generally the one which expedites the operation AND provides accepted safety practices. This allows the victim to be rescued in a timely manner and the rescuers to return from the task unharmed.
- Keep in mind that when the team deploys, the Rescue team will face the probability of many challenges and multiple rescues over extended periods of time. So, stay healthy, share lessons learned and be safe.

National Urban Search & Rescue Response System
Structural Collapse Technician Training
FEMA

PHASES

- Preparedness
  - Training
  - Exercise
- Deployment
- On-site operations
- Demobilization
- Return to state of readiness

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Risk and Hazards

Response team personnel conducting SAR and support activities are exposed to many risks and hazards including, but not limited to:

- Damaged infrastructure
- Air transportation
- Secondary collapse from aftershock, vibration, and gravity, and explosions.
- Unfamiliar surroundings
- Unstable structures
- Fall or tripping hazards
- Falling material or flying objects
- Exposure to Haz Mat
- Decontamination
- Exposure to smoke, dust, etc.

National Urban Search & Rescue Response System
Structural Collapse Technician Training
FEMA

RISKS & HAZARDS

- Infrastructure Damage
- Air transportation
- Secondary collapse
- Unfamiliar surroundings
- Unstable structures
- Fall/trip hazards
- Falling material
- Exposure to hazmat
- Decontamination
- Exposure to smoke, dust, etc
- Fire & explosion
- Excessive noise
- Electrical hazards
- Electrocution
- Contaminated air & water
- Dangerous equipment
- Armed thieves & looters
- Fitness for duties
- Excessive fatigue, sleep
- Food services
- Adverse weather
- Stress
- Security
- Safety equipment
- Escape routes
- Safety zones
- Personal hygiene
- Hydration

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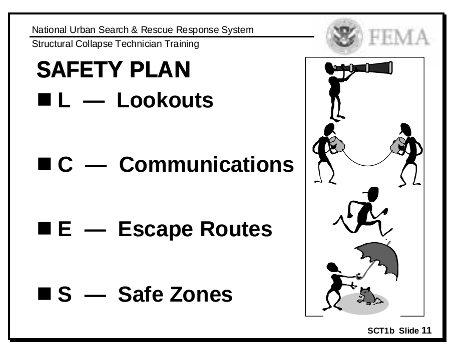
Risk and Hazards (continued)

- Fire and explosion
- Excessive noise
- Electrical hazards
- Confined space operations
- Oxygen deficient atmospheres
- Contaminated air and water
- Electrocution from damaged utilities
- Dangerous equipment
- Armed thieves and looters
- Fitness for duty
- Excessive fatigue, sleep
- Food services
- Adverse weather
- Stress
- Security
- Safety equipment
- Escape routes
- Safety zones
- Personal hygiene
- Hydration

SAFETY PLANNING

The multi-hazard safety plan is a guide to the basic elements of safety for a variety of incidents.

- The acronym is **LCES**, which stands for **L**ookouts, **C**ommunications, **E**scape routes, and **S**afe zones.
- In any operations scenario these areas must be addressed to insure the safety and accountability of all response team members.



L – Lookouts

This is normally the function of the dedicated Safety Officer. That person is the objective observer not involved in the “hands-on” portion of the operation. They are free to watch over the entire operation identifying potentially dangerous situations and mitigating them before they become disastrous

- Several categories of Safety Officer exist.
- One is the overall Safety Officer for the response team.
- A second is a site specific Safety Officer may be a person or team assigned to a single location to monitor the existence of a special hazard.

  Some examples of the latter might be one person designated to stand guard over an electrical box while rescue workers operate in a confined space; or a two person team tasked with hiking up slope to serve as early warning for rescuers working below a dam during earthquake aftershocks.

  Safety Officers or Lookouts work from a position of safety and clear visual access just outside of the direct work area.

  They should not become involved with the actual “hands-on” portion of the operation. To do so would possibly limit their ability to be that objective observer capable of identifying hazards.

  They should be readily identifiable to all, by their radio designation and by wearing a Safety Officer vest or in a small group identified during the safety briefing.

  Team members tasked with this responsibility must resist the temptation to become involved in the tactical operations itself. This requires extreme self-discipline. Remember though that the direct success of the mission depends upon the ability to counteract hazards before they become problems.

LOOKOUTS

- **Overall Safety Officer**
- **Site-specific Safety Officer**
- **Work from position of safety**
- **Must not become involved in operation**

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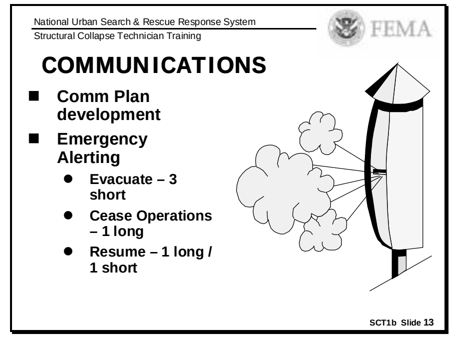
SAFETY PLANNING (continued)

C - Communication

The formal communications plan will be developed by the Communications Specialist. This plan will identify the Command, Tactical, and Special radio channels. These are the operations personnel's lifeline to the outside for resources, support, and safety. This plan will be provided as part of the Response Team Action Plan.

- period.
- The following Emergency Alerting System is to be used in the event of problems at the work site:
  - Evacuate -3 short blasts (1 second each)
  - Cease Operations - 1 long blast (3 seconds duration)
  - Resume Operations -1 long and 1 short blast
- The method of delivery may vary depending upon the device available.
- As an example, by placing two radios together, speaker to microphone, and depressing the transmit buttons a loud tone is heard on all other radios tuned to that frequency.

  Air horns, car horns, whistles, the P.A.S.S. device and clear text over the radio are all excellent methods for signaling. The point is that during the safety briefing, before beginning to work, identify the specific methods of signaling that will be used at the work site should a problem arise during that operational

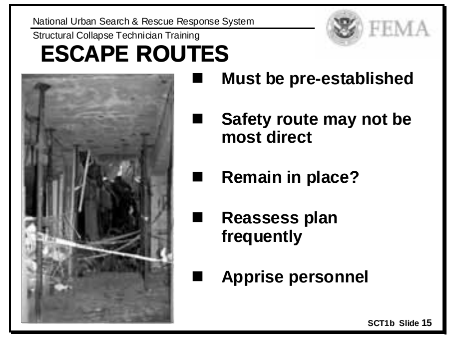


SAFETY PLANNING (continued)

E - Escape Routes

An escape route is a pre-established path to an area of safe refuge.

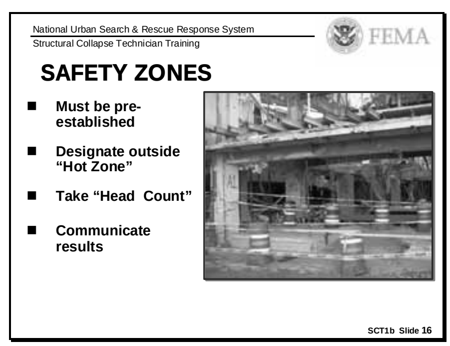
- The safest method of exiting an area may not be the most direct route.
- As an example, after an earthquake structural columns may still be standing but subject to collapse during an aftershock.
- The most direct route to safe refuge may lie directly in the collapse path of the column. The route giving the column a wide berth will be the safest.
- Another consideration is to remain in place. If the working area has been shored and leaving this area exposes the rescuer to a variety of hazards, stay put.
- The rescue situation if often dynamic, constantly changing. This can occur as a result of external forces or as a result of the rescuer's action. The escape plan should be constantly updated to reflect changes in situation.
  - As a new plan is developed, each team member must be made aware of the change in operation. An acknowledgement of understanding must also be received from each team member.
  - If the order is not repeated, the new plan is probably not clear to each member of the team. The result can be injury or death.



S - Safe Zones

Safe zones, also referred to as "safe havens" are the pre-established areas of safe refuge, safe from hazards. This could be a designated area outside the hot zone or agreed upon safe areas within the hot zone. If the safe zone is within the hot area, rescuers may have to construct that area around the victim and for rescuers themselves.

- Example: If a victim is trapped inside a collapsed structure where rescuers have shored the immediate area. In this case, the proper response for rescuers would be to hold their position during an aftershock.
- Part of the Safety Plan should provide for a designated Safe Zone where a team "head count" is taken. This count should be communicated to the next in the chain-of-command, for 100% accountability in emergency



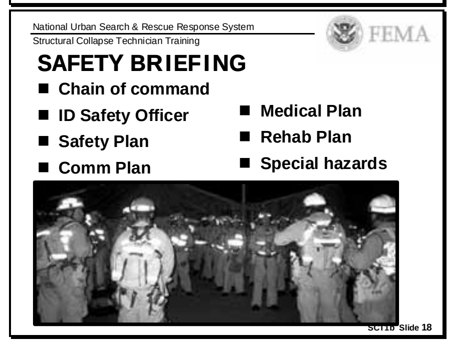
CHAIN-OF-COMMAND

Consult the Response Team Organization chart for chain-of-command. This chart will list the entire team and who reports to whom.

- The Rescue Specialist will report to the Rescue Squad Leader, who reports to the Rescue Team Manager, who reports to the Task Force Leader.

The Safety Briefing will identify who is in each Rescue Squad and who is designated as Rescue Squad Leader.

- The Safety Briefing will be given by the Rescue Team Manager or they're appointed Squad Leader. Managers and Leaders for support functions will also be identified at this time. This is the Rescue Specialists' opportunity to identify the entire team for the next operational period.



IDENTIFY THE SAFETY OFFICER

Safety Officer should be identified. for the operational period . All must know who is filling that position.

- The Safety Officer will also pass on information from the previous operational period that they have received from the Safety Officer that they have relieved.

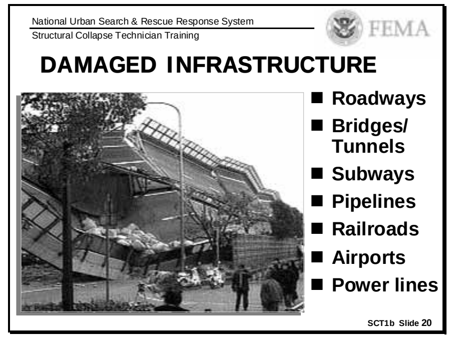
SAFETY PLAN (LCES)

This portion of the Safety Briefing will cover Lookouts (or Safety Officer), Communications, Escape Routes, and Safe Zones. This information will be developed by advance recon of the work site by Team Managers or will be passed on from the previous teams operation.

- This is a dynamic process, once the response team has arrived at the site another assessment should be made.
- If there are any changes to the Safety Plan, it should be modified then and all team members must acknowledge those changes. Those changes effecting the entire operation should be communicated up the chain-of-command immediately; those that are site specific can be passed on to the next operational team.
- The Safety Plan will review the signal for immediate evacuation, cease operations, and resume operations. It will also identify the area designated for the head count in case of emergency evacuation.

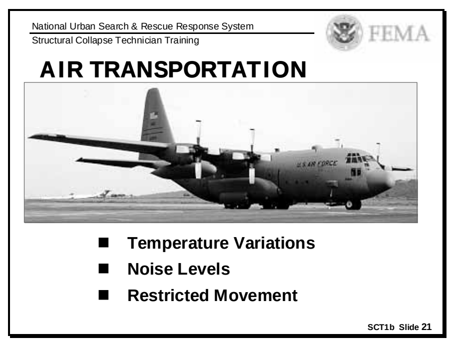
RISK ASSESSMENT COMPONENTS

Damaged infrastructure (infrastructure, including communications, roadways, bridges, railroads, air traffic control)

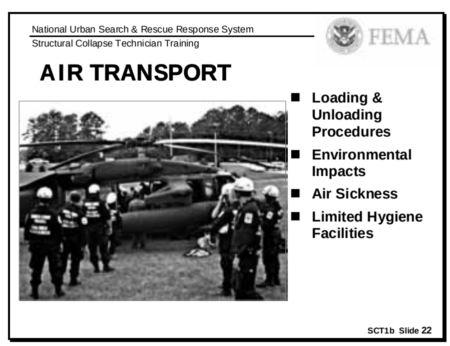


- Assume all infrastructure has been compromised even though prior intelligence may have stated otherwise. Although telephone and cell systems may have survived the disaster intact, they will soon be overloaded by responder and/or public demands.
- Traffic congestion will always occur following a disaster. The affected public will be evacuating the area as responders are moving toward the disaster.
- US&R vehicles must be clearly marked and warning lights should be used to facilitate arriving at target sites. Assessment vehicles must be equipped with four wheel drive. Standard vehicles will have difficulty traversing terrain while getting to and around work sites. Consider using ATVs as mules.

Air transportation



- One method of travel frequently used by response teams is helicopter. A word of caution: be sure to receive a pre-flight safety briefing before boarding and follow instructions furnished by the pilot or loading supervisor.
- Remember, following a disaster unusual hazards may exist that the pilot may not be familiar with. Unsafe acts on the part of the pilot and crew can also be a problem.
- Some of the issues to be concerned with include overloading, proper clearances for takeoff and landing, rotor wash, security around the helicopter, and adequate intercom capabilities so that team members can communicate during flight. Example: Philippines Assessment Flight.

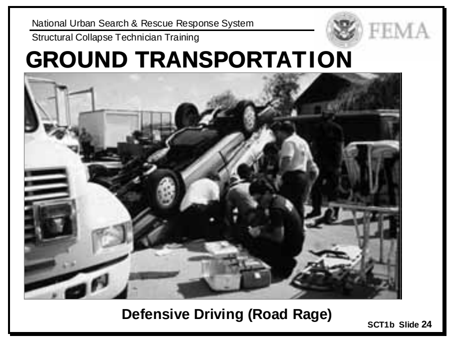


RISK ASSESSMENT COMPONENTS (cont.)

Ground Transportation

Response teams, in general have a long ways to go towards understanding and following good safety practices when utilizing ground transportation. Pay special attention to the following issues:

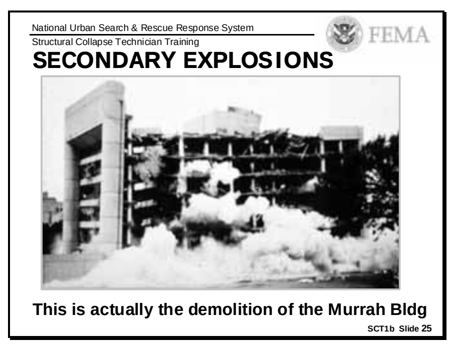
- Never transport personnel and equipment on a open vehicle
- Provide safe-seating for all personnel
- Never drive and navigate at the same time
- Cover tools and equipment for security purposes
- Familiarize team with assigned vehicle
- Conduct maintenance checks each day
- Maintain adequate fuel levels.
- Travel in convoy when possible.
- Properly identify vehicles
- Red tag unsafe vehicles



Secondary Collapse

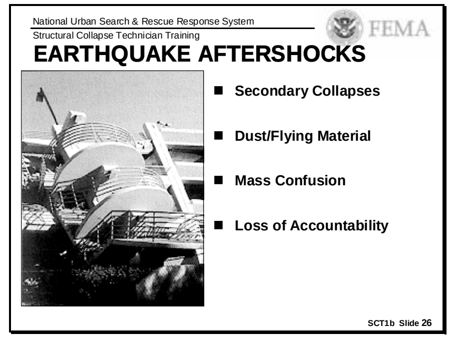
This can be caused by aftershocks, wind, vibration, removal of debris, gravity, and/or explosions.

- With the constant threat of terrorist attacks it is essential that response teams pay special attention to a very new and potentially deadly threat. Secondary explosions are becoming common techniques used to cause serious injury and possibly mass death for response teams.
- Every one has to heighten their awareness to their surroundings. There are no second chances when explosions are used for this purpose. It is safe to assume that a secondary devise is involved, unless proven otherwise.



RISK ASSESSMENT COMPONENTS (cont.)

Earthquakes aftershocks

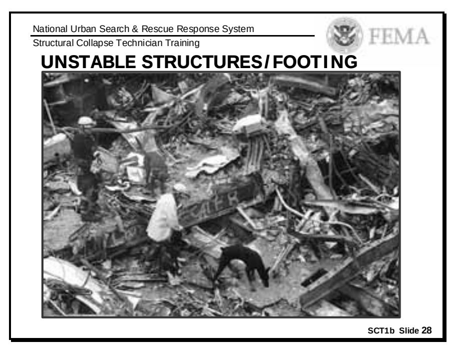


- Severe after shocks following a major earthquake are common and can create additional injuries and fatalities.
- Unstable structures including bridges, overpasses, high rises and water towers may suffer further collapse as a result of after shocks.
- First responders must be constantly aware that they may be effected by such events and take necessary precautions while conducting their operations.
- Many injuries and deaths of first responders could be prevented if more precautions against additional shock waves were taken.

Unfamiliar surroundings

- Traffic directional signs and other land marks may not survive the disaster impact. Traditional road maps not be valid following a major disaster. Extra care to avoid accidents must be taken because the "new" landscape is distracting and may be confusing.
- Team members should not conduct assessments and drive a vehicle at the same time. A designated driver with no other responsibility must be assigned to provide transportation for the team.

Unstable structures



- Injuries to emergency responders, in many cases, are the result of falling debris and compromised surfaces. Team members must take extra precautions to minimize injuries by wearing the required safety gear when working in the affected area. An injury during the mission becomes a team liability, which may prevent the completion of the entire assessment task.

RISK ASSESSMENT COMPONENTS (cont.)

Fall or tripping hazards

Trip hazards are a common cause of falls resulting in injuries. This problem or hazard is commonly found in the Base of Operations (BoO) and work site. In most cases these problems can easily be mitigated once identified. Some common trip hazards are:

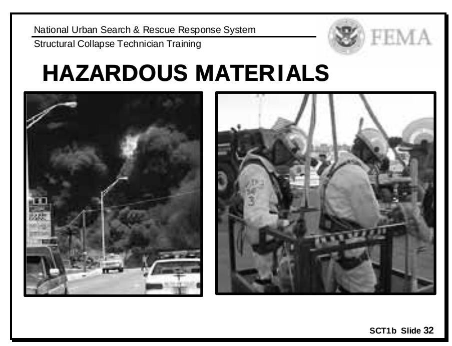
- Downed wire
- Electrical cord
- Holes
- Uneven sidewalks/roads
- Protruding rebar, etc

Falling material or flying objects

- After shocks or winds may cause loose or displaced objects to become airborne.
- Eye and head protection are essential. Eye injuries are especially painful and immediate treatment will be required to prevent further injury. Eye and head injuries are a liability to the team and may even require aerial medical evacuation.
- Contact lenses wearers are especially vulnerable. Responders with contact lenses should bringing an extra pair of glasses.

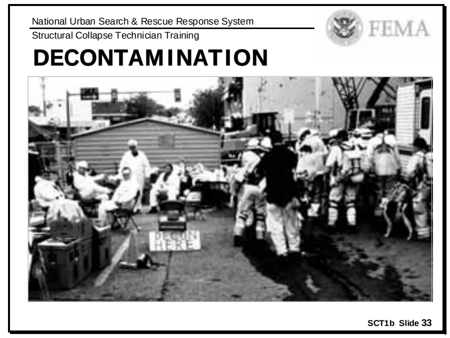
Exposure to Haz Mat

- There is a significant risk of exposure to hazardous material during the mission. Two kinds of exposure to be consider prior to entering the impact area: direct exposure from an area that has been contaminated and indirect exposure from moving water or a cloud/vapor plume moving through or beyond the impact area.
- Most facilities (major targets) such as hospitals, labs, universities, manufacturing plants and warehouses have a broad array of hazardous material on site. Other major sources of hazmats are underground pipe lines, railroad cars, and trucking companies. Displaced power line transformers may also pose a significant risk to assessment teams.



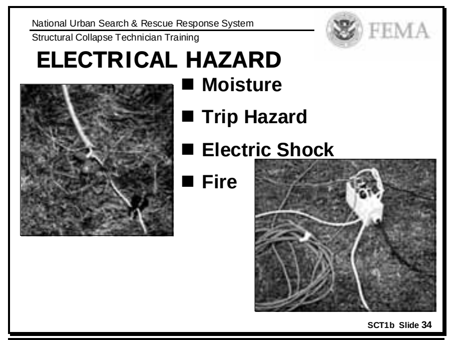
RISK ASSESSMENT COMPONENTS (cont.)

Decontamination



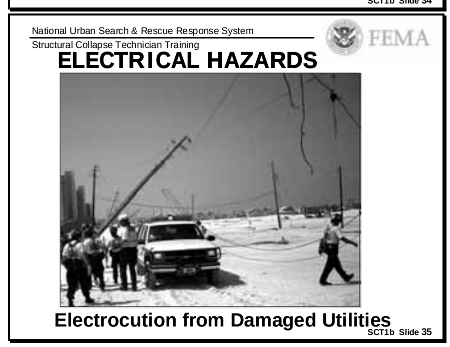
- When initiating patient care or working around body fluids, use all proper protective equipment.
- This includes at least gloves, mask, and eye protection.
- The Team member should remove gloves carefully in order to prevent contamination.
- All medical waste should be properly disposed of in devices such as sharps containers and BioHazard bags.
- If possible, wash hands thoroughly after each victim contact.
- Clean all equipment not discarded as soon as possible. Ensure canine are decontaminated.

Electrical hazards



Response teams have to be especially aware of electrical hazards that are commonly found during disaster response operations. There are many electrical related fatalities associated with disaster response operations. Some of the things to consider are:

- Re-energizing power grids
- Improper electrical cord for current requirements
- Jury rigged connective boxes
- No weather protection
- Line back feed (generators and solar panels)



Confined Space Ops with oxygen deficient atmospheres

Most fire department response team should be properly trained to deal with this type of hazard. Maintaining proper protocols is the key

Contaminated Air , Water, and Fuel

Contamination of air, water and fuel sources following a disaster is likely. It is best to assume contamination has occurred until proven otherwise. Ensure that you have an adequate supply of water and fuel before entering the affected area. All response teams should have water purification units as part of their cache.

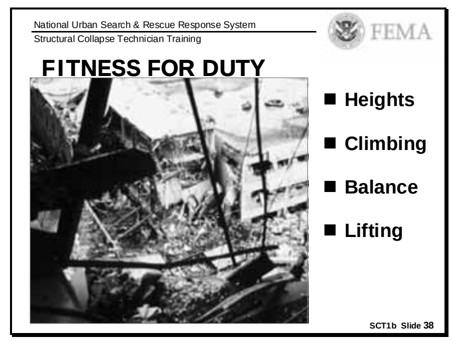
RISK ASSESSMENT COMPONENTS (cont.)

Dangerous Equipment (Cranes, Excavators, etc)

The Heavy Equipment and Rigging Specialist (HERS) is trained to aid the Safety Officer in anticipating and identifying the hazards posed by the use of heavy equipment at the disaster site. Hazards include:

- Pinch zones created as cranes rotate on their bases.
  - ♦ Need to cordon off area around cranes with flagging tape.
- No Fly Zones, when rubble is being removed
- Overloads caused by operation of excavators

Fitness for duty

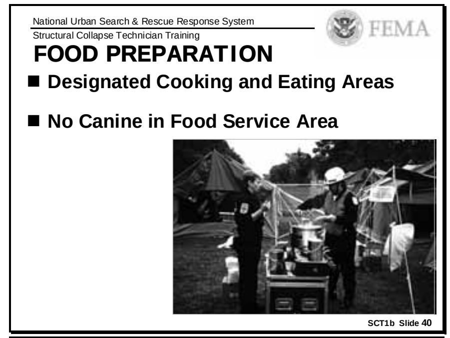


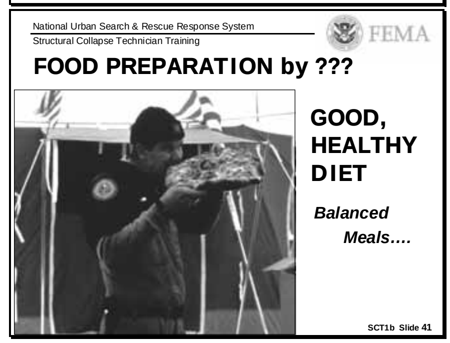
- Fitness for duty is a sometimes sensitive subject , especially when there is no national standard for response teams.
- The better physical and mental condition that a team member is in prior to deployment, the better the individual will be able to perform their duties during extended operations.
- Many of our response team members return home after a mission run down and very ill. This problem can be minimized by improving our fitness level.
- Some disaster environmental issues to prepare for are:
  - ♦ Working at heights
  - ♦ Extensive climbing
  - ♦ Prolonged heavy lifting
  - ♦ Confined space
  - ♦ Transversing on unbalanced objects
- A critical issue to remember is that the adverse effects of drugs and alcohol consumption will interfere with sharp motor skills.

RISK ASSESSMENT COMPONENTS (cont.)

Food Services

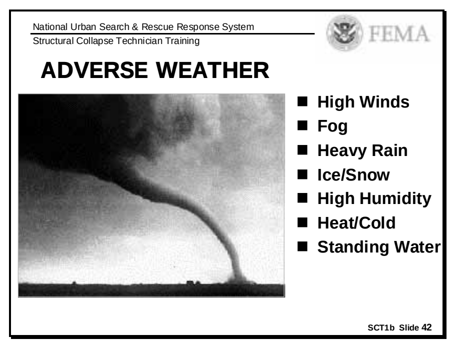
- Response team members need to be aware of diets and food preparation in the disaster environment. Ability to preserve and process food in the field is very basic.
- Perishable foods need to be continuously monitored to ensure freshness. Spoilage in hot moist climates can happen surprisingly quickly.
- Special precaution for monitoring food stock has to be followed. There is nothing more dangerous than a stale sandwich made using mayonnaise.
- Consider using freeze-dried products when possible.
- Civilians, with good intentions, will donate food to team members. Watch out! The consequences may be dysentery or food poisoning.





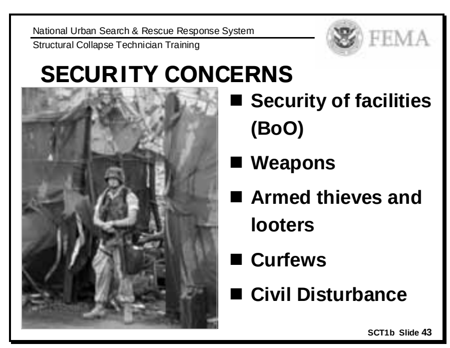
Adverse Weather

- It is essential that you are prepared for any kind of weather change prior to leaving your point of departure. A weather change that the team is ill equipped to handle could jeopardize successful and timely completion of the mission.
- Rain and cold weather gear, as well as appropriate amounts and types of clothing are required for all deployments. Wet and cold conditions could cause illness or injury among team members which would interfere with completing the assessment.



Security

- Don't always count on a disaster area being secure. In many cases one may find civil disturbance is jeopardizing response initiatives which further complicates the mission. These areas must be avoided until conditions are sufficiently safe for team members to perform their tasks.
- Area security is a State/local government's Responsibility. In some cases, police escort may be necessary. Again, in these situations, uniformed personnel may be targeted by undesirables seeking to take advantage of the damaged infrastructure.



Security (continued)

- The work site may be a target of armed thieves and looters. Individuals may represent themselves as local rescue workers and blend into the operation. Watch for suspicious behavior.
- Irate relatives may also be present. Emotions may be high and abnormal behavior can occur. Look out for potential hostile situations.

SAFETY EQUIPMENT. & PERSONNEL ISSUES

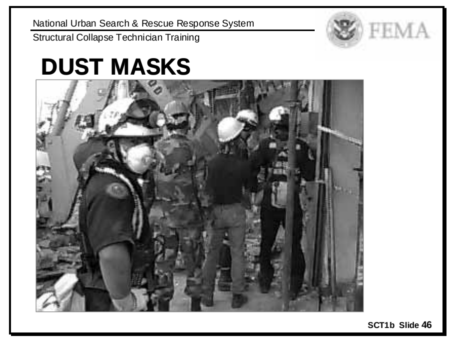
Respiratory Protection

Protect the airway. Concrete dust when inhaled is an irritant to the alveoli of the lungs. When this membrane is irritated fluid is secreted to protect the lining of the lungs.

Unprotected rescuers and patients can contract pneumonia as a result of inhaling these particles.

Doctors have calculated the danger of inhaling small amounts of toxic materials (i.e., asbestos) over years, however they cannot predict the danger associated with inhaling large quantities over a short period of time. Don't take the chance, protect your airway.

The following is the description, function, and limitations of the respiration protection devices available to rescuers.

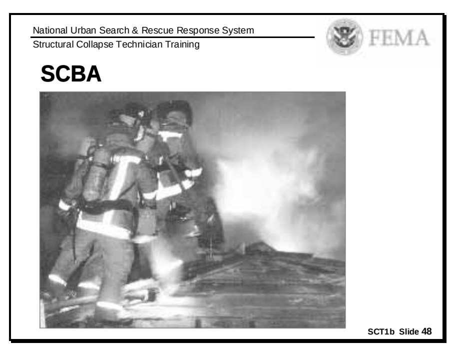


Dust Mask

- Simple paper or cloth mask which fits over the mouth and nose to filter out non-toxic particles will **NOT** filter out toxic materials and cannot be used in toxic environments or in an oxygen deficient atmosphere where the oxygen level is less than 19.5%.

Respirator

- Mask normally made of plastic which depending on design fits over the mouth and nose or has a face piece design which covers the entire face. With appropriate filters the respirator can filter out some, but not all toxic particulates. It cannot be used in an oxygen deficient atmosphere where the level is less than 19.5%.



SAFETY EQUIPMENT. & PERSONNEL ISSUES (continued)

Respiratory Protection (continued)

Self Contained Breathing Apparatus (SCBA)

- SCBA supplies air to the wearer for a limited amount of time, from 10 to 40 minutes. It can be used in toxic and oxygen deficient environments. The SCBA face piece covers the entire face as well as the mouth and nose. SCBA is bulky and can be difficult to use in confined spaces. When low on air, the bottle must be recharged or replaced. SCBA is portable to the rescue site and is not tied to an external air source.

Supplied Air Breathing Apparatus (SABA)

- SABA supplies air to the wearer for virtually unlimited amounts of time via an air source (large bottles or compressor) outside the area of use. It can be used in toxic environments as well as oxygen deficient atmospheres.
- The air is supplied from the source through a supply line, through the regulator where the pressure is reduced, and to the rescuer who wears an SCBA style face piece.
- The rescuer also carries a small emergency air supply tank in case of emergency. This emergency supply is rated at 10 minutes, but may only deliver from 2 to 3-1/2 minutes of air depending upon the exertion rate of the wearer.
- SABA is not as bulky as SCBA and is easier to use in confined space, but the rescuer is limited in distance by the length of line and most importantly time to escape in the event the emergency air supply is needed.
- For confined space entries, SCBA or SABA will be used if atmospheres are toxic or the oxygen levels are below 19.5%. Also the rescuer should never place themselves in a position where they remove any portion of the breathing apparatus to get closer to the victim. Removing any portion of the breathing apparatus may cause the seal of the face piece to be broken, even just for seconds, causing severe consequences.

SAFETY EQUIPMENT. & PERSONNEL ISSUES (continued)

Respiratory Protection (continued)

Monitoring Devices

Ensure that appropriate monitoring equipment is available and utilized to support on-site operations including:

- Atmospheric monitoring devices for checking toxic and oxygen levels
- Structural stability monitoring equipment for determining movement of building.

RESCUE TOOLS AND EQUIPMENT

All rescue tools should be operated and maintained in accordance with the manufacturer's guidelines. The maintenance should be documented. Many of these tools are dangerous in that they cannot distinguish the rescuer from the material to be cut, broken, crushed, bent, folded, spindled or mutilated. Always operate tools with respect.

- The Rescue Specialist should only use tools that they have been properly trained to use. Some on-the-job training may occur out of necessity; when this happens always emphasize the safety aspects of the operation. Use tools only for their designed purpose. Failure to do so will add a victim to the rescue and take a tool out-of-service.
- Anticipate the consequence of your actions. Observe those around for your safety as well as theirs. Turn off tools when not in use and store them in a tool staging area or return them to Logistics in Base. A cluttered work site will lead to tripping hazards and damaged tools.
- Light dim or dark areas during rescue operations to ensure proper operation of all tools and equipment. Protect personnel from electrical shock hazards. Fuel gasoline or diesel powered equipment in a designated safe area, away from operations. Whenever possible, rotate rescue tools to provide for on-site inspection and maintenance.

RESCUE TOOLS AND EQUIPMENT (cont.)

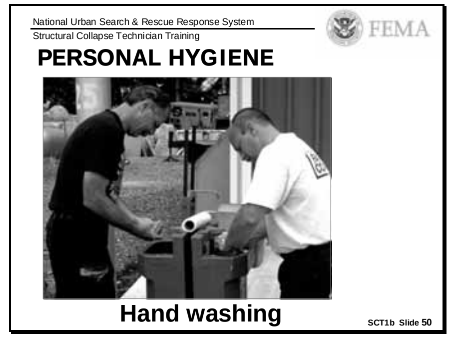
- Provide hearing protection to rescuers and patients to protect them from excessive noise levels (greater than 90 decibels).
  - Provide patients with helmet, goggles, blanket or other protection when necessary.
  - Advise patients of your operation before starting. This will help prepare them for what will follow.
  - Allow patients the ability to participate in their own rescue, do not treat them like a rescue manikin.
  - Do not be surprised if the patient comes up with a better suggestion for own rescue.
  - They are a captive audience and subject to your plan, but some do know their immediate position better. From that perspective, their input may be invaluable.

SAFETY EQUIPMENT

All response team members must take personal responsibility to ensure that when they are deployed they have appropriate safety equipment assigned to them.

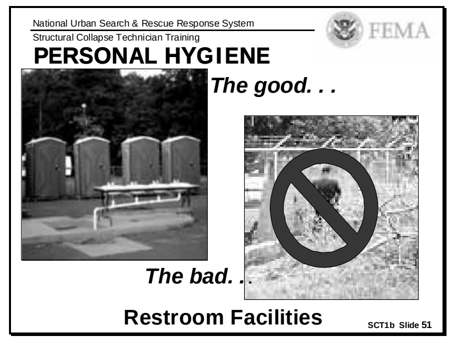
- You are responsible for the accountability of such property. The response team equipment cache may have additional equipment and supplies for expendable items.
- The following items, at a minimum, should be with the team member at all times:
  - Safety boots
  - Respirator
  - Helmet/Headlamp
  - Spare batteries
  - Ear & eye protection
  - Gloves
  - Protective clothing
  - Radio (optional)

PERSONAL HYGIENE

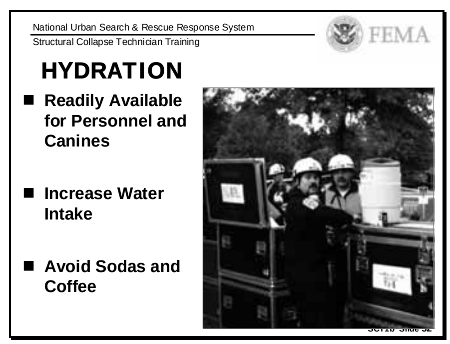


Maintaining good personal hygiene is critical during disaster response operations.

- Having adequate changes of clothing is essential for maintaining good health practices.
- Exposure to unhealthy situations is an inevitable part of disaster response but it is the team member's responsibility to take extra precautions to minimize the exposure.
- Special consideration should be given to the following:
  - Feeding and hydration at the BoO and at the work site.
  - Keeping sleep and rehab areas free of unnecessary negative health exposures.
  - Hand wash stations where ever possible.
  - Canine relief and rehab areas need to be established and enforced.



HYDRATION



Ensure all team members are following appropriate hydration practices.

- An ample amount of fluids should be readily available at all facilities including:
  - BoO
  - Work site
  - Command Post
  - Rehab area
  - Transport vehicles
- Avoid the use of carbonated drinks. Stay with water and juices if possible.

SAFETY CONCERNS DURING MOBILIZATION

Safety concerns during mobilization include:

- Assessment of their current physical fitness.
- Successful completion of a current physical examination.
- Current health assessment
- Proper inoculations.
- Appropriate personal safety equipment on hand.
- Adequate prescription drugs

RESPONSE TEAM WELFARE CONCERNS

A long hour, multiple days operation soon leads to fatigue and increases the chances of injury to team members. Proper shift length needs to be enforced and appropriate rehab facilities should be provided if possible. These facilities (i.e. tents, bldgs) should be inspected to ensure quality rest can be obtained. Some things to consider are:

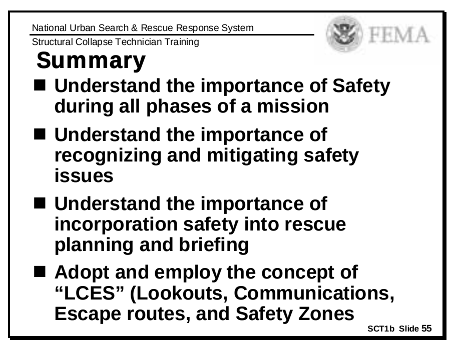
- Individual sleep habits (snoring or talking in sleep)
- Barking canine
- Pagers/cell phones
- Aircraft overflights
- PA systems
- Noise from generators

SUMMARY

All members of the rescue team must understand the importance of Safety to the efficient performance of all critical tasks.

The old cliché “Safety is No Accident” applies doubly here, since the focus is on reducing the risk to rescuers and victims, and not creating additional problems.

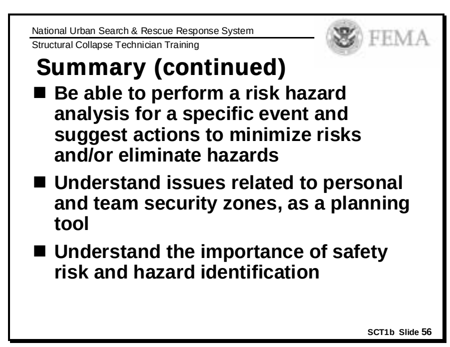
We need to adopt and employ the concepts of “LCES”, since this will mitigate some of the hazards that are inherent in what we do



The Safety Officer must perform a risk hazard analysis at every specific event and suggest ways to minimize risk.

The HERS and Structures Specialist should give input regarding the special hazards associated with their specialties.

Finally, a Safety Plan should be developed for each operational period, so all may understand the risks and act accordingly



STUDENT MANUAL
MODULE 1C STRUCTURAL ENGINEERING SYSTEMS

Module Purpose and Configuration

This module is intended to provide the Structural Collapse technician with information on the engineering aspects of structural collapse

The module is divided into five parts as follows:

Part 1 Materials, Structural Systems & Building Characteristics

Part 2 Causes of Collapse

Part 3 Collapse Patterns

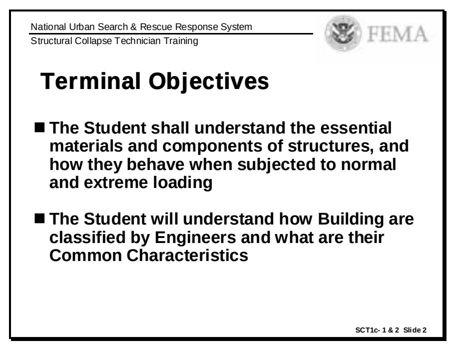
Part 4 Hazard Identification, Introduction to Assessment and Mitigation

Part 5 US&R Strategy & Structure Size-up

Part 1 - Materials, Structural Systems & Building Characteristics

In this introductory section the Terminal Objectives are as follows:

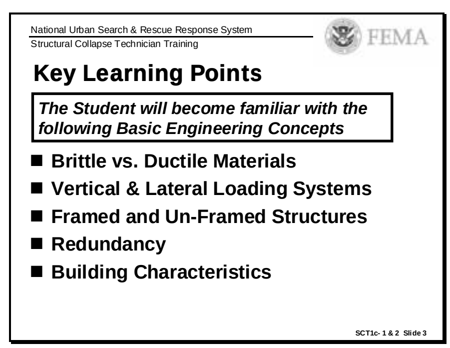
The student shall understand the essential materials and components of structures, with emphasis on how they behave when subjected to extreme loading.



Key Learning Points are listed in the adjacent slide. We will quickly review the basics of how various building materials resist forces, the importance of Ductile vs. Brittle behavior, the concepts of Vertical and Lateral Load Resisting Systems, and Structural Redundancy.

Following this we will discuss the characteristics of

The most common types of building found within the United States

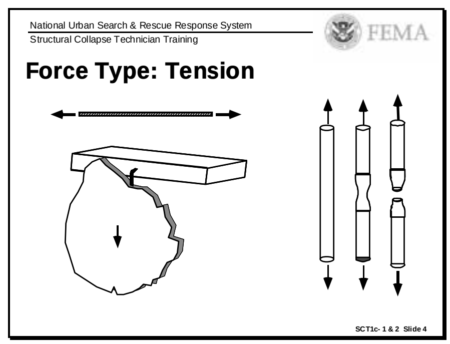


Force Types

Individual **loads**, usually referred to as **forces**, can be divided into four types: **tension, compression, bending, and shear.**

- When a **force** is applied to an individual member, it produces **stress**, which is defined as the force divided by the cross-sectional area on which it acts.
- **Example:** A 1000 lb **force** (also called 1 kip or 1k) acting in tension on a 2 in x 2 in steel bar produces a tension stress of 250 lbs per square inch. (psi)
- For simplicity, we will we will discuss the effects of forces, and assume that the student understands the relationship between **force** and **stress.**

Tension Forces



Tension forces stretch members of steel or wood. Concrete and masonry have no reliable tension strength.

- When a moderate tension force is applied, a steel bar will lengthen. When the force is removed, the bar will return to its original length. This change is called **elastic** behavior and can be repeated many times in competent steel or wood members.
- If a much larger force is applied to the steel bar, however, it will start to lengthen more rapidly. When this rapid lengthening occurs, the cross-section of the bar will start to get smaller (neck down), and when the force is removed, the bar will not return to its original length since it has experienced permanent yielding (**ductile** behavior).
- The **ductile** behavior of steel in tension provides the special property of forgiveness (warning of failure) and response that makes it especially desirable in resisting dynamic loading.
    - ♦ **Ductile** behavior is the ability of a material to stretch and/or bend without suddenly breaking; after the load is removed, it can remain stretched or bent and then be re-loaded.

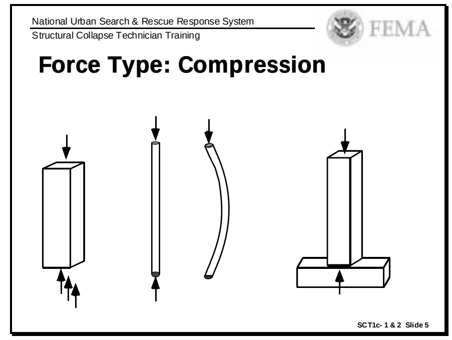
      Example: One can bend a hook on a rebar, and even unbend it without breaking it.
    - ♦ **Brittle** behavior means that the material will break without warning (**catastrophic failure**).

Compression Forces

- Compression forces push on members and can lead to the crushing of materials when members are short and relatively fat (small length to width ratios, L/D).
- At bearing surfaces between wood or concrete beams and columns, crushing can also occur.

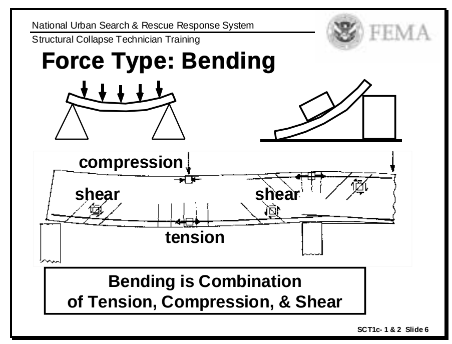
  Crushing failures tend to give warning, such as local splitting of concrete and the noisy, slow, compression of wood fibers.
- When long, slender members are loaded in compression, they can fail suddenly by **buckling** (bowing).

  This type of sudden failure should be avoided.



Bending Forces

- **Bending forces** occur mostly when vertical loads subject to gravity are applied to floor slabs and beams. Bending forces also occur in sloped roof rafters and in the sloped slabs found in rubble piles.
- Bending causes the bottoms of simple beams to become stretched in **tension** and the tops of beams to be pushed together in **compression**.
- Continuous beams and cantilever beams experience tension forces at the top in addition to compression at the bottom near their supports. In the mid-span of continuous beams, the forces are in the same locations as for simple beams and slabs.
- Vertical cracks develop near the mid-span of concrete members since the tension force causes the concrete to crack in order for the reinforcing steel (rebar) to resist the tension force.
  - ♦ Observing this cracking in damaged structures can aid in monitoring and determining the potential for collapse.
  - ♦ Stable hairline cracks are normal, but widening cracks indicate impending failure.
- Structural steel and reinforced concrete, moment-resistant frames experience tension and compression stresses on opposite faces (similar to continuous beams). These stresses can reverse themselves during earthquakes and high winds.
- Shear forces are also produced in beams and slabs and will be discussed next.



Shear Forces

Shear forces occur in all beams and are greatest in areas adjacent to supports.

- Shear stress can be described as the tendency to tear the beam's surfaces apart.

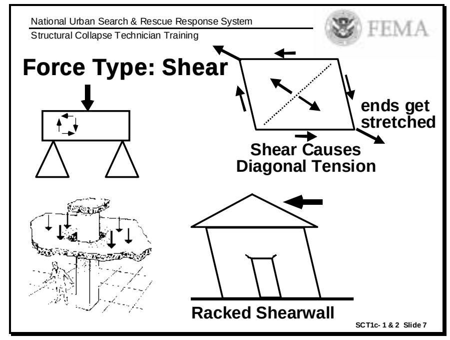
  Example: Consider a beam made from a group of individual books as they sit on a bookcase, with a long threaded rod extending all the way through them, tightened with nuts at each end. If this beam is placed so that it spans the gap between two tables, and one attempts to push one of the books down to the floor, a **shear force** will be exerted on the surface of the books immediately adjacent to the one being pushed.

- In concrete beams, these shear stresses develop diagonal tension cracks because concrete is very weak in tension.
  - ♦ As shown in the slide, when an element is loaded in shear, it will tend to change from a square to a parallelogram. As this change happens, the element stretches in one direction, thereby causing tension across the diagonal.
  - ♦ This diagonal cracking can also be monitored in damaged beams, girders, columns, and walls.
- Wood beams are strong in tension and compression but are particularly weak in shear along the horizontal plane of the softer springwood.

Punching shear occurs where a flat, two-way, concrete slab is connected to a column and the tendency of the slab is to drop as a unit around the column.

- The column appears to punch through the slab.
  - ♦ The cracking that indicates the over-stress leading to this type of collapse is most visible on the top surface of the slab, which is often covered by debris during US&R activities.
  - ♦ The debris may be causing the overload, and also make it difficult to assess, since the cracking may not be visible.

Bolt shear is the tendency of a steel, pin-like connector (such as a bolt, nail, or screw) to break across its cross section.



Example: A roll of coins is sheared off as each coin slips past another.

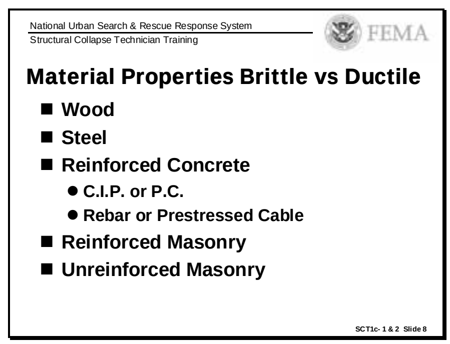
- This type of failure can be sudden.

Nail failures in wood structures, which involve some degree of pullout, can occur with enough deformation to give warning.

Building Wall Shear and Overturn Forces

- Lateral forces (forces applied horizontally to a structure) derived from winds or earthquakes cause shear and bending forces in walls.
- The shear forces tend to tear the wall surface, just as if one had a piece of paper attached to a frame and changed the frame’s shape from a rectangle to a parallelogram.
  - ♦ This changing of shape is called **racking**.
  - ♦ When shear walls are pushed out of plumb in their plane, they are said to have been **racked**.
- At the ends of shear walls, there is a tendency for these walls to be lifted at the end where the lateral force is applied and a tendency for the wall to be pushed down at the end away from the force.

  This action is called **overturning**.



Material Properties

Wood

- Wood is tough, light, fibrous, fire supporting, cut from living trees, and graded by humans.
- It has defects like knots, splits, and non-straight grain that concentrate stress.
- The growth pattern of fast-growing springwood versus that of slower-growing summerwood leads to structural problems. These problems include:
  - ♦ Weakness in cross-grain tension and compression;
  - ♦ Weakness in shear strength parallel to grain;
  - ♦ Shrinkage and splitting.
- Live wood may be as much as one half water, while older, seasoned wood (as found in a structure) may contain as little as 10 percent water.

  Wood’s volume can change as much as 10 percent over this range.

- Shrinkage (usually in width or depth, not length) causes special problems in bolted connections.

  Splits may be formed that allow the bolt to slip out of the joint along the split.

- Connections are best made by bearing one member on its supporting member; however, metal connection devices can be successfully used.

  Nailed connections perform well as long as splitting is avoided, and bolting may be successful if adequate spacing and edge distances are provided.

- Properly proportioned wood structures can exhibit **ductility**.
  - ♦ When wood posts are kept short and bear on the cross-grain surfaces of beams or sole plates, slow crushing of the cross-grain can warn of failure.
  - ♦ Box cribbing will exhibit this same failure mode since all the load is transferred in cross grain bearing.
- The plywood sheathing of wood structures makes them very tough and earthquake resistant as long as the sheathing is nailed properly.

<u>**Steel**</u>

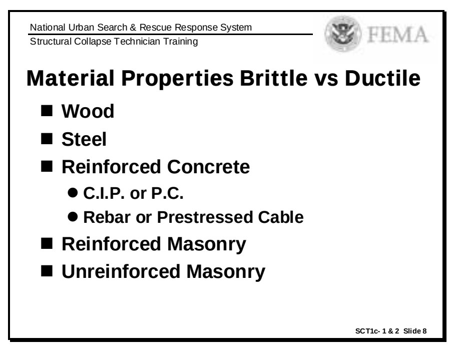
- Steel is tough, light, strong, ductile, and formable into any shape but needs to be fireproofed.

  It starts to lose strength above 700° F.

- It has the almost magical property of **ductility**; that is, it can be stressed beyond its elastic limit and severely bent but still have enough strength to resist failure.

  This property makes it the ideal structural material, in that it gives warning of collapse (has forgiveness).

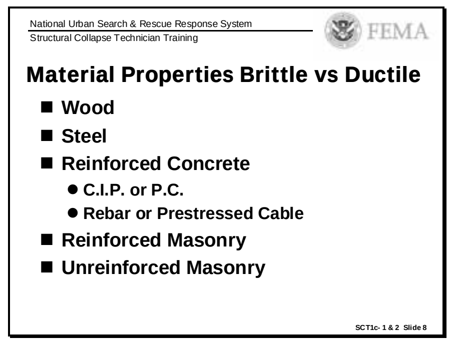
- Steel is strong with respect to tension, compression, and shear.
- Steel beams must be laterally braced so as not to buckle about their weak axis, especially if the ductile performance required for earthquake resistance is expected.



- Steel-framed structures must be properly proportioned in order to avoid the overloading of columns.

  As will be discussed later, diagonal bracing members can overload columns during earthquakes if these columns are not proportioned such that their strength exceeds the total force that can be delivered to them by the diagonals.
- Steel can be very efficiently connected by bolting or welding (older structures used rivets instead of bolts).
- Welded joints must be properly designed and constructed, or they can lead to a brittle failure.

Concrete



- Concrete is essentially cast rock that is strong with respect to compression but weak in terms of tension and shear.
- Steel bars are cast into concrete to provide for the longitudinal tension force, and enclosing type steel ties and stirrups are added for confinement and shear resistance.

  Sufficient steel can be added to provide adequate toughness for seismic resistance, enabling reinforced concrete to exhibit **ductile** properties similar to those of structural steel.
- Concrete can also be reinforced by adding high strength cable or bars that are pre-tensioned prior to their being loaded by the structures weight (pre-stressed concrete).
- Structures of this type may be pre-cast in a factory using **pre-tensioned** reinforcing that is stretched in a form and then bonded to the concrete when it is cast.
- Another method is to place cables that are enclosed in plastic sleeves in the forms at a job site, pour the concrete, and then stretch and anchor the cables after the concrete has cured and achieved sufficient strength. (**post-tensioned**).
  - ♦ In this case, the cables are not bonded to the concrete but only anchored at the edges of the structure.
  - ♦ These **unbonded** cables can cause difficulties when dealing with a damaged **post-tensioned** structure.

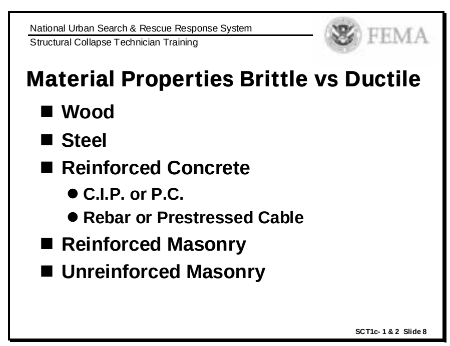
- Concrete shrinks, cracks, and creeps under normal circumstances, and this **normal** behavior needs to be differentiated from the cracking and spalling that indicates failure.
- Concrete is easily connected together if cast in place but must be very competently connected together if it is pre-cast.
- Since pre-cast concrete members (especially pre-stressed, pre-cast members) can be very strong, the joints that connect then must be very tough (**ductile)** in order to resist the high dynamic forces generated by an earthquake.
- Properly reinforced concrete can provide seismically resistant construction if the reinforcing is proportioned such that the confining tie, hoop, and stirrups are sufficient to resist the shear that can be generated by the overall structural configuration and longitudinal reinforcement.
- Wall-like structures of cast-in-place and pre-cast concrete have outperformed frame type construction in most earthquakes.

<u>Unreinforced Concrete</u>

- Unreinforced concrete walls can be found in structures built before about 1910.
- These structures perform very poorly in earthquakes, as they tend to break into large pieces defined by shrinkage cracks or original pour joints (**very brittle material**).

<u>Reinforced Masonry</u>

- Reinforced masonry is made from clay brick or hollow concrete blocks formed into walls using mortar joints and concrete grout filling of interior cavities in seismically resistant construction.
- Since masonry properties are similar to concrete, reinforcing steel bars are normally added to provide tension and shear resistance.
  - ♦ In reinforced brick masonry, two, single-brick thick outer layers (wythes) are laid up and then rebar and grout are placed between the layers.
    - o The wythes are connected with large wire to prevent blowout when the grout is poured.
    - o Small, heavy wire, ladder-type reinforcing is used at the joints in some cases.

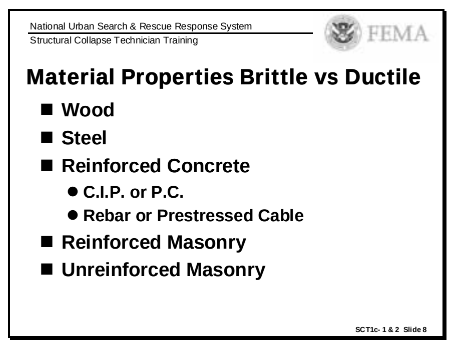


- ♦ In Concrete Hollow Unit Masonry (CMU), each block comes with preformed cavities.
  - o As the units are laid up, horizontal reinforcing (small rebar or large wire) is placed in the joints.
  - o After the wall reaches a predetermined height, vertical rebar is placed in specified cells and then grout is poured to bond the reinforcing steel to the concrete units.

- Masonry wall construction is highly dependent on workmanship if it is to provide adequate mortar and grout strength.

  These products are often mixed on the job in small quantities.

- Adequately reinforced masonry walls can be used in seismically resistant construction and can exhibit very good **ductility** if carefully designed and constructed.



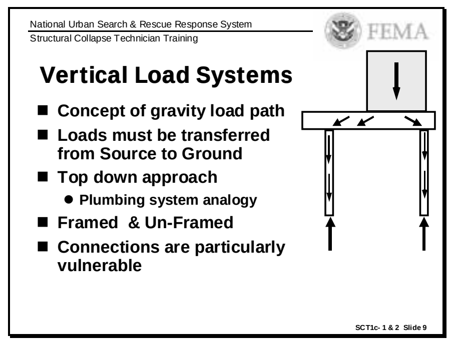
<u>Unreinforced Masonry (URM)</u>

- Unreinforced masonry structures are not currently built in seismic risk areas, but many structures with URM walls still exist throughout the world.
- This is a **very brittle material**.
- Walls were constructed with a thickness of three or more bricks laid long ways, side by side, five or six layers high (courses), and then a layer was placed with the bricks at 90° (header course), and so on.
- URM buildings date back to the late 1800's in California and back to the 1700's in other parts of the U.S. The strength of the bricks is generally higher outside of California.
- The strength and seismic performance of unreinforced masonry is highly dependent on the mortar strength.
  - ♦ The shear strength of mortar can vary from 15 psi to over 150 psi and is determined both by the proportion of lime to Portland cement and the workmanship.
  - ♦ Lime produces a nice, buttery mortar, but too much of it produces a low strength.
  - ♦ Lime can also be leached out of the mortar by water over time.

- Decorative veneers are a special seismic problem.
  - ♦ Veneers were often laid up with building paper between them and the URM wall, and were anchored with wire or galvanized ties.
  - ♦ The ties normally corrode away within 20 years or so, leaving a heavy brick face just waiting to peel off when subjected to a lateral load.
  - ♦ Masonry veneers are also found on the outside surfaces of wood walls.
- There veneers are subject to the same anchorage problems, as well as being dynamically incompatible with the flexibility of the wood walls.
- URM walls are made from native stone in many places in the world and have performed very poorly in earthquakes.

Vertical Load Systems

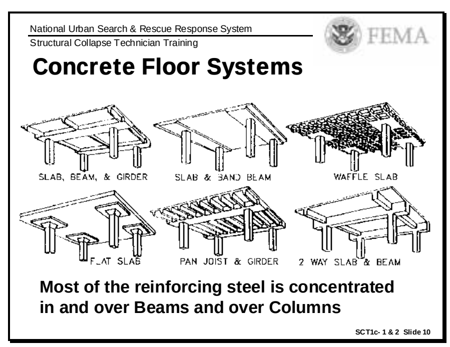
Structural members in these systems can be divided into two types, those that form horizontal (or sloped roof) planes and those that provide the vertical support for these planes.



<u>Horizontal Members</u>

- Horizontal members support floor and roof planes and are normally loaded in bending, such as:
  - ♦ Wood: rafters, joists, purlins, beams, and girders;
  - ♦ Steel: corrugated sheets (filled with concrete), joists, purlins, beams, and girders.

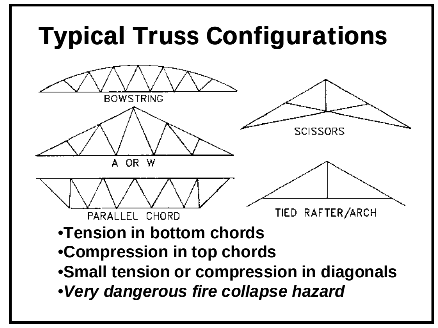
- Reinforced concrete floor systems may be of many types. All have some relationship to the economy of providing adequate structural depth with available forming materials.



- Pre-cast concrete floors may contain planks, cored slabs, single or double tees, beams, and girders. Most modern systems in California combine a cast-in-place overlay slab to provide adequate interconnection of individual members and overall planar stability.
- These individual members need to be interconnected to their supported planes in order to provide the lateral stability to resist the extreme fiber compression forces associated with bending, which occur on the top or bottom of the members.

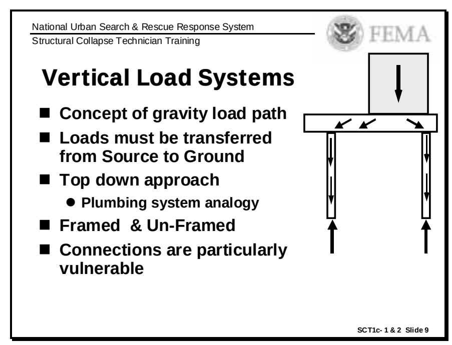
Trusses

- Trusses are special vertical, load-resistant members that use greater depth for structural efficiency but require lateral bracing of compression members.
  - ♦ Trusses are usually made from wood or steel, although concrete is used in some areas of the world.
  - ♦ Individual members are stressed in either tension or compression, although stress may reverse itself in some members because of changes in live load (for example, people, vehicles, and rain/snow).
  - ♦ Compression members are usually governed by buckling, and tension members are usually governed by their connections.
  - ♦ Trusses have not performed well in many situations of overload, fire, and when wood tension have performed poorly. We will discuss this later in this section under Redundancy



Vertical Support Members

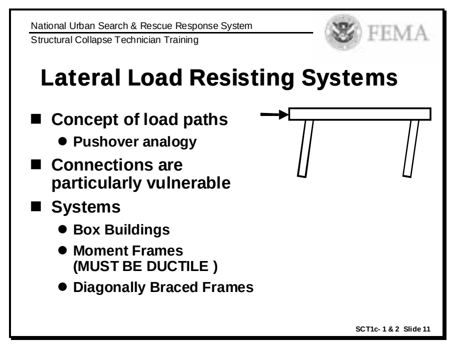
- Vertical support members are normally configured as bearing walls or columns.
- In wood and light framed steel systems, the bearing walls are made using closely spaced columns (studs at 16 in to 24 in o.c.) that must be interconnected by a skin in order to provide the lateral stability that will allow the individual members to be loaded with respect to compression without buckling.
- Concrete and masonry bearing walls are proportioned so as to carry heavy vertical loads depending on their height-to-thickness ratios.
- Individual columns (posts) normally carry large compression forces and may be made of wood, steel, or reinforced concrete. In all cases, the load capacity is based on the member's slenderness ratio (l/r, l/d) as well as the adequacy of the connection between column and horizontal system.
- All vertical load systems need some system to provide for lateral stability (that is, the proper alignment of the vertical load path). These lateral load systems need to be capable of resisting lateral forces that constitute at least two percent of the structure's weight (much more in seismic zones).



- Vertical Load Systems are usually configured as either **Framed or Unframed systems**, but may be a combination of both
  - **Framed** systems have a uniform grid of columns and beams. Steel and Concrete Frame buildings are common examples.
  - **Unframed** systems usually employ bearing walls for vertical supports. Most residential structures from 1 to 12 stories have unframed systems.
  - Since **Unframed** systems normally have shorter spans and more redundancy (discussed later) they tend to perform better under extreme loading. Collapsed area may be limited to only one room, or between one pair of walls.
  - In **Framed** systems, since spans tend to be longer, the collapse of one column may involve an area twice the column spacing in each direction

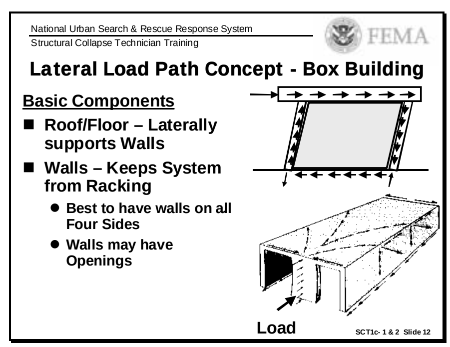
Lateral Load Resistant Systems

Most structures can be grouped into two basic types of lateral load systems: shear wall/box systems and frame systems. Buildings may contain sections of each type. Some buildings have been designed with a dual system containing both types of lateral bracing in order to provide a more redundant system, which is highly desirable.

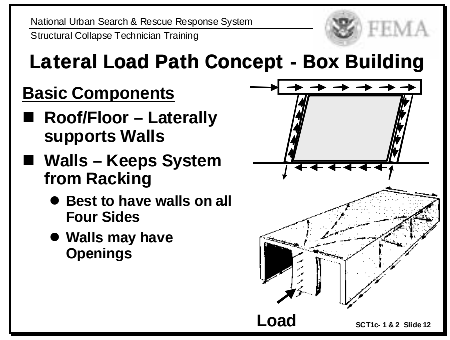


<u>Shear Wall/Box Buildings</u>

- Shear wall/box buildings are buildings with exterior walls that provide bearing strength as well as seismic resistance. They may or may not have interior, structural walls. Floors and flat or sloped roof planes called diaphragms form the horizontal surfaces to complete the boxes, with the walls forming the sides.
- The typical action of a box structure subjected to lateral loads is illustrated in the adjacent slide. Floor and roof planes act like giant beams as stresses in tension and compression are generated at the edges and shear stresses are distributed throughout the plane.

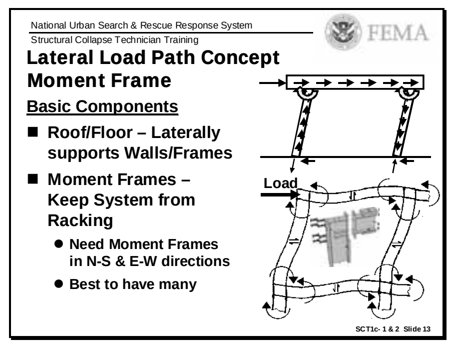


- The floor and roof planes (diaphragms) span horizontally between exterior (and sometimes interior) walls, which provides each horizontal plane with lateral support. The shear walls are in turn loaded by the floor diaphragm and must be capable of resisting both the shear stresses and bending stresses caused by overturning.
- Floor and roof diaphragms are made of plywood, diagonal wood sheathing, corrugated metal deck (with and without concrete topping), and concrete.
- Shear walls are made of plywood and solid wood sheathing over studs, concrete, and concrete block.
- In the very lightweight wood systems, the skin (sheathing) carries all of the lateral shear force but is a minor vertical support member. In concrete and concrete block systems, the vertical and lateral loads are carried by bearing walls and the relatively heavy reinforced concrete slab.



Moment-Resistant Frame Buildings

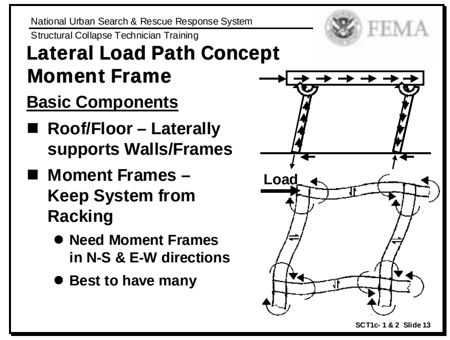
- The walls for this type are normally constructed for enclosure purposes only and may be of glass, light framing with a non-structural covering (such as plaster veneer, brick or stone, or finish wood), or a combination of pre-cast concrete and glass. Large, evenly spaced columns of steel or reinforced concrete carry the vertical load.
- The floor and roof diaphragms are constructed as in the box system. However, the forces developed in the diaphragms are usually smaller since they do not have to span as far.
- Lateral load resistance is provided by the interconnection of large, tough floor beams or girders and the columns. The “frame” made by the beams and columns is kept from changing into a parallelogram by making the connections as strong as the members. Structural steel and well-confined, heavily reinforced concrete are used today for these moment-resistant frames.
- Structural toughness—the ability to repeatedly sustain reversible stresses in the inelastic range without significant degradation—is essential for a moment-resistant frame. Most concrete frames built before 1965 in California (and other seismic zones with similar building codes) were not constructed with much structural toughness.



The Simpson Strong-Frame, bolted moment frame joint is shown inside the graphic of the 4-joint moment frame.

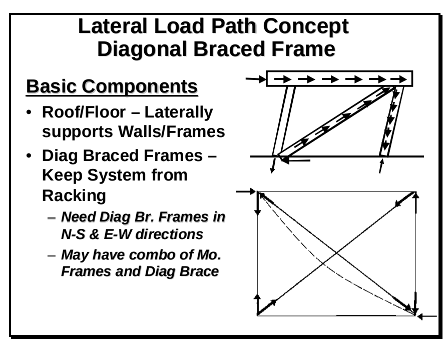
This is just one variation, showing a lower cost, bolted method, for making a moment frame for smaller, wood-frame structures.

Moment-Resistant Frame Buildings (continued)



- Structural steel frames have out performed concrete frames in the past. There are examples of lightly connected steel frames that survived the San Francisco 1906 earthquake. However, they were susceptible to fire damage.
- Tall buildings with moment-resistant frames may generate significant tension and compression forces in the exterior and/or corner columns. High tension can be very detrimental to older concrete frames since severe cracking can result in catastrophic failures when the loading is reversed and the
  member is also required to resist bending. High compression forces in steel frames can cause buckling of either tube or wide-flange columns.
- Modern building codes require that the columns be stronger than the sum of the connecting beams at any story so that when inelastic action occurs, it will form plastic hinges in the beams, not the columns. Since modern steel moment-resistant frames are connected by welding, good workmanship is critical. Visual inspection and ultrasonic testing are normally required to assure quality.
- Moment-resistant frames can be used in combination with concrete shear walls to provide a dual system.
- Older, pre-1960, steel moment-resistant frames may be covered with cast-in-place concrete fireproofing (important identification information).

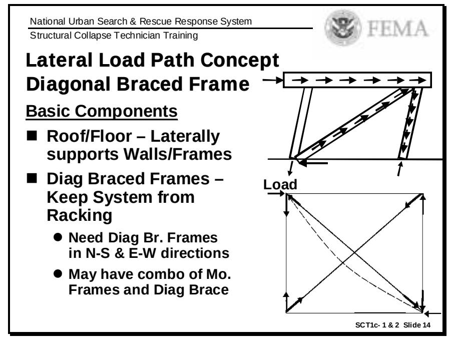
Frame Buildings—Diagonally Braced



- These systems are constructed similarly to moment-resistant frame structures.
  - ♦ Their lateral load resistance is provided by adding diagonal members between columns to prevent lateral racking.
  - ♦ Alternately reversing tension and compression forces are generated in the diagonal members, which are usually made of structural steel, although reinforced concrete has been used, especially in Central and South America.

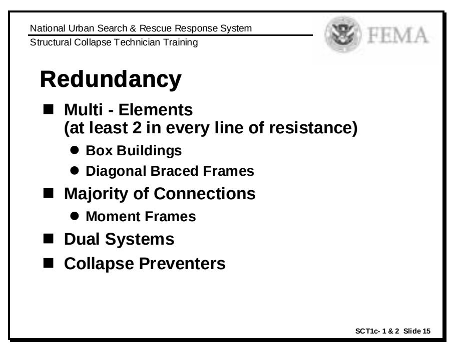
Frame Buildings—Diagonally Braced (continued)

- Diagonal members should be able to resist both tension and compression since the whipping action of slender rod cross-bracing can allow too much distortion. An exception is that light, steel frame, industrial buildings have performed reasonably well with slender rod cross-bracing, since corrugated metal finishes are quite flexible.
- The columns in diagonally braced frames need to be proportioned so that they are stronger than the tension capacity of the braces that are connected to them. This proportion assures that failure will not occur in the columns, yet it has only been required in recent building codes.
- Diagonal members are normally made from double angles or tube sections, and connections must be carefully detailed and built in order to prevent local buckling and/or other joint failure.
- Diagonally braced frames have been used in combination with moment-resistant frames to provide a highly desirable, dual system. They are configured as eccentric braces within a moment-resistant frame bay to provide a bracing system that combines the toughness of a moment-resistant frame with the rigidity of a braced frame.

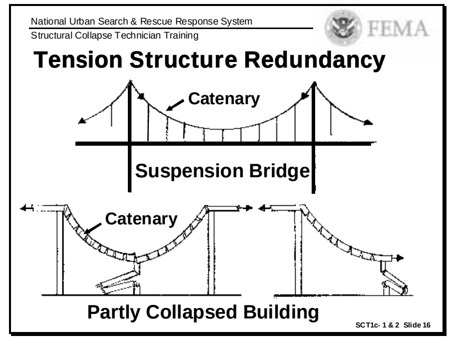


Redundancy

- Especially in seismic zones, it is important for the lateral load system to possess some degree of redundancy.
- Redundancy in a structure means that there is more than one path of resistance for lateral forces.
- Redundancy can be achieved by having:
  - ♦ More than one shear wall panel or more than one diagonal brace in every line of resistance;
  - ♦ A moment-resistant frame with many columns and beams, all with ductile connections;
  - ♦ A dual system, like shear walls in addition to a moment-resistant frame.

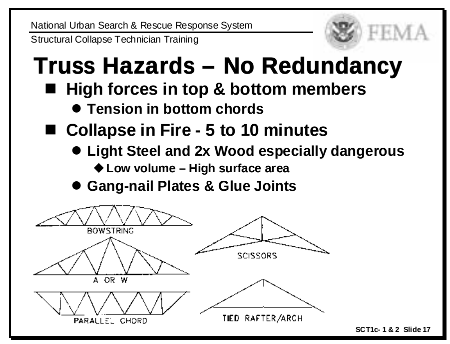


Suspension/Tension Structures



- Suspension/tension structures are not commonly used in building structures. These very efficient structures require significant height (cable drape) to span great spaces.
- Earthquake-damaged, reinforced concrete slabs often form tension-like structures after the failure of a vertical support (as shown in the slide). Failures of a vertical support will cause unplanned tension forces in the remainder of the structure, which may cause lean-over of the remaining walls.
- This action can prevent complete collapse, but it leaves a condition that is difficult to assess. The slabs may be hanging on reinforcing steel with unknown and/or unreliable embedment.

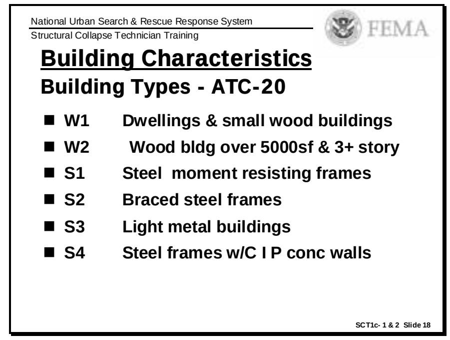
Truss Hazards – No Redundancy



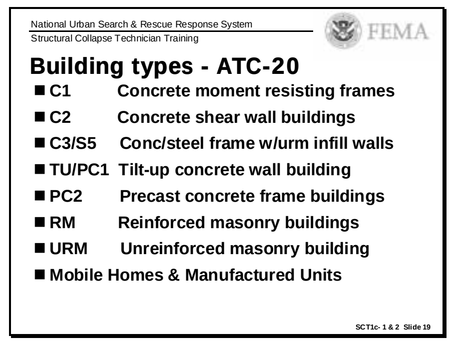
- Wood trusses have failed many times due to seasoning defects. Wood checks (splits) that occur near the ends of tension members have led to many pull-through bolted connection failures. Overloads due to rain or snow can lead to sudden collapse resulting from a compression member buckling or tension connection failure. The use of closely spaced trusses with gang-nail connection plates and specially fabricated wood with steel pin connected bars has improved the reliability of wood trusses.
- Steel trusses have been fairly reliable, but they are also susceptible to sudden compression member failures due to temporary overload and loss of stability resulting from inadequate bracing.
- Trusses present special problems when shoring a hazardous structure. The support provided by the shoring must be applied so as not to cause a stability problem or overload of a small or inadequately braced individual truss member. It is usually a bad idea to shore a truss at the bottom
- Light wood and steel trusses are very susceptible to sudden collapse due to fire.
  - ♦ Wood trusses with 2x members, connected by gang nails or glue, provide an abundance of fuel in ceiling space, and collapse quickly.

Building Types & Characteristics

ATC-20, Procedures for Post Earthquake Safety Evaluation of Structures and ATC-21, Rapid Visual Screening of Buildings for Potential Seismic Hazards, were funded by FEMA and written by the Applied Technology Council (ATC) in 1988. The ATC was created by the Structural Engineers Association of California to develop and manage research and other projects that add to the body of knowledge regarding structures.



- ATC20 & 21 defined 13 specific building types based on how they respond to earthquakes. We have added Mobile Homes & Manufactured Units.
  - ♦ They are defined by the type of material used in construction as well as the type of lateral load resistant system employed.
  - ♦ As an example for concrete construction, we have a C1 Type that has a moment-resistant frame, a C2 Type that is a box building with shear walls for lateral resistance, and a C3 Type to cover the many buildings that have a moment-resistant frame with masonry infill walls for fireproof exterior enclosure.



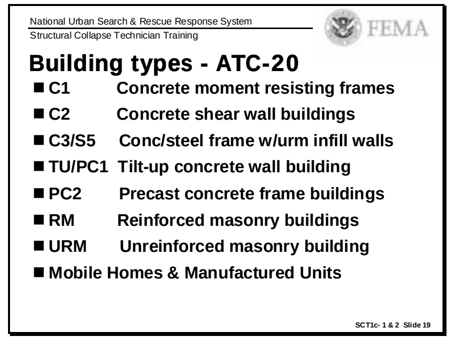
- One exception is that Wood Buildings are subdivided by size into W1 for smaller, residential structures, and W2 for structures over 5000 sq feet.
  - ♦ The W2 classification covers 2 and greater story apartments as well as commercial, institutional and industrial structures
- There are also the other more descriptive definitions, such as: TU, PC2, URM, and Mobile Homes & Manufactured Units
- The FEMA US&R Response System has adopted the ATC-20 nomenclature for use in identifying damaged structures.

  It is used in this training manual and for the Structures Specialist Forms.
- Other systems, such as the Building Code and Francis Brannigan's *Building Construction for the Fire Service*, are based on resistance to fire.

  They are not as specific enough to differentiate to be useful in describing structural response to earthquake and the other destructive forces encountered in US&R.

- Another book, written for the Fire Service that is highly recommended is "Collapse of Burning Buildings", by Chief Vincent Dunn, Fire Department of the City of New York. It describes many actual incidents, and gives insight from lessons learned.

Problem Buildings



The slide lists some of the building types that have been susceptible to earthquake and/or wind damage in the past. The list includes most structural types.

- S2, C1, C3/S5, TU, PC2, and URM are expected to be most susceptible to earthquake damage throughout the U.S.
- W1 & W2 residential structures have also experienced a large number of failures on the U.S. West Coast, since they are, by far, the most prevalent building type. There is the potential for the entrapment of victims in the W2 wood structures.

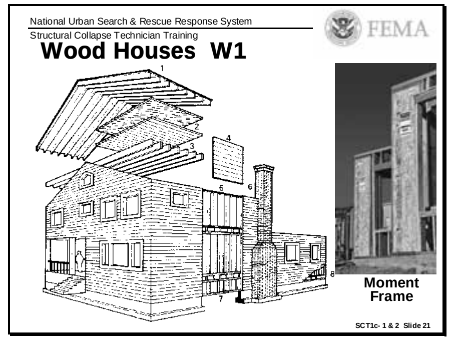
  Poorly connected W1 & W2 wood structures are also very vulnerable to wind damage.
- Type S3 is listed since it is very susceptible to damage by wind.
- Mobile Homes & Manufactured Units are susceptible to damage in earthquakes and winds
- Many S1 structures experienced cracks in their welded connections during the Northridge (Los Angeles) earthquake, which is of great concern to the design profession.

  None of these buildings were damaged to an extent that would cause collapse, but they may become a problem in future earthquakes.
- Earthquakes consistently cause damage to buildings with irregular shape and inconsistent stiffness.
  - Remembering that quakes produce motions (not Forces) , and the shaking is able "find" these inconsistencies, thereby causing severe overloading.
- For the most part quakes and windstorms effect different types of structures.
  - Mass and rigidity develop high forces during quakes, but provide resistance to high winds

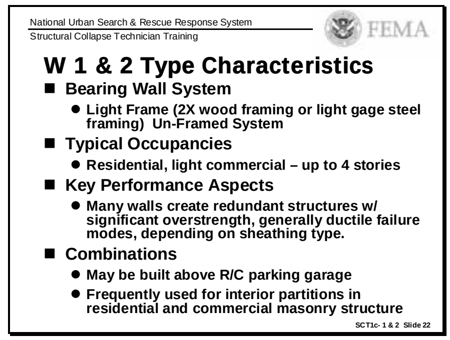
The characteristics of the various types of buildings are discussed on the following pages.

Wood Frame Buildings – W1 & W2

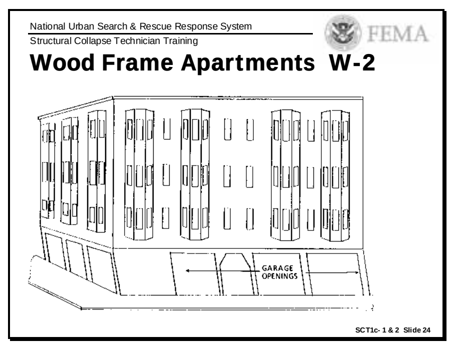
These structures can vary from 1 to 4 stories and contain from 1 to over 100 living units. W2 structures are larger than 5000 sq feet



- Lateral resistance of wood structures is dependent on the type and amount of wall sheathing.
- The adjacent slide shows a method of providing lateral resistance for very short walls. This is a factory built strong-wall that is cantilevered off the foundation using well embedded bolts
- Wood structures are unique in that the vertical load resisting systems (joist, beams, studs and posts) are covered with a “skin” to form the lateral load resisting system. This is different than other bearing wall systems. See adjacent slide for characteristics.



- Common problems in strong earthquakes are:
  - Walls are weakened by openings & becoming racked (rectangles become parallelograms).
  - This weakening can cause a significant offset of one floor from another, and in severe cases, collapse has occurred.
- Relatively modern, W2, 2- and 3-story wood apartment buildings may have walls that are braced using only plaster/gypsum board, let-in bracing, or inadequately designed plywood.
  - These structures may experience brittle, first-story failures, especially when upper story walls do not align with lower-story walls.
  - These structures are especially vulnerable to earthquake damage when lightweight concrete fill has been added to provide better sound control (greater mass means that greater earthquake force is generated).



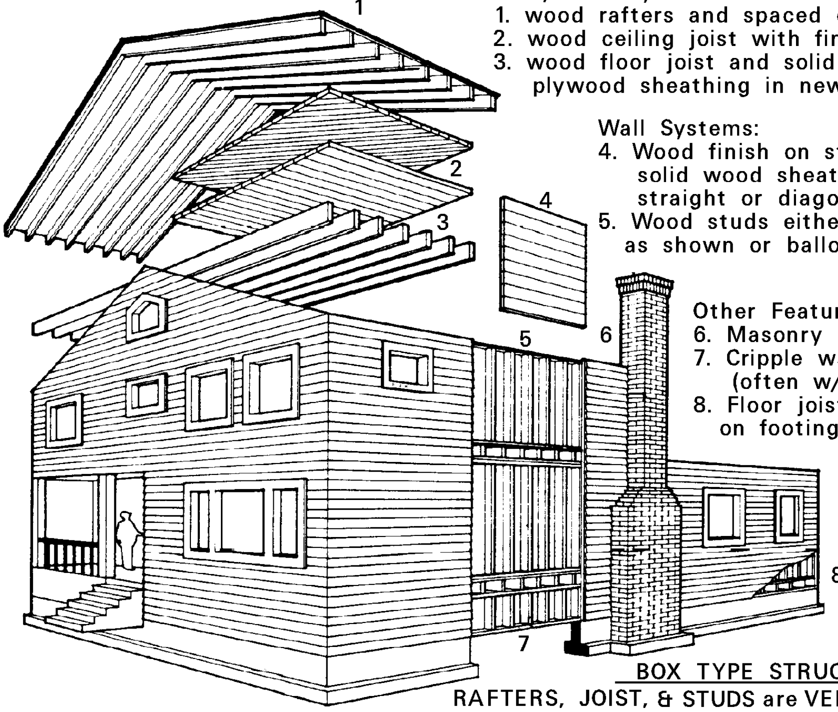
- W1 houses with crawl spaces can shift or slide off their foundations.
- Masonry chimneys can crack and fall-off or into the structure.
- Masonry veneers can fall off walls and shower adjacent areas with potentially lethal objects. (Especially deadly for W2 Types)
- Structures can separate at offsets in floor/roof levels (such as porches and split level houses).
- A great danger of fire exists for these structures due to the presence of so much fuel.

WOOD RESIDENCES - W1

Roof/Floor Systems:
1. wood rafters and spaced or solid sheathing
2. wood ceiling joist with finish
3. wood floor joist and solid 1x sheathing or plywood sheathing in newer houses

Wall Systems:
4. Wood finish on studs or Stucco on solid wood sheathing: plywood, 1x straight or diagonal boards.
5. Wood studs either platform framed as shown or balloon framed

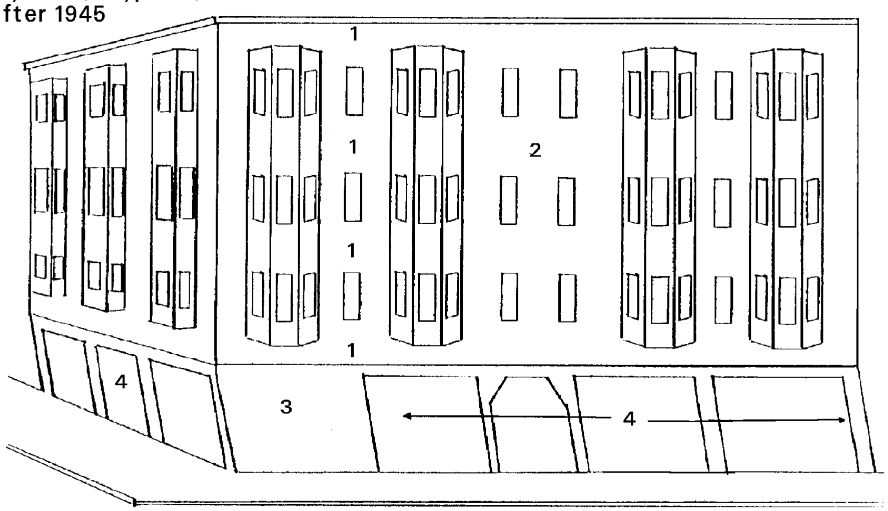
Other Features:
6. Masonry chimney
7. Cripple wall below 1st floor (often w/vent holes)
8. Floor joist may bear directly on footing.



BOX TYPE STRUCTURE
RAFTERS, JOIST, & STUDS are VERTICAL LOAD SYS.
SHEATHING is LATERAL LOAD SYSTEM

WOOD FRAME APARTMENT BUILDINGS - W2

1. 2x wood joist at roof/floors with 1x wood sheathing or plywood (post 1945)
2. Wood studs, platform framed with wood sheathing:
   1x horizontal - pre 1935
   1x diagonal - pre 1945
   Plywood, Gypsum, or wire after 1945
3. Walls may have masonry veneer especially in first story
4. First story garage openings create a weak/soft story. This can be overcome by using properly designed shearwalls or by changing the garage to a concrete structure with strong shearwalls.



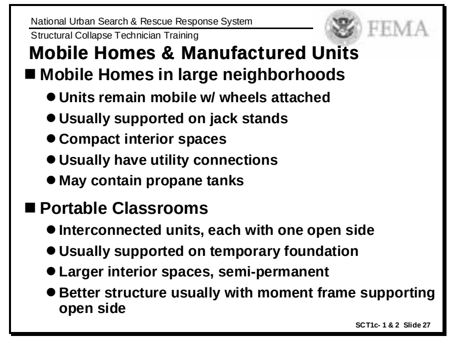
Mobile Homes and Manufactured Units

These are relatively small structures that may have been made stationary on a "Park".

In the case of portable classrooms there are two or more 8 foot wide units that have been attached together to form 16ft x 40 (or more) ft units.

All types have relatively light walls, and are box structures that have been moved over the highway on a steel base frame (usually a tubular frame)

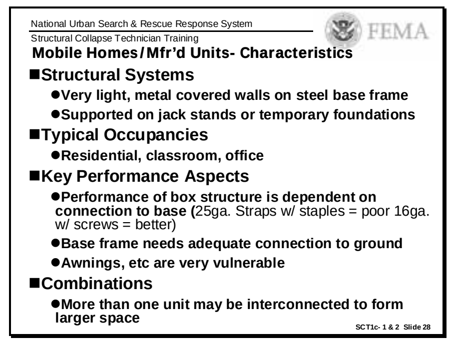
Characteristics are shown in adjacent slide



The portable classroom units have more substantial framing than mobile home units, since they have at least one open side that is framed with a steel moment frame

The performance of these units when subjected to wind, quake, or blast pressures is related to how well they are attached to their bases and their bases connected to the ground/foundation.

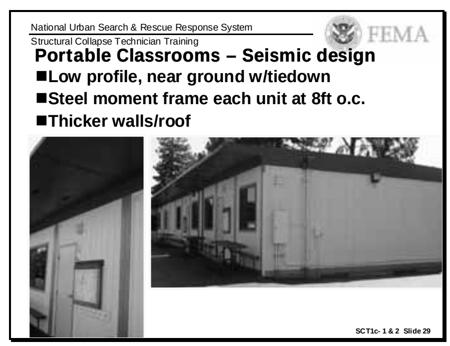
Older mobile homes used 25 gage straps and staple connectors to connect walls to the frame, but newer units have 16 gage straps and screws.



Some portable classroom units have concrete foundations to which they are semi-permanently connected

In California, these structures are designed to resist earthquakes, and are carefully reviewed by State Building Officials.

These have much better connections at the base and may have concrete foundations.

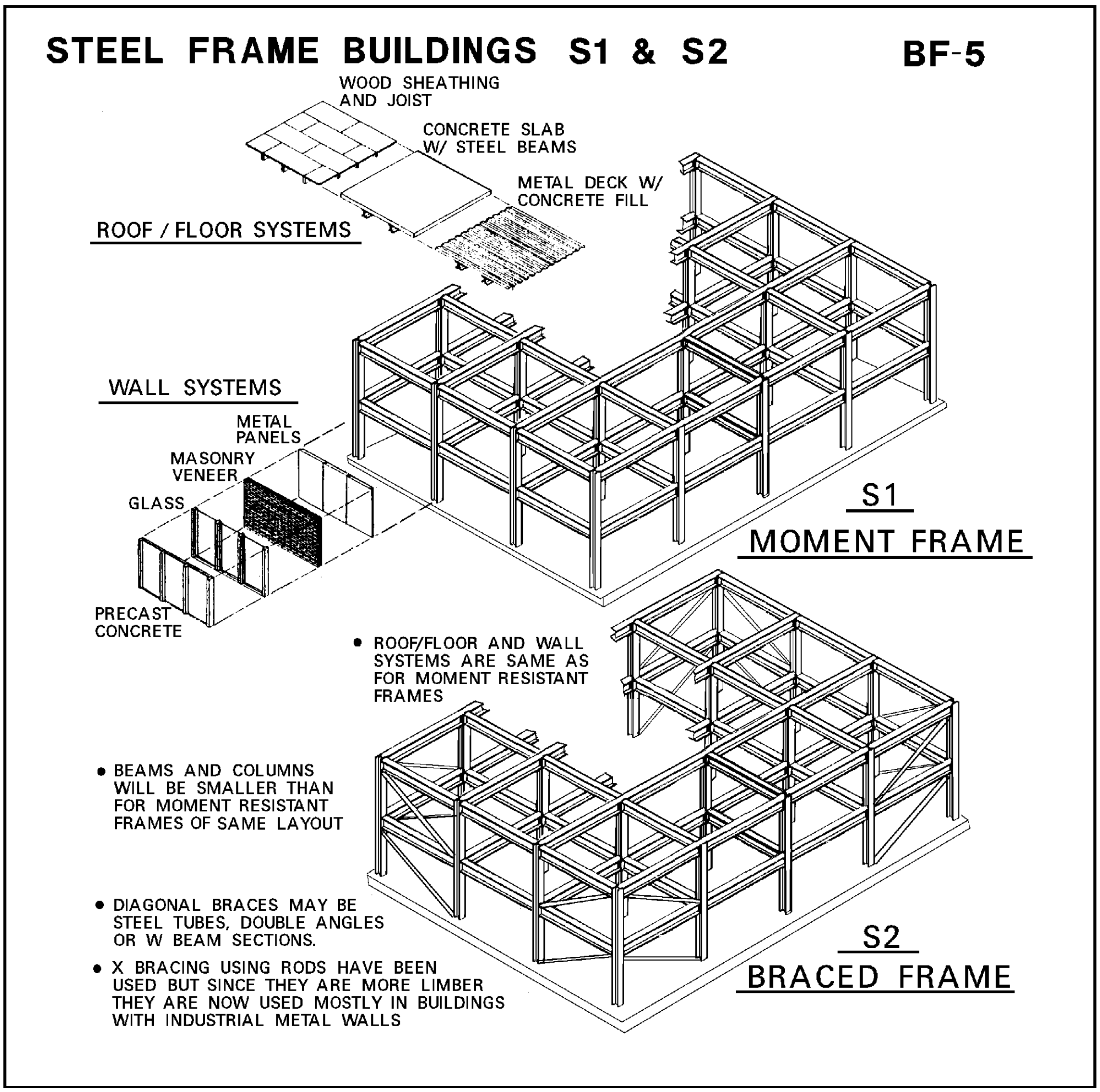


In some cases, what start out to be temporary structure, remain for many years on relatively poor bases

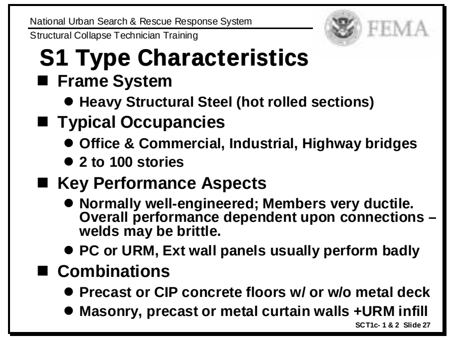
Here is an example of how poorly connected modular units may become almost permanent structures .

Steel, Moment-Resistant Frame Buildings—S1

- Steel, moment-resistant frame buildings may be from 1- to over 100-story office buildings with glass or other non-structural exterior covering.
- Steel buildings in general have performed well, but in recent earthquakes **moment-resistant frames** have exhibited the following problems:
    - ♦ In both the Northridge and Kobe earthquakes, the violent shaking caused some welded connections to crack.
    - ♦ No buildings of this type collapsed during these earthquakes, but a few were racked out of plumb, and new, better performing joints have been designed to repair or replace questionable ones.

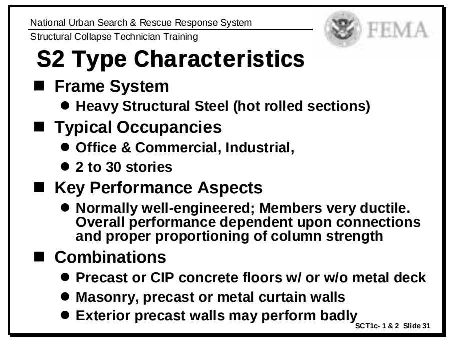


- Since these connections are what give moment-resistant frames their lateral resistance, it is possible that a future great earthquake (magnitude 7.5 to 8.5) could cause a catastrophic collapse, especially if the following occur:
  - ♦ Shaking lasts for more than 30 seconds.
  - ♦ A structure has little redundancy (only a few columns with welded joints), and the joints are the types that can crack and fail.
- The characteristics of Steel Moment Frame Structures are listed in the adjacent slide.



<u>Diagonally Braced Steel Frame Buildings—S2</u>

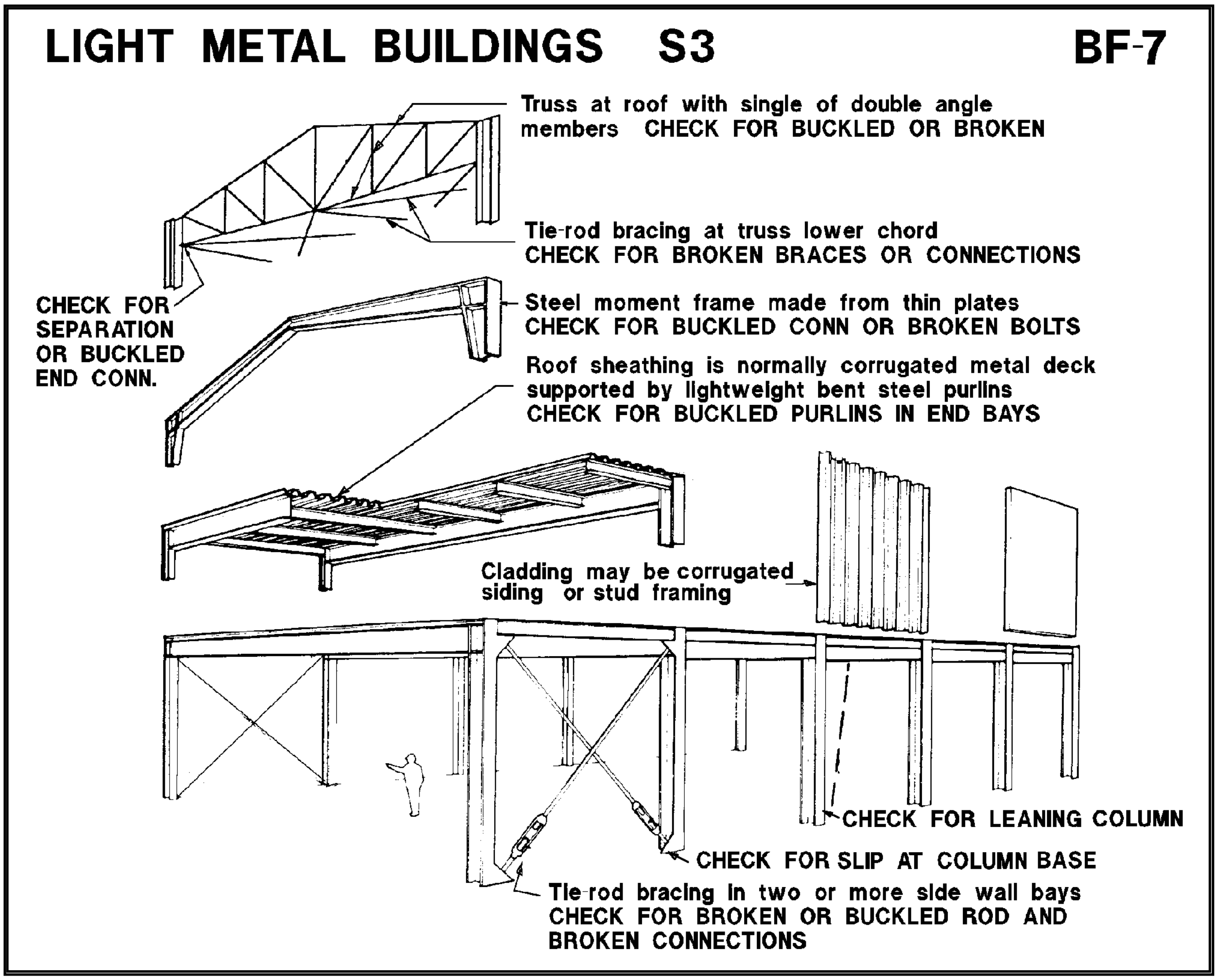
These buildings may be from 1- to 20-story office buildings with glass or other non-structural exterior covering. Characteristics are listed on adjacent slide. Steel buildings have performed well, but those with diagonal bracing have had problems.



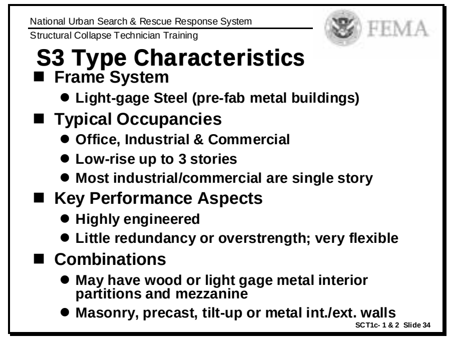
- Buildings that contain slender-rod cross-bracing may experience excessive distortion (story drift) that can lead to shedding or significant damage to brittle finish materials such as glass, masonry veneer, or pre-cast concrete panels. The whipping action has caused some slender cross-braces to break.
- When the braces/columns are not properly proportioned, especially in taller frames, the great tension strength of the braces can cause compression (buckling) failure of columns.
- The 1985failure of the 20-story Pino Suarez tower in Mexico City is attributed to this effect.
- When tube-type members are used for diagonals, local crippling at cross-section corners has resulted. This crippling can occur when cold-rolled tubes are used since high stresses are originally induced during forming.
- Inadequate detailing or workmanship of connections has caused local failures, such as the buckling of connection plates and the rollover of beams. Although collapse has not resulted from these failures, significant non-structural damage has occurred.

Light Metal Buildings—S3

Light metal buildings are normally one-story, pre-engineered buildings sheathed with metal siding and roofing. These structures have been damaged during earthquakes due to poor connections and field errors such as the incomplete welding of joints. However, most of these structures respond well to earthquakes because of their lack of mass and abundance of flexibility. During strong windstorms, however, light metal structures have exhibited the following problems; building walls and roof lose sheathing and the purlins plus girts that were braced by the sheathing will buckle, often leading to the progressive buckling collapse of the entire structure.

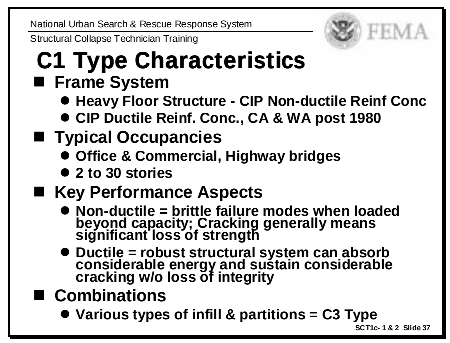


- Doors and windows are blown in, leading to greatly increased outward pressures on the leeward wall and roof followed by the shedding of sheathing and, in most severe cases, progressive collapse.
- Tie-rod bracing can be broken or stretched by whipping action. Also, rod end connections can fail as a result of pullout or prying action.
- Lower chord bracing at end walls can buckle due to wind pressure against the wall.
- Since these structures have little redundancy, performance is usually governed by “weakest link” behavior (the failure of one element can lead to progressive/domino type collapse).
- The characteristics are listed on slide



<u>Concrete Frame Buildings—C1 & C3</u>

C3 Types have infill walls and C1 do not. Older frames are from 1 to 13 stories high and may have URM infill walls. Older frames in California had thin concrete infill walls on property lines in some cases. The most hazardous configurations include soft (high and open) first stories, open front buildings (typical of retail one and two story), and corner buildings (torsion problems). Characteristics are shown in adjacent slide. See next page for graphic of C1 & C2.



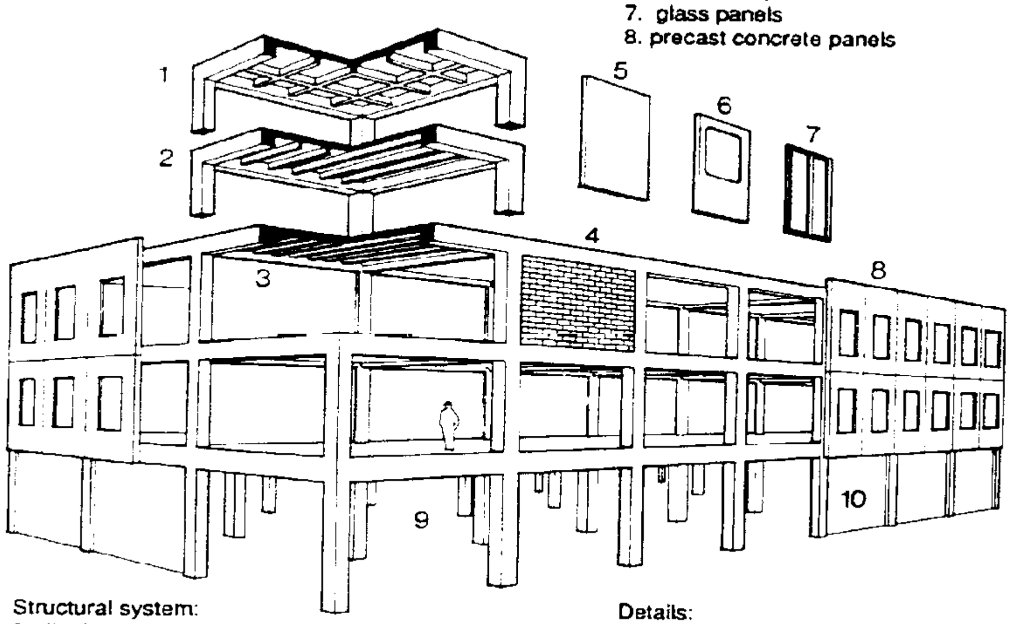
The common earthquake problems are:

- Columns break at intersections with floor beam. Inadequate rebar and ties do not confine the concrete when subjected to high shear and tension stresses. Failures may be driven by a strong P-Delta effect.
- Short columns in exterior walls experience high shear and tension stresses focused into them by surrounding concrete mass.
- Bending and punching shear failure occurs at intersections of flat slabs (for example, waffle) and columns.
- URM infill can fall off or pop out of frames. In addition, URM infill can cause columns to shear off at the floor line or at the top of URM.
- Weak concrete and poor construction can make all the above conditions worse.

CONCRETE MOMENT RESISTING FRAME C1 BF-8

Roof/floor diaphragms:
1. concrete waffle slab
2. concrete joist and slab
3. steel decking with concrete topping

Curtain wall/ non-structural infill:
4. masonry infill walls
5. stone panels
6. metal skin panels
7. glass panels
8. precast concrete panels



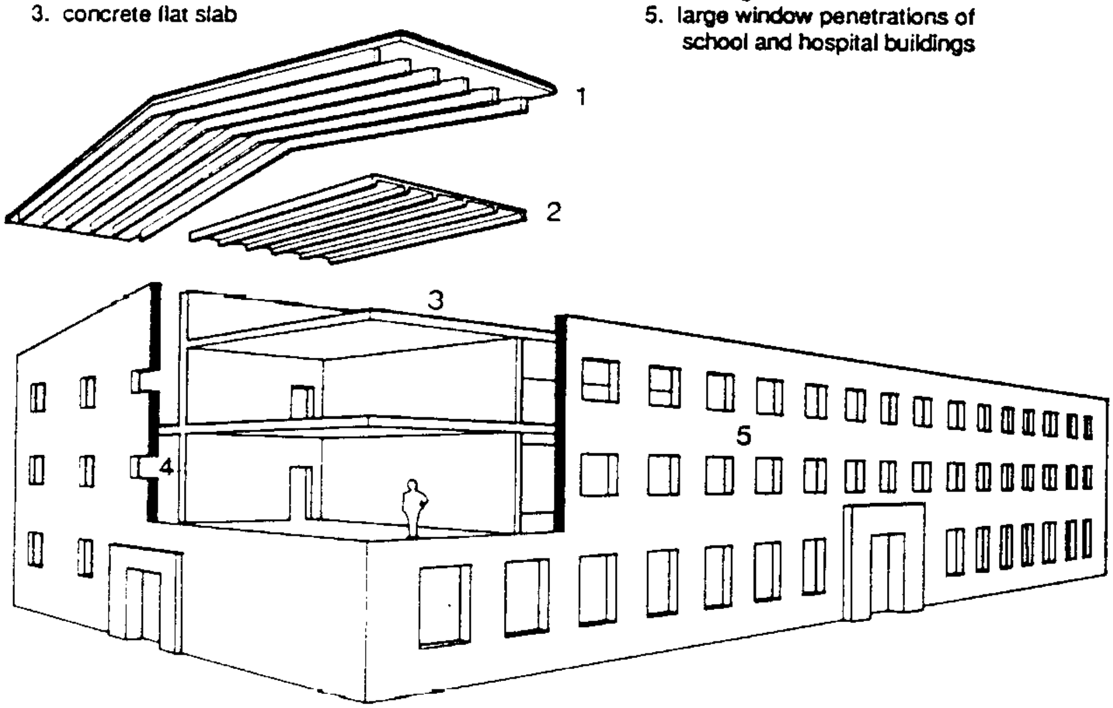
Structural system:
9. distributed concrete frame

Details:
10. typical tall first floor (soft story)

CONCRETE SHEARWALL BLDG C2 BF-9

Roof/floor span systems:
1. heavy timber rafter roof
2. concrete joist and slab
3. concrete flat slab

Wall system:
4. interior and exterior concrete bearing walls
5. large window penetrations of school and hospital buildings

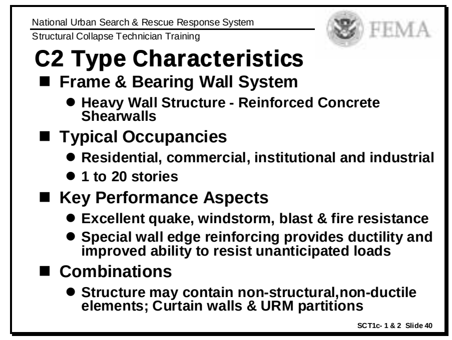


Concrete Shearwall Buildings - C2

These are from one to thirteen stories high with walls on all four sides and/or within the structure as corridor/stair or other divisions between spaces. Walls may have openings "punched in" as doors or windows, but in more modern buildings, the openings may be in groups that are placed between solid wall sections. See graphic on bottom of previous page.

These buildings **rarely collapse** in earthquakes but damage can occur, such as:

- X-cracking of wall sections between openings.
- Severe cracking of shallow wall/floor header sections that frame between solid wall sections.
- Severe cracking or collapse of columns that occur in "soft stories" of otherwise uniformly stiff shearwall buildings (soft first-story, etc.).

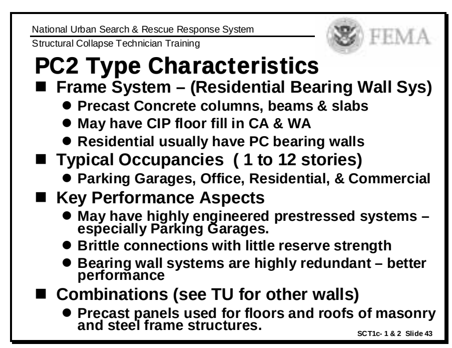


Precast Concrete Frame - PC2

Are usually one to ten stories tall, although precast wall panels may be used in taller buildings. Floors/roof may be tee, double tee, or hollow core concrete plank sections supported by precast girders and columns. Lateral resistance is often provided by reinforced masonry or concrete walls, but buildings that rely on moment frame resistance have performed very poorly (Armenia).

The common earthquake failures are:

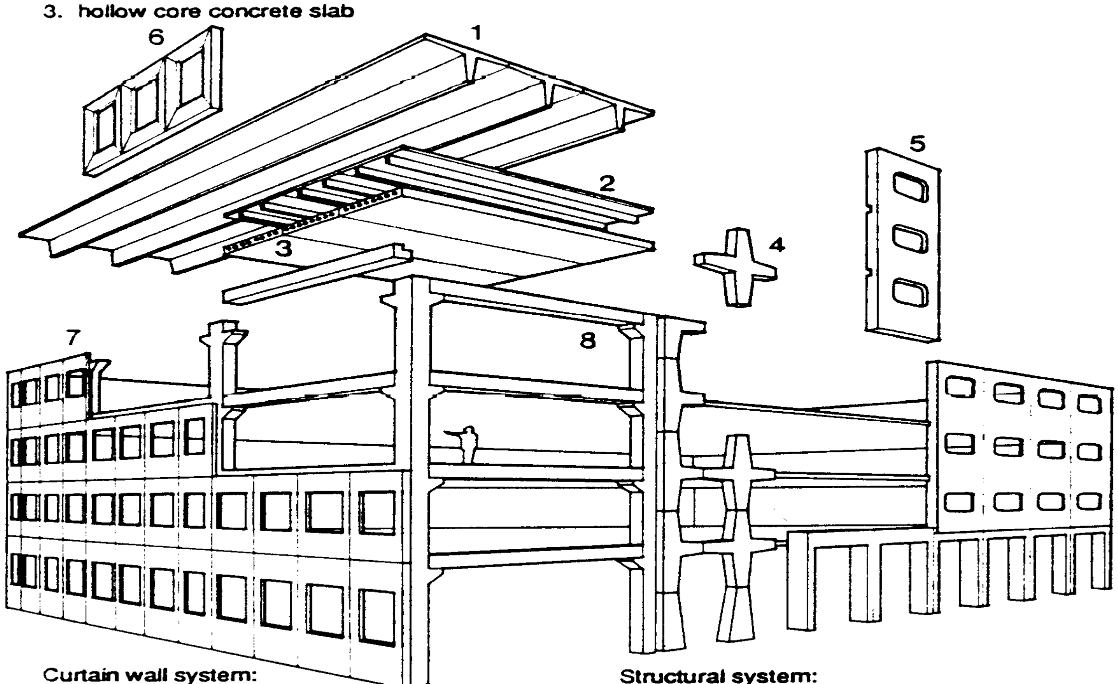
- Joint failures at joints between roof/floor and walls, between roof panels, between wall panels and floor beam-column joints. This can lead to complete collapse as the building breaks into its original precast concrete parts.
- Wall panels separate from building and can fall. If panels are non-bearing only local failure may be the result. In cases the floors/roof supported by the walls can also collapse.
- Progressive collapse can be caused by a joint failure between column and beam or slab and wall panel. This then results in failure of the structure just above, due to lack of support, and also to the structure below, due to debris loading.



PRECAST CONCRETE BUILDINGS PC2 — BF-10

Roof/floor span systems:
1. structural concrete "T" sections
2. structural double "T" sections
3. hollow core concrete slab

Wall systems:
4. load-bearing frame components (cross)
5. multi-story load-bearing panels



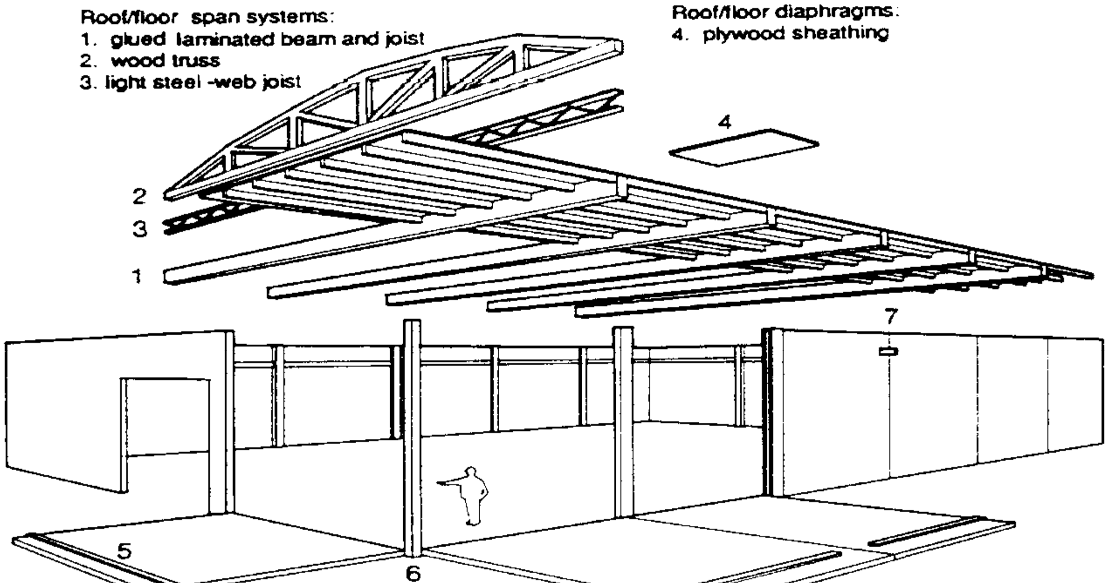
Curtain wall system:
6. precast concrete panels
7. metal, glass, or stone panels

Structural system:
8. precast column and beams

TILT-UP CONCRETE WALL BUILDING — BF-12

Roof/floor span systems:
1. glued laminated beam and joist
2. wood truss
3. light steel -web joist

Roof/floor diaphragms:
4. plywood sheathing



Details:
5. anchor bolted wooden ledger for roof/floor support

Wall systems:
6. cast-in-place columns– square, "T" shape, and "H" shape
7. welded steel plate type panel connection

ONE STORY TILT-UP BUILDING (MAY ALSO BE 2 OR 3 STORY)

Tilt-Up Concrete Wall Buildings - TU

These are usually one-story buildings with wood roof, but may be up to three stories. May have wood floors, concrete floors, steel framing with concrete filled metal deck floors, or with up to 1½ " concrete fill on wood floor.

See adjacent slide for characteristics.

The common earthquake problems are:

- Walls separate from wood floors/roof causing at least local collapse of floor/roof, possible general collapse of walls and floor/roof.

- This problem occurred during the Northridge Earthquake to approximately 400 buildings, most of which had strap connections that were cast into walls and bolted to roof members.

- More substantial connections, that can resist both tension and compression, appear to be required, since it has been demonstrated that forces as high as 200% g can be generated at the mid-span of wood roof diaphragms.

- Suspended, precast concrete wall panels can fall off buildings. (Note: suspended concrete wall panels could be a problem on S1, S2, C1, C2, PC2, and RM buildings.)

- Walls may have short, weak columns between window openings that fail due to inadequate shear strength. Large buildings that are TEE, L, or other non- rectangular plan configuration can have failures at the intersecting corners.

- The major weight of these buildings is normally in the walls, and most failures are limited to exterior bays of the buildings, supported by the walls.

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FEMA

TU Type Characteristics

- Interior Frame & Exterior Bearing Wall System
  - Modern low-rise, most single story but up to 4 stories.
  - Long span roof (50ft+) and floors (25ft+).
- Typical Occupancies
  - Office, commercial, light industrial and institutional
- Key Performance Aspects
  - Robust wall panels dependent upon diaphragms for out-of-plane support.
  - Wall/diaphragm connection vulnerable – Retrofit in CA
- Combinations
  - Light frame or steel joist diaphragms
  - Lt wt. concrete floor fill in multi story bldgs

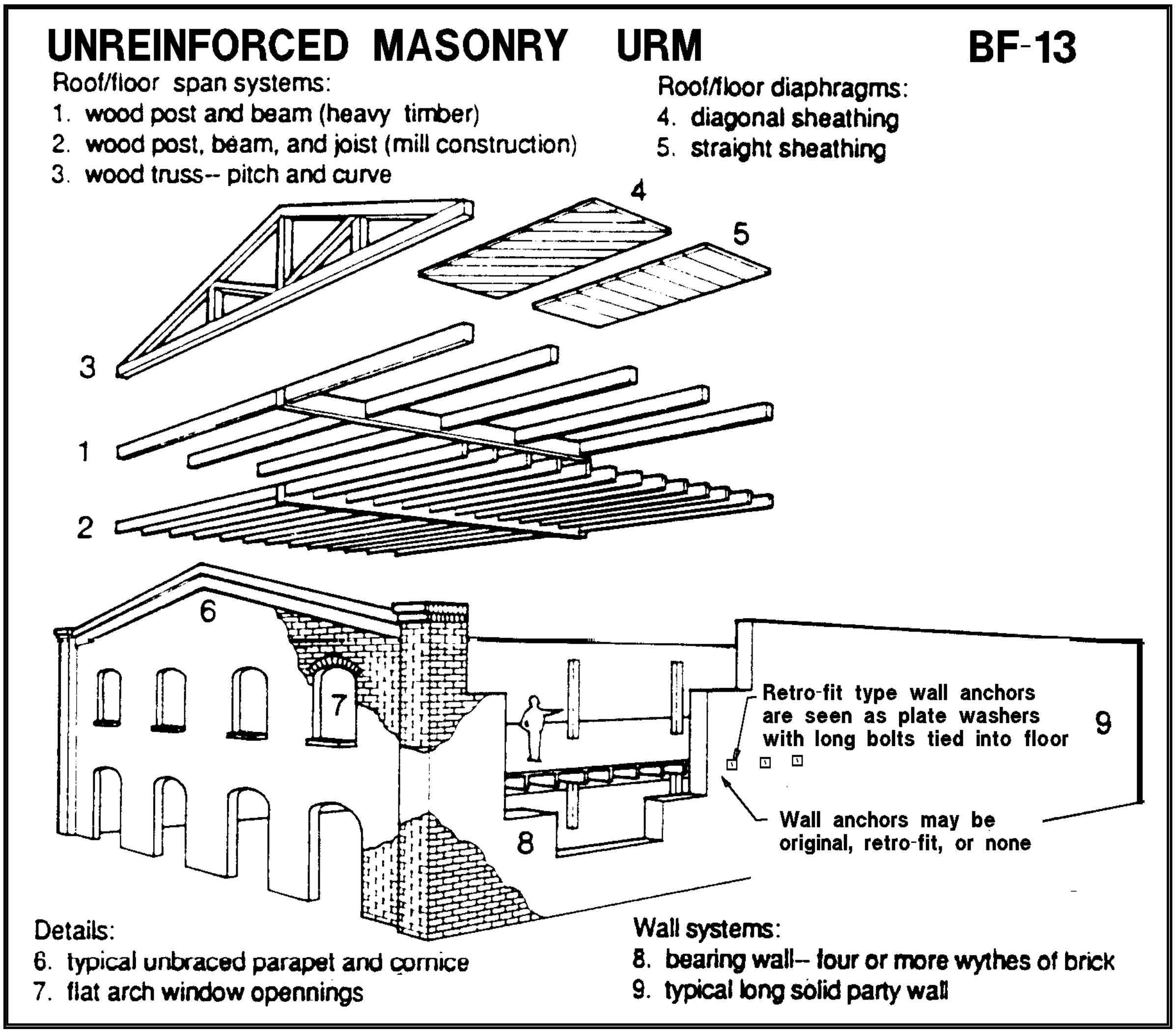
SCT1c- 1 & 2 Slide 47

Unreinforced Masonry Buildings—URM

Are usually from one to six-story buildings with URM bearing walls, wood floors, and wood interior, bearing and non-bearing partitions. There are estimated to be as many as 50,000 in California, however, most have been strengthened. This would include steel and concrete frames with URM infill.

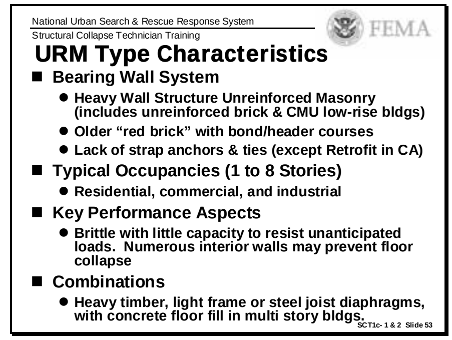
In addition to bearing wall URM, there are structures with unreinforced or under-reinforced hollow concrete block walls, and native stone, adobe, etc., bearing wall structures.

Masonry veneer may be found one URM bearing wall structures, and wood or light metal frame structures.



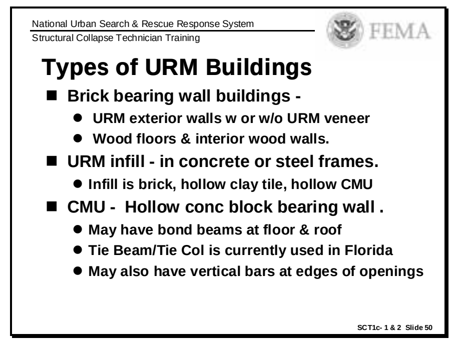
Unreinforced Masonry Buildings – URM

See adjacent slide for characteristics.

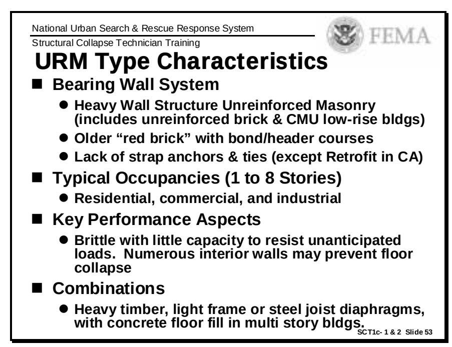


The following problems are common in earthquakes.

- Parapets and full walls fall off buildings due to inadequate anchors.
    - ♦ The parapets and upper story walls are most likely to fall first, due to experiencing higher inertial loads
- Multi-thickness walls split and collapse or break at openings.
- Mortar is often weak and made with too high a lime content.
- URM walls that are more heavily loaded by roof and floors tend to perform better than ones that are parallel to framing, since the load of the floor tends to compress the URM together.



- Roof/floors may collapse if there are no interior wall supports and if long duration earthquake occurs.
    - ♦ Interior wood bearing and non-bearing walls, will often support the roof and floors, especially in building with shorter spans
- Older steel frame buildings with unreinforced or lightly reinforced masonry infill, often shed this brittle covering as they flex to resist the quake.
- Broken bricks often line the streets where these buildings are located, and people can be trapped on the sidewalk or in automobiles.
- Cavities are usually formed by wood floors in familiar patterns of V, lean-to, and complicated pancake (which will be discussed later under Earthquake Collapse Patterns).



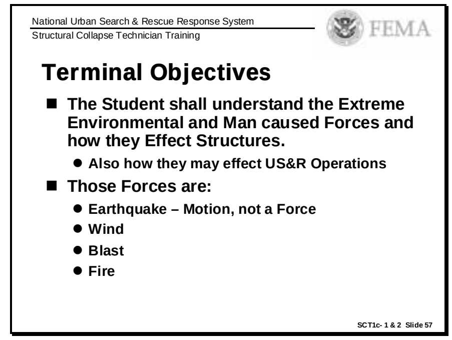
SUMMARY

We have reviewed the basic concepts of structural materials, structural systems and common building characteristics in order to focus on how buildings behave when subjected to extreme loading.

PART 2 - CAUSES OF COLLAPSE

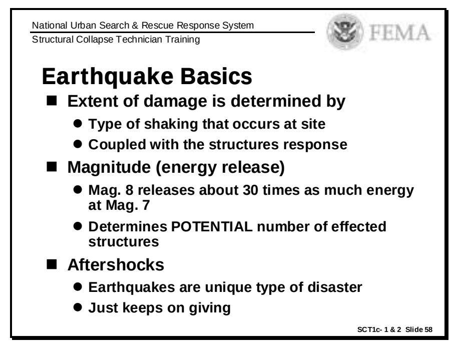
The objectives for this section are listed in the adjacent slides. In this section, we will discuss the following:

- The types of forces that load structures,
- The method that is used to classify structures and the types of problems that buildings have experienced in the past,
- The collapse patterns that have occurred that will give us some insight into how structures will behave in the future.



Earthquake Basics

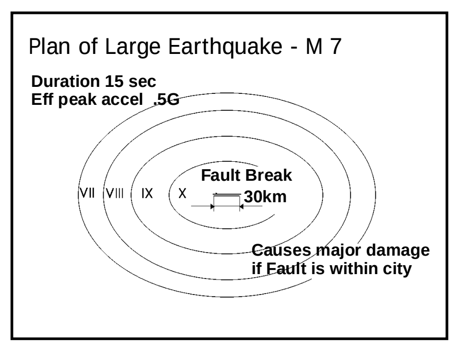
Earthquakes are catastrophic events that occur mostly at the boundaries of portions of the Earth's crust called tectonic plates. When movement occurs in these regions, along faults, waves are generated at the Earth's surface that can produce very destructive effects. We will summarize the things that US&R response personnel **need** to know about these events.

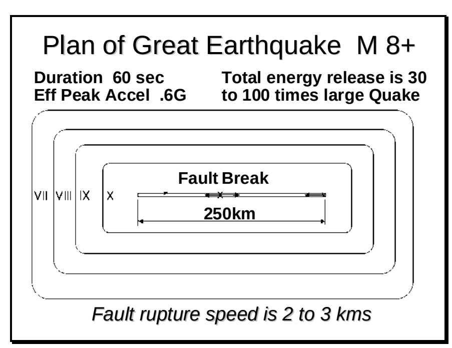


<u>Earthquake Magnitude</u>

Earthquake magnitude refers to a way of measuring the total energy released by a quake, which could also relate to the total damage done (all else being equal). If we compare the two quakes illustrated (Large Quake and Great Quake) on the slides, we can demonstrate what this means to US&R. With respect to a quake with a larger magnitude, the following can be said:

- The maximum intensity of shaking may be similar.
- The duration of the shaking (at the fault) is longer.
- The length of the fault break is longer (directly related to duration).
- The area of the Earth that will be effected by intense shaking is MUCH larger, and, therefore, the potential for greater US&R involvement is MUCH larger.





Aftershocks

These smaller quakes occur after ALL large earthquakes. They are usually most intense in size and number within the first week of the original quake.

- They can cause very significant re-shaking of damaged structures, which makes earthquake-induced disasters more hazardous to US&R than most others.
- A number of moderate quakes (6+ magnitude) have had aftershocks that were very similar in size to the original quake.

Aftershocks

- Smaller quakes that occur on same fault as original quake.
  - Minor fault adjustments
- Occur after most quakes regardless of size of original shock
- On average largest is 1.2M less than original
  - Some have been almost as large as original. (in range of M 6)
- Will occur during US&R Ops since are most prevalent in first week.

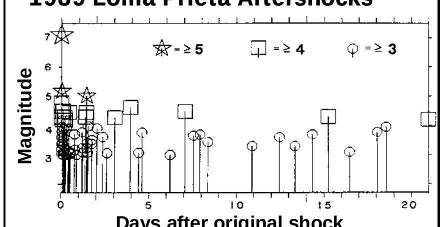
- Arrays of strong motion instruments can be set out after an earthquake, and data from aftershocks will allow the mapping of the fault surface. These instruments can also be coupled with a warning system to notify US&R TF before the effect is felt at a building site (discussed in Monitoring).
- Aftershocks diminish in intensity and number with time. They generally follow a pattern of there being at least one large (within one Richter magnitude) aftershock, at least ten lesser (within two Richter magnitude) aftershocks, one hundred within three, and so on (see the adjacent slide).

How Many Aftershocks ?

- USGS - Rule of Thumb
  - For every single decrease in magnitude, get 10 fold increase in number
- If original quake is M 7
  - 1 or so aftershock in range of M 6
  - 10 " " " " 5
  - 100 " " " " 4
  - 1000 " " " " 3
- Have fewer as time passes
  - Day 2 = 1/2 as many as day 1
  - Day 3 = 1/3 as many as day 1
  - Day 4 = 1/4 as many as day 1, etc

- The Loma Prieta earthquake had many aftershocks, but the largest was only magnitude 5.0 with the original quake being near magnitude 7.1.
- Wood, masonry, and concrete structures have collapsed during aftershocks, (even during one of the relatively moderate [5.0] Loma Prieta aftershocks).
- In the 2010-2011 earthquakes in Christchurch, New Zealand, the aftershocks have lasted for almost a year. The 22Feb11 aftershock was larger than the original, Sep10 quake, and it may be said that it was a separate earthquake. In any case, it illustrates that the patterns of aftershocks can vary, greatly, depending on the underlying, local geology.

1989 Loma Prieta Aftershocks

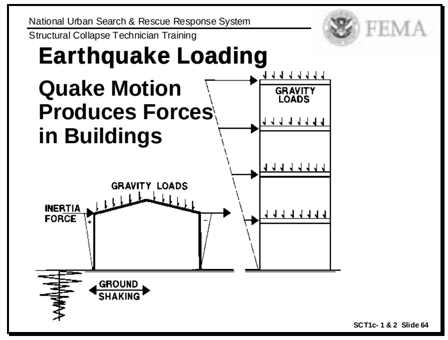


Basic Structural Loading

Earthquakes

- Some of the most destructive effects caused by earthquake shaking are those that produce lateral loads in a structure. The input shaking causes the foundation of a building to oscillate along a more or less horizontal plane. The building mass has inertia and wants to remain where it is. Therefore, lateral forces are exerted on the mass in order to bring it along with the foundation. This dynamic action can be simplified (in an upside-down way) as a group of horizontal forces that are applied to the structure in proportion to its mass, and to the height of the mass above the ground. These loads are often expressed in terms of a percentage of gravity weight and can vary from a few percent to nearly fifty percent of gravity weight.
- The mathematical relationship is expressed:

  Force = Mass (weight) x Acceleration.
- (The acceleration, as noted above is expressed as a percent of the acceleration of gravity (32 ft per second, per second)
- In multi-story buildings with floors of equal weight and relatively light walls, the loading is further simplified as a group of loads, each being applied at a floor line and each being greater than the one below, a triangular distribution. Seismically resistant structures are designed to resist these lateral forces through inelastic action and must, therefore, be detailed accordingly.
- There are also vertical loads generated in a structure by the vertical acceleration induced by earthquake shaking, but these forces rarely overload the vertical load resisting system. Earthquake induced vertical forces have caused damage to heavy concrete structures with high dead load compared to design live load. These vertical forces also increase the chance of collapse in concrete frame buildings due to either increased or decreased compression forces in the columns (increased compression that overloads columns or decreased compression that reduces column bending strength).

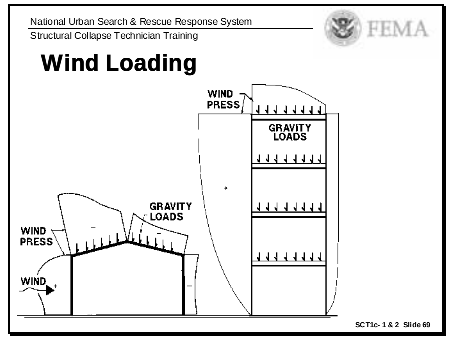


Windstorms

- Forces are generated on the exterior of the building based on its height, local ground surface roughness (hills, trees, other buildings), and the square of the wind velocity. The weight of the building, unlike the earthquake condition, has little effect on wind forces but is helpful in resisting uplift.
- Unless the structure is penetrated, all the forces are applied to the exterior surfaces of the building, in contrast to earthquakes, in which both exterior and interior walls are loaded proportionally to their weight.
- Wind pressures act inward on the windward side of a building and outward on most other sides and most roof surfaces. Special concentrations of outward force resulting from aerodynamic lift occur at building corners and roof edges, especially overhangs.
  - ♦ Wind pressure becomes much greater with increased speed.
  - ♦ The Pressure is proportional to the Speed^2. (That is the pressure from a 100 mph wind is 4 times as great as a 50 mph wind.)
  - ♦ Hurricane speeds vary from 74mph to 155mph.
  - ♦ Tornado speeds can exceed 250mph.

    (Therefore the pressure from a 250mph wind is 25 times (5x5) that of a 50mph wind)

    Fortunately there are few Tornados that have winds greater than 200mph, but even so the pressure from a 200mph wind is 4 times a great as the 100mph winds of a significant hurricane.
- The overall structure must be designed for the sum of all lateral and uplift pressures. Individual parts must be designed to resist the outward and inward pressure concentrations and must be connected to supporting members (beams, columns, walls, and foundation) to form a continuous resistance path. Forces are also generated on structures by airborne missiles that vary in size from roofing gravel to entire sections of roofs.

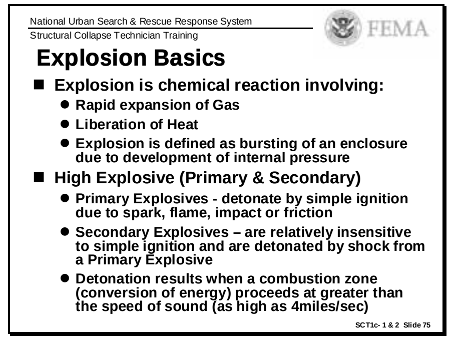


Destructive Windstorms

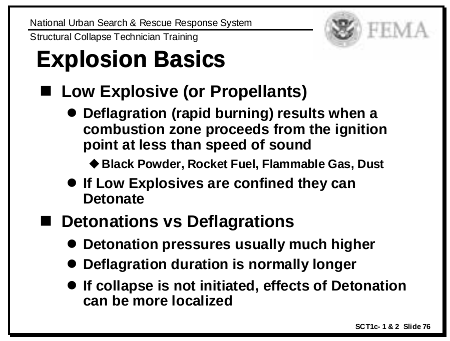
- **Hurricanes**
  - – **Large circular systems created by low pressure over ocean near equator**
  - – **May be 100 + mi. in diameter, winds up to 150mph**
  - – **Damage due to wind + storm surge**
  - – **Wind Force is Proportional to Speed^2**
    - **Force from 100mph = 4 times that from 50mph**
- **Tornadoes**
  - – **Violent vortices originating over land, usually created by colliding air masses.**
  - – **May be 1 mi. in diameter, winds up to 300mph**

Explosion

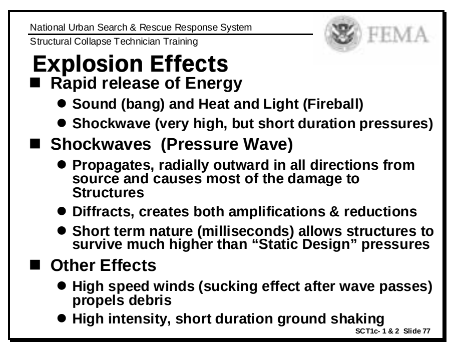
- Explosions occur when a solid or concentrated gas is transformed into a large volume of hot gases in a fraction of a second.
- In the case of high explosives, detonation (conversion of energy) occurs at a very high rate (as high as 4 mi/sec) .

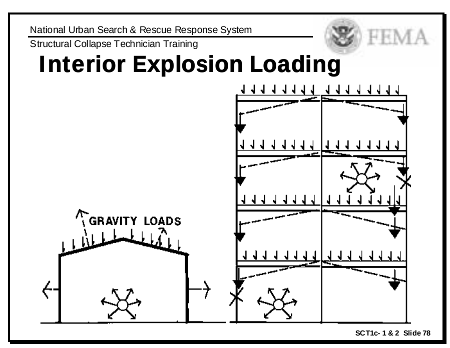


- Low explosives (such as gunpowder) undergo rapid burning at the rate of about 900 ft/sec.
- The resulting rapid release of energy consists of sound (bang), heat and light (fireball), and a shock wave that propagates radially outward from the source at subsonic speeds for most low explosives and at supersonic speeds for high explosives.

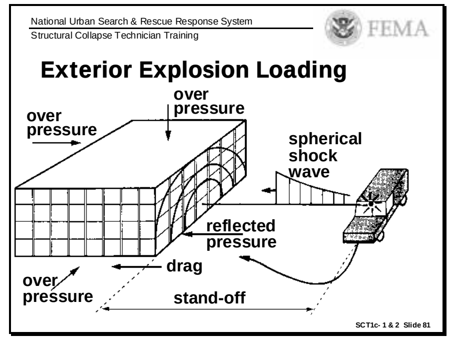


- It is the high magnitude, very short duration (milliseconds) shock wave, consisting of highly compressed particles of air that causes most of the damage to structures.
- When natural gas explosions occur within structures, gas pressures can build up within confined spaces, causing extensive damage.
- In all explosions, large, weak, and/or lightly attached wall, floor, and roof surfaces may be blown away.
    - ♦ The columns and beams in steel frame structures may survive a blast, but their stability may be compromised by the removal of their bracing elements (floors, shear walls).
    - ♦ In large explosions, concrete slabs, walls, and even columns may be blown away, leading to conditions that will produce progressive collapse as illustrated in the slide.
- In 1960, a progressive collapse started when a natural gas explosion caused the collapse of an exterior wall on the 18th floor of a 22-story building.
- The force of the falling weight of the floors above caused all the floors to collapse to the ground.

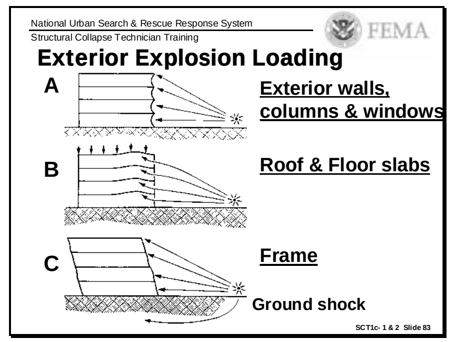




- In the case of an exterior explosion from a bomb, the shock wave is initially reflected and amplified by the building face and then penetrates through openings, subjecting floor and wall surfaces to great pressure.
  - ♦ Diffraction occurs as the shock propagates around corners, creating areas of amplification and reduction in pressure.
  - ♦ Finally, the entire building is engulfed by the shock wave, subjecting all building surfaces to the over-pressure.

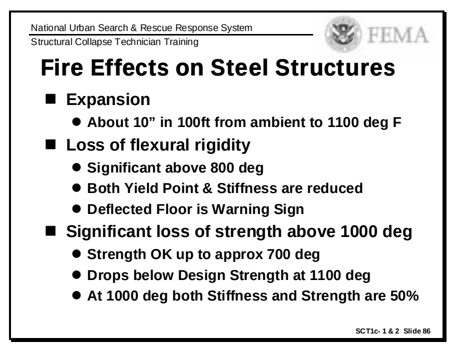


  - ♦ A secondary effect of an air-blast is a very high velocity wind that propels debris outward (as deadly missiles). In addition, a high intensity, short duration ground shaking (earthquake) may be induced.
- In very large explosions at close proximity to reinforced surfaces, the effect can be so severe that the concrete is locally disintegrated and separated away from the reinforcing steel.
  - ♦ Lighter wood, steel frame, and even pre-cast concrete buildings can be leveled by explosions as the wall and floor and/or roof planes are blown away, leading to an overall stability loss.

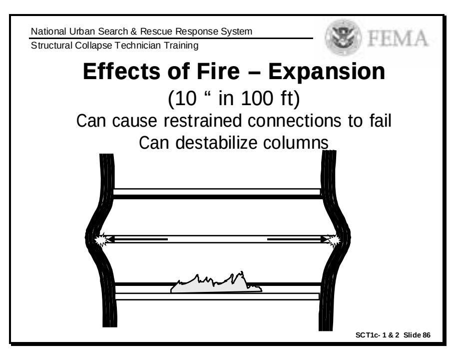


Effects of Fire on Steel Structures

The excess heat caused by fire will have the following negative effects: expansion, loss of flexural rigidity, and loss of strength.

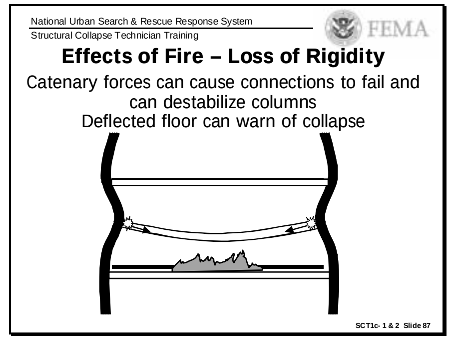


- **Expansion**
  - ♦ The coefficient of thermal expansion increases with temperature. At 70° F, it is .00065 for a 100° change in temperature, and this increases to .0008 inches per inch at 1000° F.
  - ♦ The total change in length for a change in temperature of 1000° is about 10 in.
  - ♦ In structures where lateral restraint is provided by walls or rigid columns, this excessive expansion can cause connections to fail and horizontal members to buckle.
  - ♦ Excessive expansion can also induce destabilizing forces in columns and exterior



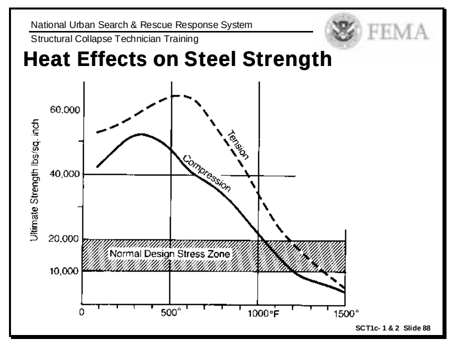
walls.

- **Loss of Structural Rigidity**



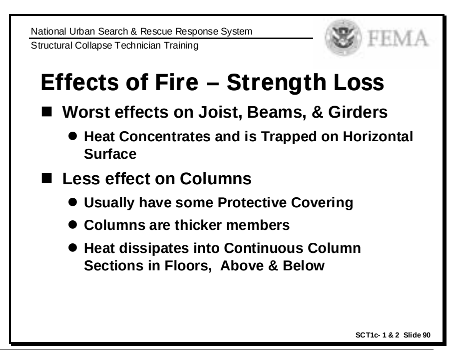
  - ♦ Both the yield strength and modulus of elasticity of steel drop to about 75 percent of normal values when the temperature reaches 800° F. They drop at an increasing rate at greater temperatures.
  - ♦ In fires, this drop results in the formation of “draped” or “bellied” beams and girders that generate significant tension stresses in their connections.
    - o These stresses can lead to the failure of the joints and collapse of floor sections.
    - o By being forewarned of this behavior, firefighters may avoid a deadly collapse.

- **Loss of Strength**



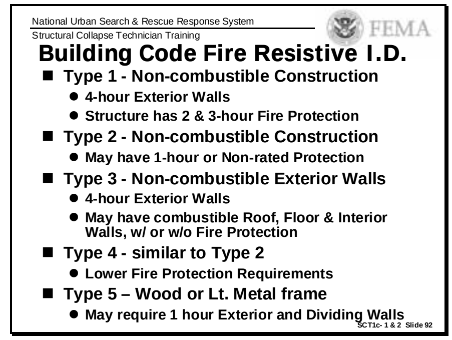
  - ♦ Steel actually gains strength when the temperature is raised from ambient to about 700° F.
  - ♦ For the normal structural steel used in buildings (A-36), both the strength and stiffness are reduced to about 50 percent at 1000° F.
  - ♦ Steel drops below the “design” strength at about 1100° F, and failure of a loaded structure will occur more quickly above this level (see the slide).

    - o Collapse due to strength loss is usually seen first in floor members, especially lightweight members such as bar joists and other trusses.
    - o Heat is concentrated at the undersides of floors, and low mass, high surface area members will be heated most rapidly.



  - ♦ Columns have a much better chance of surviving the effects of fire.
    - o They usually have some sort of covering, even if it is not “fire rated.”
    - o They are usually made from heavier, more compact sections.
    - o They may be able to dissipate the heat if they extend to floors above the fire area.

- **Building Code Fire Resistive I.D.**
  - ♦ Building Codes divide buildings into five categories based on the combustibility of their materials and amount of fire resistance.
  - ♦ They are listed as Type 1 through Type 5, with Type 1 being the most fire resistive and Type 5 the least fire resistive.
  - ♦ These Types are defined in the adjacent slide.

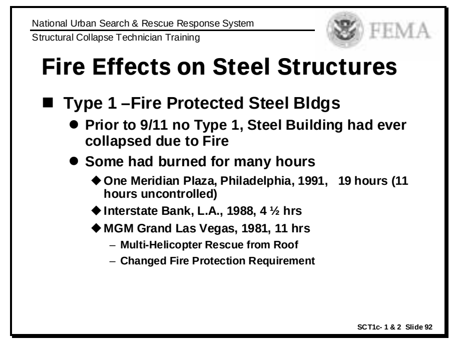


- **Fire Effects on Type 1 Steel Structures**

  Before the attack on the World Trade Center on 9/11/01, no Type 1, multi-story, fireproofed steel structure had ever collapsed due to fire.
  - ♦ A few of this type had burned for several hours, but none had collapsed.
  - ♦ The most notable fire of this type occurred at One Meridian Plaza in Philadelphia, when, based on the inadequacy of water supply, the decision was made to withdraw fire forces.

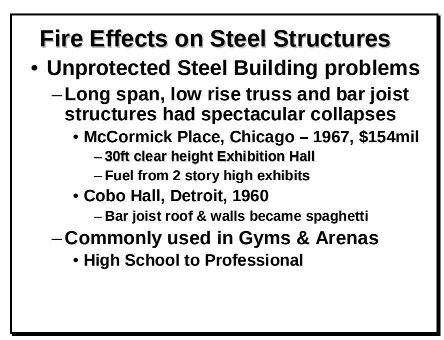
    The fire then burned through 10 floors, slowly transferring from floor to floor, until it was extinguished by an upper floor fire sprinkler system.
  - ♦ Spectacular high-rise fires in both Los Angeles and Las Vegas burned for hours but did not cause structural collapse.

    Well-organized evacuations were accomplished in both cases, with helicopters being used successfully in the early 1980's to remove occupants from the Las Vegas fire.



- **Fire Effects on Unprotected Steel Structures**

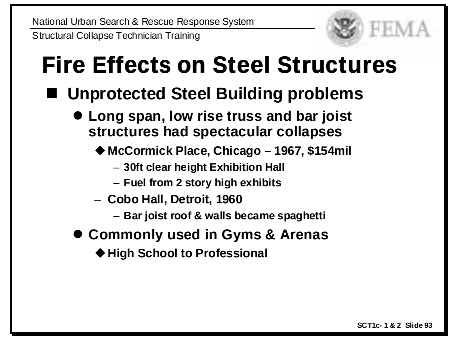
  Several spectacular fire-caused collapses of unprotected, long-span, low-rise steel structures have occurred.
  - ♦ McCormick Place was a large exhibition hall in Chicago that burned in 1967 (loss of $154 mi).
    - o No fireproofing was required since the steel truss roof structure was more than 30 ft above the floor.
    - o Exhibition booths that in some cases were two-stories high produced the fire load.
    - o Once started, the fire was able to produce



enough heat to collapse the roof structure.

- ♦ Cobo Hall in Detroit was also an exhibition facility whose roof was constructed of unprotected, light steel trusses.

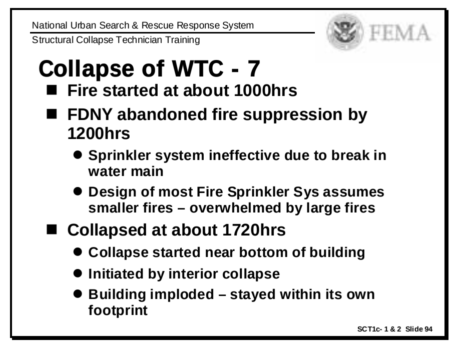
  The roof and some walls completely collapsed into spaghetti due to a contents fire in 1960.
- ♦ NFPA has published reports regarding these incidents, to inform firefighters of the dangers of sudden collapse in these light and long-span steel structures. Building codes have been changed to limit the use and permitted fire load for this type of structure.



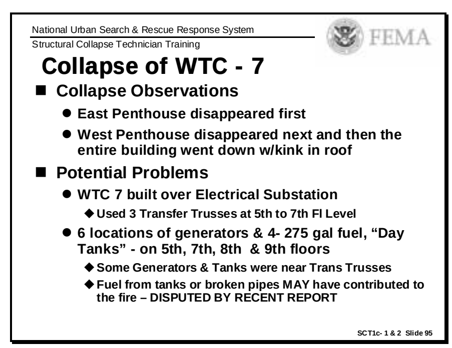
- **Collapse of World Trade Center, Building 7**

  The collapse of World Trade Center, Building 7 was probably the first Type 1, high-rise steel structure to collapse solely due to fire. It collapsed, starting at the bottom, after burning for about 7 hours, and it appeared that the interior collapsed first. There are several factors that could have contributed to the collapse.

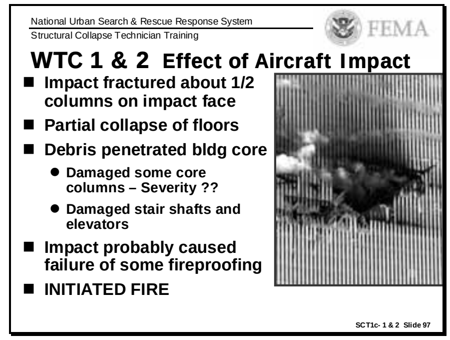
  - ♦ The fire sprinkler system was ineffective because of an inadequate water supply and the situation made worse by a broken water main. (Most systems are designed to extinguish only localized fires.)

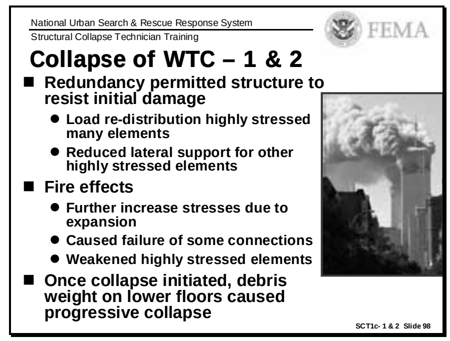


  - ♦ The building was constructed over an existing electrical substation that required the use of several transfer trusses. Main columns were terminated at the 5th floor.
  - ♦ Emergency generators and 275 gal fuel “day tanks” were placed on the 5th, 7th and 9th floors.
  - ♦ Pipes from a 6,000 gal tank on the 2nd floor and/or two, 11,000 gal buried tanks supplied most of the day tanks.
  - ♦ Fuel from broken pipes and/or the tanks could have contributed to the fire (though this theory is subject of study).



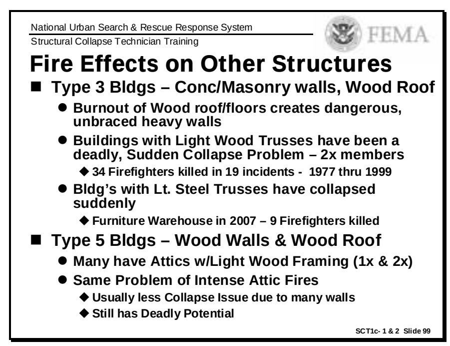
- **Collapse of World Trade Center Tower 1 and 2**
  As noted in the adjacent slides, the WTC Towers 1 and 2 probably collapsed due to a combination of factors.
  - ♦ After the jetliner struck the towers, the redundant outrigger truss system at the top of the structure redistributed the vertical loads that had been carried by the severed and badly damaged exterior columns to adjacent columns.
  - ♦ The debris from the jetliner probably dislodged a significant amount of the sprayed-on fireproofing, especially from the floor trusses.
  - ♦ The jet fuel fire ignited the contents of the building.
  - ♦ The ensuing fire then caused the initial collapse of the un-fireproofed floors.
  - ♦ Once the collapse was started, the load of the upper floors and the dynamics of the moving mass made it impossible to stop.
  - ♦ The World Trade Center Building Performance Study, Report 403 is available from FEMA at 1-800-480-2520.





Effects of Fire on Other Structures

- Type 3 and Type 5 buildings that have light wood trusses, especially those that “clear-span” between walls, have been a sudden-collapse problem.
  - ♦ The situation is especially dangerous when the light trusses are constructed in the hidden space above a ceiling. In this case an undetected fire can spread rapidly, fed by the abundant fuel, and cause a sudden collapse.
  - ♦ The National Fire Protection Association states that 34 firefighters have been killed in 19 incidents involving wood trusses from 1997 - 1999 (see www.nfpa.org for reports).
- Type 3 buildings with concrete or masonry walls and wood roofs have also been the sites for deadly fires.
  - ♦ The wood roof/floors often collapse due to burn-through and can pull exterior masonry or concrete walls in or leave them standing in an unbraced condition (as in the case of the Worchester, Massachusetts fire in 1999).



- These structures tend to have longer span trusses, and a Lean-to collapse or fire caused expansion can push-out the exterior walls into a collapse.
- The collapse of a roof truss that supports sloped rafters in an end bay can also cause exterior walls to be pushed out (parapets over storefronts are especially vulnerable).

- Type 3 buildings with light steel roofs have also been the site of deadly fires
    - In 2007 the sudden collapse of a light steel roof at a furniture warehouse caused the deaths of 9 firefighters
- Concrete structures can be damaged due to spalling, and shear walls can be cracked due to floor expansion. This situation is less deadly, but it should be carefully considered.

Flood

- Forces are generated on buildings due to hydrostatic lateral and lifting pressure, hydrodynamic forces, and debris impacts.
- Hydrostatic pressures can highly load foundation and basement walls and lift structures, when the water level is not equalized between exterior and interior spaces.
  Hydrostatic pressure can also lift wood floors and roofs off their bearings.
- River and ocean currents will load frontal and side walls that are submerged, and ocean waves and step-up flows can produce pressures as high as 1000 psf.
- Debris varying in size from floating wood pieces to floating structures can impact a building causing anything from broken windows to a total collapse.

Flood – Storm Surge & Tsunami

- Water in motion can do considerable damage to substantial structures as seen in the 2004 & 2005 Hurricanes, as well as the Indian Ocean Tsunami.
- Events that may lead to a US&R deployment include floods that may result from a swollen river or a failed dam, or tidal surge associated with a Hurricane or a Tsunami
    - For Hurricane-induced Storm Surge, evacuation of threatened areas generally minimizes or prevents victims.

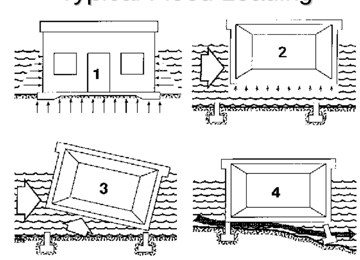
National Urban Search & Rescue Response System
Structural Collapse Technician Training

Fire Effects on Other Structures

- Type 3 Bldgs – Conc/Masonry walls, Wood Roof
    - Burnout of Wood roof/floors creates dangerous, unbraced heavy walls
    - Buildings with Light Wood Trusses have been a deadly, Sudden Collapse Problem – 2x members
        - 34 Firefighters killed in 19 incidents - 1977 thru 1999
    - Bldg's with Lt. Steel Trusses have collapsed suddenly
        - Furniture Warehouse in 2007 – 9 Firefighters killed
- Type 5 Bldgs – Wood Walls & Wood Roof
    - Many have Attics w/Light Wood Framing (1x & 2x)
    - Same Problem of Intense Attic Fires
        - Usually less Collapse Issue due to many walls
        - Still has Deadly Potential

SCT1c- 1 & 2 Slide 99

Typical Flood Loading



Flood Types

- Riverine
    - Slow Inundating Type
    - Fast moving, Flash Flood
- Hurricane - Tidal Surge
    - Fast Moving at Coast
    - Rains may lead to Riverine Flooding
- Tsunami
    - Create Catastrophic Waves – more than one
    - Can move inland for one mile or more
    - Create massive debris flows

Soil- Landslide, Mudslide, Debris Avalanche

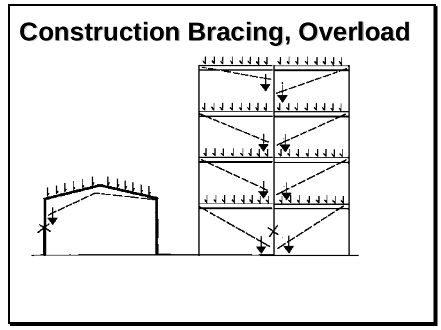
- Avalanche is a closely related hazard involving frozen water rather than soil.
- Devastating Mudslides, sometimes called Debris Avalanches, have occurred in many locations throughout the World.
- They most often occur due to the saturation of surface soils, caused by torrential rain. This may cause a mass movement of soil that can devastate most everything in its path.
- On steep hillsides, where upper soils may be marginally stable, at "normal" moisture content, the saturation can de-stabilize the equilibrium by:
  - ♦ Increasing the weight of the soil mass,
  - ♦ Reduce the shear strength of the soil by separating the grains/particles, and,
  - ♦ By lubricating the interface between shallow soils and a more dense, impervious rock material below.
- Examples of landslide disasters are the Love Creek debris flows in Northern CA in 1982 and La Conchita in Jan2005.
  - ♦ In most circumstances, viable voids are unlikely, given the flowability and pressures of the material and the lack of oxygen within the material.
  - ♦ The greatest concerns for Rescue Teams in these events would be dealing with potentially unstable soil masses and collapsed structures shifting under the pressures and movement of the debris. As water flows out of the mass, it may consolidate, causing continual later movement and settlement.
  - ♦ At higher water contents, the soil behaves as a very heavy (i.e. 145pcf concrete) fluid, therefore trenches into the soil/debris mass should be shored/braced for twice the forces normal assumed in heavy trench rescue.
  - ♦ The head-scarp and upslope debris, and debris mass, all should be monitored for movement.

Landslide, Mudslide – Debris Avalanche

- **Often occur due to saturation of surface soils**
  - **Torrential rains – 6 or more in/day**
- **Soils on steep hillsides may be marginally stable**
  - **High water content increases weight and reduces shear strength (inter-pour pressure)**
  - **Lubricates underlying soil/rock interface**
- **Produces four US&R issues**
  - **Continued flow from Headscarp**
  - **Consolidation/movement as debris mass gives-up water**
  - **Trench bracing to resist concrete like material**
  - **Flowability reduces chance of survivable voids**
- ***Need Monitoring of Headscarp and Debris Mass***

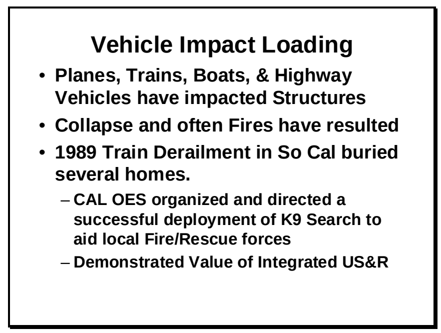
Construction Bracing, Urban Decay, and Overload

- These sudden collapses usually occur due to gravity loading when a vertical support is either inadequate, overloaded by snow, overloaded because of a plugged roof drain, or reduced in capacity because of age, corrosion, or non-engineered alteration.
- Failures of this type occur all too frequently, but most often affect only one structure at a time. In some cases, building structures with very hazardous conditions have been left standing in this type of collapse (for example, multi-story URM walls left unsupported when wood floors pancaked).



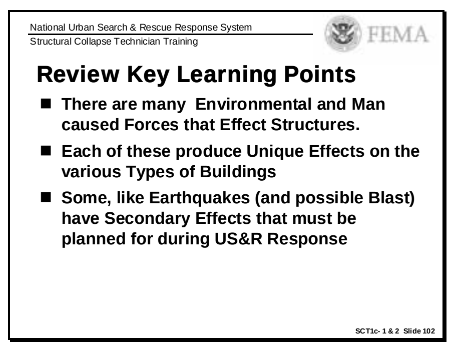
Vehicle Impact Loading

- Structures have been severely damaged and set on fire by vehicle impacts.
- A 1989 train derailment in California led to a well-organized, integrated response that was successful in saving a victim in what was originally perceived as an un-survivable condition.



Summary

- We have discussed both Natural and Man-made effects that have been the Causes of Collapse in the past. Each produces unique effects on structures that must be understood.
- Some like Earthquake and possibly Blast can have secondary effects that need to be planned for during US&R incidents.



PART 3 - COLLAPSE PATTERNS

The Objectives for this section are listed in adjacent slides. We will discuss the Collapse Patterns that have occurred which will give us insight on how structures behave when subjected to different types of extreme loading. **The student should then be able to use this knowledge in determining the most probable location of victims.**

Most building collapses occur due to loss of stability. In other words, the basic shape is significantly changed when subjected to a combination of forces. The new, changed shape is much less capable of carrying the forces; therefore, the structure will rapidly continue to change until it finds a new shape that is stable. A typical example of lost stability is that of the slender column that "gets out of the way of the load by buckling" as the load comes to rest on the ground.

Basic Collapse Patterns include the following:

- Inadequate shear strength,
- Inadequate beam/column joint strength,
- Tension/compression failure,
- Wall-to-roof interconnection failure,
- Local column failure,
- Single floor collapse.

a. Inadequate Shear Strength

Inadequate shear strength failures are normally caused by earthquake shaking, but high velocity winds can produce the same effect. It is most commonly seen in wood structures that have weak wall sheathing or walls of insufficient length. It may also be seen in buildings with unreinforced masonry and/or unreinforced concrete walls, as well as in diagonally braced steel frames. In rare instances it could occur when reinforced concrete walls are present.

Basic instability occurs when gravity load is offset a distance that is large enough to overcome the shear capacity of walls at a particular level, in first story.

The horizontal resistance required to maintain stability in the racked condition is proportional to the percent of offset. For example, when a 10-foot-high story is offset 1 foot, then 10 percent of the total gravity load above that level is required to keep the parallelogram from becoming flatter. This is the **Offset Collapse Pattern.**

National Urban Search & Rescue Response System
Structural Collapse Technician Training

Terminal Objectives

- The Student shall understand the how building structures can be separated into specific types that exhibit unique collapse patterns when subjected to extreme forces due to Earthquake, Wind , and Explosions
- The Student will be able to use this knowledge to assist in determining locations of Potential Victims

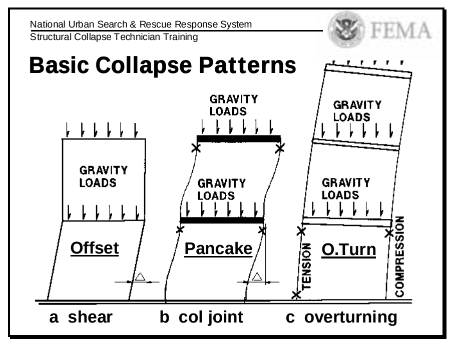
SCT1c- 3 Slide 2

National Urban Search & Rescue Response System
Structural Collapse Technician Training

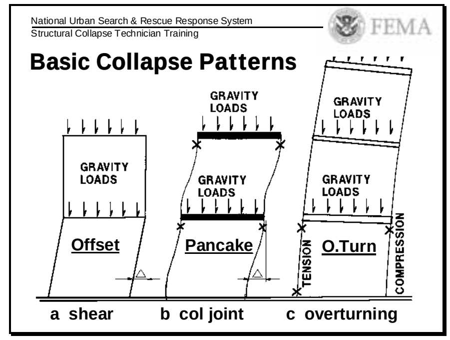
Key Learning Objectives

- Quake, Wind and Blast produce Unique Effects on Different types of Structures
- Each of these produce Unique and Recognizable Collapse Patterns
- This Knowledge will allow us to Recognize the Survivable Voids and potential victim location

SCT1c- 3 Slide 3



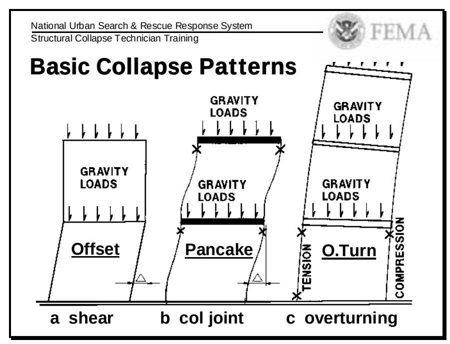
b. Inadequate Beam/Column Joint Strength



Inadequate beam or column joint strength failures are caused mostly by earthquake shaking of buildings that have joints with poorly confined concrete.

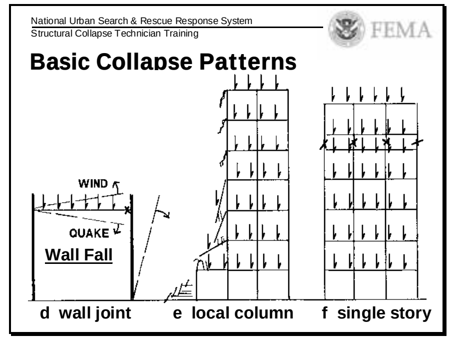
- The cycling of the structure when excited by the earthquake causes moment-resistant joints to unravel as concrete chunks are stripped away from the reinforcing steel cage.
- The gravity load can no longer be supported by these columns, and it drives the structure earthward until it stops on the ground or lower floors that have sufficient strength to stop the falling mass.
- This type of collapse may result in a pancaked group of slabs held apart by broken columns and building contents, or a condition in which columns are left standing, punched through the slabs. The slabs may or may not be horizontally offset from each other. This is a **Pancake Collapse Pattern.**

c. Tension/Compression Failure



Tension or compression failure is caused mostly by earthquakes and usually occurs in taller structures with concrete shear walls and/or concrete or structural steel moment-resistant frames.

- The tension that is concentrated at the edges of a concrete frame or shear wall can produce a very rapid loss of stability.
- In walls, if the reinforcing steel is inadequately proportioned or is poorly embedded, it can fail in tension and result in the rapid collapse of the wall by overturning.
- A more common condition occurs when the tension causes the joints in a concrete moment-resistant frame to lose bending/shear strength. As previously discussed, a rapid degradation of the structure can result in partial or complete pancaking, as is the case with beam or column failure.
- The failure of the Pino Suarez Tower is an example of how poorly proportioned, steel structures can catastrophically overturn as a result of the compression failure of the columns. We will call this an **Overturn Collapse Pattern.**



d. Wall-to-Roof Interconnection Failure

In a wall-to-roof interconnection failure, stability is lost since the vertical support of the roof/floor is lost in addition to the horizontal out-of-plane support of the wall.

This condition can be triggered by any of the destructive forces previously mentioned.

We will call this a **Wall Fall Collapse Pattern.**

e. Local Column Failure

Local column failure can lead to a loss of stability and/or a progressive collapse in a part of a structure and may, again, be caused by any of the previously mentioned forces.

Pre-cast concrete and structures that have wood floors tend to be more susceptible to a progressive type failure because of a lack of continuity in these construction configurations.

f. Single Floor Collapse

Single floor collapse has occurred in earthquakes due to pounding or vertical irregularities that focus the damaging effects on a single story.

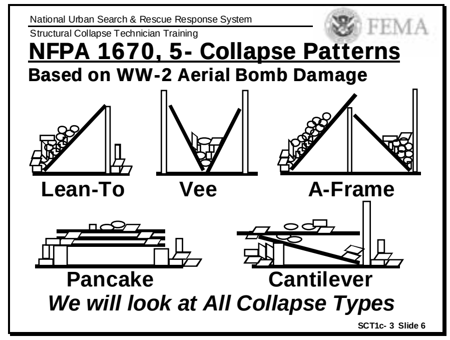
Most common of this type of collapse is a **Soft First Story Collapse**, which we will discuss later.

Summary, Basic Collapse Patterns

In summary, in most collapses (except cases in which wind causes lifting), the driving force is the gravity load acting on a structure that has become unstable because of horizontal offset or insufficient vertical capacity. In addition, subsequent lateral loads from wind or aftershocks can increase the offset, exaggerating the instability. The structure is often disorderly as it collapses. Some parts may remain supported by adjacent un-collapsed bays as tension structures.

The issue in US&R is not the academic one of how the structure collapsed but what additional collapse is possible, how stable is the existing configuration, and where are the most probable location of survivors.

NFPA, 5 Collapse Patterns



There are five collapse patterns that have been defined by the NFPA 1670 Committee. This committee sets the standards for various types of training that involves first responders.

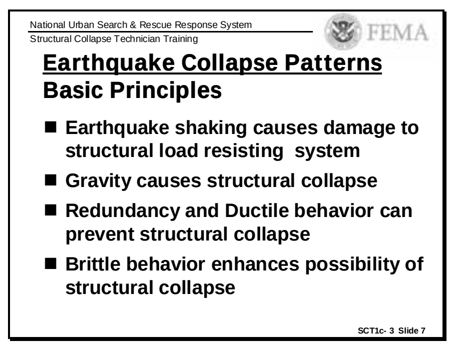
These five were taken from WW-II Civil Defense documents, and are useful in communicating basic patterns. In this manual we will present additional collapse patterns that better describe collapses that involve more modern construction.

Understanding the types of collapse patterns will provide valuable information in determining everything from the need for shoring, the types of shoring to be used, possible victim location, and victim access to the probability of victim survivability.

It should be noted that one may find more than one collapse type in addition to the primary type at a given incident.

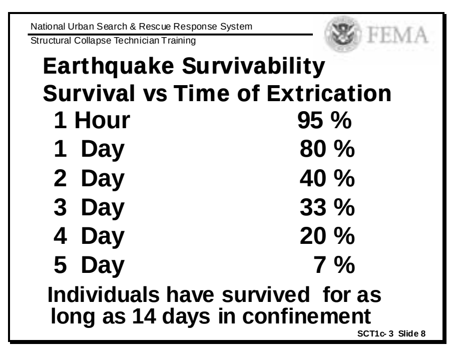
EARTHQUAKE COLLAPSE PATTERNS

The Basic Principals



- Earthquake shaking causes damage to structure.
- Gravity causes collapse.
- Redundancy and ductile behavior can prevent or reduce the extent of a collapse.
- Brittle behavior enhances the possibility and increases the extent of a collapse.

Earthquake Survivability



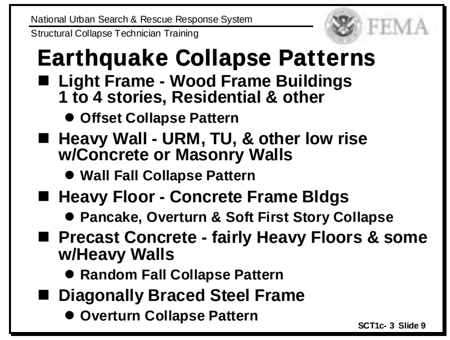
As discussed on Section I, the focus of US&R is to find and remove as many trapped victims as possible. As shown on adjacent slide, the survival rates decrease with time. The first 24 to 36 hours are often referred to as the **Golden Hours**. Even though survivors have been located and removed after as many as 14 days for earthquakes, these are rare occurrences. It is important that responders use their knowledge of collapse patterns to assist search in prioritizing the disaster site.

We will later discuss that survivability following blasts is very low, as few, have survived within the collapse zone

Basic Building Types

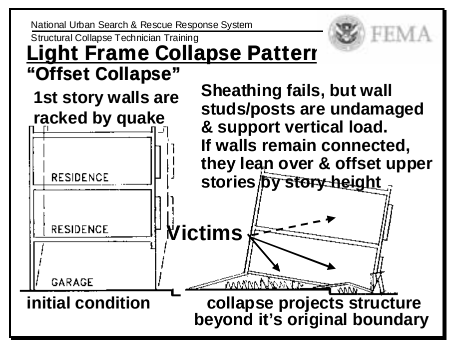
Based on previous earthquakes, the ATC-20 building types can be further divided into five separate groups, each exhibiting a distinctive collapse pattern. These groups are:

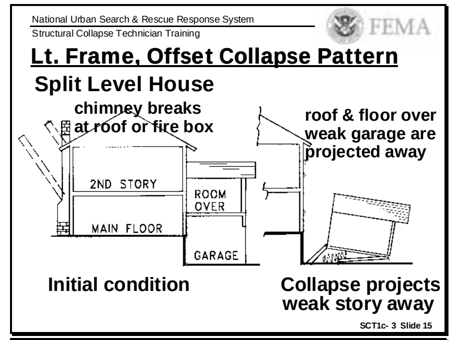
- **Light Frame**: mostly wood frame;
- **Heavy Wall**: URM, tilt-up, and other low-rise buildings with concrete and masonry walls;
- **Heavy Floor**: concrete frame buildings and highway bridges;
- **Pre-cast Concrete Buildings**: fairly heavy floors and some heavy walls.
- **Steel Frame Buildings**: either moment frame or diagonally braced frame buildings. Most collapse problems have occurred in diagonally braced buildings.

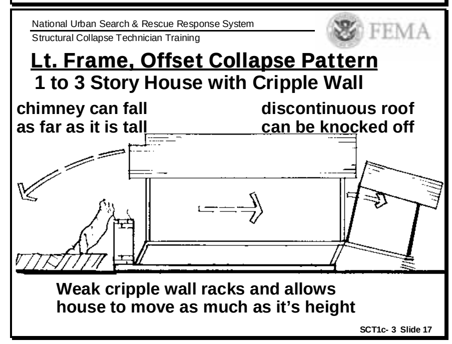


Light Frame Collapse Patterns

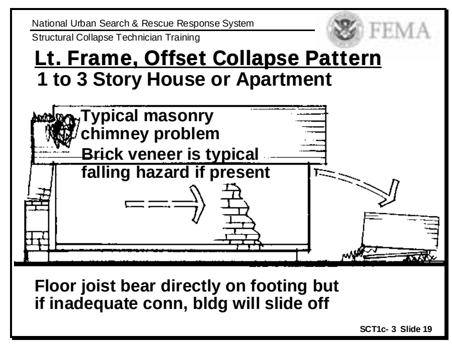
- These structure are unique in that they may be described as **Skin and Bones** structures. The lateral load resisting Skin is separate from the vertical load resisting studs, posts, and columns. In an earthquake the sheathing is the element that attempts to resist the lateral movement, and the bones only receive additional stress if they are located at the edges of walls
- Collapse usually occurs when the sheathing on the lower walls have insufficient strength to resist the lateral forces and the walls rack (become parallelograms). This is called an **Offset Collapse Pattern.**
- If there is a sufficiently heavy load on these walls, they can completely collapse as the wall top moves sideways a distance equal to its height, as shown in the slides.
- This movement causes the structural collapse to be in the form of part or all of the building being projected away from its original foundation by the height of the story walls that fail.





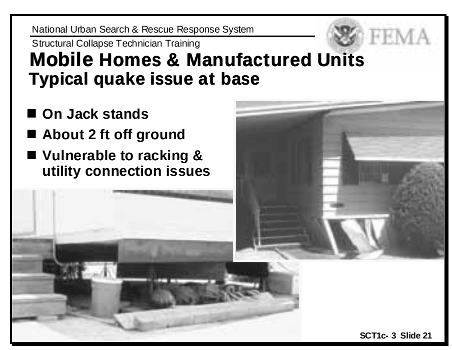


- This offset can occur in a split level house as well as a 3 or 4 story building.
- When the bottom story of a multi-story structure fails in this way, additional stories can collapse due to the impact of the first story hitting the ground.
- In an **Offset Collapse**, most victims will be found within the story or stories that have offset and collapsed. Due to the light nature of wood buildings, furniture, appliances, kitchen cabinets, etc may form voids. Safest access will be achieved by cutting through the wood floors from the story above. However, in multi-story, stacked construction, rescuers must recognize that there has been an offset between stories
- Victims may be found above the offset story, as they may have been injured due the sudden and violent movement of these upper stories as the structure below offsets.



- In some light frame, wood construction, there is a crawl space below the first story. Structures of this type may be as tall as 3 stories. In older buildings of the type the crawl space walls may not have structural sheathing, and are vulnerable to an Offset Collapse, in the weak story.
- Most modern buildings of this type have plywood sheathing in the crawl-space story, and many older building of this type have been strengthened
- In wood structures, when the lower floor rests directly on the foundation, but is not well connected to that foundations, the entire structure can slide over or off the foundation
- In all cases, a great danger of fire exists as a result of the combination of broken gas (or other fuel) lines and combustible debris.

Mobile Homes & Manufactured Units

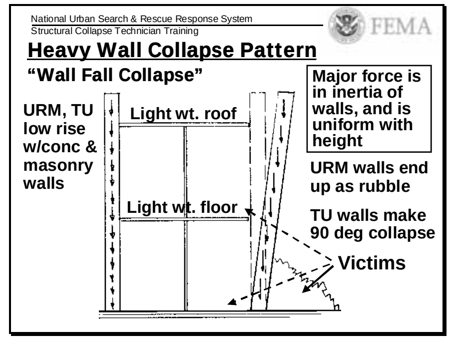


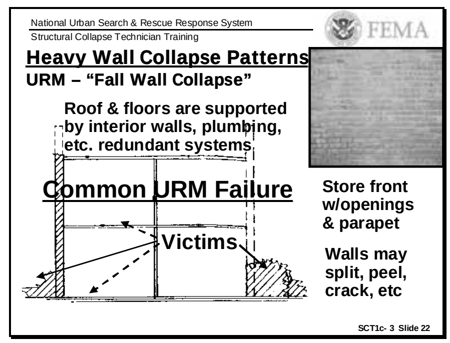
Mobile homes are a problem in quake and just about any disaster type. Base connections are usually critical These are the common problems:

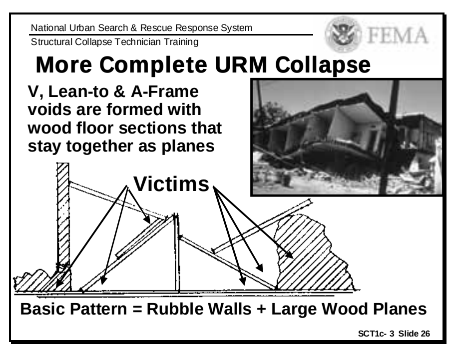
- Units will offset off their jack stands
- Jacks can punch through floors
- Utility connections may be broken.
- If propane gas is used for fuel, there may be a fire/explosion hazard

Heavy Wall Collapse Patterns URM

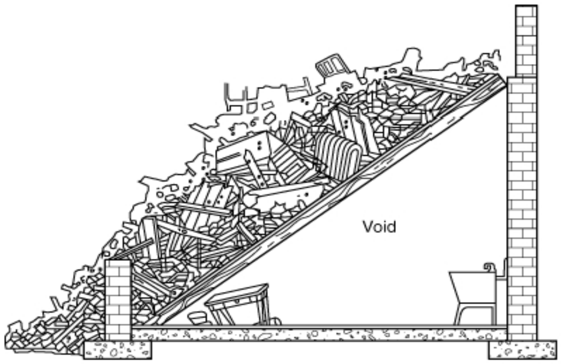
- Collapse is usually partial and is strongly related to the heavy, weak bearing walls falling away from the floors. This is the **Wall Fall Collapse Pattern.**
- In URM buildings, the walls normally fall away from their original position but most often do not project out as far as their height.
- The combination of the weak interconnection of the masonry pieces and gravity tends to cause the debris to stay within 10 to 15 feet of the building face.
- When property line walls fall on an adjacent, lower building, these structures will usually have some sort of roof/floor collapse.
- In many URM Wall Fall Collapses, large, room size, void spaces remain within the structure. Most occupants in that case are likely to have exited. Areas outside and adjacent to the walls where parts of the heavy walls have fallen often contain badly injured or dead victims.
- When sections of the wood roof and/or floors collapse, many easily accessible voids can be created by furniture, machinery, appliances, etc
- However, in collapses resulting from the failure of interior columns or fire, a very precarious situation involving multi-story heavy walls that are left standing without any laterally supporting floors/roof is possible. Under such conditions, it is probable that the walls could fall in such a way that they extend their full height along the ground, and trap and kill anyone outside the building
- The combination of broken gas lines and debris can lead to fire.
- As mentioned previously the experience with this type of building lead to the development of the 5 NFPA collapse patterns as shown on the following page. We will discuss probable victim location for these on the page following



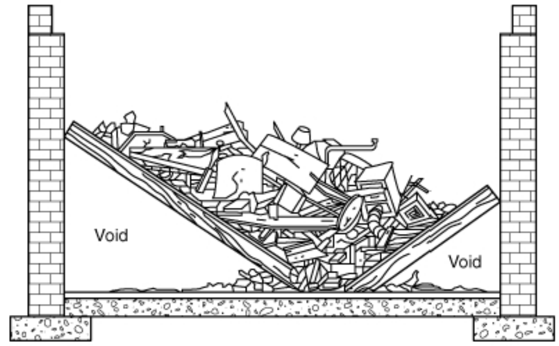




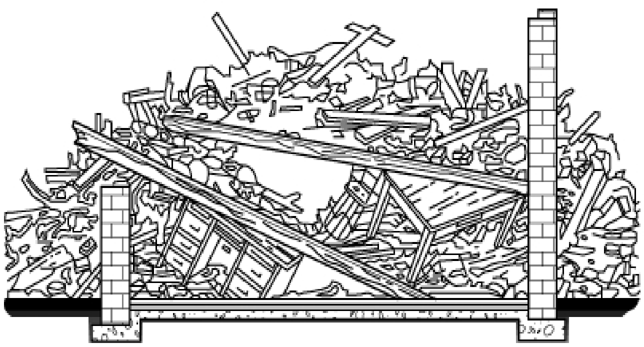
FIVE COLLAPSE PATTERNS DEFINED BY NFPA 1670
(taken from WW2 Civil Defense Publications)



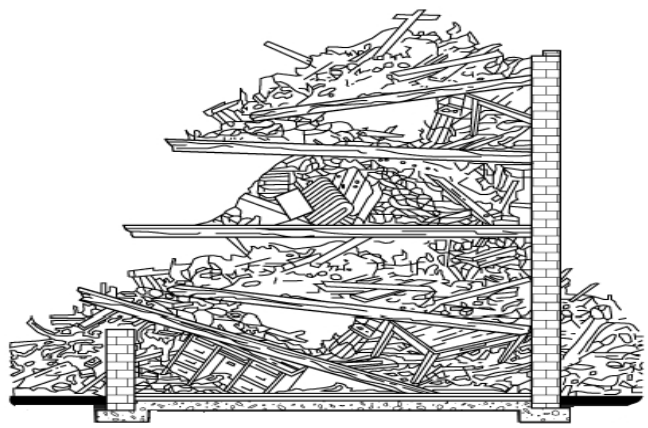
LEAN-TO
Formed when one wall collapses, leaving other end with questionable support
(URM, TU, Heavy Floor & PC Concrete)



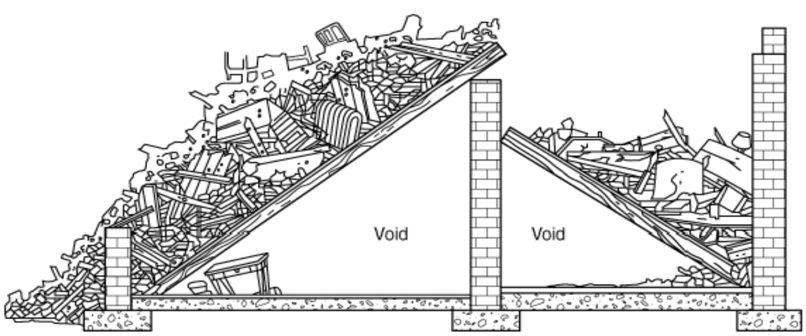
VEE
Occurs when interior support fails
More common in decay/overloaded column
(URM, Heavy Floor and PC Concrete



PANCAKE
Occurs when all vertical support fails
(URM, Heavy Floor and PC Concrete)

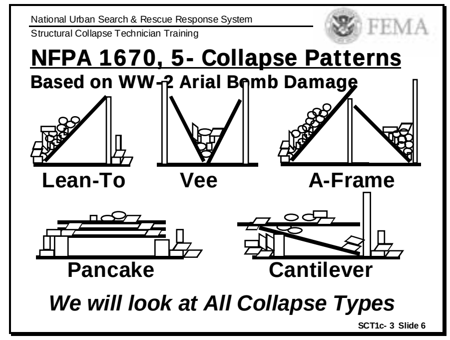


CANTILEVER
Essentially a Pancake with extended floors
(URM, Heavy Floor and PC Concrete)



A-FRAME – Occurs with Lead-To collapse in adjacent spaces or buildings

Heavy Wall Collapse Patterns URM (continued)

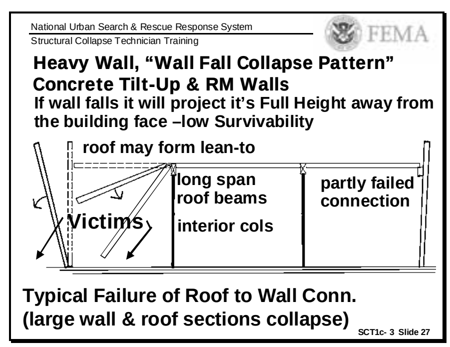


- In the Lean-to, V and A-Frame collapse patterns, large voids may be created as shown in the diagrams on the previous page. However the trapped victims may be found on top of the sloped floor, near the bottom. The contents of this space above the floor have slid to this location, and may have captured victims as well. It should be easy to access this type of collapse, but care must be taken when moving heavy objects, and some shoring may be advisable.

  In this type of collapse, victims may also be trapped below the sloped floor at the shallow end. In this case access may be made by cutting through the floor. Unless it has been carefully evaluated by a Structures Specialist, the URM walls should not be breached
- For Pancake and Cantilever collapse patterns, survivable voids may be formed between floors by furniture, machinery, appliances, etc, if the weight on the floor is relatively light. Access may be made by cutting the wood floors, or by finding roof hatches, stairs, or elevator shafts

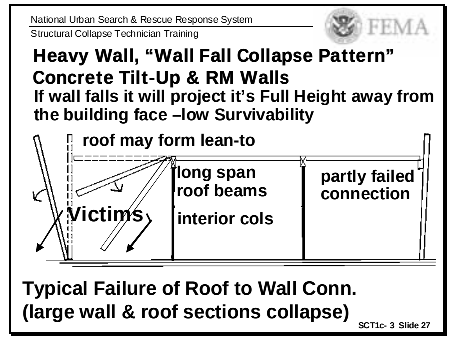
  In Heavy Floor Concrete construction, the voids are usually smaller and are created by broken parts of the structure, like columns and walls. Access is still made by breaching the concrete slabs from above with saws and drills

Heavy Wall Collapse Patterns – Tilt-up



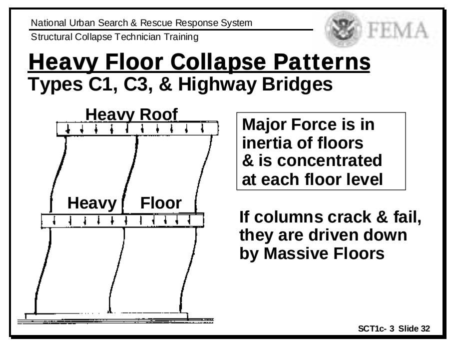
- **Walls in tilt-up buildings** normally fall away from the roof or floor edge, but since they are very strong panels, the top of the wall will fall as far away from the building as its height. This **Wall Fall Collapse** is somewhat different from one that involves URM construction
- Since tilt-ups have longer roof/floor spans, the adjacent section of roof will usually collapse, although it may still be supported at it's far end, and form a Lean-to collapse.
- Tension forces will be imposed on the roof system; therefore, all beam-to-beam and beam-to-column connections may be damaged and/or pulled out.

Heavy Wall Collapse Patterns – Tilt-up (continued)

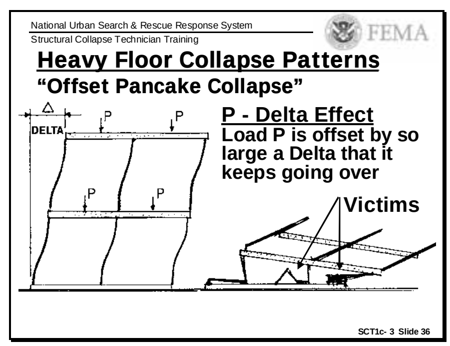


- Since tilt-up walls are relatively strong and collapse as a unit, it is unlikely that victims in the wall fall zone can survive
- Within the structure, since the roof is relatively long span and light, lean-to voids may be created. In this case, victims should be found under to sloped surface near to bottom.
- If there are interior partitions within the structure, many types of survivable voids can be formed, including Lean-to, A-frame, Vee, or one or more levels of a pancake condition

Heavy Floor Collapse Patterns



- A heavy floor collapse can be partial to complete. It is usually caused when columns are weakened at the column-floor joints by earthquake motion, are then, unable to support the heavy floors.
- The collapse patterns are varied, as will be discussed. They include pancake, offset pancake, soft story (mostly first story), overturned, and torsion (corner buildings)

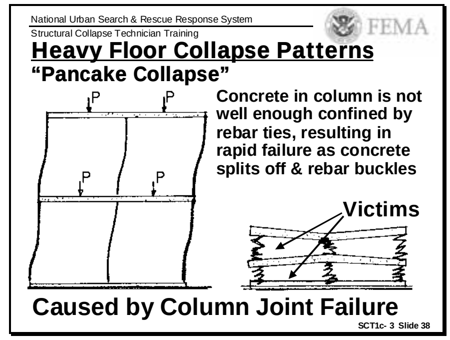


- These heavy floor structures usually fall on themselves, but they can project laterally as they fall, if the columns and/or walls are strong enough not to fracture. In other words, the columns can fail due to hinging at the top and bottom, and then the collapse becomes an **Offset Pancake**.
- The voids can be very difficult to access; they are usually still well interconnected with reinforcing steel, and fairly well in tact. Although time consuming, access can be made by breaching the concrete slabs from above with saws and drills
- If the floors are sloped, similar to a lean-to collapse, triangular voids can be formed. It is most likely that entrapped victims will be found above and below floors at the bottom of the slope, and access should be sought within the void

  However, since the floors are heavy and may have been forced down by upper stories, fully pancaked floors may also be found in this type of collapse. Heavy pancake will be discussed next

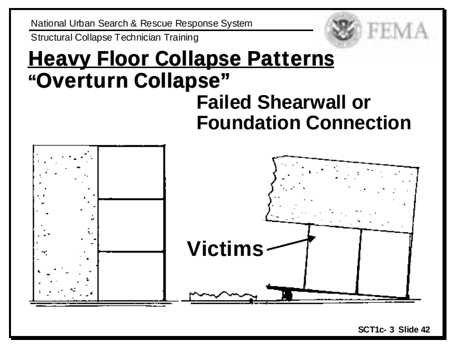
Heavy Floor Collapse Patterns (continued)

- Complete pancake collapse can occur when the column-floor joints fail and the structure is so heavy that gravity causes it to collapse onto itself.
- The height of the remaining voids between floors in **Pancake Collapsed** buildings will depend on what projections the slabs originally had (like beams and thickened slabs at columns) and broken concrete columns or partly crushed contents.



- As discussed in Offset Pancake, victim access is difficult, but can be done by saws and drills in the hands of trained rescue personnel. The mostly in-tact slabs can span obstructions and form life saving voids, but they are also much more difficult to breach than wood floors

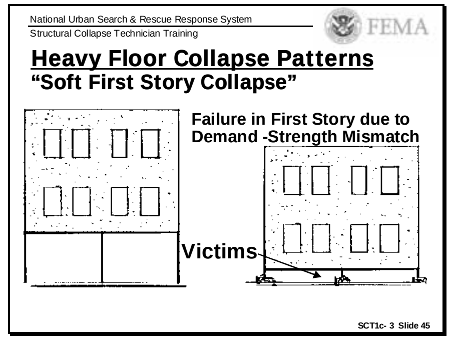
- Earthquake motion can cause reversing tension and compression forces at the faces tall, moment-resistant frame structures. When these quake induced forces in the exterior columns abruptly change from tension to compression, a sudden and progressive failure can occur. If several stories are effected this can lead to a pancake collapse. However some taller heavy floor structures have been subjected to overturning collapses



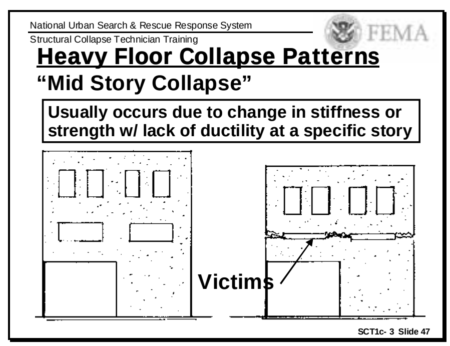
- **Overturned Collapses** have occurred in these taller structures when columns or walls fail due to tension and shear failure at the base. The leading cause of this is inadequate anchorage to the foundation.
  - ♦ Under these conditions, the structure can project sideways by its full height.
  - ♦ Survivability has been high in this type of collapse, since the original structural configuration has been maintained above the lower story.

  The victims in the upper stories may have been thrown about and injured, but they can be easily accessed using ladders, man lifts, etc.
  There were many collapses of this type following the Taiwan Earthquake in 1999, and most of the occupants survived

Heavy Floor Collapse Patterns (continued)



- A **Soft First-Story Collapse** occurs in buildings that are configured such that they have significantly less stiffness (many fewer walls or no walls) in the first story than in the stories above.
  - ♦ This configuration often occurs in building where the first story occupancy is commercial (few if any walls are desired) and the upper stories are residential.
  - ♦ The quake damage becomes focused on the "Soft Story", and what lateral resistance that is present becomes overwhelmed.
  - ♦ Soft first story configuration is not viable in and type of rigid construction (concrete, masonry, etc), and even wood structures with this defect perform poorly .
  - ♦ The collapse is often limited to the one "soft story", as the building becomes about one story shorter.
  - ♦ Most all victims will be found within the first story, and the survival rate is very high above the second floor.
  - ♦ The first story should be accessed by cutting through the second floor, although properly tanned search dogs can be directed into the first story voids from ground level



- A **Mid-Story Collapse** can occur when a middle story is configured with much different stiffness than the stories above and below. **Can occur at any abrupt change in stiffness**
  - ♦ It can occur when a story has no walls and the ones above and below have significant walls.
  - ♦ It can occur when a story has stiff, short columns and the ones above and below have longer, more limber columns.
  - ♦ Survival should be high above and below the collapsed story, however access to stories above may be blocked.
  - ♦ The victims within the collapsed stories should be accessed by breaching from the story above. Also an access to the upper stories from below needs to be created in order to allow those trapped above the collapse to exit and rescuers to access the floor to be breached

Heavy Floor Collapse Patterns (continued)

- **Pounding** can cause a mid-story collapse, leaving a difficult problem to assess because the remaining floors are overloaded.
  - ♦ A pounding collapse normally occurs when two adjacent buildings have floors that are at different elevations.
  - ♦ The very stiff /strong edge of a floor in one building will cause the collapse of the adjacent building's column when they collide.
- The victim access issues are essentially the same as noted previously for Mid-Story Collapse

- **Torsion effects** occur in concrete frame structures when URM infill is placed within the concrete frames on the exterior property line walls for fire resistance. This occurs in corner buildings, where the street-side concrete frames have only light-transparent, infill – "Open Sides"

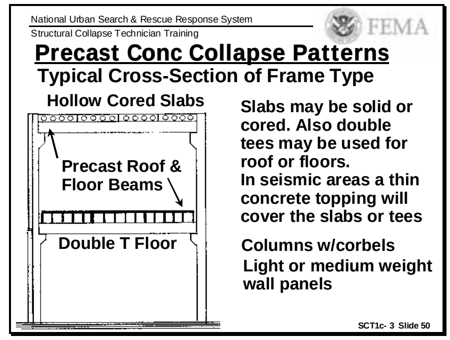
  The property-line walls, prior to being cracked by earthquake motion, are stiffer than all the other moment resistant frames in the building. This can cause a temporary eccentric condition that can lead to collapse of the beam-column frames on the "Open", street sides of the building.
- In most cases, only the structural bays next to the street sides will collapse, leaving a significant part of the structure relatively undamaged

  The collapse zone will normally be some combination of a pancake and lean-to collapse, since some of the floor slab will be hanging off the uncollapsed area.
- Most of the victims will be found in these collapsed areas, adjacent to the two street sides
  - ♦ Search and the following victim access should be attempted by working from the uncollapsed area at each floor level, into the collapsed area
  - ♦ Voids will be created by pieces of structure and projecting structural elements, as well as the shape if slabs remain hanging from the uncollapsed structure
  - ♦ If viable victims are found, local and multi-story shoring may be used to reduce risk

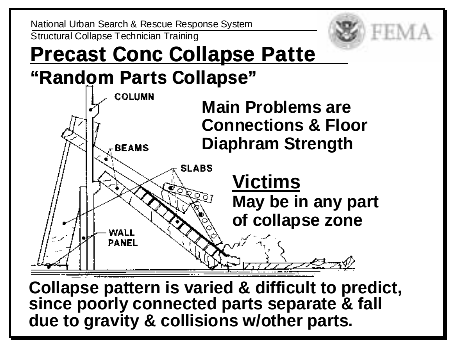
Pre-Cast Concrete Collapse Patterns

- A pre-cast concrete collapse is usually caused when the pre-cast parts become disconnected from one another and the structure very rapidly loses stability.
- The collapse normally contains numerous layers of broken and unbroken pieces of slabs, walls, beams, and columns. The best description of this is **Random Parts Collapse.**
- It is difficult to predict how far the parts can be projected away from the original structure's position or if survivable void spaces will be created.

  Gravity normally will drive parts downward without projecting them laterally away from the building, but they may form a relatively compact rubble pile.



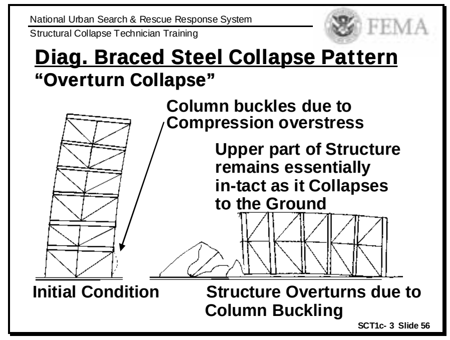
- Victims are normally located within the rubble, but survivability has been low. Voids can be created, but there is not regular pattern.
- The voids can be difficult to access, but the slab can be removed, layer by layer, since interconnection is normally poor to non-existent.
- If the structure contained single or double tee floor members, they have two inch slabs through which access openings can be cut. If a topping slab originally covered the tees, breaching will be more difficult
- Precast Concrete Parking Garages have performed particularly badly.
  - ♦ They may be as very large as 400ft x 400ft and be as many as 8 stories tall.
  - ♦ Outside of California, most do not have a cast in place floor topping to help tie the structure together.
  - ♦ In some cases a cast in place slap may be installed that is supported by precast beams and columns. This configuration should perform better, especially if there are shear wall



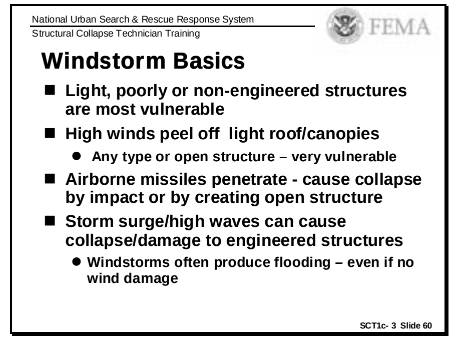
Steel Frame Collapse Patterns

- Collapse is usually caused when columns are not proportioned so that they are capable or receiving the combination of structure weight and all the vertical component of the quake load that can be delivered by the diagonal braces connected to them.
  - ♦ In this case the affected column or columns can buckle, causing a catastrophic, overturning failure.
  - ♦ This effect is attributed to the catastrophic failure of the Pino Suarez, 20 story tower during the 1985 Mexico City Earthquake.
  - ♦ The victims in this type of collapse should be found in the overturned part of the structure as explained in the discussion of Heavy Floor, Overturned Collapse.

    The victims may be accessed within the open areas of the structure that are now laying nearly horizontal
- In some cases when tube type members are used for diagonals, sudden local crippling at cross-section corners has resulted. This can occur when cold rolled tubes are used, since high stresses are originally induced during forming.
  - ♦ Inadequate detailing or workmanship at connections has caused local failures, such as buckling of connection plates and roll over of beams.
  - ♦ The result of this type of failure rarely caused collapse, but damage can be caused to non-structural elements such as rigid wall panels, stairs, and interior finishes

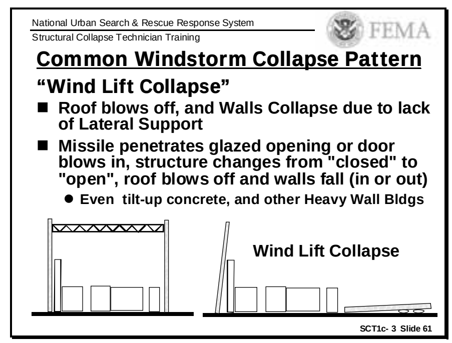


WINDSTORM/FLOOD COLLAPSE & DAMAGE PATTERNS



<u>Windstorm Basics.</u>

- They normally affect light, poorly, or non-engineered structures and generate both static and dynamic pressures on exterior surfaces and impact forces from missiles/debris.
- High winds can peal off light roof/canopies, and any type of “Open” structure is very vulnerable.
- Well-engineered structures are designed to resist wind forces by elastic action (in contrast to the inelastic response that is assumed in earthquake design); therefore, it is unusual to have this building class sustain significant wind damage.
- A very common occurrence is a **Wind Lift Collapse**, as shown in the adjacent slide.



  - ♦ If the roof is blown off the wall support is lost and the walls may collapse inward or outward, depending on what other elements (such as wall corners/intersections of intermediate floors) are available to provide redundancy.
  - ♦ As noted this type of collapse can even occur in heavy wall buildings, especially if large, metal doors are present.
  - ♦ Missile penetrates glass opening or doors blow in, structure changes from "closed" to "open type", roof and/or leeward wall are blown out.
  - ♦ Victims, if they have not evacuated prior to the hurricane, would not likely survive if caught beneath the heavy wall shown in the adjacent slide
- Storm Surge, associated with coastal windstorms, can produce collapse of lighter structures and even damage to engineered structures.
  - ♦ The destructive Tidal Surge of Hurricane Ivan Sep04 caused damage to freeway bridges and concrete buildings as well as lighter structures.
  - ♦ Windstorms often produce flooding – even if there is little “Wind Damage”.

- Tornados, with winds above 200 MPH, can damage all but the most well engineered and well constructed buildings.
  - ♦ The most destructive tornados have lifted as large of structures as Train Locomotives.
  - ♦ Light structures are extremely vulnerable to the lifting forces generated by tornadoes.
  - ♦ The most effective defense against loss of life, is to have some part of a structure be designed as a shelter.
- In some cases, tornado warning can be given, but they are only warning that the conditions are present in a general area, and not the precise location where one will occur.

Most Common Wind Collapse

- Probably the most vulnerable structures are Light Metal Buildings and Mobile Homes.
  - ♦ Light metal buildings are often penetrated by the wind and the skin and supporting roof members are compromised. Something as simple as not having a flutter resisting rubber gourmet under the roof panel screw heads, can start a “Weak Link Behavior” collapse.
- Mobile Homes are often factory built at minimum cost. In older models the connection between the metal frame and wood walls were made using very light 24 gage straps and staples. More modern models use 16 gage straps and screws.
  - ♦ In any case, the “Tie-down Straps” need to be properly installed, not taken out of the way for convenience.
- Part or all of light roofs may be blown off and the walls, could then, collapse due to lack of lateral support.
- Very tall walls may be blown in or out causing the roof to collapse.

Common Windstorm Collapse Pattern

Most Vulnerable Structures

- Light Metal Bldgs - collapse due to buckling or bending failure of long span roof, pull out of frame base
  - Weak Link Behavior – starts with something as simple as roof sheathing being blown off due to lack of rubber grommet under screw head
- Mobile Homes – collapse due to inadequate connection to base frame
  - Newer models use 16ga strap w/screws
  - Older models used 24ga. w/ staples

Problematic Building Types

- Wood Houses
- Mobile Homes
- Other Frame, multi-residence condos
- Light Metal Buildings
- Commercial & Industrial - URM, RM, TU
- Aircraft Hangers
- Large, Long Span Structures

- Types of structures that are seriously damaged by hurricanes usually fall into three categories:
  - **Pre-engineered buildings** usually consist of moderate span steel framing with metal siding or masonry wall construction. They are usually commercial and light industrial buildings.
  - **Marginally-engineered buildings** have some combination of partly reinforced masonry, light steel framing, steel joist, wood trusses, and/or wood rafters. The exterior walls may be masonry, stucco, or siding, and there may be large truck-doors.
  - **Un-engineered buildings** such as homes and apartments.

National Urban Search & Rescue Response System
Structural Collapse Technician Training

Problematic S3, URM, RM, TU
- Light Metal Buildings
- Commercial / Industrial Buildings
  - Walls of URM, RM, TU
    - Larger problem if large opngs are penetrated

SCT1c- 3 Slide 74

- **Storm Surge** can damage large, heavy structures that have not been designed for adequate uplift.
  - Precast concrete highway bridge slabs and dock slabs can be displaced by this surge.
  - Second story flat slabs have been collapsed due to the uplift pressure causing a punching shear failure at supporting columns (upward punch).
  - Scouring has caused the undermining of foundations, leading to the partial collapse of multi-story structures.

National Urban Search & Rescue Response System
Structural Collapse Technician Training

Hurricane - Storm Surge Damage
Even to Larger Structures
- Surge/Buoyancy Lifts and Displaces PC Slabs & Highway Bridge Slabs
- Surge/Buoyancy Lifts and causes Uplift Failure of Flat Slabs
- Scouring Undermines Foundations and causes Partial Collapse

SCT1c- 3 Slide 77

Common Windstorm Damage

Structural hazards created by windstorm damage include:

- The partial removal of the roof and/or wall skin in a light frame building. Partial loss of the lateral load resisting system.
- Peeling of outer layer of multi-layer, cavity-type, masonry bearing wall (lightly reinforced, eastern-type construction).
- Removal of masonry veneers on wood and metal frame walls.
- Removal of roofing materials: clay/concrete tile, shingles, gravel, etc.

  All items can be destructive missiles.

Common Windstorm Damage
- Partial removal of roof/wall skin
- Masonry wall peel - older URM or modern, insulated, masonry cavity walls
- Removal of masonry veneers - low & high rise
- Loss of roofing material - tile, shingle, gravel
- All become destructive missiles

Common Flood Collapse Problems

Common flood collapse problems include:

- Structures move partly or completely off their foundations.
  - ♦ They can slide if moved completely off or tumble if one side stays attached. Structures that have been moved may be repaired but should initially be considered hazardous.

- Foundation and/or basement walls may have walls broken, offset, and/or badly cracked due to hydrostatic and/or hydrodynamic forces.
- Slabs on graded and shallow foundations can be undermined by swift moving water.

  Undermined foundations may result in a hidden problem that would need to be carefully investigated.
- Wall, floor, and/or roof collapse may be caused by impact from objects as large as residential structures.

Flood Damage Patterns

- Riverine or Coastal Flooding
- Most damage is to light structures
- Moving water can impact & collapse or flow past & peel off the lt. walls of bldgs
- Waterborne debris - can cause collapse by penetrating structures
- Fast moving river or tidal surge can cause collapse/damage to engineered structures
- Slow moving water can produce buoyancy + standing water effects

Common Flood Damage Problems

- **A high water mark will normally indicate the extent of flood damage in structures that have remained in place.**
- Buoyancy can cause parts of the structure to be lifted.

  Wood floors and roofs can be lifted off their bearings by hydrostatic pressure, leading to a hidden hazardous support condition.
- Long-standing water can cause geotechnical problems, leading to subsidence.
- In addition to structural damage, wood floors that have been submerged may become warped.
- Flooding can cause black mold to occur, especially in hidden, enclosed spaces that are not dried rapidly.

  Black mold can cause severe health problems.
- **Flooding may also lead to many HAZMAT problems.**

Common Flood Damage

- Light frame structure shifted off foundation
  - Buildings can slide if free of foundation or will tumble if one side stays attached
- Broken and/or tilted foundation walls
- Undermined foundations & slab on grade
  - Potential for subsidence, geotechnical effects
- Buildings impacted by debris
- 1st & 2nd floor joist may be lifted off bearings, in unstable condition
  - Need to determine high water mark

EXPLOSION EFFECTS ON BUILDINGS

Basic Explosion Effects

These effects are very different from those caused by earthquakes where the collapse causing damage is the vertical elements (column connections & shearwalls)

The pressures exerted on buildings by explosions may be many orders of magnitude higher (5000 psi+) than normal design pressures, but their duration is in milliseconds, and they are inversely proportional to the cube of the distance from the center of the source.

- Damage to structures may be severe, but it is only a fraction of what a proportional static pressure would cause.
- When large surfaces are engaged by blast pressures, they will be moved as the shock wave passes, but the direction of the net force (initial uplift – overpressure) will be determined by the complexities of the wave path and time.

- Heavy columns tend to survive but may have some of the floors that load and laterally brace them removed.
- Steel frames, beams, and columns may also survive but without all their intended bracing.
- The wall and floor planes in frame as well as box buildings have large surfaces that will receive most of the blast pressure. They likely will be ripped away from their connections, leading to the collapse of at least part of the structure.
- Occupants within the blast zone are usually killed or severely injured. There is little record of anyone surviving when they have been exposited to the direct blast pressure.

  However, if individuals are “shaded” from the blast pressure by concrete walls or other heavy-strong structure they may survive
- Since the floors of a structure are usually thrust upward, and then collapse into a dense rubble pile, survivability is very low

  If somehow protected from the direct effects of blast, victims may be injures by flying objects, especially glass shards

Blast Collapse Patterns

Effect is different from Earthquake,where damage is to vertical elements.
Blast has devastating effect on all surfaces especially uplift on floors

Basic Explosion Effects

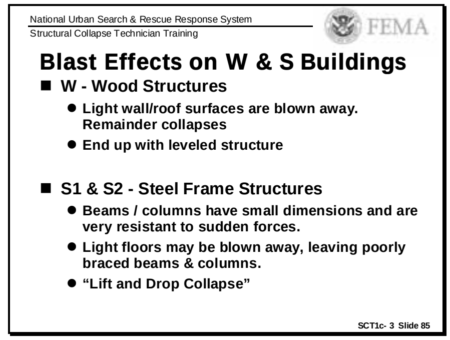
- Large pressures exerted by explosions
  - Can be 5000 psi +
  - Short Duration - only Milliseconds
  - Inversely proportional to cube of distance from source (not exactly since hemisphere)
- Severe damage to structures
  - But not proportional to static pressure effects
- Effects of fast moving shock wave
  - May be very complex

Blast Effects on Buildings

- W - Wood Structures
- S1 & S2 - Steel Frame Structures
- S3 - Light Steel Structures – Blown away
- C1, C2 & C3 - Concrete Frames
- PC2 - Precast Structures, Frame & Box
- Post-Tensioned Concrete Structures
- Heavy Wall Structures - TU, RM, & URM

Few Survive within the Collapse Zone due to Blast and Crush Effects

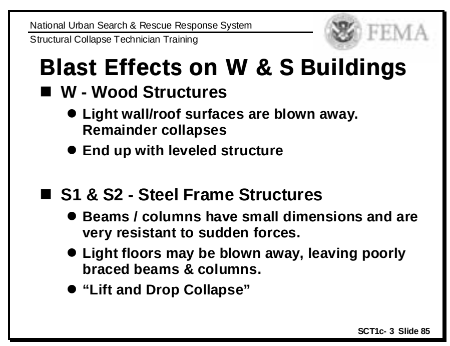
Explosion Effects on Specific Buildings



The following is a brief description, by type, of the most predictable blast damage.

- **Wood frame – W:** The light wall and roof planes can be blown away and/or shredded. Leveling of all or at least a significant part of the structure can occur.
  - ♦ Occupants within light structures have little protection, and normally killed or severely injured
- **Steel frame – S1 and S2:** A well-designed steel frame may be relatively resistant since beams and columns have resistance to both upward and downward loads as well as tough connections and small dimensions.
  - ♦ Light floor framing such as metal deck with concrete fill or bar joist may be separated from beams since they have large areas and small connections that can be unzipped.
  - ♦ The most likely scenario is for at least part of the frame to remain, but beams may be twisted, with large areas of the floor diaphram missing. This is called a **Lift and Drop Collapse.**

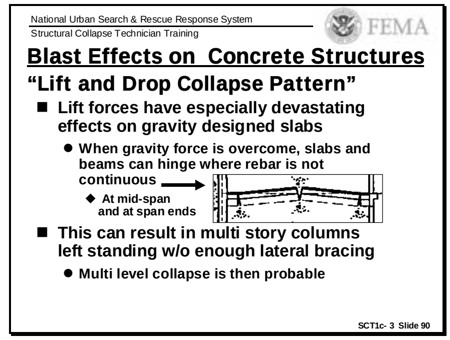
  The occupants on the floors that are lifted and collapse have little chance of survival. They are normally found within the tightly packed rubble at the "ground" level.



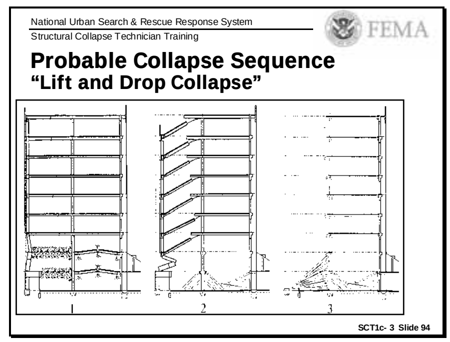
- **Light metal – S3:** The light metal roof and wall panels can be easily blown away, leaving a bare, poorly braced frame.
  - ♦ Roof, purlins, and wall girts normally have relatively light connections and may be removed with the metal panels.
  - ♦ The frames may collapse from lack of lateral support and/or push from the blast pressure.
  - ♦ The result can be a completely collapsed pile of bent and twisted steel members (structural steel spaghetti).
  - ♦ Again, occupants within these light structures have little protection, and normally killed or severely injured. They may be found at some distance from their original position

Explosion Effects on Specific Buildings (cont.)

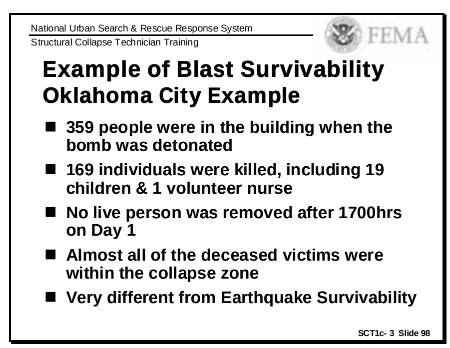
- **Concrete frames – C1, C2, and C3:** The lift pressures have had devastating effects on concrete slabs in gravity-type designs.
- One-way slabs hinge up because of the lack of top reinforcing at mid-span and continuity splices in bottom bars at supports.
- A critical location for flat slabs occurs at columns when the uplift pressure fails the slab column joint in upward punching shear, followed by a combination of gravity and positive overpressure that tends to drive the already damaged slab downward. **Lift and Drop Collapse Pattern.**



- The remaining structure may contain columns that are standing, exposed for several stories without the lateral bracing that the collapsed floors used to provide.
  - ♦ This occurred in both the 1993World Trade Center and Murrah Federal Building disasters, large areas of several floors collapsed, leaving columns that extended a far as six stories without lateral support.
  - ♦ These columns, still heavily loaded were vulnerable to a sudden collapse and needed to be braced to reduce the risk to rescuers



- As previously stated, the occupants on the floors that were lifted and collapse had little chance of survival. They were found within the tightly packed rubble at the "ground" level, some as far as 50 feet from their original position.
- In the Murrah Building collapse several individuals were sparred since they were standing and waiting for the elevator that had very strong concrete walls. The walls "shaded" them from the blast pressure, any the elicitor walls kept the floors in that area from collapsing
- The adjacent slide discusses the low survivable that has been experienced in blast-caused collapses.
  - ♦ No one within the collapse area survived, and no live victims were removed from the rubble after the first 10 hours



Explosion Effects on Specific Buildings (cont.)

- In **C3 type Concrete Frames**, the URM infill is also particularly vulnerable to blast pressure (large areas and very little resistance to the lateral pressure).
- **Pre-cast concrete – PC2:** In pre-cast frame type structures, the lightly (gravity) connected floor slabs and wall planes can be blown away, leaving unbraced beams and columns.
  - ♦ If beam/column connections are minimal, entire sections of the structure could collapse.

    Progressive collapse has occurred when only one column was dislodged by a relatively small gas explosion in a multi-story, pre-cast structure.

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Blast Effects – Precast Concrete

- ■ PC2 - Frame Type Structures
  - ● Pressures can dislodge walls, slabs
    - ◆ Beams & columns then effected by lack of bracing.
  - ● Break/damage many connections
  - ● Progressive collapse possible.
    - ◆ Due to missing supports and discontinuous members.
- ■ PC2 - Box Type Structures
  - ● Pressures can dislodge walls & slabs
    - ◆ Break/damage many connections
  - ● Better response in multi wall buildings

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  - ♦ In Box type PC2 (such as the barracks in Saudi Arabia), the wall and floor slabs nearest the blast may be dislodged and broken loose at their joints.

  The multi-cellular character of these structures (created from closely spaced bearing walls) will, however, tend to limit the collapse damage to those areas where the bearing capacity of wall panels is lost.

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Compare Murrah Bldg w/ Kobar Towers

Similar size Bomb & Number of Occupants

■ Brittle, Conc Details	■ Ductile Connections
■ Anti-Redundant	■ Highly Redundant
■ 45% Collapse	■ 10% Collapse
■ Collapse/Falling Haz	■ Falling Haz
■ 168 Killed	■ 19 Killed

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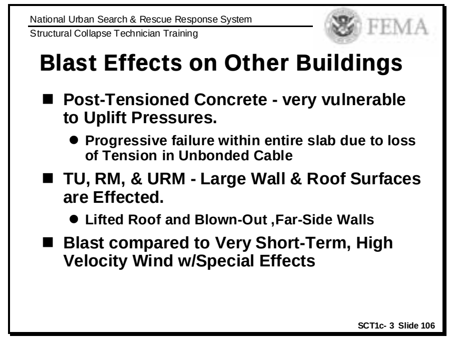
- The adjacent slide compares the survivability of the Murrah Bldg and Kobar Towers, to demonstrate that ductility really does make a difference. There were the same number of occupants and blast size for these structures.
  - ♦ The Murrah Bldg, even though it was a cast in place concrete structure, performed poorly due to brittle reinforcing steel configuration (few continuous bars) and anti-redundancy (all columns did not extend to the ground at the building face exposed to the blast.
  - ♦ Kobar Towers was a highly redundant, PC concrete multi-wall structure with reasonably ductile connections, and the collapse was limited for the blast facing walls.

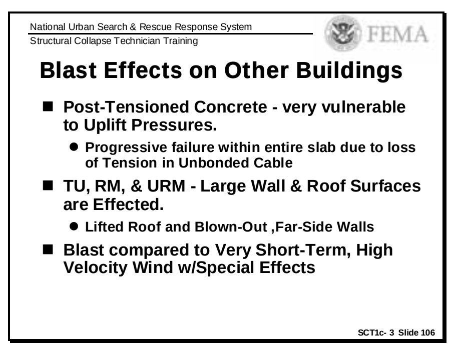


- **Post-tensioned concrete:** If the unbonded cables are damaged, becoming un-tensioned in only one small area of a floor slab, the entire length of the these cables can be affected, which can lead to the collapse of the full length of the floor.
  - ♦ This type of slab is also very susceptible to upward pressures since the cables are normally draped to lift the weight of the structure.

  Therefore, the original structure will have less resistance to the blast uplift pressure than reinforced concrete. Also the concrete may break into very small pieces
  - ♦ Pancake or some sort of draped slab pancake collapse can be formed in the floor structure adjacent to the blast zone.

  Victim survivability within the blast area would be low, and access by breaching the concrete slabs, if pancaked, should be used to access victims.

  However, in areas where these slabs are still in-tact there are special problems that should be address by a Structures Specialist.
  - ♦ If the post-tensioned forces have been released, the slabs will act as brittle, un-reinforced concrete.
  - ♦ If the post-tensioning forces are still active, great care must be taken if any of the cables need to be cut



- **Heavy wall buildings – TU, RM, and URM:** Blast pressures will tend to engage the wall and roof surfaces, severing connections and blowing large sections away.
  - ♦ For interior blasts, walls will blow out, and roof sections will be lifted. Adjacent parts of the structure can also collapse from the loss of vertical and/or lateral support.
  - ♦ For blasts initiated outside the building, the near walls may be shattered or blown in, followed by roof sections being lifted, then dropped, and sections of the far side blown out.
  - ♦ Again victim survivability is very low within the blast affected area, as well as in the area where the heavy walls will fall

In summary, the effects of explosions can be compared to those of a very short term, very high velocity wind. There may be special effects at corners and other discontinuities and shading of one part of a structure by another or one building by another.

KEY LEARNING POINTS

They are listed on the adjacent slide. The student is encouraged to review this section, since it contains information that forms a basis for understanding the performance of structures that will be encountered during US&R incidents.

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Review Key Learning Objectives

- **Quake, Wind and Blast produce Unique Effects on Different types of Structures**
- **Each of these produce Unique and Recognizable Collapse Patterns**
- **This Knowledge will allow us to Recognize the Survivable Voids and potential victim location**

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Review of Enabling Objectives

- In this section, we have discussed:
  - Basic Collapse Patterns,
  - Earthquake Collapse Patterns,
  - Windstorm Collapse Patterns,
  - Flood Damage Collapse Patterns,
  - Blast Collapse Patterns.

  We have focused on recognizing survivable voids and Potential Victim Locations.
- In the following section, Hazard Identification, we will focus more specifically on the US&R issues of how to deal with damaged and collapsed structures.

Part 4 - HAZARD IDENTIFICATION, plus INTRO to ASSESSMENT & MITIGATION

In this section, you will become familiar with the most common signs of distress exhibited by damaged structures. We have discussed material behavior and collapse patterns and will now apply this knowledge to the disaster site.

In this section, we will:

- Discuss concrete and masonry cracks and how to "read" the cracks to predict future performance of these structures.
- Identify the most common hazardous conditions that will occur in the five types of buildings that we have previously identified.
- Discuss the various tools and methods that are currently available to monitor buildings.

Cracks in Reinforced Concrete and Masonry

A favorite statement in building design and construction is "if it's not cracked, it's not concrete" because cracks must form in concrete for the reinforcing steel to be stressed in tension. Most normal concrete develops cracks that are narrow (hairline) from shrinkage, temperature change, and predictable structural behavior.

Shrinkage Cracks

- Shrinkage cracks usually occur in slabs, beams, walls, and even in columns within 60 days of the pour, after the concrete is allowed to dry-out.
- Diagonal cracks will originate from most re-entrant corners in slabs and walls, that is, window, door, and floor openings.
- Straight cracks (more or less) occur often at 5 ft to 20 ft on center in long walls and/or floor surfaces, depending on the amount of reinforcing steel, numbers of pour joints, and curing conditions.
- The reinforcing steel within the structure is intended to hold the structure together as it shrinks and keep these cracks small.

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Terminal Objectives

- **The Student shall understand the most common signs of distress exhibited by damaged structures.**
- **The Student shall understand to the most common Hazards found in damaged structures, and methods that have been used to used to Mitigate them**

We need to apply our knowledge regarding Structure Behavior & Collapse Patterns to the Disaster Site

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Key Learning Objectives
We will discuss the following

- **Crack patterns in Reinf Conc & URM**
- **Structure Hazard I.D. in five types of Bldgs**
  - **Light Frame**
  - **Heavy Wall**
  - **Heavy Floor**
  - **Precast Concrete**
  - **Steel Frame**
- **Introduction to Structure Hazard Assessment & Mitigation**

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Cracks in Reinforced Concrete & Reinforced Masonry

- **Shrinkage cracks**
- **Temperature cracks**
- **Tension cracks**
- **Diagonal tension cracks in beams**
- **Diagonal tension cracks in walls**

If it's not Cracked it's not Concrete

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Shrinkage & Temperature Cracks

- **Occur in slabs, walls, beams, & columns.**
- **Diagonal cracks originate at re-entrant corners in slabs & walls (openings)**
- **Transverse (more or less straight) cracks occur at 5 to 20 ft apart in long slabs & walls**
- **Nominal rebar normally keep cracks small**

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Temperature Cracks

- Temperature cracks occur in roughly the same pattern as shrinkage cracks and are difficult to differentiate from them.
- When the temperature of a concrete structure is decreased, it must shorten (shrink); therefore, it cracks, and the reinforcing steel attempts to hold it together.
- Reinforced concrete structures will, obviously, experience plainly observable temperature/shrinkage cracking when subjected to the winter cold.

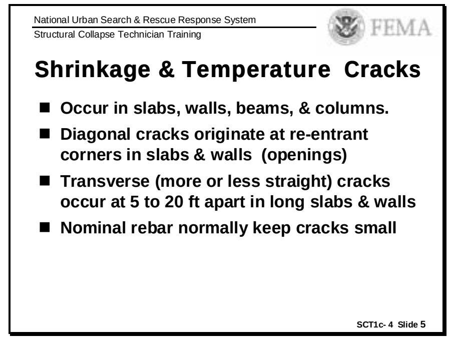
Tension Cracks

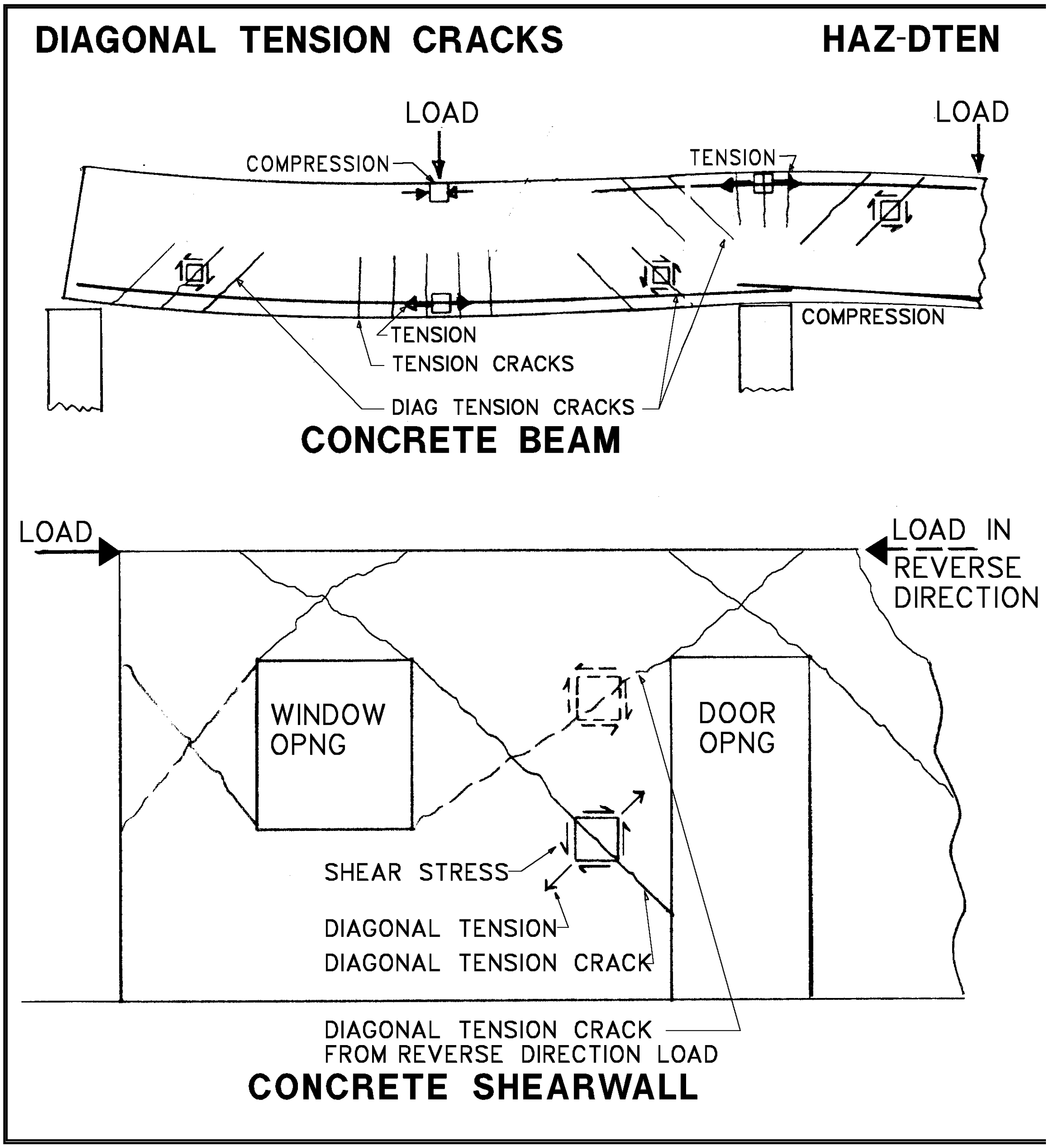
- These cracks most often occur in concrete slabs and beams when bending-caused tension forces stretch the reinforcing steel.
- Cracks must form in the concrete in order to transfer the force to the steel, but the cracks are normally quite numerous, small, and undetectable (except to the trained eye).
- They form perpendicular to the long axis of the member, and as long as they remain hair like, the structure is behaving normally.

Diagonal Tension Cracks

Refer to explanation of Shear Forces in Sect II, pg 21

- Diagonal tension cracks occur in the high-shear stress zones of beams and girders in a typical pattern (HAZ-DTEN) under normal vertical load conditions.
- In shear walls, large diagonal tension cracks will form when the walls are heavily loaded by severe earthquake shaking (HAZ-DTEN).
- Earthquakes will normally cause a diagonal crack in each direction (cross cracking) in the highly stressed areas of shear walls (that is, between window openings and over-stacked door openings) since the shear force reverses, causing diagonal tension cracking in each direction.




DIAGONAL TENSION CRACKS
HAZ-DTEN
LOAD
LOAD
COMPRESSION
TENSION
TENSION
TENSION CRACKS
COMPRESSION
DIAG TENSION CRACKS
CONCRETE BEAM
LOAD
LOAD IN REVERSE DIRECTION
WINDOW OPNG
DOOR OPNG
SHEAR STRESS
DIAGONAL TENSION
DIAGONAL TENSION CRACK
DIAGONAL TENSION CRACK FROM REVERSE DIRECTION LOAD
CONCRETE SHEARWALL

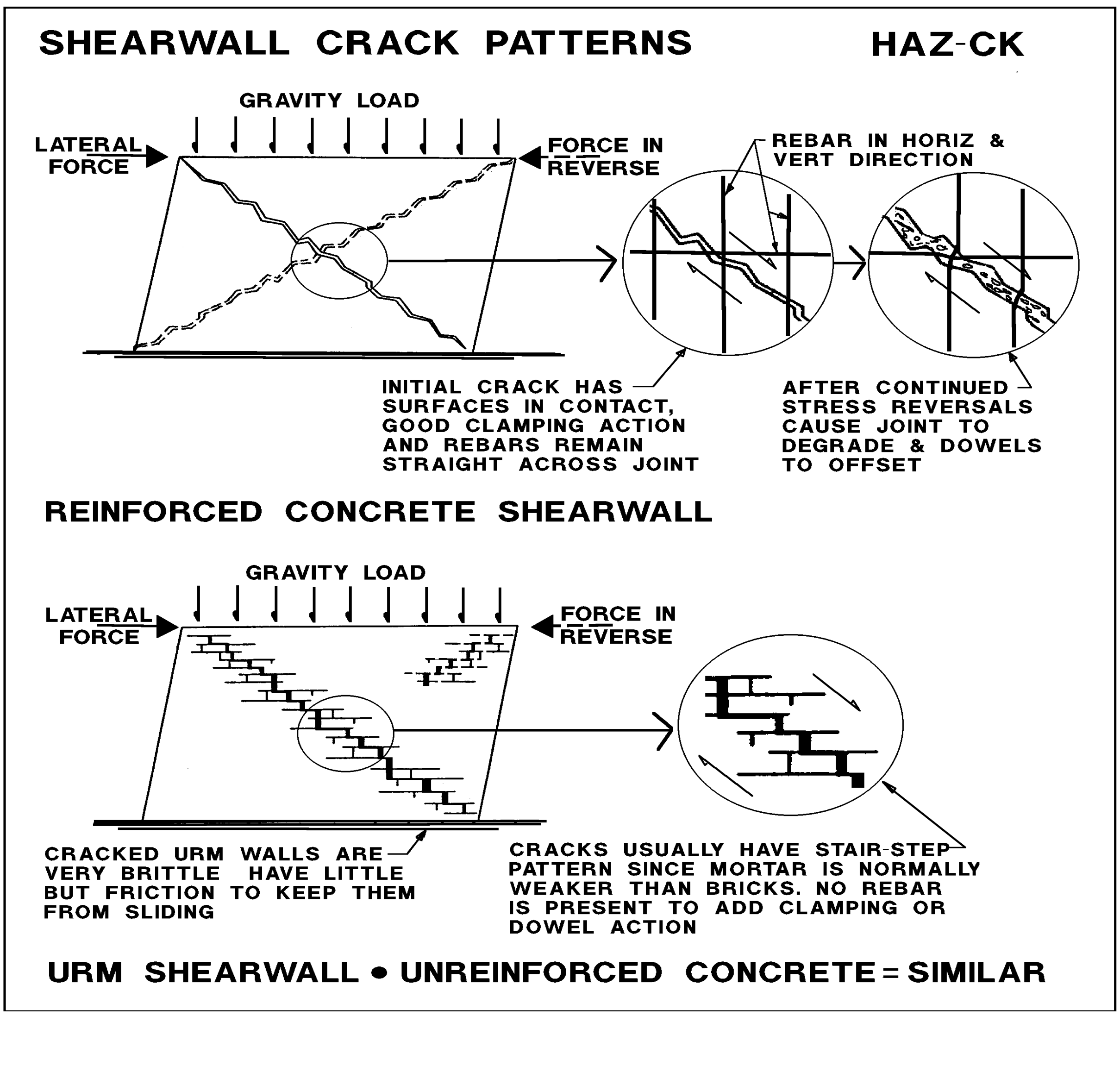
Cracks in Reinforced Concrete Walls

- The stability of concrete box buildings will probably depend on the post-cracked strength of the shear walls. Even with unsightly diagonal cracking, a shear wall may still have significant strength (HAZ-CK).
- The clamping action of the gravity loads, as well as the vertical rebar, will tend to hold the irregular surface of the cracks together, preventing the opposing surface from sliding. In addition, the rebar that cross the crack can act as dowels.
- Both these resistive actions are lessened when there is enough shaking or continued re-shaking from aftershocks. The crack widens, concrete chunks fall out, and the rebar can be seen in an offset curved condition. In this latter degraded condition, a shear wall has become unreliable and must be evaluated accordingly.

Cracks in Unreinforced Masonry Walls – URM

- Shrinkage, temperature, and diagonal tension/shear wall cracks occur in URM walls as well as unreinforced concrete walls. In these walls, however, cracking indicates a significantly degraded structure.
- Diagonal tension cracks form in these walls between openings, as they do in reinforced concrete walls because of earthquake shaking. In addition, cracks are often created at wall corners, with the bottom of the crack at the corner and the top extending up to the roof. These cracks are caused by the action of the disconnected roof diaphragm pushing against the corner, attempting to push it out. URM diagonal cracks tend to follow a stair step-pattern (HAZ-CK); that is, the crack follows the weaker mortar, rather than going through the bricks. This action results in cracked surfaces that are smoother than those in reinforced concrete.

- **Masonry walls** with significant diagonal tension cracks must be considered capable of a sudden, brittle failure. Some clamping force on the horizontal steps of the cracks exists due to the gravity force, but no vertical bars exist to add clamping or dowel action. The greater smoothness of the joints also reduces the friction that could be developed by the clamping of the vertical force.
- **Unreinforced concrete walls** also perform poorly during quakes. They tend to break apart in pieces defined by whatever crack pattern existed before and/or according to the original pour joints. Fortunately, there are very few of these in earthquake areas.



Hazard Identification in Damaged Structures

In damaged, partly collapsed and collapsed structures we can identify three types of hazards:
(we will discuss the first two)

- **Falling**, when part of the structure or its contents are in danger of falling (especially heavy objects);
- **Collapse**, when the volume of an enclosed structural space will be reduced as stability is lost;
- **Other**, which includes toxic gas, carbon monoxide, asbestos, and other hazardous materials

- The degree of hazard in both cases strongly relates to mass and how additional failure may occur. Brittle, sudden failure potential must be recognized as opposed to structures in which material ductility and redundant configuration could provide some warning of an additional collapse.
- In making judgments, one should consider:
  - ♦ Partially collapses are most likely to be involved in a secondary collapse, since they contain the potential energy of heavy objects that can fall.
  - ♦ In many heavy impact collapses, the forces that were required to stop the collapse are probably greater than will be experienced later.
- The problem of identifying and evaluating, these hazards, is difficult. The trained engineer should be able to rate the risk of various hazards as low, medium and high. We must consider that:
  - ♦ Judgments cannot be precise, but we need to assess the chances of secondary collapse.
  - ♦ The way a collapsed structure "comes to rest" will give clues regarding the amount of energy that is remaining. (Can it fall further?)
  - ♦ If aftershocks or high winds can occur, then the structure will receive significant lateral loading.

- In evaluating, a damaged, but stationary structure, one could state, positively, that the structure that was moving had enough resistance to stop and come to an "At-Rest" condition. However, the damaged structure is difficult to assess, weaker, and more disorganized than the original.
  - ♦ Try to identify the load path and visualize what happens during an aftershock or wind gust.
  - ♦ Smaller elements & debris, may be most hazardous during aftershocks and high winds.

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Hazards in Damaged Structure

- ■ Hazard Types
  - ● Falling Hazards – heavy objects that fall
  - ● Collapse Hazards – voids are reduced
  - ● Other Hazards – mostly health hazards
- ■ Basis of making judgments
  - ● Partially collapses are most unpredictable.
    - ◆ Remaining Potential Energy.
  - ● High impact collapse expends most energy.
    - ◆ Much energy is absorbed as collapse stops.

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Identification Problems

- ■ Judgments cannot be precise.
  - ● What is chance of secondary collapse?
- ■ Collapsed Structure has "Come to Rest".
  - ● But it is weaker and less organized.
  - ● Heavy, brittle parts still have potential energy.
- ■ Aftershocks, high winds, etc will add additional lateral forces.
  - ● Identify most susceptible part of remaining structure.
  - ● All types of buildings have collapsed in aftershocks.
- ■ See SOG (or StS FOG), Sect 1 (& following slides)
  - ● Lists of typical issues for various building types.

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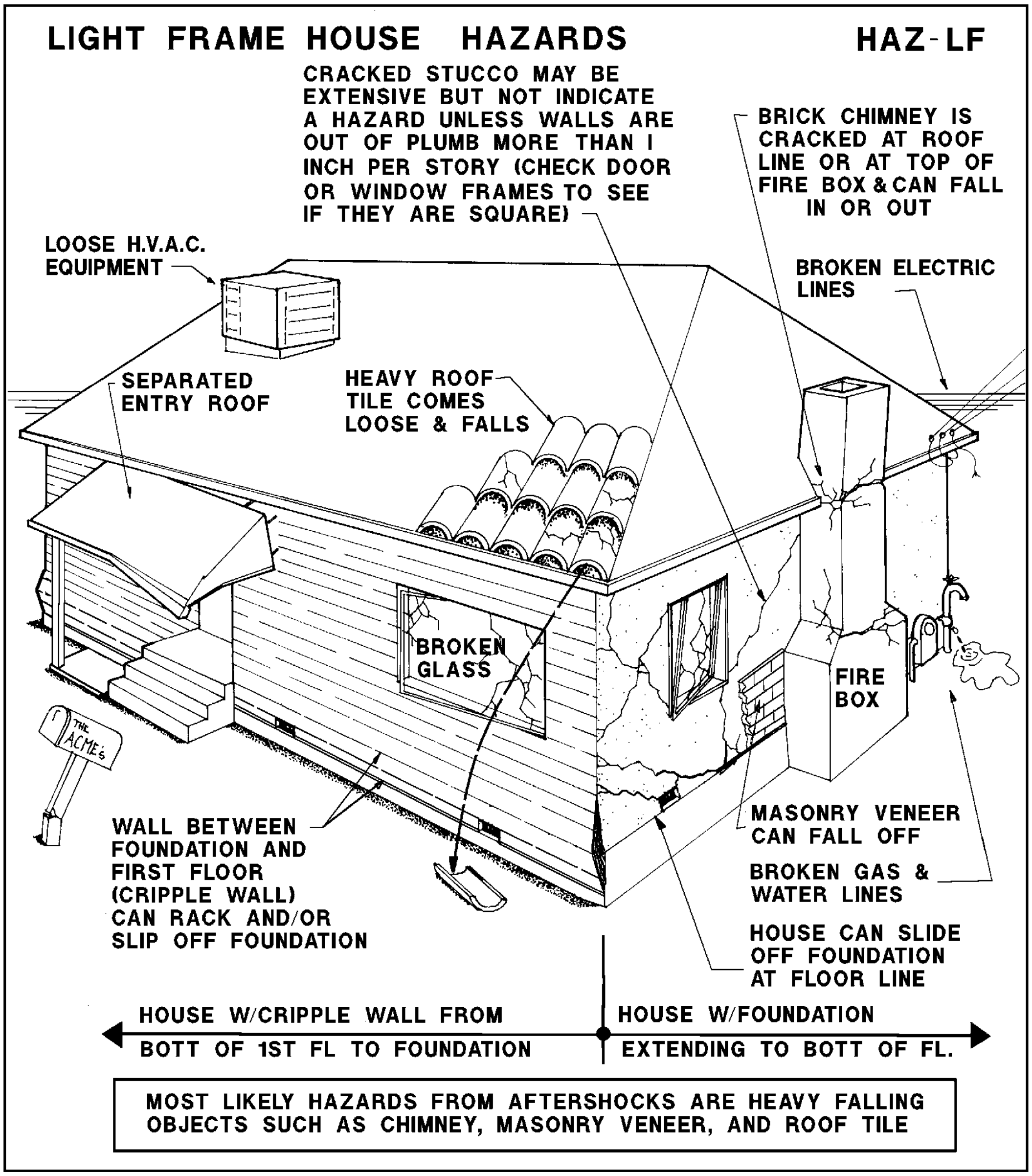
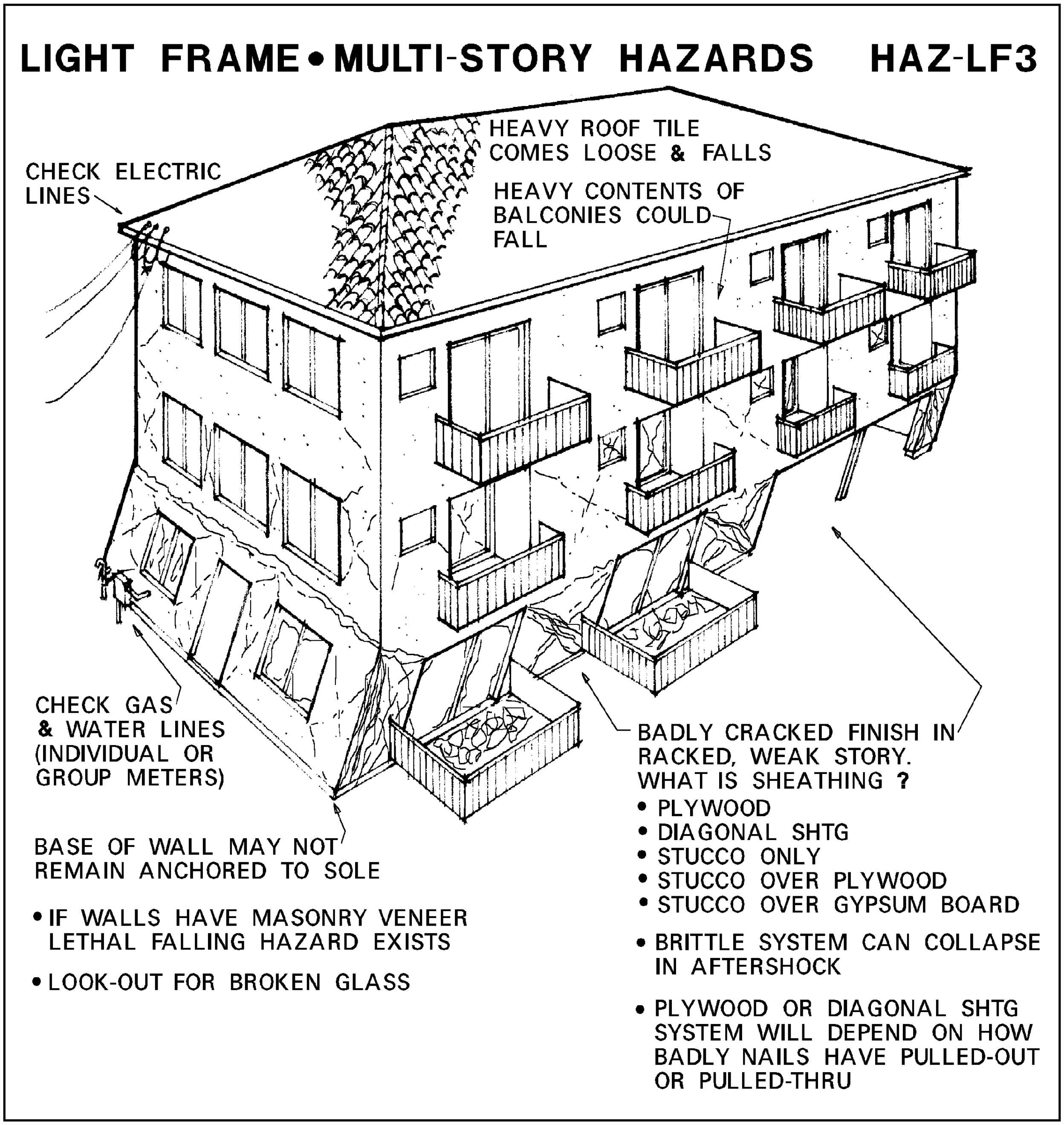
Light Frame Building Hazards

The principal weakness is in the lateral strength of walls and connections.

- **Check Points: (HAZ-LF):**
  - Badly cracked or leaning walls;
  - Offset residence from foundation;
  - Leaning first story in multi-story buildings;
  - Cracked, leaning masonry chimney or veneer;
  - Separated porches, split level floors/roof.



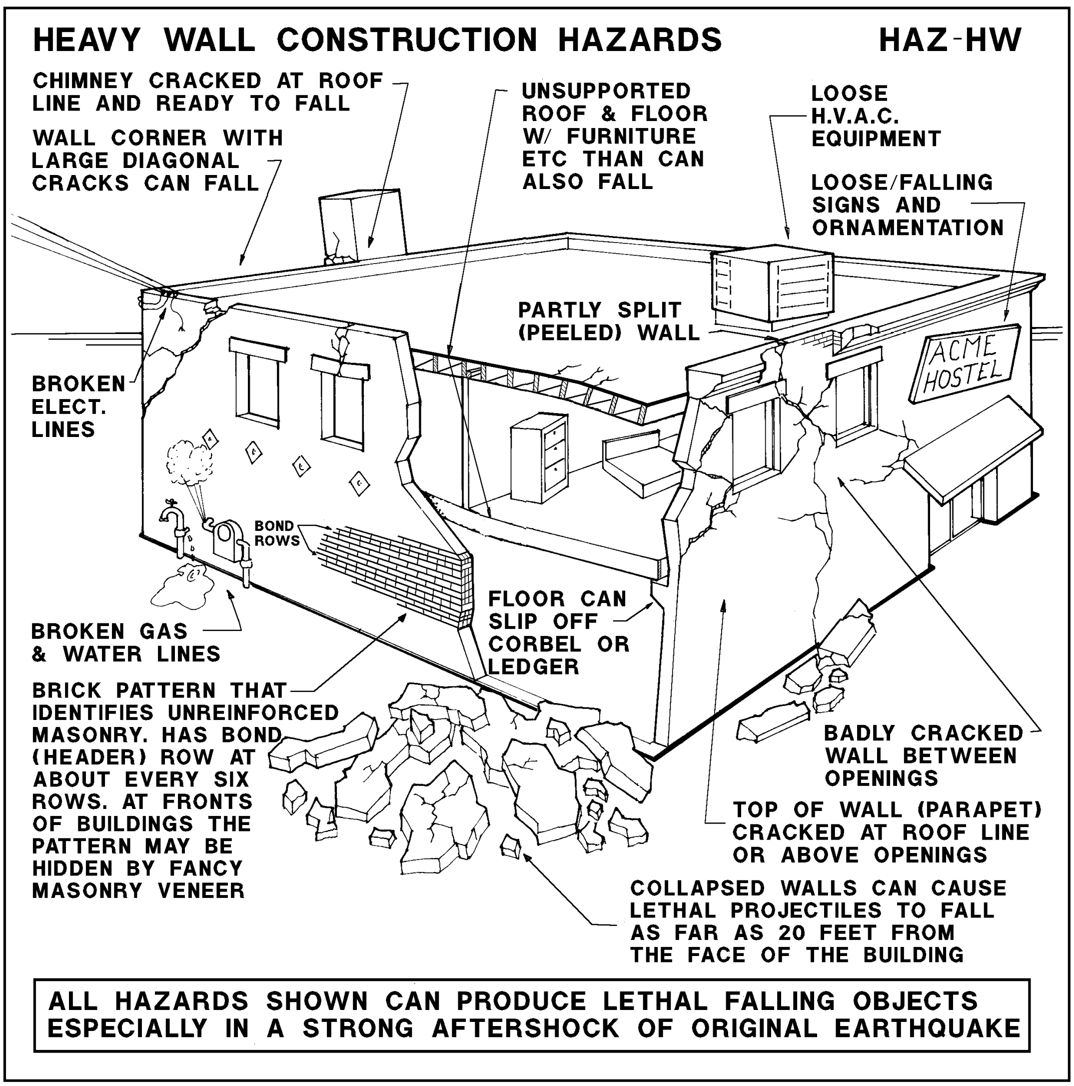
- In structures of less than three stories, additional collapse is unlikely because of the light weight of this type of construction.
  - ♦ Collapse of this type is often slow and noisy.
  - ♦ Falling masonry chimneys and masonry veneers are the most brittle types of behavior for these structures.



Heavy Wall Building Hazards

The principle weakness is in the lateral strength of walls and their connections to floors/roof.

- **Check points: (HAZ-HW):**
  - ♦ Loose, broken parapets and ornamentation;
  - ♦ Connection between floor and wall;
  - ♦ Cracked wall corners, openings;
  - ♦ Peeled walls (split thickness);
  - ♦ Unsupported and partly collapsed floors.
  - ♦ **All failure will probably be brittle.**
- Falling hazards are very common in unreinforced masonry buildings because of the combination of weak and heavy wall elements. Collapse of adjacent buildings can occur as a result of the falling hazard of party walls.

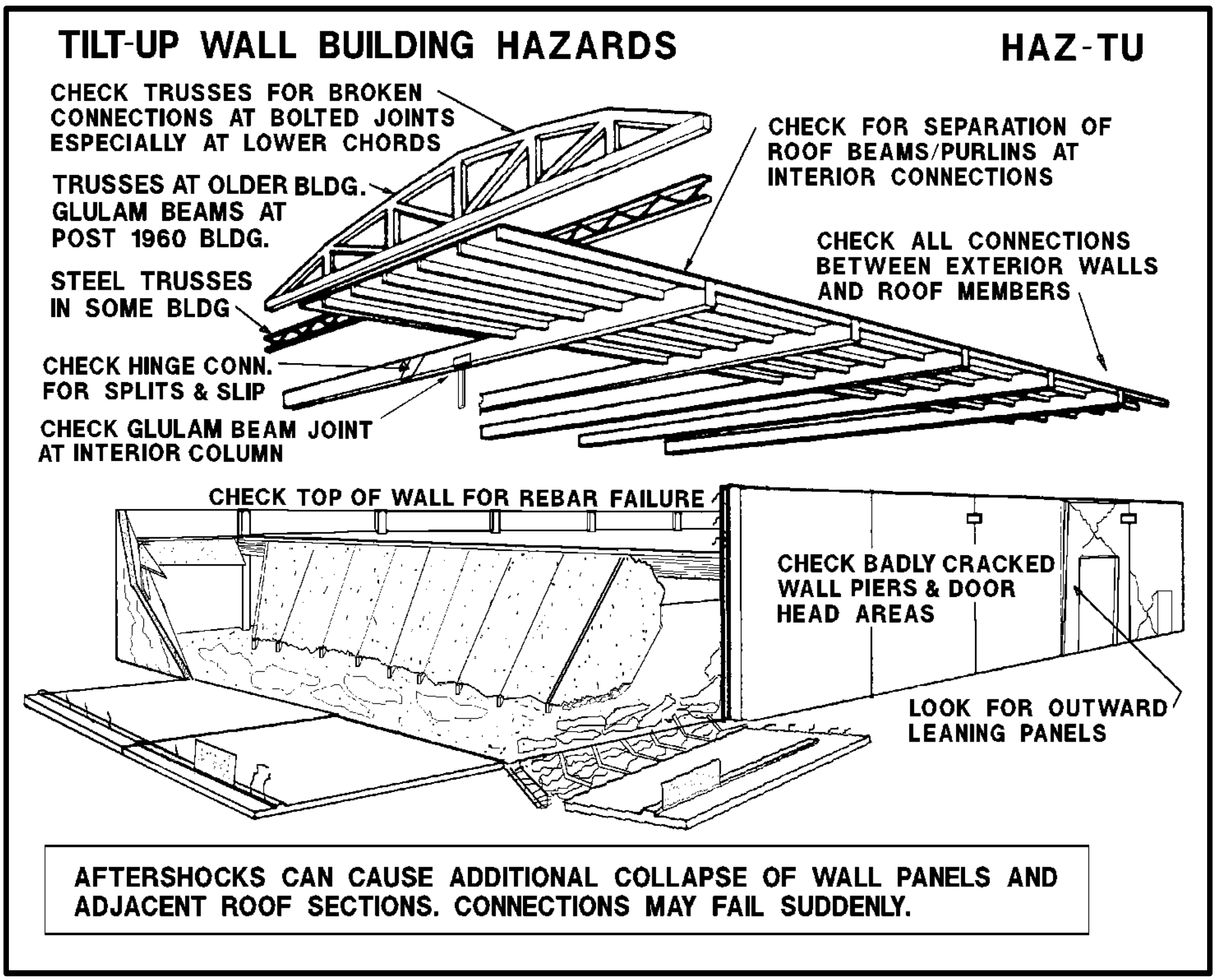


Heavy Wall Building Hazards – Tilt-Up

(Low-rise, reinforced masonry wall buildings with light roofs are similar.) The principle weakness is in the connections between the wall and floor/roof.

- **Check Points: (HAZ-TU):**
  - ♦ Connection between floor/roof and exterior wall.
  - ♦ Connection between beams and columns, both exterior and interior.
  - ♦ Hinge connectors at cantilevered glued-laminated beams.
  - ♦ Cracks in wood at bolted joints of trusses, especially at lower chords.
  - ♦ Out-leaning wall panels.
  - ♦ Badly cracked walls and/or columns.
  - ♦ Rebar tension failure at tops of walls, especially at joints.

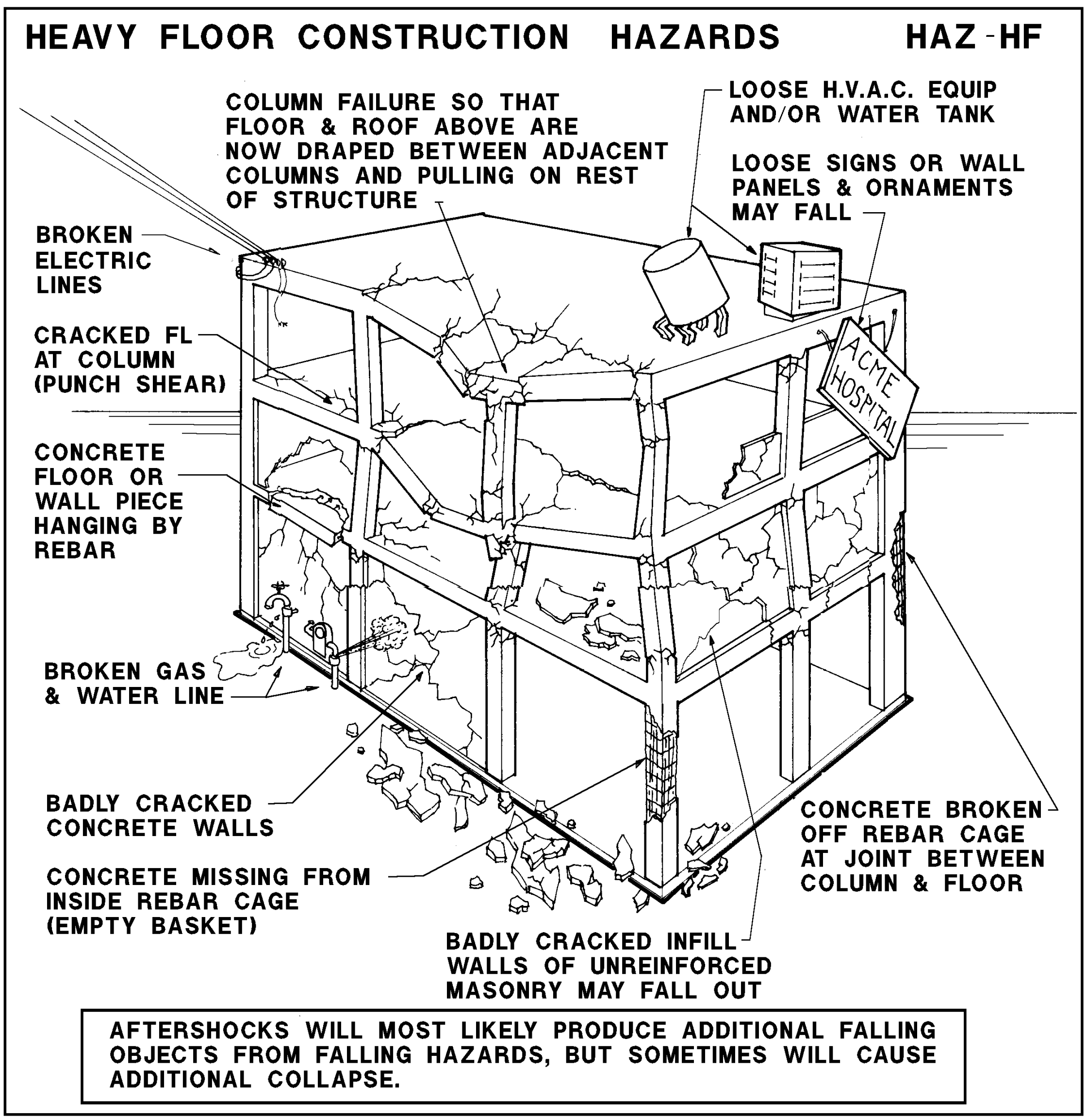
- The connection failure will often be brittle. The wall/column failure and shear failure may be more ductile, but single curtain wall reinforcing provides little confinement.



Heavy Floor Building Hazards – Concrete Frames

The principle weakness is both a lack of adequate column reinforcement that can properly confine the concrete and an inadequate connection between slabs and columns.

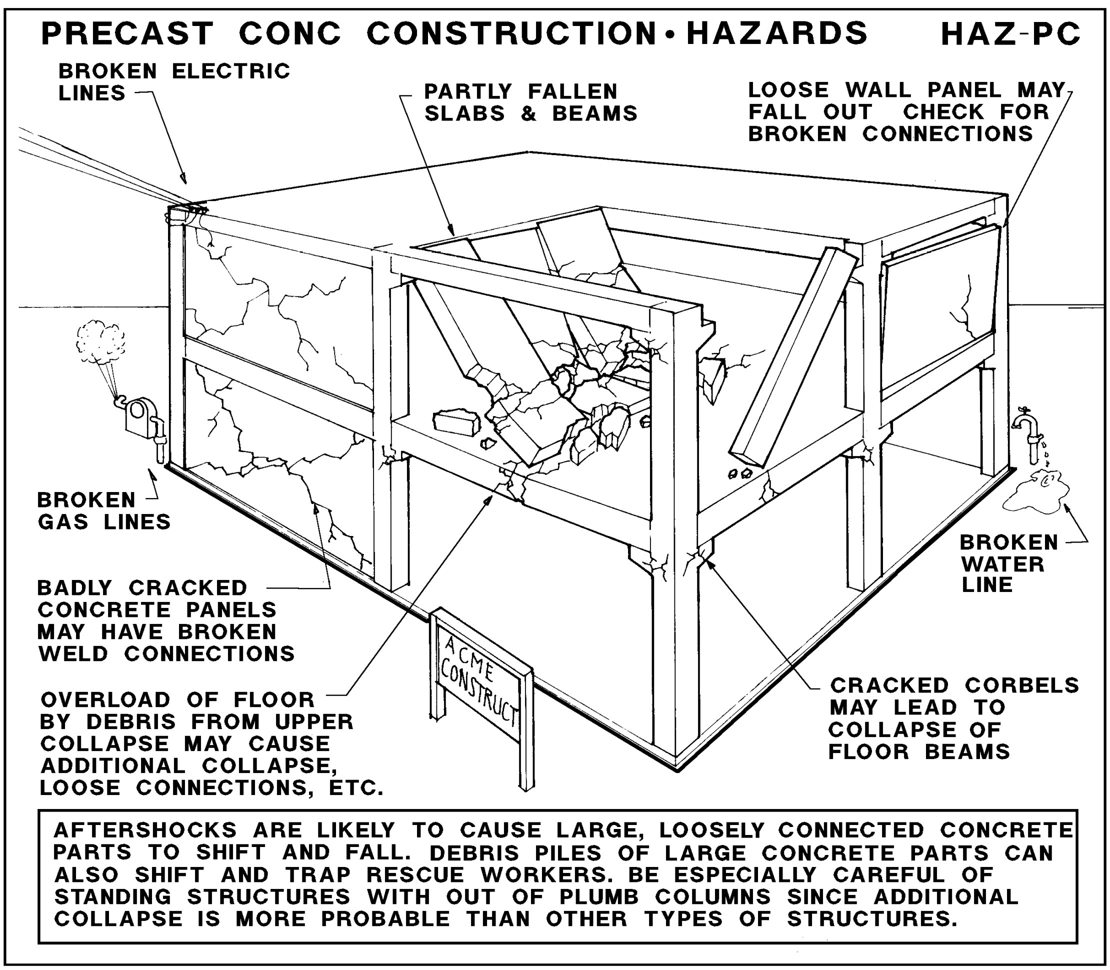
- **Check Points: (HAZ-HF)**
  - ♦ Confinement of concrete in columns (empty basket).
  - ♦ Cracking of columns at each floor line (above and below floor).
  - ♦ Diagonal shear cracking in beams adjacent to supporting columns and walls.
  - ♦ Cracking in flat slabs adjacent to columns.
  - ♦ Attachment of heavy non-structural, unreinforced masonry walls (infill walls).
  - ♦ Cracks in concrete shear walls and/or stairs.
- Ductile behavior may still be possible if the concrete is confined by reinforcing and the reinforcing is still within a lower yielding range.



Pre-Cast Building Hazards

The principle weakness is the interconnection of parts: slabs to walls/beams, beams to columns, walls to slabs, etc. It is very difficult to make connections adequate enough to transfer the strength of parts, connections necessary to survive a maximum earthquake. These buildings can have fairly heavy walls and floors, but neither is as heavy as heavy wall or heavy floor types.

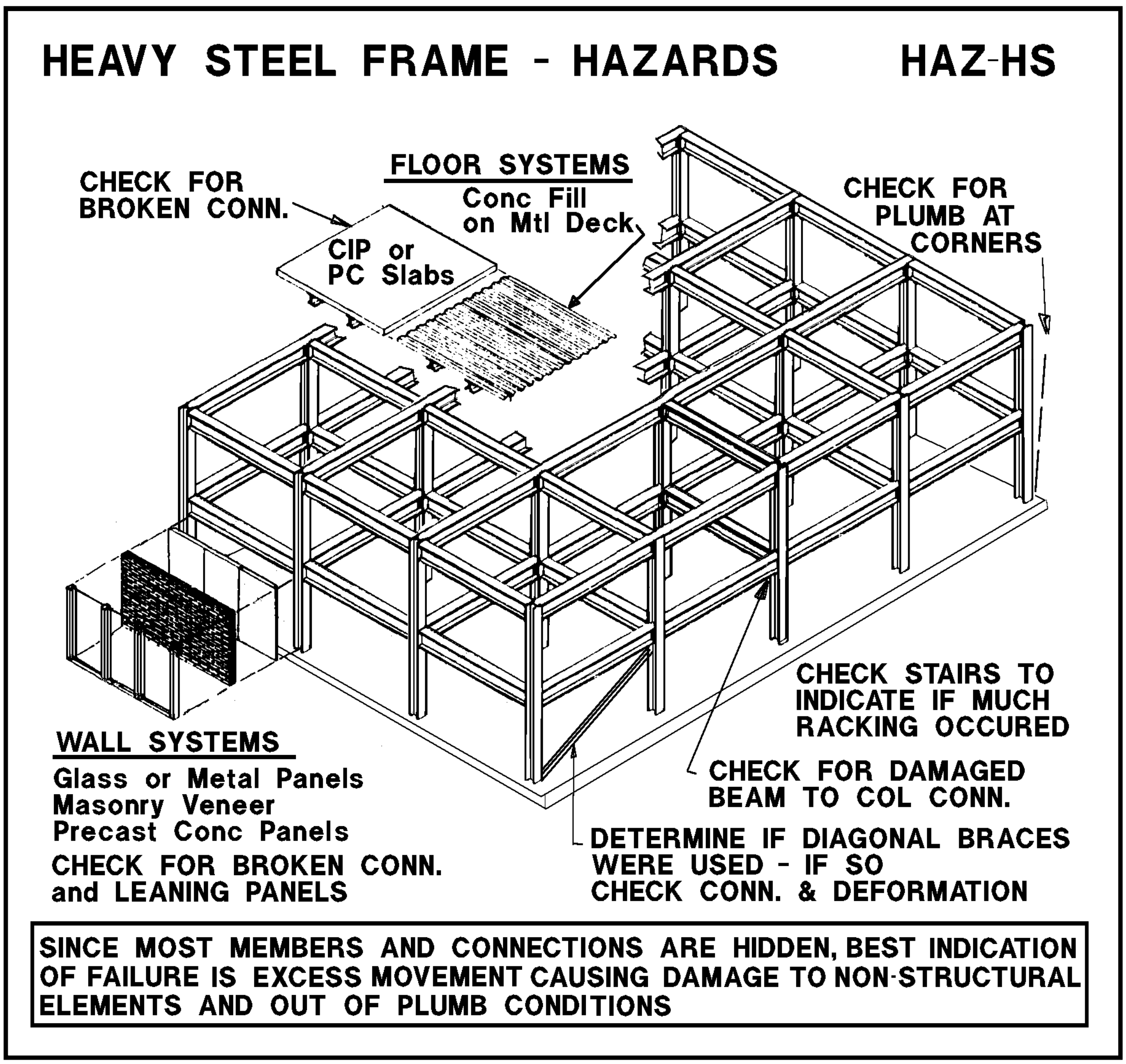
- **Check points: (HAZ-PC)**
  - ♦ Beams to column connections, broken welds, and cracked corbels.
  - ♦ Column cracking at top, bottom, and wall joints.
  - ♦ Wall panel connections.
  - ♦ Shear wall connections at floors and foundation.
  - ♦ Badly cracked walls.
- These structures are often made from lightweight concrete. It should be noted that lightweight concrete splits more easily than normal weight concrete.
- Most failures that occur due to broken connections will be brittle.
- Since individual building parts may be quite strong, cracked concrete failures may be ductile if adequate bonded reinforcing is present.
- Depending on extent of collapse, many falling hazards may be present.



Heavy Steel Frame Building Hazards

Principal concerns are the potential for building cladding to become Falling Hazards, and the cracking of welds in the main, moment resistant connections. Both of these hazards have occurred during earthquakes. Following earthquakes in 1985, 89, 93 and 94, building codes now require improved ductility in both the cladding attachments and the moment resistant connections.

- **Check points: (HAZ-HS)**
  - ♦ Exterior Cladding for leaning or broken connections.
  - ♦ Indications of movement – plumb corners, stair and non-structural damage – as clues to potential structure damage.
  - ♦ Main Beam-Column connections – may need to remove finishes or fireproofing.
  - ♦ Broken/damaged floor beam connections and, if present, broken PC slab connections.

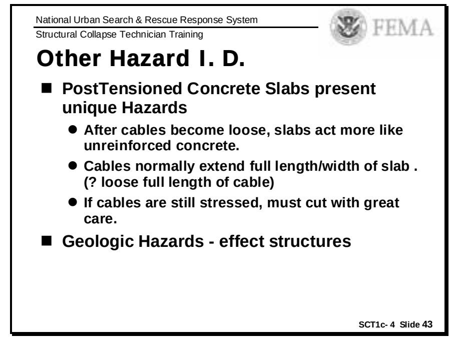


Post-tensioned Concrete Slab Hazards

- There are many types of structures that have floor slabs that are reinforced by high strength cables that are cast in place in a sheath, then stressed after the concrete is cast and cured (Post Tensioned).

These structures can perform very badly when subjected to extreme loading, and most always exhibit brittle behavior. Most common examples of structures where P.T. slabs may be found are:

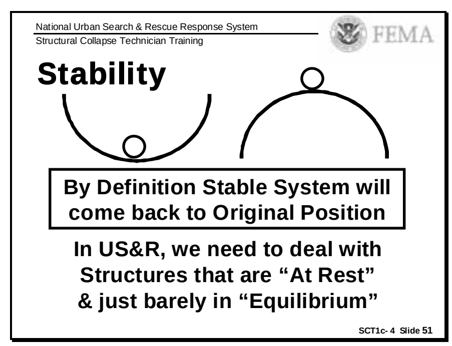
- Multi-story Parking Garages.
- First floors of apartment houses that are built over parking.
- Since the cables often extend the full length of these slabs, if it becomes damaged at one end or section, it will become "unstressed" over the entire length of the structure.
  - ♦ Therefore this type of slab has the very undesirable characteristic of being "Anti-Redundant".
- It may become necessary, during a US&R Incident, to cut through a P/T. slab that still has stressed cables. This takes proper care and protection.



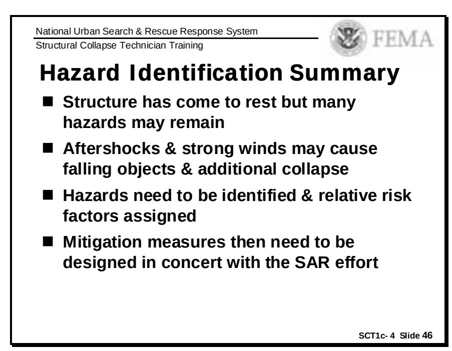
Summary, Hazard Identification

The problems of identifying hazards after a structural collapse are extremely difficult.

- Buildings are often complicated, and there are many different types and configurations.
- What remains after the triggering event may have come to rest, but the danger of further collapse and/or falling objects is often present.
- As shown in the adjacent slide, damaged structure may be "At-Rest", but that does not mean that they are "Stable".



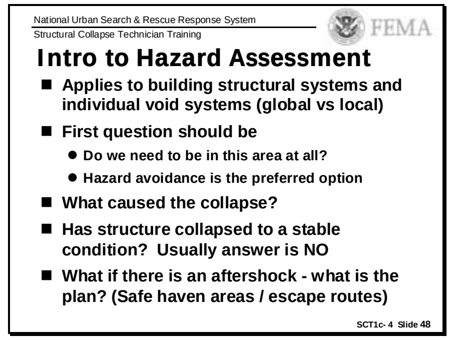
- A properly trained US&R engineer (Structures Specialist) should help identify these hazards.
  - ♦ Hazards should have probable risk factors assigned to them. (Low, Medium, High)
  - ♦ Measures to mitigate the danger can then be factored into the overall search and rescue effort, on the basis of Risk vs. Reward
  - ♦ Brittle conditions pose the greatest threat because of the possibility of sudden failure.



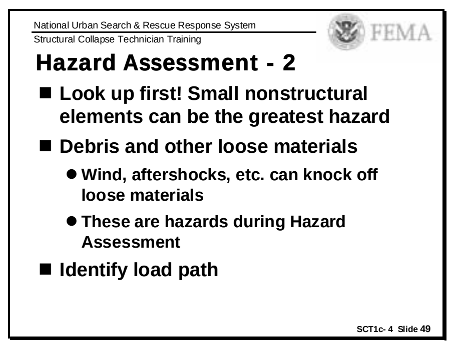
HAZARD ASSESSMENT FOR US&R

Based on the previous section on Hazard Identification, we need to add some additional considerations for US&R, since we may need to enter damaged structures.

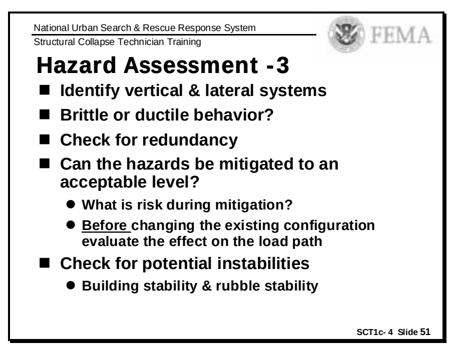
- Assessment applies to building structural system and individual void systems. (global vs. local)
- The first question should be “do we need to be in this area at all?”
  - Hazard avoidance is the preferred option
- What caused the collapse?
  - Quake, Wind, Explosion, unknown?
- Has the structure collapsed to a stable condition?
- What if there is an aftershock?
  - What is the plan?
  - What are the escape routes and/or safe havens?



- **Look up first**! Small, nonstructural elements may be the greatest hazards.
- Debris and other loose materials can fall in wind gusts and aftershocks—these are hazards during hazard assessment.
- Identify how the load paths have been changed due to the collapse.
  - Can we add mitigation to better stabilize without significant risk



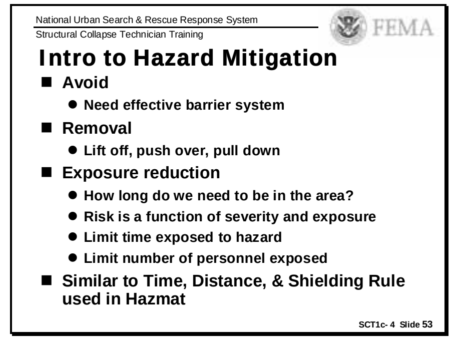
- Identify vertical and lateral load systems.
  - How have the load carrying systems been changed?
  - Will the structure exhibit brittle or ductile behavior?
- What redundancy is present?
- Can the hazards be mitigated to an acceptable level?
  - What is the risk during the mitigation?
  - Before changing the existing configuration, evaluate the effect of the change on the load paths.
- Check for potential instabilities: building stability and rubble stability.



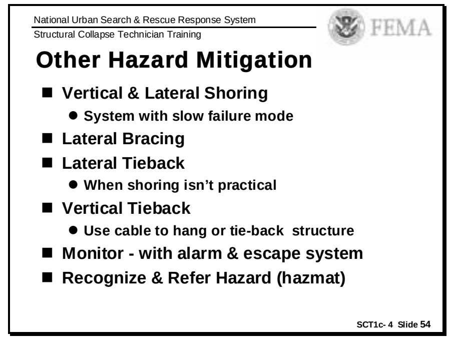
HAZARD MITIGATION

The basic alternatives to deal with structural collapse or falling hazards are as indicated below.

- **Avoid:** Plan the direction of SAR activities as far away as possible from a hazard and its effects.
    - ♦ Access of a badly collapsed structure should start from the top rather than from the edge (between layers) or by tunneling.
    - ♦ The use of mining techniques of tunneling and shoring with individual vertical posts has led to aftershock-caused shore failures. Consider alternatives, consult with others, and be as resourceful as possible.
- **Exposure reduction:** One of the most efficient methods of hazard reduction is to limit the time of exposure of rescuers exposed to a potentially dangerous situation.
    - ♦ Because of the natural tendency of rescuers to be helpful and to be **part of the action**, one will often find more than the minimum required number in a confined space especially when a live rescue is nearing completion.
    - ♦ Risk is a function of both severity and exposure.
- **Remove:** Removal may be more efficient than shoring.
    - ♦ Parts of URM walls may be removed by hand using aerial ladders for upper portions or in larger pieces using crane and clamshell.
    - ♦ Pre-cast concrete sections are more easily removed by small cranes or other concrete removal machines because of their moderate size and lack of interconnections compared to cast-in-place concrete.
    - ♦ If at all possible, Lift Off, Push Over, or Pull Down (safely of course) should be a first choice.

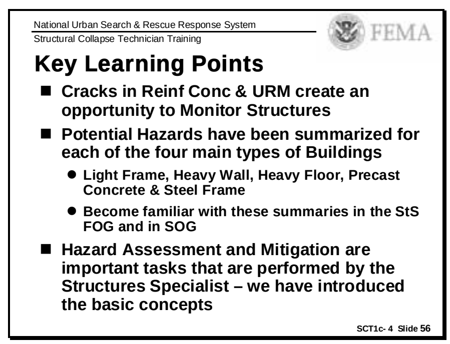


- **Shore:** Provide both vertical and lateral support; build safe haven areas. This topic will be discussed in detail in its own section, with special emphasis on slow/forgiving failure modes. The lateral bracing of damaged columns, beams, and entire leaning buildings may be required. Tension tieback bracing can also be effective for holding walls, and cranes have been used to temporally suspend parts of damaged buildings.
- **Monitor:** Methods include the use of crack measuring devices, Theodolites & Total Stations, and other tilt measuring devices (Change in Tilt) to monitor damaged structures. To be effective, these devices must be continually read and have the data recorded. There should also be an effective alarm system that activates an efficient evacuation plan.
- **Recognize** and refer hazardous materials to HAZMAT Specialists. Eliminate/shut off all possible fire hazards.



SUMMARY, HAZARD ID & INTRO TO MITIGATION

- We discussed "READING" concrete and masonry cracks in order to predict structural behavior.
- We then learned to IDENTIFY the most common hazardous conditions for simple buildings.



We have completed our discussion of Hazard I.D., and introduction to Assessment and Mitigation. The Key Learning Points are listed on the adjacent slide.

US&R operations will need to be carried out in partially collapsed and badly damaged, uncollapsed structures that pose the greatest threat of additional collapse and entrapment of rescue workers. Using the suggested monitoring methods, it is possible, in most cases, to recognize when further collapse is likely.

We will now discuss the FEMA US&R Marking System.

METHODS TO MONITOR STABILITY

The fundamentals of structural monitoring for SAR include: a Monitoring Plan; effective Emergency Communication Plan; Monitoring Tools, and Trained Monitoring Personnel

Elements of Monitoring

- Monitoring Plan
- Record Keeping
- Emergency Communication Plan
- Monitoring Tools
- Properly Trained Personnel

Monitoring Plan: Similar to a design performance memorandum, the monitoring plan establishes the expected performance levels for the structure being monitored.

Monitoring Plan

- Where and how
- Control/Reference Points
- Directions of movement
- Caution vs Alarm
- Record Keeping
- Report Info in Incident Action Plan
  - Info gets to those who need it

Monitoring Plan:

- Identifies what structure or component is being monitored, why, and for how long monitoring, should continue.
- Establishes control and reference points ensuring the accuracy of the monitoring. Identifying survey targets on a damaged structure may not be possible so finding appropriate targets that will telegraph incipient movement is critical.
  - Control points should be visible in various conditions and from at least two monitoring locations (to observe movements in X-Z and Y-Z directions.
- Must establish the tolerances, which create a “CAUTION” or an “ALARM” notification.
  - Caution levels might include movements that are out of the expected, but not large enough to warrant evacuation.
  - Alarm levels would include movements that telegraph impending collapse and evacuating rescue personnel is appropriate.
  - NOTE: Expected movements due to thermal expansion/contraction shouldn’t initiate a “CAUTION”.
- Must utilize an effective emergency communication system used to inform command of changing site conditions and the potential for site evacuation.

Monitoring Plan (continued)

- Must document all readings, expected direction of movement(s), potential failure-modes and effects, observations, and readings.
  - An effective record keeping system is well organized and keeps the Task Force Leader and Incident Command informed of site conditions
  - Typically, the documentation is included in the Operational Action Plan.

Emergency Communication Plan: Effective monitoring must utilize an effective **warning system** that informs Incident Command of potential structural movement (CAUTION) and includes a signal system to communicate **site evacuation** (e.g. three long horn blasts).

- The FEMA Incident Support Team and Task Force Leader(s) must persuade the Local Incident Command to integrate the local monitoring plan into the overall site safety plan.
- All rescue personnel must understand and be able to hear the warning device.
- All must know their evacuation route, and to whom they are to report –Accountability

Monitoring Tools - The following indicators have been used to monitor damaged structures in an attempt to warn of change in stability:

- Engineers Transit and/or Total Station.

  (Total Stations are used by most FEMA US&R TF)
- Electronic Tilt-meter Systems
  - Wireless Building Monitoring System
- Electronic Levels
  - SmartTool and SmartLevel
- Laser pointers or Level
- Plumb bob.
- Crack measuring device
- Wind Speed Measuring Devices

Record Keeping

- **Written Records need to be kept of all Monitoring Devices (forms shown next)**
  - **Record at least Hourly during first 5 days**
  - **All Monitoring Devices, inc Crack Monitors**
- **Recording System could be setup and kept by IST Structure Spec Staff**
  - **Each TF Structure Spec should keep own Unit Log (ICS 214) including Monitoring Data**
  - **Need to share data at every shift change, assuming no significant movement**
    - **Part of normal Hand-Off**
  - **Report info in Operational Action Plan (OAP)**
  - **OAP is generated by the IST, TAP by the Task Force**

Emergency Comm. Plan

- **Effective Warning System**
  - **For Caution and Alarm Warnings**
- **Involves Coordination**
  - **FEMA Task Force Leaders**
  - **FEMA Incident Support Team**
  - **Incident Command**
- **All must understand, and be able to Hear Warning Signals**
- **All must know their Evacuation Routs, and to Whom they Report**

US&R Monitoring Devices

- **Theodolite and Total Station**
  - **Reflectorless Total Station**
- **Electronic Tilt Meter**
- **Electronic Level**
  - **SmartLevel & SmartTool**
- **Laser Levels**
- **Plumb bob**
- **Crack measuring devices**
- **Wind Speed Measuring Devices**

Theodolites and Total Stations have been successfully used to monitor damaged structures, including Falling and Collapse Hazards.

- They are capable of very remote sightings on damaged structures that allow the observer to operate without significant risk.
- It is not required that the monitoring point be able to be physically accessed (only clearly observed).
- For reliable and repeatable results it is necessary to establish control points, such as back sight lines, that allow for re-setup of the instrument.

  This may be problematical following earthquake Aftershocks when many structures and ground surfaces have been moved and possibly disrupted

Theodolite/Total Station Surveying Methods: There are at least three methods that may be used when operating a Theodolite

- **Method One** is to establish a vertical control line that will compare a point on the structure to a fixed point on the ground, in order to monitor any changes in a leaning column or wall.
  - This method is simple and provides reliable control and repeatability – **Especially post Aftershock**
- **Method Two** is to use the Theodolite is to establish a reference point on an adjacent, stable structure, and then turn a series of horizontal angles to locations of interest on the damaged structure.
  - In this case we may be limited by the angular accuracy of the Theodolite.
  - This method requires the additional step of crosschecking the reference point, to assure that an observed movement has been accurately measured.
- **Method Three**, the Theodolite may be used to spot check a single point on a structure, measuring any movement using the telescope crosshairs.
  - This method is inefficient, not repeatable, and not normally recommended.
  - There may be instances where quick, short term monitoring of this type is all that is required, based on short term risk

Use of Devices
Theodolite/Total Station

- **Theodolite/Total Station may be used to detect small movement in remote structures**
  - **Method 1 - Establish a vertical line that will compare a point on a dangerous building to a point on the ground to detect additional tilt / movement**
  - **Method 2 - Use a Reference Point on an adjacent building, and turn an angle to several locations of potential movement on a questionable structure**
  - **Method 3 - Just do a spot check on an individual point on a damaged structure, such as Falling or Collapse Hazards (Total Station could measure X, Y, & Z)**

Theodolite Advantages and Disadvantages

Advantages: Allows for observation w/o making contact w/structure, and very distant observation with ability to zoom in on structure

Disadvantages: Expense, Need well trained personnel, subject to false readings when instrument is accidentally bumped, reading are not as intuitive to unfamiliar personnel

Use of Devices
Theodolite/Total Station
- Advantages
  - Observation w/o contacting structure
  - Make Distant Observations
  - Ability to Zoom - In on structure
  - Observe many points from One Location
- Disadvantages
  - Cost of instrument
    - 20sec Theodolite = $2000
    - 5sec Reflectorless Total Sta = $6500
  - Need Trained Operators
  - Readings not Intuitive
  - Need stable Reference/Control points
    - Difficult establishing post aftershock control?
  - Can't Use w/Face Mask

Theodolites have been used poorly, without reference marks, as well as proper records and warning systems.

- As a result erroneous readings have caused false alarms to be sounded.
- The most common cause of false readings is inadvertent moving of the tripod.
- It is much easier to eliminate these errors with a Total Station, the operator establishes a repeatable grid that is easily re-established if the instrument is moved, however:
  - One needs to establish effective barrier systems around monitoring stations.
  - Back sights and reference points should be established during setup.
  - At earthquake caused incidents, one must also plan for Aftershocks by setting up the instrument and the reference points properly

Use of Devices
Theodolite/Total Station
- Theodolite have often been used Poorly and without Reference/Control
- False Movements have been reported at several major incidents
  - Most often as a result of someone inadvertently bumping the tripod, without having an adequate Reference/Control mark system
  - This can lead to a lack of confidence in this very important system
- This is a very effective device that must be used properly

A Wireless Building Monitoring System is available from: Exponent Technology Development - (602) 206-4126 www. Exponent.com

- A full-system consists of four, bi-directional sensors that can be read by either one of two iPAQ Pocket PC (or a laptop computer) A full-system has 2 spread spectrum receivers.
- Receivers have range to 1000ft with clear sight line, but is less if signal is obstructed be heavy structures and/or metal
- The software is set to poll each sensors at 10 sec intervals. It checks the signal for interference, and a audible ping is heard as each sensor "reports" good data
  - A lower frequency "clunk" is heard if a sensor is not operation properly or turned off

Use of Devices – WBMS
- Wireless Building Monitoring Sys (WBMS)
  - System uses up to 4 Sensors, placed structure(s), to measure & transmit movement as an angle change.
    - Measures angle change of 0.05 degree (repeatable)
  - Signal is sent to 900mh Spread Spectrum Receiver
    - Range is up to 1000 ft. (clear sight)
    - Not as far thru Heavy Concrete & Metal Structures
  - Receiver is linked to MS Pocket PC PDA or a Laptop by wireless, blue-tooth connection
    - PDA software polls sensors at 10 to 15 sec interval
    - PDA chirps for each coherent signal received
    - May set software to alarm for any amount of angle change
  - USACE purchased 7- Sys in 2004 (6-deploy & 1-Train)
  - FEMA purchased 6 - Sys for IST in 2005
  - Mount using Hat Channel, screwed to concrete.
    - Strap Sensor to Hat Channel – Cargo Strap & Bungee

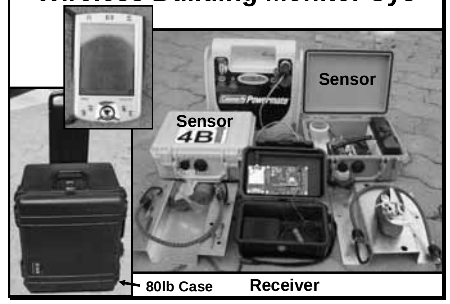
Wireless Building Monitoring System (continued)

- The software can be set to trigger an alarm at any preset angle change (alarm can be sounded through an earpiece)
- The tilt meters are sensitive to angle change of .05 degrees
- WBMS units are packaged in Pelican Cases, each having:
  - Two Sensors with 7 day, 12v. batteries & cables
  - One Receiver w/ Blue Tooth communication
  - One PDA with Pocket PC 2003 or Mobile 5 Op System
  - Software, Manuals & connecting hardware
- In 2005, FEMA purchased, two full systems for each IST (Four Pelican Cases + small case with drill-driver, etc)
- Advantages and Disadvantages of WBMS are shown in adjacent slide

Electronic levels, sensitive to an angle change of 0.1 degree, with digital read-out, can be purchased at Home Depot type stores and tool mail order houses for about $100 (2005).

- They can be mounted on a structure, the angle recorded, and any subsequent change would then need to be read by a TF member.
- In order to mount the SmartTool on a concrete structure, one may do the following:
  - Place a 1 x1x1/8 x 0'-9" steel angle that has been attached to the structure with putty type epoxy or 1/4" concrete screws placed thru 5/16" holes that have been drilled in the angle (angle may be left in place)
  - One should then use a 2 ½" C-clamp to make a removable, but positive connection

Wireless Building Monitor Sys



Use of Devices – WBMS

- Advantages
  - Monitor 4 or more locations at once
  - Very accurate and can set Alarm for any amount of movement
  - Portable Receiving/Alarm System
  - Remote Observation (up to 1000 ft)
  - Can Use w/Face Mask
- Disadvantages
  - High cost ($18,000 per full-system, 2005)
  - Need Qualified, Techno-Operator
  - Need planned, periodic battery recharge system
  - Need to place Sensors on Structure
    - They have remote, 7-day, 12v batteries

Use of Devices – Electronic Levels

- Electronic Levels should be placed in pairs on structure to measure change in any angle (Vertical or Horizontal)
  - Measures angle change of 0.2 degrees
  - Cost is in $100 range, each
  - Must be continually read (no alarm)
    - New lower cost model cannot be set on zero when placed in vertical position
  - Use binoculars for remote reading
  - Must alter device to turn battery saver off
  - Mount on steel angle using magnetic tape and/or a C-clamp

Electronic levels (continued)

- They are supplied with a battery saver feature that turns them off in 5 min. if no change in angle is sensed.
  - This feature can be defeated by a modification: contact djhammond@sbcglobal.net

  Made by: MACKLANBURG-DUNCAN
  www.amazon.com\toolcrib
- Advantages and Disadvantages of Electronic levels are shown in adjacent slide

Use of Electronic Levels

- Advantages
  - Low cost
  - Long battery life (about 40 hours)
  - Easy to read
- Disadvantages
  - Not as accurate as Tiltmeter
  - Need to place on structure
  - Need to place 2 in each location to measure angle change in N-S + E-W direction
  - Need to dedicate someone to read them – line of sight
  - Need to modify Battery Saver Function

Laser Levels, may also be used to measure an angle change of about 0.2 degrees.

They may be purchased a Home Depot stores for less than $100 (RoboToolz) in a 3-beam or single beam configuration, and come with magnets embedded in their bottom surface.

There are also more versatile models, such as the Hilti PMP-34 that are sold in kit form. It can be configured as a 3-beam, 2-beam or 1-beam tool. It also is self leveling, but one may cancel this feature

Use of Devices – Laser Levels

- Laser Levels - placed on structure to indicate movement by changed position of the light beam on a specified target
  - May measure angle change or lateral/vertical movement
    - Accuracy depends on setup – maybe 0.2 degrees,
    - 1/8"Must be continually read (no alarm)
    - Target should be set in safe area
  - RoboToolz Laser Level
    - Low cost, but less useful
  - Hilti Laser Level - PMP-34
    - Moderate cost w/ lots of extras

- The RoboToolz may be mounted on a structure using the same steel angles as for the SmartTool, however they have a strong magnet, so the C-clamp is not required
- The Hilti PMP-34 also has magnets, plus several mounting devices
- One would then need to place a target within 75ft of the device with an **X** on it to observe the structure's movement
- One could use the 3-beam laser level with 2 targets to observe movement in two directions. Otherwise it would require that two single beam lasers be mounted in a mutually perpendicular orientation (same as SmartTools)
- The RoboTolz use AAA batteries that last only 12 hours, but the Hilti PMP-34 uses 4-AA batteries that last 40 hours
- The advantages and disadvantages of Laser Levels are listed on the adjacent slide

Use of Laser Levels

- Advantages
  - Low cost
  - Easy to read
- Disadvantages
  - Not as accurate as WBMS
  - Need to place on structure
  - Need to place 2 targets for each location to measure angle change in N-S + E-W direction
  - Someone to read them – line of sight
  - Need to replace batteries
    - Every 12 hrs for RoboToolz
    - Every 40 hrs for Hilti

Plumb Bob and string can be used for moderate structures to determine changes in position of one story from another, between a story and the ground, or between an upper part of the wall and the ground.

- This can allow one to measure and record the changes in a leaning structure when no other device is available.

Benefits: inexpensive and simple to use. No special skills are required

Disadvantages: Personnel must attach plumb bob to structure and constantly observe it

Use of Devices - Plumb Bob

- Use a Plumb bob hung from small structure to compare to a point on the ground/pavement
  – Allows one to observe change in a leaning structure
- Advantages
  – inexpensive, easy to use, no special skills (a rock on a string will suffice)
- Disadvantages
  – requires one to attach to structure, constant observation, not too accurate

Crack Measuring Devices can be used to monitor cracks in concrete or masonry shearwalls or concrete moment frame in several ways. It is important to know if the cracks in a damaged building are of a constant width or enlarging.

Methods that have been used include:

- Marking an "**X**" across the crack with the center on the crack. Significant lateral movement changes can be observed.
- Placing folded paper in cracks or use automobile thickness gages (.004" to .025") to measure a specific location.
- Adhesive or other tape may be placed across the joint to measure change, but dusty conditions may prevent tape from adhering.
- Two parallel sticks (rulers) can be taped across a crack with a perpendicular line being drawn across both of them (or existing lines on two rulers can be aligned). If the crack changes width, then the originally straight line will be offset.
- Plastic Strain gages (about $16 ea. in yr. 2000) may be placed across cracks to also indicate change. (mount with paste type, quick set epoxy or concrete screws)

  Made by: Avongard, (www.avongard.com)
- One may epoxy inexpensive glass slides across a crack. If the crack moves the slide will crack

Crack Monitoring

- Draw or sawcut ‘x’ centered on crack
- Use inexpensive ($15) plastic strain gage can be placed at crack
- Spray paint cracked area
- Place shims/cards in cracks
- Inexpensive, easy to read change, but need to be checked (up close) periodically

Note that if a structure has significant changes in temperature, the cracks will change width, due to the temperature change. The larger the structure the larger the change.

Method to Monitor Disaster Site

Seismic Trigger Device can be installed at the site to sense the initial **P** waves of strong aftershocks. Since the P waves travel at 5 km/sec max. and the damaging **S** waves follow at approx. 3 km/sec, a warning signal could be triggered at a building site prior to the damaging effects of the **S** wave.

- The device comes in a portable carrying case and would need to be bolted to a solid slab/foundation, etc. somewhere near a damaged building.
- For sites within 10 km of the aftershock origin there would not be enough warning to be useful.
- For sites over 50 km away there would be would be time to escape to cover etc. (seven seconds +)
- A device of this type was used at a site after the Loma Prieta Earthquake. The current cost of the device is approximately $6000.00 and is manufactured by:

Earthquake Safety Systems
2064 Eastman Ave., Ste 102 Ventura, CA 93003
(805) 650-5952

Aftershock Warning System

The U.S.G.S., and others, have discussed making an aftershock warning system available to US&R Task Forces during the first week after an earthquake.

- The system uses an array of sensors near the fault to detect aftershocks.
- A warning signal is relayed by repeaters to individual pagers that will be given to each task force that is involved in rescue operations.
- For sites that are about 10 km from the active fault, there will be only 3 seconds warning.
- For sites that are 50 km away there will be 12 seconds warning (proportionally greater warning for greater distance from aftershock origin).

Method to Monitor Disaster Site

- **P vs S wave - time delay**
  - **P wave travels faster than S waves**
  - **If distance from Fault to Site is more than 50km there is opportunity to warn of Aftershocks**
- **Seismic Trigger deployed at Disaster Site**
  - **Warns when P wave arrives**
  - **Destructive S wave arrives later**
- **Pager System**
  - **Pagers at disaster site are signaled from sensors at fault that measure Aftershocks**

Summary Of Hazard I.D. & Monitoring Methods

- We discussed to "**READ"** Concrete and Masonry cracks in order to predict structural behavior

- We then learned to **IDENTIFY** the most common Hazardous Conditions for simple buildings

- And finally it should be understood that US&R operations will need to be carried out in partially collapsed and badly damaged, uncollapsed structures.

  These pose the greatest threat for additional collapse and entrapment of rescue workers. Using the suggested Monitoring Methods, it is possible, in most cases, to recognize when further collapse is likely.

Key Learning Points

- **Structure Mitigation requires initially rapid and then continuing Prioritization & Planning**
  - **Creative Alternatives are what is needed**
- **Monitoring needs careful planning & the reporting of reliable information**
  - **The StS must become familiar with the Operation and Care of all Monitoring Tools in the Task Force Cache**

Part 5 – US&R Strategy & Structure Size-up

Strategies will be presented from a Structures Hazards point of view. Other input such as medical urgency, availability of special equipment and/or trained personnel, other hazardous conditions will also need to be considered.

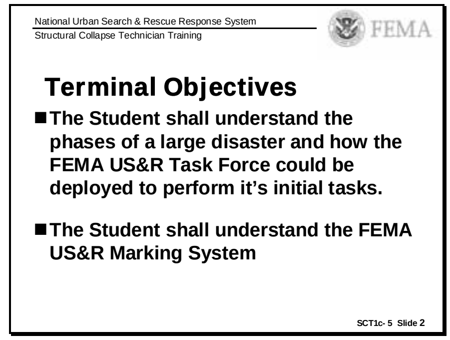
THE THEME OF US&R MUST BE TO SAVE TRAPPED VICTIMS WHILE MINIMIZING THE RISK TO THE VICTIM AND THE US&R FORCES

The Terminal Objectives are:

The Student shall understand the phases of a large disaster, and how the FEMA US&R Task Force could be deployed to perform its initial tasks.

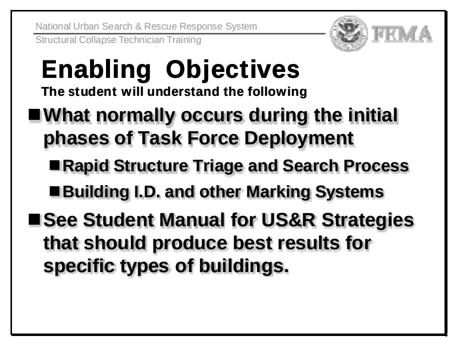
The Student shall understand the FEMA US&R Marking System

The Student shall understand the most appropriate strategies to be used in order to effect rescues in various types of structures.



We will discuss the following:

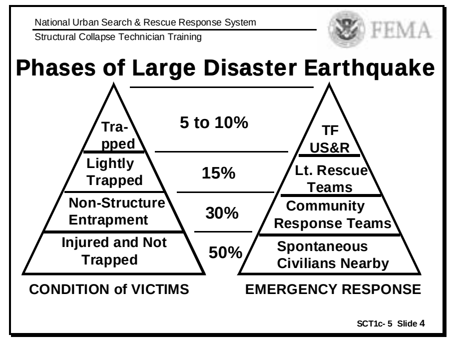
- Phases of a Large Disaster
- Information Gathering
- First hours of a deployment, options
- Rapid Structure Triage and Search Process
- Identification of Individual Buildings
- Structure/Hazards Evaluation and Marking
- Search and Rescue Assessment Marking
- Victim Marking
- Example of Search and Victim Marking
- Basic Building Search & Rescue Strategy (Student Manual only)
- Metal Detector & Cutting of Post-Tensioned Concrete, Cables (Student Manual only)



Phases of a Large Disaster

It is important for all to understand the typical chronology of a US&R incident, especially one caused by a devastating earthquake. The emergency response normally occurs in the following phases:

Initial spontaneous response unskilled, neighbors, community response teams, passers-by will heroically help remove lightly trapped and/or injured victims. These rescuers have often acted far beyond their normal skill level and often save three-fourths or more of the total. Survival rates are relatively high, since victims are normally not entrapped. Professional firefighter, law enforcement officers, and emergency medical personnel may participate and better organize the response. This phase will often end during the first night.



Planned Community Response by local trained community response teams. Call-out and visual search would be used to locate and rescue the non-structurally trapped. Some lifting of objects (furniture, bookcases, etc.) would be done as well as mitigation of hazards (extinguish small fires, turn off gas, observe/refer hazardous materials).

Void Space Rescue by local emergency services rescue forces. Search elements would help prioritize site to make better risk vs. benefit judgments. Rescue would proceed using existing cavities, duct/plumbing shafts, basements, and/or small cut openings in easily breachable floors and walls. Some shoring might be done to provide safe haven areas and otherwise protect emergency responders and/or victims. This phase may start the first day, but often, not until after some organizing efforts have taken place, requiring at least one hour.

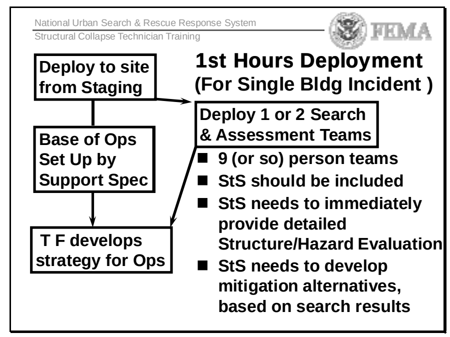
Technical, Urban Search & Rescue by trained US&R forces, aided by equipment. Site or sites would be re-evaluated, re-searched, and prioritized for the ten-daylong effort. Extensive cutting, shoring, etc. may be done to penetrate the structure. Cranes may be used to remove layers of structural debris or parts of the structure that are hazardous.

<u>Typical First Hours Deployment –</u> for large, sudden incidents, like an earthquake.

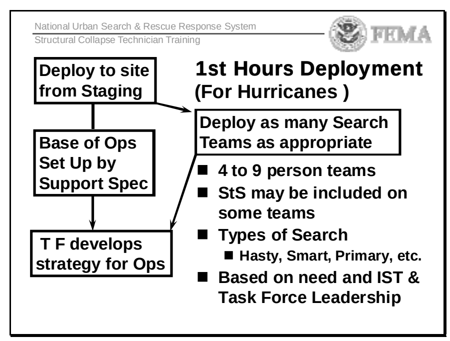
There are many possible scenarios to which a US&R Task Force or a number of Task Forces could respond. However, our Operating System Description envisions that, during initial setup, a decision needs to be made as to the most appropriate deployment of TF Assessment and Search components. Some initial questions that need to be answered are:

- Is Rapid Structure Triage needed or have others established initial priorities?
- How many building have been assigned to the TF, and does Assessment and Search need to be carried out at one or more locations?
- Will the Task Force need to deploy Team(s) in order to pre-prioritize the structures?
- What sort of Search Team configuration will be used? (Detection Team(s), Location Team(s))
- How remote are the buildings assigned to TF?

The adjacent slide illustrates how Task Force members might be deployed during this initial phase for a single building incident.



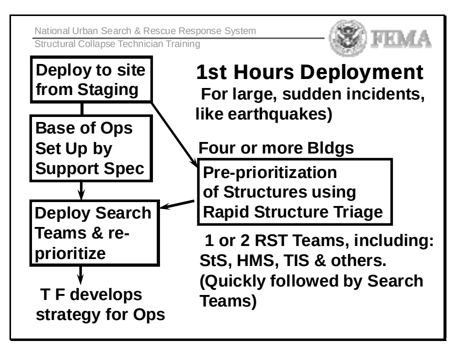
The adjacent slide illustrates how Task Force members might be deployed during this initial phase for a hurricane where many buildings have been affected, but most occupants have evacuated due to warnings.



It should be noted that the Lead Agency for Hurricane Disasters is the U.S. Coast Guard, and they may have an influence on the deployment od FEMA and other Task forces

The adjacent slide illustrates how Task Force members might be deployed during this initial phase for a sudden onset event such (large earthquake), where many buildings are affected and many may be trapped.

As mentioned, there are many possible scenarios, and Leadership should deploy a TF as is most appropriate



We will discuss, in detail, how the Rapid Structure Triage Process is intended to aid the Task Force in pre-prioritizing the large number of damaged structures, so that the Search Process will be most efficient

Initial Information Gathering

Information gathering techniques will be crucial to the efficient transition of the US&R forces into the incident. It is important for these incoming forces to carefully verify information obtained from the first responders and other individuals at the disaster site. By the time the information exchange takes place, the first responders will probably be subjected to the following:

- A many hour period of physically and emotionally draining work. Feelings that it's not possible that other victims have survived within a badly collapsed structure.
- A need to experience closure; that the incident is over.
- Feelings by relatives/friends of the missing that they have surely survived and are entrapped.
- The information gathering must therefore, proceed as swiftly and unemotionally as possible, while testing all current assumptions.

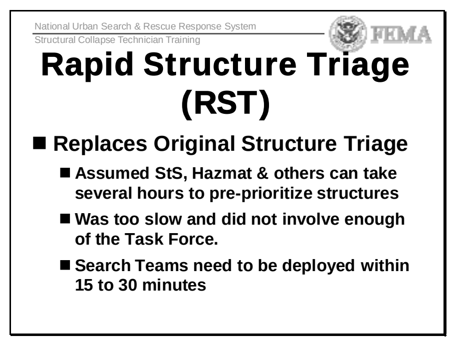
Rapid Structure Triage (RST)

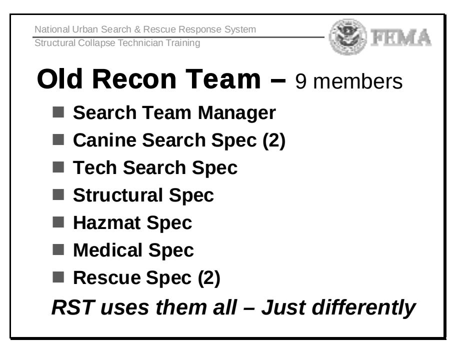
The intent of pre-prioritization and identification of structures for a large, earthquake-like incident is to make more efficient use of search teams.

This can be done immediately after a suddenly occurring disaster by special assessment teams or local responders.

It can also be done by FEMA US&R Task Force(s) after they have been assigned to a specific area

- The assumption in this case is that local responders have been overwhelmed, and a rapid recon process will help focus the task forces on their life saving work.
- As previously stated, Task Force Leadership, may deploy teams as is indicated in the following information. The makeup of the teams may be as described here, or there may be some other ways of more efficiently locating the entrapped survivors.

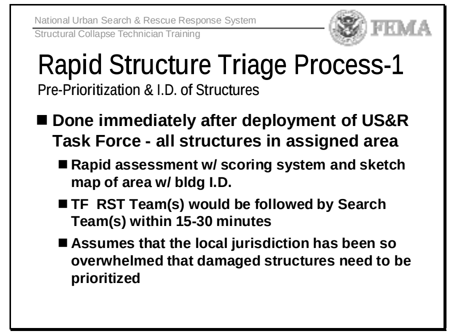




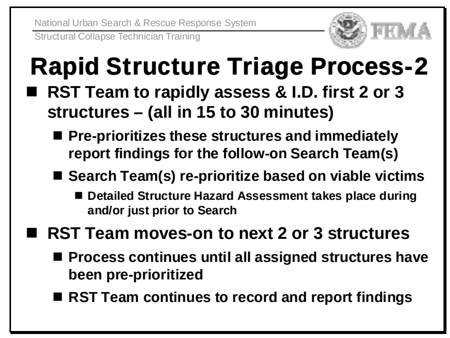
Rapid Structure Triage Process

This more rapid method for pre-prioritization and identification of structures for a large, earthquake-like incident was adopted in 2010.

Previously, it was envisioned that a Structure Triage would be accomplished by the Structures Spec.(StS) and Hazmat Spec.(HMS) during the first hour or more of a deployment. In this process, Search Teams would not be deployed until the triage was completed. This would be too time consuming, and the newly adopted process proceeds as follows:



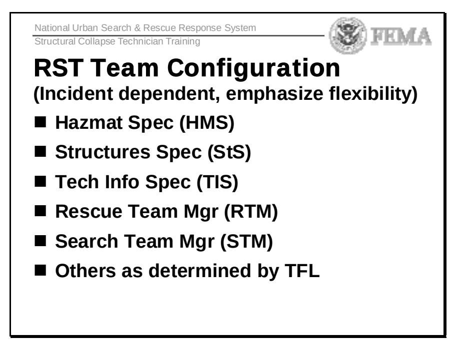
- The RST Team (explained next) would be sent-out first to quickly assess and identify the first two or three structures.
- They would report their findings to the Search Team Manager (or other designated leader).
- Search teams would re-prioritize these 2 or 3 structures, based on viable victim finds, and rescue could be started in the highest priority structure
- The RST Team would have moved-on the next two or 3 structures, and report those findings.



The process would continue until all assigned structures had been searched, and task force was clearly focused on rescue operations in the highest priority structures.

RST and Search Team Configuration

Although this rapid recon process is intended to be flexible and incident dependent, the teams are most likely to be staffed by the following:



RST Team – Search Team Manager (STM), and/or Rescue Team Manager (RTM), Structure Spec **(**StS), Hazmat Spec. (HMS), & Technical Info. Spec. (TIS)

Search Detection Team –STM, Canine Search Spec, Tech Search Spec, Medical Spec, Rescue Spec, StS.

Search Location Team – Similar to Detection Team

It is also possible that the detection and location would be performed by each search team. This could allow for a Task Force to deploy two Search Teams at once.

<u>Team Tasks</u>

RST Team(s)- provide initial hazard assessment and detection, with a scoring system based on expert judgment. They would then provide feedback of initial prioritization.

Search Detection Team(s) – provide victim detection that could re-prioritize the structures for the Search location Team(s). They would also provide detailed hazard assessment, and mark the structure with appropriate Search and or Structure Hazard Marks.

Search Location Team(s) – would locate victims, assess their condition, and start rescue. They would also mark the appropriate areas with Victim Marking.

RST Team Tasks

- **Structure, size, type, location, & occupancy**
  - **TIS would provide photo documentation and record RST information**
- **Hazmat Evaluation and Detection**
- **Rapid Structure Triage/ Assessment**
  - **Scoring based on "Value Judgment"**
  - **Provides initial prioritization**
  - **Identify Slo-Go Situations**
  - **RTM would provide important input**
    - **Especially for victim access**

RST Critical Information

The following information needs to be considered in determining risk/benefit that will aid in prioritization.

- **Occupancy** the type of activity done in the building, and where most individuals would have been located. May be time of day dependent.
- **Time of Day** refers to the time of the event which caused the collapse. This is a critical factor when combined with the occupancy.
- **Disaster Type** The type of disaster would determine several things such as:
  - Potential for aftershocks following earthquakes
  - Severity of damage from blasts.
  - Unknown existing deficiencies for sudden collapse without apparent cause
- **Structure size/type** indicates potential number of victims, plus difficulty of access and hazards
- **Collapse Type –** indicates type(s) of voids and potential for victim survival.

RST – Critical Information

Info considered to determine Risk / Benefit

- **Occupancy - type of activity and where the most individuals would have been located.**
- **Time of day - when disaster occurred**
- **Disaster Type - possible after-forces & risk of secondary collapse**
- **Structure size & type - potential no. of victims + difficulty of access & hazards**
- **Collapse type - indicates type of voids & potential for victim survival**

<u>Other Considerations</u>

Prior Intelligence information from the general public, local authorities, first responders, etc. relating to known trapped victims.

Search and Rescue Resources Available does the particular building require resources beyond what is readily available to the task force (i.e., is heavy equipment required to gain access).

Structural Condition of the Building generally, can search and rescue operations proceed with a minimum of stabilization effort.

RST Scoring Criteria

The following will be evaluated in assessing the **Probability of having Viable Victims**:

- Potential number trapped - low medium high
- Victim access effort reg'd - difficult medium high
- Type of voids - compact separated open

The following will be evaluated in Assessing Risk:

- Chance of further collapse - low medium high
- Number. of Falling Hazards - low medium high
- Void support condition - good poor unknown

The selection of the applicable level of **relative risk** requires that the Structures Specialist uses his/her best judgment. The Rescue Team Mgr should be consultation in selecting from the **victim probability** criteria. All on the RST, including the StS must be prepared to quickly make these decisions.

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RST Scoring Criteria

- **Criteria for Probability of Viable Victims**
  - **Potential Number Trapped - low med high**
  - **Victim Access Effort - difficult med easy**
  - **Type of Voids - compact separated open**
- **Criteria for Assessment of Risk**
  - **Chance of Further Collapse - low med high**
  - **Number of Falling Hazards - low med high**
  - **Void Support Condition - good poor unknown**

RST Building/Structure Ratings

Each building/structure would be given a two letter Rating to indicate the probability of being able to rescue viable victims, and a two letter Rating for Assessment of Risk.

These Ratings would be based on the Scoring Criteria presented above, and require "Expert Judgment" to be applied by the StS and HMS

For probability of being able to rescue viable victims:

- **LP** indicates Low Probability
- **MP** indicates Moderate Probability
- **XP** indicates High Probability (consistent with XR)

For Assessment of Risk

- **LR** indicates Low Risk
- **MR** indicates Moderate Risk
- **XR** indicates High Risk (HR = Human Remains)

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RST Building/Structure Ratings

- **For Probability of Viable Victims**
  - **LP = Low Probability**
  - **MP = Medium Probability**
  - **XP = High Probability** (be consistent w/ XR)
- **For Assessment of Risk**
  - **LR = Low Risk**
  - **MR = Medium Risk**
  - **XR = High Risk** (HR used for Human Remains)

"No Go" Conditions (Slo-Go).

These would include structures that are on fire, have significant hazmat spills or otherwise have conditions that would make search and rescue operations too risky. Buildings with "**No Go**" conditions would be expected to be re-evaluated when those conditions were mitigated, and some comment would be made regarding this should be communicated to the STM or other designated leadership.

A better term for these conditions would be **"Slow-Go"**, since that would better indicate that after the extreme hazard has been eliminated, the building might be searched

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Slo-Go Conditions

(Replaces the temporary No-Go)

- **FIRE**
- ***HAZMAT***
- **Need to add information as to when Slow/Delayed-Go is to be re-evaluated and/or revisited**

How Ratings are applied

After assessing each of the three Criteria for Victim Probability, each structure would be given a Rating of LP, MP, or XP

After assessing each of the three Criteria for Risk , each structure would be given a Rating of LR, MR, or XR

- This process required the StS & HMS to make rapid, value judgments in a very short time
- Victim probability should include considerations such as potential numbers and ease/difficulty/risks involved with their extrication.
- It should be understood that it is possible to have more than one structure with the same classification.

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How Building Ratings are applied

- **Each building/structure would be rated for Probability and for Risk.**
  - **Requires StS, HMS, & RTM (or STM) to make rapid, value judgments.**
  - **Probability includes considerations such as potential number of victims and ease of extrication**
  - **More than one building/structure could have the same rating.**
- **Examples**
  - **XP, LR and LP, XR**

Examples of Risk Level

The companion RST form RST-2 will provide a list of collapsed structure conditions that could be considered low, medium and high risk.

This will provide the StS some backup information to aid in making the difficult judgments that are required in this Rapid Structure Triage Process

The adjacent slide lists some of those conditions

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Examples of Risk Level

- **Low**
  - **Pancake concrete slabs**
  - **Soft 1st story collapse**
  - **Wood 1 & 2 story**
- **Medium**
  - **Partly collapsed concrete**
  - **Racked wood 3 story+**
  - **Free standing URM/Conc walls – plumb**
  - **URM w/ Lean-to, V, Wall Fall collapse**
- **High**
  - **Partly collapsed PC or PT conc.**
  - **Uncollapsed & leaning**
  - **Free standing URM/Conc walls – leaning**
  - **Many falling hazards**

New RST-1 and RST-2 Forms

New forms RST-1 and RST-2 have been developed to replace the Triage Forms, TRI-1 & TRI-2

Form RST-1 is shown on the next page. RST-2 is similar, and has instructions for using the RST forms

Rapid Struct Traige RST-1 Date/Time:________ By:________ Page ___ of ___

Task Force: ____________ Date/Time of Disaster: ____________ See Form RST-2 for Instructions

AREA MAP

BLDG. ID:

FLOOR AREA: ....
No. STORIES: ....
OCCUPANCY: ....

MATERIAL: (Circle all that apply)
WOOD CIP CONCRETE STEEL
URM TILT-UP PT CONC PC CONC
OTHER:

CRITERIA for PROBABILITY of VIABLE VICTIMS (check one in each line)

POTENTIAL NUMBER TRAPPED LOW___ MEDIUM___ HIGH___
VICTIM ACCESS EFFORT DIFFICULT___ MEDIUM___ EASY___
TYPE OF VOIDS COMPACT___ SEPARATED___ OPEN___

CRITERIA for ASSESSMENT of RISK (check one in each line)

CHANCE OF FURTHER COLLAPSE LOW___ MEDIUM___ HIGH___
No. OF FALLING HAZARDS LOW___ MEDIUM___ HIGH___
VOID SUPPORT CONDITION GOOD___ POOR___ UNKNOWN___

BLDG RATINGS (Circle one each line)
LP MP XP
LR MR XR

GPS Coordinates ....

SLOW- GO (circle if applies) FIRE HAZMAT OTHER: ....
Notes: ....

BLDG. ID:

FLOOR AREA: ....
No. STORIES: ....
OCCUPANCY: ....

MATERIAL: (Circle all that apply)
WOOD CIP CONCRETE STEEL
URM TILT-UP PT CONC PC CONC
OTHER:

CRITERIA for PROBABILITY of VIABLE VICTIMS (check one in each line)

POTENTIAL NUMBER TRAPPED LOW___ MEDIUM___ HIGH___
VICTIM ACCESS EFFORT DIFFICULT___ MEDIUM___ EASY___
TYPE OF VOIDS COMPACT___ SEPARATED___ OPEN___

CRITERIA for ASSESSMENT of RISK (check one in each line)

CHANCE OF FURTHER COLLAPSE LOW___ MEDIUM___ HIGH___
No. OF FALLING HAZARDS LOW___ MEDIUM___ HIGH___
VOID SUPPORT CONDITION GOOD___ POOR___ UNKNOWN___

BLDG RATINGS (Circle one each line)
LP MP XP
LR MR XR

GPS Coordinates ....

SLOW- GO (circle if applies) FIRE HAZMAT OTHER: ....
Notes: ....

BLDG. ID:

FLOOR AREA: ....
No. STORIES: ....
OCCUPANCY: ....

MATERIAL: (Circle all that apply)
WOOD CIP CONCRETE STEEL
URM TILT-UP PT CONC PC CONC
OTHER:

CRITERIA for PROBABILITY of VIABLE VICTIMS (check one in each line)

POTENTIAL NUMBER TRAPPED LOW___ MEDIUM___ HIGH___
VICTIM ACCESS EFFORT DIFFICULT___ MEDIUM___ EASY___
TYPE OF VOIDS COMPACT___ SEPARATED___ OPEN___

CRITERIA for ASSESSMENT of RISK (check one in each line)

CHANCE OF FURTHER COLLAPSE LOW___ MEDIUM___ HIGH___
No. OF FALLING HAZARDS LOW___ MEDIUM___ HIGH___
VOID SUPPORT CONDITION GOOD___ POOR___ UNKNOWN___

BLDG RATINGS (Circle one each line)
LP MP XP
LR MR XR

GPS Coordinates ....

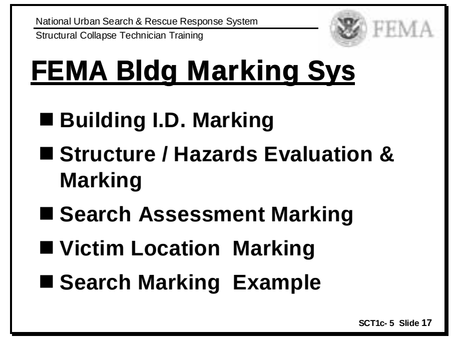
SLOW- GO (circle if applies) FIRE HAZMAT OTHER: ....
Notes: ....

FEMA Building Marking System

What follows is a discussion of the FEMA building marking system. The marks are as follows:

- Building Identification Marking
- Structure/Hazards Evaluation Mark
- Search Assessment marl
- Victim Location Mark

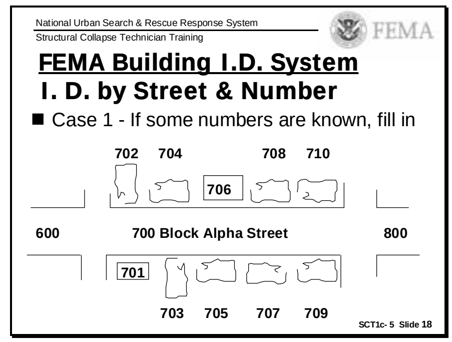
Following the explanation of the marks, is an example of how the Search and Victim marks are applied.



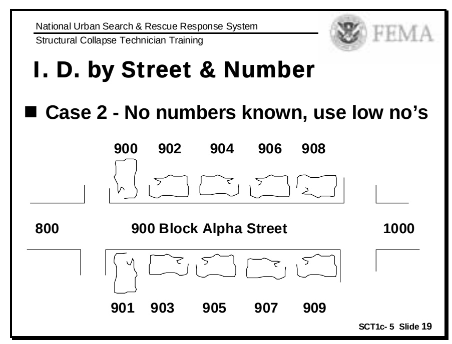
Identification of Individual Buildings

The standard system for locating a building on any block involves the following considerations:

- Use existing numbers and fill in unknowns.



- If the numbers are all unknowns, keep numbers small, on odd and even sides.

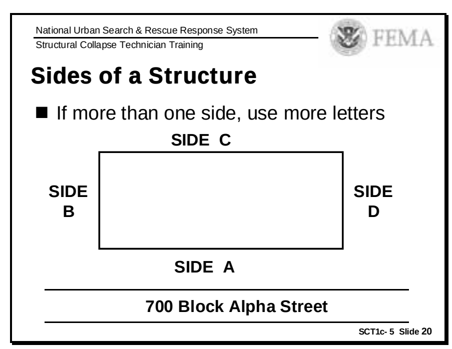


The standard system for building layout is as follows:

- Sides A, B, C, and D start at the street and go clockwise.
- Stories are designated as 1 (or ground), 2, 3, 4.

Make sure that everyone understands where the 1st (or ground floor) is and whether there are any basements.

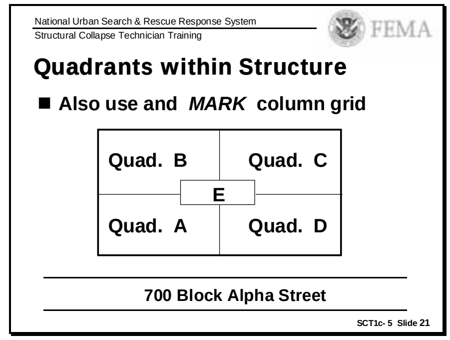
- Basements are designated as B1, B2, and B3.



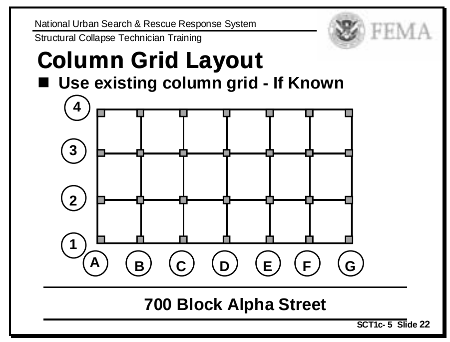
Identification of Individual Buildings (continued)

Quadrants within a building are marked according to the following system:

- Mark A, B, C, D, etc. on the long side, and 1, 2, 3, etc on the short side.



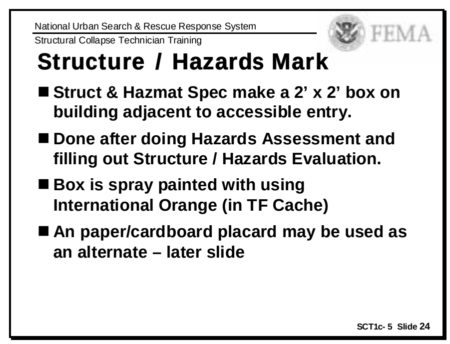
- It is more helpful to mark an appropriate number on each column for structures with a regular (or irregular) layout.
- Column numbers should be large enough to be read from a distance (such as by a crane operator).
- Use existing column numbers if known.
- If designation is unknown, best to use letters on long side & numbers on short side, starting at left-front corner.



Structure/Hazard Evaluation and Marking

This mark would normally be drawn on structures in a large incident with many damaged buildings, when the Struct. and Hazmat Specs need to leave a particular site, and assess another.In single structure incidents, when the Struct. and Hazmat Specs remain at the site, there would be no need to draw the mark .

This mark may be made using spray paint, crayon, or by placing a placard as shown on following pages.

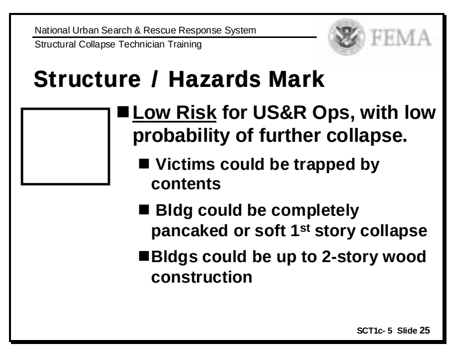


The explanation of what this “Open Box” means is being clarified in this 2008 document.

The “Open Box” indicates a structure with low risk for US&R Operations. It may be significantly damaged, but is a low probability of further collapse.
The previous versions of this mark said “Structure is accessible and safe for search and rescue operations. Damage is minor with little danger of further collapse”

The term “Safe” was inaccurate, since all structures that would be the focus of US&R would be hazardous. The new term “Low Risk”, is more appropriate

The graphic on the following page contains, new, more appropriate explanations for the three levels of hazard that are intended for the three different boxes.



Structure/Hazard Evaluation and Marking (continued)

Detailed Structural/Hazard Evaluation should take place **after** a priority list of structures has been established by the leadership using recon or just common sense if only a few structures are involved. The Structure/Hazards Evaluation Form has been made deliberately different from Search and Victim Marks. The greatest area of concern is not with the fully collapsed structures but with those that have only partly collapsed. The Structures and Hazmat Specialist should be prepared to fill out the US&R Structure/Hazard Evaluation Form, identifying structure type, occupancy, hazards, etc (probably at the beginning of search operations). In addition, the Structures Specialist will generate notes and diagrams regarding search operations. However, in some cases, the assessment will only indicate that the building is too dangerous to conduct US&R operations until significant, and time-consuming mitigation is completed.

TASK FORCE BUILDING MARKING SYSTEM

STRUCTURE/HAZARDS EVALUATION UHR-4 08

STRUCTURAL SPECIALIST MAKES A 2'x2' BOX ON BUILDING ADJACENT TO MOST ACCESSIBLE ENTRY. THIS IS DONE AFTER DOING HAZARDS ASSESSMENT AND FILLING OUT HAZARDS ASSESSMENT FORM. BOX IS SPRAY PAINTED WITH INTL ORANGE AND MARKED AS FOLLOWS:

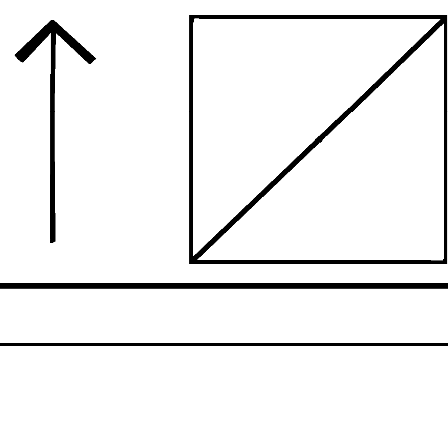
<u>LOW RISK</u> FOR US&R OPERATIONS (BUT NOT SAFE) DAMAGE IS SUCH THAT THERE IS A LOW PROBABILITY OF FURTHER COLLAPSE. (may be pancaked bldg, soft 1st story, or up to 2-story wood construction)

<u>MODERATE RISK</u> FOR US&R OPERATIONS STRUCTURE IS SIGNIFICANTLY DAMAGED. SOME AREAS MAY BE LOW RISK, BUT OTHER AREAS MAY NEED SHORING, BRACING, MONITORING, OR REMOVAL OF HAZARDS.

<u>HIGH RISK</u> FOR US&R OPS AND MAY BE SUBJECT TO SUDDEN COLLAPSE. REMOTE SEARCH OPS MAY PROCEED AT SIGNIFICANT RISK. IF RESCUE OPS ARE UNDERTAKEN, SIGNIFICANT, TIME CONSUMING MITIGATION SHOULD BE DONE.

ARROW LOCATED NEXT TO THE MARKING BOX INDICATES THE DIRECTION OF SAFEST ENTRY TO THE STRUCTURE.

HM INDICATES HAZMAT CONDITION IN OR ADJACENT TO STRUCTURE. S&R OPERATIONS NORMALLY WILL NOT BE ALLOWED UNTIL CONDITION IS BETTER DEFINED OR ELIMINATED.

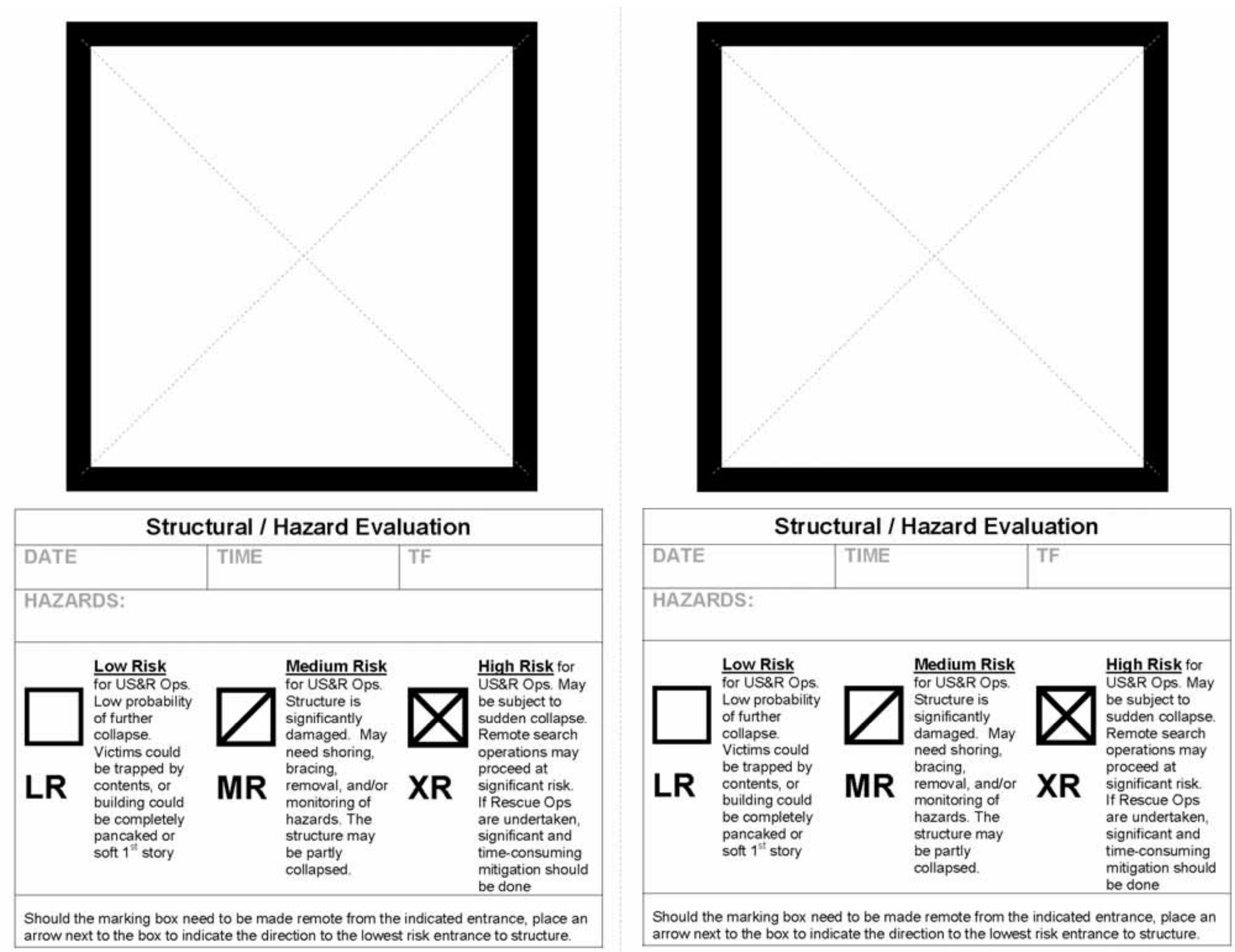


15JUL92 1310 HRS
HM - NATURAL GAS
OR-1

(DO NOT ENTER BUILDING UNTIL GAS IS TURNED OFF)

Structure/Hazard Evaluation and Marking (continued)

- As noted the three different marks indicate the level of risk, and are consistent with the terms used during Recon. For a large, multi-structure incident, this detailed assessment would most likely be completed by a Structures and Hazmat Spec assigned to the Search Detection Team (as they are starting search operations). The StS and Hazmat Spec. that are part of the Recon Team would only have time to complete the Recon Forms, and a rapid assessment
- Following this evaluation, the Structure/Hazard Evaluation Marking would be placed on the building near each entry (as noted on the previous page).
- As an alternative to the painted marking, a paper or cardboard placard may be used. It is illustrated below and is intended to be in 8.5" x 11" (portrait) , and made with black ink on white paper (Stick-on, Rite-in-Rain, or light cardboard.



Structure/Hazard Evaluation and Marking (continued)

- The US&R Structure/Hazards Evaluation Form is filled-out by the StS during the detailed assessment. It provides places to quickly record the critical information, and acts as a check-list. It is shown below:

US&R STRUCTURE / HAZARDS EVALUATION FORM - HAZ-1 **BY:**

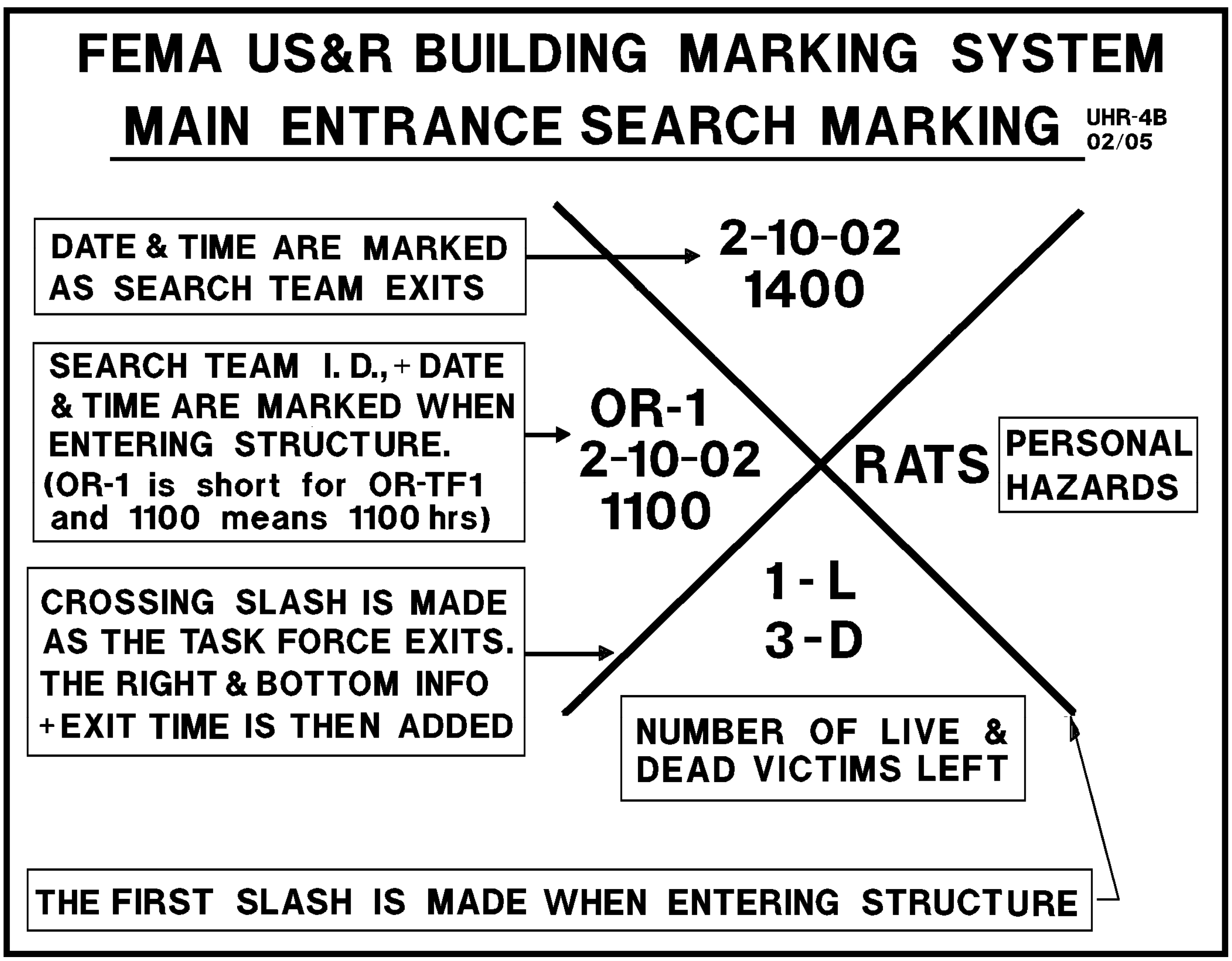
Where required, circle all the information or items that apply. NOTE: AFTERSHOCKS MAY CAUSE ADDITIONAL DAMAGE OTHER THAN NOTED.

STRUCTURE DESCRIPTION: Bldg ID: No. Stories: No. Basements:	**BUILDING MARKING:** Date/Time of Evaluation: Date/Time of Catastrophe:
MATERIALS: Wood Concrete Steel URM PC Concrete Other:	**TYPE OF COLLAPSE:** Pancake Soft 1st Floor Wall Failure Torsion Middle Story Overturn Other:
FRAMING SYSTEM: Shearwall Moment Frame Braced Frame Other:	**LOCATION OF VOIDS:** Between Floors Basement Shafts Other:
OCCUPANCY: Hospital Police Station Fire Station Emergency Operations Center Office Building School Public Assembly Industrial Hotel Apartment Retail Store Other:	**DESCRIPTION OF UNSAFE AREAS & HAZARDS:**
VICTIM & OTHER INFORMATION:	
LOCATION OF BEST ACCESS & SAR STRATEGY:	
SKETCH:	

Search and Rescue Assessment Marking

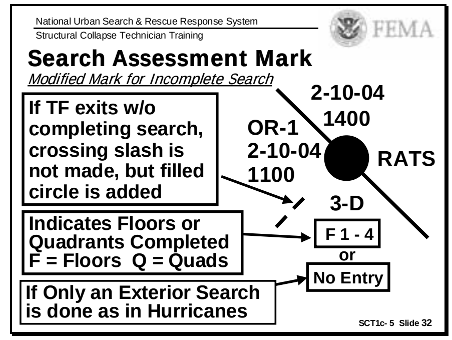
Standard SAR assessment marking is designed to perform two functions:

- First, when SAR personnel enter the building or parts of the building, they draw an initial line so that others will be informed of **ongoing operations**. In addition, they mark in the left quadrant the Task Force identifier, plus date and time they have entered. The time, date and I.D. will inform others as well as provide critical data should there be a question regarding the Task Force's safety in the event of a secondary incident.
- Upon entering, the searcher(s) should proceed in a consistent pattern in order to assure that all areas are searched. Go to the right and always keep to the right in every room is a common method, but go left, stay left is also used. Be consistent and search all areas.
- When operations are completed in the building (or parts of the building), the crossing diagonal line will be drawn and information in the remaining three quadrants will be added to indicate what was found and accomplished. **This marking will also indicate that the Task Force has exited safely.**
- The finished mark can then indicate to other SAR forces the outcome of previous operations.



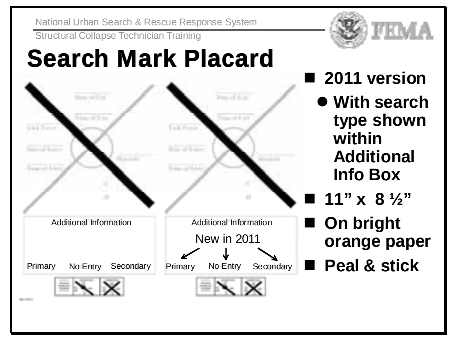
Incomplete Search Assessment Mark

- The slide shows the new mark to provide a method for a task force to indicate it has performed and incomplete search. The TF may have entered the structure and only completed some of the floor or, as in the case of hurricanes; the search may have been done without entering the structure.
- The extent of the search is to be recorded by placing information in a box below the Search Mark



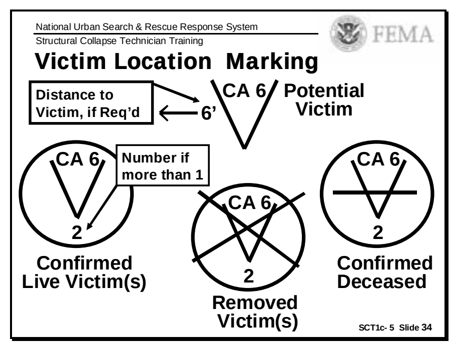
Search Mark Placard

In Sep06 an adhesive backed, stick-on Search Mark Placard was approved, in order to reduce the use of paint at incidents like hurricanes where many structures are involved. In 2011 it was modified to add information regarding the type of search. This information is to be added in the box below the main part of the Search Mark. See adjacent slide.

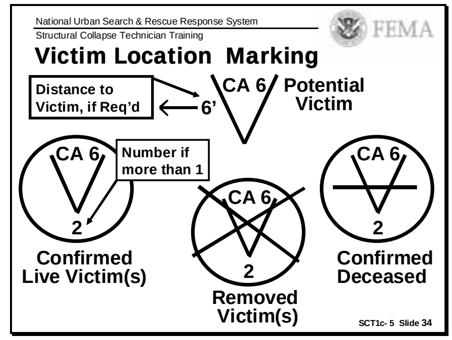


Victim Marking System

This series of marks is used to indicate the location of each victim discovered on the US&R site.



- The marks are made with orange spray paint or crayon.
- Marks will normally be initiated after a search is performed unless the victim is immediately removed.
- The **V** is intended to be about 2 feet high and located as near to the victim as practicable.
- It could be painted on a nearby wall surface or directly on a piece of rubble.
- An arrow may be added to indicate the exact victim location.
- The TF identifier example "**CA 6**" should be included as shown.
- The circle is added when the victim is **confirmed**.

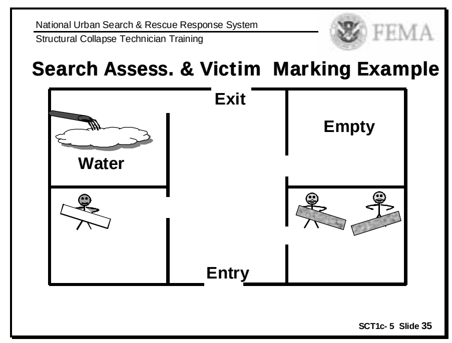


- ♦ As an example, the **V** could be placed when only one K9 has indicated that a victim has been located. The circle could be added when the initial **find** is **confirmed** by another K9 or some other search tool.
- ♦ However, when K9s are working in pairs, no mark should be made after the first dog indicates a victim because it may influence the second dog.

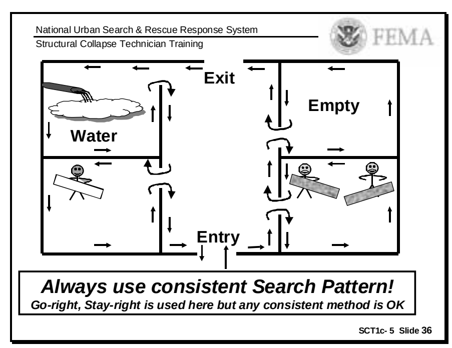
- A horizontal line is added if the victim is confirmed to be dead.

An large **X** is drawn completely through the circle after the victim has been removed.

Search Assessment & Victim Marking Example



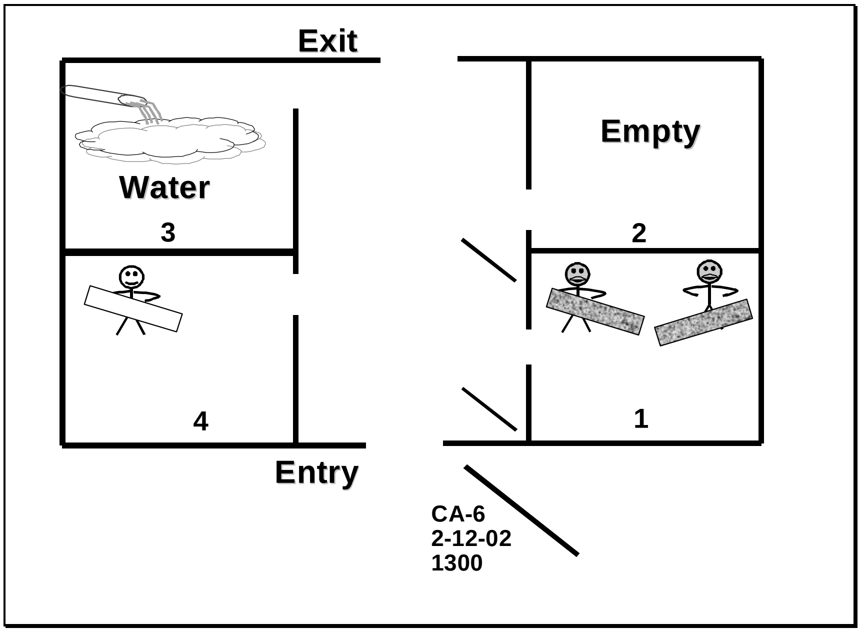
- An **example** that illustrates the use of the **Search Assessment** and **Victim Location Marks** is illustrated on the following two pages.
- The basic information is as follows:
  - ♦ It has a front entry and a rear entry/exit.
  - ♦ There are four enclosed rooms in the building.
  - ♦ Room 1 has four dead victims.
  - ♦ Room 2 is empty except for normal contents.
  - ♦ Room 3 has a broken water pipe and is flooded.
  - ♦ Room 4 has one live victim.



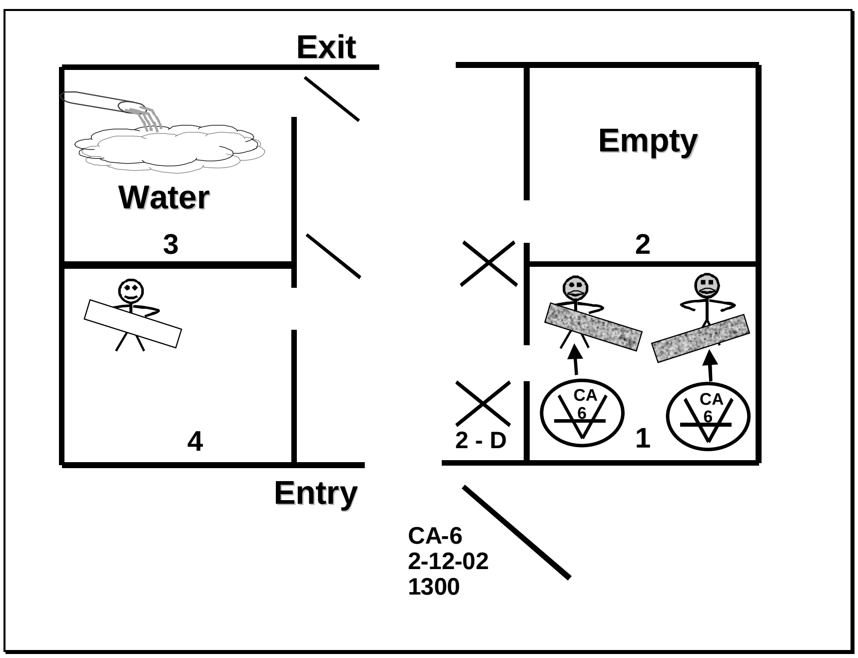
- The search team will need to decide what search pattern to use, as they search the building
  - ♦ The pattern that is illustrated here in the "Go Right, Stay Right Pattern
  - ♦ Any pattern may be used, as long as it is consistent and covers all areas of the building
  - ♦ The Search Team Manager should determine the most appropriate pattern, no later than when the search team is planning to enter the building

Search Assessment and Victim Location Mark: Example

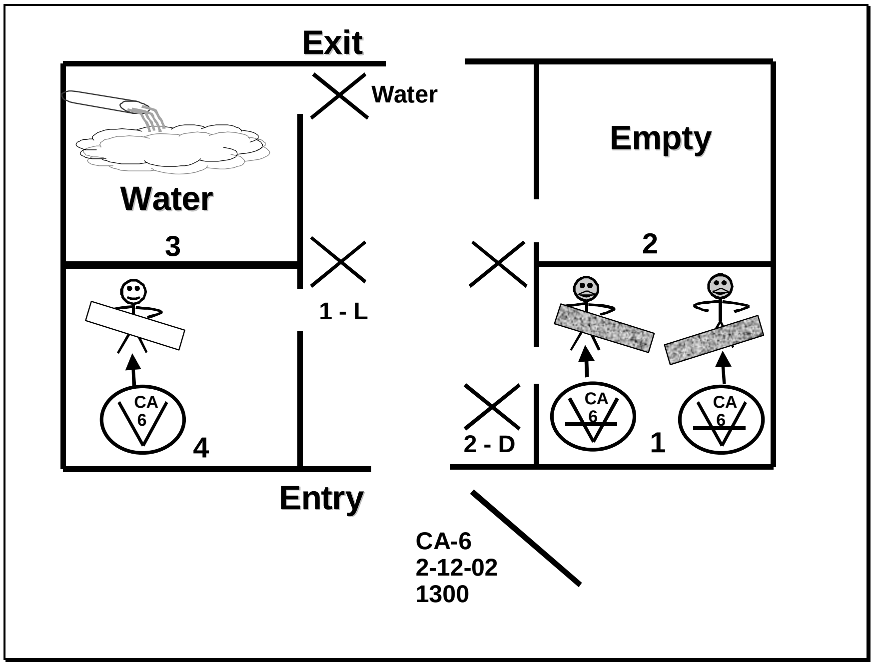
- In this example, we will search in a Go-right, Stay-right Pattern. It should be noted that any consistent search pattern is acceptable, as long as all areas are searched.
- Enter the building, make first slash, TF ID, date and time, and enter Rooms 1 and 2 after making a single slash by each door.



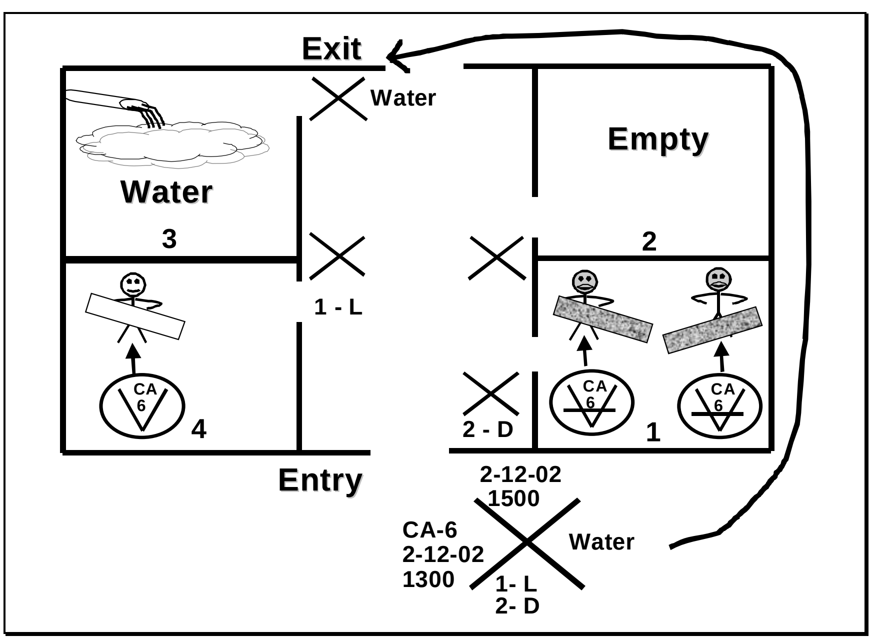
- Exit Rooms 1 and 2; draw a second slash and record findings. Then enter Rooms 3 and 4.



- Exit Rooms 3 and 4; draw a second slash and record findings.



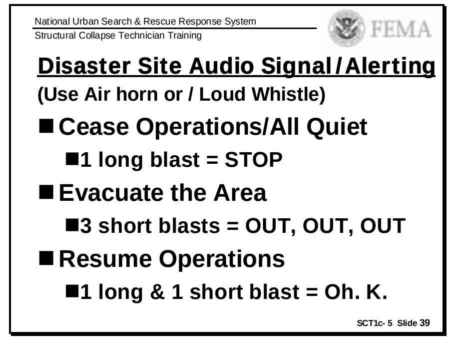
- Exit the building, draw a second slash, complete all data, and prepare to go to the next building or assist Rescue at this building. If the exit might be approached by another SAR unit without seeing the front entry, repeat the marks at the exit location.



Disaster Site Signaling and Barricades

General Requirements

- Effective emergency signaling is essential for the safe operation of SAR Team personnel operating at a disaster site.
  - ♦ These signals must be clear and universally understood by all SAR Team personnel.
  - ♦ These signals are used throughout the world.



Disaster Site Audio Signaling/Alerting

Air horns or other appropriate hailing devices shall be used to sound the appropriate signals as follows:

- Cease Operation/All Quiet:

1 long blast (3 seconds) = **STOP**

- Evacuate the Area:

  3 consecutive short blasts (1 second each)

  = **OUT, OUT, OUT**

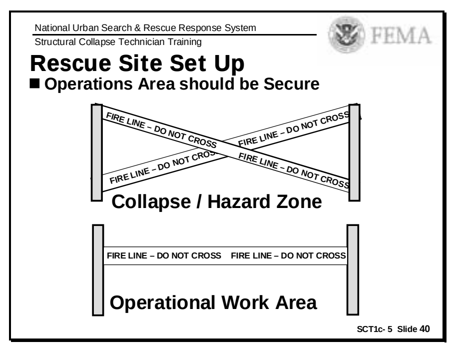
Conduct a radio roll call to account for all personnel. When all are accounted for, the radio signal "all clear" will be broadcast on the command channel.

- Resume Operations:

  1 long and 1 short blast = **O, KAY**

Disaster Site Barricades

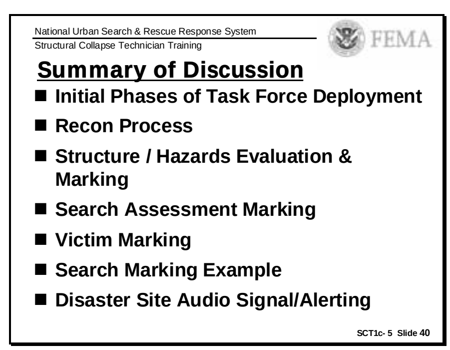
- General cordon markings (cordon banners, flagging, etc.) are used for a small, defined area. They can be enlarged to include other non-buildings (for example, a bridge, dangerous zones, NBC, or security). Large areas may require fences and/or patrol.
  - ♦ Operational Work Zone—see slide at right.
  - ♦ Collapse/Hazard Zone—see slide at right.



Summary, FEMA US&R Marking System

In summary, we have discussed the FEMA US&R marking system that US&R Task Forces and others involved in urban search and rescue should use to document the actions they have taken at a particular disaster site.

Please review this system to make sure you are completely familiar with it



Basic Search & Rescue Plans

Basic Plan – for Individual Buildings

Reconnoiter Site collecting as much information as possible

- Determine structure type - to better assess type of failure, type of hazards, ease of entry and cutting.
- Interview neighbors, survivors, interested people (how many potential victims; where last seen, location of stairs, elevators, basement, etc.).
- Obtain building plan an/or draw crude plan with special emphasis on probable location of voids, existing shafts, basement.
- Search Specialists re-assess building in detail to re-identify hazards.

Prioritize site use collected data to obtain best risk/benefit ratio.

- Conduct callout/listen search.
- Plan shoring at access, and/or use most efficient access.
- Determine condition of basement.
- Avoid falling hazards unless they can be removed and/or shored.

Initial Search Properly trained search dogs and electronic locators can be used successfully to locate deeply buried victims.

Even properly trained dogs may only be able to indicate direction of scent, which is not necessarily the direction of the victim.

Electronic devices, operated by trained personnel, can detect victims that are instructed to make tapping noises.

- "Send out" search dogs as far as possible. Check alerts with second dog/observer/handler.
- Use listening/seismic finders to hear victim noise.
- Explore all existing vertical shaft openings.
- Explore horizontal openings with great care (send dog in and keep people out).
- Search from safe, stable areas into unstable.
- Re-prioritize site vs. location of potential live victims.

Selected Cutting & Removal based on priorities of initial search vs. probable hazards.

- Cut vertical openings and re-search, re-check with dogs and/or listening/viewing devices.
- Initial shoring for access.
- Avoid un-shored overhead structures.
- Recheck all shoring after cutting and removal, loading can change.
- Continue process of cutting layers, re-searching, and re-prioritizing.
- Stabilize area at victim to give medical aid.

Heavy Search & Rescue

- Continue search after prolonged cutting and/or removal.
- Give victim aid and gain information regarding additional victims.
- Re-check all shoring after cutting and removal, since loading can change

We will now discuss how these strategies should be adapted to the following construction types

- Light frame
- Heavy Wall – URM & Tilt-up
- Heavy Floor- Concrete Frame
- Precast Concrete

SAR Plan – Light Frame

Search Items

- Callout/listen search may be effective due to lower density of wood floors.
- Acoustic listening devices will probably be more effective than seismic type sensors in these buildings that have wood floors and walls. Broken wood is relatively poor transmitter of vibrations.
- Dogs may be able to sent through cracks in wood floors if they are not heavily covered.

Hazard Reduction Items

- Shut off gas (and electricity) and reduce other fire hazards. (**This applies for all types of buildings)**
- Assess / refer chemical hazards. **(What's in the typical kitchen?)**
- Remove / avoid or topple leaning chimney
- Place vertical and / or lateral shores as required

Victim Access Items

- Use horizontal entry thru cavities or thru walls.
- Make vertical access thru holes cut in roof / floor
- Remove / shore hazards as required.

SAR Plan – Heavy Wall – URM & Tilt-up

Search Items

- Callout / listen search may be effective due to lower density of wood floors.
- Acoustic listening devices will probably be more effective than seismic type sensors. Most of these structures will have wood floors that have collapsed in large planes and badly broken masonry, both of which are relatively poor transmitters of vibrations.
- K9 may be able to scent through cracks in wood floors if they are not heavily covered.

Hazard Reduction Items – URM

- Shore hazardous floors with vertical shores.
- Remaining uncollapsed URM walls are brittle, aftershock / wind falling hazards. Either avoid, remove, tieback, or raker shore them. May need to shore in both IN and OUT direction.
- Beware of all falling hazards - peeled, cracked, & split URM walls are very brittle. High potential for falling & collapse hazards.

Hazard Reduction Items – Tilt-up & Low Rise

- Use diagonal or raker shores for hazardous walls.
- Shore hazardous roof / floor beams, etc.

Victim Access Items – URM

- Use horizontal entry thru existing openings with great care.
- Vertical access through wood floors should be easy and least dangerous.
- Avoid cutting large beams and more than two joists in a row.
- Avoid cutting walls. Holes can greatly reduce strength of poorly cemented walls - most are important bearing walls
- Beware of roof / floor joist / beams that are not sitting on their original flat bearings or ledges, they can slide down walls and produce outward forces as they move to find next stable position.
- Basement may provide good access, but should shore for safety. Failure of wood column or beams can be sudden.
- Hand removal of bricks may be required.
- Large pieces of wall may be removed by clamshell or other bucket with thumb. (need to prevent parts from falling)

Victim Access Items – Tilt-up & Low Rise

- Use horizontal entry thru existing openings with great care.
- Vertical access through wood roof / floors should be easy and least dangerous.
- Holes in wall panels should be made 2 ft minimum away from joints. If wall has concrete pilaster / column, one may cut opening next to column on side away from joint.
- Wall panels and large pieces of roof may be lifted by crane or other equipment.

SAR Plan – Heavy Floor, Concrete Frames

Search Items – Heavy floor

- Not likely to hear callout of victims through floors due to high density of concrete.
- Seismic listening devices can be most effective in these, heavy structures, especially when floor slabs remain intact and form thin void spaces as in pancake type collapse.
- K9 will indicate direction of scent that may be flowing around large slabs, back and forth across the building. (**Location of victim must be interpreted from conditions**) Area should be re-checked by dogs after layers have been removed. The best time to use dogs is in early morning and at dusk when scent is rising.

Hazard Reduction Items – Heavy Floor

- In partly collapsed building (upper floors, etc.) is very important to check floors that support debris load.
    - Read cracks to determine if more and progressive collapse is probable.
    - Multi-story shoring may be only safe procedure.
    - It normally takes at least three un-damaged floors to support shores from one damaged floor that contains little debris (if heavy concrete debris from upper floors is present, shores need to extend down to additional, undamaged floors - two more floors per 12" of debris)
- Shore / avoid badly cracked beams.
- Shore / avoid hanging slabs / beams.
- Shore heavily loaded flat slabs (beamless slabs) - punching shear.
- Beware of all falling hazards - parts of slabs, walls, etc. May be hanging from exposed rebar - how well is rebar embedded?
- Monitor structure for Lateral Movement with Theodolite or other tilt measuring device

Victim Access Items – Heavy Floor

- Use any existing vertical shaft.
- Basement may be good access, but need to evaluate floor slab above and possibly shore. How many basement levels?
- Preferred access is usually made by cutting thru slabs from above collapse.
- Best to cut slabs mid-way between beams & columns.
- Check for thinnest slab area. Pan joist and waffle slabs have ribs spaced 3 ft or so with 3 to 4 inch thick slab between.
- Do not cut columns - usually do not need to.
- Avoid cutting concrete / masonry walls. They may be bearing walls. If have masonry infill wall in concrete frame cutting is possible - check first to see if frame is loading wall due to collapse.
- Remove concrete slabs with Crane after all rebar is cut

SAR Plan – Precast Concrete

Search Items – Precast Concrete

- Callout / listen search may be effective. It depends on size of voids between larger pieces of concrete.
- Effectiveness of listening devices will depend on the interconnection of the collapsed, structural parts. Acoustic sensors may not be effective in compact rubble, and seismic sensors may not be effective due to poor transfer through badly broken concrete parts.
- K9 search may be effective - again depending on compactness of concrete rubble.

Hazard Reduction Items – Precast Concrete

- Remove / avoid hanging pieces of structure. There may be many loose or poorly connected pieces of precast concrete. Use cranes and other equipment.
- Shore beams adjacent to badly cracked columns.
- Remove / shore tilted wall panels or pieces.
- Partly collapsed buildings may have adjacent slabs and/or wall panels that have damaged connections that may break loose in aftershocks or if loading shifts.

Victim Access Items – Precast Concrete

- Cutting of cored slabs & tee slabs should be done at edges (Thinnest part of section, away from ribs).
  - Cut half of hole in each of two adjacent precast pieces.
- Don't cut ribs in Tees or walls & do not cut columns.
- Walls may be cut with care.
  - Cut holes at least 2 ft away from joints.
  - Consider problems of shoring vs. removal (removal may be more efficient).
  - Check wall welded joints for signs of movement.
- Some walls may be infill URM and may be cut if not loaded by collapsed concrete pieces.
- Basements may not be good access unless basement walls and first floor slab are cast in place concrete. Shoring may be required in any case.
- Use horizontal access thru existing cavities - use great care
- Lift off loose concrete pieces with cranes or other equipment
- Great care must be taken when lifting and/or shoring large concrete pieces, since adjacent pieces may shift.
- Precast concrete will often weigh about 75% of normal (150 PCF) concrete. It also splits more easily.

Metal Detector

Metal detectors should be used to locate rebar or prestress cables prior to cutting slabs and walls. This can keep from dulling bits and inadvertently cutting cables. Metallescanner Pro by Zircon is magnetic type that is small and can determine location of rebar as much as 4" deep. Cost $100

- Devices are available with costs from $400 to $2000.

Cutting Post Tensioned Concrete – Cables

Post-tensioned concrete contains steel cables (½" dia.) enclosed in a long plastic casing. They are placed in the forms prior to the pour, and when the concrete hardens, the cables are tensioned using a special hydraulic jack assembly.

Post-tensioning Cables (P.T.) are then anchored in special steel fittings at each edge of the concrete floor, but remain separated from the concrete by the plastic casing. (Un-bonded) . This is discussed in SCT03

- When P.T. cables need to be cut during US&R Ops, special care needs to be taken to deal with the tension force that will be released.
- Cables are most often placed in a Draped Configuration within the concrete. The cable is placed near the bottom of slab / beam near mid-span, and near the top where cables pass over supporting columns or beams.
- It is best to use a Torch to cut the P.T. cables, since the tension should be released slowly. A carbide saw could be used to carefully cut the cables, one wire at a time.
- If the cable is not cut slowly so that the force can be gradually released, parts of the cable may violently project out of the concrete structure.
- Depending where the cable is cut it may project above the floor walls or columns, below the floor near mid-span, or project out of the concrete slab edges like a spear.

The TF can mitigate this problem by clearing an area that measures, at least, 10 feet either side of the cable for the full length of the slab / beam. In addition the area outside the building should be cleared for 100 feet and barricaded to deal with the threat.

- See SCT03 for more information, including pictures of the cables, their anchorages, as well as methods to recognize concrete structures that may contain PT cables.

Summary for Part 5 US&R Strategy & Structure Size-up

We have discussed the following:

- Phases of a Large Disaster
- Information gathering
- Rapid Structure Triage and Search Process
- Identification of Individual Buildings
- Structure/Hazards Eval. Marking, Search Assessment Marking, and Victim Marking
- Basic Building Search & Rescue Strategy (Student Manual only)
- Metal Detector & Cutting of Post-Tensioned Concrete, Cables (Stu. Man. Only)

It is important for all Rescue Specialists to remember this information. During an incident the safety and efficiency of the rescue operation depends on everyone involved being able to quickly respond to common terms, marking systems, and warning signals.

The information regarding search, hazard reduction and victim access for the different types of construction should lead to finding ways to most effectively approaching Search and Rescue in Collapsed Structures

STUDENT MANUAL

STRUCTURAL COLLAPSE TECHNICIAN COURSE

MODULE 1D

UNIT 1: RESCUE TOOL SYSTEM APPLICATION & ASSESSMENT

UNIT 2: RESCUE TOOL SYSTEM OPERATING PRINCIPLES & MAINTENANCE

UNIT 3: RESCUE TOOL LAB FIELD LECTURE & TROUBLESHOOTING

Practical/Instruction Time 4 Hours

Materials Tools for Demonstration

Unit Objective At the conclusion of this section, the Student shall demonstrate proficiency in the inspection of, operation of, maintenance of and the safe use of all power tools.

Enabling Objectives You will:

- Understand the operator's influence on tool performance
- Understand Electrical power sources, the electrical loads, and tool safety
- Understand the tool assessment criteria
- Be able to perform a pre-use inspection of all gas, fuel, pneumatic, hydraulic, and electric power tool systems

UNIT: 1 RESCUE TOOL SYSTEM APPLICATION & ASSESSMENT

Systems Approach to Tool Selection and Operation

Generally in the fire service we do not use complicated tool systems or if one is used it is ether per-connected or stored as a "system" and easy to deploy. In the Federal USAR system we don't have that luxury. Our tools are stored in small boxes that only allow parts of a tool system to fit, then placed on 2 semis, transported to an unknown location, and stacked for possible use. This system of deployment does not make for quick or easy tool acquisition or deployment, but it is the system that we must live with.

Imagine if the pre-connected hose on your pumper was broken down into the following parts, nozzle, hose, washers, outlet valve, pump, water tank, intake valve, supply hose, hydrant adapter and hydrant wrench and then all stored in separate boxes that were mixed in with 200+ other boxes. It would take a lot of thought and preparation to bring that system together. That is the system we live with.

The Rescue Technician must know and think in these terms. They cannot rely on the logistics team members to provide a complete tool system when requested. There are just too many items in the cache for logistics to remember every complete tool system that could be requested by search, planning, rescue, hazmat, rigging, or any one else on the team. You will be using the tool system and you are responsible to make sure it is all there when you leave the Boo. Many times the rescue site will be miles from the tool cache and a missing part can place the whole operation in jeopardy and make the difference between a rescue or recovery.

Let's look at all the parts needed for a Stanley DS11 Concrete Chain Saw operation to place hole in slab for entry.

Stanley power unit, unleaded gasoline, motor oil, hydraulic hose (3/4 &1/2), DS11 chain saw, spare chain, wrench (chain changing), screwdriver (chain tensioning), garden hose, water pressure booster pump (depending on chain and water pressure), 1 ½" to garden hose adapter, fire hose 1 ½" (bring water from remote source), hydrant adapter 2 ½" to 1 ½" , possible adapter from local standard to NST carried by task force, hydrant wrench.

That is one complete system for the cutting operation. Many of those parts are carried in separate boxes and no part is more important then the next. You can set up the whole system but nothing can happen if you are missing the 1 ½" to garden hose adapter. It seems like a small part but the whole rescue operation waits while it is requested, picked up and brought to the scene. Depending on the situation at hand that could take hours. Think about being delivered by helicopter to a remote rescue location and you may never get it.

These tools or parts must be identified on the cache list to find box number, the box must be located among the 200+ others at the Boo, they must be opened and tools/parts collected and delivered to rescue site. One problem with just identifying the needed boxes and taking them is that they may have parts from another tool system inside and removing them from the Boo could place that tool system in jeopardy of missing some items.

Now think about the system and tools that will be needed to control and lift out that slab of concrete once you have cut it out with your saw. Imaging that this whole evolution is happening at night and the tool system needed to provide power for lights and electric tools.

RESCUE TOOL SYSTEM APPLICATION & ASSESSMENT

Rescue Tool System Application

The goal is to assemble, operate, and maintain rescue systems to efficiently extricate victims. Inability to do this will; result in further pain and suffering for the trapped victim. The professional rescuer needs to be proficient and capable of quickly determining the proper application and safe operation our rescue tool systems.

When your *"Rescue System"* is not working typically there will only be one thing wrong. Most trouble shooting analysis operates from this premise. The most efficient way to trace the problem will be to start at one end (usually the power source) and work toward the tool, inspecting/isolating/testing each component. It's usually something simple. This way even if there are multiple problems you are likely to find them. Resist starting in the middle of your system, this will often result in you going back and forth looking for the problem, and if there are multiple problems you will quickly be frustrated not to mention that the rescue process will be losing irreplaceable time.

Experience has taught us that many times the issue is one of application or operation. We must choose the right tool for job, or when forced to use an alternative tool/system, know its limitations. Sometimes this is dictated by environment or proximity to the victim, excessive noise produced by a pneumatic breaker may aggravate the situation. If you need to cut steel but have a concern about heat transfer you may need a colder cutting technique than a torch, i.e. a reciprocating saw or electric rebar cutter. Working in confined spaces often limits what kind of tools we can use. Inherent system inefficiencies such as friction loss can limit our tool operation (Stanley Tool ½ hose), or even work place regulations like the 300 hundred feet OSHA limit on SABA lines. When operating gas engines plan for, and predict the accumulation of carbon monoxide, always monitor the atmosphere.

Therefore within these confines we apply our tools and techniques. Some basic operating principles can help maintain an efficient rescue operation.

1. Know the cache.

   Do not become overly dependent on others knowing where and how your tools are stored. Many of our systems can be useless without a single adapter or other seemingly minor component. Assure that when leaving the BoO you have an adequate size up of what you are to do, know where the boxes are, and what is in them. A couple of minutes verifying the inventory, and in service status will save time once deployed to the field and then find out (for example) the extension cords are in a separate box. Think *"Systems"* know that when you finish the floor breech, ropes/ladders may be needed to make entry. Anticipate tool packages and have them staged for use, stay ahead of the rescue operation.

Rescue Tool System Application

2. Proper application and operation of tool systems.

As an example; our diamond saws/cores will not cut cured, engineered concrete at the same rate some of us may be used to with the “training” concrete often used in SCT classes. Blades, bits, torches, cores etc. have specific applications; make sure you have matched the tool system to the work piece.

Speed/Feed Rate of Tool

A good rule of thumb when running a saw, drill, or jack, either electric, hydraulic, or gas powered, is to not load, or apply so much pressure on the tool to slow the RPM’s down more than 15% of full speed. Keep the saw cutting at full speed. Keep in mind that you will run into situations that will require full speed all the time, or for you to start off in a slower speed to begin the cut and then increase RPM’s. If the operator of the tool is pressing too hard and slowing the tool down too much, typically the motor/pumps, and saw blades will overheat, further compromising performance. If the tool can not cut “fast” enough, assess if you are using the right tool/bit/blade or get multiple tools in operation. By maintaining 80% to 90% of full speed RPM or BPM the tool/bit will cut/grind as efficient as it can. Heat, one of the by products of our systems must be controlled. Overheating the working ends of our drills and saw bits can cause irreparable damage. Diamond segments (grinding) will mushroom, cutting edges will round off, and motor insulation will break down.

Some techniques to keep your blades/bits cool:

A. Ensure adequate lubrication, water or oil
B. If dry cutting, pull tool blade/bit out of cut every 10 to 20 seconds to run in ambient air to cool.
C. Make sure a properly dressed/sharp bit/blade is in the power tool.
D. If the motor is too hot to touch you may need to switch it out, or change tool systems.

3. Anticipate long term operations and plan for replacement of consumables.
4. Keep conductors of energy as short as possible, air hoses, electric extension cords, and hydraulic lines.
5. Particularly when operating pneumatic and hydraulic systems with long hoses, consider jogging the tool against the work piece to counter act the friction loss in order to prevent out running the systems ability to keep up with energy consumption.
6. Consider what type of force you wish to apply to your work piece. Attack the barrier in its weakest mode, i.e. concrete in shear, not compression. If you can locate the rebar and cut these first you remove concrete’s ductile capability. This consideration can also be applied to hand tools vs. power tools choice. Such as a dirty breech executed with sledge hammers in lieu of heavy power tools. Take time to thoroughly size up the barrier and develop a coordinated plan (with back up) to get through it. Make sure the tool and technique are matched to the material being worked on.

Rescue Tool System Application

7. Anticipate the action/re-action of the tool and the barrier. Be prepared to deal with rubble, weight of the cut out, and the speed of the release.
8. Continuously assess the working end of your tool. Keep the bits dressed and sharp. Inspect diamonds for any deformation and integrity. Ensure bits/blades are compatible with the barrier and the desired result i.e. the bull point of a jack hammer will create circular lines of force (general demolition), a chisel bit will create linear lines of force for a more precise/predictable break.
9. Listen for pressure relief valves venting. The tool system may be over loaded.
10. Stay within the operating envelope of your tool package. When you have questions or problems refer to your supervisor and the operating manuals.

General Tool Operation Safety Considerations

When operating power tools always wear the appropriate PPE, gloves, ear protection, safety glasses, helmet, respiratory protection, and work uniform. Do not wear loose fitting clothing or other items that could get entangled in the power tool. Prepare to mitigate any hazard your tool operation may produce, dust, dirty water run off, exhaust fumes, etc. All tools require a general inspection prior to use checking for lose, cracked, or broken components. Check for lose fasteners, proper lubrication, blocked vents, cord damage, and proper operation. Never operate power tools when too tired or under the influence of drugs. A moment of inattention could result in serious injury. When operating tools try to maintain a firm and balanced body position, and try not to over reach. Keep your work area as well lighted as possible. If your tool is not operating properly, place an “Out of Service Tag” on it and turn it in for repair.

There are no perfect or trouble free tool packages. The Rescuer’s ability to keep their *“Rescue Systems”* working in the field will be directly proportional to safe and successful rescues.

Rescue Tool System Assessment

The Urban Search and Rescue Response system is a young and evolving program. Part of the evolutionary process is a constant evaluation of tools and equipment. As Rescue Specialists, who better to evaluate the tools and equipment in the cache?

When assessing the tools' effectiveness, it is important to draw your opinions when the tools are being operated in a manner for which it was designed. Often times in a rush to complete a rescue, we tend to operate our equipment outside the parameters for which they were designed. This would not produce an accurate assessment of the tools' true effectiveness.

Rescue Tool System Assessment

Operators Influence on Tool Performance

- No other factor will influence the tools' performance more than the level of training and experience of the operator.
    - Cutting large sections of concrete, with new equipment and equipment that we just don't use every day is a relatively recent addition to the fire service.
    - As a result, operators are inexperienced and tools are not being properly operated. The result is poor performance and increased maintenance.
    - Proper assessments must take this into account and resist the tendency to black ball a piece of equipment due to operator inexperience.

Assessment Criteria

The following is a list of equipment evaluation criteria that will assist in the assessment process.

- Does the tool perform in field situations as well as in training?
- Weight
    - Does the weight of the equipment restrict its transportability when compared to like equipment? Is the equipment too heavy to operate in confining spaces or on poor footing?
- Power source
    - The power sources can be anything from battery powered equipment to propane, gasoline, etc.
    - Batteries should be assessed on duration, ease of recharging and availability.
    - Fuel should be assessed on type, capacity, and transportability. Does the fuel type restrict locations where the tool can operate and is that a hindrance?
- On scene maintenance
    - Can the equipment be serviced and maintained on the rescue site?
    - How often does maintenance need to be performed?
    - Is special equipment required to perform the maintenance?

Rescue Tool System Assessment

- Operating conditions - Can be any other condition which may affect tool performance or how the tool impacts on the operator:
  - Environmental
  - Hazards
  - Confined space
  - CO
  - Noise
  - Fire
  - Atmosphere
  - User interface
  - Ease of operation
  - Day/night
  - Number of personnel required to operate
  - Technical skill required to operate
  - Specialized training
  - Certification
- The only way to improve the task force cache is with feed back from the users. Make notes on tool and operator performance during incidents and training activities. After the incident is over, put these notes in memo form to be given to your Task Force Leader.

UNIT: TWO —GENERAL OPERATING PRINCIPLES &TOOLS MAINTENANCE

Operating Principles of Two Cycle, and Four Cycle Engines

- The key to any successful US&R operation is a thorough knowledge of the tools in the task force's cache. The Rescue Specialist must not only be able to select the appropriate tool to accomplish the task quickly and safely, but be able to trouble shoot minor tool problems and make the necessary on site repairs.
- Unfortunately, the US&R task force is not overly abundant with tools, small tool mechanics, or personnel to shuttle tools back and forth from the work site to the Base of Ops. This requires the Rescue Specialist to pick up the slack and make the minor tool repairs.

<u>2-CYCLE ENGINES</u>

- The predominant engine used for most gasoline powered rescue tools is the 2-cycle engine. The 2-cycle engine has many advantages over the conventional 4-cycle engine for rescue work but requires distinct starting and maintenance considerations.
- By understanding the operating characteristics of a 2-cycle engine, the Rescue Specialist can better prepare for and trouble shoot maintenance issues.
    - The 2-cycle engines have no oil sump. The gasoline oil mixture provides the fuel and lubricating oil. This allows the 2-cycle engine to be operated at almost any angle without loss of lubrication. It is important to mix and maintain the proper fuel/oil mixture. A 2-cycle engine run on a fuel/oil mixture too rich in oil may end up fouling the spark plug and smoke excessively when operated. But an engine run on too lean of an oil mixture can permanently damage the engine.
    - Two cycle engines operate at a higher RPM than 4-cycle engines. The higher Rpm’s generate higher operating temperatures. After periods of running under load and at high RPM, the engine should be allowed to cool before shutting off. Allow the engine to run for 10 to 15 seconds at idle. This slows cooling reducing the chance of mechanical damage.
- With every down stroke of the piston, the fuel/oil mixture is drawn into the cylinder. This makes the 2-cycle engine more susceptible to flooding than the 4-cycle engine. To start a 2-cycle engine and reduce the possibility of flooding, the following guidelines should be used when starting a cold engine.
    - Turn the on/off switch to the on position and close the choke. Pull the starter cord briskly until the engine starts. If the engine fires but will not start, open the choke and attempt to start again.
- If after repeated attempts to start have failed, the engine is probably flooded. Remove the spark plug and dry. Replace and repeat the above procedure. If the engine still fails to start check the maintenance items listed below.

Operating Principles of Two Cycle, and Four Cycle Engines

- The maintenance and trouble shooting of all 2-cycle engines no matter what the applications are very similar. The three areas the Collapse Technician may be required to perform maintenance are replacing air filters, spark plugs and clearing fuel systems.
  - Clogged airs filter can result in loss of power and prevent starting. Air filters should be checked after every tank full of fuel or more often in dusty conditions. Before removing any air filter, always close the choke. This will reduce the possibility of dirt getting into the engine and causing damage.
  - Spark plugs can become fouled from too rich of an oil mixture or when the engine idles to long. If an engine fails to start or during operation quits, check to see if the spark plug has fouled.
  - The fuel tank on 2-cycle engines is most often vented with a one-way valve to let air in and prevent fuel from leaking when operated at different angles. If after starting, the engine runs only to stall 10 or 15 seconds later, the one-way valve may have become clogged. Open the fuel tank cap slowly and listen for a rush of air to enter. This is a telltale sign of no fuel tank venting.

Four Cycle Engines

These engines (use straight gasoline) typically for US&R, run electric generators. They have an oil sump, or crank case which circulates oil within the engine to provide the lubrication that is done with the gas and oil mixture for 2 cycle engines.

This means that four cycle engines unless otherwise specified (pressurized oil crank case) must be up right to run properly. Aside from this, four cycle engines operate very similar to the two cycle engine.

GASOLINE POWERED CHAIN SAWS

- The chain saw is one of the most frequently used tools in the task force's cache and maybe one of the most dangerous to operate. The large exposed cutting surface requires the operators to be skilled at using a chain saw, for their safety as well as the victim’s safety. It is therefore important to know not only about the maintenance aspects of the saw but the possible reactive forces involved in cutting.

- Before every use, the chain saw should be inspected for fuel, chain oil, chain tightness and operation of the chain brake. Most chain saws will allow for the fuel tank to run dry before the chain oil reservoir is emptied. For this reason don't be fooled into thinking that because chain oil remains in the reservoir after a tank of fuel the chain oil does not need to be added. Always refill your chain oil reservoir after each tank of fuel.

GASOLINE POWERED CHAIN SAWS (continued)

- Before beginning work check to make sure the chain is receiving oil. Point the tip of the chain saw towards the ground and run the engine at half to three quarters throttle. You should begin to observe a darkening of the ground underneath the tip of the guide bar. This indicates the chain is receiving lubrication and cutting can begin. The absence of chain lubrication can destroy the guide bar and chain.
- If no oil appears on the ground check the chain oil reservoir to make sure the reservoir has not run dry. If that is not the problem, next check the inlet hole in the guide bar for blockage.
- The chain brake should be checked while running the saw at an idle. Engage the chain brake by pushing the hand guard forward then squeeze the trigger for no longer than a few seconds. The chain should not rotate.
- There are three main reactive forces the operator may encounter during cutting. They are pushback, pull-in and a kickback.
  - A pushback occurs when the chain on top of the guide bar gets pinched which suddenly stops the chain movement. The saw will tend to pushback towards the operator.
  - The opposite of this is a pull-in in which the chain on the bottom of the guide bar gets pinched and the saw is pulled into the work.
  - Lastly, the kickback occurs when the tip of the bar comes in contact with a solid object or when it’s movement is restricted. Kickback can happen in an instant with explosive force.
- When cutting wood that may be under stress, a relief cut should first be made in the area of the wood that is under compression. The deepness of the cut depends on the thickness of the material to be cut. For example, a 2x4 may just have to be nicked and a large log may require a cut of several inches. In either case, you do not want the wood to begin to flex from this cut. Your next cut will then be on the tension side of the material completing the cut.
  - Use the “Chipper Chain” when cutting trees, the carbide tipped chain will not clear the kerf. The carbide chain works better of kiln dried lumber and mixed layered i.e. asphalt roof coverings.
- Working in areas of blown down trees or in collapsed structures is very dangerous. Always work in pairs, plan your cuts and keep the nose of the guide bar away from solid objects.
- There is three main maintenance or repair items the rescuer may be required to complete on site. They are:
  - inspecting and changing of the air filter , and spark plug
  - Inspecting and replacing the chain and or guide bar
  - Tensioning the chain and replacing fluids

UNIT: TWO — TOOLS MAINTENANCE

GASOLINE POWERED CHAIN SAWS (continued)

- A clogged air filter can reduce engine performance and increase fuel consumption. Most chain saws have two sets of filters. A pre-filter to remove the larger dirt and wood chips and a fine filter.
  - The pre-filter should be cleaned after every tank full of fuel. This is accomplished by brushing away the dirt with a small brush or by blowing the filter clean with a stream of air.
  - The fine filter can either be a mesh material or a paper filter similar to that found in automobiles. The mesh type filter may be reused after cleaning so long as there are no holes in the filter material. The paper type filters should be discarded when dirty. Mesh filters should be cleaned at least once a day and more often in dusty areas. For this reason, spare filters should accompany the saw to any cutting site.

- Although the methods for replacing air filters vary according to the brand of saw, all manufactures recommend that before the fine filter is removed, brush away any dirt near the carburetor and close the choke to prevent dirt from entering the engine.
  - If deployed to an area of significantly higher altitude then you typically work in and you experience sluggish performance from your saws the carburetor may need to be tuned to the elevation.

- Chain saw chains should be replaced or sharpened when the operator must force the saw to cut or the wood begins to smoke when cutting. A dull chain increases fatigue on the operator and increases the risk of kickback. Since sharpening the chain is time consuming and can involve complex angles, the Rescue Specialist should plan to replace the chain on site.
  - To do this remove the side cover covering the chain sprocket. Relieve the tension on the chain. Once the chain tension is released, remove the chain from the tip of the guide bar. The chain and guide bar can then be removed.
  - Once the guide bar is removed, examine the ridges on which the chain rides for uneven wear. If one side of the ridge is higher than the other, a file must be used to level the ridges. During the course of normal operation, the nose and underside of the guide bar will wear faster than the top. For this reason, every time the saw chain is sharpened or replaced, turn the guide bar over.
  - Reverse the removal procedures when reinstalling the guide bar and chain but only tighten nuts finger tight that holds the sprocket cover in place.

UNIT: TWO — TOOLS MAINTENANCE

- Now that the chain has been replaced, pull the guide bar nose up and out at the same time as turning the tensioning nut. The chain is properly tensioned when the chain is resting on the underside of the guide bar and can be easily pulled along the bar. Run the saw for two or three minutes then readjust the chain tension as necessary.
  - Chains that are overly tight will increase guide bar ware and engine strain. Chains that are too loose, run the risk of being thrown off the guide bar and injuring the operator.

CUTOFF SAW

- The rotary blade power saw goes by many names, cutoff saw, K-12, or Cutquik, but what ever you call it, these saws all have a circular blade driven by a V-belt attached to a 2-cycle engine. These saws can be used to cut wood, concrete or steel depending on the type of cutting wheel attached to the saw.

- Before using, check the cutting wheel for any nicks, cracks or missing segments that could cause the blade to be out of balance and shatter during use. Check the V-belt tension.

- Always place the wheel guard in a position to protect the operator.

- Operators should always stand to the left of the cut to protect themselves in the event of cutting wheel failure or being hit by thrown material.

- During wet concrete cutting, the slurry created can cause slick footing. Make sure you have a stable base and work in pairs.

- The following are general guidelines the Collapse Technician can use when replacing the cutting wheel. Refer to your owner's manual for specific details.
  - To replace the cutting wheel switch the engine off and prevent the cutting wheel from turning by placing the locking pin through the spoke in the V-belt pulley.
  - Remove the nut holding the thrust washer in place and remove the thrust washer. The cutting wheel can now be removed.
  - Reverse the sequence when installing the new cutting wheel. Always make sure blade rotation corresponds to the rotation arrow on the cutting wheel.

UNIT TWO – TOOLS MAINTENANCE

CUTOFF SAW (continued)

- The items that the rescuer may be required to repair or maintain in the field would be cleaning and replacing of the air filter, spark plug and replacing and tensioning of the V-belt.
  - Filters for rotary blade power saws are similar to that of chain saws. There is a pre-filter that is usually a reusable foam filter and a fine filter of mesh or paper. The pre-filter should be cleaned after every tank full of fuel. This element can be cleaned by with a soft brush or by blowing the filter clean with air. The fine filter should be cleaned daily or more often in dirty and dusty conditions such as in cutting concrete. Non-reusable paper filters should be discarded when dirty.
- Remember to close the choke and wipe away any dirt near the filter housing before removing any filter.
- The V-belt or drive belt should be inspected before every use. Look for fraying or any damage to the belt that could cause it to break.
- Most V-belts are replaced in a similar manner. Unscrew the screws holding the arbor bearing and wheel guard in place. Next remove the screws holding the drive arm in place. Place the new V-belt on the drive pulley and reassemble.
- To tension the V-belt, loosen the screws holding the arbor bearing/guard in place. Either tighten the eccentric adjuster or turn the tensioning screw (depending on the manufacturer) until the V-belt can be depressed slightly. Over- tightening of the V-belt may cause premature arbor bearing failure.

CUTTING WHEELS

- The term cutting wheel is a generic term for any number of cutting blades whether they are diamond blades, abrasive blades or carbide tip blades. These blades can be grouped according to the material they are designed to cut. Concrete or masonry blades can be either diamond or abrasive cutting blades. The concrete abrasive blades are composed of a silicon oxide matrix. Metal cutting blades are almost exclusively the abrasive types composed of an aluminum oxide. Lastly, wood cutting blades are made of steel and may or may not be carbide tipped.
- Abrasive cutting wheels no matter what the material they are designed to cut are subject to the same type of wear and use considerations.
- Abrasive blades are particularly susceptible to chipping and cracking.
  - For this reason, blades should not be transported attached to the saw.
- Before using an abrasive blade, inspect the blade for chips cracks and uneven ware. If any are found, replace and discard the damaged blade.
  - Uneven blade wear is characterized by a thinning of the blade towards the outer edge.

UNIT: TWO — TOOLS MAINTENANCE

CUTTING WHEELS (continued)

- If water is to be used during cutting, make sure the blade is compatible for use with water.
  - Not all blades are designed for wet cutting and the application of water could result in blade failure.
- Wet cutting has several advantages over dry cutting.
  - Water helps keep the blade cool, which will prolong the blade life.
  - Water will reduce the air borne by-products of cutting which can clog air filters and breathing respirators.
- When using water, make sure both sides of the blade receive near equal amounts. Unequal water coverage can result in greater wear on one side of the blade resulting in thinning and eventual blade failure.
- After completing your cut, shut the water off first, allowing the abrasive blade to spin and remove excess water.
- Abrasive blades should only be stressed radially and never torsionally by twisting or bending.
  - This could result in sudden blade failure seriously injuring the operator.
- The diamond-cutting wheel is composed of a steel wheel, called a core on which a diamond and steel cutting matrix, called a segment, is welded. Although diamond blades are not as susceptible to chipping and cracking as abrasive blades, other problems can arise with diamond blades which when recognized and corrected, will help to extend blade life and shorten cutting time.
- The first and most important step to prolong blade life is selection of the proper wheel.
  - Wheel segments (the diamond and steel matrix) vary in hardness according to the material they are designed to cut. Some blades are designed for cutting cured concrete while others may be designed to cut asphalt or lightweight concrete. The blades we should be primarily concern with are those designed to cut cured concrete.
- After the proper blade is selected, the blade must be broken-in on the material being cut.
  - Allow the blade to begin cutting by exerting only slight pressure. This exposes the cutting diamonds without generating excessive heat. Cutting can now begin using the back and forth motion. This cools the blade by exposing it to air.
- During cutting operations, periodically examine the cutting wheel for the following problems.
  - Cracked or missing segments can occur due to stresses from twisting or jamming of the blade in the cut or by blade overheating. A telltale sign of segment loss due to overheating will be a discoloration of the core just underneath the missing segment. To prevent overheating expose the blade to air more frequently, cool with water.
  - Check for glazing.

UNIT: TWO — TOOLS MAINTENANCE UNIT:

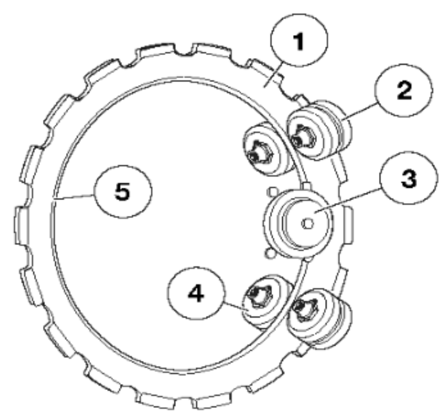
CUTTING WHEELS continued

- Glazing appears as a shiny smooth surface on the segment. The first sign that glazing has occurred is lack of cutting progress. Glazing can occur at anytime during the cutting process from contact with rebar, overheating or cutting a material to hard for the diamond segment. Once glazing has occurred, cutting progress will be slowed and overheating will result until the blade is reconditioned.
    - To recondition or dress a diamond blade, the operator must find a material softer than the material being cut. Operate the saw in the softer material as you would for the break-in period with light pressure.
- Just as abrasive blades can have uneven wear, diamond segments can also wear unevenly. The most common cause of uneven segment wear is lack of adequate water coverage to one side of the segment, which results in one side of the segment wearing faster than the other.
- The last blade we should be familiar with is the carbide tipped cutting blade. Designed to cut primarily wood, the main advantage of a carbide tipped blade is the long life of the cutting edge when compared to conventional blades. The blades work best at high RPM. Slower Rpm's can result in carbide tip loss.

GAS/HYDRAULIC RING SAW

Operating Principle

- This saw has the advantage of having no center arbor; therefore it can cut much deeper. Power from the motor is transferred from the engine to roller guides (through a belt) that contact the periphery of the diamond ring. Overall operation of the saw is similar to running a conventional rotary cut off saw. Care must be given to feed rate, push to tool into the work piece with enough pressure to reduce running speed to about 20%, typical of most powered tools. Pushing too hard or too little will reduce efficiency and cause maintenance issues. Both saws need to have a water source to help clean/lubricate the roller bearing guides. Do not side load the ring saw blade.
- A manufacturer DVD is included with the purchase of this tool. This DVD is the best source for technical information. Using the below information change out blade, inspect parts, and review troubleshooting procedures.

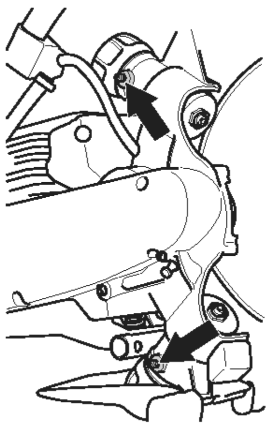


1 Blade
2 Support rollers
3 Drive wheel
4 Guide rollers
5 V-shaped edge

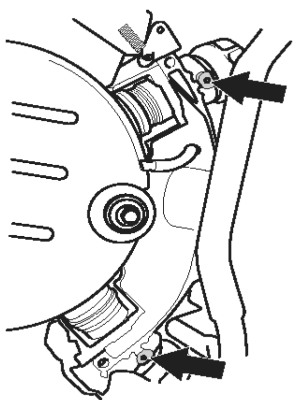
Functional Inspection and Maintainence

Lubricating the guide rollers

- Connect the grease gun to the grease nipples.



- Pump in grease until clean grease emerges from the overflow hole.

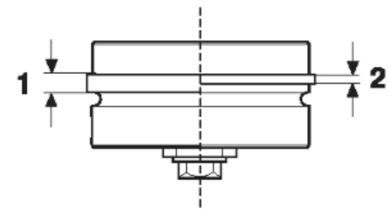


Replacing the guide rollers

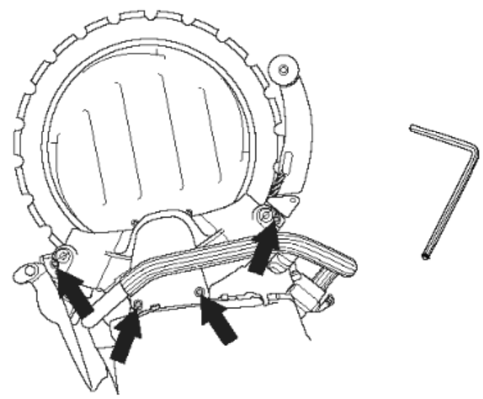
Replace the guide rollers when half of the flange on the rollers is worn.

1) New, 3 mm (0.12")

2) Worn, ≤ 1,5 mm (0.06")

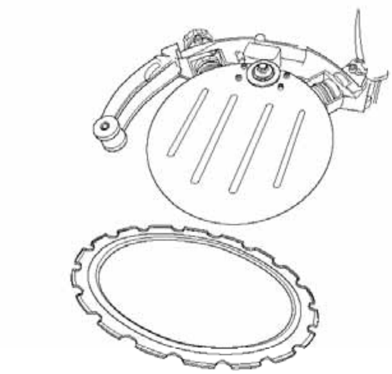


- Remove the support roller cover.



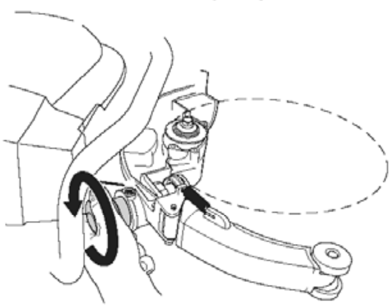
Functional Inspection and Maintainence

- Lift off the blade.

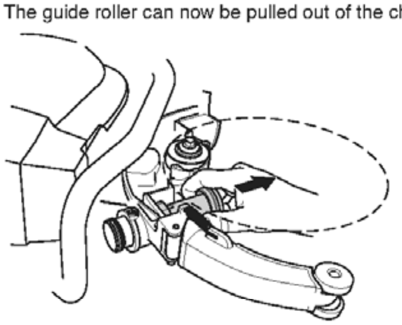


- Unscrew the knob. First turn the knob a few turns until you feel a resistance. The guide roller then follows the knob out and stops when it feels a resistance.

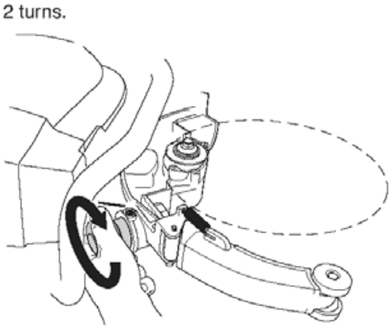
  The guide roller is pressed into the knob. In order to loosen the guide roller, you need to continue turning the knob until it loosens completely.



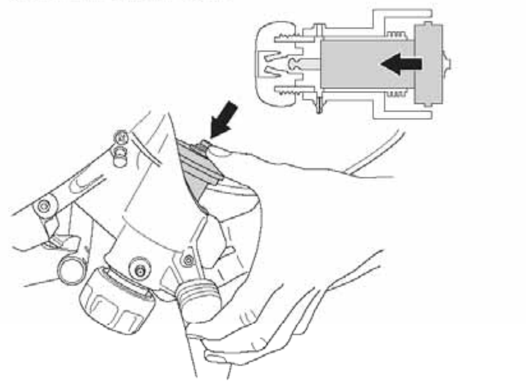
- The guide roller can now be pulled out of the chassis.



- Screw the knob until it bottoms, and then loosen the knob 2 turns.



- Insert the new guide roller in the chassis. Now press the guide roller into the knob.



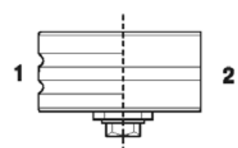
- Lubricate the guide rollers. See instructions under the heading "Lubricating the guide rollers".
- Fit the blade. See instructions in the section "Assembling and adjustments".

Support rollers

Replace the support rollers when the roller surface is flat, when the groove on the roller surface has worn away.

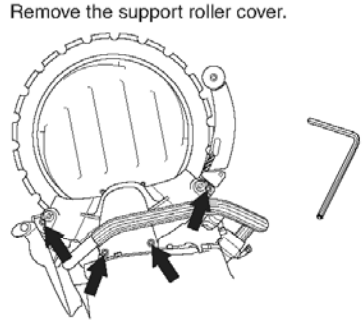
1) New

2) Worn



Replacing the support rollers

- Remove the support roller cover.



Troubleshooting Schedule

PROBLEM	PROBLEM CAUSE
Blade does not rotate	Roller knobs not fully tightened
	Blade not fitted correctly on guide rollers
	Rollers tensioned too much
Blade rotates too slowly	Roller knobs not fully tightened
	Worn drive belt
	V-shaped inner diameter of blade is worn
	Weakened springs on guide rollers
	Defective roller bearings
Blade jumps out of position	Roller set too loose
	Worn guide rollers
	Blade not correctly fitted on guide rollers
	Damaged blade
The blade warps	Rollers tensioned too much
	Blade is overheating
Segment breaks	Bent, twisted, or badly maintained blade
	Continue to use blade if only one segment is missing. If blade is warn 50%, reconstruct or discard
Blade cuts too slowly	Wrong blade for the material in question
Blade slips	Guide rollers do not move in and out freely. A seized roller cannot press the blade hard enough against the drive wheel
	Worn drive wheel. Abrasive material and too little water while cutting increases the wear on the wheel.
	Worn guide roller flange. Slips if more than half the width of the flange is warn.
	Blade's groove and inner edge are worn. This is caused by inferior flushing of abrasive material and/or a worn drive wheel.

UNIT: Two — Rescue Tool Power Sources and Operating Principles

Hydraulic Operating Principles

Hydraulic rescue systems have three basic components, power unit with a gasoline engine, hydraulic fluid pump and reservoir with associated valves to control direction and pressure. The hoses transmit the pressurized fluid to the tool, spreaders, and jack hammer etc. This is a closed system as opposed to a pneumatic system which vents/consumes (open system) its power transfer medium. Hydraulic systems have a pressure port (output of the pump), and a return port, hydraulic fluid flowing back into the reservoir. For best operations the fluid temperature should be between 60 and 140 degrees F.

Pressure is applied in all directions within the containers, the hydraulic fluid is mostly incompressible but may contain up to 10% air. The action which creates the mechanical advantage depends on Pascal’s Law which explains that a force or pressure on a small surface can be transferred to a larger surface amplifying the force. Think of the small piston attached to the pump handle of a hydraulic bottle jack and reference that to the larger piston or the column that rises as you pump the handle. The small force you create by pumping the small piston with the lever (handle) transmits the force (the pressure in psi) to a larger area (the square inches in psi). This is why by simply jacking this pump by hand you can lift several tons. This is a positive displacement pump, which means that if it pumps against a closed head for very long, the pressure will build till something relieves the strain.

Hydraulic Operating Principles (continued)

System operating pressure is directly related to the load applied, ultimately relieved by internal over pressure valves automatically or by decreasing the load on the working end tool. Think of a vehicle rescue system ram pushing against a vehicle component. The tool system will load up and build pressure till the object is displaced, the operator releases the tool, or the relief valve kicks in.

The Stanley system also has a GPM measure which is critical. This is because we use tools such as saws and jack hammers with this system. These tools reciprocate and spin, not just pushing a piston. The GPM of the pump relates directly to the speed at which the tool runs at.

When hoses are left in the hot sun or on pavement the fluid will expand, building up pressure in the hose, which can prevent coupling or uncoupling of hoses. There are two ways to relieve this pressure.

1. When the hoses are connected to the pump or a tool you can relieve the pressure back through the system by cycling the tool control valve or the flow control on the power unit.
2. When the hoses are not connected and the couplings become "locked up" you must carefully loosen the threaded connection between the coupling and the hose. This will allow a small amount of fluid to leak out lowering the pressure and allowing the connection to be made. Remember to tighten the connectors once the connection has been made.

Safety Issues;

Pressures in hydraulic systems can be 2,000 to 40,000 psi, always assume under pressure.

Treat as "hot" work, have an extinguishing capability handy.

Always wear PPE.

Pneumatic Operating Principles

Pneumatic tools weigh less, very portable, and have many excellent applications. Air tools with the exception of air bags, are often measured in not only in operating pressure but also CFM, cubic feet per minute. This is the amount of air the tool uses to work, the speed of the air is expressed as FPS, or feet per second. These factors can be affected by the friction losses in the hoses. The air in these containers when static represents potential energy and needs to be relieved safely. Cracking valves or couplings may blow "O" rings and launch projectiles. Drain your pneumatic system appropriately.

Our class "D" breathing air will dry out the system "O" rings and cause premature failure, oil regularly by adding a couple of drops into the tool. Extend your usable air supply by jogging your tool to counter act the friction losses in the system. The air consumption of the tool can exceed the regulator and hoses ability to deliver the needed CFM especially when the SCBA bottle is getting low on pressure.

Safety Issues;

Control bleeding off of pressure

Use a pressure relief valve with air bags

Electric Operating Principles

Electric tool systems have 3 general parts, power generation, transmission and tool. It is our responsibility to understand the operation of each part and know where it fits in the operational envelope. . It is also important to understand some terms and units of measure concerning electricity. This information is often displayed on the tool. One helpful way to think of these parameters is to liken them to fire ground hydraulics. Volts, is the pressure the pump creates to flow the water, amperage compares to GPM of the water flowed.

Volts, Alternating Current (AC) like our house outlets, or Direct Current (DC) which is battery power. Voltage is the pressure or amplitude of the energy of the electricity.

Amperage, all appliances have a specific amount of amps required to make them work efficiently. The operator can influence the amount of amps or load that the tools draws. For example if you push your recip saw till it bogs down and stalls in the cut, the amps will increase probably causing a circuit breaker or similar protection device to trip or shut the tool off.

Watts is the amount of energy consumed by the tool. You can calculate the amount of watts by multiplying amps and volts.

Generation of power

Generally we get our electric power from an outlet supplied by the electric company this serves us well at home but in the field we need to make and distribute electricity by our own means. Portable generators are the “life blood” in the USAR environment with the Honda 5000w and 6500w being the generators of choice. These Honda generators produce 110 & 220 volts and approximately 41 to 54 amps respectively. The electrical system is protected by circuit breakers and you are protected by Ground Fault Interrupters.

Generator issues

1. Operating with a gasoline motor can cause problems in itself. Honda generators use regular unleaded gas with a recommended minimum octane rating of 86. They also have a low oil sensor that will shut down the motor or refuse to let it start if it senses that the oil is low. This sensor is good for the motor but can cause undue problems if its operation is overlooked. The oil does not have to be very low for this sensor to operate.

2. Any time you are going to transport the generator be sure to shut OFF the fuel valve. If left on gasoline may get into the crank case and dilute the oil. If it is going to be stored for more than two months, drain the fuel from the carburetor float bowl, drain the fuel from the sediment cup and add fuel stabilizer to the fuel left in the tank.

3. Electrical production is accomplished when the motor turns a set of windings. In a 110/220 volt generator there are two of them. Each one of these windings is rated at half the total load of the generator. In 120v mode each winding supplies certain portions of available outlets. In the 120/220v mode they supply the 120v outlets and they are combined at the 220 outlet to supply its needs. It is important to understand this theory and look at the wiring arrangement for your model. Some of the Honda EB models have two duplex outlets each one fed from a different winding. This is important to know when plugging in tools and equipment because you have the opportunity to spread the load out between the windings. Instead of overloading one winding with the draw of two big tools you can opt to split that load between the two winding and allow the generator to operate better with les chance of breakdown.

Generator issues (continued)

4. Max and Rated output. All generators have these two output ratings their label usually reflects the Max output (marketing value). The rated output is what we should follow; it is the amount of power the generator can produce over an extended period of time without damage. The Max rating is for peak periods of short duration like tool startup.
5. Circuit breakers protect the generator and specific outlets from overload. Honda EB model generators generally have a main breaker to protect the windings from accumulative overload and outlet specific breakers to protect each circuit individually. They also have a GFI (Ground Fault Interrupter) circuit protector that is designed to protect humans from shock. The GFI compares the amount of electricity sent out on the hot wire to the amount received back on the neutral wire; if there is a 5mv difference it will trip and stop the electric flow. This should be quick enough to stop personnel from electrocution but is enough to cause muscle reflex which could be dangerous.
6. Most generators have an “Auto Idle” switch. When turned on this mode allows the generator to go to idle speed when it senses that there is no electric draw from any of its outlets. This idle mode saves fuel and generator wear and tear. When electricity is requested (by turning on a light or pulling the trigger on a tool) the generator will come up to full speed and supply the requested energy

Power transmission

1. Once the generator is running, it is our job to get the power to the tool. This is accomplished with extension cords and splitter boxes. All cords are size rated to electrical standards, the smaller the number the bigger the wire. This wire size is something we need to be cognoscente of because it determines the ability of our tools to operate. Electric wire has resistance that relates directly to wire size (similar to friction loss in fire hose) it is important to keep our wire length as short as possible and our wire size as big as possible. All this relates directly to the power needs of our end user, the tool. If we are only powering a 500watt light then 100 feet of 12 gauge cord will work fine but if the end user is a 60lb electric breaker that draws 2000watt and startup and 1600 to 1700watts during operation then a 10gauge cord as short as possible is a must. The matching of cord or wire size to the tool is important to keep the tool operating correctly and to keep it and the wire from overheating and melting.
2. The standard cache rescue section lists 10/3 and 12/3 wire with 20 amp twist lock connectors in 50 and 100 foot lengths. It is important to note that the twist lock connector on a Honda EB generator is a 30amp twist lock. A 20amp twist lock looks like it will fit and if pushed hard enough it will come close but it will not twist or lock in place, this is not a safe operation. We must be sure to match 20amp male to 20 amp female plugs. Having to push connectors or bend outlet prongs to make them fit should not happen. All the tools in the standard cache have regular house plugs so it is important for the rescuer to get all the needed adapters from the cache before leaving the Boo and heading to a job site. The need for male and female house to male and female 20amp twist lock along with splitter boxes can not be overlooked

Electric Tools

1. Electric tools require a predetermined amount of electricity to operate correctly. Supply less voltage or amperage because of wire mismatch, resistance or length and the tool will not be able to do its job. Most tools used by the rescue team have an electric motor somewhere inside the housing. Electric motors require a much greater amount of electricity (amperage & voltage) to start then to run. This can be seen when you start a tool and the lights dim or the motor on a generator bogs down to accommodate the required draw. Once the tool is up to speed its electrical requirements generally fall to those listed on its housing. This initial startup draw can cause circuit breakers to blow if the circuit is near it rated capacity it can also cause a GFI to operate or trip because of voltage leakage in the tool.
2. All tools have an operating envelope that meets their design criteria. Trying to make a tool to work faster by forcing it into a cut, pushing it harder into concrete or steel and overloading its blade will only cause it to heat up internally and in the long run fail. Although a FEMA cache is very large the Rescue section tool numbers are very small, two 1 ½ hammer drills is all we travel with. If we over drive and force it to work outside it's normal operating range it will work slower, heat up and in the end stop working. This would leave the whole rescue team and its entombed victims with one hammer drill to get the job done. Working a tool with the right amount of force can only be learned during training. It is important to understand this theory and work to find the correct operating forces for all the tools in the cache.
3. Generator auto idle was discussed in the generator section but needs a quick review here. The auto idle mode is a good when there is a lot of stand around time or very little tool use but when tools are constantly being cycled on and off and the generator is running up and down it can cause undue tool damage. This damage is caused when the trigger is pulled and the tool motor starts to turn, since the generator is idling it is producing very low voltage and amperage and the tool is requesting normal voltage and high amperage to get the motor turning this delay can cause heat to build up in the tool. Anytime you are using the auto idle you should let the tool and the generator come up to full speed before putting the tool to work. If there will be a lot of on off cycles it is best to turn off the auto idle and allow the generator to run at full speed all the time.

Operating Principles **CUTTING TORCHES**

Description of Process

- Oxy-fuel cutting is a process whereby a metal is heated to it's kindling temperature (temperature below the melting point) by an oxy-fuel gas flame and then burned rapidly by a regulated jet of pure oxygen. Cutting torches, whether hand held or machine operated are used for this operation.
- The cutting process is a chemical reaction between iron and oxygen. When iron is heated to a temperature in excess of 1600 F (870 C) and then exposed to a stream of high purity oxygen, the iron oxidizes rapidly and produces a mixture of molten oxides and iron called slag. When cutting a narrow slot called the kerf is formed as a result of the loss of metal by the cutting oxygen jet.

Operating Principles CUTTING TORCHES (continued)

- The oxy-fuel cutting process is generally used on materials ranging from 1/32 in. to a thickness in excess of 100 in. The majority of oxy-fuel cutting is done on materials ranging from ¼ in. to 2 in. in thickness.

Equipment and Supplies

- In order to perform oxy-fuel flame cutting, the following equipment is required as a minimum:
    - Oxygen
    - Fuel gas(Acetylene, Propane, or MAPP gas)
    - Pressure regulators
    - Hoses and fittings
    - Torch
    - Cutting tips
    - Tip cleaners
    - Strikers
    - Protective clothing and safety equipment meeting ANSI-Z49.1

Oxygen

- Oxygen of high purity (99.5% Minimum) is required to perform the operation of oxy-fuel flame cutting. This can be supplied in a variety of high-pressure cylinders and/or in bulk liquid tanks. CAUTION: Oxygen supports combustion! Improper use can result in fires or explosions. Never use oxygen in pneumatic tools, to clean equipment or parts, or to blow dust off clothing.
- Oxygen safety precautions
    - Do not permit smoking or open flames in area where oxygen is stored, handled or used.
    - Liquid oxygen at –297 F can cause freeze burns to the eyes and skin if it comes in contact with them.
    - Keep materials such as oil, grease, wood, kerosene, cloth, tar, and coal dust away from contact with oxygen.
    - Do not place liquid oxygen equipment on asphalt or surfaces with grease or oil deposits.
    - Remove all clothing, which has been saturated with oxygen gas. Such clothing is highly flammable, and should not be worn for at least 30 minutes.

Fuel Gas

- Many different fuel gases are available for oxy-fuel cutting. They include acetylene, propane, methylacetylen-propadiene (MAPP), natural gas, propylene, hydrogen, and several propane or propylene base mixtures. Each of these fuel gases will produce different flame characteristics.
- Acetylene cylinders contain porous filler that is used to absorb acetone. The acetylene in these cylinders is then dissolved into the acetone. This is done to prevent acetylene from being drawn faster than the acetone will release it. The maximum safe rate for being withdrawn from the cylinder is $1/7^{th}$ of the cylinder's capacity per hour. If this rate is exceeded acetone will be drawn from the cylinder resulting a flame with a purple color.
- Acetylene Safety Precautions

- Acetylene is not to be used at pressures above 15 psig in free form.
- Concentrations of acetylene between 1% and 99% by volume in air are easily ignited, and may result in an explosion.
- Keep cylinders away from overhead welding or cutting. Hot slag may fall on a cylinder and melt the fusible plug.
- Fusible plugs on acetylene cylinders will melt at 212 F.
- Acetylene forms readily explosive compounds with copper, silver, and mercury.
- Acetylene must be kept away from these metals, their salts, compounds, and high concentration alloys.
- Adequate ventilation is required. Acetylene gas produces a strong garlic odor. Acetylene may displace air in a poorly ventilated area; atmosphere that does not contain at least 18% oxygen may cause dizziness, unconsciousness, or even death.
- Leave the hand wheel, wrench, or key on the cylinder for emergency shutoff.
- Always store acetylene cylinders in an upright position. If the cylinder had been laid down on its side put in the upright position for at least 3 hours before using.

Pressure Regulators

- Regulators are pressure-controlling devices that reduce high pressures to a desired working pressure. A pressure adjusting screw adjusts these regulators. Regulators may be single or two stage.
- Regulator Safety Precautions
  - Keep contaminates such as oil, grease, dust, and dirt away from all inlet and outlet connections on regulators.
  - Never use oil on any threads or fittings on any regulator.
  - Before attaching an oxygen regulator to a valve, check to make sure that the regulator meets the pressure requirements of the supply.
  - All regulators should have the pressure adjusting screw backed out before opening the cylinder or station valve.
  - Never use acetylene above 15 psig.
  - Never stand in front of a regulator when the cylinder valve is being turned on.

Operating Principles **CUTTING TORCHES (continued)**

Hoses and Fittings

- Oxygen hoses in the United States are always color coded green. The fittings have right handed threads and a smooth outside surface.

- The fuel gas hoses are always color coded red. The fittings have left hand threads and a notch on the outside.

- These fittings are designed to form a gas-tight seal with the application of very little mechanical pressure.

- The use of undersized or excessively long hoses can result I pressure drops that can result in a low flow rate. Insufficient flow rates can result in overheating of torches and backfires.

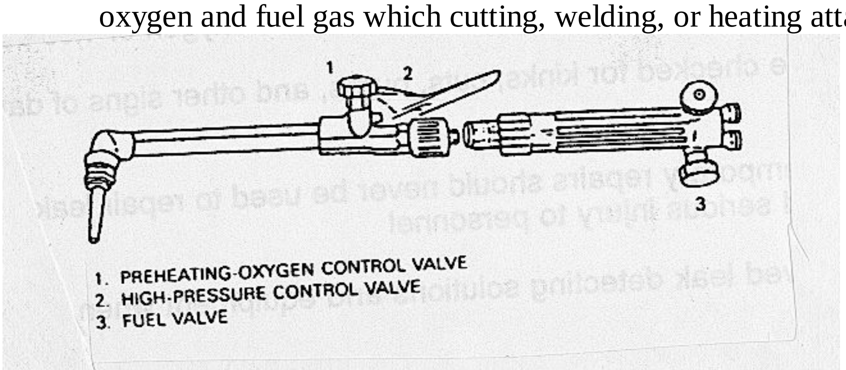
- Hose and fittings safety precautions

- A fuel gas hose should never be used to transfer oxygen or vice versa.
- Hoses should be checked for kinks, cuts, burns, and other signs of damage before use.
- Tape or other temporary repairs should never be used to repair leaks; this could lead to fires and serious injury to personnel.
- Use only approved leak detecting solutions and equipment when checking connections.

Torches

- There are basically three different types of cutting torches. However these torches come in many different styles and shapes.

    - Hand torch: A torch equipped with a one piece body with valves to control the flow of preheated oxygen and fuel gas, a spring loaded valve for the cutting oxygen, tubes carrying the gases to the head which accepts the cutting tip.
    - Combination Hand Torch: A welding torch equipped with valves to control the flow of oxygen and fuel gas which cutting, welding, or heating attachments may be attached.



    - Machine torches: A torch equipped with valves controlling oxygen, fuel gas, and cutting oxygen with tubes encased in a body with a head to accept the cutting tip.

Operating Principles **CUTTING TORCHES (continued)**

- Torches are classified as being either a positive pressure or injector type (low pressure). In the positive pressure torch both the oxygen and the fuel gas are supplied at pressures high enough to sustain sufficient flow of both gases. In the injector type torch the fuel gas is supplied at a low pressure, relying on the high pressure of the oxygen to pull the fuel gas to obtain the correct flow of gasses.

- Torch safety precautions

  - A fire extinguisher should always be at hand when flame cutting for use if an emergency arises.
  - Always extinguish a torch whenever it is not in your hand.
  - If a torch backfires, shut it down, find the trouble, and remedy it before continuing to use the torch.
  - Be careful that a torch is not being directed at another person when lighting.
  - Be sure that the area where the cutting/welding is to be performed is clear of any hazardous or flammable materials.

Cutting Tips

- All oxygen-cutting tips have preheat flame ports (orifices) which are commonly arranged in a circle around the cutting oxygen port. The size of these ports will determine the thickness of the materials to be cut as well as the amount of gas supplied.

- Tips for use with acetylene are usually one piece in design and being flat on the flame end. Tips for use with MAPP and propane gas are usually two pieces in design with milled spines.

- Of all the items needed to perform the oxy-fuel cutting process, besides oxygen itself, the cutting tip has the greatest effect on the quality of the cut.

- During cutting procedures slag will form around the pre-heat and oxygen cutting ports. This will disrupt the pre-heat flame as well as the oxygen cutting jet, resulting in poor performance and quality cut. When this occurs the tip should be removed and cleaned.

Tip Cleaners

- Cleaning is done by means of tools called tip cleaners. There are different types of tip cleaners available to clean the surfaces of oxy-fuel cutting tips.

  - Tip drills; wire broaches (normally called tip cleaners), these are designed to clean the ports of the cutting tip.
  - Re-facing tools are designed to keep the face of the tip flat, providing preheat flames of the same length.

Operating Principles **CUTTING TORCHES (continued)**

Strikers

- When lighting your cutting torch it is important to use an approved spark lighting device. The use of lighters, matches can lead to personnel injury as well as injury to others around you.

Protective Equipment

- Appropriate protective clothing and equipment is required at all times when using oxy-fuel cutting equipment. As cutting operations vary so will the required protective clothing and equipment, size and the location of cutting will determine this. Some or all of the following may be required:
  - No. 4 or 5 lens tinted goggles or face shields
  - Welding cap or hardhat
  - Safety glasses
  - Leather gloves suited for oxy-fuel cutting
  - Flame resistant clothing
  - Respirators use appropriate respirator for type of fumes that will be produced.

Start Up and Shut Down Procedures

- Secure the cylinders to cart or a substantial support.

- Attach regulators to the valves; ensure valves are free from oil, dust and obstructions. Tighten inlet connection nuts firmly with a close fitting wrench.

- Inspect the hoses for cuts, burns, and kinks. Have them repaired or replaced, if damaged.

- Connect hoses to proper regulators (green oxygen, red fuel gas).

- Attach hoses to the correct torch inlet.

- Before opening either of the cylinder valves, check to make sure that the regulator adjusting screw is backed out, so that no pressure is being exerted on the adjusting screw. This is done to protect the regulator parts from damage due to high-pressure surges.

- Open the oxygen cylinder valve very slowly to allow pressure to increase slowly into the regulator. Warning, do not stand in front of or behind the regulator when opening the valve. After the pressure in the regulator has equalized, open the oxygen cylinder valve completely so the valve will seal. Oxygen cylinder valves are designed to seal when fully opened and fully closed.
- Fuels cylinders equipped with a hand wheel should be opened no more than 1 ½ turns. Acetylene cylinders equipped with a valve that requires a key or wrench should be opened no more than ¾ turn. Fuel gas valves on cylinders should never be opened completely. This is done to allow the valves to be turned off quickly in case of an emergency.

Operating Principles **CUTTING TORCHES (continued)**

Start Up and Shut down Procedures cont.

- With the torch and tip directed in a safe direction, open the oxygen valve located on the torch body. Turn the adjusting screw on the oxygen regulator and adjust to he recommended pressure for the tip being used. Allow the oxygen to flow for at least five seconds for every 50 ft. of hose. Close the inlet oxygen valve on torch body.

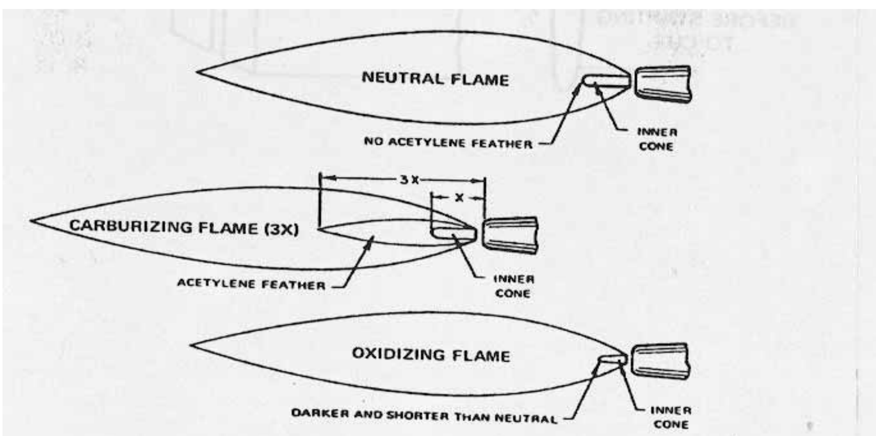
- Next open the fuel gas valve on the torch body. Turn the adjusting screw on the fuel gas regulator and adjust till recommended pressure is obtained. Allow the fuel gas to flow for at least five seconds for every 50 ft. of hose. Close the fuel gas inlet valve on the torch body.

- The recommended procedure for lighting acetylene is to open the fuel gas valve on the torch body slightly (usually 1/8 to ¼ turn) light with a striker. Adjust the fuel gas valve until the acetylene produces a semi-smokeless flame. Open the oxygen valve slightly to produce a neutral flame.
- To extinguish the flame, turn off the fuel gas valve first then the oxygen valve. This is done to prevent the flame from burning back into the torch body and producing a flashback.

- After the flame has been extinguished, close both the fuel gas and oxygen valves on the cylinders.
- Open the torch fuel gas valve and bleed off the fuel gas from the regulator, hose, and torch. Back out the regulator adjusting screw and close the torch fuel gas valve.
- Open the torch oxygen valve and bleed off the oxygen from the regulator, hose, and torch. Back off the regulator adjusting screw and close the torch oxygen valve.

Flame Adjustment

- The flame adjustment is a critical factor in attaining satisfactory torch operation. The amount of heat produced by the flame depends on the type of fuel gas, intensity of flame, and the type of flame used.



FLAME ADJUSTMENT

Unit 3; Tool Lab Field Lecture Outline

Speaking Points

Gasoline Engines -Four Cycle

Honda generators have an “auto-throttle” mode like the Stanley power unit. It helps conserve fuel and will not respond to electric loads of less than 1 amp. This system is not effective for tools that only require momentary power, i.e. if we are turning a saw off and on as we work thru the barriers. If you decide to use the auto throttle wait till the engine reaches operating temperature. Hondas have an”Oil Alert” safety switch which can shut the unit off if the oil pressure is too low. The generators should not operate at full capacity for more than 30 minutes. When transporting turn fuel valves off.

With the voltage selector switch in the 120/240 position, you can use the 120 and 240 at the same time. If you do not need the 240 turn the switch to the 120 position. Other operator switches are the main circuit breaker, engine on/off switch and a fuel valve. The Honda generators run on regular gas, however they may not perform as well if using alcohol additive fuels. Every four cycle engine needs three things to start and run.

When troubleshooting start with these three basics.

1. Proper (fresh) fuel
2. Good spark
3. Piston compression

Trouble;

Engine will not start

Possible Remedy;

Engine switch “on”

Oil alert light on, add oil

Enough fuel

Spark at the spark plug

Electric loads removed

Trouble;

Engine starts but immediately shuts down

Possible Remedy;

Check oil alert lamp

Check oil level

Trouble;

No electricity at receptacles

Possible Remedy;

AC breaker on

Check tools plugged in to generator for proper operation

Speaking Points

Chain and Rotary Saws, Two Cycle Engines

Can be operated in any position, produces more exhaust smoke due to oil/gas mix. Operates hotter than four cycles and will foul spark plugs faster. To promote smooth running:

1. Assure proper fuel mix
2. Piston compression
3. Exhaust screen in muffler is clean

Husqvarna saws require a 1:50 gas to oil mixture. Do not use marine grade oil. After 8 to 10 tanks of fuel the saw should be broken in, but may require adjustments to the carburetor and/or oil pump at this time. Train your ear to the sound of a well tuned saw so you can head off problems before they build up. The engine has a decompression valve to help reduce the pressure in the cylinder upon start up. Check chain break by engaging and trying to rotate the chain by hand, it should not move.

To start the saws, chain break off, ignition switch on, pull choke out, place unit on ground and hold firmly with foot and hands, pull the starter cord till the pawls engage then pull sharply. NO DROP STARTS. Push choke back in ½ way when engine fires, when engine starts push choke all the way in. Do not release starter cord while extended, it can damage the saw. If possible re-fuel the saws away from work area in case of fuel spill.

Review how to prevent saw kick back.

Review changing the chain, blade, spark plug, filters, and V belt.

Trouble;

Hard starting/lose of power

Possible Remedy;

Check air filter, spark plug for dust/carbon/oil build up

Wrong fuel mixture

Carburetor needs tuned

Engine flooded, dry spark plug, allow carburetor to dry

Kor-It, Promethean Gas Powered Coring tool

Powered by a four cycle Honda engine, it requires no gas mix, but can be used in any position due to a pressurized oil crank case. The water coolant back pack, water supply can be stretched by adding 7 to 9 ounces of class “A” foam to the water. The water back pack has pressure relief valves. Good centrifugal clutch located in the gear box. Comes with a vacuum operated bit locator powered off the engine adheres to smooth concrete. Troubleshooting, same as above.

Speaking Points

Pneumatic Equipment

Paratech Struts

Ensure the “O” ring is lubricated and in place at all times it is located on the inner threaded tube. If the acme threads are damages in the field use a metal file to reshape till the collar once again moves freely over them again. If the air nipple is damaged and needs replaces simply remove and install the new nipple, no thread sealant is needed.

Test quarterly.

High Pressure Airbags

Protect the air nipple, no thread sealant need for this either if replacement is needed. Use two wrenches to remove a damaged nipple to prevent damaging the connection to the bag itself. Clean with soapy water, (do not use any petroleum products to clean) fill bag with 30 psi (air) and check for leaks. If any water gets into bag, invert and allow to drain. Operating temperatures between -40 F and 150 F.

Pneumatic Gun

Only field repairable part is the retainer ring at the end of the gun. A retainer key comes with the kit. If the retainer becomes loose, use this key to tighten it back on. Since our application will primarily be powered with class “D” air, it is important that we regularly oil the gun. A couple of drops into the air nipple will suffice. This will prevent the internal rubber parts from drying out.

When operating in a dusty, damp, abrasive environment it will need to be cleaned. Immerse the air gun vertically in a dry cleaning solvent (P-D-680, or Stoddard’s Solvent), to clean. Only operate the air gun when the bit is firmly against an object. When operated without pressure against the bit, the piston may become jammed or turn the bit into a projectile. Always treat the gun as a loaded weapon, and never point it at anyone.

Trouble

Piston stops Reciprocating

Possible Remedy

No air pressure or too low pressure, check supply and hoses for kinks/bends.

Plugged air holes in shuttle valve handle assembly.

Trouble

Piston Stalls, Slow operation

Possible Remedy

Lack of lubrication

Excessive moisture or lubrication

Worn piston spring

Speaking Points (continued)

Pneumatic Gun

Trouble

Loss of Power

Possible Remedy

Air Leaks

Worn/damaged “O” ring seals

Damage to rear bumper

Dull Tool Bit

Trouble

Tool Bit Stuck in Gun

Possible Remedy

Flange on tool bit is flared, file to repair.

Tool bit too soft, check operating pressure for bit being used.

Tool bit not being held against work piece when operating.

Air pressure too high.

Low Pressure Air Cushions

A “patch kit” like you would find with nylon inflatable boat comes with the cushions. Clean and rough up the mating surfaces (patch) with emery cloth and apply three coats of adhesive. Allow each coat to become tacky before applying the next. Press together, removing any air bubbles, apply even pressure with weight or clamp and cure overnight in at least 68 F temperature. If tears/holes are greater than 1 inch in any direction return to Paratech.

Check audible relief valves, hose connections. Inflate to 2 psi and wash with soapy water to check for leaks.

Test quarterly.

Hoses

All Paratech hoses are field repairable. If a hose is damaged/cut, using a knife cut straight down creating a square edge. Using pliers remove the air fittings and ferules by unscrewing clockwise. Where you made the straight cut, replace the air fitting by screwing the ferule back on counter clock wise.

Speaking Points (continued)

Senco Nail Gun

Never use oxygen, carbon dioxide or any other bottled gas except our SCBA tanks or a tool compressor to operate any of our pneumatic tools. Keep your finger off the trigger when not actively shooting nails; carry your finger under trigger to help prevent mis-fires. Always assume the tool is powered and contains fasteners, do not point at anyone. Do not force the tool, check force setting and ensure correct fasteners for your application. Fasteners can ricochet. Disconnect tool from air when clearing a jamb or other maintenance. Do not exceed 200 psi into the tool. A male air fitting should be fitted into tool so it will bleed off pressure when disconnected. To adjust depth, disconnect air and using a wrench adjust the safety element to desired depth. Oil the gun twice a day, with Senco pneumatic oil, 5 to 10 drops into air inlet of gun.

Trouble;

Air leak at tool, sluggish/weak operation.

Possible Remedy;

Verify air supply, tighten/check connections, and tighten screws.

Trouble;

Poor feed, tool jamming

Possible Remedy;

Clean tool, lubricate magazine

Air Regulators

There are two types of regulators used for rescue tools, a larger regulator with a “T” handle is the diaphragm type, it delivers more air than the second type which is a smaller, piston type. Each regulator type uses two pressure gauges; the one on the bottle side reads the pressure in the bottle. The gauge close to the tool reads the out put pressure being sent to the tool thru the hose. This pressure is set by adjusting the “T” handle or a round knob. This changes the size of the diaphragm, or piston surface area, and adjusts the pressure. If you adjust your pressure too high and want to back it down you may find that the regulator is not self venting and the pressure will not drop till relived thru another opening.

Check that the small valve with the arrow is pointed toward the tool; this is the “on” position. The threaded coupling that attaches the regulator to the bottle has an “O” ring, check that it is in place and not broken. Check your tools operating pressure so you do not over power it. When storing, back the “T” handles, knob, out till off the diaphragm, spring, preventing a memory.

Speaking Points (continued)

Torches

Petro-Gen

Oxy-fuel torch, cuts ferrous metals, can not weld. Assure fresh gasoline with NO additives. Good for making very thick cuts, and long term operations. Requires more maintenance than an oxygen acetylene torch, but if cleaned and taken care of will provide a solid performance. Maintain adequate ventilation and/or monitoring for CO/LEL. Do not open gasoline valves too fast, open ¼ slow, then once pressurized, full open. Keep gasoline pressure at 30 psi. Consult the label displayed on the gasoline tank for operating pressures vs. tip size. Clean and purge gasoline lines, containers, hoses, with carburetor cleaner after every use before storage. Demonstrate flame start up/adjustment and shut down.

Trouble;

Poor flame, tip overheating

Possible Remedy;

Clean/replace tip

Re seat tip in torch head

Trouble;

Raw liquid fuel coming out of tip.

Possible Remedy;

Too much pressure in gas tank

Too low pressure on oxygen

Valve seats on torch varnished

Trouble;

No gasoline flow

Possible Remedy;

High flow ball valve on gas tank closed

Check valve in gas tank blocked by varnish

Speaking Points (continued)

Oxygen – Acetylene

Versatile and easily service anywhere. Quick to put into operation. Cuts and welds ferrous materials only. Set up regulators and adjust to proper pressure for tip size. Do not exceed 15 psi on acetylene. Kit comes with special PPE, goggles, tip cleaner, and a torch wrench. Open oxygen all the way, acetylene ¼ turn open so it can be turned off quickly if needed. Keep acetylene bottle upright. Maintain adequate ventilation and/or monitoring for CO/LEL. Consider posting a fire watch after the burning operations. Take care not have hoses in path of falling debris and flames. Go over torch head/valve set up. Demonstrate flame adjustment, cleaning tips, reverse thread connection, and proper shut down. Review safety precautions. Refer to student SCT manual for more detail.

Trouble;

Poor flame

Possible Remedy;

Re seat tip, clean ports on tip

Trouble;

Not able to get a neutral flame

Possible remedy;

Clean tip

Check pressures for the size tip in service

Trouble;

Blue flame with black smoke

Possible remedy;

Ambient temperature too low < 20 F

Allow bottles to warm up

Trouble;

Not cutting, melting, but not making kerf

Possible remedy;

Working on a non ferrous material

Tip too small

Moving tip too fast

Trouble;

Erratic flame

Possible Remedy;

Purge lines, 5 seconds for every 25 feet of hose.

Speaking Points (continued)

Exothermic Torch

Cutting only, creates a large fire ball. Not a precision tool. The operator needs to keep pushing the sacrificial rod into the work piece. Consumes a lot of oxygen. Will cut metal the O-A, and the Petro Gen won't; such as, bronze, stainless steel, aluminum, copper. Will also spall concrete and burn through heavily rusted metal. Always check the collet for the size rod you are using and that the gasket is in place. The collets often get damaged by burning the rod too close to the handle.

Trouble;

Won't ignite rod

Possible Remedy;

Low battery

Striker, slagged up

Poor electrical connection

Hydraulic Systems

Stanley Tool

Power unit can flow hydraulic fluid up to 2000 psi at 8 gallons per minute. Flows are adjustable via front panel switch next to the pressure out port and the pressure return port connections. All the tools in the FEMA/US&R cache operate at 8 GPM. The engine runs on regular gas, 89 octane, with an oil pressure switch that can shut off the engine if crankcase oil pressure is too low. Electronic throttle to help conserve fuel, and limits noise by controlling idle and running speed when using tools. "Power Link Invertor System" which can provide 110 VAC, between 1000 and 1500 watts depending of motor speed, turns on/off via panel switch. 12 VDC outlet is always on. Lift and latch handle and center lifting point on frame of power unit. Hoses are non-conductive. In cold weather allow tools and fluid to heat up prior to use. In hot weather the hydraulic fluid may expand to the point where you can not easily make or break hose connections, requires bleeding pressure back through the system. This unit can operate on a variety of hydraulic fluids, check with manual for a full list of compatible fluids. Operate in a well ventilated area. Consider the fluid as flammable and have suppression near by while operating.

Power Unit has a fault indicator which will display trouble codes. Refer to manual for interpretation of these codes.

Review the DS-11, Rotary saw, drill, and jack hammer operation including the changing of blades/chains/bits/belt. Review water flow requirements for DS-11.

Speaking Points (continued)

Stanley Tool

Trouble;

Engine will not start

Possible Remedy;

Make sure flow selector is off.

Check battery and battery connections.

Check for fuel.

Defective spark plug.

Fuel filter plugged.

Trouble;

Hydraulic fluid blowing out of reservoir vent.

Possible Remedy;

Hydraulic tank overfilled.

Check/tighten suction connections.

Trouble;

Hydraulic tool will not operate.

Possible Remedy;

Check for correct setting of Flow Selector Switch (5-8 GPM)

Make sure hose circuit is correct, pressure to input of tool, output of tool to return on power unit.

Hydraulic pump/engine coupling defective.

Relief valve stuck open, adjust or replace.

Hydraulic hoses kinked.

Check electrical connections.

Speaking Points (continued)

Hurst Vehicle Rescue Kit

Inspect for leaks. Check hoses for excessive wear and make sure all fasteners are tight. Make sure fluid levels are full; do not use any fluid other than Hurst phosphate ester fluid. The regular gas engine has a fuel shut off, and electrical on/off switch. When cold starting, move throttle to fully down or fast position. And choke to close position, may not need this if engine is warm. Pull recoil starter cord and gently allow it to return once engine is running/warm return the choke to the open position. Move dump valve to the run position, and cycle tool to purge air. Start engine/pump with dump valve open so the gas engine has no load on it during start up. Also have the dump valve open to change out tools. Do not use hands to check for pin hole leaks this pressurized fluid can penetrate skin. Consider the fluid as flammable and have suppression near by while operating.

Trouble;

Engine fails to start or is hard to start.

Possible Remedy;

Out of gas, check tank and fuel filter/line.

Spark plug disconnected or faulty.

Check air filter and plug gap.

Check crankcase oil level.

Trouble;

Engine overheats.

Possible Remedy;

Low oil level.

Air flow obstructed. Always operate is a well ventilated area.

Trouble

Pistons do not advance

Possible Remedy;

Low on the fluid

Loose seals, coupling

Load too heavy

Air trapped in system

Speaking Points (continued)

DC-25X Benner Nawmen Rebar Cutter

Hydraulic/electric powered tool, rated to cut grade 60, #8 or one inch rebar in 5 seconds. 110 VAC, 12 amps, generating 2 HP. Generates a cutting pressure of 30 tons. Good tool when you are concerned with heat transfer or cutting plastic or epoxy coated rebar. Cutting dies replaceable in the field with a wrench. Keep working piece at right angles to the cutting dies, wear eye protection. Check cutting dies for tightness, these blocks can be rotated once chipped for continued use. Keep vents clear of obstructions, maintain a firm grip on tool as the rebar often breaks loose close to finishing cut, this cutter weighs 50 pounds and tool reaction can injure the operator.

You may need to bleed the hydraulics on your cutter if it is running too slow or does not have the pressure to cut. Do not run with no or too low on oil.

Oil (hydraulic fluid) may need to be warmed up prior to use, run tool for two minutes to heat up.

The stopper bolt adjustment is important part of tools operation.

1. Screw in stopper to provide sufficient clearance for rebar.
2. Insert rebar fully into U-shaped support. Make sure the rebar is resting on the base support.
3. Keeping rebar at right angles to the front cutter block, screw out stopper until it is just touching the rebar. Once set, the stopper needs no further adjustment while cutting the rebar of the same diameter, but must be reset for different size rebar.

Without this adjustment the free end of the rebar may fly off, uncontrolled.

Speaking Points (continued)

Ramset Powder Fired Nail Gun

Tool system designed to drive pins into wood, brick, stone, steel, and concrete. Do not use on glass, glazed brick, cast iron, or other brittle materials. Do not use on pressurized tanks. Select the correct pins and powder charges for your application. Do not place hands around muzzle or load till ready to use. If unsure of the of charge strength needed, start with the lowest power. Dry cycle the tool before loading, check slide and magazine feed for correct movement. Properly orient pins and charges into gun. Never point tool at anyone. Do not use around flammable/explosive atmospheres, or where charges could be exposed to high heat. When ready hold tool firmly against work piece at a right angle, verify everyone around tool has safety glasses on. When the fastener is properly set the head of the pin will be flush with the surface. Adjust power and power setting (near rear of tool) as needed. When finished unload and return to case. Disassemble and clean thoroughly after each use, check for wear, and apply a light film of oil. Demonstrate loading and firing.

Treat as a loaded gun.

Trouble;

Difficult to re-cycle, rough action.

Possible remedy;

Bent or damaged piston. Excessive build up of carbon residue.

Trouble;

Reduction or loss of power;

Possible remedy;

Piston not returning to full rear position, or broken piston.

Faulty piston clip.

Dirty tool.

Damage to retractor pawl.

Trouble;

Tool does not fire**. Do not remove tool from surface for 10 seconds.**

Possible remedy;

Failure to depress tool fully.

Build up of dirt fouling firing pin.

Cartridge strip damaged.

Trouble;

Cartridge strip does not feed properly.

Possible remedy;

Cartridge strip damaged.

Strip index mechanism damaged.

Speaking Points (continued)

Electric Power Tools

Hilti DD-130

120 VAC powered tool produces up to 1900 watts. USAR cache comes with diamond and carbide tip core bits capable of making a 2 inch hole. All diamond cores and blades in our inventory can cut wet or dry. To use this system wet you need to fill the water can and attach it to the drill, and close the larger dust collector port. Pump air pressure into water can till enough pressure is developed to maintain a uniform flow. Start the hole by coring on the edge of the bit and slowly bring it upright as the kerf develops. Ensure that water is flowing (through) the center of the core, and by observing the indicator on the handle for flow. Keep a eye on the overload indicator, pressure on the core may need to be reduced if over load indicator lights. Install bit (no tools needed) by turning the chuck CCW and push in it engages. Built in GFI. Assure that the core is firmly in place by attempting to pull it out. Drill speed selector position on the side of the tool may help to select the most efficient speed for the application. Typical speeds, II or III for a 1 5/8 , to 2 ½ inch hole in concrete. Tool maybe used in any position. Water may not work when working overhead.

Keep the tools ventilation ports open and do not allow foreign objects to get inside tool. Keep tool body clean, do not pressure wash or steam clean as it may affect the electrical safety of the tool. Lubricate the chuck with Hilti spray lube, and ensure the chuck is free of debris. Apply a light coat of oil to the core bits.

Trouble;

Tool does not start.

Possible Remedy;

Check electric supply

Check electric cord, defective trigger switch, GFI tripped.

Trouble;

Motor runs but bit does not turn.

Possible Remedy;

Defective gearing.

Trouble;

Feed rate keeps decreasing.

Possible Remedy;

Reduce water pressure

Defective core bit.

Gear box defective.

Core segments needs re-surfaced.

Speaking Points (continued)

Hilti DD-130

Trouble;

Motor cuts out.

Possible Remedy;

Allow tool to cool off, motor overload has activated.

Check electronics have failed.

Is the cooling fan running.

Trouble;

Water does not flow.

Possible Remedy;

Filter or water flow indicator needs unblocked.

Trouble;

Water escapes at gear housing.

Possible Remedy;

Shaft seal, water swivel, needs replaced.

Trouble;

Core bit can not be inserted into chuck

Possible Remedy;

Repair clean/lube connection end/chuck

Trouble;

Water escapes at the chuck

Possible Remedy;

Connection end or chuck dirty.

Chuck seal defective

DeWalt Reciprocating Saw

120 VAC or battery powered saw. Double insulated with a polarized plug. Speed as determined speed selector wheel and by how far the trigger is depressed. Slower speeds should be used for starting cuts. Wood and bi-metal blades come with the saw. To change blades unplug saw and turn blade release lever up. Insert new blade (shank first) into chuck. Do not force the blades as they cut. Use adjustable saw/blade shoe to prolong blade life. Hold saw firmly against work piece. Lubricate the chuck shaft as needed.

Speaking Points (continued)

Milwaukee Die Cutter (Wizzer Saw)

120 VAC, 4.5 amps, 21,000 RPM. Caution with the paddle switch, when tool is laid down it could easily turn on. Cutting action from this tool may produce harmful dust, wear filter mask as needed along with other PPE. This saw has a special collet and collet nut. Make sure the collet matches the mandrel that holds the cutting wheel tightly. Insert mandrel a minimum of ¾ of an inch into collet. You will need a ½ and 11/16 open wrench to remove or tighten the mandrel. The tool comes with a trigger lock, to release pull the paddle switch, clicking the "on" switch will immediately unlock trigger. Keep vents free of debris, clean case with mild soap and water, do not get water in tool.

Tips for Using Diamond Blades/Cores

1. You can cut a dry blade wet, but do not use a wet blade dry.
2. Inspect diamond segments prior to use.
3. Inspect for core flatness, bent blades, segment damage, and arbor hole/chuck damage.
4. Check for proper saw machine condition. Spindle bearings should be free of end and radial play.
5. Follow manufactures recommendations on operating speeds for specific blades vs. material to be cut.
6. Maintain a firm grip on tool and wear all appropriate safety equipment.
7. When dry cutting frequently remove the blade from the cut to allow blade to cool.
8. Don't stand in front of a running/cutting rotary saw.
9. Do not cut or grind with sides of the blade.
10. Do not use blades with cracked/missing or uneven segments.
11. Diamond blades get damaged due to;
    a. Twisting blades while inserted in material.
    b. Overheating due to inadequate water supply
    c. Not applying water to both sides of blade.
    d. Cores get worn thin due to highly abrasive material being cut.
    e. Blade is too hard for the material being cut.
    f. Saw machine has defective bearings/arbor/spindle.
12. Short cutting life.
    a. Improper cooling/flushing of material.
    b. Rule of Thumb; 2 to 5 gallons per minute cutting concrete
    c. Check saw machines drive belt.
    d. Blade will not cut, not broken in properly
    e. Blade has become dull, dress the blade by grinding on material by apply light pressure to expose fresh diamonds.
    f. Saw machine/power source defective.
13. Do not force tool.

Speaking Points (continued)

Grip-Hoist Field Lecture

The "Grip-Hoist" is able to raise and lower loads due to the arrangement of two pairs of smooth jaws that alternately grip a properly sized wire rope pulling it in a straight line, as opposed to wrapping around a drum like a come-a-long. This action can be thought of as two hands that hold the rope and draw it through the "Grip-Hoist" machine. These two sets of jaws are locked by the pull of the rope, the heavier the load the stronger the grip. A big advantage of the grip hoist over a wire rope come-a-long is that we can have any length of wire rope needed.

Anchor the "Grip-Hoist" by its hook to a fixed point that will support all imposed loads, slings or chains may be used. The "Grip-Hoist" can be operated vertically or horizontally.

Do not exceed any load ratings, anchor/rig machine to be operated in line with load, avoid side loads. An appropriately sized snatch block pulley maybe positioned as a change of direction, be sure to adjust capacity as needed.

Make sure the stroke of the operating handle; reversing lever, rope release lever, and the rope exit is unobstructed. Ensure you have enough rope length to perform your operation.

To insert the wire rope, uncoil 4 to 5 feet of rope in a straight line. Open both jaws by operating the rope release lever (read instruction plate fixed to machine) insert wire rope at rope entry point push it till it comes out the opposite end and pull all slack wire rope through the machine by hand. To close the jaws on the wire rope, let the rope release lever return to its initial position.

To work the machine, place operating handle on the lifting/pulling lever, on the lever for lowering/slacking. Lock operating handle into position by twisting it. Move the handle back and forth to pull the wire rope through the machine. If pulling the rope is very hard, the work should be stopped, and consider rigging the wire rope through snatch blocks as needed to increase MA. Never operate the power stroke lever and reversing lever at the same time.

To remove the wire rope from the machine keep in mind the gripping jaws are held in place by the tension generated by the load, therefore remove the load from the machine, slacked rope, open the jaws by opening the rope release lever. Remove the wire rope by hand, and re-coil properly.

Troubleshooting

The "Grip-Hoist" machine has built in overload protection using a shear pin connecting the power stroke lever and crankshaft. Only use "Grip-Hoist" shear pins as replacements.

Keep "Grip-Hoist" clean and free of dirt. Inspect machine for any defects. Lubricate using SAE 90 to 120 oil through the openings provided, operate the machine to ensure adequate lubrication coating.

Excessive lubrication is not a problem, lack of lubrication will cause jammed bearings. Periodically use a 10W40 oil soaked rag and lubricate the wire rope.

STUDENT MANUAL
MODULE 2a SHORING BASICS

MODULE PURPOSE

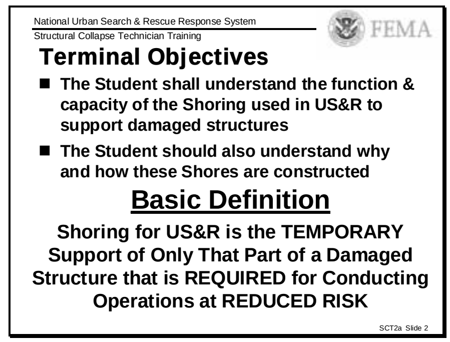
The purpose of this unit is to explain **WHY** we build shoring in the **FEMA Response System** in the way that we do. In **SHORING CONSTRUCTION, Module 2b ,** the student will be informed as to **HOW** each type of shore is constructed. Then all will be given a chance to become proficient at building them.

TERMINAL OBJECTIVES & BASIC DEFINITION:

The student will understand the function and capacity of the shoring used in US&R to support damaged structures.

The student should also understand why the shores are constructed in the configurations that are shown.

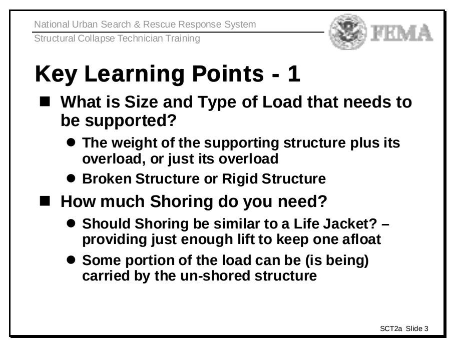
Shoring for US&R is the temporary support of only that part of the structure that is required for conducting operations at reduced risk

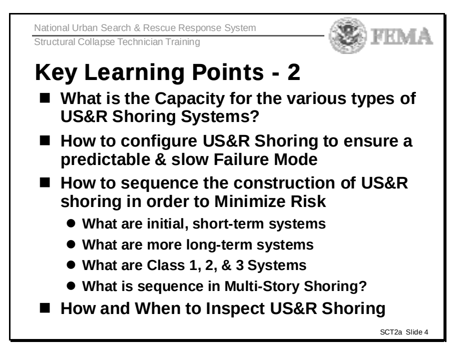


KEY LEARNING POINTS

At the conclusion of this module the student should be able to answer the following:

- What is Size and Type of Load that needs to be supported?
  - The weight of the supporting structure plus its overload, or just its overload
  - Broken Structure or Rigid Structure
- How much Shoring do you need?
  - Should Shoring be similar to a Life Jacket? – Providing just enough lift to keep one afloat
  - Some portion of the load can be (is being) carried by the un-shored structure
- What is the Capacity for the various types of US&R Shoring Systems?
- How to configure US&R Shoring to ensure a predictable & slow Failure Mode
- How to sequence the construction of US&R shoring in order to Minimize Risk
  - What are initial, short-term systems
  - What are more long-term systems
  - What are Class 1, 2, & 3 Systems
  - What is sequence in Multi-Story Shoring?
- How and When to Inspect US&R Shoring



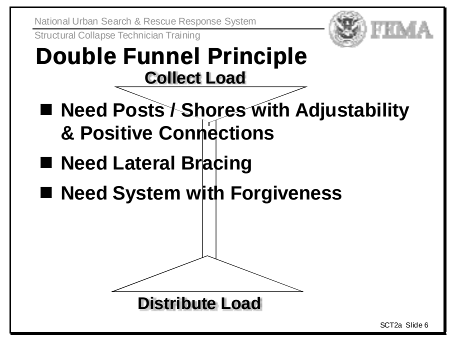


INTRODUCTION

Shoring is normally the temporary support of structures during construction, demolition, reconstruction, etc. in order to provide the stability that will protect property as well as workers and the public.

As stated above, the **Basic Definition**, shoring for US&R is the temporary support of only that part of the structure that is required for conducting operations at reduced risk

A Shoring system is like double funnel. It needs to collect the load with headers/sheathing, deliver it into the post/struts, and then to distribute it safely into the supporting structure below.



Shoring should be built as a system with the following:

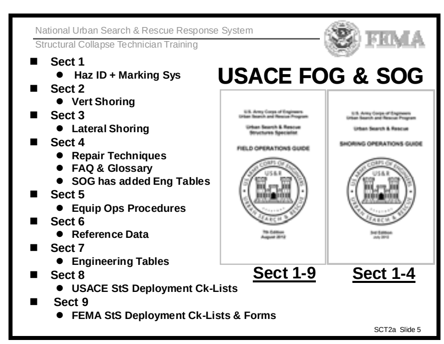
- Header beam, wall plate, other element collects load
- Post or other load carrying element that has adjust ability and positive end connections
- Sole plate, bearing plate, or other element to spread the load into the ground or other structure below.
- Lateral bracing to prevent system from racking (becoming parallelogram), and prevent system from buckling.
- Built-in forgiveness (will give warning before failure)

Minimum level of lateral strength in any vertical support system should be at least 2% of vertical load, but more is desirable where aftershocks are expected. The Structure Specialist should be consulted regarding extra lateral support

Trench Shores provide opposing lateral support - to keep trench/hole etc. from filling in. Design is normally based on Type C Soils. Manufacturers provide design aids that specify size and spacing of struts plus sheathing members

US Army Corps of Engineers StS FOG & **US&R SOG**

Sections 2 and 3 of the USACE StS FOG and US&R SOG contain graphics, information and procedures for constructing the FEMA Shores that are discussed in this Module & Module 2b.



Section 2 contains vertical shoring and Section 3 contains lateral shoring. They have both graphics and step by step procedures for assembly

The student should become familiar with these documents, since they provide a very useful “Pocket Guide” for constructing shores.

CONSIDERATIONS for DESIGN

WEIGHTS OF COMMON BUILDING MATERIALS.

- Concrete = 150 PCF — **PCF = lbs per cubic ft**
- Masonry = 125 PCF — **PSF = lbs per square ft**
- Wood = 35 PCF — **psi = lbs per square inch**
- Steel = 490 PCF
- Conc/Masonry Rubble=10PSF Per Inch (of thickness)
- **NOTE that heavily reinforced concrete Beams & Columns can weigh more than 150 PCF (up to 200 PCF and more)**
- Another way to quickly calculate the weights of concrete and steel members is to use a known weight per square foot of a unit thickness. (12" for concrete and 1" for steel)
  - A 12" concrete slab or wall weighs 150psf
    - Therefore as adjacent slide shows: 10" = 125psf, 8" = 100psf. 6" = 75psf, 4" = 50psf and so on
  - A 1" thick steel plate weighs 40 psf (exactly 40.8)
    - Therefore a 7/8" pl = 35psf. ¾" pl = 30psf. 5/8"pl = 25psf, ½" pl = 20psf, 3/8" pl = 15psf, and ¼" pl = 10psf

WEIGHTS OF COMMON BUILDING CONSTRUCTION

- Concrete floors weigh from 90 to 150 PSF
- Steel beam w/ concrete-filled metal deck = 50-70PSF
- Wood floors weigh from 10 to 25 PSF (floors w/ thin concrete fill are 25 PSF or more)
- Add 10 to 15 PSF for wood or metal stud interior walls, each floor level
- Add 10 PSF or more for furniture/contents each floor (more for storage, etc.)
- Add 10 to 20 PSF for Rescuers
  - 10 PSF on large slab that spreads out load
  - 20PSF on wood floors to allow for concentrations

EXAMPLE: shown in slide at right

- 20ft x 30ft Slab
- Total for 8" concrete slab, 6" of debris, allowance for lights & ceiling, and 10psf for rescuers = 105,000 lbs
- In this case the 10psf allows for 24-250lb rescuers – looks OK

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Weights of Building Materials

- Reinforced concrete = 150 pcf
  - Concrete columns & beams weigh more (16"sq w/ 5% rebar = 170pcf)
- Masonry = 125 pcf
- Wood = 35 pcf (dry)
- Steel = 490 pcf
- Concrete or masonry rubble

SCT2a Slide 7

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Quick way to estimate weights

Base estimate on approximate weight per square foot for unit thickness of concrete (12") and steel (1")

- 12" conc slab = 150 psf =
  - 10' conc slab = 125psf
  - 8" conc slab = 100psf
  - 6" conc slab = 75psf (and so on)
- 1" steel plate = 40psf
  - ¾" steel pl = 30psf
  - ½" steel pl = 20psf
  - ¼" steel pl = 10psf (and so on)

SCT2a Slide 8

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Weights of Building Construction

- Concrete floors = 90 to 150 psf
  - Light weight concrete is about 80%
- Steel systems w/ conc fill slabs = 50 to 70 psf
- Wood floor = 10 to 25 psf
  - (post 1960 wood floors may have concrete fill)
- Add 10 to 15 psf for wood/metal interior walls
  - each floor
- Add 10 psf or more each floor or furniture etc.
  - More for storage
- Add 10 psf or more for Rescuers

SCT2a Slide 9

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Example

- Assume that this 20ft x 30ft classroom has an 8" thick concrete roof with 6" of debris on it WHAT IS THE TOTAL LOAD TO SHORE ?

8" concrete	= 100 psf x 20 x 30	= 60,000 lb
6" debris	= 60 psf x 20 x 30	= 36,000 lb
Lights, ducts, ceiling, etc.	= 5 psf	= 3,000 lb
Rescuers	= 10 psf x 20 x 30	= 6,000 lb*
TOTAL	(105 Kips)	= 105,000 lb

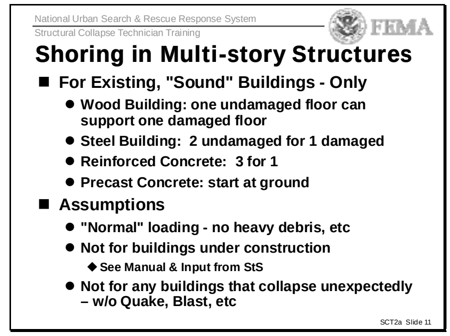
* 6,000 lb Rescuers allows for 24 - 250 lb FF
Is this reasonable ?

- If not use more, this is a MINIMUM

SCT2a Slide 10

CONSIDERATIONS for DESIGN (continued)

Shoring In Multi-Story Structures



- For existing, sound, wood structures, the excess live load capacity in an undamaged floor will usually be enough to support the weight of a damaged floor. This assumes that the damaged floor is not highly loaded with debris. Also the undamaged floor is assumed to not be heavily loaded with storage or other material, and no "occupants" (other than Rescue Forces) would be present.
- For existing, steel frame structures), it would take, **at least** two undamaged floors to support one damaged floor (with same loading assumptions as for wood floors)
- For existing, cast in place concrete (C.I.P.), it would take, **at least** three undamaged floors to support one damaged floor (again, with loading assumptions as for wood floors)
- For Precast Concrete (PC) and all Concrete parking structures, all shoring should be extended to the ground, or a "Base Slab" that has been designed to support the impact forces of a progressive collapse. Unfortunately, due to the competitive nature of many structures of this type, one must approach them with extra caution
- Special caution needs to be practiced when **Structures under Construction** have become a partially collapsed, US&R incident. This would also apply to **Existing Structures that Collapse Unexpectedly** (due to no apparent cause)
  - Since the cause of the collapse may involve an inadequacy in the original design or construction, US&R operations should proceed with great caution, and only after review by a Structures Specialist.
  - For C.I.P. concrete structures, the age or underlying floors and "Re-shoring" scheme would need to be considered in deciding if undamaged floors could safely share any additional load.
  - PC concrete and concrete parking structures, have proven to be vulnerable to secondary collapse, and must be approached only after careful evaluation. Risk of further collapse must be weighed against to possible Reward of live recoveries. De-construction may be the only viable option.
    - Since these structures may contain unconnected elements that may also bear on narrow corbels, any shoring system must be complete enough to reduce the possibility of both vertical & lateral progressive collapse

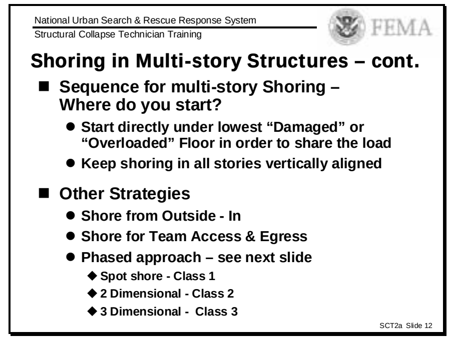
CONSIDERATIONS for DESIGN & SELECTION (continued)

Sequence Considerations

- When shoring is placed in a multi-story incident, one should begin the shoring directly below the damaged floor.
  - This should be done is as safe a manner as possible, but the intent is to “Share the Load” of the damaged floor, as soon as reasonable

Once the upper level of shoring has been accomplished, then all succeeding levels should be added, in-line with the shores immediately above

- To minimize risk the normal strategy is to shore form outside (in the Safe Zone) into the more hazardous area
  - Safe Havens plus access/egress corridors need to be established to place the shoring with minimized risk

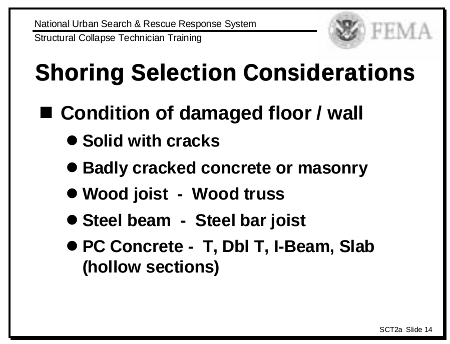


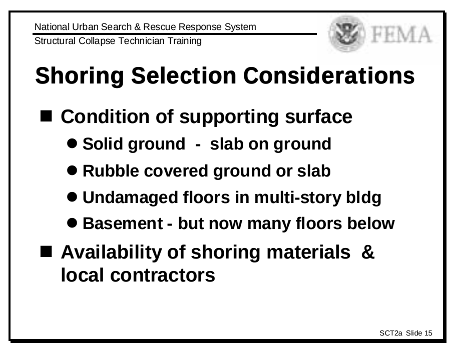
SELECTION CONSIDERATIONS

Condition of structure to be supported

Is the floor constructed with concrete beams, solid concrete slab, broken slab, etc.? Does the floor have to support masonry rubble? Does the shoring system need to contain an elaborate spreading system, or need one only to support the main beams? Are we supporting a solid concrete slab/wall or is it a broken masonry wall that needs more of a spreader system?

- **In Wood Floors** we can normally place our shoring header directly against the bottom of 2x10 or 2x12 joist, but if the floor or roof is constructed using deep, thin trusses, I-joist, or Truss-joist that may be problematical.
- **Deep, thin members** should not be shored from the bottom without doing something to keep them from tipping over.
  - A solution to this problem is to somehow shore from the top of this type of member, or to provide some way of keeping them from tipping.
- **In Steel Floors**, beams can be directly shored from the bottom, but steel bar joist present the same problem as wood trusses.
- **In PC Concrete Floors,** the configuration of the members will dictate the shoring layout. Members like the T and Double T will need major support under the T stems, but for very deep tees, stability will also have to be considered

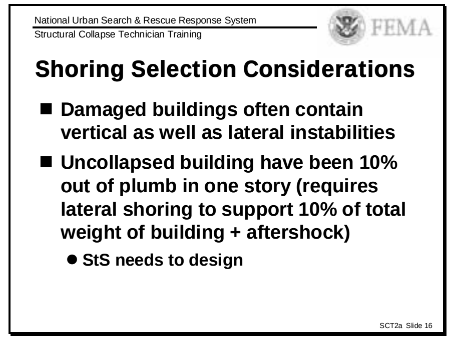




SELECTION CONSIDERATIONS (continued)

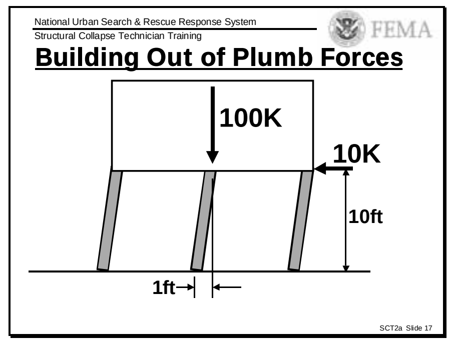
The Condition of foundation/support of shoring – solid or soft ground, slab on ground, floor over basement below, rubble, number of un-damaged stories below, determines extent of system.

Availability of shoring materials - pre-plan, local contractors. For collapsed structures want light, portable, adjustable, reliable, and forgiving shoring system.

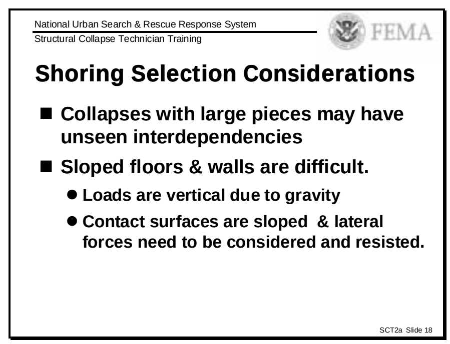


Damaged/Collapsed buildings often contain lateral as well as vertical instability.

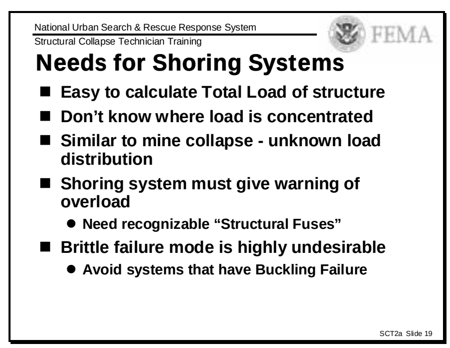
- Buildings that are out of plumb due to cracked (damaged) walls and/or columns require lateral support in proportion to the slope of the offset story
  - This is easily calculated as illustrated here.
  - Wood buildings have been found that were racked at a slope of as much as 2 feet in one 10 foot story
  - It is rare to find damaged, uncollapsed masonry walls that are racked at more than 5% (6" in 10 feet)



- If structure is partly supported by tension structure-like system, horizontal forces are induced in remaining structure.
- Collapses that have large remaining pieces can be extra dangerous. Interconnected pieces may depend on each other for support.
- Collapsed structures containing sloped surfaces are especially difficult, since loads are vertical due to gravity, but contact surfaces are sloped, and therefore, vertical and lateral forces induced in shoring are both very large.



- Total load of structure above can be relatively easily calculated, but where individual load concentrations are being applied is often difficult to determine. A shoring system that will give warning of overload is therefore most desirable.
- It is difficult to decide on the design load when a damaged structure is at rest, but of questionable stability.
  - Should vertical shoring support the weight of the damaged but currently stable floor, or only the weight of rubble resting on it?
  - A four story wood building that is offset one foot in ten in the lower story will require a ten percent stabilizing force, but what additional force should be allowed for wind or aftershock?



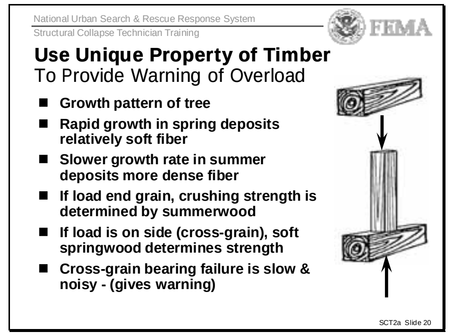
SELECTION CONSIDERATIONS (continued)

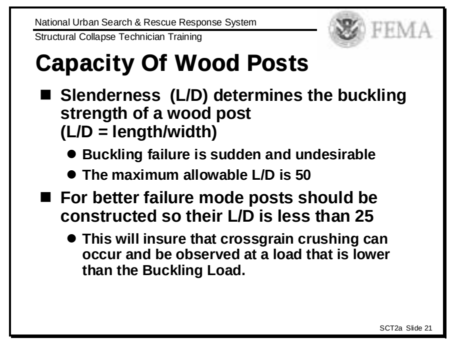
Using the Desirable Properties of Wood to Advantage

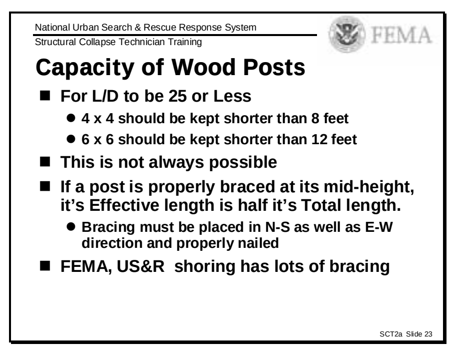
- As previously stated, a most desirable property for emergency shoring is to have a system that will give a warning when it is becoming overloaded, so that one can mitigate the situation. Wood has a built-in (or more accurately, grown-in) property that can be used in our systems to give a noisy indication of high stress. This is a useful “Structural Fuse”
- As explained in the adjacent slide, most commercial timber grows in a way that produces softer, spring fibers and harder, summer fibers. By configuring a shoring system such that the longitudinal grain bears on the cross grain of wood, and the vertical piece is kept short enough that it won’t buckle, we can cause the cross grain to crush.
- We can hear and observe this crushing that will occur when the bearing stress is somewhere between 500 and 700 psi, depending on species of timber.
- We, therefore, want to proportion our posts so that crushing of the header or sole will occur as the failure mode, not the sudden failure mode of buckling. In order to do this we need to keep the length to width ratio (L/D) of a wood post to less than 25 (for the most lumber)

Example: 4x4 length for L/D of 25 = 25x3.5 = 88" = 8ft
6x6 length for L/D of 25 = 25x5.5 = 138" = 12ft

- One can use posts and other compression members that have L/D ratios up to 50. We only would do this for bracing members or if we were sure that our loading was very light and predictable
- Strength of a wood post shoring system is governed by:
  - Perpendicular to grain bearing on the header or sole plate (allowable bearing stress varies from 300 PSI to 700PSI depending on wood species)
  - Vertical capacity of the posts.
  - Strength of header beam and/or sole plate.
    - For vertical shoring systems, posts are kept 4ft o,c, in order to keep the header size to 4x4 or 6x6
    - Often supported structure is stiffer than header.
  - Strength of ground or structure below sole plate.
  - As noted, US&R Shoring are proportioned to give warning of failure by crushing the softer cross-grain at the bearing of the post on the header and cupping of the wedges at the sole.







FEMA SHORING SYSTEMS

FEMA Rescue Specialists need to be trained to construct the following types of shoring systems:

Vertical Shores – as listed in the adjacent slide

- Most are wood systems that have the desirable properties discussed in the previous section of this manual, and are listed on the adjacent slide. (including Sloped Floor Shores)
- Steel pipe shores, Metal frames and Pneumatic Shores have been used in US&R, but their failure mode is normally, buckling. Therefore, they should only be used as temporary, spot shores

Vertical Shoring Systems

- Wood Posts
- Ellis Clamps & Jacks
- T - Spot Shore
- Window / Door
- Laced Posts
- Cribbing
- Steel Pipe
- Metal Frames & Joist
- Pneumatic Shores
- Shores for Sloped Surfaces

Lateral Shores – used in US&R are as follows

- Wood Horizontal Shores – systems that may be used to laterally brace damaged walls, or to secure access corridors.
- Hydraulic Shores – are used in Trench Shoring, and use a oil/water mixture to provide the pressure. They have the undesirable feature, there is no positive, mechanical way to secure the force in each cylinder – only the hose stop valve.
- Pneumatic Shores are used as Trench Bracing, as well as vertical shoring. They are initially actuated by air, but have a method to positively secure the load be mechanical means.
- Raker Shores & Tiebacks are discussed later.

Lateral Shoring Systems

- **Horizontal Shores**
- **Trench Shores**
- **Raker Shores**
- **Tiebacks**

US&R Shoring Technology – as listed in the adjacent slide

- It is important for clear communication that all members of US&R Task Forces speak in terms that all understand.
- To some the horizontal member on top of the posts may be called a beam, but all in US&R should use the term **"Header"**
- The horizontal that collects the load from the posts and delivers it into the ground or supporting slab is a **"Sole Plate".**
- The vertical members are **"Posts"**, not columns.
- In raker shores, the **"Wall Plate"** is placed against the wall in a vertical alignment, and the **"Raker"**, a 4x4 or 6x6, is configured as a sloping member. The Raker supports the upper part of the **Wall Plate**, and delivers its load to a **Sole Plate** or a Base.
- **Raker Cleats** are connected to deliver shear forces from the horizontal or vertical component of the sloped raker 4x4 or 6x6 into the Wall Plate and Sole
- **Gussets** are cut from 5/8" or 3/4" plywood (or OSB) and used to hold various joints together. The may be 12"x12", 6"x12", or 12"x24". They are not designed to support any direct load.
- Most FEMA Shores are built in pairs (or greater numbers) and are laterally braced using 2x6 and 2x4 members, 2x **Diagonal Bracing** is also used to reduce the effective height of posts in shores that are more than 8ft high.
- Plywood Braces are placed horizontally between posts for the Plywood Laced Post (PLP).

US&R Shoring Terminology

Header	Collects load at roof and floor
Sole Plate	Transmits load to floor or ground
Post	4x4 or 6x6 from header to sole
Wall Plate	Collects load from wall/vert. surface
Raker	4x4 or 6x6 from wall plate to sole
Raker Cleat	18" to 30" 2x connection pieces
Gussets	5/8 or 3/4 Ply (or OSB) connections (12"x12" full, 6"x12" half, 12"x24" double)
Diag brac'g	2x4, 6 as X or V between shores
Ply Braces	8" & 24" wide plywood at LP & PLP

FEMA SHORING SYSTEMS (continued)

Raker Shores – are built in 3 different configurations to stabilize walls of structures. (Discussed after Lateral Shores)

- Flying Raker – Temporary, Spot Shoring Systems
- Solid Sole Raker – Built on Paving or Soil adjacent to walls where debris next to the wall have been cleared (or not present)
  - Built in groups of 2 or more with bracing systems between
- Split Sole Raker – Built on Soil or Paving when debris are present next to the wall – also built w/bracing systems
- **Tieback Systems** – built when walls are too high for Raker Shores

VERTICAL SHORES – Wood Systems

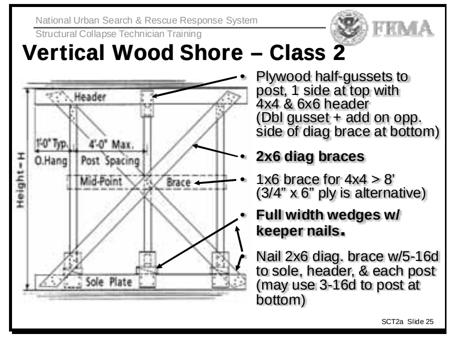
- Most all these systems use wood wedges to provide for adjustability. Wedges also provide an ideal “Structural Fuse” since they will deform and “Cup” when the posts are loaded to about 1.5 to 2x allowable bearing load (about 1000 to 1200psi)
  - Wedges should be checked at least twice a day and after and significant change in loading, inc aftershocks

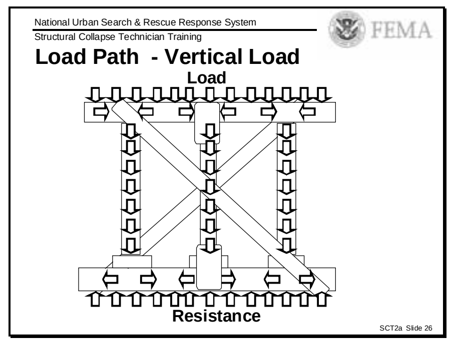
- All wood post systems should have diagonal wood bracing, in north-south and east-west direction if possible.
  - Bracing should be designed for at least 2%, of the vertical capacity of the shoring system.

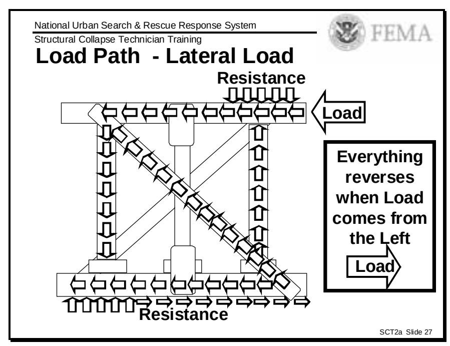
POST WOOD SYSTEMS (3 or more and 2 Post Systems)

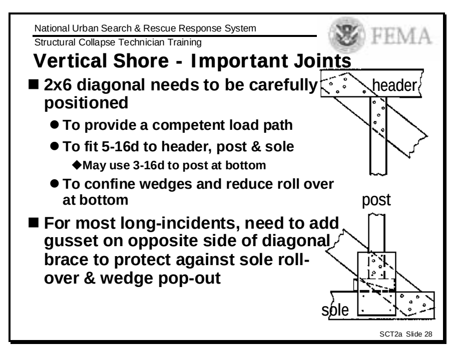
- The graphic on the second page following this one (SHOR-1) illustrates the construction and capacity of a **3 Post Wood Post, Vertical Shore.**
  - Connections at top & bottoms of posts: For 4x4 and 6x6 headers a single sided half-gusset may be used at the top, however, half-gussets should be placed each side at the bottom to prevent Wedge Pop-Out in Aftershocks
  - Diagonal braces are nailed to each post and also provide top & bottom connections for exterior posts.
  - It is difficult to provide lateral stability in the “out of plane” direction for these, two dimensional (Class 2) shores
  - Shores of this type may be built with more than three posts. **For 2 Post Vertical Shores, see page 12**

- The connection at the top & bottom of exterior posts is of special interest, since the diagonal must be carefully positioned to transfer the Lateral Load (see Load Path slides).
  - The diagonal must also be nailed to the header, post, sill, and also confine the wedges.
  - A half-gusset needs to be placed on the opposite side of posts at bottom to reduce risk of sole rollover & wedge pop-out. Also a half-gusset should be added on opposite side at top if header is deeper than their width (rollover)



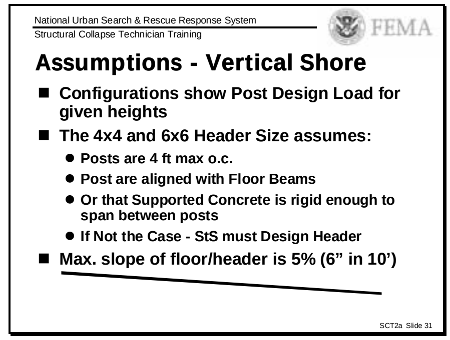


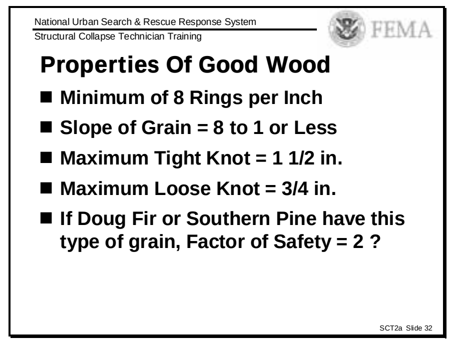


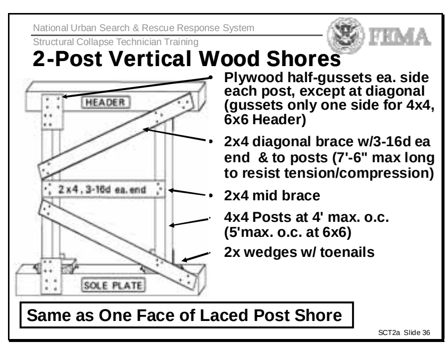


VERTICAL SHORES – 3-POST WOOD SYSTEM (continued)

- The table on the lower part next page, below the Vertical Shore diagram (SHOR-1), gives design values for two systems (4x4 and 6x6 posts) based on Post Design Strength for various lengths (Height)
  - Header size is specified as 4x4 and 6x6 minimum based on the following:
    - The maximum post spacing for 4x4 is 4 feet (6x6, 5ft), and posts are aligned under floor beams and/or joists
    - When concrete slabs and/or beams are being supported, the concrete is not badly cracked and is, therefore, capable of spanning between posts.
  - When the conditions for the 4x4 and 6x6 headers cannot be met, a Structure Specialist will need to design a larger header, based on required bending and shear resistance
    - Deeper headers will require that double half-gusset plates are used at the header to post connection, in order to prevent roll-over
- The headers of vertical shores may slope as much as 6" in 10 feet or 5 percent (about 3 degrees)
  - For slopes that are greater, one should use a Sloped Floor Shore, discussed later in this section.
- The 3-Post wood systems have been built for many years, but they have several shortcomings.
  - Because of its length, it is often difficult to prefabricate
  - It is only a two dimensional system, therefore the posts can only be braced in the plane of the X bracing.
    - Therefore the effective length of the posts cannot actually be reduced.
  - To assure stability, the header would need to be connected to the load at the top. If it is not connected, it could shift sideways during an aftershock.
  - The sole plate should also be restrained from moving sideways.
  - In order to overcome these problems, one can construct 2-Post Vert Shore in pairs, and lace them together to form Laced Post Shores.

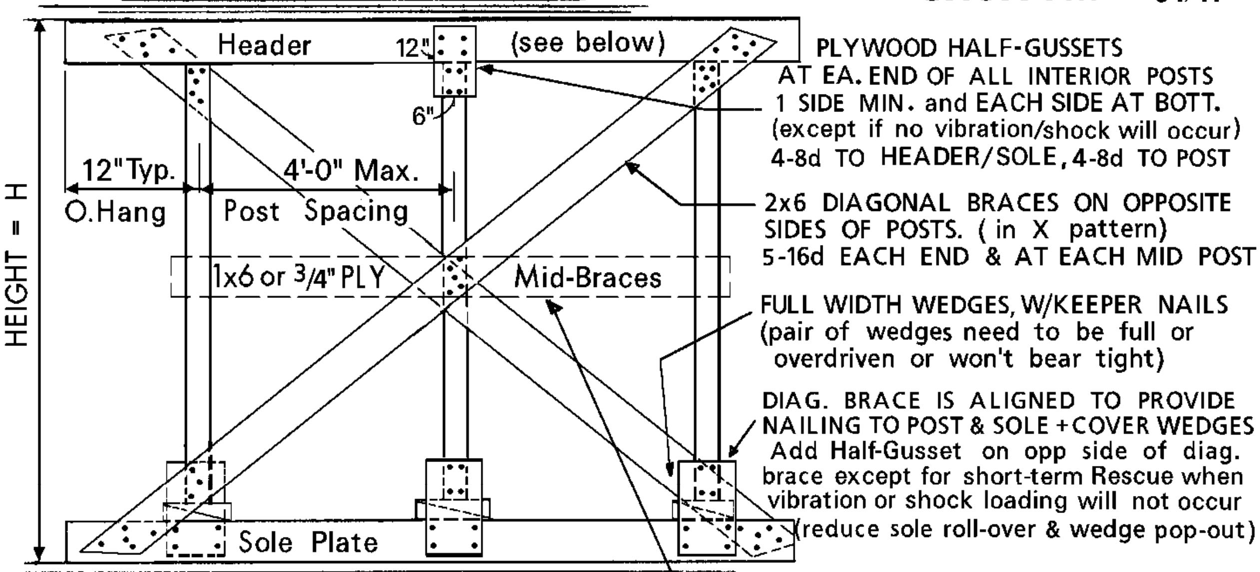






SHOR-1 R1 01/11

Load from Wood, Steel or Concrete Structure



Support from firm/sound slab, floor or ground
Align posts w/structure or shoring below

4x4 POST SYSTEM - USE 4X4 SOLE PLATE

HEIGHT = H	DESIGN LOAD, EA. POST
8'-0"	8,000 LB ✱
10'-0"	5,000 LB
12'-0"	3,500 LB

HEADER SIZE

Use 4x4 min. if place posts directly under floor beams or when supporting intact/rigid concrete slab or beam.
See Structure Specialist for other conditions

6x6 POST SYSTEM - USE 6x6 SOLE PLATE

HEIGHT = H	DESIGN LOAD, EA. POST
12'-0"	20,000 LB ✱
14'-0"	14,500 LB
16'-0"	12,000 LB
18'-0"	9,000 LB
20'-0"	7,500 LB

HEADER SIZE

Use 6x6 min. if place posts directly under floor beams or when supporting intact/rigid concrete slab or beam.
See Structure Specialist for other conditions

SPECIAL NOTES:

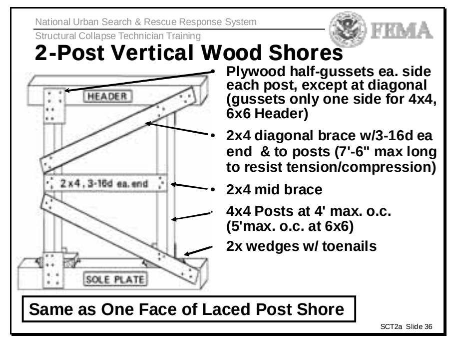
- ✱ = Limited by 660 psi Cross Grain Bearing on Wood.
- Spacing of Posts may be closer than 4ft in order to increase system capacity and/or align Posts under floor beams or joist.
- Header Size is HIGHLY dependent on ability of The Shored Structure to bridge between the Shoring Posts. If in doubt check w/Structure Spec.

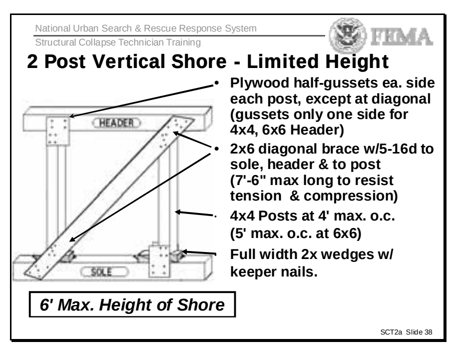
VALUES GIVEN FOR ALL WOOD SHORES IN THIS TEXT HAVE AN APPROXIMATE FACTOR OF SAFETY OF 2 TO 1 IF NO. 1 DOUGLAS FIR OR SOUTHERN PINE ARE USED. PIECES SHOULD BE SELECTED FOR GOOD GRAIN (MIN. OF 8 RINGS PER INCH, SLOPE OF GRAIN NOT GREATER THAN 8 TO 1, AND HAVING 1 1/2 INCH OR SMALLER TIGHT KNOTS / 3/4" MAX LOOSE KNOTS)

VERTICAL SHORING SYSTEMS (continued)

2-POST SYSTEM

- This Shore is preferred by engineers for constructing a vertical shore using wood posts
  - One would prefabricate the 2 posts, header, and upper diagonal and horizontal braces. This is a 2 dimensional, Class 2 shore, same as a 3 or more post vertical shore.
  - After positioning the prefabricated part, the sole, wedges, lower diagonal and half-gussets would be installed.
  - An additional 2 post systems could later be placed in an adjacent location in order to form the stable, 3 dimensional Laced Post System – a Class 3 Shore
- The 2-Post Wood Systems is shown in the adjacent slide
  - A full height 2 Post Shores, the diagonal bracing is best configured as shown in the adjacent slide.
    - Posts should be spaced 4ft max o.c. for 4x4 and 5ft max for 6x6
    - Maximum height using 4x4 posts is 12 feet. (6x6 is 20ft) If the 2-post shore becomes a part of a laced post the height may be greater (see Laced Post info)
    - The 2x diagonals are configured the same as a Laced Post, so their L/D is small enough to allow them to resist both compression and tension.
    - Diagonals should not be greater than 7’-6” long from end to end (6.5 ft clear between posts on diagonal)
    - The safest way to build this shore is to prefabricate as discussed above, then the sole, wedges, half-gussets and lower Diagonal can be added in Collapse Zone.
  - For heights from between 11 and 17 feet, 2 horizontal braces and 3 diagonals should be used
  - For conditions in Collapse Zones where shoring heights are 6 feet and less, the short, 2 Post Vertical Shore, as shown in adjacent slide may be used.
    - In this case, again, the 2x diagonal brace is short enough so that it can resist Compression and Tension, and, therefore, “X” bracing is not required
    - Cribbing may be the best choice at heights 3ft and less. (to be discussed later)



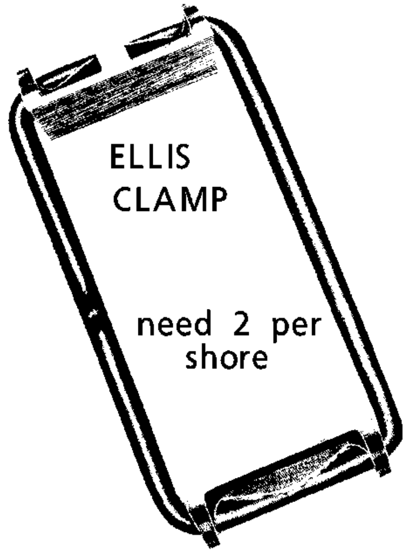


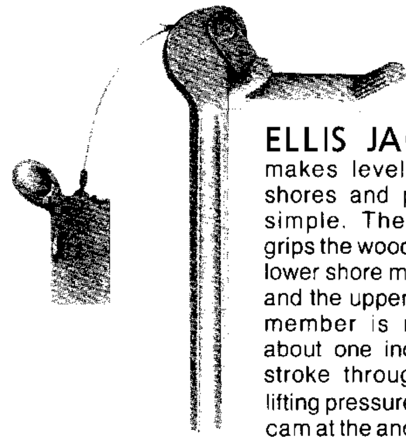
VERTICAL SHORING SYSTEMS (continued)

ELLIS CLAMP - WOOD POST SYSTEMS

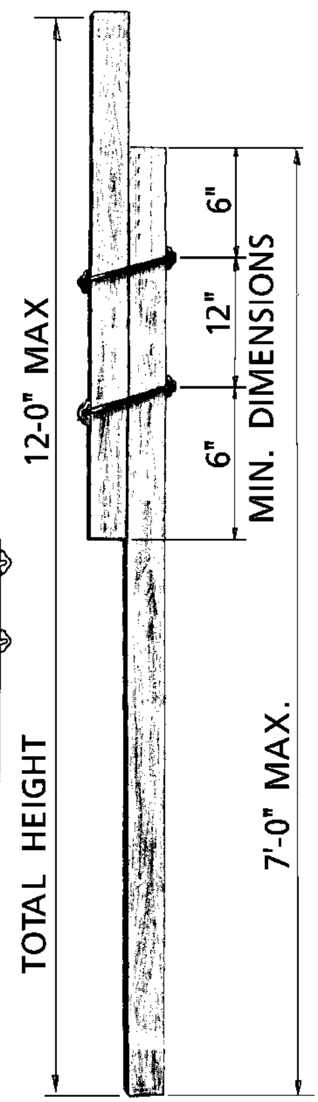
ELLIS SHORES - ADJUSTABLE 4x4 SHOR-2

6/99



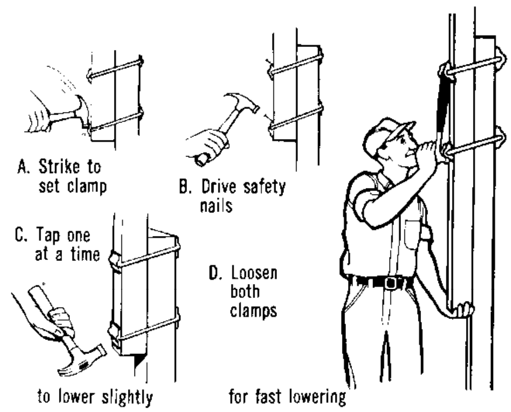


ELLIS JACK makes leveling of shores and purlins simple. The Jack grips the wood of the lower shore member and the upper shore member is raised about one inch per stroke through the lifting pressure of the cam at the anchored end of the Jack handle.



How to Use Ellis Shores:

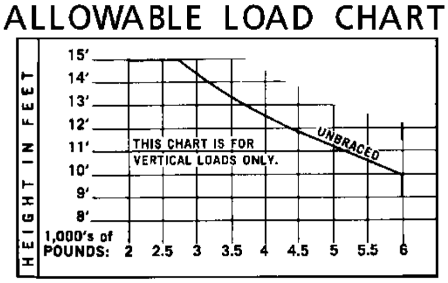
First, get the proper length lumber to make an Ellis Shore of the desired height — that being a 7' lower shore member and an Ellis Stick of the proper length. The sketches at the right give some suggestions for best results in the operation of Ellis Shores. The picture at the left shows a man raising the upper shore member to the approximate shore height, final adjustment is made with the Ellis Jack. When the desired height is obtained, the clamps should be tapped down (a hammer lug is provided on the clamp plate) to seat them and a safety nail is driven in the shore above each plate. This nail does not support any load, but simply keeps the clamps from vibrating loose.



ELLIS CLAMPS MAKE A PAIR OF 4x4 POSTS INTO AN ADJUSTABLE 4x4 SHORE

Max allowable load is 6000 lbs for shore that is 10ft or shorter with a factor of safety of more than 2 (based on No.1 Doug. Fir/So. Pine)

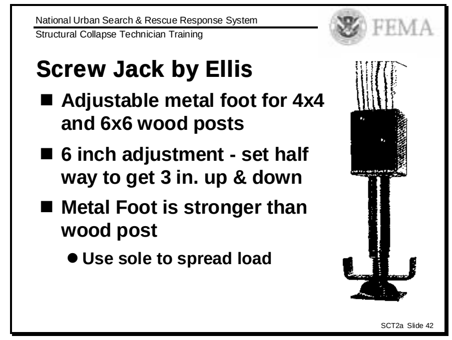
ALLOWABLE LOAD CHART



VERTICAL SHORING SYSTEMS (continued)

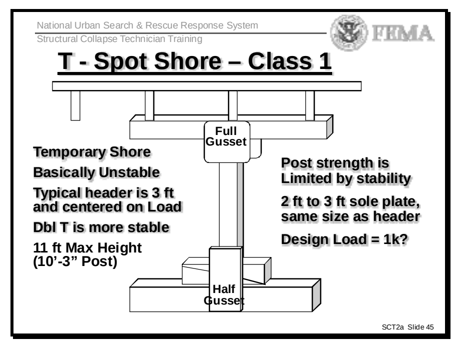
ELLIS CLAMP - WOOD POST SYSTEMS

- 4 x 4 posts can be assembled with Ellis Clamps that give them adjustable length. The failure mode of these assemblies is usually indicated by the crushing of the wood under the clamps. (If shores are 10 ft. or less in height)
  - This gives the system some forgiveness.
- These shores use more lumber than single posts, but they can be very useful when working with short 4x4's.
- Metal, adjustable post feet for 4 x 4 & 6 x 6 are made by Ellis and called Screw Jacks. The foot base plate has nail holes for positive attachment.



T - SPOT SHORE

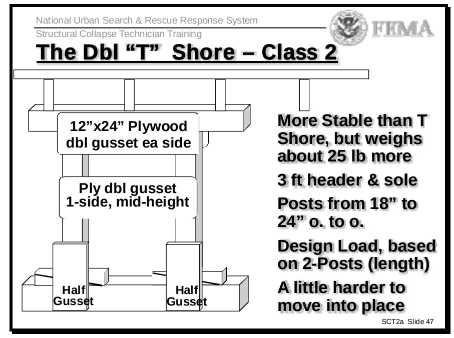
- This type shore is used for initial stabilization of dangerous areas where fully braced systems (such as 2 or more post Vertical Shores) are to be constructed.
  - They provide temporary support of damaged floors, but they are basically unstable.
  - They can only support loads that are balanced about the vertical post, and therefore the header needs to be kept to a maximum of 3 feet long. **Previous versions of the FEMA US&R Student manuals allowed the use of a 4 ft header if the gusset plates were increased to 18" square. The 4 ft header makes the T even more unstable, and is not recommended. It also makes the shore less portable.**
  - They can be prefabricated into the "T" shape, carried into the area that needs support, and then the sole, wedges and half-gusset (or cleat) can be quickly installed

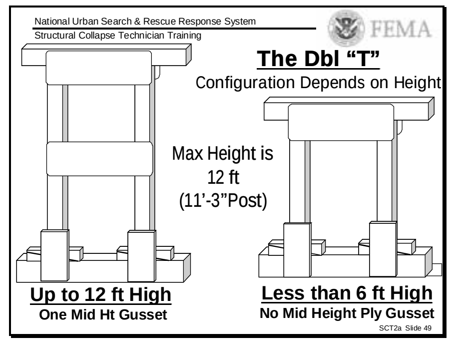


- The capacity of the 4x4 post depends on length as in Vertical Shores (8ft long 4x4 safely supports 8000lb)
  - However, one would expect that stability would govern the failure mode
  - The suggested capacity of these shores should be somewhere in the range of 1000 to 3000 lbs
  - **Maximum Height of T Shore should be 11 ft**
- They are normally installed with Wedges, Sole Plate & half-gussets to spread the load & tighten the shore against the load.

DOUBLE T SHORE

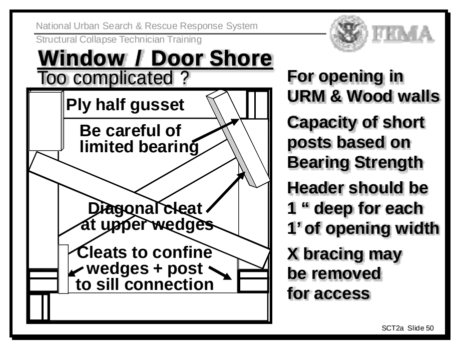
- This type shore may also used for initial stabilization of dangerous areas.
  - They would provide temporary support of damaged floors, and are much more stable than the “T” Shore.
  - With a 3 foot header and the posts places 24 inches out to out, most of the load would be centered between the posts
  - Due to its limited width of 3 feet, this shore is not a desirable as the 2 or multi post vertical shores, but its portability allows it to be installed with minimum exposure of rescue workers
  - For shore height less than 6ft, omit mid-height gusset.
  - For heights over 11ft, mid-height gussets should be places at 1/3 height and 2/3 height. **Max Height of shore is 12ft.**
- The capacity of the 4x4 posts depend on length as in Vertical Shores (1-8ft long 4x4 safely supports 8k, 10ft long = 5k)
- They need to be installed with wedges, sole plate, and half-gusset to spread the load & tighten shore against the load.

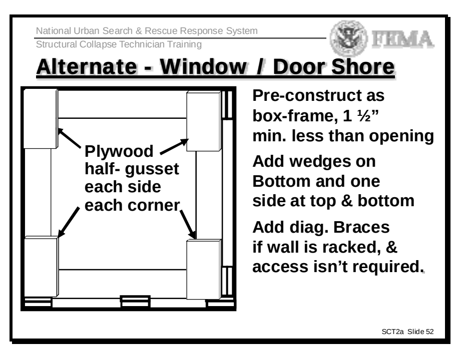




WINDOW & DOOR SHORES

- They are used mostly in URM buildings to confine and support loose masonry over openings in the URM walls.
  - They are quite complicated if all corners are properly connected and wedges are confined
  - They may also be used in Wood or other buildings where door or window headers have been damaged.
  - They also have been used in badly racked wood buildings, as diagonal bracing (use 4x or larger Compression Diagonals that are on same plane as Header, Sole and Posts)
- The capacity of the wood posts (which are usually short) usually depends on the cross grain bearing strength (between 300 and 700psi depending on wood species)
  - A rule of thumb for headers size is to make the depth the same in inches as the opening width in feet.
  - The header width should be 6 inches for thick, URM walls, but may be 4 inches for thinner walls, such as wood and hollow concrete block (cinder block)
- A simpler, pre-constructed configuration is shown in adjacent slide, which uses 2x wedges under sole over and at one side
  - It can be built in safe area and possibly reused
  - It can Support as much vertical load as the standard Window Shore, but may not be practical for badly racked openings

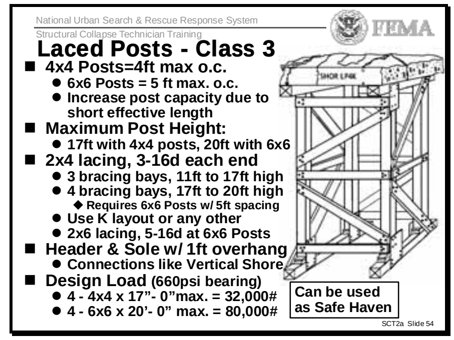




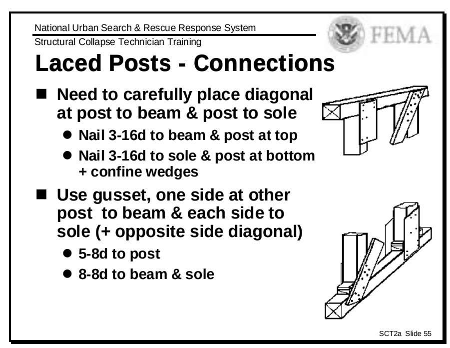
<u>VERTICAL SHORING SYSTEMS</u> (continued)

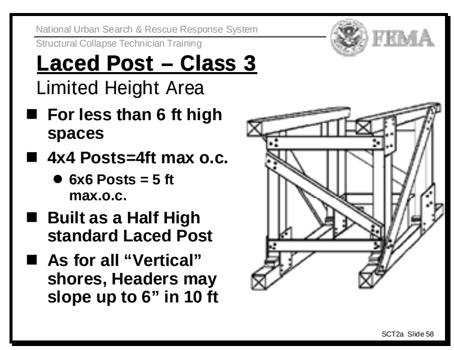
LACED POSTS

- Four posts may be placed in a square pattern and laced together with 2x4 or 2x6 horizontal and diagonal bracing.
  - The spacing of posts is 4 ft max for 4x4 (5ft for 6x6) so that the length of 2x diagonal braces is 7'-6" max to allow them to resist compression as well as tension forces.
  - The max height with 4x4 posts is 17ft (20ft for 6x6)
  - 2x4 Diagonals, 3-16d each end, are used with 4x4 posts
  - 2x6 Diagonals, 5-16d each end, are used with 6x6 posts
  - This is a three dimensional, Class 3 Shore – most stable
- The connections between diagonals and header/sole need to be made with care as for the vertical post shore, since the 2x diagonals must be nailed properly to header, post, sole, and confine the wedges as shown in the adjacent slide.
  - A half-gusset is, again, useful opposite the diagonal to sole connection to guard against roll-over and wedge pop-out
- The strength of each post may then be calculated on the basis of the length/height between the Horizontal Braces. (8K for 4x4 and 20K for 6x6)
- Header beams and Sole plates usually are required to collect and distribute the load, as criteria as for Vertical Shores.
  - The surface that is being supported may have a slope of 6" in 10 ft in any direction.
  - Use Sloped Floor Shores for larger slopes.
- The space inside the laced posts may be useful as a safe haven, since it is relatively strong and one may climb in relatively quickly
- The safest and most effective way to construct laced posts is to build two, 2 post vertical shores, then lace them together.
  - 2 Post vertical shores should be prefabricated, without their sole plates, then assembled in the collapse zone.
- The most common configuration of laced post has one mid-point horiz. brace & two sets of diagonal braces, these should be used for shoring heights between 6 ft and 11 ft.
  - For heights from 11 ft to 17 ft, use horizontal brace at one-third points and 3 sets of diagonal braces.
  - For heights below 6 ft, in limited height areas, one can build a short, braced shoring system, that is essentially a half height, Laced Post
  - The configuration of the diagonals is discussed above-right. The K configuration is easy to teach and remember.



The diagonal bracing is shown in a 4-K configuration. In previous editions of this manual, 3-K plus one reverse K was shown. This may have been a better layout for Torsion, but it placed a large group of nails at one post – leading to possible splitting
. **Since the capacity of diagonals is likely governed by the shear loading on the nails, any**





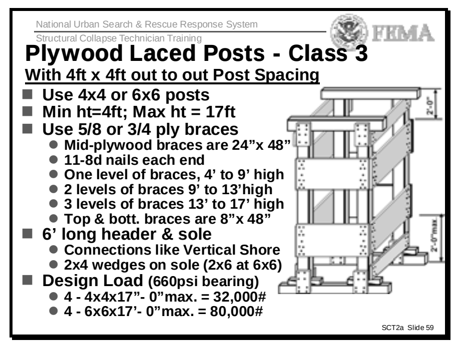
VERTICAL SHORING SYSTEMS (continued)

PLYWOOD LACED POSTS (PLP)

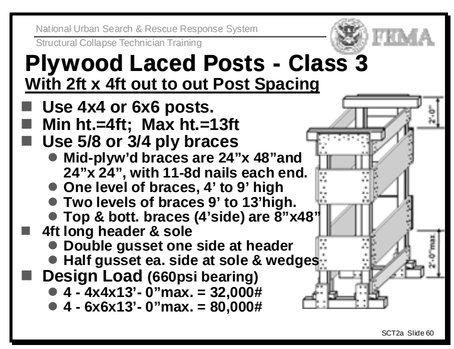
- Four posts may, also, be placed in a square pattern and laced together with plywood strips as bracing. Use 4x4 or 6x6 posts
  - Posts are spaced, 4 ft x 4 ft out to out for the 4x4 PLP
  - Posts are spaced, 2 ft x 4 ft out to out for the 2x4 PLP
  - The maximum height of a 4x4 PLP is 17ft.
  - The maximum height of a 2x4 PLP is 13ft
  - The minimum height for all PLP is 4ft. It is assumed that other shores would be used at heights less than 8ft.
  - The plywood bracing may be 5/8 or 3/4 ply or OSB.
  - **Note** that the middle braces are to be spaced 2 ft from each end of the shore, in order to provide bracing where the potential buckling curve has its greatest slope.
  - The plywood braces are cut in 8 inch and 24 inch strips.

This is a very stable, three dimensional, Class 3 Shore, with strength and properties similar to a laced Post Shore.
The design strength for PLP is same as for LP: 32k for 4x4 posts & 80k for 6x6 posts.

- **The 4x4 PLP** is shown in the adjacent slide
  - Posts are spaced, 4 ft x 4 ft out to out for the 4x4 PLP
  - The headers and soles are 6 ft long.
  - The plywood bracing at the top and bottom for the sides are 8" x 48" and have 5-8d to each post
  - The ply middle braces are 24" x 48" and have 11-8d to each post.
  - There is 1 level of ply braces for PLP from 4ft to 9ft high, 2 levels from 9ft to 13ft high, and 3 levels for heights from 13ft to 17ft
  - The posts are connected to the sole with a half-gusset each side that confines the wedges.
  - At the top, only a half-gusset is required on one side as long as the header is 4x4 or 6x6.



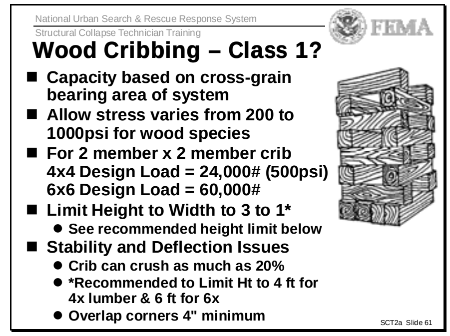
- **The 2x4 PLP** is shown in the adjacent slide
  - Posts are spaced, 2 ft x 4 ft out to out for the 2x4 PLP.
  - The headers and soles are 4 ft long, and max. ht. is 13ft.
  - The plywood bracing at the top and bottom for the 4ft sides are 8" x 48" and have 5-8d to each post
  - The ply middle braces are 24" x 48" and 24" x 24" and have 11-8d to each post. There is 1 level of braces for from 4ft to 9ft high, and 2 levels from 9ft to 13ft high.
  - The posts are connected to the sole with a half-gusset each side that confines the wedges, and the header is connected using a double gusset one side.



VERTICAL SHORING SYSTEMS (continued)

CRIBBING

- Cribs have a multi member lay-up of 4x4 to 8x8 lumber in two, three or more members per layer configuration.
- The Design Load is determined by the perpendicular to grain loading on the sum of all bearing surfaces. 500 psi is used for Douglas Fir and Southern Pine lumber
- Failure is slow, noisy crushing of the softer wood fibers, which make system desirable for the unknown loading of US&R work.
- Heavily loaded cribs will crush so that they may lose from 10% to 20% of their height.
  - This is a good thing as far as providing warning of overload, but may present problems regarding stability and the need to adequately support the damaged structure.
  - It means that one must figure that cribbing cannot “share “load with the damaged structure. The structure must completely fail, and “give-up” the load to this system.
- Stability of cribs is an important issue
  - Height to width of crib and should not exceed 3 to 1.
  - Need to overlap corners a minimum of 4” to guard against splitting off corners of individual pieces.
  - Testing has shown that stability of taller cribs is an issue. It is recommended to limit the total height of cribs with 4x lumber to about 4 feet and 6x lumber to about 6 feet.
  - Stability is also dependent on, more or less, uniform crushing under each line of crib bearing. The presence of knots and different density/angle of grain at the bearings can provide non-uniform conditions, leading to stability failures.
- Lateral movement between individual crib pieces during aftershocks is normally resisted by friction.
  - Individual pieces may be notched like Lincoln logs, to improve lateral resistance, but this is very time consuming and all notches must be same height.
  - Metal clips may also be used to improve lateral strength, as well as diagonal braces between pairs of cribs.
  - Sheathing the crib with plywood would help lateral resistance, but is incompatible with crib vertical deflection
- Solid levels can be used spread the load at the ground level.
- Shrinkage of green lumber will cause crib to shorten and they should be checked daily for tightness.
- Cribs used on sloped surfaces as will be discussed later



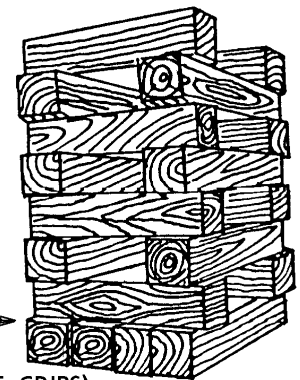
VERTICAL SHORING SYSTEMS (continued)

DESIGN STRENGTH is BASED on CROSSGRAIN BEARING
(VARIES FROM 200 PSI TO 1000 PSI DEPENDING ON WOOD SPECIES
500 PSI IS USED HERE - EXAMPLE 500 x 3.5 x 3.5 x 4 = 24,000)

FOR 2 MEMBER x 2 MEMBER LAYOUT

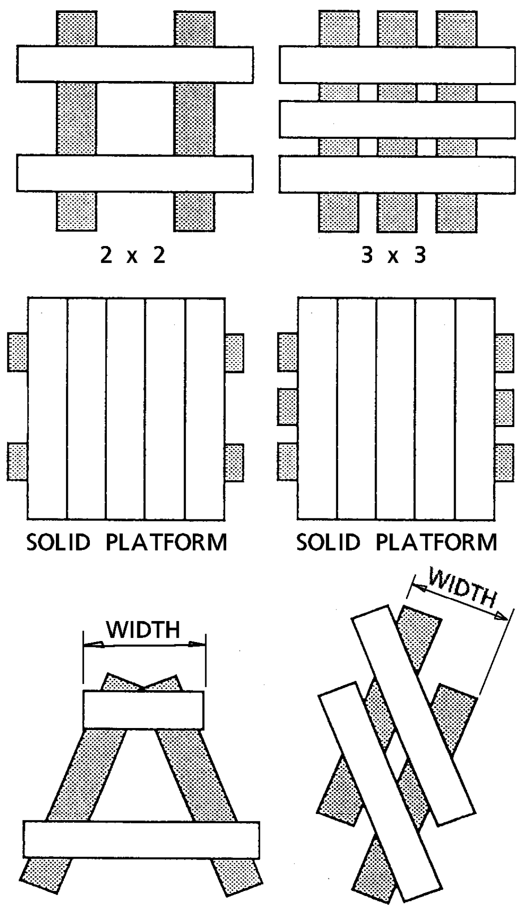
4 x 4 CRIB DESIGN LOAD = 24,000 LBS (12 TONS)
6 x 6 CRIB DESIGN LOAD = 60,000 LBS (30 TONS)

FOR 3-MEMBER x 3-MEMBER CRIB, DESIGN LOAD IS 9/4 AS MUCH
500 x 3.5" x 3.5" x 9 = 55,000, 500 x 5.5" x 5.5" x 9 = 136,000



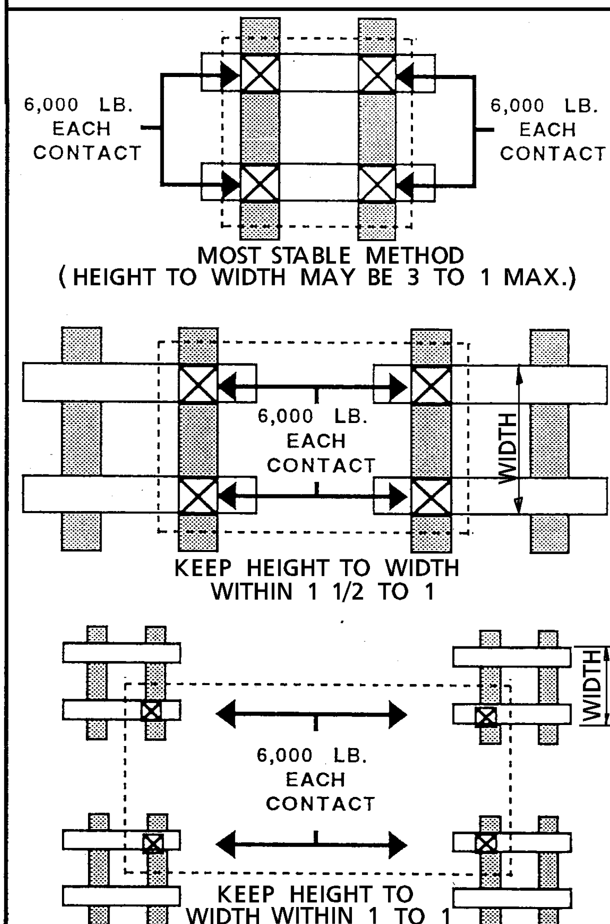
- BOTTOM LAYER SHOULD BE SOLID TO SPREAD THE LOAD ESPECIALLY ON SOIL OR ASPHALT PAVING
- LIMIT HEIGHT TO 3 TIMES WIDTH (SHORTEST WIDTH FOR NON-SQUARE CRIBS)
- OVERLAP CORNERS BY 4 INCHES TO ASSURE SLOW CRUSH TYPE FAILURE

SHOR-4 06/06



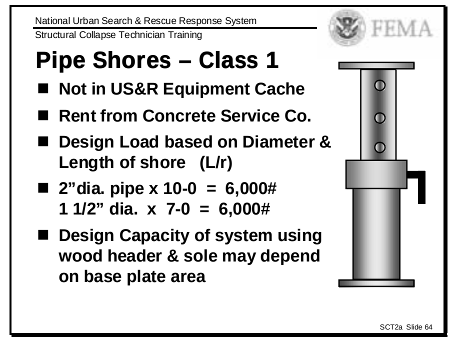
BOTH ARE NOT VERY STABLE, KEEP HEIGHT TO WIDTH WITHIN 1 TO 1

4" X 4" CRIBBING WITH FOUR BEARINGS



<u>VERTICAL SHORING SYSTEMS</u> (continued)

STEEL PIPE SYSTEMS



- Pipe capacity depends on buckling strength.
- Design Load = Fc x Area
  - Fc (Allow. Compression Stress) given in Sect 7 StS FOG
  - Fc is dependant on L/r (L = length in inches; r = radius of gyration = average radius of pipe)

Example: Design Capacity of 2" diameter Standard Pipe x 8 ft long

(2.375" O.D., Area = 1.07 sq in, from Sect 7 StS FOG

L/r = 96"/.787 = 122; from StS FOG, Fc = 10ksi
Design Capacity = 10ksi x 1.07 sq. in. = 10.7 kips = 10,700 lbs
(The author uses about 90% of this value, based on the manufacturing tolerances of pipe)

- Retractable pipe shores are normally adjustable by screw end and/or sleeve and pin. They may have square steel feet that may even have slope adjustment and nail holes for attachment.
- Pipe shores used for bracing tilt-up concrete walls come in lengths up to 30 feet and have rated capacities listed in tables supplied by rental companies.
- Pipe systems are often used with wood spreader beams and sills, which could limit their capacity. Engineers should be used to design these systems.
- Pipe systems normally fail by buckling, and are, therefore, less desirable than well braced wood systems that can be proportioned to initially fail by crushing of wood

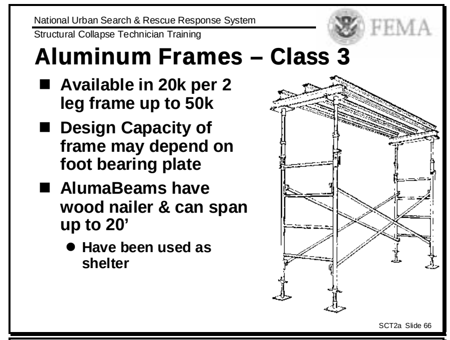
TRENCH JACKS

- Vary from about two to more than eight feet long and normally have a rated capacity. They are intended to support the opposing sides of a trench, with the addition of spreaders & sheathing. They should be Schedule 40 Pipe
- May be used as initial, unbraced shoring to permit building of more stable system. Not first choice
- They could be used as a two or 3-post system, nailed to header and sole. Diagonal X bracing would need to be only nailed to the header and sole

VERTICAL SHORING SYSTEMS (continued)

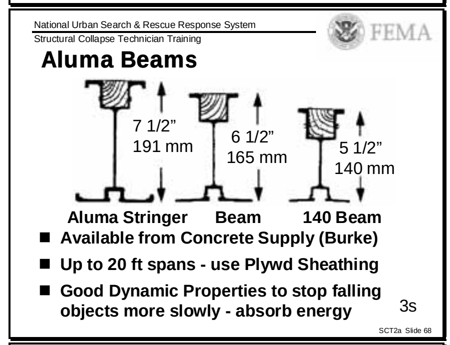
DIAGONALLY BRACED METAL FRAMES

- Steel and aluminum tubular frames are available in design capacities up to 50,000lb. per two post frame. They have adjustable height and spreader systems. They may be stacked and guyed to reach great heights, and have diagonal bracing members.



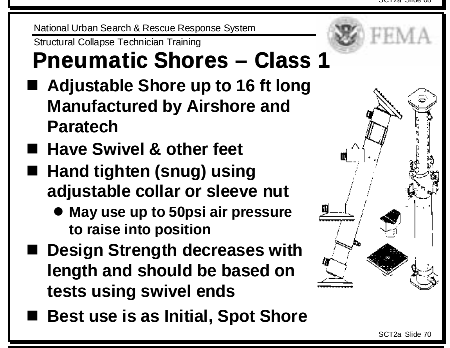
ALUMA BEAMS

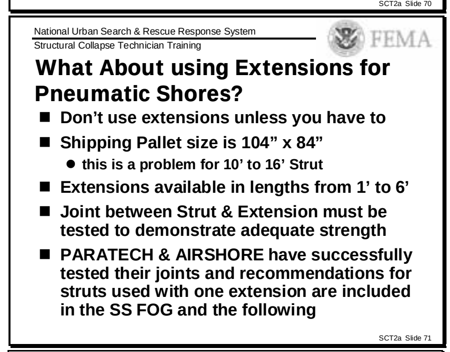
- These are light gage, shaped aluminum joist or beams that are normally used as shoring for wet concrete.
- They have been used to construct shelters from falling debris, as plywood sheathing can be placed between the Aluma Beams and nailed too them to provide a surface that is quite flexible but strong.
- The flexibility of the aluminum (3 times that of a similar steel structure) is ideal for catching falling objects, since the flexibility reduces the strength required for the CATCH structure.

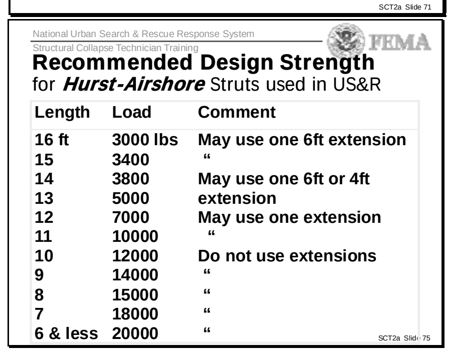


PNEUMATIC SHORES (STRUTS)

- Lightweight aluminum pneumatic piston ram shore, which is highly adjustable with ranges up to 16 ft. They can be configured with various end connections (see slide).
  - Airshore manufacturers 3½" diameter Struts in seven ranges of length. (From 2 to 16 feet)
  - Paratech manufactures 3" diameter Struts in four ranges of length (from 2 to 8 feet). **Dark Grey anodized color**
  - Paratech also makes a 3½" diameter, Long Strut, in three ranges of length (from 6 to 16 feet). **Gold anodized**
- When used in trenches, these shores are initially set with pressurized air.
  - After securing the shore in place with a large locking nut or steel pins with collar, the safe working load can range from 20,000 lbs. for a 6-foot shore to 3000 lbs. for a 16-foot shore.
  - Load charts for the two manufactures are listed in the adjacent and subsequent slides and the US&R Structural Specialist FOG, Sect 7.
    - Loading is based on using swivel end connections







Length	Load	Comment
16 ft	3000 lbs	May use one 6ft extension
15	3400	"
14	3800	May use one 6ft or 4ft
13	5000	extension
12	7000	May use one extension
11	10000	"
10	12000	Do not use extensions
9	14000	"
8	15000	"
7	18000	"
6 & less	20000	"

<u>VERTICAL SHORING SYSTEMS</u> (continued)

PNEUMATIC SHORES (continued)

- When used in US&R, these shores should be hand tightened, so as not to apply any sudden pressure to a damaged structure.
  - Air may be used to raise vertical struts, but the pressure must be limited to 50 psi max – due to accident potential
  - The sleeve nut or steel pins are used to adjust length.
  - They may be included in a system with headers, sole plate, and bracing, but are considered best as temporary shores that allow braced systems to be installed at reduced risk.
- The manufactures also make simple aluminum tubing extensions in lengths from one to six feet.
  - Extensions should only be used when other alternatives are not available.
  - Only one extension should be used with each strut
  - See slide at right regarding use of extensions.

<u>SPECIALTY SHORES</u> (Airbags are lifting device - not shores)

- **AIRBAGS** – tough neoprene bags that come in sizes from six inches to thirty-six inches square.
  - They are pressurized to lift very heavy objects a short distance, and are helpful in releasing an entrapped victim.
  - Note that they can be punctured by rebar, and that objects that are lifted must be laterally restrained by other means, since the bags have little lateral strength.
- **STEEL OR REINFORCED CONCRETE CULVERT** sections could be used as a protection device for entry thru an area where protection from smaller falling hazards was required.
- **SHORING AT COLUMN/SLAB CONNECTIONS** - The danger of a punching shear failure occurring at a flat slab/column joint is often present due to heavy debris loading on slabs that do not collapse initially.
  - Since most of the cracking that warns of this type of collapse hazard is on the top of the slab and may be covered by the debris, it is best to increase the column's periphery by adding vertical shoring on all four sides.
  - Shoring consisting of vertical posts that are tied around the column could be used. All the normal problems i.e. what's the load, support system, need to be considered.

National Urban Search & Rescue Response System
Structural Collapse Technician Training
FEMA

Recommended Design Strength
For Paratech Long Shore Struts in US&R

- **Paratech Long Shore Struts are 3½" in diameter (Gold Anodized), which is larger than original 3 " dia. Paratech Rescue Struts.**
- **Paratech Rescue Struts (3" dia., Dark Grey) should be used ONLY up to 8 feet long**
  - **They have a strength similar to the 3½" struts for lengths up to 6 feet**
  - **Strength drops to about 14,000 lb for 8 ft**
  - **See Mfr's recommendations following.**

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Recommended Design Strength
For Paratech Long Shore Struts in US&R

Length	Load	Comment
16 ft	3500 lbs	May use one 6ft extension
15	4500	"
14	5500	May use one 6 or 4ft ext.
13	6500	"
12	7500	May use one extension
11	10000	"
10	12000	"
9	16000	Do Not Use Extensions
8	20000	"
7 & 6	22000	"

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***PARATECH* Rescue Struts – Load Table**
Based on Tests by Paratech,
Reviewed by Wiss, Janney, Elstner, Engineers
Available from 1.5 to 7ft
Extensions avail. In 12", 24" and 36" lengths
(use max. of one extension per strut)

Length	Ave Ult	Design Strength Based on Safety Factors	
		3 to 1	4 to 1
2 ft	87,000 lb	29,000 lb	21,750 lb
4 ft	71,750 lb	23,920 lb	17,940 lb
6 ft	56,500 lb	18,830 lb	14,125 lb
8 ft	48,100 lb	16,030 lb	12,025 lb

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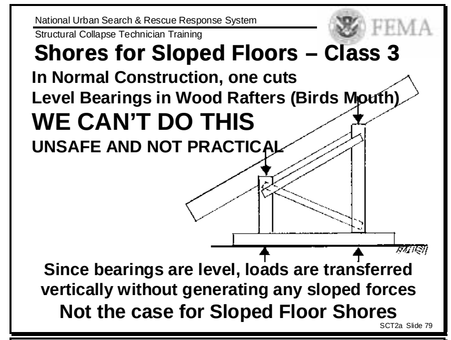
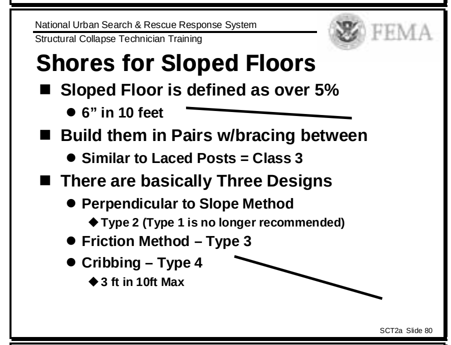
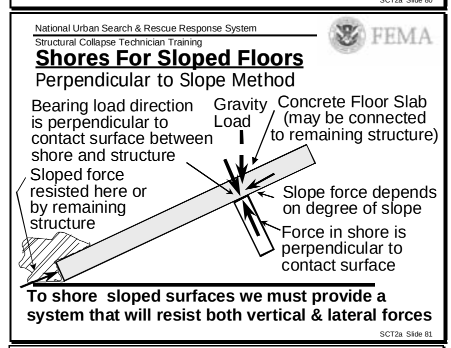
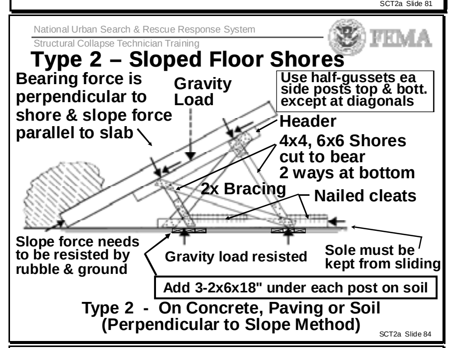
VERTICAL SHORES ON SLOPED SURFACES

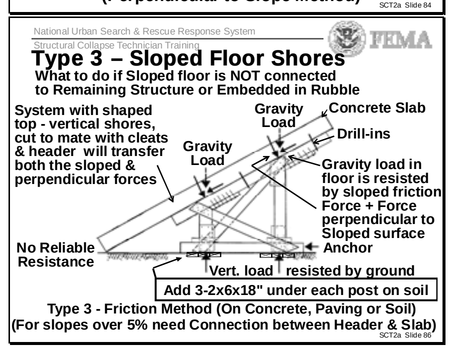
- In normal sloped roof construction, sloped rafters are fabricated with horizontal bearings cut-in, so that the vertical, gravity load can be directly transferred into the supporting structure.
- When attempting to shore a damaged, sloped floor, however, the vertical, gravity load is transferred from structure to shoring through a sloped surface where two forces are generated.
  - A force that is Perpendicular to the sloped surface, and
  - A force that will act down the Slope – Slope Force
- In many cases, especially for reinforced concrete slabs, the Slope Force may be assumed to be resisted by:
  - The connection of the Sloped Floor to the remaining structure at the top, or
  - The Sloped Floor is firmly embedded in rubble at the bottom.
  - When this is the case, the **Perpendicular to Slope Method** shores may be used to successfully support the sloped floor.
- Two variations of the Perpendicular Method of Sloped Floor Shore were previously shown – Type 1 and Type 2.
  - **The Type 1**, placed on an earth surface, with bearings cut into ground, perpendicular to the shores, is no longer recommended, since it is too difficult & dangerous.
  - **Type 2** may be built on concrete, paving or soil, and uses cleats nailed to the Sole, and needs a Sole Anchor.
  - Since the posts for the Type 2 are placed on an angle, wedges are not needed to tighten the posts.
- When the sloped floor is not reliably connected to the remaining structure or embedded in rubble, the **Sloped Friction Method - Type 3** Shore should be used. This may be used on Concrete, Paving or Soil SHOR-8
  - In this case the Perpendicular and Slope force are combined within the system to allow the shore posts to be placed in a vertical alignment.
  - For Type 3, wedges may be used to tighten the posts.
  - Since the reliance on friction, especially during Aftershocks may be problematical, the header should be positively attached to the sloped floor, especially if floor is sloped greater than 5%.
    - Small bars (½” to ¾” diameter) could be drilled into bottom of slab (through pre-drilled holes in header) and held in place with epoxy (or by interference fit)
    - Shore could bear on sides of beams, etc.



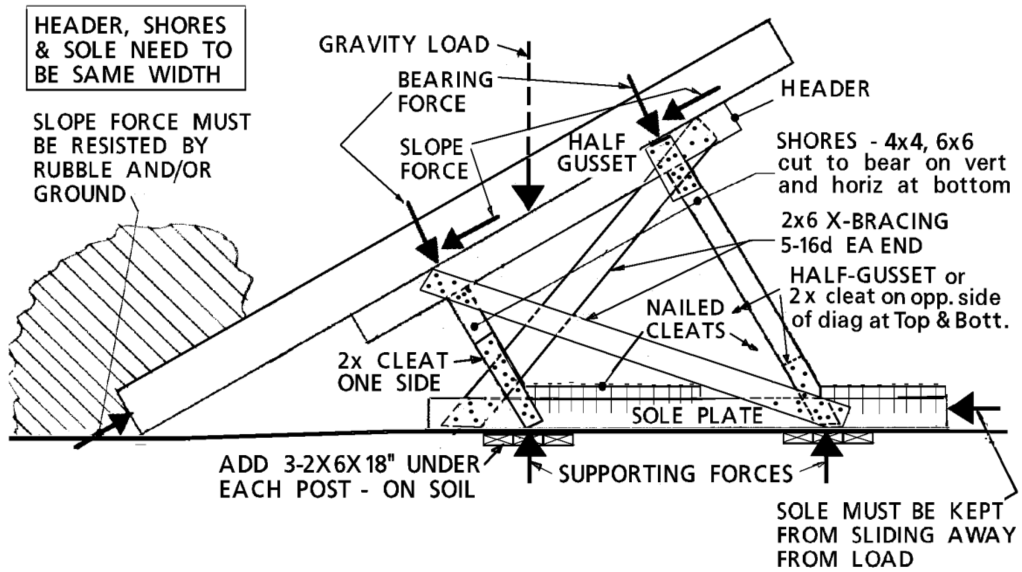






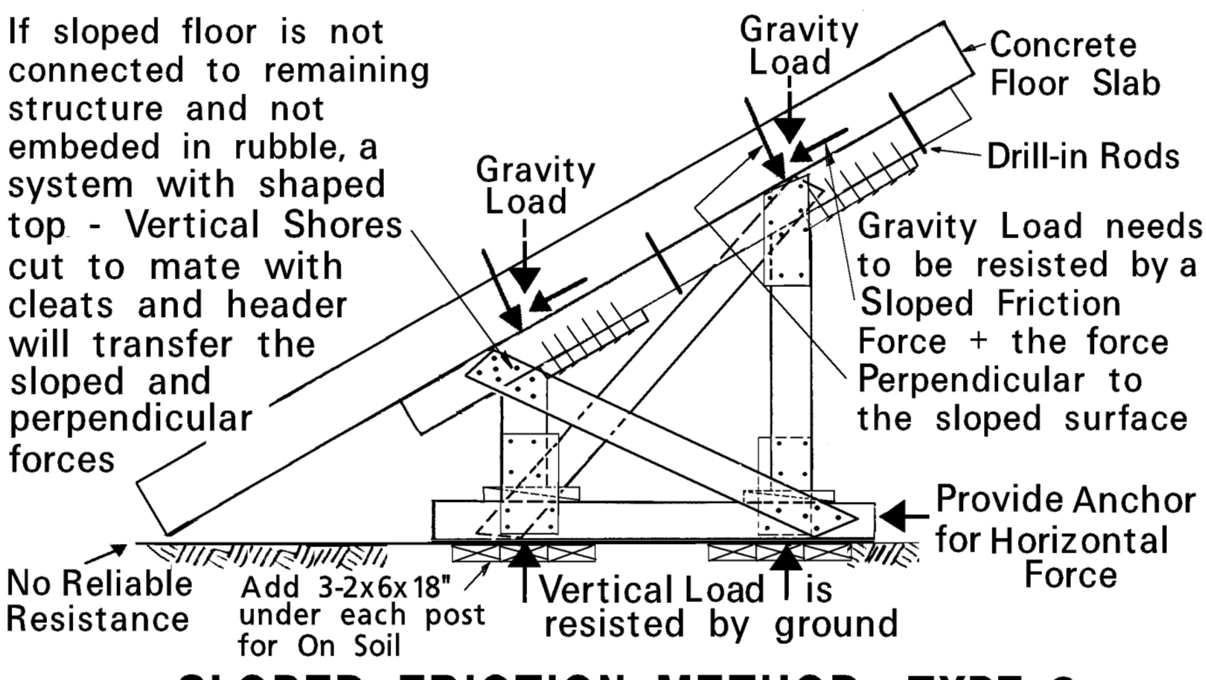


SHORES FOR SLOPED FLOORS SHOR-8 12



PERPENDICULAR TO SLOPE METHOD • TYPE 2

May be built on Concrete, Paving or Soil Surface



SLOPED FRICTION METHOD • TYPE 3

May be built on Concrete, Paving or Soil Surface

At slopes over 5% need to enhance Friction by making some type of Connection between Header and Sloped Floor

VERTICAL SHORES ON SLOPED SURFACES (continued)

- Sloped floor shores should be built as three dimension, Class 3 Systems, similar to Laced posts
  - Construct systems as a minimum of two, two post shores.
    - 4x4 Posts spaced 4ft max and 6x6 posts spaced 5ft max
  - Diagonal bracing (X bracing) should be placed in the plane of the shore (as shown in SHOR-8)
    - Bracing should be designed for 10% min, weight of supported structure.
  - Bracing between shores should be configured as lacing (Laced Post Shores) if shores are kept within 5 ft o.c.
    - However if shores are spaced more than 5 ft but less than 8 ft o.c., they should be laterally braced using horizontal and **X** bracing as for Raker Shores
  - When the height of to shorter end of the shore gets as small as three feet, a 12" to 24" wide strip of ¾" plywood should be used between shores instead of **X** bracing.
    - Nail plywood with 8d @ 3" o.c. staggered each end
  - 6x6 shore posts should be used where heavier, concrete floor systems are encountered
- For conditions where the shore height is less than 4 feet, Cribbing can be used to support sloped floors.
  - Slope for crib-supported floor should not exceed 30%. (3 feet in 10 feet, approx. 15 degrees)
  - Cribs can be built into the slope, but care must be taken to properly shim the layers in order to maintain firm, complete bearings. These will be called **Type 4** Sloped Floor Shores
  - Notches, nails, or metal clips could be used to interconnect crib members so they would better transfer lateral loads.
- Well braced systems using normal Vertical Shores (SHOR-1) may be used when floors are sloped less than 5% (6" in 10ft)
  - Use the shores in pairs with either lacing or horizontal plus **X or V** bracing in between

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Lateral Bracing

For Paired Sloped Floor Shores

- **For pairs of shores, spaced up to 5 ft o.c. use bracing between shores as in Laced Posts**

  or
- **For pairs of shores, spaced up to 5 ft o.c. use solid plywood strip when height is 3 ft and less**

  or
- **For 2 or more shores, spaced up to 8 ft o.c. , use longitudinal and X and/or V bracing as in Raker Shores.**

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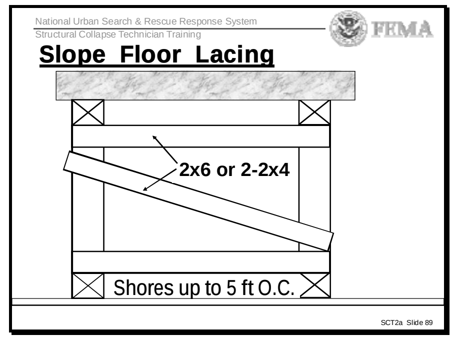
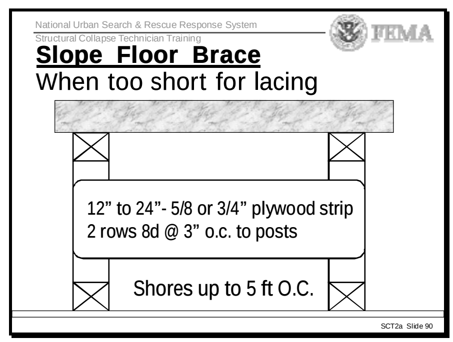
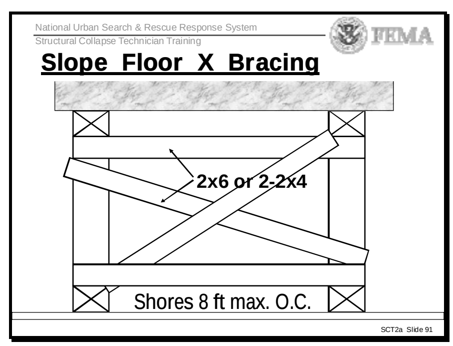
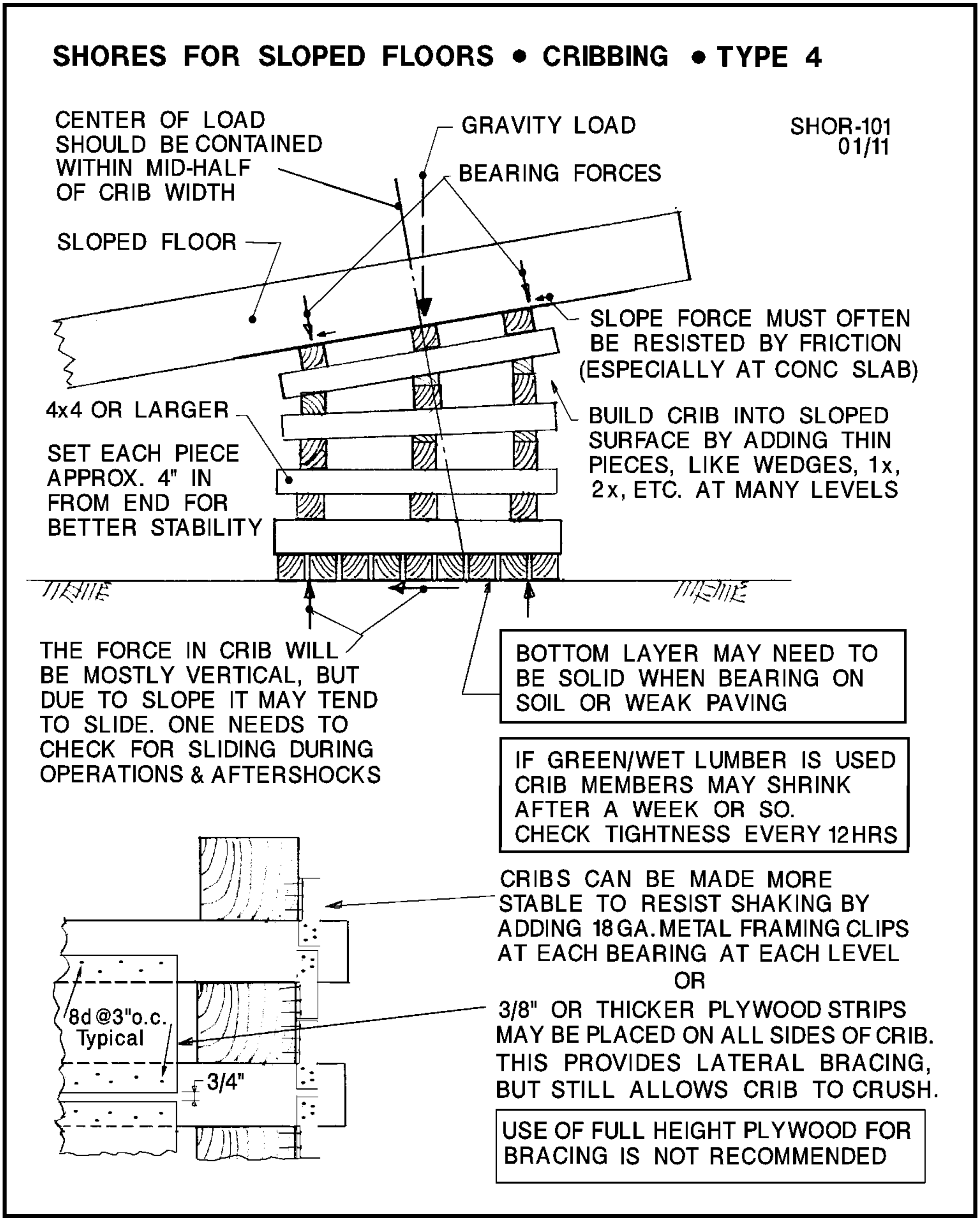


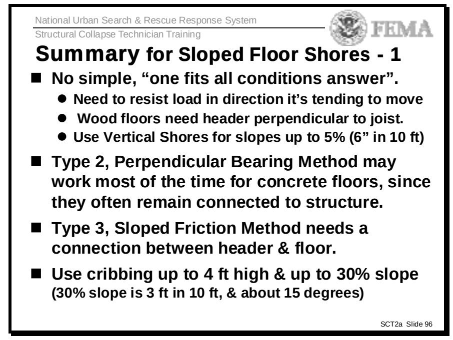


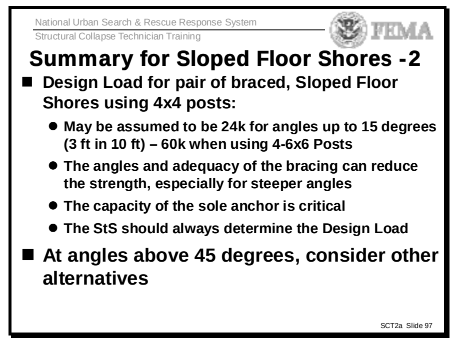


VERTICAL SHORES ON SLOPED SURFACE – CRIBBING



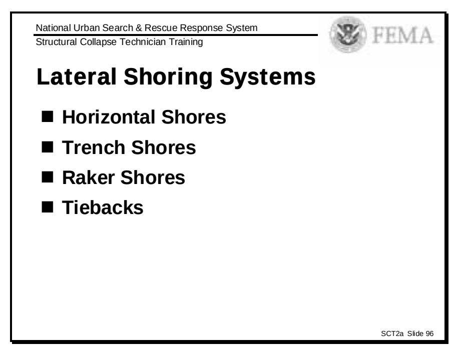
- **Summary for Sloped Floor Shores**
  - Sloped Floor Shores are complicated. No one solution will work for all conditions. Need to resist load in direction that it is tending to move.
    - To shore sloped wood floors the header needs to be placed perpendicular to the joist
    - Very adequate bracing is required
  - Perpendicular Bearing method works best in cases with concrete floors that are still somewhat connected.
  - Friction Method requires a connection between header and floor. That may not be possible in wood floors.
  - Cribbing should be limited in height and slope
  - Design Load of a pair of braced Sloped floor Shores:
    - Would always be less than a Laced Post system.
    - May be assumed to be 24,000lbs (24k) for slopped floors at angles up to 15 degrees (3ft in 10ft)
    - The angular forces, adequacy of the bracing, and sole anchor strength can significantly reduce the capacity – especially over 15 degrees
    - The StS should always be asked to determine the size and number of shores that are needed.
  - For slopes above 45 degrees, one should consider other alternatives.
    - Work with StS and develop solution that best fits the actual conditions.





<u>**LATERAL SHORING SYSTEMS**</u>

We will now discuss the Lateral Shoring Systems shown in the adjacent slide:



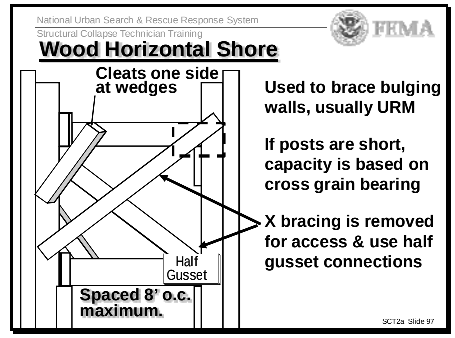
- **Principles of trench shoring** may sometimes need to be applied to US&R, where pulverized masonry rubble tends to cave into an otherwise accessible space.
  - As previously discussed, Pneumatic Shores may be used in vertical applications since they have positive locking devices
- There are several systems used as Lateral Shores, such as
  - Wood Horizontal Shores
  - Hydraulic Shores,
  - Pneumatic Shores,
  - Tieback Systems
  - Drilled-in Solid or Pole Systems.

The design of these systems is very competently presented in the CALTRANS, Trenching and Shoring Manual.

WOOD HORIZONTAL SHORES

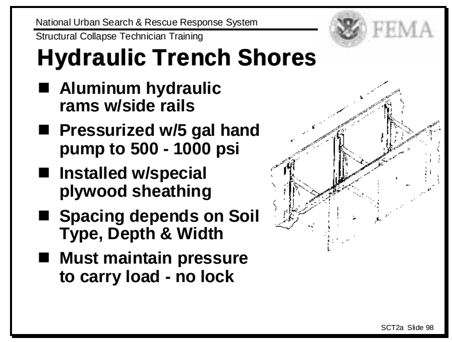
- Are used in damaged buildings to support bulging walls.
- Horizontal wood posts are usually short; their capacity is based on cross grain bearing strength (300 to 700psi)
- Wall plates are used to spread load from 2 or more posts.
  - Wedged are used to tighten the horizontal struts.
  - Bracing and cleats are added to complete each shore.
  - The normal **X** braces may need to be eliminated to allow for access, corner, plywood gussets are added to help connect corners and brace the shore

The shores are normally spaced at 8 feet on center, depending on the situation.



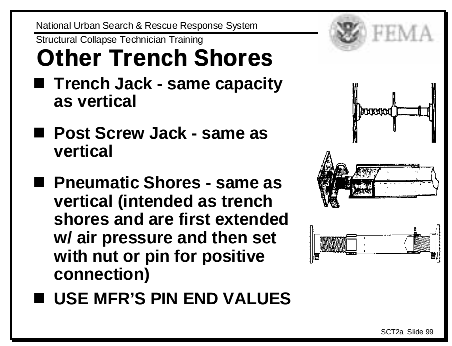
HYDRAULIC TRENCH SHORE

- These are frames made from aluminum hydraulic ram(s) with continuous side rails
- They are intended to be dropped into open trenches from the top and pressurized with a 5-gallon hand pump to between 500 - 1000 PSI.
  - Plywood panels are added against the soil to spread the load and confine soils.
  - There is no locking device as for pneumatic shores, therefore **hydraulic shores are not recommended** for supporting vertical loads.
- Hydraulic Shores can have a single ram with 2 feet long rails or double rams with rails up to 12ft long. Standard double ram frames have rails in 3.5ft, 5ft and 7ft lengths



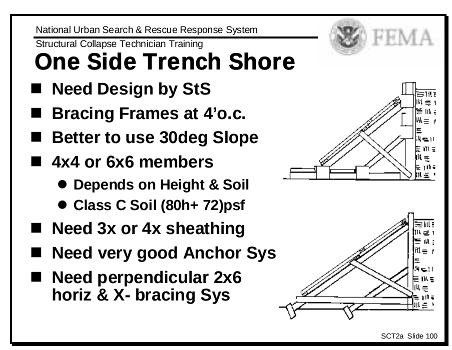
OTHER TRENCH SHORES

- Trench Jack (Screw Jack)
- Post Screw Jack
- Pneumatic Shore
- All have same capabilities as in vertical application.



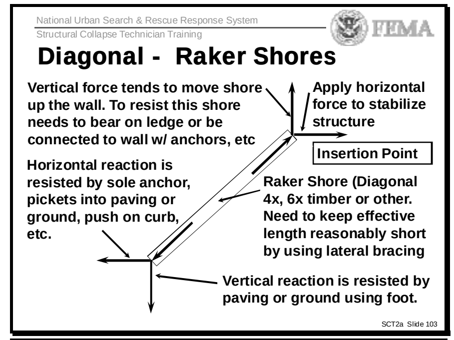
ONE-SIDED TRENCH SHORE

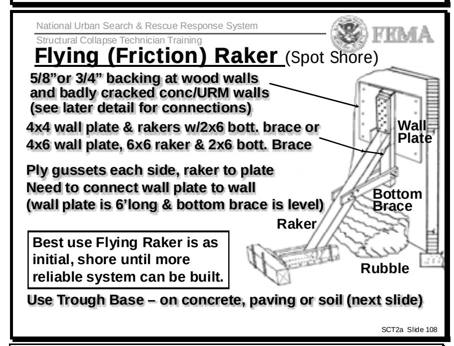
- This type of shoring is needed when one side of a trench has caved-in, or for basement excavation cave-ins.
  - This type of shore needs to be designed by a qualified Structures Spec
  - If no Soil Evaluation is available, one must assume Class C Soil (Uniform Pressure = 80h + 72psf)
- Bracing Frames (like Double Rakers) may be placed 4ft o.c.
  - Use 30 or 45deg slope with 4x4 or 6x6 members, depending on height
  - Sheathing between Frames may need to be 3x or 4x
  - Anchor System is very important
  - Perpendicular Bracing needs to be installed

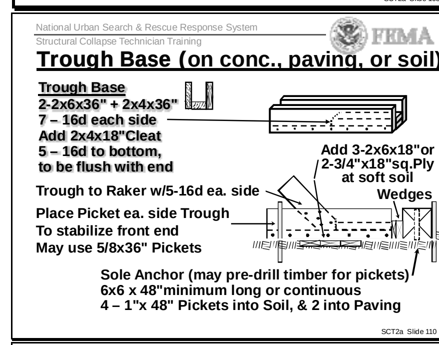


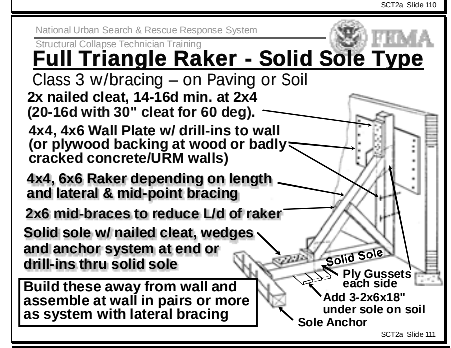
RAKER SHORES

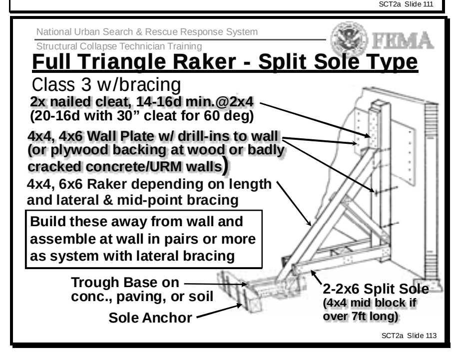
- Useful in bracing URM and other heavy walls that have cracked, as well as wood walls that are leaning.
- Need to be configured in system that will account for both vertical & horizontal components of force in the raker.
- The vertical component may be resisted by:
  - By placing drilled-in anchors thru the wall plate into the masonry or concrete walls
  - By bearing the wall plate against a projection in the wall surface, or by placing the raker at an opening and nailing a cleat onto the wall plate so that it will bear on the opening head.
  - For wood walls, plywood backing should be used, in order to connect to studs and wood floor. In this case the raker should be centered on a stud.
- The required horizontal force may be less than two percent of the wall weight, since URM walls are seldom left standing very far out of plumb. However, since aftershocks are likely to occur, raker systems should be designed for about 10 percent of the weight of the wall and roof that is within the tributary area that they support.
- Rakers should be built away from dangerous area next to wall and then carried/walked into place
  - Rakers should be spaced at 8ft maximum on center
  - When the **Insertion Point** is greater than 8ft, the Raker needs to be configured with a mid-height brace.
  - **Insertion Point** is the location on the wall where the raker will intersect. This should be near the floor line.
- Rakers may be configured using the Full Triangle method (called Fixed raker) or as a Flying Raker (Friction Raker)
  - Full Triangle Rakers may be configured as Solid Sole or Split Sole Rakers
  - The preferred **Solid Sole Raker** may be built on concrete slabs, paving or soil.
  - The **Split Sole Raker** may also be built on slabs, paving or soil. Since the Bottom Brace may be sloped, this Raker may be constructed in locations where some rubble is present next to the base of the wall.
  - Full Triangle Rakers should always be built in groups of 2 or more, with Lateral Bracing Systems connecting them together (see following pages)
  - When the length of a 4x4 raker is greater than 11ft and a 6x6 is greater than 17ft, a mid-point brace is needed. (corresponds to 8ft and 13ft Insertion Point.)





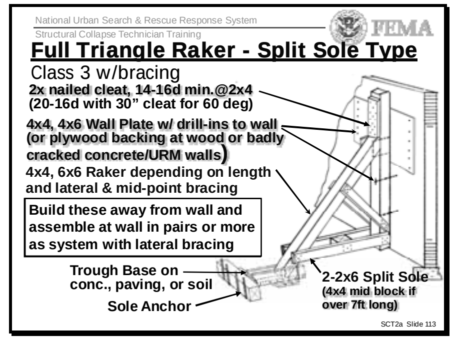


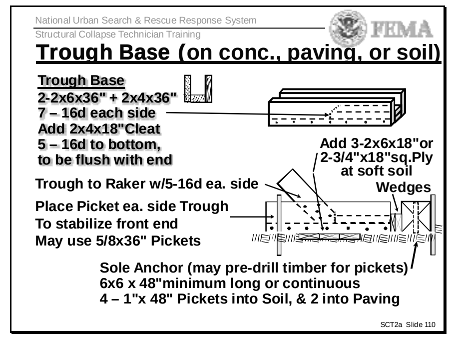


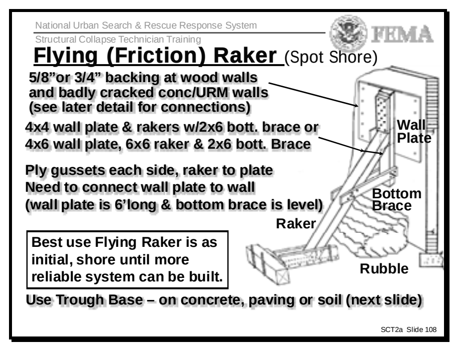


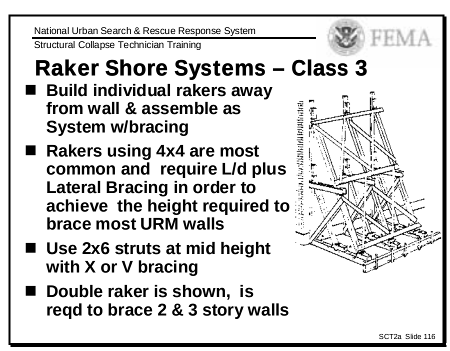
RAKER SHORES (continued)

- **Backing** may be needed between the wall plate & wall and the sole plate & soil. Backing is centered on the raker.
  - 5/8” or 3/4” plywood backing is used behind wall plate to aid in supporting badly cracked concrete and masonry walls. (usually 4ft x 4ft or full sheet)
  - A 2ft high x 4ft wide plywood backing is used to provide for a positive connection from wall plate to wood walls.
  - A 18” x 18” foot made from 3-2x6x18” is placed under a Solid Sole or Trough where the Raker intersects when rakers are built on soil, in order to spread the load.
- The capacity of Rakers is usually limited by the nailed cleat connections, and/or the connection to the ground.
  - A Trough Base is used along with a Sole Anchor for Flying and Split Sole Rakers that bear on concrete slabs, paving or soil. This base keeps the rescuers farther from the collapse zone during its installation.
- It is difficult to obtain lumber over 20 ft. long, but splices may be made in rakers as long as they are located near where the diagonal and lateral braces connect.
  - See Raker Shore Connections in module SCT02b.
- Flying Rakers can be used as Spot Shores to temporarily restrain a wall that has rubble piled up near its base (without removing it). They are intended for limited use.
  - Flying Rakers should be quickly constructed using:
    - Six foot wall plate with a 24” cleat,
    - A pair of 2x6 as bottom brace, placed on horizontal.
    - Raker is configured at 60 degrees and uses a trough base.
  - In most conditions, final wall stabilization will be done using solid or split sole, full triangle raker system
- Lateral bracing, consists of continuous horizontal struts and diagonal bracing (in either **V** or **X** configuration)
  - Raker spacing is 8ft max. to use 2x bracing
  - When the raker requires a mid-brace, horizontal struts are placed at the bottom, mid and top of the raker.
- Solid Sole Rakers can be built into tall, multi-raker configurations using 4x4 members with lateral bracing to bring the L/D ratio to between 35 and 40. (next page)
  - Multi-raker is fairly complicated, but shows how the smaller timbers can be used in a system to stabilize a two-story wall. **Note** that bracing is placed in two mutually perpendicular directions. See SCT02b for raker splice and horizontal bracing splice.

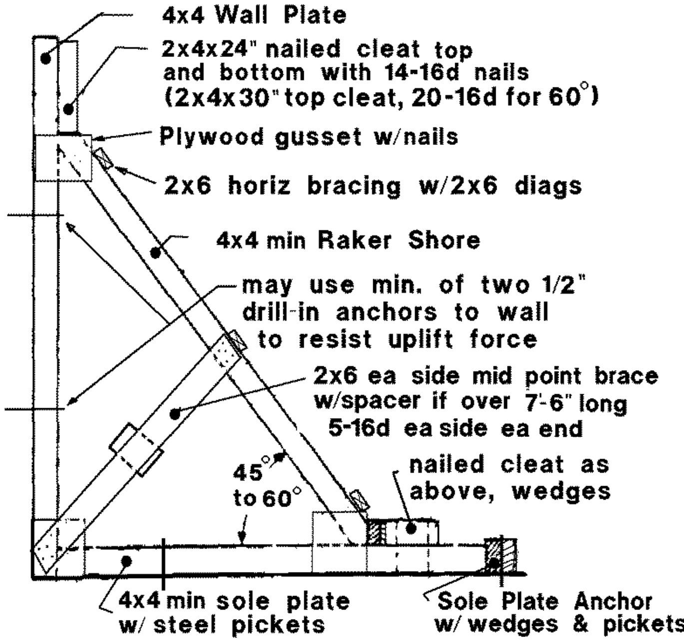








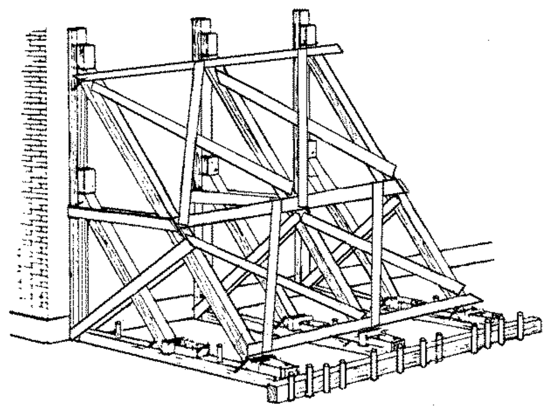
RAKER SHORE SYSTEMS SHOR-14 R 09/06



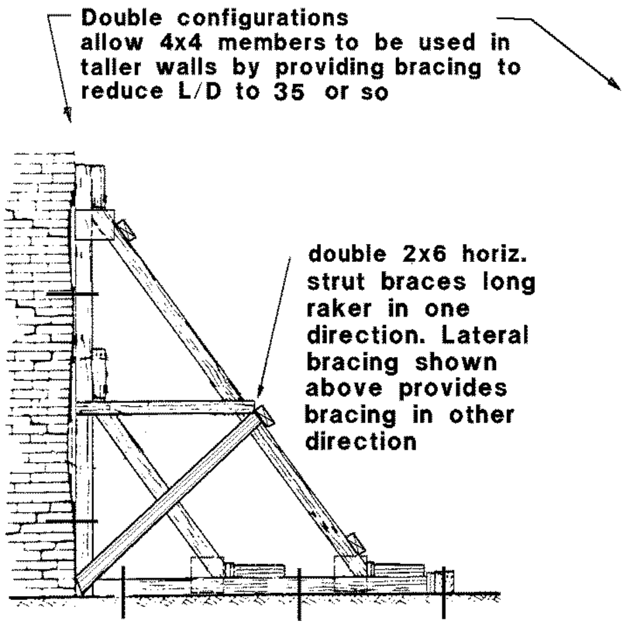
PREFERRED FULL TRIANGLE RAKER SHORE CONFIGURATION
(SOLID SOLE FULL TRIANGLE RAKER)

All systems using 4x4 members over 11ft long should be braced in two directions in order to limit L/D to 25±

Its better to have a 2x6 continuous at top, mid, & bottom w/ X-braces every forty ft or so than what is shown here.

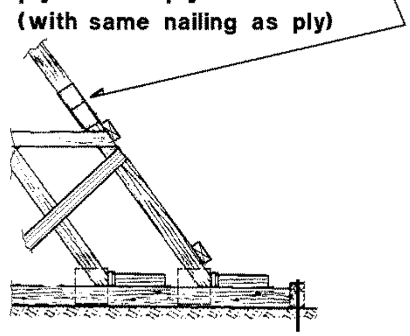


RAKER SHORE FRAMES MUST BE BRACED



DOUBLE RAKER SHORE

4x & 6x Rakers may be spliced using 36" long plywood strips x full width of Raker, placed each side. Splice needs to be located near intersection of lateral braces with raker. 8 - 8d in 5 nail pattern to each Raker, each side.
Use 1x material, same size as plywood if ply not available (with same nailing as ply)

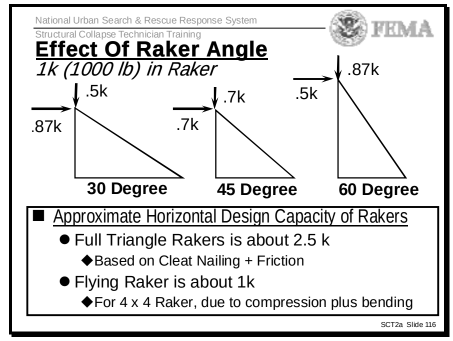


LATERAL SHORING SYSTEMS (continued)

RAKER ANGLE

The angle between the ground and a diagonal (Raker) brace member should be as small as practicable.

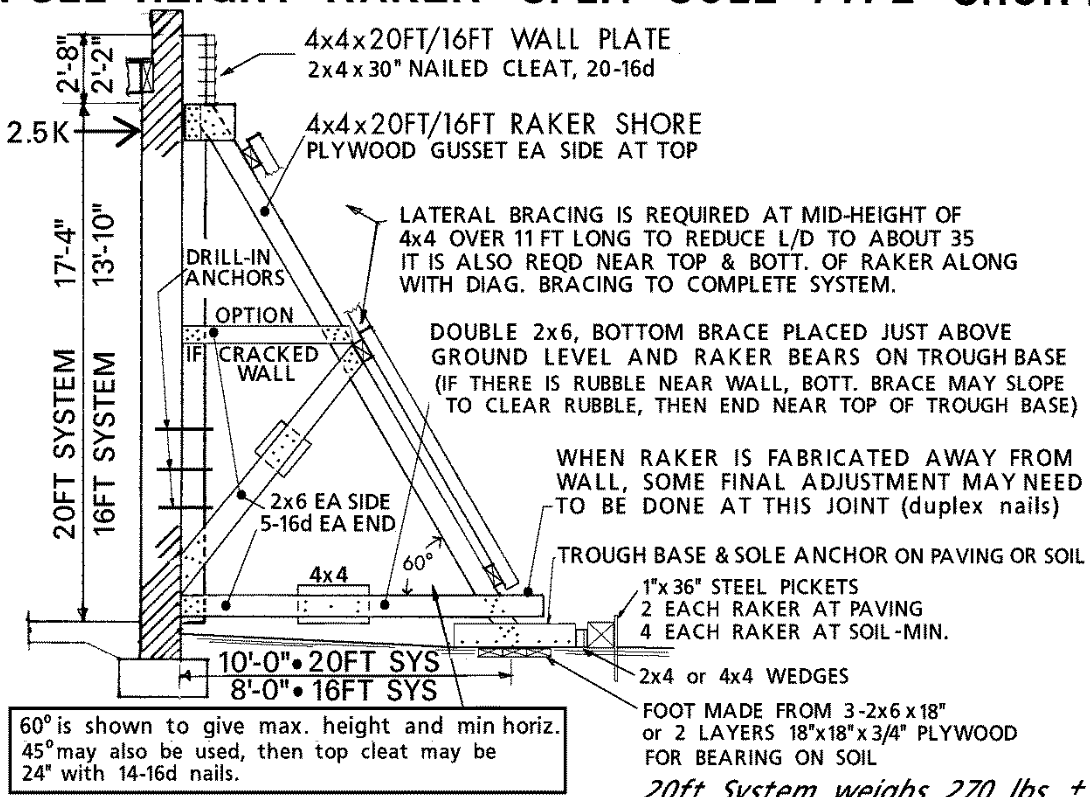
- If the angle is 30 degrees, the horizontal force applied to the wall is 87% of the force in the diagonal, and the upward force that needs to be resisted at the wall face is only 50% of the diagonal force. Limited access may be a problem
- When the angle increases to 60 degrees the horizontal is 50%, and the vertical is 87%.
- At 45 degrees the two are equal at 71% of diagonal force.
- The disaster "field" conditions, such as need for access, available timber length, and/or clearance, normally limit the choice to either 45 or 60 degrees.
  - The simplest to build are 45 degrees (1 to 1) and 60 degrees (1.7 to 1). Both are extensively used in US&R
  - The 60-degree angle is preferred for the Flying Raker, but the Solid and Split Sole Rakers may be at 45 or 60 degrees.



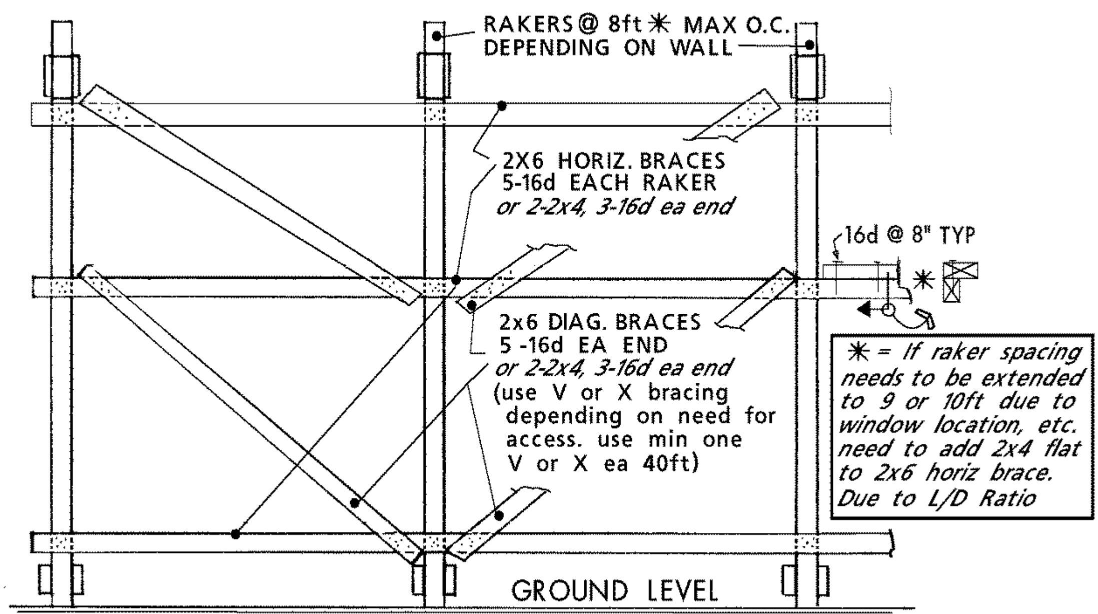
RAKER SHORE CONSTRUCTION

- The Design Strength of individual, single, full triangle Rakers is in the range of 2500 lbs. (2.5k). This is normally sufficient to brace most masonry or concrete walls up to about 20 ft high.
  - This is the capacity based on the horizontal load of the wall. (The force in the sloped Raker member may be as much as twice the horizontal load)
  - The 2500 lbs is based on the cleat nailing of 14-16d nails plus some friction between the Raker and its bearings.
  - The Design Strength of Flying Rakers is about 1000 lbs (1.0k) based on a 4x4 Raker that may need to resist bending plus compression (if the wall bulges).
- The full Triangle Rakers can be configured with a split sole (next page), which is most useful when rubble is found next to the wall. This example shows how a 4 x 4 lumber x 20 ft. long can be used to brace a 20 ft. wall.
  - Lateral bracing is required at mid-height of the 4 x 4 raker in each direction.
  - Overall lateral bracing is required to stabilize the system of Rakers, especially during aftershocks.
- A second configuration of full Triangle Raker is shown with solid sole plate (following next page). This raker may be used on concrete slab, paving or soil. It requires the same types of bracing as stated above.

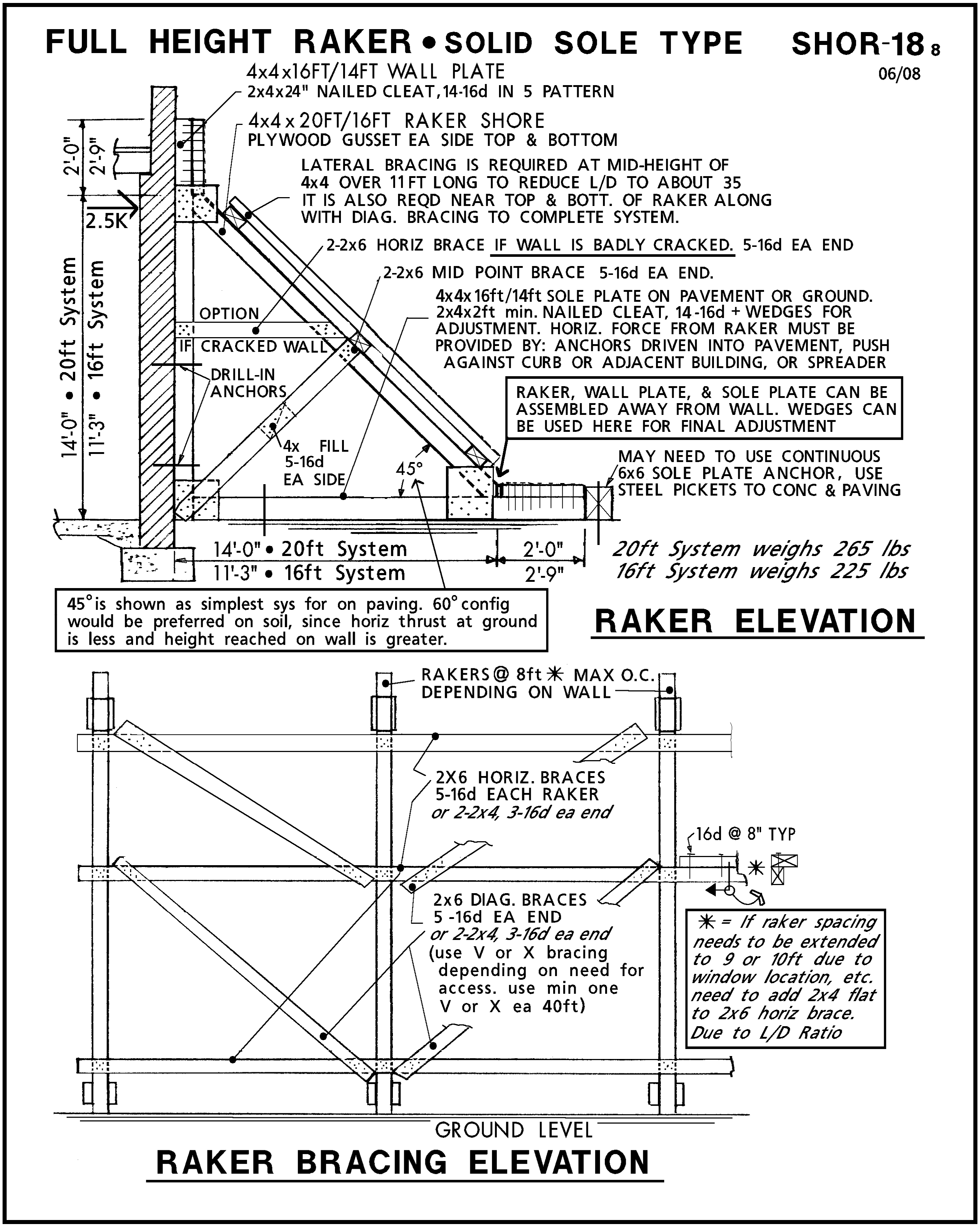
FULL HEIGHT RAKER • SPLIT SOLE TYPE • SHOR 17₁₂



RAKER ELEVATION



RAKER BRACING ELEVATION


FULL HEIGHT RAKER • SOLID SOLE TYPE
SHOR-18 8
06/08
4x4x16FT/14FT WALL PLATE
2x4x24" NAILED CLEAT, 14-16d IN 5 PATTERN
4x4 x 20FT/16FT RAKER SHORE
PLYWOOD GUSSET EA SIDE TOP & BOTTOM
LATERAL BRACING IS REQUIRED AT MID-HEIGHT OF 4x4 OVER 11 FT LONG TO REDUCE L/D TO ABOUT 35 IT IS ALSO REQD NEAR TOP & BOTT. OF RAKER ALONG WITH DIAG. BRACING TO COMPLETE SYSTEM.
2-2x6 HORIZ BRACE IF WALL IS BADLY CRACKED. 5-16d EA END
2-2x6 MID POINT BRACE 5-16d EA END.
4x4x16ft/14ft SOLE PLATE ON PAVEMENT OR GROUND. 2x4x2ft min. NAILED CLEAT, 14-16d + WEDGES FOR ADJUSTMENT. HORIZ. FORCE FROM RAKER MUST BE PROVIDED BY: ANCHORS DRIVEN INTO PAVEMENT, PUSH AGAINST CURB OR ADJACENT BUILDING, OR SPREADER
RAKER, WALL PLATE, & SOLE PLATE CAN BE ASSEMBLED AWAY FROM WALL. WEDGES CAN BE USED HERE FOR FINAL ADJUSTMENT
MAY NEED TO USE CONTINUOUS 6x6 SOLE PLATE ANCHOR, USE STEEL PICKETS TO CONC & PAVING
2'-0"
2'-9"
2.5K
14'-0" • 20ft System
11'-3" • 16ft System
OPTION
IF CRACKED WALL
DRILL-IN ANCHORS
4x FILL 5-16d EA SIDE
45°
14'-0" • 20ft System
11'-3" • 16ft System
2'-0"
2'-9"
20ft System weighs 265 lbs
16ft System weighs 225 lbs
45° is shown as simplest sys for on paving. 60° config would be preferred on soil, since horiz thrust at ground is less and height reached on wall is greater.
RAKER ELEVATION
RAKERS @ 8ft ✳ MAX O.C. DEPENDING ON WALL
2X6 HORIZ. BRACES 5-16d EACH RAKER or 2-2x4, 3-16d ea end
16d @ 8" TYP
2x6 DIAG. BRACES 5 -16d EA END or 2-2x4, 3-16d ea end (use V or X bracing depending on need for access. use min one V or X ea 40ft)
✳ = If raker spacing needs to be extended to 9 or 10ft due to window location, etc. need to add 2x4 flat to 2x6 horiz brace. Due to L/D Ratio
GROUND LEVEL
RAKER BRACING ELEVATION

LATERAL SHORING SYSTEMS (continued)

PNEUMATIC SHORES USED AS RAKERS

A quick, temporary raker can be constructed using pneumatic shores. (see next page)

- They can be used as individual units, but should be configured in a system of two Rakers that are interconnected with 2x6 wood bracing or with strut bracing that resists both tension and compression.
- Special rails and connections are available from Airshore and Paratech, as well as base plate and bracing connections.
- Some load values for both are shown in adjacent slides, and all are shown in the StS FOG, Sect 7

TILT- UP WALL BRACES

- Can be used to brace concrete tilt-up walls and other reinforced masonry walls. They are available for rent from Concrete Supply Firms.
- The walls would need to be pretty well intact and only in need of bracing, due to connection failure. (Spreading of the load would induce bending moments in the wall).
- Connection of braces to the wall could be by drill-in anchors and anchorage at the base could be to a wood curb/pad or slab on grade with a drill-in. These braces act in tension & compression

TIEBACKS

- When URM walls are over thirty feet tall it is probably impractical to attempt to brace them with raker shores.
- Vertical and/or horizontal strongbacks could be placed on the face of a hazardous wall and tied across the structure to a floor beam or the opposite sidewall. (See Shor-16a on next page)
- The strongbacks could be made from double 2x6 wood members with the tie being placed between them. Solid 4x or 6x members could also be used.
- The ties that have been placed by contractors were steel rods with turnbuckles, bearing washers etc. Cables with come-along could also be used as well as utility rope, chain, etc. One may need to be creative to obtain an adequate tie, but climbing rope, used by firefighters should be considered only as a last resort. (Climbing rope is considered unreliable with the rough treatment of this type of application and would be discarded)

National Urban Search & Rescue Response System
Structural Collapse Technician Training

Recommended Design Strength
for *Hurst-Airshore* Raker System – 45 deg

- System is made from 2 rakers spaced 8ft max. apart with X-bracing.
- Rakers need to be attached to wall surface and restrained at ground.
- If raker is mid-braced (each way), use 10,000 lb.

Raker Length	Height to Insertion	Horiz. Design Load on 2 Rakers w/ X-bracing
16 ft	11.0 ft	4200 lbs
15	10.5 ft	4800
14	10.0 ft	5400
13	9.0 ft	7100
12 & less	8.5 ft	10,000 lbs

SCT2a Slide 123

National Urban Search & Rescue Response System
Structural Collapse Technician Training

Recommended Design Strength
For *PARATECH* Raker System – 45 deg

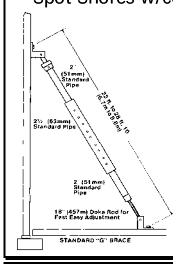
- System is made from 2 rakers spaced 8ft max. apart with X-bracing.
- Rakers need to be attached to wall surface and restrained at ground.
- If raker is mid-braced (each way), use 10,000 lb

Raker Length	Height to Insertion	Horiz. Design Load on 2 Rakers w/ X-bracing
16 ft	11.0 ft	5000 lbs
15	10.5 ft	6400
14	10.0 ft	7800
13	9.0 ft	9200
12 & less	8.5 ft	10,600 lbs

SCT2a Slide 128

National Urban Search & Rescue Response System
Structural Collapse Technician Training

Tilt-up Wall Bracing
Spot Shores w/conn ea end



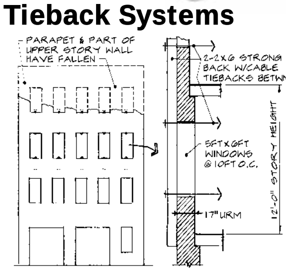
- Can be used to brace reinforced concrete or masonry wall
- Use Drill-in Anchors for connections to wall & floor slab.
- Can act in Tension or Compression

SCT2a Slide 129

National Urban Search & Rescue Response System
Structural Collapse Technician Training

Tieback Systems

- Used to keep wall from falling when too high for Rakers
- Strongbacks - 4x4, 4x6, 2-2x6
- Strongbacks go floor to floor
- Tiebacks - rope, cable, chain
- Extend tiebacks across bldg or tie to floor bms or columns

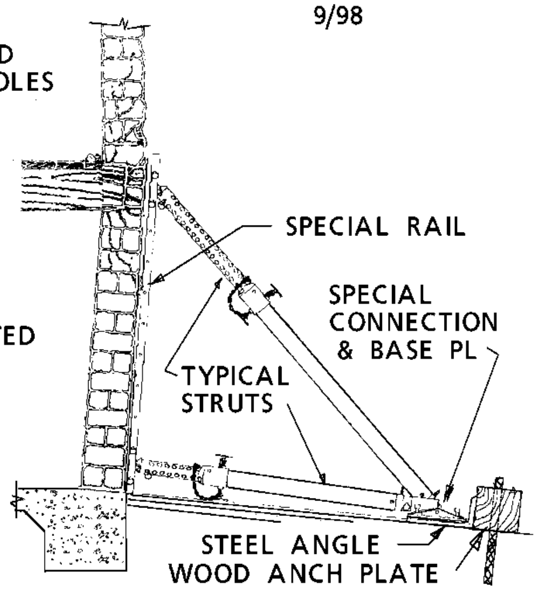


SCT2a Slide 131

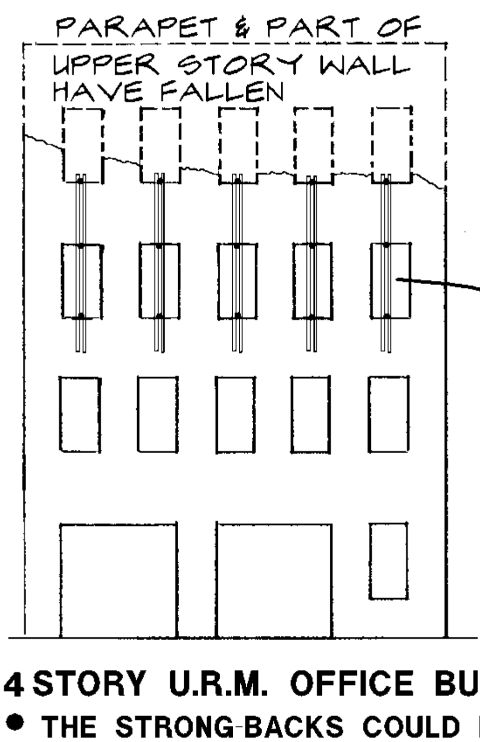
PNEUMATIC STRUTS USED AS RAKERS

SHOR-16a
9/98

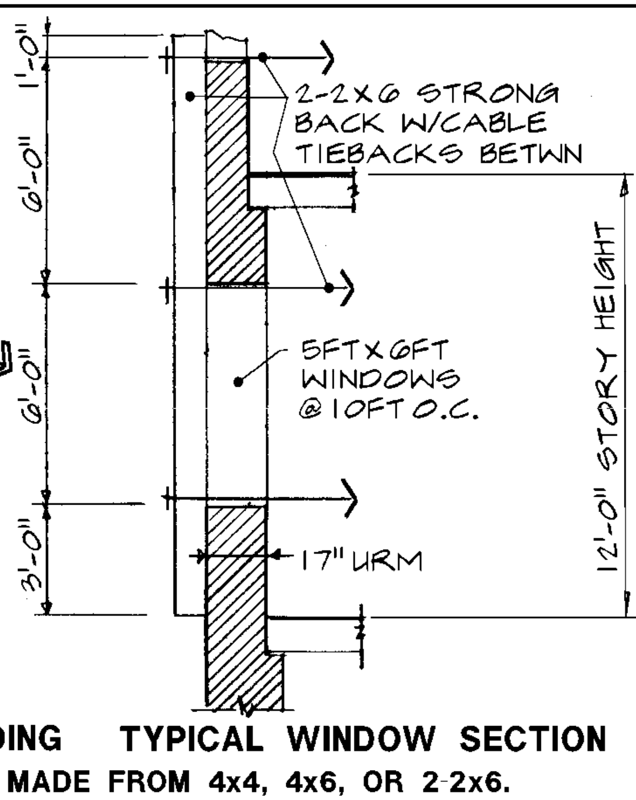
- INDIVDUAL RAKERS CAN BE CONFIGURED FROM TWO STRUTS (UP TO 16FT LONG) AND A SPECIAL RAIL THAT HAS CONNECTION HOLES
- MANUFACTURED BASE PLATE CAN BE CONNECTED TO PAVING THRU EXISTING HOLES USING STEEL BARS/DRILL-INS. STEEL ANGLE CAN BE ADDED UNDER BASE PLATE TO PROVIDE SURFACE TO BEAR ON TYPICAL WOOD SOLE PLATE ANCHOR
- THESE CAN BE MADE INTO SYSTEM USING TWO OR MORE INDIVIDUALS, INTERCONNECTED WITH HORIZONTAL + DIAGONAL 2x6 WOOD BRACING CONNECTED TO MANUFACTURED CLIPS (THAT HAVE WOOD NAILERS)
- RAKER RAILS NEED TO BE PINNED TO WALL AS W/TYP RAKERS. THESE CAN PROVIDE A QUICKLY PLACED, INITIAL SYSTEM TO BE FOLLOWED W/TYP WOOD SYSTEM



WALL TIEBACKS



4 STORY U.R.M. OFFICE BUILDING



TYPICAL WINDOW SECTION

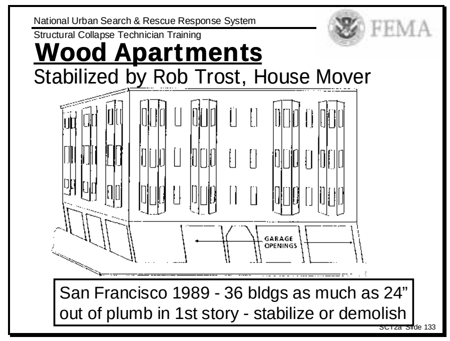
- THE STRONG-BACKS COULD BE MADE FROM 4x4, 4x6, OR 2-2x6.
- THE STRONG-BACKS SHOULD EXTEND FROM FLOOR TO FLOOR IN ORDER TO HAVE THE FLOOR PLANES TO PULL AGAINST.

LATERAL SHORING SYSTEMS (continued)

SHORING SYSTEMS USED IN US&R

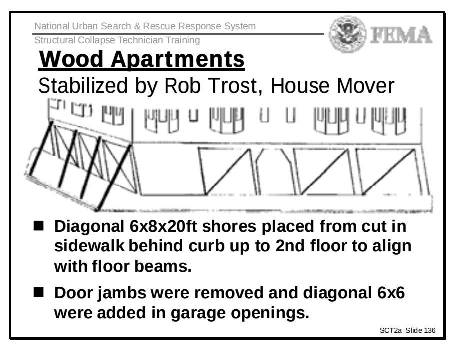
The Special Medical Response Team, a group of medical first responders organized to aid mine collapse victims, has a plan to use a combination of pneumatic shores and cribbing to assure vertical support in order to provide medical care within the collapse. They first set the pneumatic shores and then follow with the cribbing.

STABILIZE WOOD APARTMENT



The House Moving Contractor, R. Trost, provided emergency shoring after the 1989 Loma Prieta Quake for twenty-five buildings in the San Francisco Marina District. The 3 & 4 story wood buildings were out of plumb in the first story as much as 2 feet. As shown in SHOR-21 & 22, they provided lateral stability by placing 6x8 diagonal shores from the inside of the street curb to the second floor, and added 6x6 diagonals in doorways. They later placed story high cribbing and large steel beams to provide better vertical support, and allow for later straightening of the buildings.

- One must carefully consider where this type of bracing is connected to the structure in order for it to effectively obtain a vertical reaction while it is providing the horizontal resistance



STABILIZE TALL HIGHWAY STRUCTURES

At the Highway 880 collapse, Loma Prieta Earthquake, shoring contractors used 12x12 vertical posts to support the concrete frames in the first story that were damaged by the collapse of the second story. The 20 ft. height was too great for cribbing, and a spreader system was used to interconnect the posts at the ground level. Diagonal bracing was added to same locations of those rows of posts, but it was very light for the potential load.

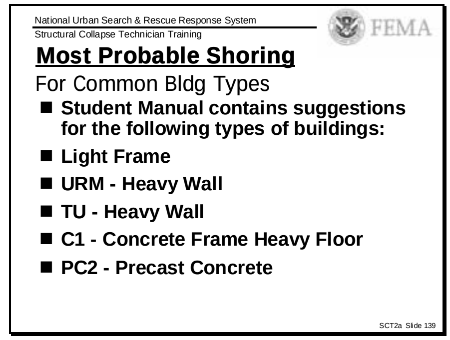
USE OF NON-TRADITIONAL SHORING DEVICES

Large back-hoe/excavator or bucket-loader vehicles have been used to provide lateral (raker) support to leaning walls and buildings at several disaster sites. Very good idea for an emergency condition.

SHORING FOR SPECIFIC BUILDING TYPES

SHORING for LIGHT FRAME, MULTI-STORY BLGS

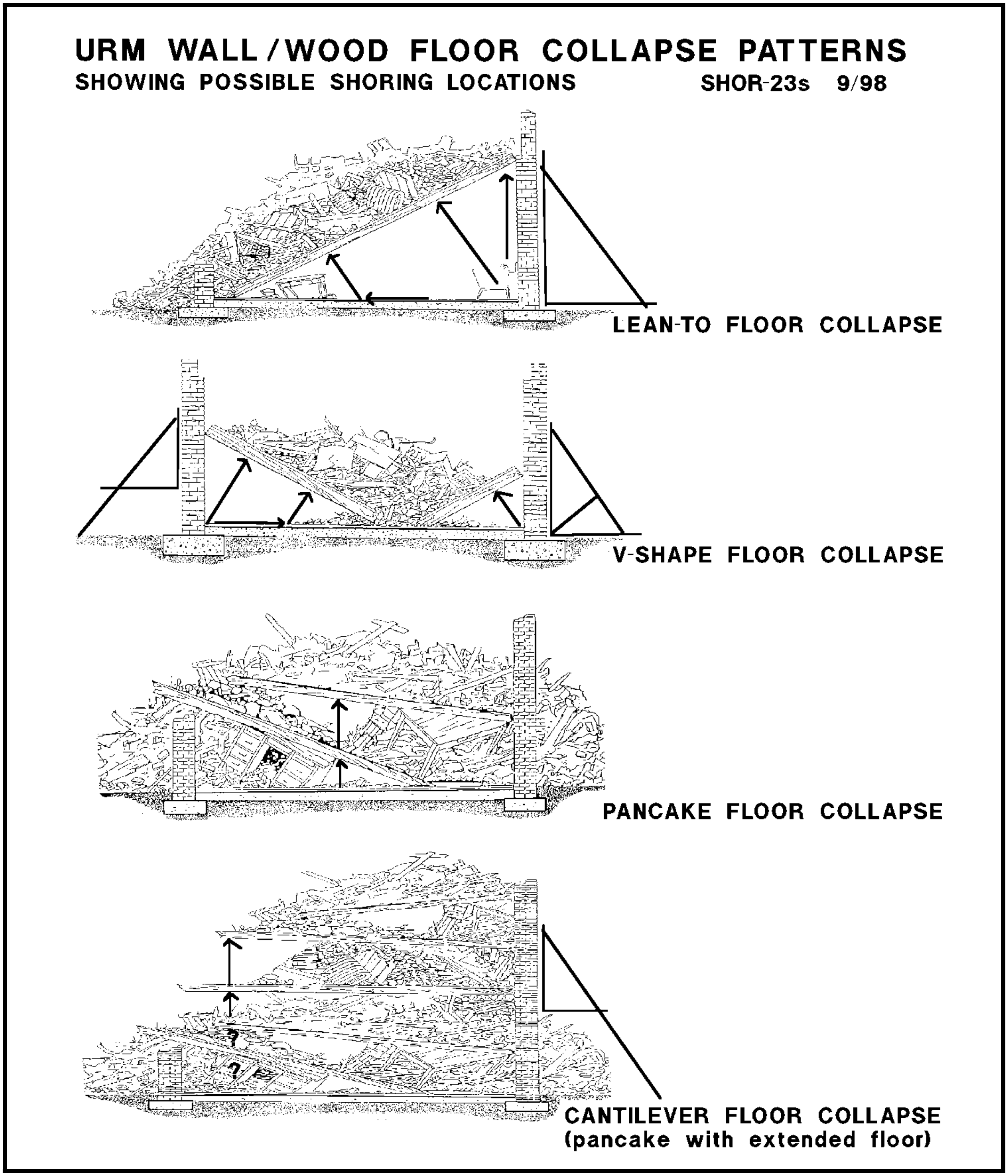
- Multi-story frame with leaning first story need lateral/diagonal shoring that acts against the floor plane
- Wood building with crawl space that have moved off foundation have normally come to rest, but roof and upper story floors may also be offset/cracked and need vertical shoring
- Brick veneer on wood frame walls often are falling hazards in aftershocks, and may need to be shored or protective tunneling type structure may be required to protect access.



SHORING FOR URM BUILDINGS (HEAVY WALL)

- URM walls may be cracked (especially at corners) or peeled and need diagonal/raker shores.
- Cracked URM walls may also require shoring of openings.
- When URM exterior walls have collapsed, the remaining wood floors may require vertical shoring.
- Floors often collapse into the following patterns:
    - **LEAN-TO** - shoring is usually required under the suspended floor and possibly on the outside wall, opposite where the floor is still connected. Victims might be found under the suspended floor and on top of this floor at the lowest end
    - **V-SHAPE** - shoring is usually required under the two suspended floor pieces and possibly on the outside walls, opposite where the floors are still connected. Victims might be found under the two suspended floor pieces and on top of the floor in the middle of the V.
    - **PANCAKE** - shoring is usually required under the floors. Victims might be found under the floors. Voids are formed by building contents and debris wedged between floors
    - **CANTILEVER** - this type is similar to the pancake pattern with the added problem of some of the floor planes extending, unsupported from the debris pile. Shoring is usually required under and above the floors starting at the lowest level. Victims might be found under the floors as in the pancake condition.

SHORING FOR SPECIFIC BUILDING TYPES (continued)



SHORING FOR SPECIFIC BUILDING TYPES (continued)

SHORING FOR REINFORCED CONCRETE BUILDINGS

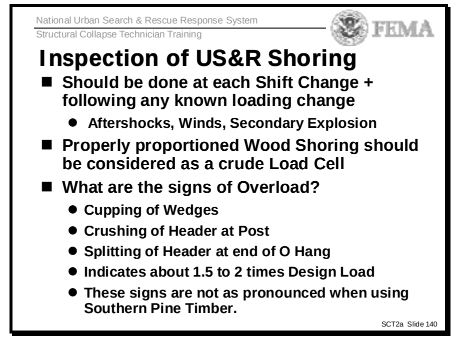
- Will often have fairly unbroken planes that can be easily shored w/ vertical shores.
- When floors have beams & girders intersecting at the columns, diagonal tension, shear cracks will give indication of potential failure.
- In flat slab (beamless) floors that are heavily loaded with debris, a punching shear (rapid) failure is possible. Since the cracking that indicates this type of overload usually is best seen from the top of the slab (covered by debris), it is very difficult to assess.
- If concrete floor plane is badly broken, a system with sheathing, spreaders, and safe haven areas may be needed.
- Lean-to, V-shape, and Pancake collapse patterns may be found in heavy floor buildings. (especially pancake)
- In floors where post-tensioned, cable reinforcing is present, a double hazard may be present. If the cables are loose, then the collapse will contain a mass of closely spaced, unreinforced pieces that are difficult to shore. If the cables are still tensioned, then they can become lethal missiles.

SHORING FOR PRECAST CONCRETE STRUCTURES

- Collapses of this type will normally contain large pieces of lightweight concrete. Shapes like single and double tees are difficult to shore.
- Lean-to, V-shape, and Pancake collapse patterns may be found in precast concrete buildings. (especially lean-to)
- Shoring of sloped surfaces will probably be required. Large pieces may be lightly interconnected and there will be the potential of their shifting.
- Using cranes to remove critical pieces may be the best strategy to access voids

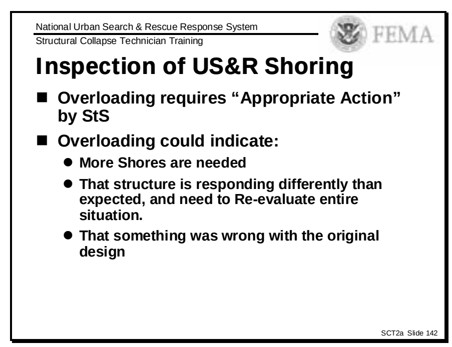
INSPECTION OF US&R SHORING

- Following its installation, US&R Shoring should be periodically inspected. The Structure Specialist should perform inspections at the following times:
  - Just prior to and/or following the 12-hour shift change.
  - Following any significant change in loading, such as following Earthquake Aftershocks, when expecting and following the occurrence of High Winds, and following any secondary disturbance like a secondary explosion
  - Prior to and following the removal of significant amounts of debris



- Properly proportioned shoring with adequately braced posts, should be considered as a crude "Load Cell".
  - When the posts are braced so that buckling is limited, a slow failure can be achieved. In order to achieve this the effective L/D should be limited to between 20 and 25 for each post (in each direction).
  - Signs of overload should be able to be seen at approx 150% to 200% of Design Load for Douglas Fir.
    - These signs are not as pronounced for Southern Pine, since most available 4x4s are cut from the heart of very small trees (Boxed heart)
  - One should then be able to observe:
    - The cupping of wedges
    - Crushing of the Header under its contact with the post
    - Splitting of the Ends of the Header

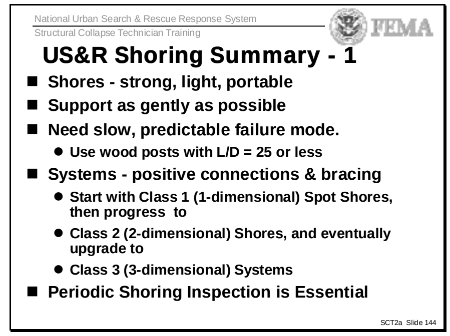
  Note that Header-end splitting is caused by the Catenary Action of the longitudinal wood fibers that are trying to resist the vertical forces applied by the Post. As these fibers are crushed, they indent and form the catenary that, then, induces Longitudinal Tension Forces in the bottom one inch or so of the Header. The Tension Forces then cause the Header to split along a soft, Spring-Wood plane



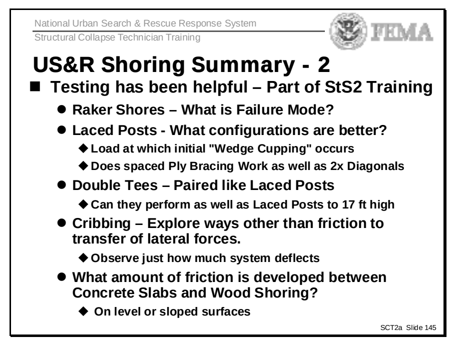
- The Struct. Spec. will need to take Appropriate Action, when any sign of Overload is observed
  - Appropriate Action could include:
    - Adding shores inline with the existing ones, or at a location that will reduce or share the load.
    - Re-evaluate the entire situation, since the structure may be responding differently than expected
    - Re-assessing the original design to check for errors in assumptions, and/or calculations

SUMMARY FOR EMERGENCY SHORING OF STRUCTURES

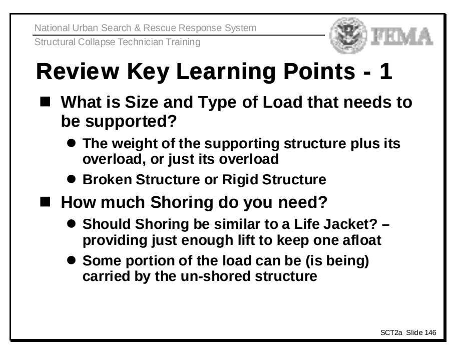
- Shores need to be strong, light, portable, adjustable, and reliably support the structure as gently as possible.
- Systems should be used that are positively interconnected, laterally braced, and have slow, predictable failure mode.
  - A typical shoring scenario would begin with the placement of Spot Shores (Class 1) to initially stabilize,
    followed by
  - Individual multi post shore systems with in-plane bracing, (Class 2)
    followed by
  - Pairs (or greater numbers) of multi post shores that are X braced together as two-dimensional systems. These would be called Class 3 Shores (3-dimensional)
  - As just discussed, periodic inspection of US&R Shoring is essential. It should be made part of the every day checklist.



- Braced Wood Post Systems and Cribbing are desirable since they can be constructed to have the following properties:
  - Made from light pieces that are adjustable & can be built into most any conceivable situation including sloped surfaces
  - Relatively wide and stable. Will spread the load.
  - Can be proportioned to have slow failure mode that will give warning

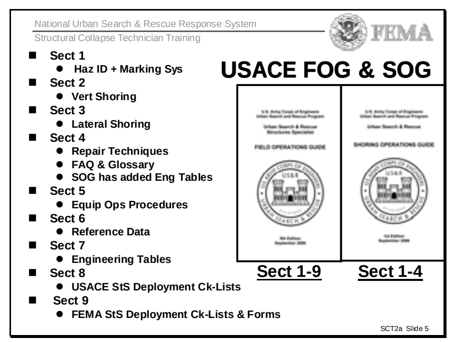


- Testing of Rakers, Laced Posts, Paired Double Tees and Cribbing has been done as a port of Advanced Struct Spec Training (StS2) starting in Sep04. These test have indicated:
  - As long as the Sole Anchors are adequate, properly braced Rakers can resist up to 6 times Design Load before failure.
    - More than 20 Raker Pairs have been tested as of May08
    - The high Safety Factor is justified, since it is very difficult to calculate what Lateral Force to Rakers will be subjected to during the term of an incident.
    - Since rakers are designed and constructed to resist lateral forces, earthquake aftershocks may apply very high loads to rakers, so what may appear to be excess capacity, turns out to be needed protection for Rescuers.



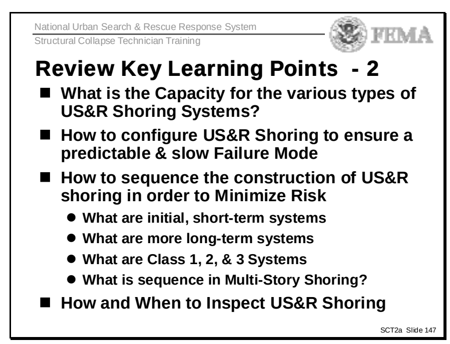
SUMMARY FOR EMERGENCY SHORING OF STRUCTURES

- Testing of Rakers, Laced Posts, Paired Double Tees and Cribbing (continued)
  - Laced Posts normally fail at just above 3 times allowable load. Cupping of wedges can normally be observed as soon as the load exceeds 1.5 times allowable load. Horizontal Splits often form in the ends of the Header Overhang when load exceeds 2 times allowable.
    - Failure occurred when individual posts were broken and diagonal braces come free from their connections.
    - Over 18 Laced Posts have been tested – as of May08
    - Therefore, the wedges can be observed as a good indication of Shore Overload – a Structural Fuse
  - Paired Dbl-T failed at from 85% to 100% of the load at which Laced Posts failed. However, only 7 have been tested as of May 2008. – more tests are planned using more extensive plywood bracing, ½” plywood instead of ¾”, and using OSB.
  - Two Tests of Cribbing have been done by end of 2005
    - Tests indicated that 6ft high cribs (4x4x 48” pieces in 2 x 2 lay-up) crushed 6” when loaded to about 1.5 times allowable load.
    - This performance indicates that cribbing installations will have significant deflection.
    - This “Softness” would indicate that Cribbing needs to be proportioned so that it is capable of carrying all the Vertical Load in a specific location, instead of being able to assume the remaining structure could “Share” in resisting some of the Load
- Copies of the USACE StS FOG & US&R SOG have been sent to all FEMA US&R Task Forces
  - Electronic copies can be obtained from the DisasterEngineer.org website
  - The SOG should be most useful to Rescue Specialists



FINAL SUMMARY

In a disaster we need to consider any viable system based on availability of material, special contractors, and special equipment. The basic principles of engineering will always apply, but creative thinking and co-operation between all members of the Task Force is essential.



Review the Key Learning Points

The student should have a basic understanding of these Objectives in order to provide Effective Advice to US&R Forces

STUDENT MANUAL
MODULE 2B SHORING CONSTRUCTION

MODULE PURPOSE

The purpose of this unit is to explain **HOW** we build shoring in the **FEMA Response System** so that the process is always consistent and efficient.

There are many other types and methods to construct shoring, however, it is important that all rescue personnel within this program learn to efficiently construct these systems.

They have been engineered as well braced, reliable systems that can be rapidly constructed in emergency conditions.

TERMINAL OBJECTIVES

- The student shall learn how to maintain the integrity of all structurally unstable elements
- The student shall learn how to properly transmit or redirect the collapse loads to stable ground or other stable structural elements, capable of handling the additional loads

Terminal Objectives

- The Student shall learn how to maintain the integrity of all structurally unstable elements
- The Student shall learn how to properly transmit or redirect the collapse loads to stable ground or other suitable structural elements capable of handling the additional loads

ENABLING OBJECTIVES

At the conclusion of this module the student should:

- Have a basic understanding of how to conduct a proper size-up
- Be able to identify locations for proper shoring placement
- Understand the shoring team concept and identify the positions and purpose
- Understand the different types of FEMA shoring components and equipment

Enabling Objectives

- Have a basic understanding of how to conduct a proper shoring size-up
- Be able to identify locations for proper shoring placement
- Understand the shoring team concept and identify positions & purpose
- Understand the different types of shoring components and equipment

MITIGATION BASICS

- **Avoid It** - barrier tape around a hazardous area preventing access.
- **Remove It** - pull down a cracked and leaning brick chimney.
- **Shore It** - constructing shoring and/or bracing systems.
- **Monitor it** – setup Monitoring with a warning system and pre-planned escape/evacuation plan.

SHORING SIZE-UP

- The Shoring Size-Up provides a survey of structural damage and potential victim locations in buildings identified during the initial building triage and Structure/Hazards Evaluation process.
  - Identify structural hazards, damage and potential victim locations.
  - Determine best method to mitigate the structural hazards and damage. Avoid, remove, shore, or monitor.
  - Determine the type and placement of shoring systems in relation to structural hazards, damage and potential victim location.
- The shoring size-up should be performed by at least a Structural Specialist, Rescue Team Manager and/or Rescue Squad Officer.
- The shoring size-up must be extensive, accurate and continue throughout the rescue operation.

Shoring Size-up
- Identify structural hazards, damage and potential victim locations
- Determine best method to mitigate the hazard and damage
- Determine the type & placement of shoring systems in relation to structural hazards and potential victim location

Size-up Cont.
- Performed by at least a structural specialist, rescue team manager and / or a rescue squad officer
- It must be extensive, accurate and continue throughout the rescue operation

SHORING SIZE-UP CONSIDERATIONS

Victims

- How many victims are trapped and where are they located?
- Is the information coming from reliable sources and can it be confirmed?

Size-up Considerations
- VICTIMS
- SIX SIDED APPROACH
- STRUCTURAL ELEMENTS
- AGE & CONDITON OF STRUCTURE
- COLLAPSE WARNING SIGNS

SHORING SIZE-UP CONSIDERATIONS (cont.)

Six-sided Approach

- Survey all four sides, the top and the bottom of the entire structure paying particular attention to the collapse area.
- The top survey is extremely important because loose or hanging debris, structural elements and other overhead hazards must be identified and addressed.
- Gravity being constant, will continually try to pull the remains of the structure and its contents to the ground.
- Surveying the bottom is equally important because shifted loads created by the collapse must be transferred to other stable structural members or back to stable ground.

Structural Elements

- Walls out of plumb determine building stability immediately on arrival.
- Bearing walls are the most important structural elements in an unframed building and failure of any part of these walls can cause extensive damage and further collapse.
- Identification and assessment of all beams, columns, arches, joists and other structural supporting elements under the main debris pile or the victim's location should be among the top priorities of the shoring size-up.
  - All severely stressed, broken, missing, bowed or cracked supporting elements which could affect the rescue operation must be shored up before any personnel are committed to work in the area.
  - The building elements they supported must also be examined and re-supported.

Age and Condition of the Structure

- The shrinkage of structural elements over time results in a loss of strength and the loosening of important hangers and connecting supports which may require more shoring.
- Supporting elements of a well-maintained building may be utilized to help support and transfer the collapse load throughout the structure. However, if the building's condition was in a state of disrepair or suspect prior to the collapse, do not assume any structural support exists without a thorough inspection.

Size-up Considerations

- VICTIMS
- SIX SIDED APPROACH
- STRUCTURAL ELEMENTS
- AGE & CONDITON OF STRUCTURE
- COLLAPSE WARNING SIGNS

SHORING SIZE-UP CONSIDERATIONS (continued)

Collapse Warning Signs

- Continual surveillance of the structure from several vantage points must be maintained from the time of arrival to the time the last rescue personnel have exited the building.
- Surveyor total stations/theodolite are excellent tools for detecting any wall and floor movement.
- Pay particular attention to signs of a possible secondary collapse, including shifting debris, airborne dust, sliding plaster & structure sounds like creaking, moaning & groaning.

Size-up Considerations
- VICTIMS
- SIX SIDED APPROACH
- STRUCTURAL ELEMENTS
- AGE & CONDITON OF STRUCTURE
- COLLAPSE WARNING SIGNS

SHORING PLACEMENT

Two Main Objectives

- Maintain the integrity of all structurally unstable elements
- Properly transmit or redirect the collapse loads to stable ground or other suitable structural elements capable of handling the additional loads.

Shoring Placement Considerations – Multi Story Structures

- From the previous Manual Section – when shoring a single damaged floor in multi-story, sound, existing bldg the following procedure may be used:
  - For Wood-frame, one undamaged floor can supported one damaged floor
  - For Steel-frame, it takes two undamaged floors to support one damaged floor
  - For Reinforced Concrete, it takes three undamaged floors to support one damaged floor
  - For Precast Concrete, the shoring should extend to the slab that is supported by the ground
  - This assumes that the structure is a reasonable structure, and not heavily loaded with furniture, storage or debris.
  - This does not apply to structures that are under construction, or subject to cascading/progressive collapse
  - This also does not apply to structures that have collapsed suddenly, without any apparent cause
- Shoring primary structural supporting elements such as walls, girders, columns & arches will more effectively utilize shoring materials and existing construction features of the building.

Shoring Placement & Sequence
- Where to place Shoring
  - Support unstable Structural Elements
  - Under Debris Pile
  - Under Victim Location
- Sequence
  - Shore from Outside - In
  - Shore for Team access & egress
  - Phased approach – Class 1, 2 & 3
    - Spot shore - Class 1 T, but Dbl T is better
    - 2 Dimensional - Class 2 2 or more Post Vertical
    - 3 Dimensional - Class 3 Laced Post, Sloped Floor

Shoring Placement Considerations (continued)

- The area beneath the main debris pile must be examined and shored to provide additional support to the existing, loaded structural elements, before any personnel can be committed to rescue operations on top of the debris pile.
- Also, the area directly underneath the victim(s) and rescue forces must be shored up before significant debris removal operations are attempted. Shores may need to be re-tightened continually as debris are removed.
- Shoring system(s) must be located where they will not interfere with the removal of the victim(s).
- All loads transferred to earth (or other structural element capable of handling the additional load) require the shoring systems(s) to be located where they will bear on each other.
  - The best strategy for multi-story shoring is to start directly under the damaged floor, and work down
- Access into the building may require shoring to be started from the point of entry to where the victim is located. Sections of shoring may have to be built to create safe zones & safe passageways.
- In the most dangerous conditions, it is best to use a phased approach, where Class 1, spot shores (Dbl T is preferred) are placed first to reduce risk.
  - These shores may be followed by Class 2, two dimensional, and then Class 3, three dimensional shores, as risk is further reduced

Shoring Placement & Sequence

- Where to place Shoring
  - Support unstable Structural Elements
  - Under Debris Pile
  - Under Victim Location
- Sequence
  - Shore from Outside - In
  - Shore for Team access & egress
  - Phased approach – Class 1, 2 & 3
    - Spot shore - Class 1 T, but Dbl T is better
    - 2 Dimensional - Class 2 2 or more Post Vertical
    - 3 Dimensional - Class 3 Laced Post, Sloped Floor

Shore at Missing Structural Supports

- Walls
- Beams
- Columns
- Girders
- Arches

THE SHORING TEAM

To conduct shoring operations safely and efficiently two separate teams are formed.

- The **Shore Assembly Team** - Performs the actual shoring size-up and construction of the shores.
- **The Cutting Team** -Establishes the equipment area and cuts the shoring lumber.
- For most cases, a single Rescue Squad can normally fill the six individual shoring team positions
- Larger or more complex shoring operations may require two complete Rescue Squads, with one squad assigned to the Shore Assembly Team and the other assigned to the Cutting Team.

The Shoring Squad

SHORING TEAM	*CUTTING TEAM*
SHORING OFFICER	*LAYOUT FF*
MEASURING FF	*CUTTING FF*
SHORING FF	*TOOL & EQUIP FF*

THE SHORE ASSEMBLY TEAM – MINIMUM SIZE

- The **Shoring Officer** (Rescue Squad Officer) in charge of the operation and works with the structural specialist to determine where to place and erect the shores.
- The **Measuring** performs all the measuring required in the erection of the shoring and relays all measurements and lumber sizes to the layout of the cutting team.
- The **Shoring Fire Fighter** clears away debris and obstructions that could interfere with constructing the shore, assists the measure as needed and erects the shores.

THE CUTTING TEAM – MINIMUM SIZE

The initial responsibility of the cutting team is to secure an area as close as possible to the collapse operation so as to minimize the number of personnel needed to relay the materials to the shore assembly team.

The assistance of several other personnel may be required to help expedite the movement of lumber and tools to the collapse area.

- The **Layout** in charge of setting up the cutting station and readying the materials to be cut.
  - Performs all measuring and layout of angles and should be in direct contact with the shore assembly team measurer via portable radio to eliminate problems in mis-communicating measurements of lengths to be cut.
- The **Cutter** cuts the shoring material.
- **Tools and Equipment** directs the movement of tools and equipment to be placed where they are requested, anticipates logistical needs of the shoring team and keeps an inventory checklist/log sheet for easier retrieval of tools and equipment at the conclusion of rescue operations.

The Shoring Squad

SHORING TEAM	***CUTTING TEAM***
SHORING OFFICER	*LAYOUT FF*
MEASURING FF	*CUTTING FF*
SHORING FF	*TOOL & EQUIP FF*

THE SHORE ASSEMBLY TEAM – FULL SQUAD

- The Shoring Officer (Rescue Squad Officer)
- The Measurer
- Shoring FF (these two work together assembling
- Shoring FF and erecting shores in place)
- Safety
- Runner ensures tools, equipment, & shoring materials are moved from the shoring operation access point to the shoring site and assists in the erection of shores.

THE CUTTING TEAM – FULL SQUAD

(1 Cutting Tm Squad provides for 3 or 4 Shoring Squads)

- The Cutting Team Officer (Rescue Squad Officer)
- The Layout
- The Feeder moves and feeds measured and marked shoring material from the Layout to the Cutter and helps secure it when being cut.
- The Cutter
- Tool and Equipment
- Runner - ensures tools, equipment and shoring materials are moved from the cutting area to the shoring operation primary access point.

SHORING TERMINOLOGY

The following are terms used to specify the various components of FEMA US&R Shoring Systems

- The **Header** collects the weight from above and spreads it throughout the shoring system.
- **Sole Plate** provides a foundation for the shoring system by supporting the weight being transferred from above or from a Raker.
- **Posts** support the weight being collected by the header & transfers it to the sole plate where it is distributed.
  - The **sole plate**, **header** and **posts** should be the same width for a more secure attachment.
- **Raker** post-like member that extends diagonally from wall plate to sole to support a leaning wall.
- **Wall Plate** collects the load from leaning or damaged wall.

Shore Assembly Team	Cutting Team
SHORING OIC	*CUTTING TEAM OIC*
MEASURING FF	*LAYOUT FF*
SHORING FF	*FEEDER*
SHORING FF	*CUTTING FF*
SAFETY FF	*TOOL& EQ FF*
RUNNER	*RUNNER*

Shoring Terminology

Header	Collects load at roof and floor
Sole Plate	Transmits load to floor or ground
Wall Plate	Collects load from wall/vert. surface
Post	Transmits load from header to sole
Raker	Transmits load from wall plate to sole
Raker Cleat	24” to 30”, 2x used as connection piece to resist sliding

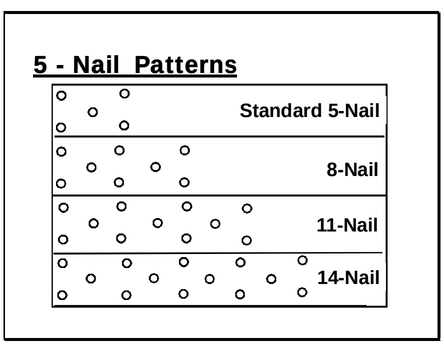
Shoring Terminology (cont)

Gussets	12” Sq. ply connection for rakers
Half Gusset	6” x 12” ply connection for vert shores (Use 2x4x18”cleat if have no Ply)
Dbl Gusset	12” x 24” Gusset used for Dbl T
Mid Pt Brace	Lumber used to connect rakers or posts at mid point for bracing
Diagonal Bracing	2x lumber placed on diagonal in X or V to keep shoring from racking

Make gussets from (5/8 or 3/4) plywood or OSB

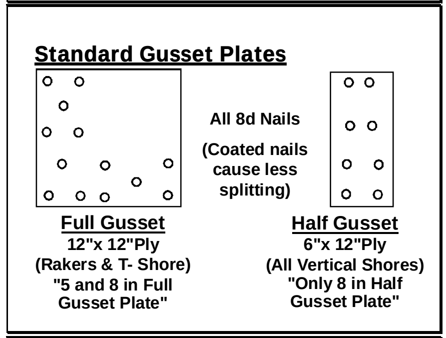
SHORING TERMINOLOGY (continued)

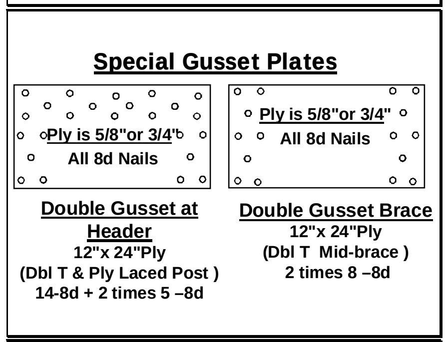
- **Gusset Plates** - 12" x 12" plywood used to connect header to post for T-shore and each end of the Raker.
  - All plywood may be 5/8" or 3/4" thick or OSB.
- **Half-Gusset or Cleat** – 6" x12" plywood or 2x4x18" used for connections at vertical shore headers & soles.
- **Double Gusset** 12"x 24" ply used to connect posts to header at the Double-T and 2x4 PLP.
- **Raker Cleat** 2x4x 24" and 30" nailed to the raker sole and wall plate to resist sliding.
- **Mid-point Braces** 1x(or 6" x ¾" ply) and 2x lumber used to brace rakers or posts at mid-point.
- **Diagonal Bracing** 2x lumber placed in an X or V to keep shoring from racking or buckling.
- **Plywood Braces** 8" and 24" wide plywood strips placed horizontally to brace plywood laced posts.
- **Window/Door Cleats** 2x4 x 14" min. up to 18"
- **Wedges** two wooden incline planes **married** together and placed under the bottom of the post or at end of raker. They are simultaneously tapped together until the shoring system is fully supporting the intended load.
  - 2x wedges are more stable than 4x wedges. 2x wedges do not allow for as much adjustment, but they are preferred due to their better stability.
- Shims any piece of lumber, wedge shaped or flat that is used to fill-in voids between shore and the structure.
- 5 Nail Patterns – most nailing is done as a group of nails that are placed in the triangular pattern as shown here.

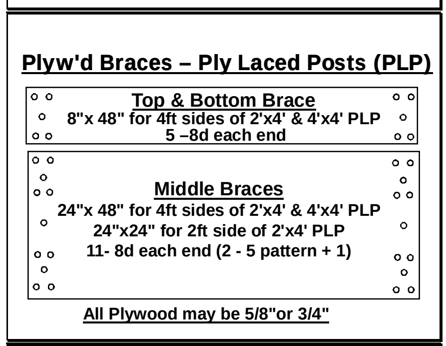


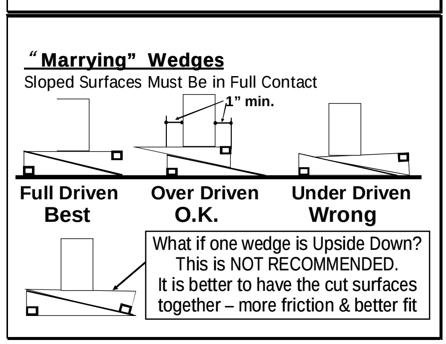
Shoring Terminology (cont)

Ply Braces	5/8" or 3/4" plywood cut in strips of 8" x 48", 24" x 48", & 24" x 24", used to brace Plywood Laced Posts (PLP)
Window & Door Cleats	2 x 4 x 14" minimum – up to 18"
Wedges	2x or 4x lumber cut, diagonally into 2 pieces to allow for adjustments in height/length (2x are more stable)
Shims	Any piece of lumber, wedge shaped or flat that is used to fill-in void spaces









USE OF GUSSET PLATES IN INTERIOR SHORING.

- In Disasters where any type of vibration or shock loading is possible, it is very important to make the connections strong enough to resist repeated impacts and lateral movement.
  - To do this it is necessary to provide a Half-Gusset or 2x6 bracing connection on each side at the bottom of each post in order to confine the wedges and prevent the sole from possible rollover.
  - At the tops of these same posts, it is adequate to provide a one sided connection if the header is no deeper than its width (4x4 & 6x6) . That is, on end posts the 2x6 bracing connection is adequate. For interior posts, one may use a half-gusset or 2x cleat on one side only
  - The 2x6 and half-gussets are nailed with standard nailing that will be discussed later in this section.
  - Note that 5/8" or 3/4" plywood or OSB may be used for gussets (OSB = Oriented Strand Board, but should not be used in conditions where it will remain wet.)

Use of Gusset Plates in Vertical Shoring

- Gussets are placed on one side at post to header for 4x4 & 6x6 headers at the inner posts.
  - At the end posts, the 2x6 diagonal on one side replaces the need for a gusset plate
- When headers are deeper than 4", gussets are needed both sides to prevent header roll-over
- Gussets are needed on both sides of posts at the base of shores to keep wedges in place.
  - For wood floor/roof support, 1-sided connections may be used, where displacement of shore caused by lateral loads, vibrations, or shifting is unlikely.
- Gussets may be made from 5/8"or 3/4"plywood
  - OSB of same thickness may also be used

SHORING NAILS

It is the best practice in timber construction that the number and size of nails should not split the wood. For FEMA Shoring use 8d nails to connect plywood gussets and braces, and 16d nails (preferred reduced gage coated sinkers or coolers) to connect 2x cleats and braces. The recommended sizes are shown in the adjacent slide.

- The FEMA US&R Rescue Cache contains Paseload and Senco pneumatic nailers. There are Palm Nailers are also included – used in confined spaces.
- 16d Box Nails may be used if other 16d nails are not available. No nails need to be added for nailing diagonals or braces, but need to add 3 nails at raker cleats.
- All nails should have full heads, but most gun-nails have the heads slightly offset from the shank in order to minimize the length of the clip.
  - Heads with a small piece removed from one edge may be used without much loss of strength, however nails with a V-notch cut out should not be used, since they tend to cut into the wood.

Shoring Nails – Repeated from previous

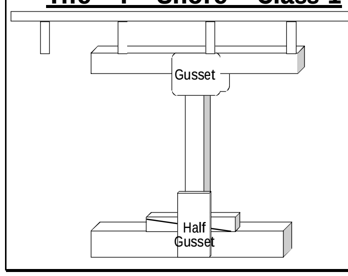
- For best results, nails should not split the wood
  - Use Pasload &/or Senco Nail Guns & Palm Nailers
  - 16d common duplex may only be used in training
- Recommended Nails
  - For Plywood – 8d Common, Coated (.131 x 2.5")
  - For 2x – 16d Sinkers/Coolers (.148 x 3.25 coated) (same as 12d common nails)
  - If only have 16d Box nails (.135 x 3.5) – O.K. except add 3-nails in raker cleats
- Nail Heads for Nail Guns
  - Full (offset) heads are preferred
  - Clip Headed nail are OK for 2x and 5/8", 3/4" Ply
  - V-cut heads are least desirable – Not Recommended

THE "T" SPOT SHORE

- The main purpose of the "T" shore is to initially stabilize damaged floors, ceilings or roofs, so that the more substantial shoring can be constructed at less risk.
- The T Shore is basically unstable.
  - That is if the supported load is not centered directly over the Shore, it will tend to tip over.
  - The header beam is deliberately kept short so as to minimize to effect of tipping.
- The size of lumber most commonly used in the T shore is 4 X 4 douglas fir. The estimated weight of the floor and its contents will help to determine the number of shores that will be required.
- Structural Components of the T shore
  - The **Sole Plate** provides a foundation for the shoring system by supporting the weight being transferred from above/distributes it over a wider area.
  - The **Header** collects the weight from above and spreads it throughout the shoring system.
  - The **Posts** supports the weight being collected by the header or spreader beam and transfers it to the sole plate where it is distributed.
  - The **sole plate**, **header** and **posts** should be the same width for a more secure attachment.
  - **Full-Gusset Plates** - 12" x 12" plywood nailed each side, to the top of posts to ease secure the posts to header. (5/8" or 3/4" all gussets)
  - **Wedges** two wooden incline planes **married** together and placed under the bottom of the post. They are simultaneously tapped together until the shoring system is under compression and resists the weight of the structural materials above.
    - 2x wedges are more stable than 4x wedges. 2x wedges do not allow for as much adjustment, but they are preferred due to their better stability.
  - **Half-Gusset or Cleat** – 6" x12" plywood or 2x4x18" nailed on one side to connect bottom of post to sole after wedges have been tightened

The " T" Shore
- INITIAL SAFETY SHORE
- STANDARD " T "
- TEMPORARY SHORING
- TYPICAL HEADER LENGTH = 36"
- TYPICAL SOLE LENGTH = 24" to 36"
  - (typical same as header, can be 24" on slab)
- MAXIMUM HEIGHT IS 11 ft
- Load must be centered on the post or it is UNSTABLE!

The "T" Shore – Class 1



THE "T" SPOT SHORE (continued)

"T" SPOT SHORE

OH-T
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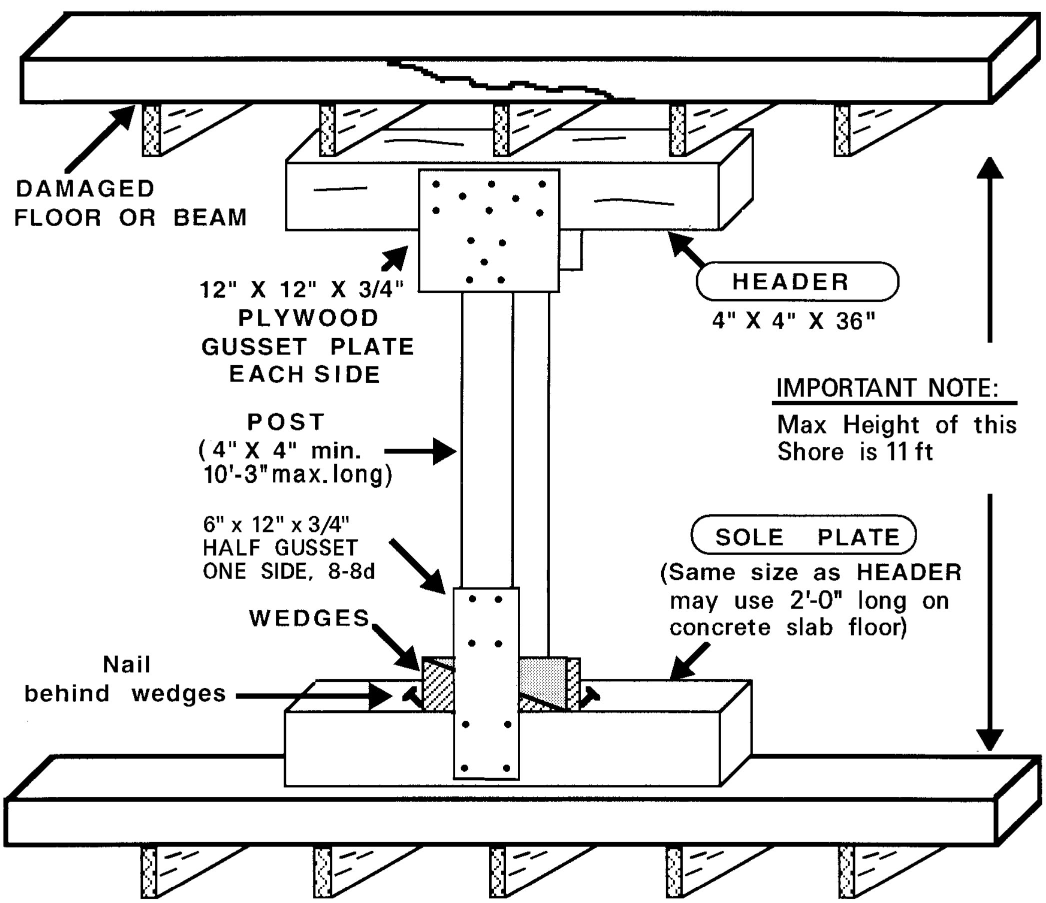
CLASS 1 SHORE

Position the HEADER & SOLE PLATE across the floor and ceiling joists and align the POST under the joists

Prefabricate Post & Header, then install on Sole

Temporary shore <u>ONLY</u> until
a complete shoring system can be erected



<u>DESIGN LOAD</u>
1,000 TO 4,000 Lbs
BASED ON UNKNOWN
STABILITY.

LOAD MUST BE
CENTERED ON POST

SHORING PRINCIPLE

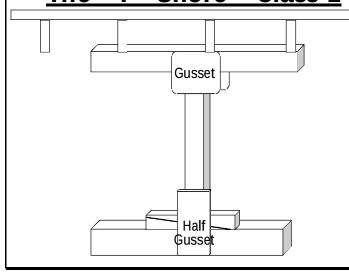
"T" SPOT SHORES CAN
BE CONSTRUCTED
W/ PNEUMATIC SHORES,
ELLIS CLAMPS, & POST
PIPE SCREW JACKS

THE "T" SPOT SHORE (continued)

HOW TO CONSTRUCT THE "T" SHORE

1. Determine where Spot Shores should be built in order to quickly reduce risk. (Prior to building more stable shores).
2. Determine overall height of area to be shored and remove least amount of debris required to place shore.
   - 4x4 post should be 10'-3" max long, so the Total Height of the shore is not more than 11 feet
3. Measure and cut header and sole to 3 feet long
4. Cut post to proper height. (remember to deduct header, sole and wedge height when cutting post)
5. Prefabricate "T" shore as follows:
   - Toenail post to header at its center,
   - Place 12"x 12" full-plywood gusset plate over joint and nail into position.
   - The post will get 5 nails and the header will get 8 nails.
   - Flip over and nail other gusset in position, utilizing the proper 5 and 8 nail pattern
6. Place "T" in position, centered under the load.
7. Position header across (perpendicular to) roof/floor joist with the post directly under a joist, for wood buildings
8. Slide sole plate under "T" and tap wedges in position
   - Length of sole plate is typically made same as header, except on concrete floors a 2 foot length may be used.
9. Check shore for straightness and stability and tighten wedges
10. Install bottom, 6"x 12" half-gusset and nail 4-8d to post & sole.
11. Note that a 2 x 4 x 18" cleat may be used, but 3-16d nails to post and to sole may tend to split the cleat and require stronger pounding within the Danger Zone.
12. Anchor the shore to the floor beams above and nail sole plate into the floor below.

The "T" Shore – Class 1

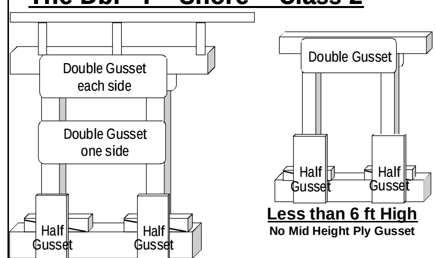


THE DOUBLE "T" SHORE

- The Double "T" shore may also be used to initially stabilize damaged floors, ceilings or roofs
- Double T Shore more stable than the T spot shore.
  - It has 2 posts with small header overhang so the load is more likely to be applied between posts.
  - The Double T is about 25 lbs heavier than the T, and a little more difficult to carry through a window
  - The mid height plywood gusset acts as a stiffening brace as well as keeping the posts aligned as the shore is being carried into place
- The size of lumber most commonly used for the Double T shore is 4 X 4 Douglas Fir. The estimated weight of the floor and its contents will help to determine the number of shores that will be required.
- Structural Components of the T shore are the same as for the T Spot Shore except that top connection uses dbl gussets each side that are 12" x 24".
  - There is a mid-height gusset, which may be omitted for heights less than 6 feet.

The Dbl " T" Shore
- INITIAL SAFETY SHORE
- DOUBLE " T "
- TEMPORARY SHORING
- HEADER LENGTH = 36"
- MIN. SOLE LENGTH = 36"
- POSTS 18" to 24" o. to o.
- Much more stable than "T"
- Maximum height is 12 ft

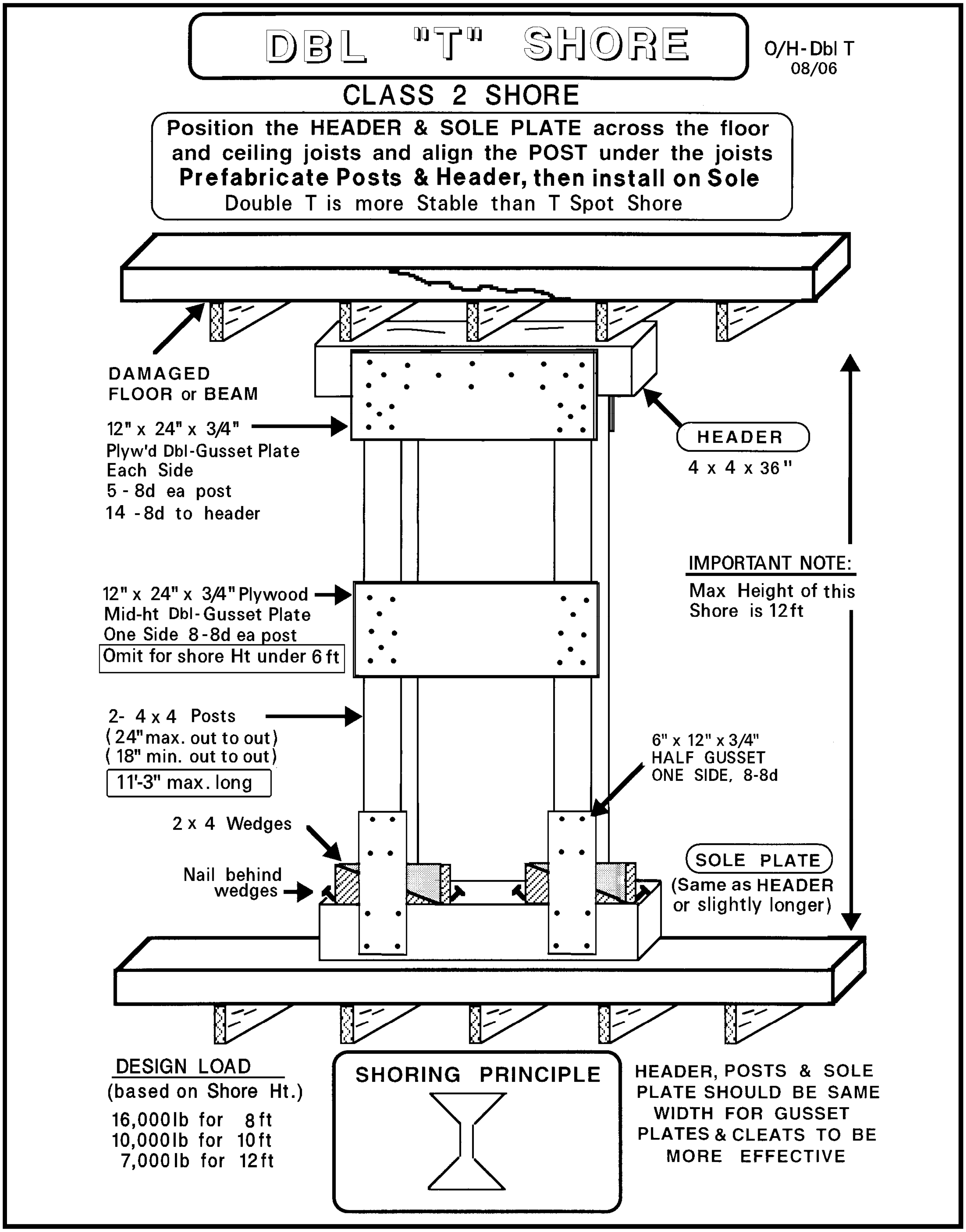
The Dbl "T" Shore – Class 2



HOW TO CONSTRUCT THE DOUBLE "T" SHORE

1. Find height, cut header, post & sole as for T Shore.
2. Prefabricate Double "T" shore as follows.
   - Toenail posts to header spaced 18" to 24" out to out, and centered on header.
   - One post may be tacked to header and temporarily configured to meet other post at bottom for access.
   - Place upper, double-gusset plate over joint and nail as noted below. (12" x 24" Dbl Gusset)
   - 14 – 8d to header and 5 –8d each post.
   - Flip over and nail the 2nd upper gusset in position
   - Place mid-height, single plywood gusset and nail 8-8d to each post
3. Place Dbl-T in position, centered under the load.
   - If one post has been placed on slope for access, straighten it and complete nailing of Dbl-gussets
4. Slide sole plate under Dbl "T" and tap 2x4 wedges, each post, into position
   - Sole plate needs to be at least as long as header
5. Check for straightness/stability and tighten wedges
6. Install bottom half-gussets & nail 4-8d ea. post & sole.
   - 2x4x18" cleats may be used w/ 3-16d ea end
7. Anchor the shore to the floor beams above and nail sole plate into the floor below.

THE DOUBLE "T" SHORE (continued)



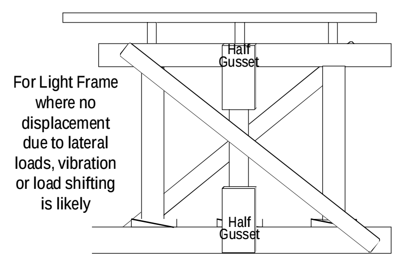
THE VERTICAL SHORE

- The main purpose of the vertical shore is to stabilize damaged floors, ceilings or roofs. It can also be used to replace missing or unstable bearing walls or columns.
- The two sizes of lumber most commonly used in vertical shoring are 4 X 4 and 6 X 6 Douglas Fir (or Southern Pine). The estimated weight of the floor and its contents will help to determine the size of shoring materials and their spacing.
- Businesses and commercial occupancies with heavier structural elements and greater floor height and/or loading may require 8 X 8 or even 12 X 12 lumber. The Structural Specialist should be used to help determine the correct size and placement of shoring materials.
- Structural Components of the Vertical Shore
  - The **Sole Plate** provides a foot for the shoring system by supporting the weight being transferred from above/distributes it over a wider area.
  - The **Header** collects the weight from above and spreads it throughout the shoring system.
  - The **Posts** supports the weight being collected by the header or spreader beam and transfers it to the sole plate where it is distributed.
  - The **Sole Plate**, **Header** and **Posts** should be the same width for a more secure attachment.
  - **Wedges** two wooden incline planes **married** together and placed under the bottom of the post. They are simultaneously tapped together until the shoring system is under compression and resists the weight of the structural materials above.
    - 2x wedges are more stable than 4x wedges. 2x wedges do not allow for as much adjustment, but are preferred due to their better stability.
  - **Diagonal Braces** these double as connections and bracing for the vertical shore. They should be long enough to span its entire length and be attached to the header, each post and sole plate to lock the entire shore together as one unit .
    - A 2 x 6 nailed on both sides of the shore in opposite directions of each other to resist lateral deflection from either side.

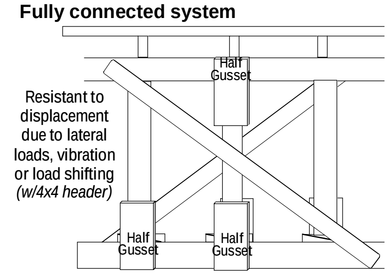
Vertical Shore – Class 2

- SUPPORT UNSTABLE FLOORS or ROOFS
- POSTS UNDER FLOOR BEAMS
- MID-POINT BRACING > 9 ft CEIL. HT (Posts over 8ft plus header & sole)
- 3 post type is shown – may be more posts
- (2 post type shown following this)
- Maximum slope is 6" in 10 ft

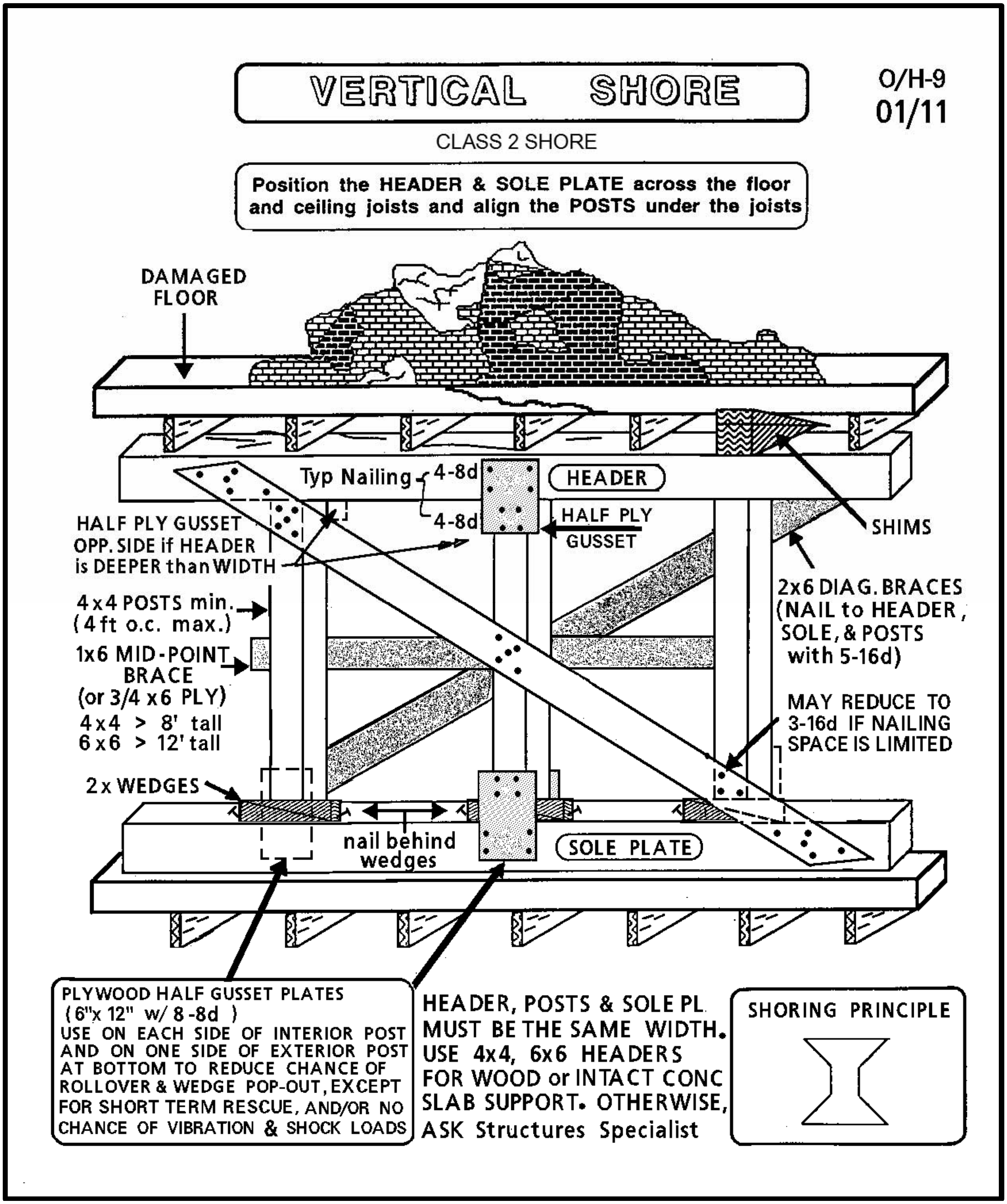
Vertical Shore
Short Term & Light Load, with no Lateral Displacement



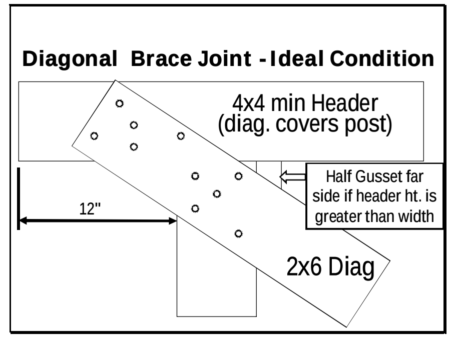
Vertical Shore
Fully connected system



THE VERTICAL SHORE (continued)



- **Structural Components of Vertical Shore (cont)**
  - **Mid-Point Braces** are needed when 4x4 posts are greater than 8 ft long (6x6 greater than 12 ft)
    - A 1 x 6 (or ¾" x 6"plywood strip) nailed to the mid-height of posts on one side, unless posts are badly bowed, then both on sides.
    - If 1 x 6 or ¾" plywood is not available, 2 x 4 or 2 x 6 may be used as mid-point braces. This is the least desirable, since it must be installed after diagonal braces. (2x 4x18" cleats must be added to sides of posts to provide a step out)
    - To maintain the full capacity of posts, when 4x4 are over 8ft long (6x6 over 12ft), one would need to build two parallel, 3 or 4 post vertical shores and place lacing (as in Laced Posts) between each post in each shore. This is normally impractical, and a better option is to use two pairs of Two Post Vertical Shores that have been made into Laced Posts
  - **Half-Gusset Plates** – 6" x 12" plywood nailed to the top and bottom of posts to ease shore placement and secure posts to header & sole pl.
    - May use 2x4x18" Cleats, but they require 16d nails and may tend to split



HOW TO CONSTRUCT THE VERTICAL SHORE

1. Determine where to erect the vertical shore.
   - After initial temporary shoring has been installed as needed, clear the area of debris, down to the floor, removing thick carpeting if necessary. A clearance of three to four feet wide is usually adequate.
   - If the vertical shore is to bear directly on soil, examine the ground for stability. If the earth is soft, additional supports should be installed under the sole plate to transfer the load over a wider area. (2x8, or 2x10 under sole, or if very soft, 3-2x6x18" placed perpendicular under sole at each post)
2. Lay the sole plate on the floor or ground directly under and in line where the header will be installed.
   - The sole plate should be as level as possible.

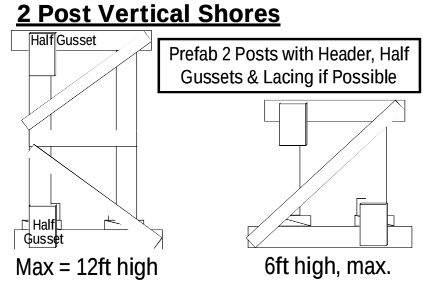
HOW TO CONSTRUCT THE VERTICAL SHORE (cont.)

3. Measure and cut the posts to the proper height.
   - Place the header on top of the sole plate.
   - With the end of tape measure on top of header where the posts are to be installed, slide tape up to bottom of structure to be shored and measure at least 3 places (deduct for the width of wedges).
4. If possible, anchor the header to the area that is to be shored, square and in line with the sole plate.
   - Secure it at the lowest point and shim the structural elements down to the header to keep it as level as possible.
5. Install the posts between the header and sole plate under each structural element to be supported.
   - The first two posts are installed at opposite ends at least 12 in. from each end of the sole plate.
   - Toenail posts to header to hold them in place.
   - Keep posts in-line & plumb w/ header & sole plate.
6. Install a set of wedges under the bottom of each post and tap them together simultaneously until the posts are under compression and tight.
   - Toenail behind wedges to secure them in place.
7. Attach the diag. braces to each side of vertical shore.
   - Mid-point braces, when needed, should be installed prior to the diagonal braces. (except when 2x material is used, then the mid-point braces are placed over the diagonals)
   - The diagonal braces should be long enough to span its entire length and be attached to the sole plate and header and each post.
   - If possible, diagonal braces should be installed in an **X** pattern on opposite sides of the system.
   - Vertical shoring systems which span a long area may require several sets of diagonal braces to connect multiple posts.
8. Attach 6"x 12" half-gusset plates to at least one side of the header and posts, if not done previously.
9. Attach half-gusset plates to at least one side of the sole plate and posts. (2x4x18" cleats may be used)
   - Half-gussets should be placed both sides to confine the wedges, except in light frame buildings where lateral displacement of shore due to vibration, shock loading, shifting, etc. is unlikely.

2 Post Vertical Shore – Class 2

- **FASTER to BUILD THAN 3 or 4 POST**
- **SAME AS ONE SIDE OF LACED POST**
- **(Can later convert a pair into a Laced Post)**
- **USE LACING or X BRACING**
- **Lacing must be 7'-6" max long so it can resist Tension & Compression**
- **POSTS are 4ft Max. o.c. for 4x4 (5ft for 6x6)**
- **Header is 1" min deep for each 1ft Span**

2 Post Vertical Shores



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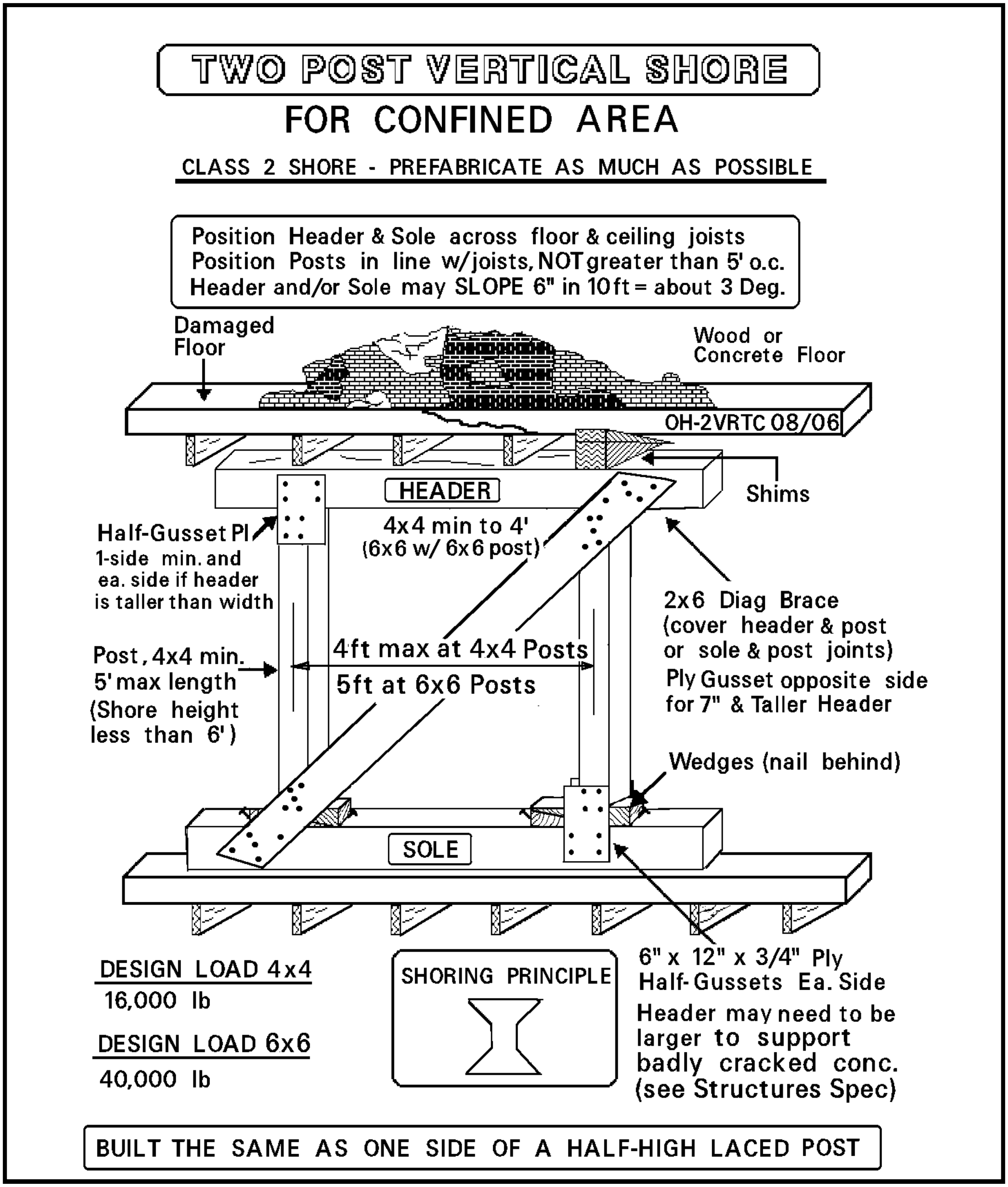
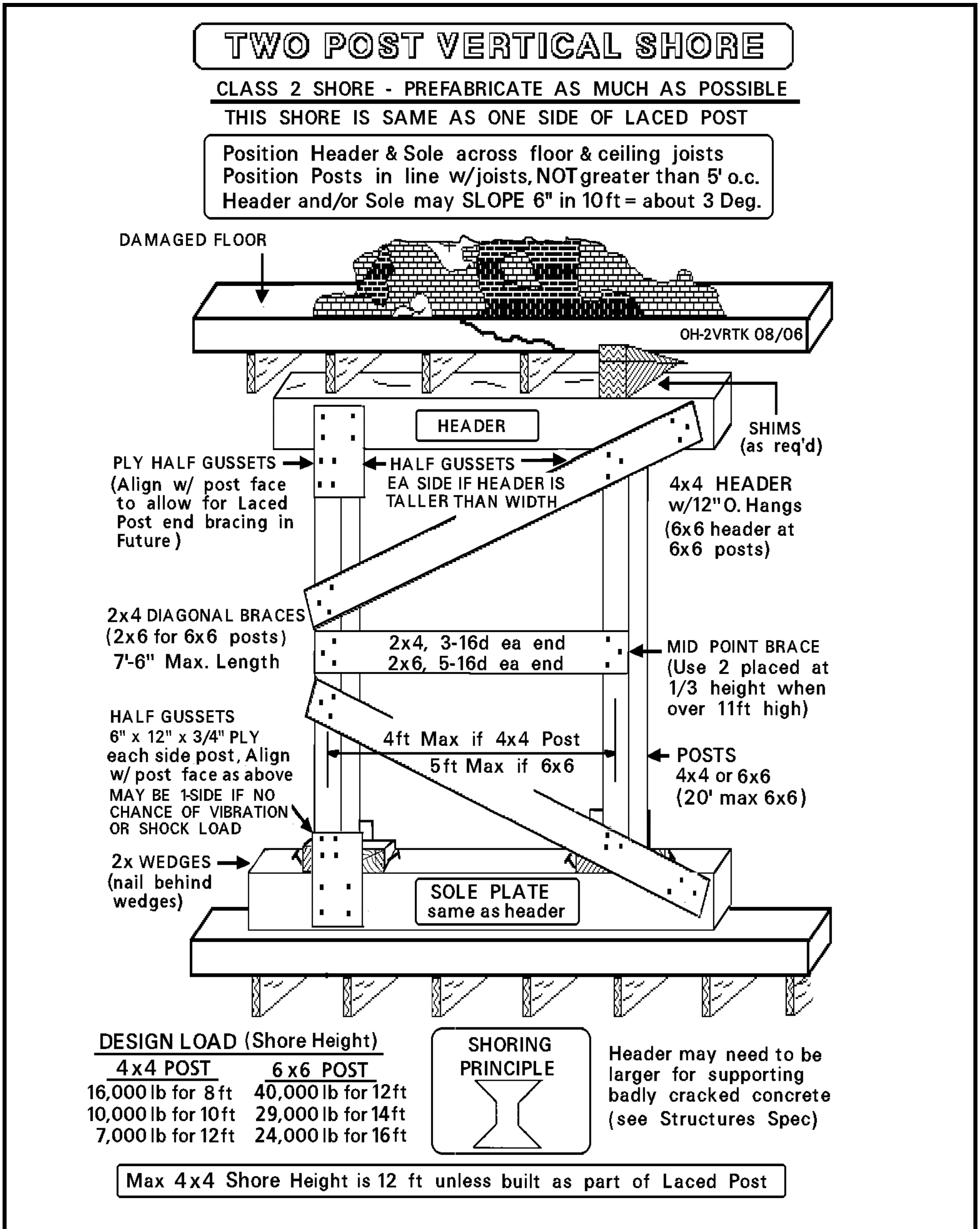
TWO POST VERTICAL SHORES

- The Limited Height Area, Two Post Vertical Shore is constructed the same as a Half High, Single Side of a Laced Post Shore
- This Two Post Vertical Shore is constructed the same as Single Side of a Laced Post Shore




TWO POST VERTICAL SHORE
CLASS 2 SHORE - PREFABRICATE AS MUCH AS POSSIBLE
THIS SHORE IS SAME AS ONE SIDE OF LACED POST
Position Header & Sole across floor & ceiling joists
Position Posts in line w/joists, NOT greater than 5' o.c.
Header and/or Sole may SLOPE 6" in 10 ft = about 3 Deg.
DAMAGED FLOOR
OH-2VRTK 08/06
HEADER
SHIMS (as req'd)
PLY HALF GUSSETS
(Align w/ post face to allow for Laced Post end bracing in Future)
HALF GUSSETS
EA SIDE IF HEADER IS TALLER THAN WIDTH
4x4 HEADER w/12" O. Hangs
(6x6 header at 6x6 posts)
2x4 DIAGONAL BRACES
(2x6 for 6x6 posts)
7'-6" Max. Length
2x4, 3-16d ea end
2x6, 5-16d ea end
MID POINT BRACE
(Use 2 placed at 1/3 height when over 11ft high)
HALF GUSSETS
6" x 12" x 3/4" PLY
each side post, Align w/ post face as above
MAY BE 1-SIDE IF NO CHANCE OF VIBRATION OR SHOCK LOAD
4ft Max if 4x4 Post
5ft Max if 6x6
POSTS
4x4 or 6x6
(20' max 6x6)
2x WEDGES
(nail behind wedges)
SOLE PLATE
same as header
DESIGN LOAD (Shore Height)
4x4 POST
16,000 lb for 8 ft
10,000 lb for 10 ft
7,000 lb for 12 ft
6 x 6 POST
40,000 lb for 12 ft
29,000 lb for 14 ft
24,000 lb for 16 ft
SHORING PRINCIPLE
Header may need to be larger for supporting badly cracked concrete (see Structures Spec)
Max 4x4 Shore Height is 12 ft unless built as part of Laced Post

HOW to CONSTRUCT the 2-POST VERTICAL SHORE

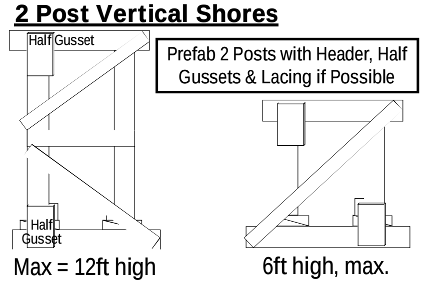
1. Determine where to erect the 2-Post vertical shore and the condition of the supporting structure and/or ground.
   - If practical, this shore should be partially prefabricated, same as for the Laced Post
   - If using 4x4 posts, space them 4 feet, max on center. 6x6 posts may be 5 feet max on center. If access is limited, post spacing may be reduced to 3 feet o.c.
   - The intent would be to support the damaged structure as quickly and safely as possible, but be able to later convert two adjacent, single 2-post vertical shores into a Laced Post for better stability
2. Measure and cut the posts to the proper height. (Remember to deduct for header, sole & wedges when cutting posts) Also, cut the mid-brace and diagonals to proper lengths.
   - Header shall have a 12 inch overhang each end
   - Nail the header, posts, mid brace and upper diagonal together outside the damage zone, if practical.
   - Toenail posts to header as assembly, first step.
   - Use half-gussets at Post to Header (Remember to shift the half-gusset so its outside edge is flush w/ outside of post)
3. Cut sole and wedges. Sole is same length as header
4. Place shore in position, centered under the Load.
5. Slide sole plate under shore and tap wedges into position.
6. Check for straightness plus stability, then tighten wedges.
7. Install lower diagonal and bottom half-gussets (or cleats), then nail properly.(Outside face of half-gusset should be placed flush w/ outside face of Posts)

8. Backing under Sole on Soil:
- Use 3-2x6x18" under sole centered on each post

9. Anchor the shore to floor above and sole to floor below, if practical.

2 Post Vertical Shore – Class 2
- FASTER to BUILD THAN 3 or 4 POST
- SAME AS ONE SIDE OF LACED POST
- (Can later convert a pair into a Laced Post)
- USE LACING or X BRACING
- Lacing must be 7'-6" max long so it can resist Tension & Compression
- POSTS are 4ft Max. o.c. for 4x4 (5ft for 6x6)
- Header is 1" min deep for each 1ft Span

2 Post Vertical Shores



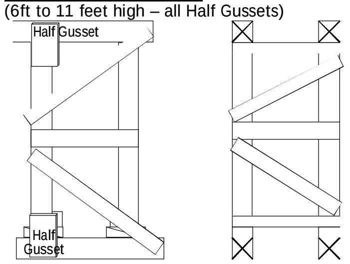
THE LACED POST SHORE

- The main purpose of the Laced Post Shore is to stabilize very heavy, damaged floors, ceilings or roofs.
  - They can also be used to provide a safe haven.
  - It is a very stable system, since each vertical post is braced in each direction
- The two sizes of lumber most commonly used as laced posts are 4 X 4 and 6 X 6 Douglas Fir. The estimated weight of the floor and its contents will help to determine the size of shoring materials and their spacing.
- The structural components of a Laced Post Shore are very similar to the Vertical Shore
  - A Laced Post is essentially two, 2 post vertical shores, constructed separately and laced together.
    - Use one middle brace and two diagonals per side up to 11ft high, and two mid braces + 3 diag, 11ft to 17ft, and three mid braces + 4 diag. above 17ft high.
    - Note: Maximum Ht for 4x4 posts is 17 ft.
    - See graphic on next page
  - When 4 x 4 posts are used, the diagonal braces and center, or mid point braces, are constructed using 2 x 4 lumber for most cases.
    - Nail 2 x 4s with 3-16d each end, and take care not to split the 2x or post.
  - When 6 x 6 posts are used, the diagonals and center braces should be 2 x 6 lumber, using 5-16d each end..
  - The diagonals in a Laced Post System may be configured in a parallel or in a "K" configuration
    - The diagonals are less than 7'-6" feet long, and, therefore, they can resist both Tension and Compression forces, and may be placed in any diagonal direction.
    - The preferred configuration is four K . It is also easy to remember. Any configuration is O.K.
    - In order to reduce the potential for Torsion Failure, it was stated in previous manuals that at least one side of each Laced Post should have its diagonals configured opposite the other 3 sides. That can lead to having too many members nailed to a 4x4 post in a single location and splitting – That layout of diagonals is no longer recommend above any other.

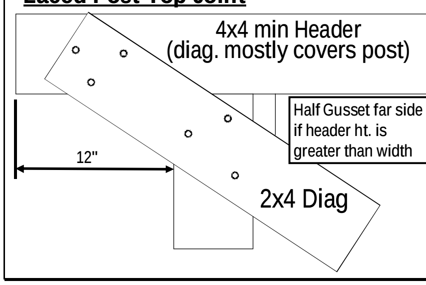
Laced Post Shore – Class 3

- **STRONGEST, MOST STABLE SHORE WE BUILD.**
- **CAN BE UTILIZED AS A SAFE HAVEN AREA.**
- **USE 4x4 & 6x6 POSTS**
  - **4ft max. spacing for 4x4, and 5ft max for 6x6**
  - **Spacing may be out to out or center to center**
- **ONE MID BRACE FROM 6' to 11' HIGH**
  - **2 mid braces from 11' to 17'**
  - **3 mid braces from 17' to 20' (6x6 post systems only)**
- **NO MID POINT BRACE IF UNDER 6' HIGH**
- **2x4 DIAGONAL BRACES, 3-16d ea. end for 4x4.**
  - **2x6 diagonal braces, 5-16d each end for 6x6.**

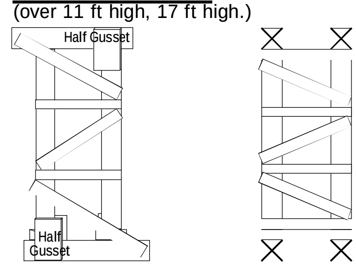
Laced Post Shore
(6ft to 11 feet high – all Half Gussets)



Laced Post Top Joint

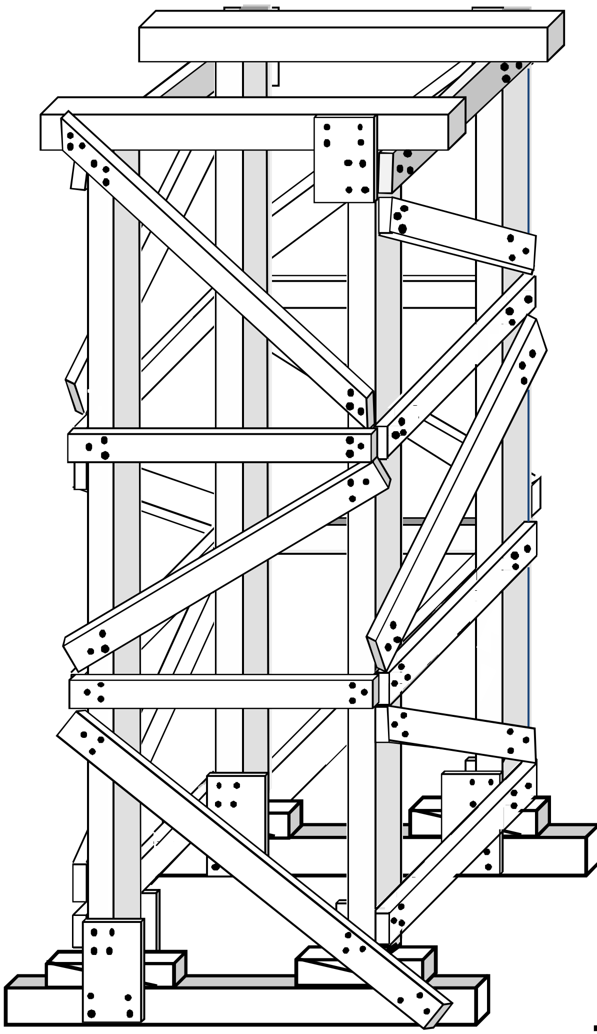


Laced Post Shore
(over 11 ft high, 17 ft high.)



LACED POST SHORE – 4 POST BRACED SYSTEM

Class 3 Shore: Designed as a high capacity, braced, 4-post system.
May be built from 4ft to 20 ft high (17ft max for 4x4 Posts)



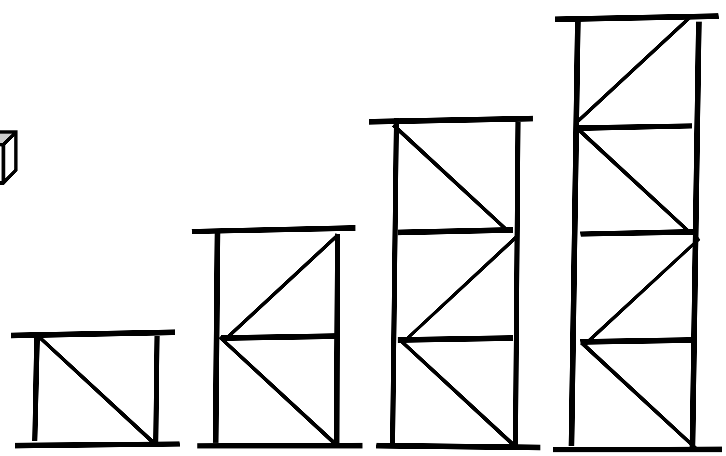
6ft Headers w/12" O. Hang.
4x4 min. w/ 4x4 Posts.
6x6 w/ 6x6 Posts
Half gussets one side at top,
and each side at bottom.

Post Spacing:
4x4 spaced 4ft x 4ft on center, or out to out.
6x6 spaced 5ft x54ft on center, or out to out.

Horizontal & Vertical Lacing is made from:
2x4s, and have 3-16d each end for 4x4.
2x6s, and have 5-16d each end for 4x4.

The diagonals may be configured in a K or parallel layout, but not more than 4 - 2x4 should connect to a post at any location.

SOLE, 4x4 x 6ft, or 6x6 x 6ft
2x4 wedges at 4x4
4x6 wedges at 6x6
Half gussets each side



4 ft to 6 ft | 6 ft to 11ft | 11 ft to 17 ft | 17 ft to 20ft

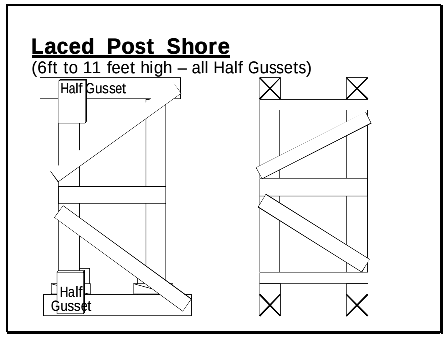
Configure lacing depending on height

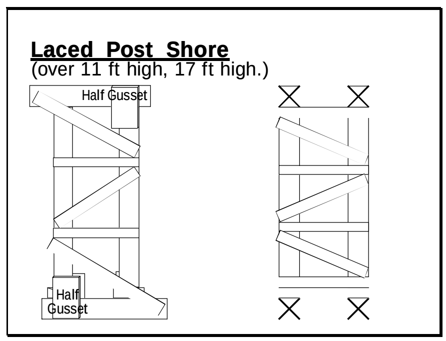
Note: Maximum height for 4x4 poses is 17ft

DESIGN LOAD: 4-4x4 = 32,000lb (32 kips) 6x6 = 80,000lb (80kips)

HOW TO CONSTRUCT A LACED POST SHORE

1. Survey area and determine load displacement, and structurally unstable elements
2. Clean area to be shored.
   - Install temporary, Spot Shores (prior to clearing)
3. Determine the length and height of the shore.
   - Cut header and sole 24 inches longer than width of the shore to allow for 12 inch end overhangs.
   - Cut posts to allow for header, sole, and wedges.
4. Nail posts to the header with toenails
   - Check to see if posts are straight. If not, set both with bow-out (corrected later with mid horiz-brace.)
5. Make Posts Square to the Header.
   - Do overall check by making X measurements (outside top right to outside bottom left, should be same as outside top left to outside bottom right)
   - Nail a half-gusset plate to one post/header joint. (Outside face of half-gusset is flush w/ outside face of post)
   - Nail the mid-point brace (braces) in position and re-check X measurement. If posts bow out, pull them in w/ mid-point brace (braces)
6. Measure and install the top diagonal.
   - It must overlap the post and tie into the header, use the proper nail patterns.
7. Fabricate the second section using first as template
8. Precut horizontal. tie-in braces for ease of assembly.
9. Bring both sections and the sole plates into position & place the prefabricated units on top of sole plates.
10. Install wedges under posts, & check post spacing.
11. Nail horizontal braces to the two sections, both sides.
12. Measure for the diagonals, and install them in either a K or other configuration as dictated by access.
13. At the sole plate, make sure the bottom diagonal extends past the post and nails into the sole plate.
    - Place a half-gusset plate on the opposite side of this post and to each side of the other posts at the base. (outside edge of half-gusset is flush w/ outside of post)
14. Anchor the shore to the ceiling & floor, if appropriate.
15. Make sure all wedges are snug and the proper nail patterns are done.





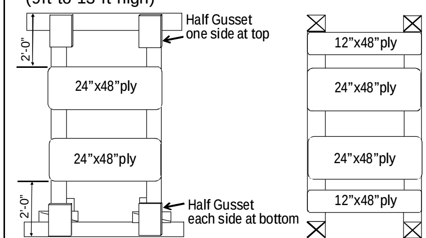
THE PLYWOOD LACED POST SHORES

- The Plywood Laced Post Shore (PLP) was developed to provide an alternative way to construct the high capacity Standard Laced Post (LP).
  - They are lighter and faster to build. (if plywood is available)
  - They have very similar strength and performance properties to the LP
- The two sizes of posts used in constructing PLP are 4x4 and 6x6. The estimated weight of the floor and its contents will help determine the size of shoring materials.
  - The posts are spaced 4 feet out to out, each way for the 4x4 PLP.
  - The posts are spaced 2 ft x 4ft out to out for the 2x4 PLP
  - Post spacing is determined by the size of standard plywood sheets, since the ply braces are intended to cover the posts.
- The structural components of a PLP Shore are very similar to those of the LP Shore
  - A PLP is essentially two, 2 post vertical shores with plywood braces, that are constructed separately and then laced together using plywood braces instead of 2x material.
    - Plywood braces are cut from 5/8 or 3/4 plywood.
    - Use two middle braces up to 13ft high, and three mid braces from 13ft to 17ft high.
    - The height of the 2x4 PLP is limited to 13ft.
    - The minimum recommended height is 10ft, since other shores should be used for shorter conditions
    - The connections to soles use 2x wedges and half gussets each side.
    - Connections to header for the 4x4 PLP is a half gusset one side for each post
    - Connections to header for the 2x4 PLP is a double gusset on one side.
    - **See graphics on next page.**
  - When either 4x4 or 6x6 posts are used for the 4x4 PLP, the plywood braces are as follows.
    - 24"x 48" middle braces with 11-8d each end
    - 8"x 48" top & bottom braces with 5-8d each end.
  - When the 2x4 PLP is constructed, the plywood braces for the 4ft sides are same as in the 4x4 PLP, but those on the 2ft side are as follows
    - **24"x 24" middle braces with 11-8d each end**

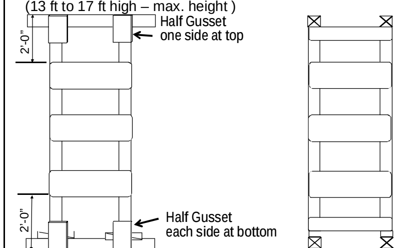
Plywood Laced Post Shore (PLP)

- **CLASS 3 & SIMILAR to STD LACED POST**
  - **LIGHTER & FASTER TO BUILD**
- **CAN BE UTILIZED as a SAFE HAVEN AREA**
- **POSTS ARE SPACED 4'x4' or 2'x4' out to out USING 4x4's & 6x6's (usually 4x4s)**
  - **DETERMINED by the PLYWOOD**
- **HAVE 2 or 3 LEVELS of PLY'WD BRACES**
  - **USE 3 LEVELS for HEIGHTS OVER 13'**
- **MAX. HT. for 4'x4' = 17'; for 2'x4' = 13'**
  - **MINIMUM HT is 4', but not practical less than 9ft**

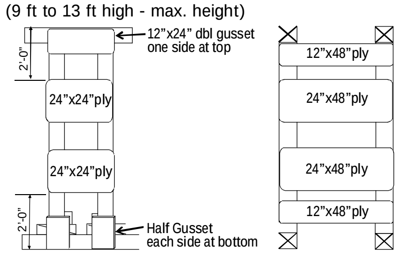
4'x4' Plywood Laced Post Shore (4x4-PLP)
(9ft to 13 ft high)



4'x4' Plywood Laced Post Shore (4x4-PLP)
(13 ft to 17 ft high – max. height)

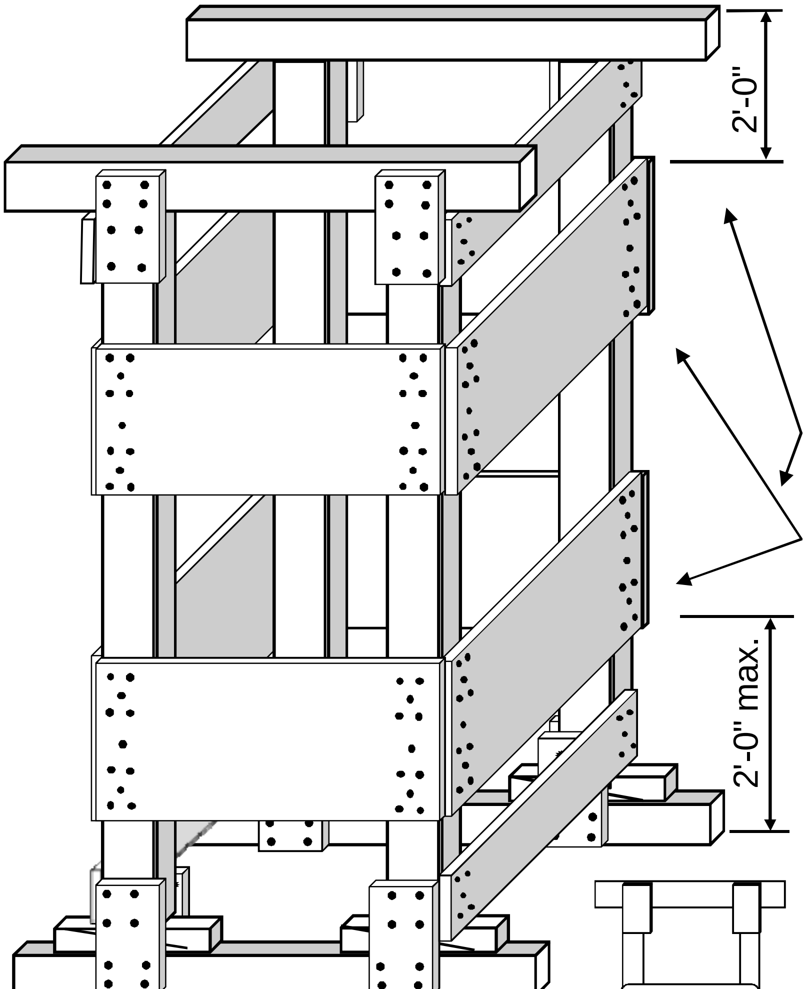


2'x4' Plywood Laced Post Shore (2x4-PLP)
(9 ft to 13 ft high - max. height)



PLYWOOD LACED POST SHORE – 4ft x 4ft POST SPACING

Class 3 Shore: Designed as an alternative to the standard laced post shore. It is lighter and faster to build, and has the same high capacity as laced post. (4ft to 17ft high)



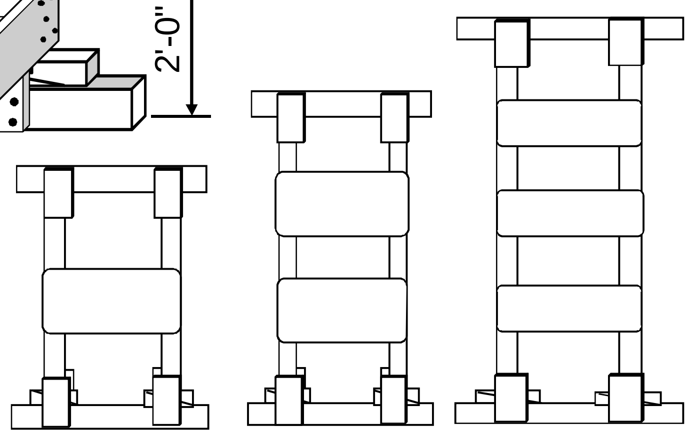
6ft Headers w/12" O. Hang.
4x4 min. w/ 4x4 Posts.
6x6 min. w/ 6x6 Posts.
Half gussets one side at top, and each side at bottom.

Posts are 4x4 or 6x6
Spaced 4ft x 4ft out to out

8"x48" Ply Braces top & bott.
5-8d each end

24" x 48" Ply Middle Braces
11-8d each end
Configure as shown below:

SOLE, 4x4 x 6ft, or 6x6 x 6ft
2x4 wedges at 4x4
4x6 wedges at 6x6
Half gussets each side



4 ft to 9 ft high — 9 ft to 13 ft — 13 ft to 17 ft high

Use 5/8" or 3/4" Plywood Ties and Gussets

DESIGN LOAD: 4-4x4 = 32,000lb (32 kips) 6x6 = 80,000lb (80kips)

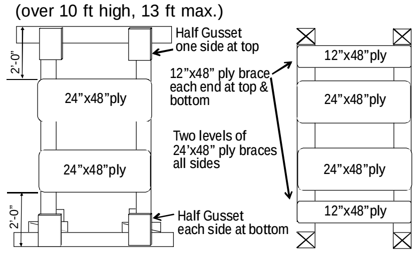
HOW TO CONSTRUCT A 4'x 4' PLY LACED POST

1. Survey area and determine load displacement, and structurally unstable elements
2. Clean area to be shored.
   - Install temporary, Spot Shores if required (prior to clearing)
3. Determine the height & width of the shore.
   - Use 6 ft long header & sole for typical 4 ft o. to o. of posts, and allow for 12" overhangs each end
4. Nail posts to the header with toenails
   - Check to see if posts are straight. If not, set so both with bow-out (to be corrected later with ply mid-braces.)
5. Make Posts Square to the Header.
   - Do overall check by making X measurements (outside top right to outside bottom left, should be same as outside top left to outside bottom right)
   - Nail a half-gusset plate to each post/header joint. (Edge of half-gusset is flush w/ outside face of post)
   - Nail the ply mid-braces in position and re-check X measurement. If posts bow out, pull them in w/ braces
6. Fabricate the second section using first as template
7. Have all the plywood braces precut for ease of assembly.
8. Bring both sections and the sole plates into position and place the prefabricated units on top of the sole plates.
9. Install wedges under each post, and check post spacing. (4ft out to out to allow for 4ft plywood)
10. Nail all the plywood mid braces in place.
    - Start with the lower one, so may use it to climb-up to do the higher ones.
11. Nail the top and bottom ply braces in place.
12. .Place a half-gusset plate on the each side of each post to sole. (outside edge of half-gusset is flush w/ outside of post)
13. Anchor the shore to the ceiling and the floor, if appropriate.
14. Make sure all wedges are snug and nail patterns are done.

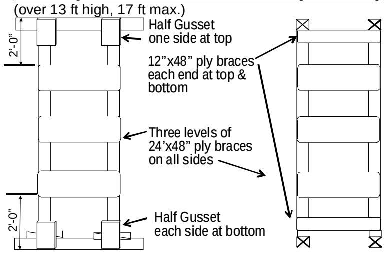
Plywood Laced Post Shore (PLP)

- **CLASS 3 & SIMILAR to STD LACED POST**
  - **LIGHTER & FASTER TO BUILD**
- **CAN BE UTILIZED as a SAFE HAVEN AREA**
- **POSTS ARE SPACED 4'x4' or 2'x4' out to out USING 4x4's & 6x6's (usually 4x4s)**
  - **DETERMINED by the PLYWOOD**
- **HAVE 2 or 3 LEVELS of PLY'WD BRACES**
  - **USE 3 LEVELS for HEIGHTS OVER 13'**
- **MAX. HT. for 4'x4' = 17'; for 2'x4' = 13'**
  - **MINIMUM HT is 10' (NO NEED IF LESS)**

<u>4'x4' Plywood Laced Post Shore (4x4-PLP)</u>
(over 10 ft high, 13 ft max.)

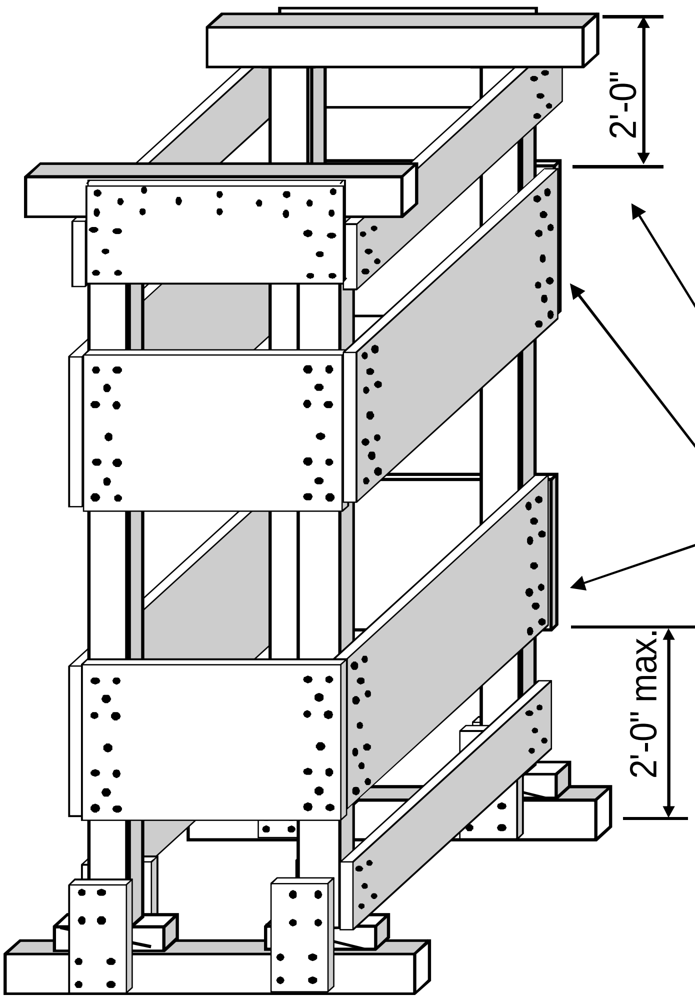


<u>4'x4' Plywood Laced Post Shore (4x4-PLP)</u>
(over 13 ft high, 17 ft max.)



PLYWOOD LACED POST SHORE – 2ft x 4ft POST SPACING

Class 3 Shore: Designed as an alternative to the standard laced post shore. It is lighter and faster to build, and has the same high capacity as laced post. It is also easier to carry and install, since the header & sole are only 4ft long.

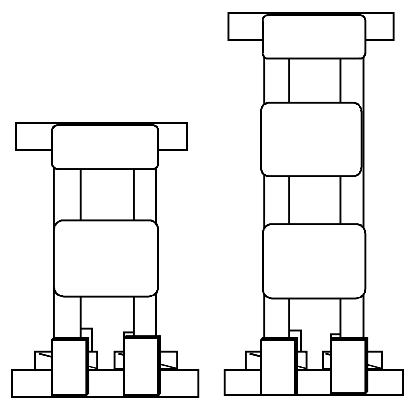


6ft Headers w/12" O. Hang.
4x4 min. w/ 4x4 Posts.
6x6 min. w/ 6x6 Posts.
12" x 24" gussets one side
(14-8d to header, 5-8d each post.)

Posts are 4x4 or 6x6
Spaced 2ft x 4ft out to out

8"x48" Ply Brace top & bottom
On 4ft sides, 5-8d each end

24" x 48" Ply Braces on 4ft sides
24" x 24" Ply Braces on 2ft sides
11-8d each end
Configure as shown below:



SOLE, 4x4 x 4ft, or 6x6 x 4ft
2x4 wedges at 4x4
4x6 wedges at 6x6
Half gussets each side

Use 5/8" or 3/4" Plywood Ties and Gussets

DESIGN LOAD: 4-4x4 = 32,000lb (32 kips) 6x6 = 80,000lb (80kips)

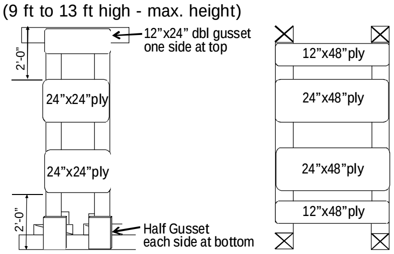
HOW TO CONSTRUCT A 2'x4' PLY LACED POST

1. Survey area and determine load displacement, and structurally unstable elements
2. Clean area to be shored.
   - Install temporary, Spot Shores if required (prior to clearing)
3. Determine the height of the shore.
   - Use 4 ft long header & sole for 2 foot out to out of posts, and allow for 12" overhangs each end.
4. Nail posts to the header with toenails
   - Check to see if posts are straight. If not, set so both with bow-out (to be corrected later with ply mid-braces.)
5. Make Posts Square to the Header.
   - Do overall check by making X measurements (outside top right to outside bottom left, should be same as outside top left to outside bottom right)
   - Nail a double-gusset to header and both posts.
   - Nail the ply mid braces in position and re-check X measurement. If posts bow out, pull them in w/ braces
6. Fabricate the second section using first as template
7. Have the plywood braces precut for ease of assembly.
8. Bring both sections and the sole plates into position and place the prefabricated units on top of the sole,.
   - Note that the prefabricated units are placed 4ft out to out in order to be properly spaced for the 4ft long braces.
9. Install wedges under each post, and check post spacing.
10. Nail plywood mid braces to the two sections on both sides.
    - Start with the lower one, so may use it to climb-up to do the higher ones. Use proper nail pattern.
11. Nail the top and bottom ply braces in place.
12. Place a half-gusset plate on the each side of each post to sole. (outside edge of half-gusset is flush w/ outside of post)
13. Anchor the shore to the ceiling and the floor, if appropriate.
15. Make sure wedges & snug and nail patterns are done.

Plywood Laced Post Shore (PLP)

- **CLASS 3 & SIMILAR to STD LACED POST**
  - **LIGHTER & FASTER TO BUILD**
- **CAN BE UTILIZED as a SAFE HAVEN AREA**
- **POSTS ARE SPACED 4'x4' or 2'x4' out to out USING 4x4's & 6x6's (usually 4x4s)**
  - **DETERMINED by the PLYWOOD**
- **HAVE 2 or 3 LEVELS of PLY'WD BRACES**
  - **USE 3 LEVELS for HEIGHTS OVER 13'**
- **MAX. HT. for 4'x4' = 17'; for 2'x4' = 13'**
  - **MINIMUM HT is 4', but not practical less than 9ft**

2'x4' Plywood Laced Post Shore (2x4-PLP)
(9 ft to 13 ft high - max. height)



SLOPED FLOOR SHORES

- The main purpose of the Sloped Floor Shore is to stabilize damaged floors, ceilings or roofs that have collapsed into a sloped configuration
  - Vertical shores may be are used to support floors with slopes up to 5% (6 inches in 10 feet).
- This shore is essentially a two-post vertical shore system, constructed with the posts placed perpendicular to the sloped surface or placed vertical. (They are connected together like a laced post)
  - These shores should be built in pairs and laterally braced in two directions, to make them Class 3 Shoring Systems.
  - Posts in each shore should be 3 to 5 ft on center, and shores may be spaced from 4 to 8 ft on center
- The posts may be 4 x 4 and 6 x 6 Doug. Fir.
- Sloped Floor Shores can be configured in two ways
  - Perpendicular Bearing Method is used when shoring a floor slab that is hinged off remaining structure or otherwise restrained from sliding. At this time only the Type 2 Shore is recommended. The Type 1 Shore requires digging-in its base and is not recommended
    - Type2 is constructed on hard surface like concrete or paving, but also on soil if 3-2x6x18" are placed under the sole at each post
  - Sloped Friction Method is used when floor slab is free to slide. This is called Type 3 and may be used for on soil or hard surfaces.
- Cribbing may be built to support a sloped surface
  - The crib is built into the slope by adding nailed, full width shims in various layers, so the top members end up flush and tight against the sloped surface.
  - Limited cribbing to 4 ft high and a 30% slope.
- Horizontal and diagonal bracing should be placed between pairs of Sloped Floor Shores, same as for Laced Posts for shores spaced not more than 5 ft o.c.
  - When spaced 5 ft to 8 ft o.c., the bracing should consist of 2 horizontals plus **X** bracing as for Raker Shores.
- When these shores are under four feet tall, one may use 3/4" plywood strips (12" to 24" wide x 5 ft long) as the lateral bracing between pairs of shores.
  - Nail plywood to posts w/ 8d @ 3" in 2 rows, and the plywood should extent to within about 12" of the top & bottom of shore.

Sloped Floor Shore – Class 3

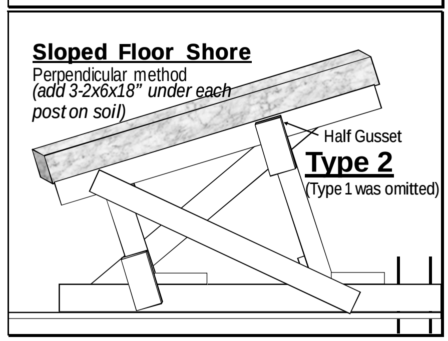
- Must be erected in pairs and cross braced
  Post spacing is 4ft max. 4x4 (5ft max. for 6x6)
- Space shores from 5ft to 8ft apart
  for 5 ft spacing, cross brace like Laced Posts,
  more than 5ft, cross brace same as for Raker Shores
- Erect Posts "Perpendicular" to the floor, where concrete floors remain attached (Type 2)
- Erect Posts Vertical as "Friction System" where floor is not attached, and/or prevented from sliding (Type 3)
- Use 2 - 1/2" Pins, (min.) as anchors to concrete
- Use 2 - 1" Pins, (min.) as anchors to soil

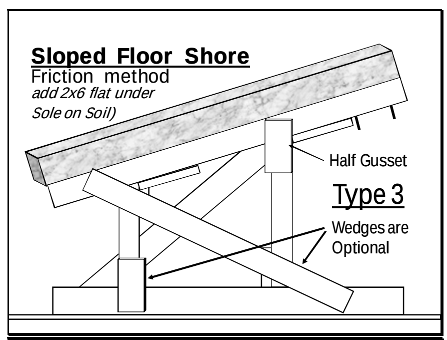
Sloped Floor Shores
vs. Box Cribbing

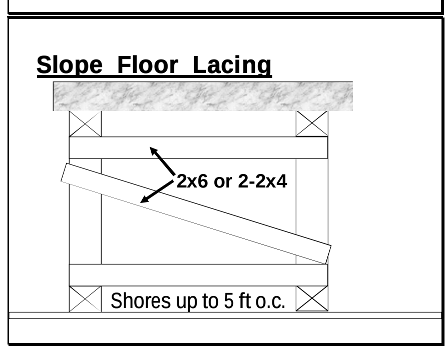
- **Cribbing should be used only if Slope of Floor is less than 30%**
  (3 ft in 10 ft, or approx. 15 degrees)

and

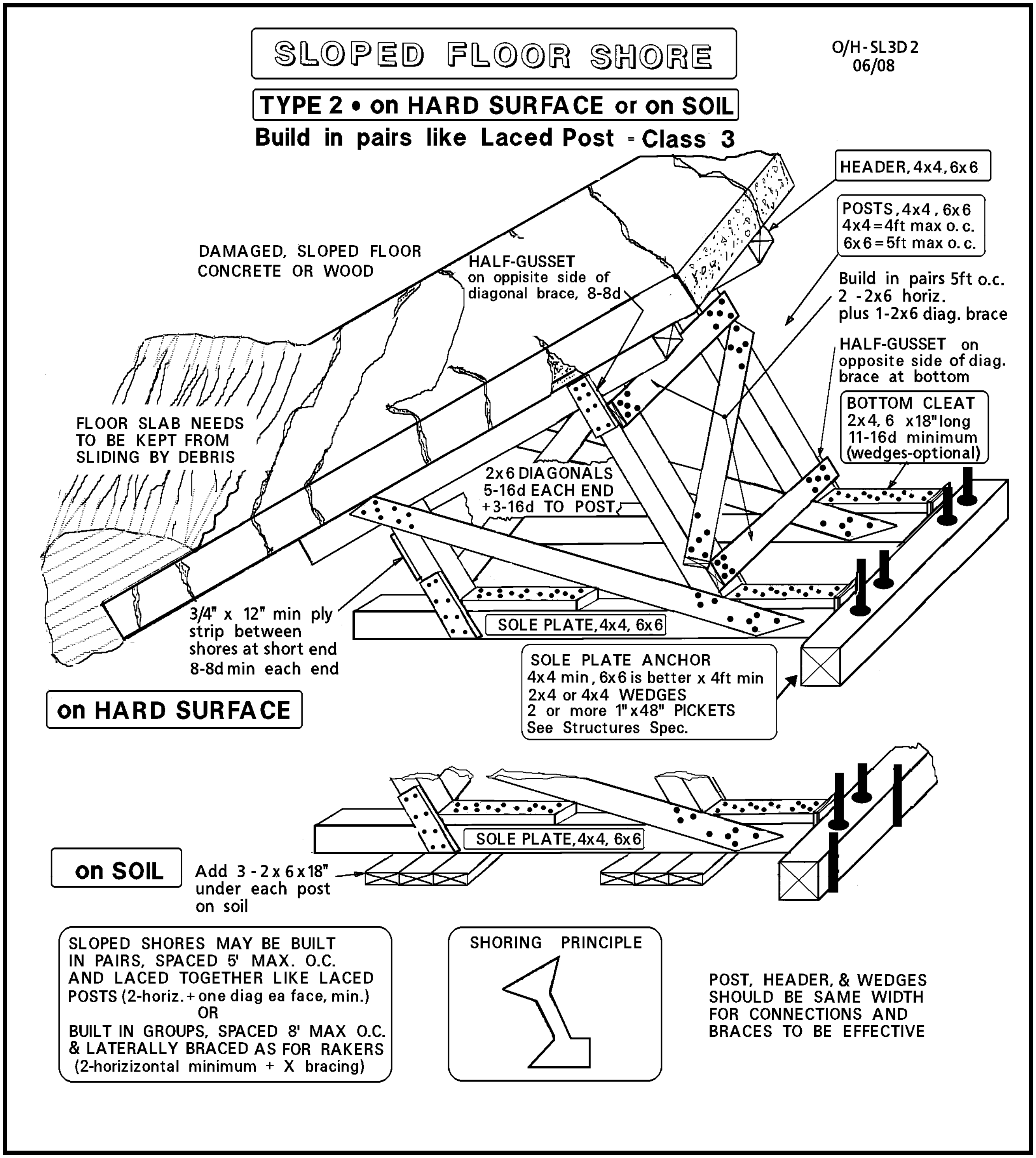
- **If Max. Height of Shore is 4 ft or less**







SLOPED FLOOR SHORES – TYPE 2 ON CONCRETE, PAVING or SOIL



Design Load using 4-4x4 Posts is 24,000lbs for slopes up to 15 degrees (3ft in 10ft) (for 4-6x6 Posts is 60,000lb) May be limited by bracing and sole anchor conditions. All Sloped Floor Shores should be designed by a US&R Structures Specialist

HOW TO CONSTRUCT A TYPE-2 SLOPED FLOOR SHORE (On Concrete, Paving or Soil Surface)

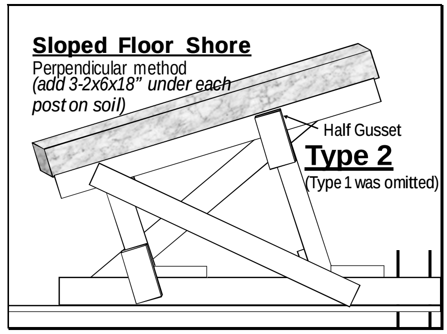
1. Survey area and determine load displacement, and structurally unstable elements
2. Clean area to be shored.
   - Install temporary Spot Shores if required.
3. Find length and width of shore and post locations.
   - Headers must overlap at least 12 inches.
   - The sole plate is at least 24" longer at the base of the back post, to allow for anchors. (add 3-2x6x18" under sole at each post on soil)
   - These shores should be built in pairs. (2 sections spaced from 5ft to 8ft on center)
   - Install the header/sole plates, and anchor header.
4. Measure and install the two posts to each section

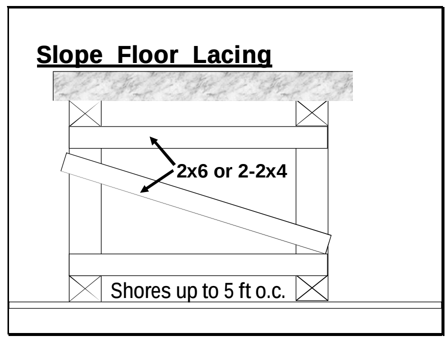
- Make angle and return cut similar to rakers.
- Toe-nail to the header, and drive the bottoms up tight

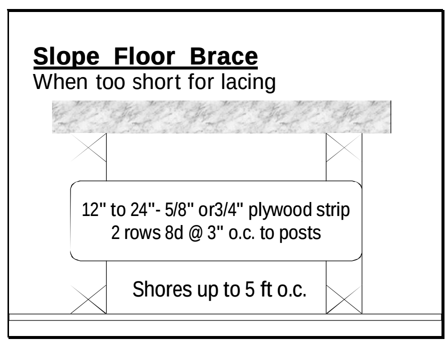
5. Place the bottom cleats tight against each post and install proper nail pattern. Note that wedges should not be used at bottom cleats, since they tend to interfere with the placement of diag. brace.

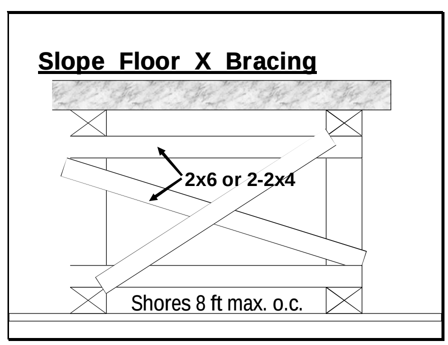
6. Anchor down the sole plates as follows.
   - Anchor sole using drilled in anchors or large rebar to anchor to concrete or paving, based on Structure Specialist recommendations.
   - Alternate Sole anchor using Sole Plate Anchor system shown with Rakers.
7. Measure for diag. braces inside & outside each shore
8. Install the 2x6 braces in position and nail into posts, headers, and sole plates.
   - Half-Gusset plate (or use 2x cleats) the opposite side of the posts, top & bottom, using the 4 & 4 nail pattern.
   - Need to place half-gussets to clear horizontal and diagonal braces (installed next) or use 2x cleats instead of half-gussets
9. Tie the two sections together, same as in Laced Posts or Raker Shores (depending on spacing).
   - Ties are placed between posts at the taller and the shorter ends of the shore sections.
   - Use a wide piece of 5/8" or 3/4" plywood (12" to 24" wide) if shorter end is too short to fit X braces.
   - The plywood or 2x6 bracing may be placed on the inside of posts, if that is easier.

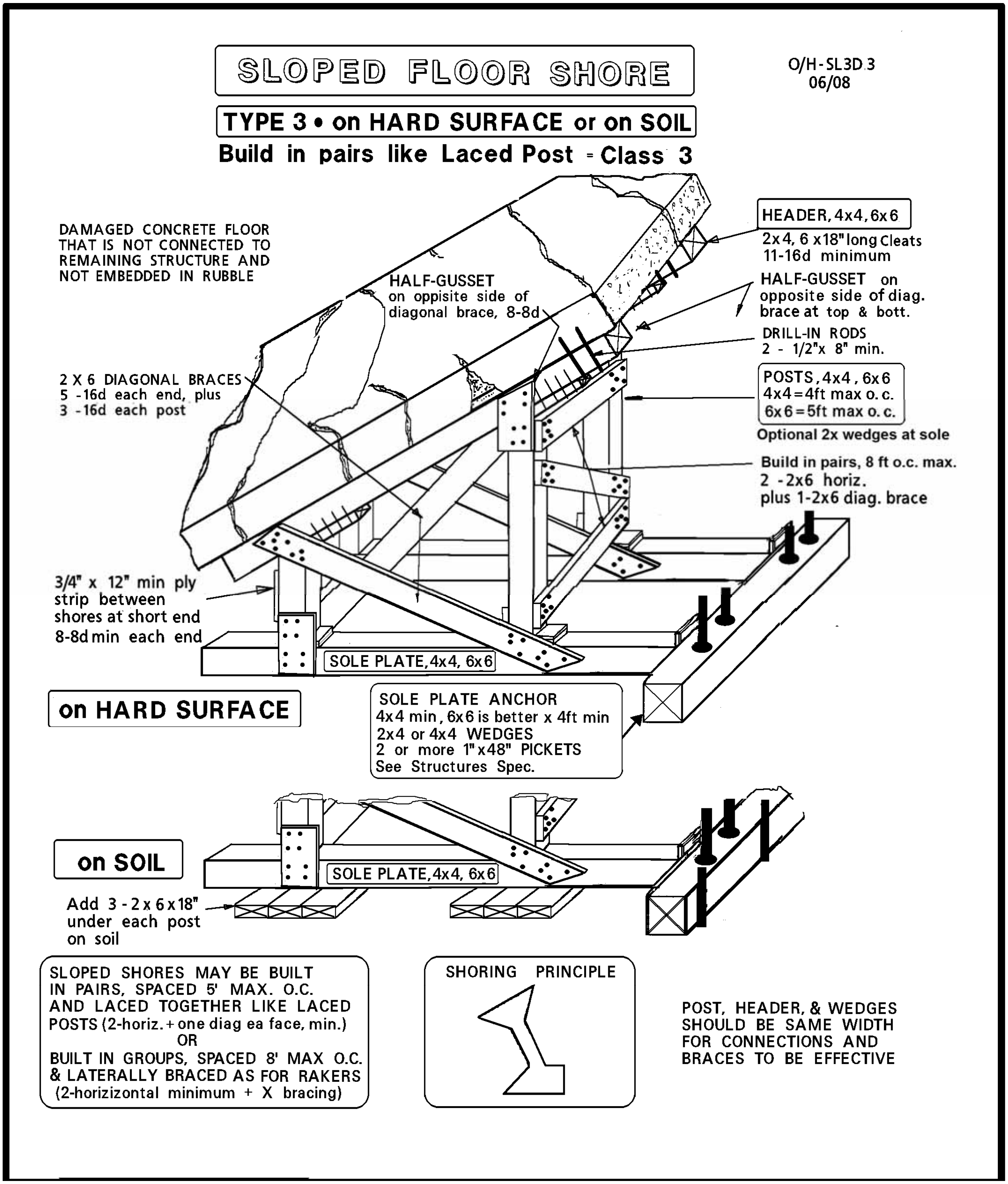
11. Attach shore to floor and ceiling, if practical.







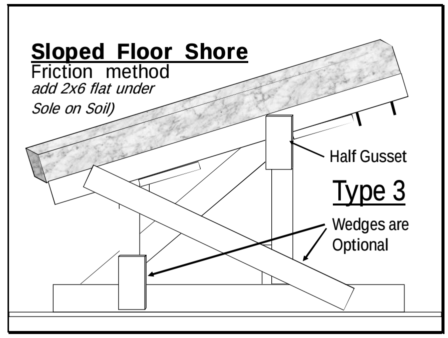


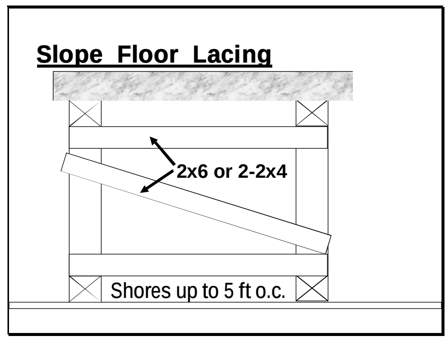


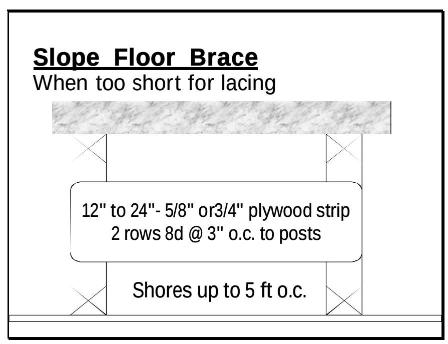
Design Load using 4-4x4 Posts is 24,000lbs for slopes up to 15 degrees (3ft in 10ft) (for 4-6x6 Posts is 60,000lb) May be limited by bracing and sole anchor conditions. All Sloped Floor Shores should be designed by a US&R Structures Specialist.

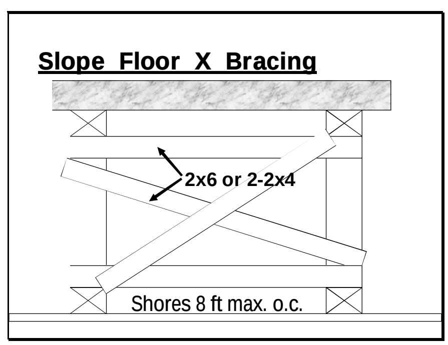
HOW TO CONSTRUCT A TYPE-3 SLOPED FLOOR SHORE (On Concrete, Paving or Soil Surface)

1. Survey area and determine load displacement, and structurally unstable elements
2. Clean area to be shored.
   - Install temporary Spot Shores if required.
3. Find length and width of shore and post locations.
   - Headers overhang is 12" on lower end, but should be increased to 24" at higher end.
   - The Sole Plate should extend 12 inches beyond posts (add 3-2x6x18" under the sole at each post on soil)
   - Shore is built as a pair of 2-post sections, like a Laced Post; spaced from 5ft to 8ft on center.
   - Install headers & sole plates, and anchor header.
4. Measure, angle/return cut, & install two posts for each section; toe-nail to sole, then drive post, tight and plumb. Wedges are optional, but may be used the same as with vertical shores.
5. Install one 18 inch cleat for each post on underside of header with 11-16d nails (pre-install one or more of these cleats on header, when practical, to reduce nailing in Collapse Zone)
6. Make sure posts are driven tight, then place a half-gusset one side of each post, only nail to post.
7. Attached header to ceiling with at least 2 – 1/2" bar or rebar, embedded at least 3" into concrete
8. Anchor the sole plate, if required, & re-tighten posts.
9. Measure for diagonal braces inside & outside each section of the shore.
10. Install the 2x6 braces in position and nail into posts, header, and sole plate.
    - Place Half-Gusset plate the opposite side of the posts, top and bottom. (if not installed w/ posts)
    - Need to place half-gussets to clear horizontal and diagonal Braces (installed next).
11. Tie the two sections together, same as in Laced Posts or Raker Shores (depending on spacing).
    - Ties are placed between posts at the taller and the shorter ends of the shore sections.
    - Use a wide piece of 5/8" or 3/4" plywood (12" to 24" wide) if shorter end is too short to fit X braces.
    - The plywood or 2x6 bracing may be placed on the inside of posts, if that is easier.
12. Attached shore to floor & ceiling, if practical.









WINDOW AND DOOR SHORE

- The main purpose of the window and door shore is to stabilize a window, doorway or other access way. An extensive collapse can generate a tremendous amount of debris that blocks the primary entrances into a building and/or sometimes require a window entry.
- The window and door shore is usually installed in entry points intended for use by rescue personnel to hold up or stabilize loose headers or lintels that have lost their integrity.
- Additional load is usually exerted from above and therefore, constructed similar to the vertical shore.
  - If additional load is exerted from the side, the window and door shore should be constructed similar to the horizontal shore.

STRUCTURAL COMPONENTS - WINDOW & DOOR SHORE

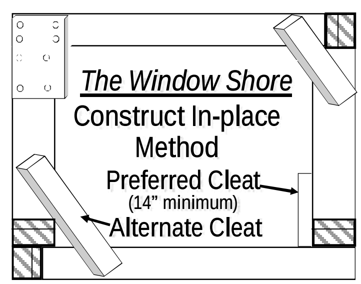
- The **Sole Plate** provides a foundation for the shoring system by supporting the weight being transferred from above and distributing it over a wider area.
- The **Header** collects the weight from above and spreads it throughout the shoring system.
  - Make header depth 1" for every foot of opening.
  - Have StS design headers for openings over 4ft wide
- The **Posts** supports the weight being collected by header and transfers it to the sole plate, where it is distributed to the wall below.
  - The sole plate, header and posts should be the same width for a more secure attachment.
  - Buildings with large structural elements or openings greater than four feet usually require lumber larger than 4 X 4 for the sole plate, header and posts – check with StS.
- **Half-Gusset Plates** and **Cleats** – 6"x12"x 5/8"or 3/4" ply and nailed short pieces of 2 X 4 (Cleat) to both ends of the posts and struts to ease in the placement and securing the posts to the header and sole plate.
  - Cleats placed flat against the inside of the post are preferred, but diagonal cleats may be used
- **Wedges** two wooden incline planes "married" together and placed under bottom of posts or struts.
  - Simultaneously tapped together until the shoring system is under compression.

The Door Shore

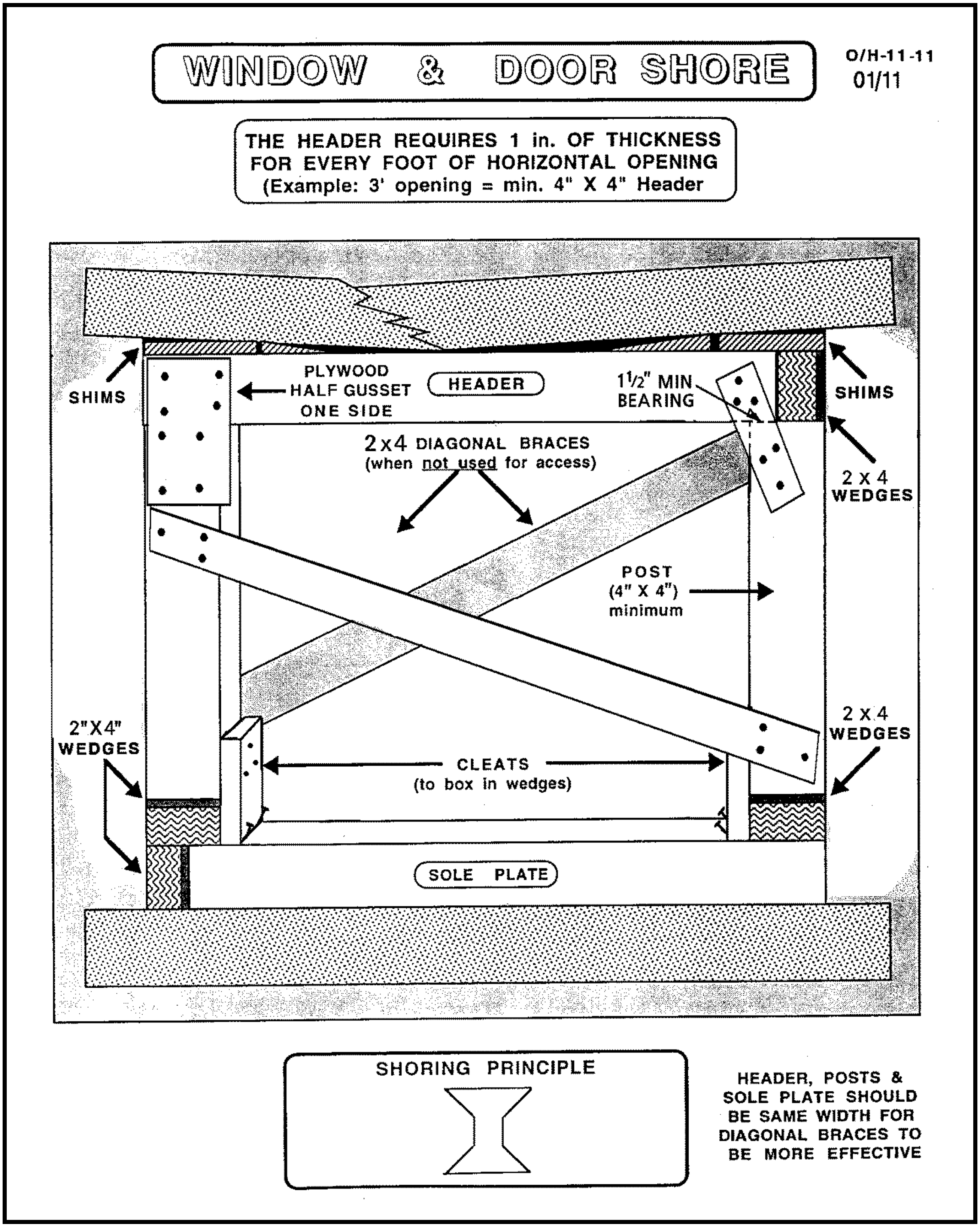
- RESUPPORT ENTRANCE
- SUPPORT WALL BREACH
- 1 inch THICKNESS FOR EVERY FOOT of HEADER LENGTH

The Window Shore

- STABILIZE WINDOW OPENING
- SUPPORT DAMAGED HEADER
- 1 inch THICKNESS FOR EVERY FOOT OF HEADER OPENING

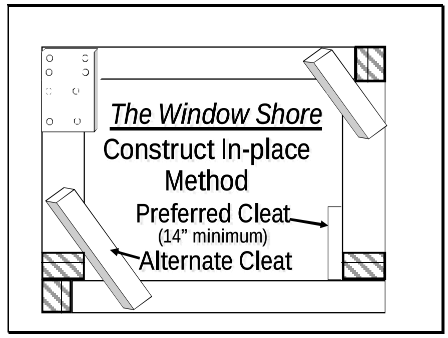


WINDOW AND DOOR SHORE (continued)



STRUCTURAL COMPONENTS - WINDOW & DOOR SHORE (continued)

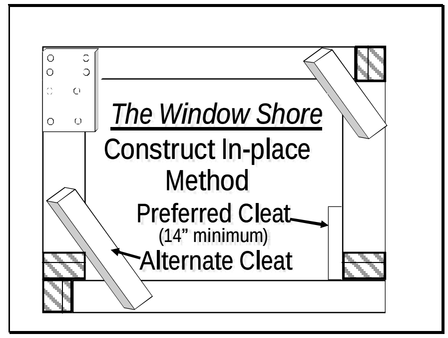
- **Diagonal Braces** the last items to be installed on the window and door shore when the opening is **not used** for access or egress.
  - The diagonal braces should be long enough to contact the top of the posts on one side and the bottom of the posts on the other to lock the entire shore together as one unit and support against possible eccentric loads applied to it.
  - A 2 X 4 or 2 X 6 nailed on both sides of the shore in opposite directions of each other to resist lateral deflection from either side.
- **Built-up Header** may be used when additional support is needed or if the opening is more than four feet wide and only 4 X 4 material is available.
  - Prior to installation of header, cut 2- 4 X 4 to proper length for header and set them one on top of the other. Place 6" wide plywood strips (as long as the headers) on each side to join the two pieces, and nail 8d @ 3" o.c. from each strip of plywood to each 4 X 4.
    - Total nailing will be 4 rows of 8d spaced 3"o.c.
    - Header will be 7" high, almost equivalent to a 4 x 6.



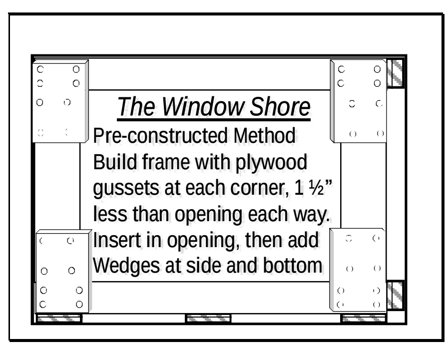
HOW TO CONSTRUCT THE WINDOW AND DOOR SHORE

1. Determine where to erect the window and door shore
   - After initial temporary shoring has been installed clear area of debris or remaining framing material.
2. Measure and cut the sole plate to the proper length deducting the width of the wedges to be used.
3. Measure and cut the header to the proper length deducting the width of the wedges to be used.
   - Consult StS for openings over 4ft wide
4. Measure and cut the posts to the proper height.
   - Place the header on top of the sole plate.
   - With the end of the tape measure on top of the header where the posts are to be installed, slide the tape up to the bottom of the structural element to be shored on both sides deducting the width of the wedges to be used.
   - Use the shorter of the two measurements.

HOW TO CONSTRUCT THE WINDOW AND DOOR SHORE (continued)



5. Install the sole plate with a set of wedges at one end and tap them together simultaneously until the sole plate is under compression and tight.
   - The sole plate should be as level as possible, use shims as necessary under the sole plate.
6. Install the header with a set of wedges at the opposite end of the sole plate and tap them together simultaneously until the header is under compression and tight.
   - The header should be as level as possible, use shims as necessary above the header.
7. Install the posts between the header and sole plate and against the sides of the opening.
   - Install the first post under the wedge side of the header to prevent accidental movement if the header wedges loosen up.
   - Keep the posts in line and plumb with header & sole plate.
   - A set of wedges is installed <u>under</u> each post, on top of the sole plate. The wedges are then tightened to lock the shore in place.
8. Attach cleats and half-gusset plates to at least one side of the header and posts and nail in place.
9. Confine the wedges by placing a cleat against the inside face of each post at the bottom and nail them in place with 3-16d to each post and 2-16d toe nails to the sole plate
   - Nails may need to be Duplex for future adjustment of the wedges.
10. Install diagonal braces on the window and door shore when the opening is **<u>not used</u>** for access or egress.
11. Window and Door shores may also be pre-constructed as shown in adjacent slide
    - See discussion under Pre-Constructed Shores, later in this Module



THE HORIZONTAL SHORE

The main purpose of the horizontal shore is to stabilize a damaged wall against an undamaged wall in hallways, corridors or between buildings.

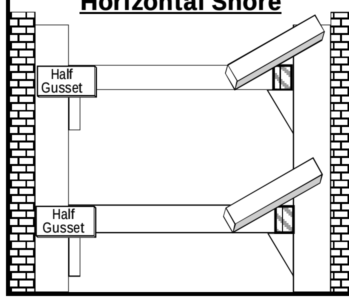
STRUCTURAL COMPONENTS OF HORIZONTAL SHORE

- The **Wall Plates** provide a foundation for the shoring system by collecting the weight being transferred laterally and spreads it throughout the shoring system.
- The **Struts** supports the weight being collected by one wall plate and transfers it to the other wall plate.
  - The wall plates and struts should be the same width for a more secure attachment.
- **Cleats** or **Half-Gusset Plates**
  - Cleats: short pieces of (2 X 4) nailed under the struts to ease in their placement and prevent the struts from being dislodged.
  - Half-Gusset Plates: 6"x12"x 5/8 or 3/4" plywood nailed on at lest one side of the wall plates and struts to prevent struts from being dislodged.
- **Wedges** two wooden incline planes "married" together and placed under one end of the strut.
  - Simultaneously tapped together until the shoring system is under compression and takes the weight of the structural materials.
- **Diagonal Braces** the last items to be installed on the horizontal shore when the hallway or corridor is **not used** for access or egress.
  - Should be long enough to contact both the top and bottom of the wall plates and all the struts to lock the entire shore together as one unit and support against possible eccentric loads applied to it.
  - A 2 X 4 or 2 X 6 nailed on both sides of the wall plates in opposite directions of each other to resist lateral deflection from either side.

Horizontal Shore

- STABILIZE PASSAGEWAYS
- 2 - 3 SUPPORT STRUTS
- DEBRIS WEIGHT WILL DETERMINE THE SIZE AND NUMBER OF STRUTS NEEDED

Horizontal Shore

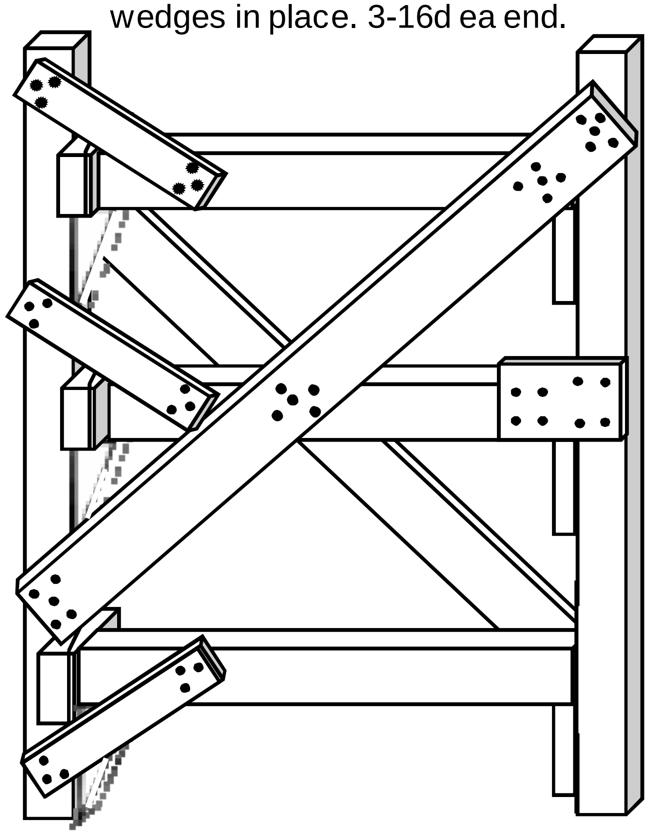


THE HORIZONTAL SHORE (continued)

HORIZONTAL SHORE

Class 2 Shore: Used to resupport damaged or bulging walls. Spacing will depend on conditions, but should not exceed 8 feet.

2x4 Diagonal Cleats
Place as shown in order to hold wedges in place. 3-16d ea end.



Struts are 4x4 or 6x6
Spacing is dependent on condition, but 6 ft maximum. Wedges are best installed at least damaged side (toenail in place)

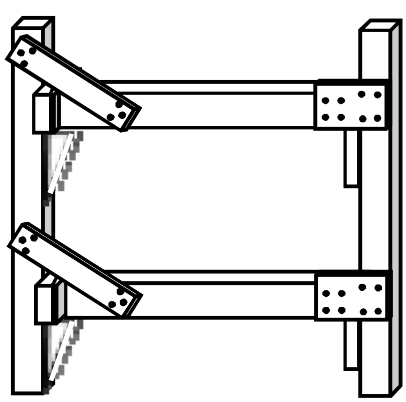
2x4 x14" Cleats
Place as shown under struts at non-wedge ends. 3-16d

4x4 x18" Single Wedge
Place as shown under struts at wedge ends. 3-16d
Use 2x4 wedge + 2x4x14" as alternative.

Half-gussets
Place as shown on one side of each strut, except at diagonals.

2x6 Diagonal Braces
Place in X as shown, except when area is used for access. 5-16d ea end and ea strut.

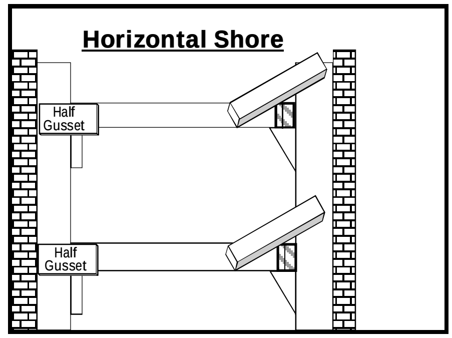
Note:
Bottom strut may be placed at bottom when area is used for access



Note:
Configuration when only 2 struts are needed

HOW TO CONSTRUCT THE HORIZONTAL SHORE

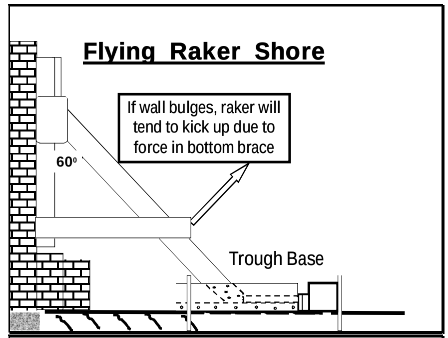
1. Determine where to erect the horizontal shore
   - After initial temporary shoring has been installed as needed, clear the area of debris.
   - A clearance of three to four feet wide is usually adequate.
2. Measure and cut the wall plates to the proper length.
3. Measure and cut the struts to the proper length.
   - Place both wall plates against the walls.
   - Measure between the wall plates where the struts are to be installed, deducting the width of the wedges to be used.
4. Place both wall plates next to each other and attach cleats and single 4 x wedge to the wall plates just below where the struts will be installed.
   - If a 4x wedge is not available, use a 2x wedge on top of a 2x cleat.
5. Place the wall plates in the area that is to be shored, square and in line with each other and as plumb as possible by shimming any void spaces behind the wall plates.
6. Install the struts between the wall plates. Keep the struts in line and flush with the wall plates.
7. Install a set of wedges behind one end of each strut and tap them together simultaneously until the struts are under compression and tight.
   - Secure the wedges in by toe-nail the wedges to the wall plate, and by adding a 2 x 4 x18" cleat from wall plate to strut. (on top if possible)
   - Nails may need to be Duplex for future adjustment of the wedges.
8. Attach cleats or half-gusset plates to at least one side of the wall plates and struts at non-wedge end.
9. If possible, attach the wall plates to the walls. (as for rakers)
10. Attach the diagonal braces to each side of the horizontal shore when **<u>not used</u>** for access or egress.
    - The diagonal braces should be long enough to span entire length and be attached to both wall plates and each strut.
    - When used, diagonal braces should be installed in an **X** pattern on opposite sides of the system.

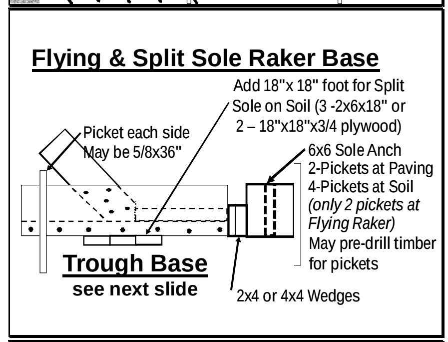


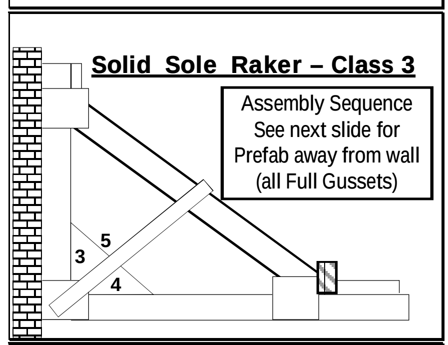
THE RAKER SHORE

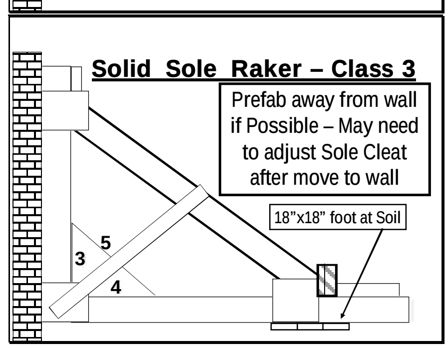
The main purpose of the Raker shore is to support leaning or unstable walls and columns by transferring additional weight down the Raker, to the ground or other supporting members, and away from the wall or column.

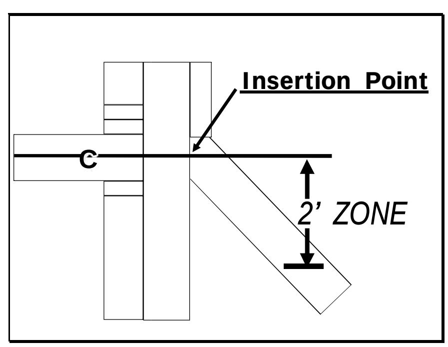
- Full Triangular, Raker shores must always be installed in series; **at least two** must be erected in any given situation and braced together with a maximum spacing of 8 feet.
- Two general styles of Raker shores are the (Flying) Friction Raker Shore and the (Full Triangle) Fixed Raker Shore. As indicated below there are two configurations of Full Triangle, Fixed Rakers.
- The (Flying) **Friction Raker Shore – Spot Shore**
  - May be considered for initial temporary shoring due to its ease of construction and fewer shoring materials when followed with a group of well-braced (Full Triangle) Fixed Raker Shores.
  - Attach the wall plate directly to the wall to eliminate slippage/shifting and increase stability.
  - This Raker should be configured at a 60 degree angle (from horizontal) in most cases
  - Trough is preferred base.
- (Full Triangle) **Fixed Raker Shore – Class 3 w/bracg**
  - All of the structural elements are tied together, making the shore one integral unit and provides the best method of anchoring and bracing, but requires the most shoring material.
  - The shore itself is stable and because of its ability to stay together this style of shoring is most often recommended for rescue situations.
  - Both type of Fixed Rakers may be constructed on concrete, paving, or soil
- The two types of (Full Triangle) Fixed Raker Shores are the solid sole plate and the split sole plate.
  - The Solid Sole Raker Shore is utilized in locations where concrete/asphalt cover the ground, or when there is open ground
  - The Split Sole Plate Raker Shore is utilized in locations where rubble is piled-up against a wall (which would be dangerous to remove) .
- Raker Shore Insertion Point (Support Point)
  - The insertion/support point at which the Raker shore should intercept the buildings load is within two feet below the center of the floor or roof joist.
  - Rounding-off height of the raker support point to the nearest foot will make it easier to measure.











THE RAKER SHORE (continued)

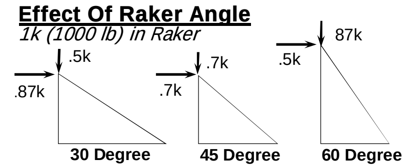
- The two common angles used are 45 and 60 degrees.
  - 60 degree angle is the max. recommended angle.
  - 60 degree angle is preferred for Flying Rakers and may be used for Solid & Split Sole Rakers.
  - 45 degree angle if most often used for Solid Sole Rakers, and may be used for Split Sole.
  - 30 degree angles have been used to brace some structures when adequate space was available.
- Determining the height at which the raker shore needs to intersect the wall will identify the angle to work best with the available lengths of lumber.
  - A 45 degree angle raker shore requires longer lumber than a 60 degree raker shore to reach the same insertion point.
- **Length of a 45-degree** angle raker shore: Height of the raker shore support point in feet multiplied by 17 will give the length of the raker, tip to tip, in inches. (8 ft x 17 = 136" or 11'- 4" & horiz. distance is 8 ft).
- **Length of a 60-degree** angle raker shore: Height of the raker shore support point in feet multiplied by 14 will give the length of the raker, tip to tip, in inches.
- (8 ft x 14 = 112" or 9'- 4" & horiz. dist. is 8 x 7" = 56" or 4'-8").

RAKER DIMENSIONS TABLE (based on info above)

Insertion Point, Ft	45° Raker L Inches / Feet	60° Raker L Inches / Feet	60° Horiz. Dist. Inches / Feet
3	51" / 4'- 3"	42" / 3'- 6"	21" / 1'-9"
4	68" / 5'- 8"	56" / 4'- 8"	28" / 2'-4"
5	85" / 7'-1"	70" / 5'- 10"	35" / 2'-11"
6	102" / 8'- 6"	84" / 7'- 0"	42" / 3'-6"
7	119" / 9'- 11"	98" / 8'- 2"	49" / 4'-1"
8	136" / 11'- 4"	112" / 9'- 4"	56" / 4'-8"
9	153" / 12'- 9"	126" / 10'- 6"	63" / 5'-3"
10	170" / 14'- 2"	140" / 11'- 8"	70" / 5'-10"
11	187" / 15'- 7"	154" / 12'- 10"	77"/ 6'-5"
12	204" / 17'- 0"	168" / 14'- 0"	84"/ 7'-0"
13	221" / 18'- 5"	182" / 15'- 2"	91" / 7'-7"
14	238" / 19'- 10"	196"/ 16'- 4"	98" /8'-2"
15	255" / 21'- 3"	210" / 17'- 6"	105"/ 8'-9"
16	272" / 22'- 8"	224" / 18'- 8"	112"/ 9'-4"
17	289" / 24'- 1"	238" / 19'- 10"	119"/ 9'-11"
18	306" / 25'- 6"	252" / 21'- 0"	126"/ 10'-6"
19	323" / 26'- 11"	266" / 22'- 2"	133"/ 11'-1"
20	340"/ 28'- 4"	280" / 23'- 4"	140"/ 11'-8"

The Insertion Point may be measured from the ground, and or the top of the Sole Plate without causing much change in the Raker Angle

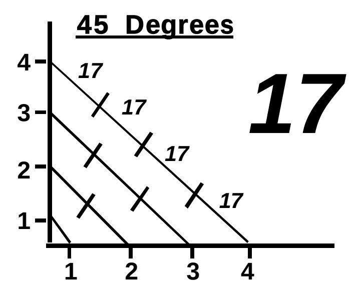
Effect Of Raker Angle
1k (1000 lb) in Raker

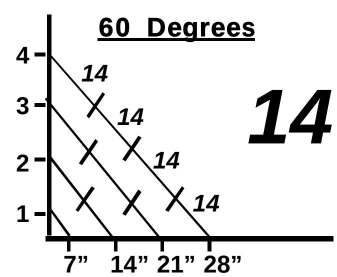


- Approximate Horizontal Design Capacity of Rakers
  - Full Triangle Rakers is about 2.5 k
    - Based on Cleat Nailing + Friction
  - Flying Raker is about 1k
    - For 4 x 4 Raker, due to compression plus bending

Raker Shore Angles

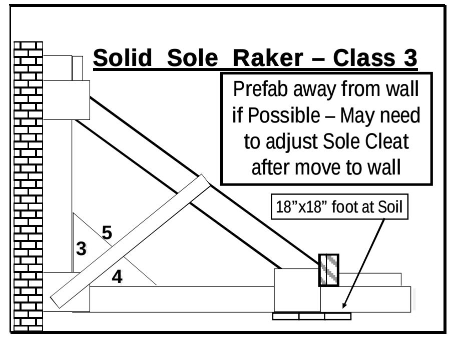
DEGREE	PITCH	LENGTH
45 deg	12/12	17
60 deg	12/7	14

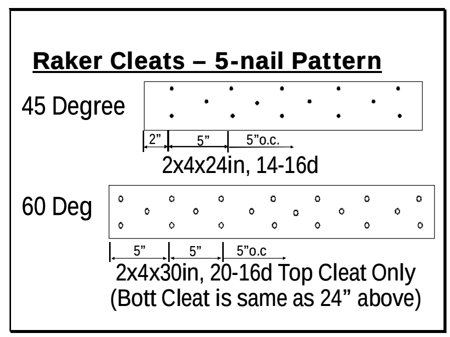


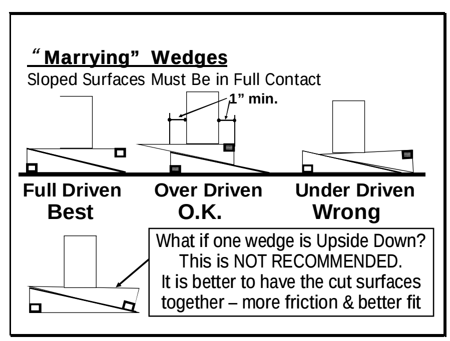


STRUCTURAL COMPONENTS of the RAKER SHORE

- The **Wall Plate** provides a foundation for the shoring system by collecting the load being applied laterally (horizontally) and spreads it into the shoring system.
- The **Sole Plate** receives the load being transferred both vertically and horizontally distributes it into the ground and other structural supporting members.
  - For rakers on soil, add 3-2x6x18" under sole where raker intersects (unless soil is very hard)
- The **Raker** supports the load being collected by the wall plate and transfers it to the sole plate.
  - The wall plate, sole plate and raker should be the same width for a more secure attachment.
  - Buildings with heavy structural elements or support points taller than 16 feet may require lumber larger than 4 x 4 for the wall plate, sole plate and raker. (or spliced 4x)
- The **Top Cleat** a piece of 2x lumber nailed to the top of the wall plate to keep the raker from riding up the wall plate.
  - Use 2 x 4 , twenty-four inches long, with 14-16d for 4x4 Rakers at 45 degree angles or less.
  - Use 2 x 4, thirty inches long, with 20-16d nails for 4x4 Rakers at 60-degree angles.
  - See **O/H-17,** later in this Module, for others
- The **Bottom Cleat** two foot piece of 2x lumber nailed to the top of the sole plate to keep the raker from riding back on the sole plate. **(14-16d for 2x4, at both 45 & 60 degree angles)**
  - If possible and practical, the bottom cleat and sole on the solid sole plate raker shore should be made long enough to return back to a solid object, such as an adjoining wall.
- **Wedges** two wooden incline planes married together and placed against the back end of the raker and the bottom cleat.
  - Simultaneously tapped together until the shoring system is under compression and takes the weight of the structure
  - **2x wedges are more stable than 4x, and are preferred**

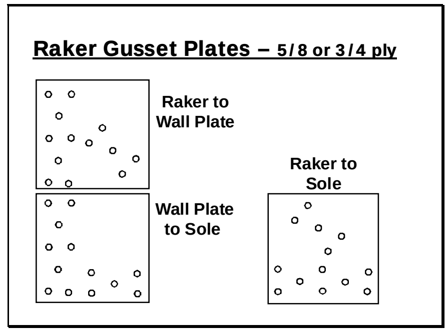


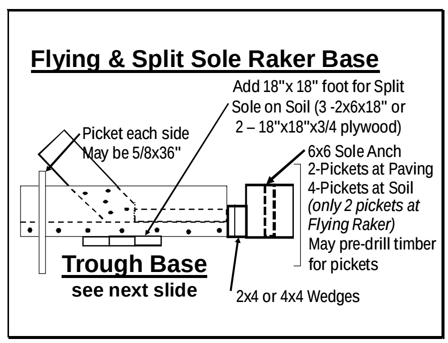


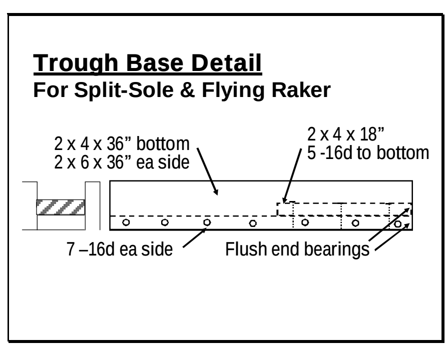


STRUCTURAL COMPONENTS of the RAKER SHORE (cont)

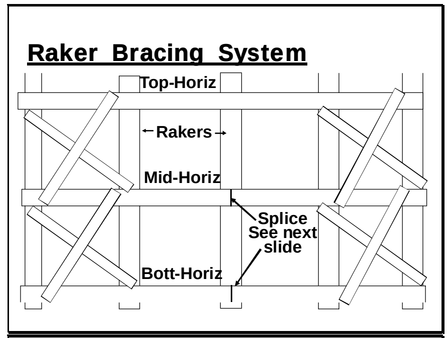
- **Gusset Plates** 12" X 12" pieces of 5/8 or 3/4" plywood nailed on both sides of the wall plate and sole plate connection and the top and bottom of the raker to prevent the them from being dislodged.
  - Split sole raker shores require gusset plates on both sides of wall plate at the top of the raker only.
- **Mid Point Braces** increase the strength of the raker by reducing the L/D ratio.
  - These braces should be long enough to reach from the wall plate and sole plate connection to near the mid point of the Raker.
  - On the solid sole Raker shore, a 2 X 6 or two 2 X 4 are nailed to both sides of the wall plate and sole plate connection and mid point on the Raker.
  - On the split sole Raker shore, a 2 X 6 or two 2 X 4 are nailed to both sides of the wall plate and just above the bottom braces connection and mid point on the Raker.
- **Bottom Braces** on split sole raker shores, a 2 X 6 or two 2 X 4 are nailed just above the ground and attached as close to the bottom of the raker as possible and the bottom of the wall plate with a fill block near the middle for additional stability.
  - For Friction (Flying) Raker Shore, the bottom brace is placed perpendicular to the wall plate (level with horizontal), within a few inches of the bottom of the wall plate.
- **Trough** is the preferred foot for the Friction and Split Sole Raker when bearing on Paving or Soil
  - It needs to be anchored against a Sole Anchor w/Pickets, and existing curb, or some other reliable object. On paving, drilled-in metal anchors may be used.
  - When bearing on soil, the standard 18"x 18" Foot is added under the Trough, and centered on the intersection of the raker. The Foot is made from 3-2x6 x 18" or two pieces of 18"x 18"x 3/4" plywood.



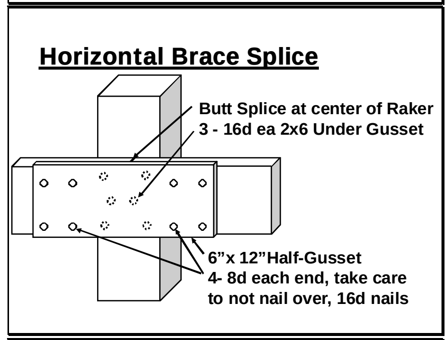




STRUCTURAL COMPONENTS of RAKER SHORE (cont)



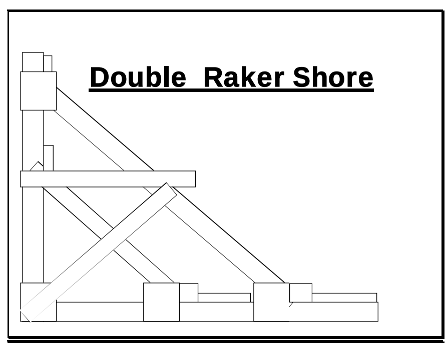
- **Horizontal Braces** horizontally connects the raker shores together near the top and bottom of the raker to provide additional stability to the raker shore system.
  - Horizontal braces attached to the mid-point of the raker increase the strength of the raker by reducing L/D ratio.
  - Splice the horizontal brace at center of Raker and cover splice with half-gusset, as shown in adjacent slide.
- **X** and **V Braces** connects the raker shores in an **X** or **V** pattern near the bottom and middle of the raker depending on access needs and available lumber.
  - Provides additional stability to the raker shore system and decreases the lateral movement when at least a pair are used at the beginning and end of the raker shore system.
  - This bracing should be placed no farther than 40 feet on center for a multi-raker system



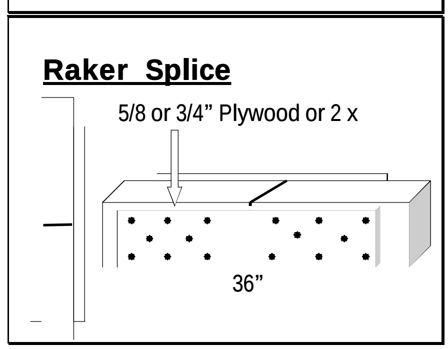
- **Backing Material (Optional, Only if Needed, See Pg. 54)**
  - 5/8"or 3/4" plywood or two sheets of 1/2"plywood nailed together.
  - For connecting **Wall Plate to Wood Walls:**
    - Use 2ft high x 3ft wide plywood, (or 4ft x 4ft if needed)
    - Nail 16-16d to Wall Plate.
    - Center Raker on a stud, and nail ply with 8-16d each side to adjacent studs, and/or edge of floor.
  - For providing better distributed support to badly cracked **Concrete and URM Walls:**
    - Use 4ftx 4ft plywood, (or 4ft x 8ft if needed)
    - Nail 16-16d to Wall Plate.
    - Connect plywood backing to the wall using standard 1/2" x 12" bars (2 min) each side of raker. Make sure bars penetrate into sound concrete or URM.
  - Backing material must contact the wall at the raker Insertion/support point and at the bottom of wall plate. Use shims, or plywood to fill void spaces, if needed.

Backing for Rakers at Wall Plate

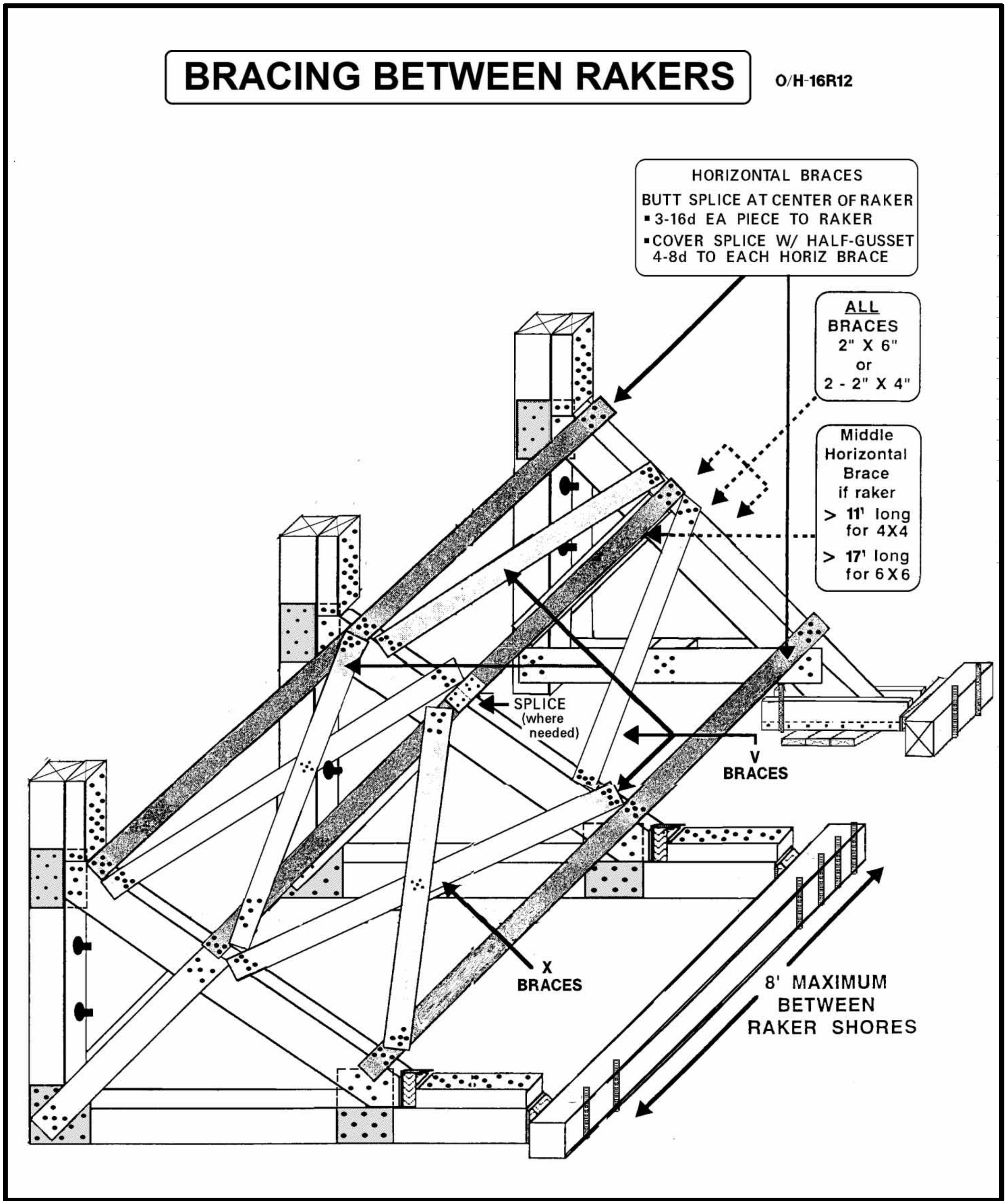
- Backing may be 5/8" or 3/4" plywood (or 2 layers of 1/2" plywood)
  - Nail backing to wall plate with 16-16d nails
  - See later details for connection to walls.
- Backing for badly cracked Concrete or URM Walls
  - Use 4ft x 4ft ply. (or 4ft x 8ft if needed) to spread-out the raker supporting effect.
- Backing used for Wood Walls
  - Use 2ft high x 3ft wide ply. to connect to studs. (or 4ft x 4ft if needed).
  - Center Wall Plate on a stud



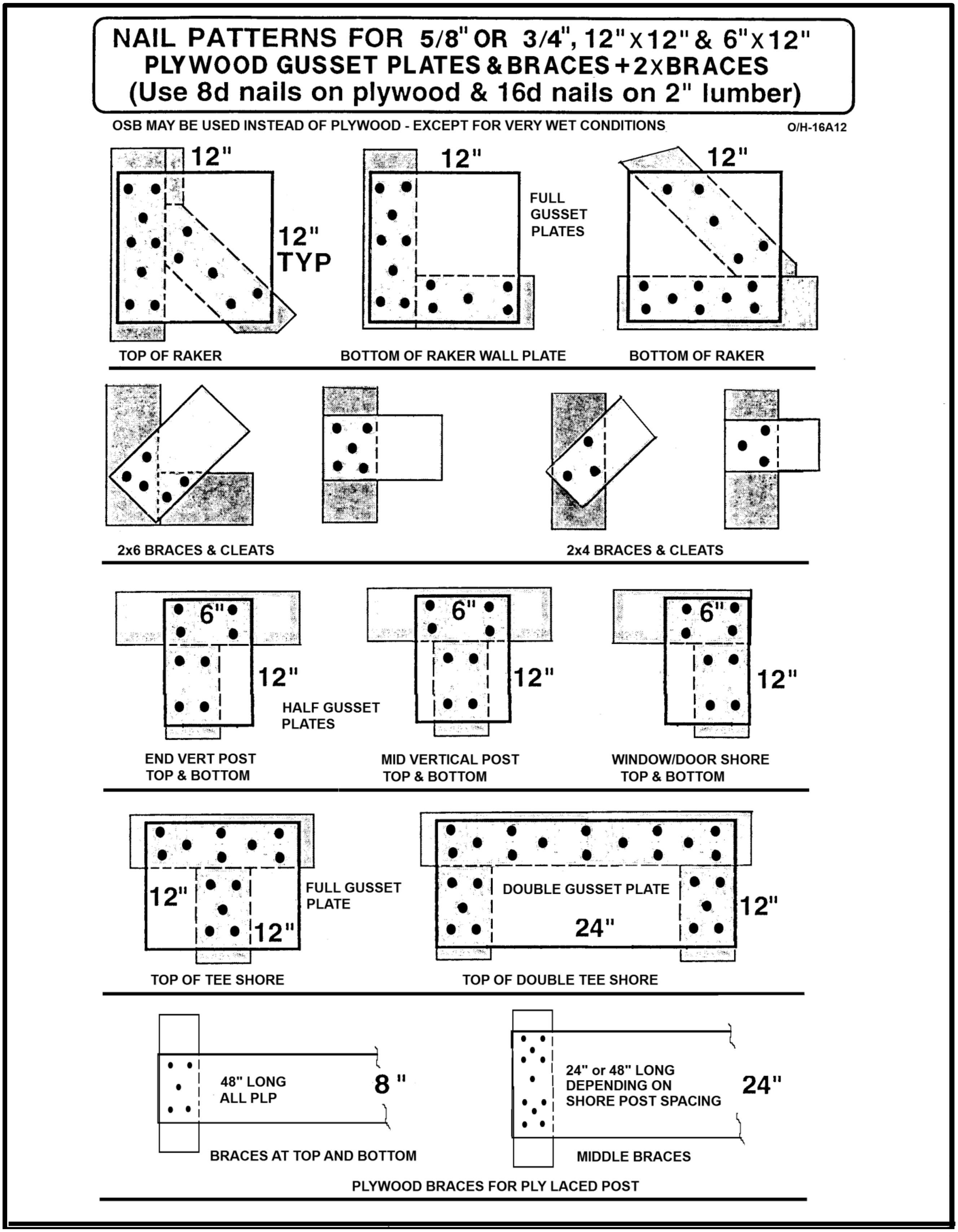
- **Splicing the Raker Shore**
  - If available length of 4x4 or 6x6 is insufficient to extend to the required insertion point, the Raker may be spliced.
  - The splice should be constructed where mid-brace and mid horizontal lateral brace intersects
  - The splice may be most necessary for the Double Raker, as shown in the adjacent slide above the splice



STRUCTURAL COMPONENTS OF THE RAKER SHORE (continued)



NAIL PATTERNS FOR RAKER AND OTHER SHORES

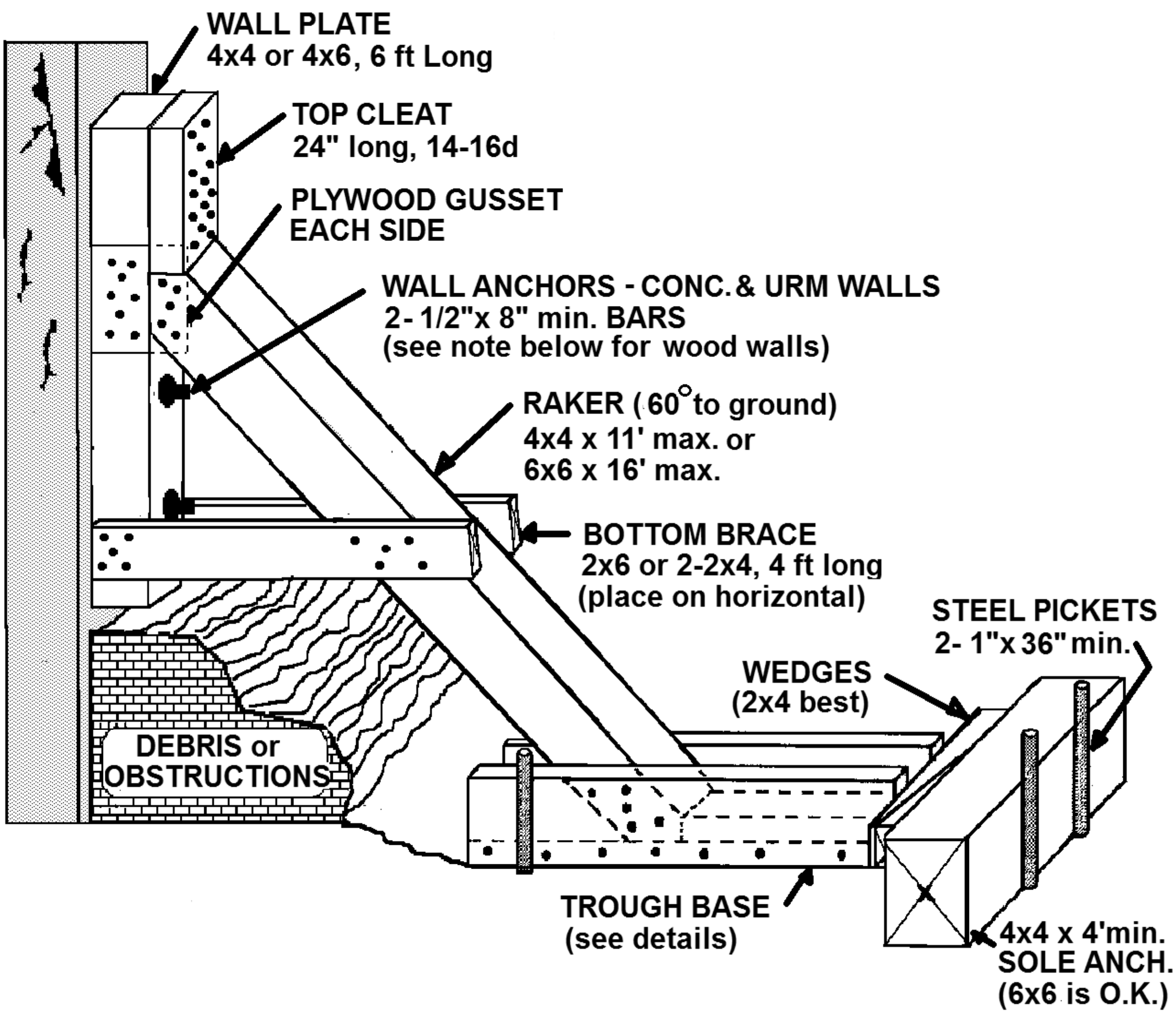


THE RAKER SHORE (continued)

FLYING RAKER SHORE

WITH LEVEL BOTTOM BRACE and TROUGH BASE

THIS RAKER IS BEST TO BUILD AS A TEMPORARY SHORE. IT MAY BE FOLLOWED BY BUILDING A BRACED, FULL TRIANGLE RAKER SYSTEM.



ANCHOR WALL PL TO WOOD WALL
W/ 2'x3'x 5/8"or 3/4" PLY (center on raker)
16 -16d into WALL PLATE
8 -16d each side RAKER into STUDS/FLOOR
CENTER RAKER ON A STUD, IF POSSIBLE

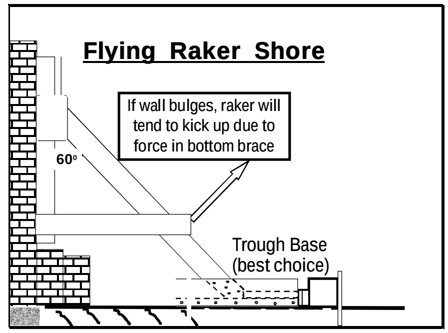
RAKER, WALL PLATE, & SOLE SHOULD BE THE SAME WIDTH

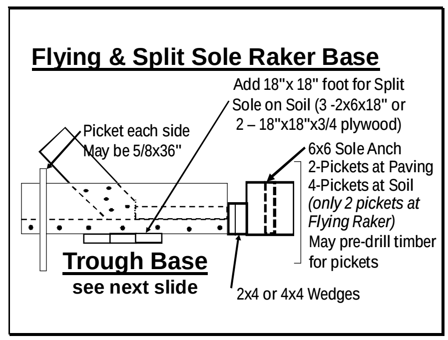
THIS RAKER MAY BE BUILT ON CONCRETE or AC PAVING, and on SOIL AS SHOWN.

HOW TO CONSTRUCT A FLYING RAKER SHORE

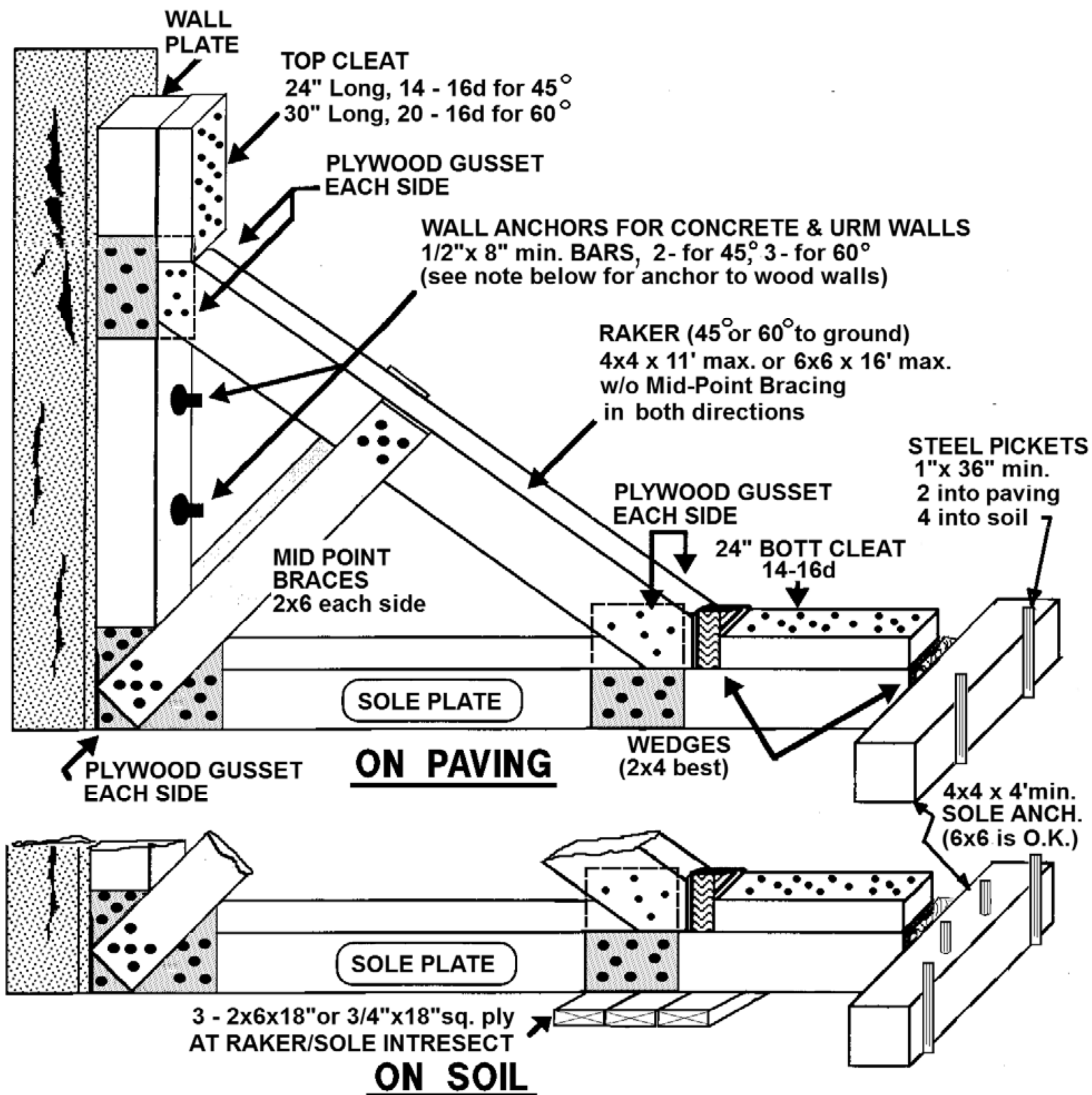
All shoring should be **pre-fabricated** if possible, to **Minimize the exposure of Rescue Personnel to Risk**

1. The areas to be supported by rakers should be considered extremely dangerous. Temporary Flying Rakers may need to be erected prior to building more permanent, Full Triangle Raker systems.
   a. Determine where to erect the Raker shores and the height of its Insertion Point.
2. Flying Rakers can be erected against the wall without removing the Debris that may be piled up against it.
   a. They may be used as single Spot Shores, or may be built in pairs with horizontal & X bracing added between pairs.
   b. Flying Rakers should be prefabricated, fit into their Trough, wedged and/or shimmed, then attached to the wall with a minimum of two 1/2" x 12" bars or drill-ins.
   c. In some cases the bars/drill-ins may be omitted if the top of the Wall Plate can bear against a protrusion in brick/concrete wall**. OR d.**
   d. At brick/concrete wall, Raker may be built at one edge of a window, with a single or double 2x4 (24" min w/14-16d) pre-nailed to the Wall Plate so it will bear on the bottom of Window Header **(Only if header is not badly cracked).**
3. In order to pre-fabricate, cut raker, wall plate & bottom brace to proper length, & perform raker angle cuts.
   a. Layout Wall Plate, Raker and Bottom Brace at selected angle (normally 60 deg raker angle), and toenail Raker to Wall Plate.
   b. Nail on Top Cleat, then nail gusset to one side of this joint.
   c. Nail one-Bottom Brace to Wall Plate in position to clear debris, but only tack-nail it to Raker.
   d. Turn Shore over and nail-on other gusset and bottom brace (nailed to Wall Plate, tack to Raker).
4. Anchor Trough, (normally using Sole Anchor), then carry the partly assembled Raker into place. Snug-up the Wedges, and complete the nailing of bottom brace to Raker.
   a. Make whatever connection to wall that is selected, as indicated above, and retighten the Wedges.
   b. A Trough Base is used to reduce the risk of digging adjacent to the Collapse Zone, and may be used on concrete, paving, or soil.





THE RAKER SHORE (continued)



ANCHOR WALL PL TO WOOD WALL
W/ 2'x3'x 5/8"or 3/4" PLY (center on raker)
16-16d into WALL PLATE
8 -16d each side RAKER into STUDS/FLOOR
CENTER RAKER ON A STUD, IF POSSIBLE

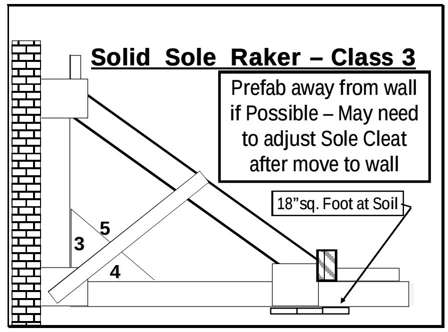
RAKER, WALL PLATE, & SOLE SHOULD BE THE SAME WIDTH

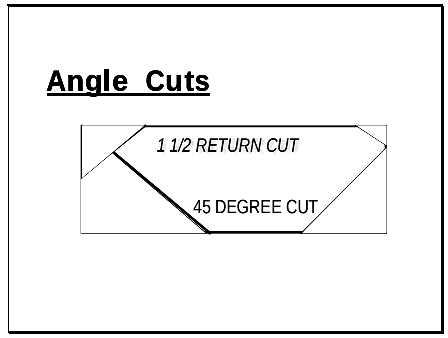
THIS RAKER MAY BE BUILT ON CONCRETE or AC PAVING, and on SOIL AS SHOWN.

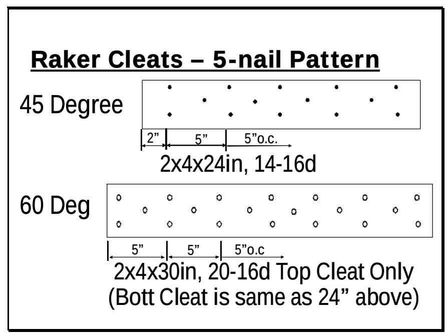
HOW to CONSTRUCT a SOLID SOLE RAKER SHORE

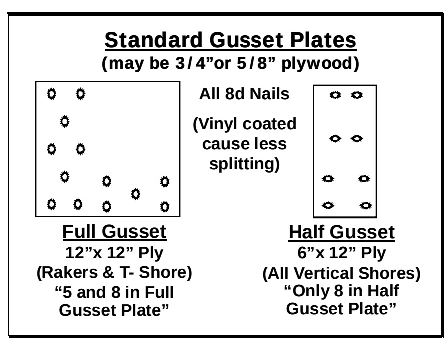
All shoring should be **pre-fabricated** if possible, to **Minimize the exposure of Rescue Personnel to Risk**

1. Determine where to erect the Raker shores & height of its support points. Find height of Insertion Point
   a. After initial temporary shoring has been installed as needed, clear the area of debris.
   b. If area is not easily cleared of debris, consider Split Sole Raker
2. Select angle of Raker, then measure and cut the Wall Plate, Sole Plate and Raker to the proper length.
   a. Sole plate and Wall Plate must extend at least 24 inches from where the Raker intersects them to allow for the Cleats to be nailed.
   b. Both ends of the Raker to be angle-cut with 1½ " return cuts for full contact with the wall plate, top cleat, sole plate, and wedges.
3. Pre-fabricate Wall Plate, Raker and Sole
   a. Toenail Sole to base of Wall Plate, square inside to 90 deg, and secure with bottom, full- gusset plate, one side
   b. Layout Raker at selected angle, intersecting with Wall Plate and Sole. Then install Top Cleat and nail on gusset one side of this top joint
   c. Nail one Sole Gusset to Raker, but not to Sole at this time, since Raker may need adjusting when moved to wall.
   d. Mark the Sole for the approximate position of the Bottom Cleat, allowing for the Wedges
   e. Flip Raker Shore over and nail full-gussets on opposite side, but remember to nail the Raker to Sole Gusset, to Raker only, not to Sole to allow for later adjustment
4. Carefully move the part- prefabricated shore in place at the wall and make sure it is plumb. (side to side)
   a. With Raker Shore placed against the wall, the Sole should be carefully driven-in so the Wall Plate is snug against the Wall, and the Bottom Cleat should be completely nailed, allowing space for the Wedges
   b. Full contact must be maintained between the wall plate and the support point of the Raker, and between the base of the wall plate and the wall.
      - If the wall has bulged out, shims may need to be added near bottom of wall plate



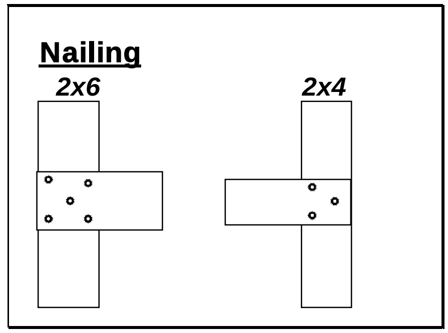


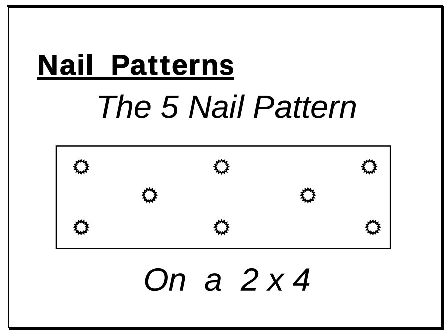




HOW to CONSTRUCT a SOLID SOLE RAKER (cont.)

5. After Anchoring the Sole Plate as noted in 10. on next page, install wedges between the bottom cleat and the base of the Raker and tighten them slightly.
    a. After adjusting the shims/spacers (if any) between the wall plate and wall being shored to ensure full contact, as in 4a. above, finish tightening the wedges and complete nailing of gusset plates on each side.
    b. When the sole is being supported by soil, add 3-2x6x18" under the sole where it intersects raker
6. With Raker shore erected, prevent the Raker shore from sliding up the wall. See following graphics.
    a. To attach wall plate to concrete/masonry wall.
        - A minimum of two 1/2" x 12"drill-in anchors, or rebar (or smooth bar) should be placed through the wall plate for 45 deg rakers and min of 3 for 60 deg. As alternative, steel angles each side of wall plate may be used. See Raker Cleats, Cuts & Anchors graphic.
        - If backing material is needed, use plywood with 16-16d nails to wall plate. Connect backing to wall using two-1/2" x 12" bars (rebar or smooth) each side of raker. Make sure bars penetrate into sound concrete or URM. See Raker Backing at Walls graphic.
    b. To attach the wall plate directly to a wood framed wall. (Top of ply should be near floor line)
        - Use 2ft high x 3ft wide (min.) plywood backing, centered on, and nailed to back of wall plate with 16-16dnails. If needed 4ft x 4ft plywood, may be used.
        - Center raker on a stud and, nail at least 8-16d nails through the backing material into wall studs, and/or edge of floor, each side of Raker
7. Attach Mid Point Braces (required if 4x4 raker is longer than 11 ft and/or 6x6 raker is longer than17 ft)
    a. One 2x6 are nailed to both sides of the Wall Plate/Sole Plate connection and mid-point on the Raker. (if 2x6 is not available, 2x4 may be used)
8. Attach Horizontal Braces
    a. Connect Raker shores together near the top and bottom of the Raker with at least 2x6, or two 2x4s.
    b. If a mid-brace is required, an additional Horizontal Brace shall be placed near mid-point of the Raker, near where Mid-Point Braces intersect

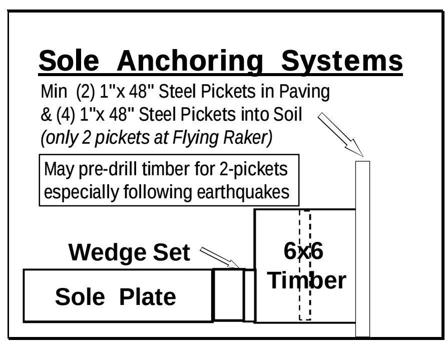




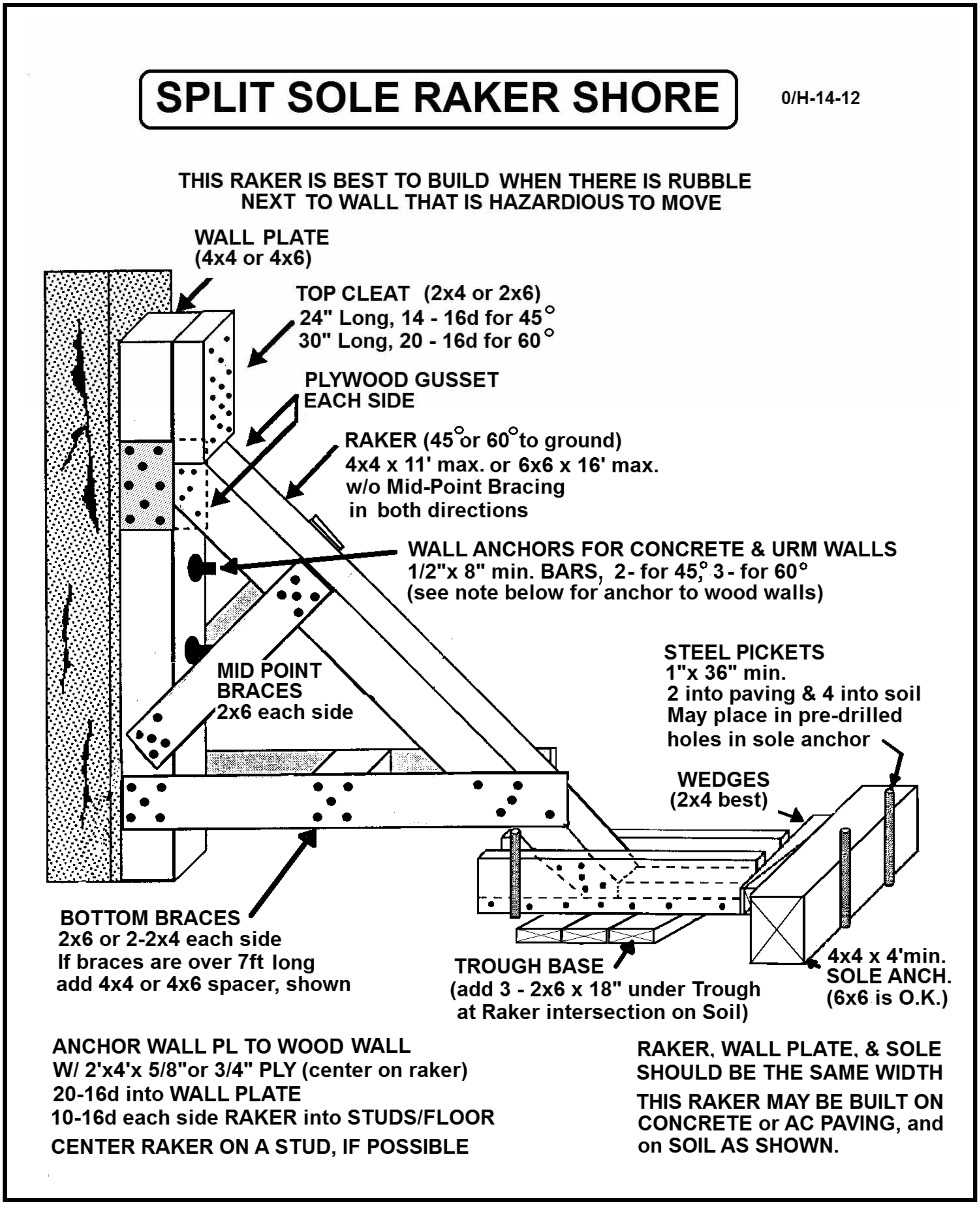
HOW to CONSTRUCT a SOLID SOLE RAKER (cont.)

9. Attach X or V Braces
   a. All Raker shore systems must be connected with either X or V bracing near the top and bottom of the Raker between at least two Raker shores with 2x4 or 2x6.
   b. Attach the **first brace to the Rakers** near the top and bottom between the upper and lower horizontal braces. (between the lower and mid-horizontal, and the mid and upper horizontal when mid-braces are required
   c. Attach the **second brace to the upper, mid, and lower horizontal braces** near the Rakers. (but not on top of the nailing of horizontals the rakers)

10. **Methods to Anchor the Sole Plate**: in order to prevent the Raker from sliding back away from the wall.
    a. **Preferred Method**: Use Sole Anchor (as shown in Raker Graphics) on concrete, paving or soil. Drive two or four, 1" x 36" steel bars or rebar into paving or soil directly behind the Sole Anchor. For concrete slabs lead holes will need to be drilled.
    b. **Alternate Method**: Attach the sole plate directly to concrete, asphalt or dirt: drill a minimum of two 1" holes through the sole plate, concrete, or asphalt and drive 1" x 36" steel pickets or rebar directly into the conc/paving. Need at least 4 – 1" x 36" pickets/rebar if driven directly into soil.
    c. **Other Alternative Methods**: (see Raker Cleats, Cuts, & Anchors graphic)
       - Use a minimum of two steel angles each side of sole that is connected to concrete/paving with drill-ins.
       - Use special steel brackets to secure the sole anchor that are attached with steel bars or drill-ins
       - Concrete curbs, walls and other nearby secure structures may also be used, by extending the sole, or adding timber fill.

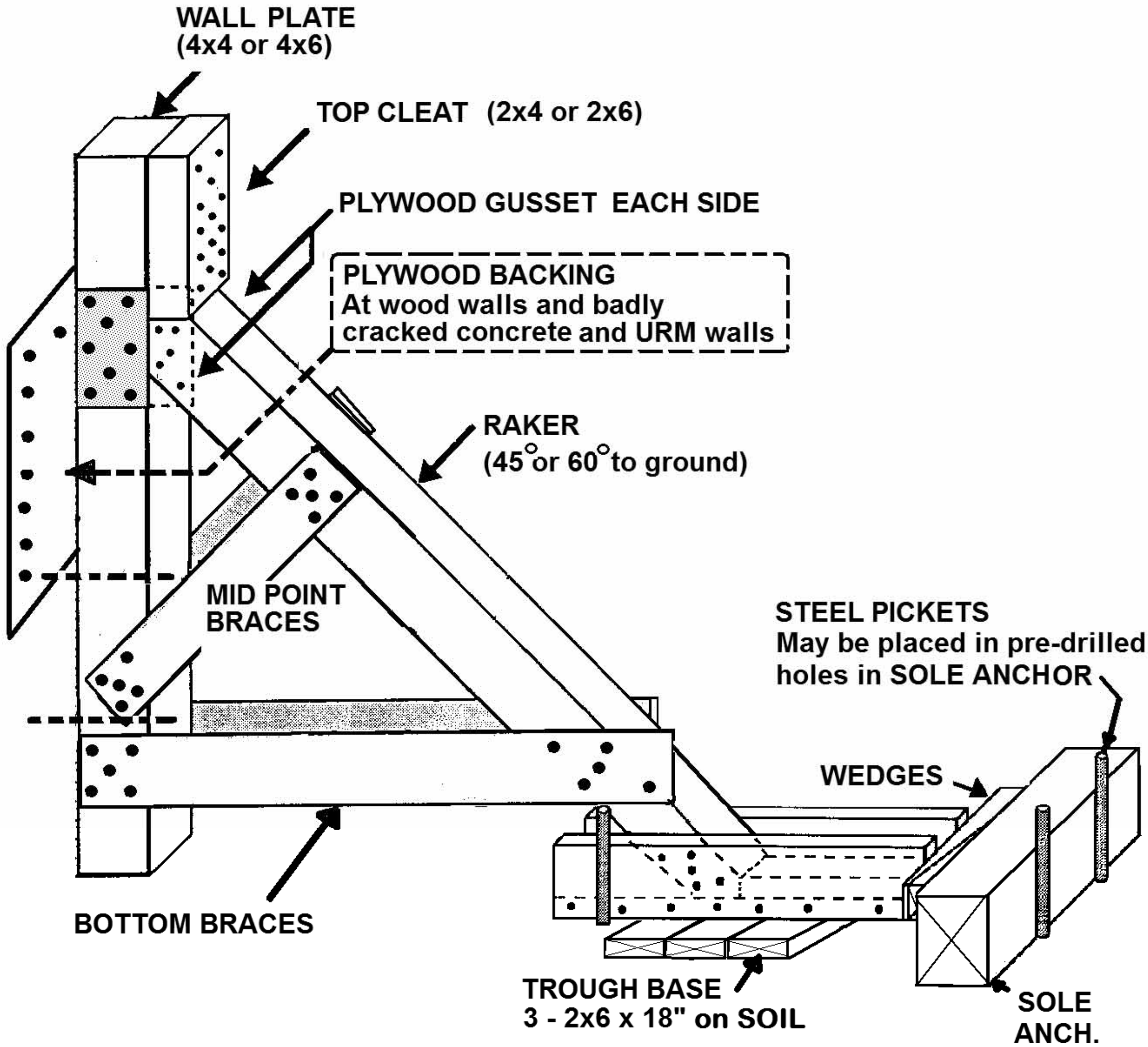


THE RAKER SHORE (continued)



RAKER BACKING AT WALLS

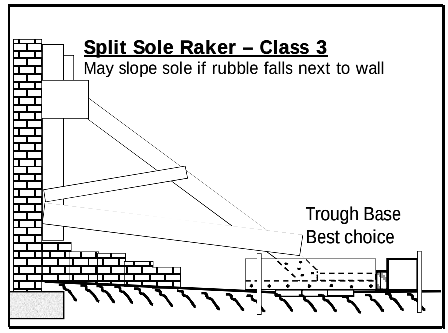
**SHOWING PLYWOOD BACKING BETWEEN RAKER AND WALL.
APPLIES TO FLYING, SOLID SOLE AND SPLIT SOLE RAKERS.**



PLYWOOD BACKING INFO

- USE 5/8" OR 3/4" PLYWOOD WITH 16-16d INTO WALL PLATE. (2 layers of 1/2" ply is alternative)
- USE 24"high x 36"wide PLY'WD FOR WOOD WALLS. (minimum)
- USE 48"x 48" or 48"x 96" PLY'WD FOR CONC & URM WALLS AS NEEDED
- AT WOOD WALL, CENTER WALL PLATE ON A STUD. NAIL 8 -16d EACH SIDE RAKER TO ADJACENT STUDS AND/OR FLOOR.
- AT CONCRETE OR URM WALLS, USE A MINIMUM OF 2 - 1/2" REBAR THROUGH PLYWOOD INTO SOUND CONCRETE OR URM EACH SIDE OF RAKER.

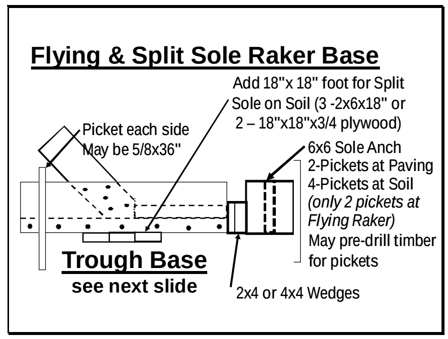
HOW to CONSTRUCT a SPLIT SOLE RAKER SHORE



1. Determine where to erect the Raker Shores and the height of its support points. Determine height of Insertion Point
   a. After initial temporary shoring has been installed as needed, clear only the amount of debris that is necessary, since bottom brace may be placed above debris that is up to about 3 feet high.
2. Select angle of Raker, then measure and cut the Wall Plate, Raker, and Bottom Brace to the proper length.
   a. If there is rubble next to wall, Wall plate will not extend to the ground, and Bottom Brace should be attached 6" from bottom of Wall Plate, and slope down to Base.
   b. Raker angle may be 45 or 60 deg if Trough Base is used.
   c. For Trough Base, both ends of the Raker to be angle-cut with 1½ " return cuts for full contact with the wall plate, top cleat, and Trough Cleat.
3. Pre-fabricate and cut, Raker, Wall Plate, Bottom Brace, and Sole Anchor to proper length, and perform angle cuts on Raker
   a. Layout Wall Plate, Raker and Bottom Brace at selected angle, and toenail Raker to Wall Plate.
   b. Nail on Top Cleat, then nail gusset to one side of this joint
   c. Nail one-Bottom Brace to Wall Plate, 12" from bottom, or in position to clear debris, but only tack-nail it to Raker.
   d. Turn Shore over and nail-on other gusset plus other Bottom Brace to Wall Plate
   e. Tack-nail Bottom Brace to Raker, so it can be moved into place at the wall.
      - If there is rubble against the wall the Bottom Brace should slope down from the wall to the Raker Base, and intersect as close to the Base as possible

HOW to CONSTRUCT a SPLIT SOLE RAKER (cont.)

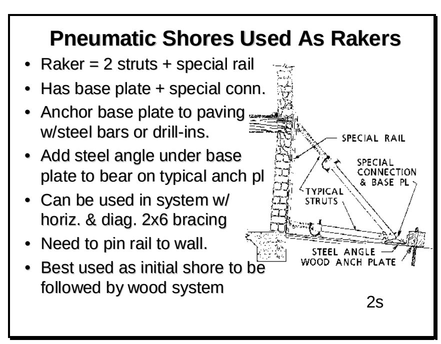
4. Carefully move the partially prefabricated Split Sole Raker Shore in place at the wall and make sure it is plumb (side to side).
   a. After securing the Sole Anchor, adjust the Trough, and drive wedges against it.
   b. Full contact must be maintained between the wall plate and the support point of the Raker, and between the base of the wall plate and the wall.
      - If the wall has bulged out, shims may need to be added near bottom of wall plate)
   c. After adjusting the shims/spacers (if any) between the wall plate and wall being shored to ensure full contact, finish tightening the wedges and/or complete nailing of Bottom Brace on each side.



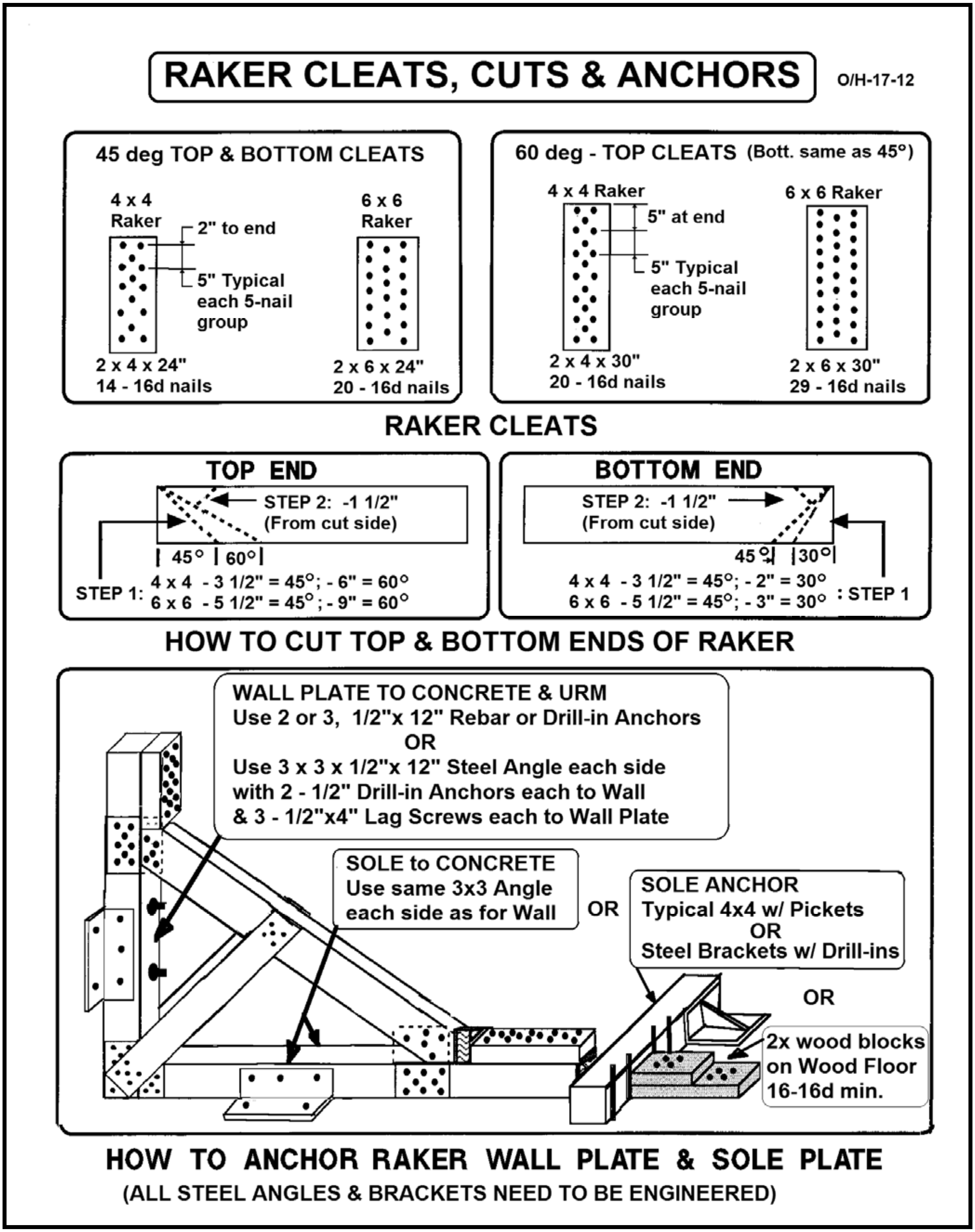
5. With Split Sole Raker shore erected, prevent the Raker shore from sliding up the wall. See Solid Sole Raker Shore
   - Common method for concrete & masonry walls is to use ½" x 12" bars through wall plate into the supported wall. (use 2 for 45 deg & 3 for 60 deg.)
   - For backing and connections for wood walls and badly cracked Concrete/masonry walls, see Solid Sole Raker
6. Place the Mid-Brace, if required by length of Raker, and erect the Horizontal and X-bracing
7. Anchor the Sole Anchor against Trough, same as for Solid Sole Raker Sole Anchor

OTHER PRE-CONSTRUCTED RAKER SHORES

- Pneumatic Shores can be used as temporary Rakers as illustrated in adjacent slide. They should be replaced with properly braced wood system for ongoing operations, lasting more than one day.
  - Pneumatic Shores are normally configured as a pair of rakers, spaced 8ft max., and with cross bracing between them.
  - When a mid-brace is installed, these rakers will provide their maximum strength, provided that the cross bracing has a mid-height horizontal that is placed within one foot of where the mid-brace connects to the raker



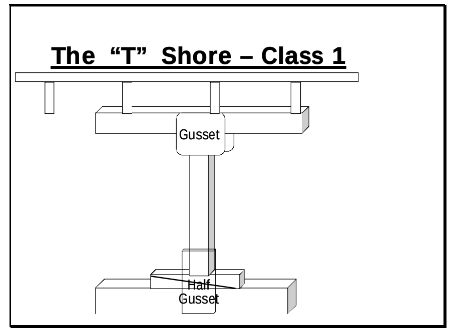
RAKER SHORE CONNECTIONS

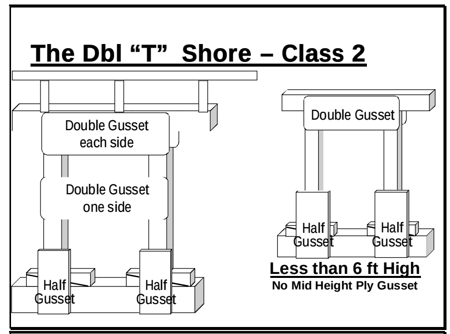


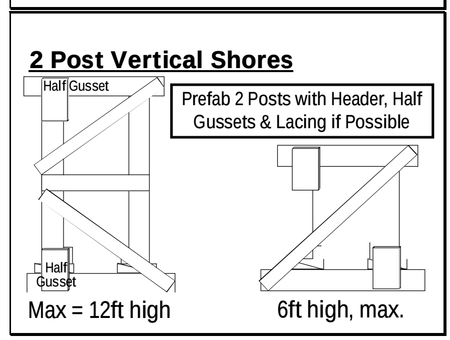
PRE-CONSTRUCTED VERTICAL SHORING SYS
All shoring should be **pre-fabricated** if possible, to **Minimize the exposure of Rescue Personnel to Risk**

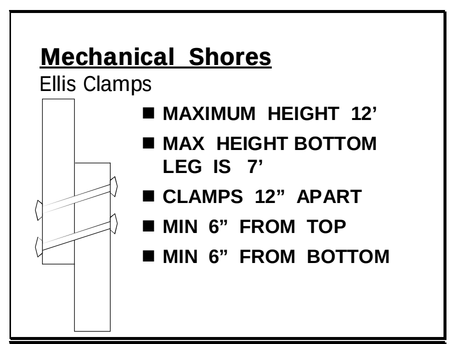
The Vertical Shoring Systems to pre-construct are:

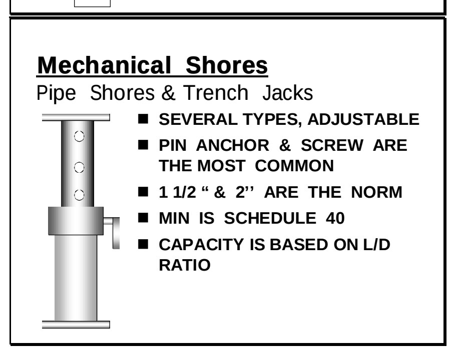
- The "T" and Double "T " Spot Shores
  - Assemble header and post by nailing the upper gussets on both sides.
  - Sole plate, wedges, and half-gussets are added after shore is positioned (as previously discussed)
- Vertical Shore with two posts, diagonal braces and half-gusset plates or cleats connecting the header to the posts.
  - Assemble entire system except for bottom diagonal brace.
  - After moving shore into position, tighten wedges, add bottom diagonal brace, add and nail bottom half-gussets.
- **Ellis Shores** used as a "T" Shore with adjustable post.
  - Ellis Clamp positions on posts are as listed in adjacent slide. (use two nails at each clamp, 8 per post)
  - Slide the upper post under the clamps and manually raise to proper height and pull down on the top clamp.
  - Attach the shore-jack to the lower post under the upper post and lift on the handle.
  - While pressure is being applied to the shore-jack, tap downward on the unsecured end plate of the top clamp and then tap downward on the unsecured end plate of the bottom clamp with a hammer to lock the clamps in place.
  - Assemble header and post by nailing the upper gussets on both sides.
  - Sole plate, wedges, and lower cleats are added after shore is positioned.





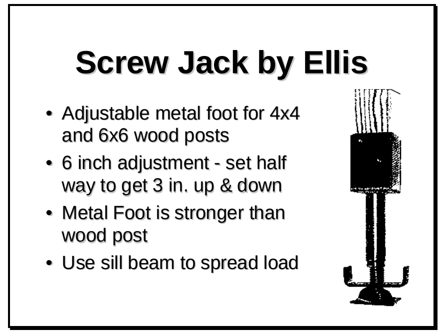




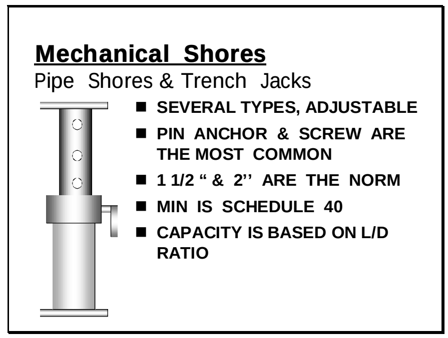


PRE-CONSTRUCTED VERTICAL SHORING SYS (continued)

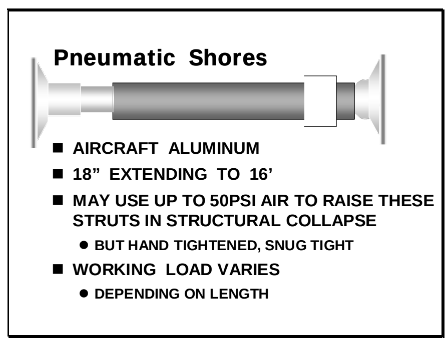
- **Post Screw Jack**, with one or two posts with gusset plates or cleats connecting the header to the posts.
  - Metal Foot should be nailed to sole.
  - Diagonal braces should be added to multi-post system as for Vertical Shores.



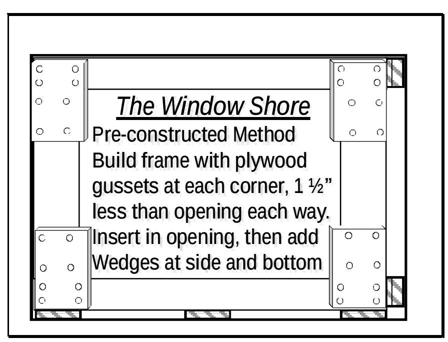
- **Pipe Shores**, with one or more shores.
  - Metal ends should be nailed to header and sole.
  - Diagonal braces cannot be attached unless a special metal fitting is provided by manufacturer.
  - Capacity of 2" pipe is similar to 4x4 wood post, and is dependent on height.
  - Special pipe frames are available that are assembled as a group of four columns with cross bracing, similar to a Laced Post System



- **Pneumatic Shores**, with one or more shores with wood or metal rail header.
  - Metal ends should be nailed to header and sole
  - One manufacturer sells a clamp fitting that allows for, nailed 2x 6 "**X**" bracing to be installed.
  - Pneumatic shores are best used as temporary shores.
  - Some manufacturers provide a Header Rail that may be pre-assembled with two or more struts to provide a pre-constructed, vertical shore.
  - **WARNING** – The use of Air Pressure to raise these shores into place has caused Accidents. Air Pressure should be limited to 50 PSI, and **All Pneumatic Struts should be Hand Tightened**



- **Window/Door Shores** may be pre-constructed as shown in adjacent slide
  - They should be made at least 1 ½" less than opening in each direction, and then tightened with wedges at one side and on bottom.
    - If header is badly damaged, great care may be taken while inserting the shore and the shims
  - They may not be practical in racked or otherwise deformed openings.
  - For large openings, they may be too heavy to carry up to locations above ground floor.
  - Their main advantage is allowing pre-construction away from the dangerous wall or collapse zone.



MEASURING NOTES

The following explain how to measure shoring materials while deducting for wedges, the proper use of wedges and maximum thickness while maintaining full contact with perpendicular shoring materials.

- When possible, round off shoring material measurements to the nearest ½ inch to ease in marking and cutting.
- When using 4 x 4 x 18" wedges deduct the thickness of one wedge from the length of the shoring material being measured.
- When using 2 x 4 x 12" wedges deduct the thickness of one wedge from the length of the shoring material being measured.
- 4 x 4 x 18" wedges can be moved together to a thickness of 6" while still maintaining full contact with a perpendicular 4 x 4.
- 2 x 4 x 12" wedges can move together to a thickness of 2 ¼" while still maintaining full contact with a perpendicular 4 x 4.

SUPPLIES AND EQUIPMENT

The use of the same dimension lumber for the headers, wall plates, sole plates, posts and struts will ease in the construction of the shoring systems and make the braces more effective.

(The use of Duplex 16d and 8d nails in Training, will assist in the dismantling of the shoring systems and reduce the amount of destroyed shoring materials during the dismantling process.)

- Cleats should be 2 x 4 x 14" min (18" for less splitting)
- Plywood gusset plates should be 12" X 12" X ¾" thick.
- Pairs of 18" square x ¾" Ground Pads are used under the U-channel for Raker and Sloped Floor Shores bearing on soil.
- Smaller gusset plates can easily be formed by cutting the larger square gusset plates in half, making four 6" x 12" gusset plates.

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USING the STEEL FRAMING SQUARE for RAKER SHORES

- The **Tongue:**
  - Shorter, part is usually 16" long and 1 ½" wide.
- The **Body** (blade):
  - Usually 24" long and 2" wide.
- The **Heel:**
  - The point where the tongue and the body meet on the outside edge.
- The **Face:**
  - The side with the manufacturer's stamp.
  - The side that is visible when the body is held in the left hand and the tongue in the right hand.
- The **Back**:
  - Opposite of the face.

THE SCALES AND TABLES

- There are seven different scales and tables on the steel framing square:
  - Four of the seven scales and tables may be used for rescue shoring.
- The Rafter Table:
  - Found on the face of the square, on the body.
  - Used to determine the lengths of common, hip, valley and jack rafters and the angles at which they must be cut to properly fit ridge board/top plates for roof framing.
  - Can be used to determine the length of the raker,
    - However, one must remember that Rafter Table is based on the Run (horizontal distance).
    - Rakers are based on the Insertion Point (vertical distance up the wall)
- The Brace Table:
  - Found along the center of the back of the tongue, giving lengths from 24" to 60" forming 45^{o} angles.
  - Determine length of short rakers/corner bracing.
- The Hundredths Scale:
  - Found on the back of the tongue, near the heel.
  - Consists of 1" divided into one hundred parts.
  - Useful to convert lengths given in hundredths.
- The Inch Scale:
  - Found on both the body and the tongue along the inside and outside edges of the square.
  - For measuring inches and graduations of an inch.

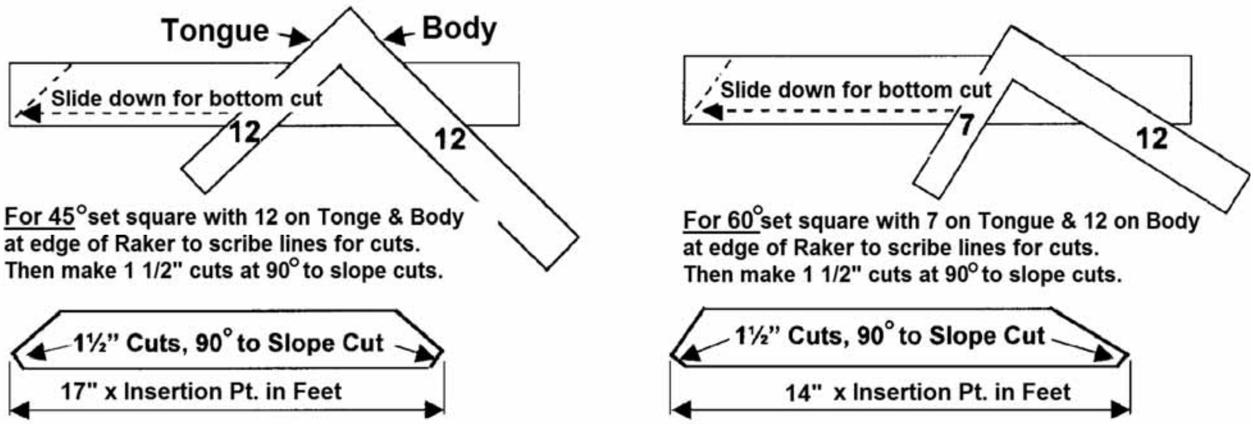
USING FRAMING SQUARE for RAKER SHORES

- The Steel Framing Square may be used to Scribe the Cut Angles for Rakers **(Figure: 1 on O/H - 18)**
  - Place the square on the raker with heel pointing up and body on the left side and tongue on the right. (It may be body at right and tongue at left)
  - **For a 45 deg** raker, position it so that the number 12" on the body and tongue are aligned at what will become the top of the raker (actually any pair of equal numbers from 6 to 12 may be used, 6 "– 6", 7" – 7", etc)
    - Scribe a line on the slope at the Right
    - Slide the Framing Square to the far end of the raker the required distance (See Raker Dimension Table, Pg 34 or use one of the methods given below)
    - Then realign the 12" – 12" to the edge of the raker and Scribe a line at the Left
    - Finally make a 1½" perpendicular cut
  - **For a 60 deg** raker, position it so that the number 12" on the body and 7" tongue are aligned at what will become the top of the raker
    - Scribe a line on the slope at the Right. This will become the Wall End of the rake
    - Slide the Framing Square to the far end of the raker the required distance
    - Realign the 12" – 7" to the edge of the raker & scribe line at left. Make 1½" perpendicular. cut
- There are Two Methods to determine the length of a raker using the Steel Framing Square
  - The Diagonal Method
  - The Step-Off Method
- The Diagonal Method **(Figure: 2 on O/H - 18)**
  - The least accurate of the two methods.
  - Use the tongue to simulate the wall and the body to simulate the floor.
  - Use the inch markings on the outside edges as "foot measurements".
  - Place the tape measure tip on the outside inch mark simulating the support point on wall and lay it across the square until it intersects the outside inch mark on body simulating support contact pt.
  - The length of the tape measure when it is intersecting the outside tongue and body inch marks will be the length of the raker from tip to tip.
  - Example: 9 ft high support point on the wall, 9 ft back from the wall will be a 12'-9" long raker.

USING FRAMING SQUARE for RAKER SHORES

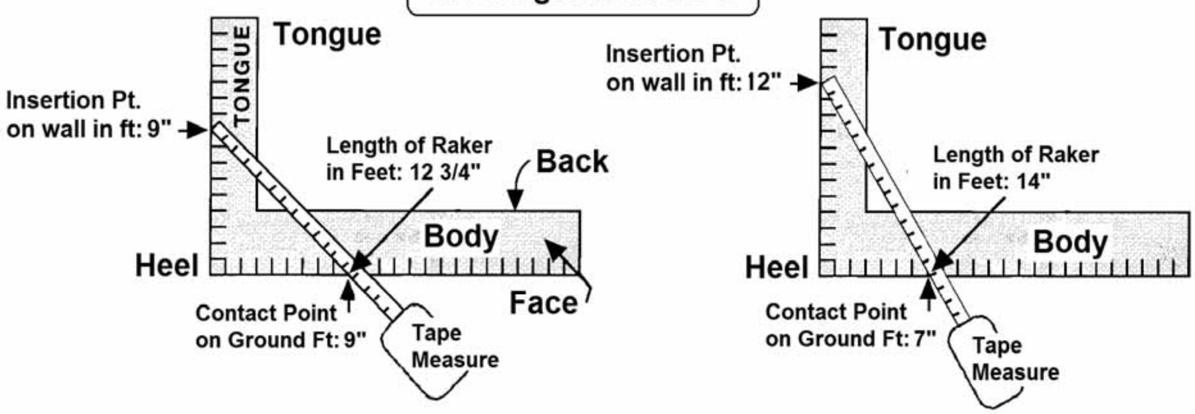
- The Step-Off Method **(Figure: 3 on O/H - 18)**
  - **Note it is much easier and more accurate to use the Raker Dimension Table**
  - Place the square on the raker with heel pointing up and the body on the left side and the tongue on the right.
  - Use the tongue to simulate the wall and the body to simulate the floor.
  - Use the inch markings on the outside edges as "foot measurements"
  - Align the tongue outside edge inch mark representing the height **in feet** of the support point on the wall with the bottom edge of the raker.
  - Align the outside edge inch mark on the body representing the length in feet away from the wall the contact point on the floor with the bottom edge of the raker.
  - Scribe a line, which will be the top cut of the raker along the outer edge of the tongue.
  - Mark the point where the outer edge inch mark of the body contacts the bottom edge of the raker.
  - Hold the square with the outer edge inch marks remaining constant and "step" over the pencil mark to the left and place outer edge inch mark of the tongue next to it.
  - Realign the same outer edge inch marks as before and mark the point where the outer edge inch mark of the body contacts the bottom edge of the raker.
  - Repeat this "step" as may times as there are feet in the length away from the wall.
  - On the last "step" scribe a line along the outer edge of body for the bottom cut of the raker.
  - Example: 9 ft high support point on the wall, 9 ft back from the wall will be a 12'-9" long raker.
    - 9" mark on the outer edge of the tongue and the 9" mark on the outer edge of the body is "stepped" over these marks twelve times.
    - Measuring the distance covered after twelve steps is 12'-9" ft tip to tip.

USING STEEL FRAMING SQUARE

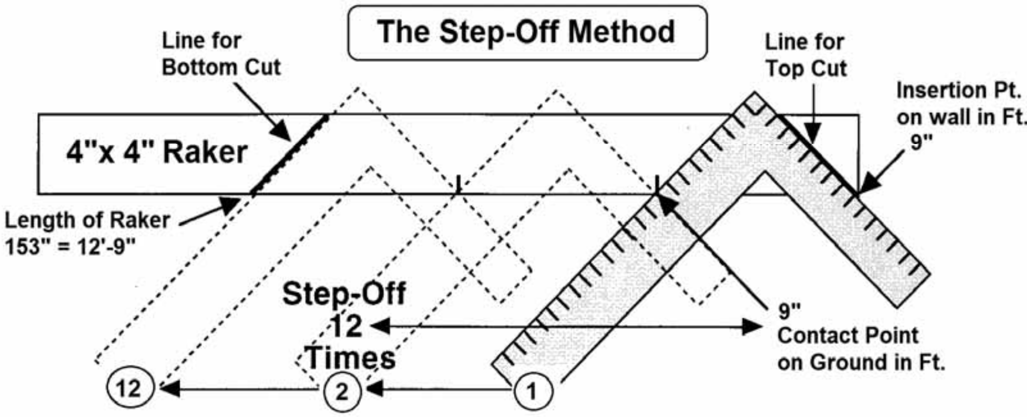


TO SCRIBE THE CUT ANGLE ON A RAKE

The Diagonal Method



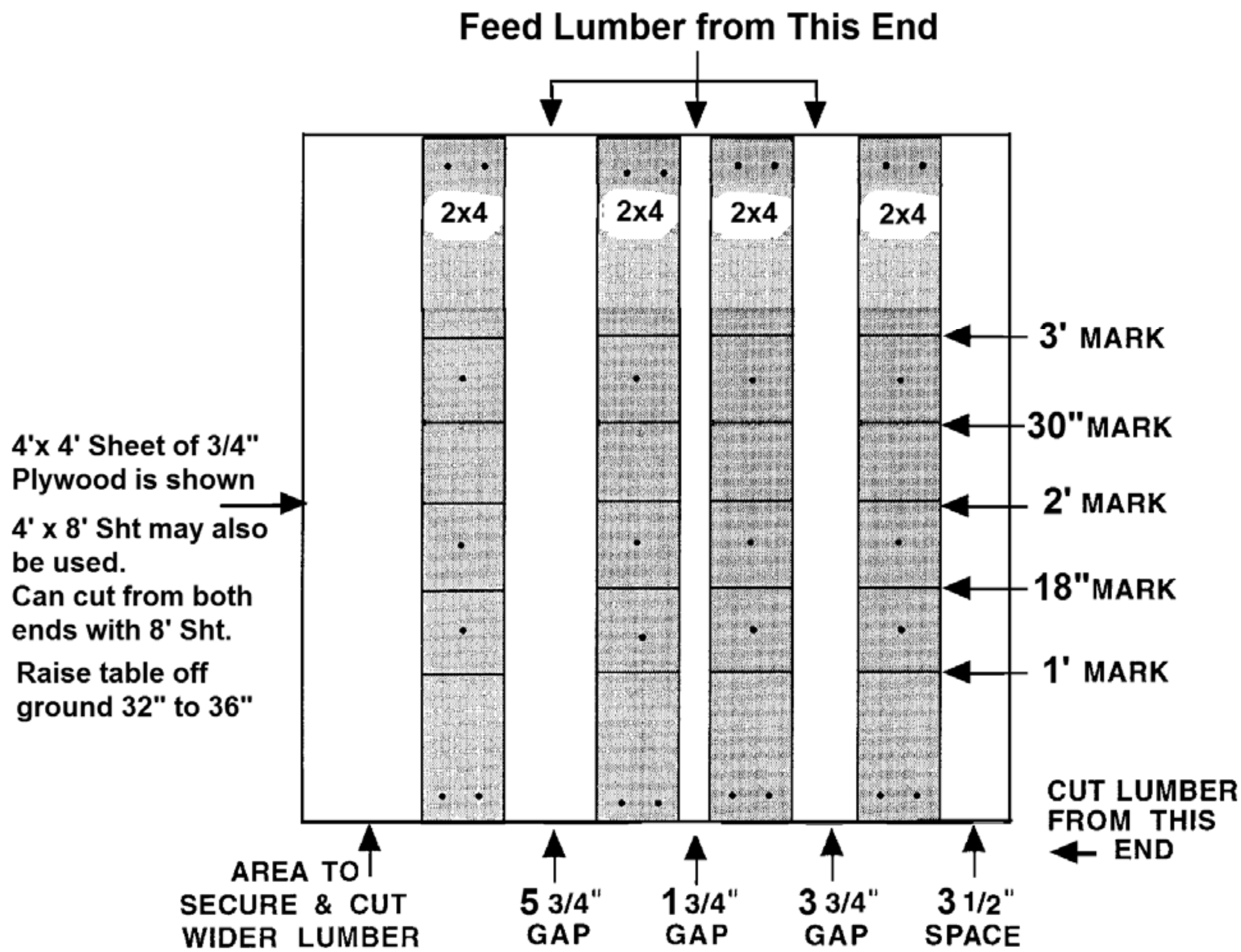
The Step-Off Method



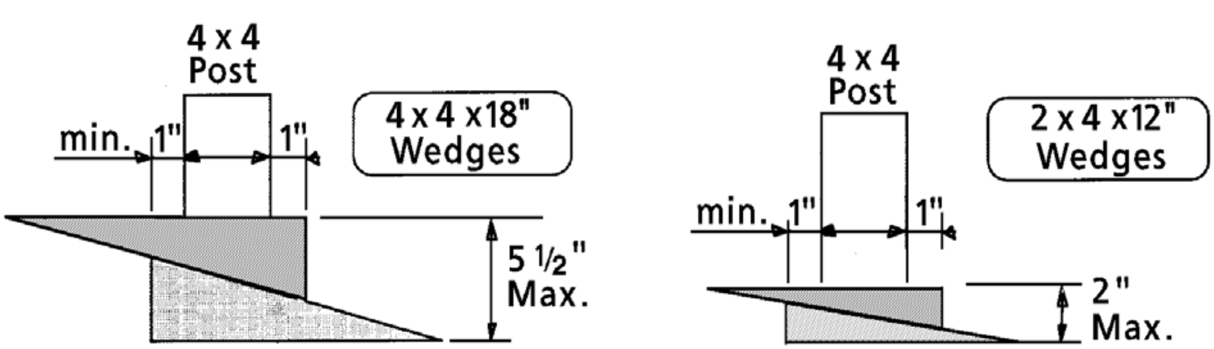
TO DETERMINE THE APPROXIMATE LENGTH OF A RAKE

EQUIPMENT AND CUTTING STATION (continued)

CUTTING TABLE & JIG



Maximum Spread for Wedges with Full Surface Contact
(Wedges must be placed with cut side to cut side)



HOW TO CUT WEDGES

- Cutting 4 x 4 x 18" wedges.
    - Mark a full length 4 x 4 x 8 ft every 18".
    - This will make five pair of wedges with a 6" piece left to secure the last pair while being cut.
    - Mark a diagonal line from the top edge of one 18" line to the bottom edge of the opposite 18" line every 18 inches.
- Cutting Wedges with a Rotary Saw
    - Score the line with the blade ½" deep.
    - Second pass cut half way through.
    - Third pass cut all the way through.
    - Cut the other half of the wedge off of the remaining 4 x 4 at the 18" line.
- Cutting Wedges with a Chain Saw
    - Align the blade with the diagonal line on the 4 x 4 with the tip of the saw pointing towards the cutting table.
    - Start cutting with the tip of the saw bar approximately 2" past the edge of the 4 x 4.
    - Once the tip of the saw bar is through the full thickness of the 4 x 4 start to drag the saw towards the opposite end of the diagonal line.
    - Once the heel of the saw is past the end of the 4 x 4, flatten the saw and cut the remaining part of the 4 x 4 with the full bar.
    - Cut the other half of the wedge off of the remaining
- Cutting Wedges with a Circular Saw
    - Difficult to do unless the saw has at least a 10 ¼" blade.
    - Circular saws with blades 10 ¼" or larger need only one pass from corner to corner along the diagonal line.
    - Circular saw with blades less than 10 ¼" require marking and cutting on both sides and do not always align correctly.

HOW TO CUT THE TOP END OF THE RAKE AT 45 & 60 DEG

- Mark the end of the rake to be cut
- 4 X 4 = 3 ½" from the end for 45 degrees
- 4 X 4 = 6" from the end for 60 degrees
- 6 X 6 = 5 ½" from the end for 45 degrees
- 6 X 6 = 9" from the end for 60 degrees
- Mark a diagonal line from the upper end of the lumber to the mark on the lower edge of the lumber and cut the end off at this angle.
- Measure 1 ½" wide on the tapered end and mark a line on the cut side for the relief cut to make full contact with the end of a cleat.
- Cut this line from the cut side with a circular saw.
- The cutting team will mark and cut the end of a rake at 45 degrees and after cutting the angle end cut off the rake, they will cut the end of the rake at 60 degrees.

HOW TO CUT THE BOTTOM END OF THE RAKE AT 45 & 60 DEGREES.

- Mark the end of the rake to be cut
- 4 X 4 = 3 ½" from the end for 45 degrees
- 4 X 4 = 2" from the end for 30 degrees
- 6 X 6 = 5 ½" from the end for 45 degrees
- 6 X 6 = 3" from the end for 30 degree
- Mark a diagonal line from the upper end of the lumber to the mark on the lower edge of the lumber and cut the end off at this angle.
- Measure 1 ½" wide on the tapered end and mark a line on the cut side for the relief cut to make full contact with the end of a cleat.
- Cut this line from the cut side with a circular saw.
- The cutting team will mark and cut the end of a rake at 45 degrees and after cutting the angle end cut off the rake, they will cut the end of the rake at 60 degrees.

HOW TO NOTCH LUMBER FOR ADDED STABILITY

- **How to notch Cribbing (Not Recommended)**
  - Mark 4" from the end of the cribbing to prevent the end piece from splitting off.
  - From the 4" mark, make a second mark the true thickness of the lumber being used for cribbing.
  - 4 X 4 = 3 ½" - 6 X 6 = 5 ½"
  - Adjust a circular saw to the depth of ½" and cut the two lines and then between the two lines every ½" to 1 inch.
  - Ensure saw is unplugged while adjusting blade depth.
  - Hit the sliced pieces of lumber with a hammer towards the remaining cribbing to break off the pieces.
  - Clean out the notch with the claw end of the hammer until smooth.
  - Have one of the squad members repeat this process on the opposite end of the cribbing.
  - Notches should only be made on each side of the cribbing to provide full interlock of each piece in each direction.

SUMMARY

We have discussed how to size-up and what considerations that need to be made in order to select the appropriate type, size and location of Emergency Shoring

In addition we have discussed the different types of FEMA Shores, and given step-by-step procedures of how to build each type.

The Structures Specialists FOG from the US Army Corps of Engineers and the Shoring Operations Guide (SOG) both have diagrams and instructions for constructing these shores.
Both guides are available in electronic form on the web site of the FEMA Structures Sub-group.
www.DisasterEngineer.org

Enabling Objectives Summary

- **Have a basic understanding of how to conduct a proper shoring size-up**
- **Be able to identify locations for proper shoring placement**
- **Understand the shoring team concept and identify positions & purpose**
- **Understand the different types of shoring components and equipment**

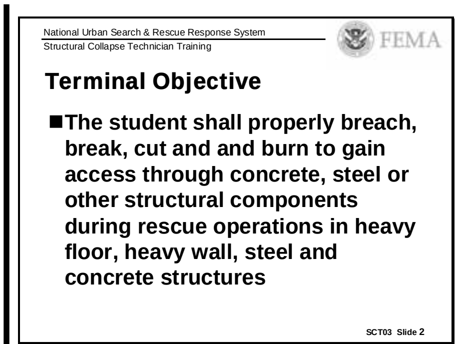
STUDENT MANUAL
MODULE 3 BREAKING AND BREACHING

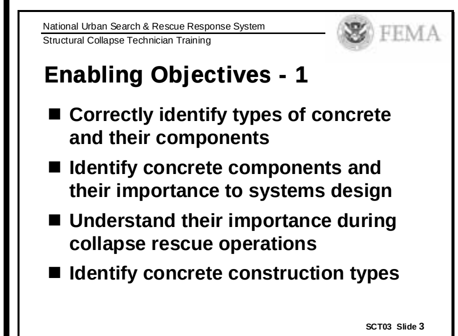
TERMINAL OBJECTIVES

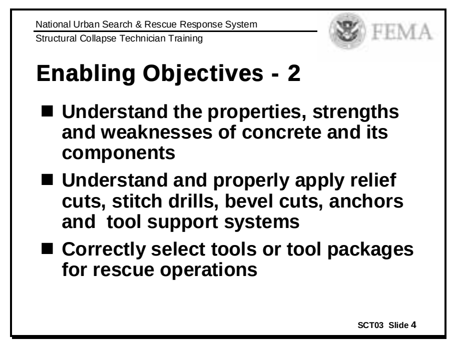
The student shall properly breach, break, cut and burn to gain access through concrete, steel or other structural components during rescue operations in heavy floor, heavy wall, steel and concrete structures

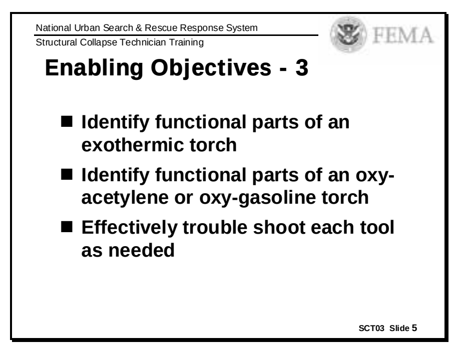
ENABLING OBJECTIVES

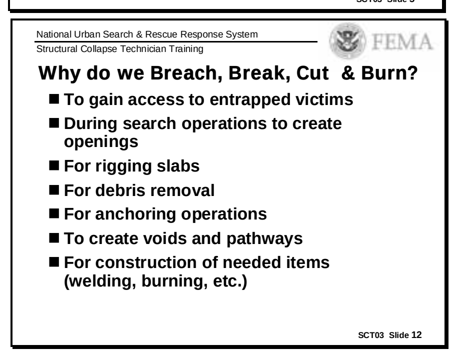
- Correctly identify types of concrete and their components
- Identify concrete components and their importance to systems design
- Understand their importance during collapse rescue operations
- Identify concrete construction types
- Understand the properties, strengths and weaknesses of concrete and its components
- Correctly select tools or tool packages for rescue operations
- Identify functional parts of an exothermic torch
- Identify functional parts of an oxy-acetylene and oxy-gasoline torch
- Effectively trouble shoot each tool as needed











CONCRETE AS A MATERIAL

History

- Initially the Romans used a cement to make concrete. They used Pozzolan Cement made from volcanic ash, sand and lime. These raw materials were simply ground together to make the cement, and they mixed their cement with broken stone and brick to produce concrete.

- In 1824 Joseph Aspdin a brick mason from Leeds, England took out a patent on a material he called Portland cement. Aspidin is generally credited with inventing a method for proportioning limestone and clay, burning the mixture at a high temperature to produce clinkers, then grinding the clinkers to produce a hydraulic cement very similar to that used today.

Hydration

- When cement and water are mixed they form a paste. It is this paste that binds particles of aggregate (sand and stone) together to form concrete.

- The reaction of cement and water is exothermic; heat is generated during the reaction. Depending on the type of structure, heat can be an advantage (thin concrete) or a disadvantage if excessive (thick concrete). This hydration reaction can last for years if the concrete is very thick and has moisture i.e., Hoover dam. Generally, however, a slab or driveway of concrete will cure to its rated strength in about 28 days.

Concrete, Mortar and Grout

- When cement and water are mixed together with sand, broken rock or gravel (aggregate) we have concrete.
  - Mortar is usually made by mixing portland cement and water with sand, and lime. The lime makes the mix take on a buttery texture, which is especially helpful when bonding blocks and bricks together.
  - Grout is a mixture of portland cement and water with sand, and sometimes pea gravel. Grout is usually proportioned to be quite fluid when it is used for filling voids, but may be made to be more buttery (without pea gravel) when used in grouting tile.

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Concrete, Mortar & Grout

- In order to form Concrete we must mix cement and water with sand and gravel
  - Sand & gravel = aggregate
- Mortar is made by mixing cement & water with sand, often lime is added
  - Used when bonding block or brick together
- Grout is also made using cement/water + sand and sometimes pea gravel
  - May be mixed to be quite fluid, as when filling voids, or may be mixed stiff as when grouting tile

SCT03 Slide 13

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Hydration

- When Portland Cement contacts water its called hydration
- Hydration creates a water cement paste, which in turn, holds the aggregate (sand & rocks) together.
- This paste and the aggregate forms Portland Cement Concrete, usually just called “Concrete”

SCT03 Slide 14

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Reaction Issues

- The reaction of water and cement is exothermic – generates heat
  - In thin concrete heat is an advantage
    - It allows the reaction to keep going at cooler outside temperatures.
  - In thick concrete heat is a disadvantage
    - It can cause the reaction to proceed too quickly with the potential of reducing strength
  - Hydration can last for years depending on the thickness of the concrete
    - Hoover Dam took many years
    - A driveway will cure in less than a month

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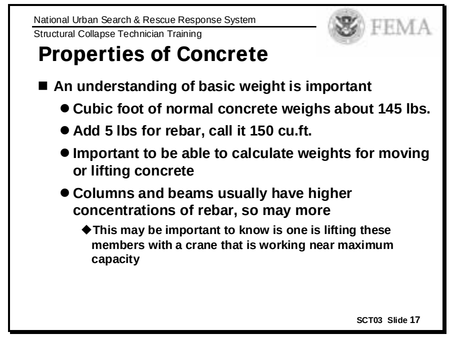
Components of a Cement

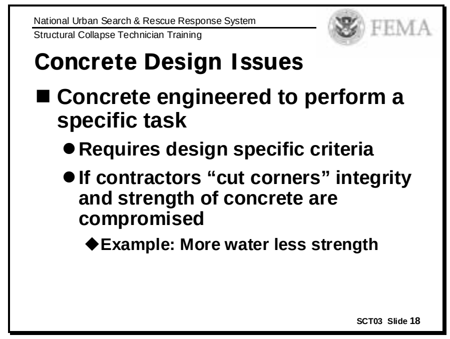
- Cement
  - Fine gray powder that contains limestone, clay, fly-ash and gypsum
    - When airborne, the silica contained in some of these components is a respiratory hazard.
    - Inhaling the dust from cutting concrete will cause damage to one’s lungs
      - It is cumulative, irreversible, and deadly

SCT03 Slide 16

Types of concrete

- People often misuse the word cement and concrete. Cement is a fine gray powder, and once mixed with water, sand, gravel or stone becomes concrete. The strength and durability of concrete depend chiefly on the amount of water used. If too much water is used the cement paste will be too weak to hold the aggregates together. Generally, within limits the less water used the stronger the concrete.
- There are a variety of concrete types. These depend on the aggregate used, the amount of water added and ultimately the end use required of the concrete.

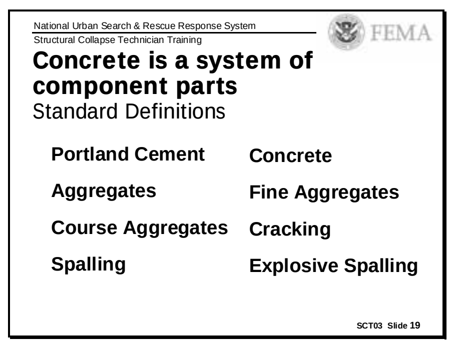




Definitions

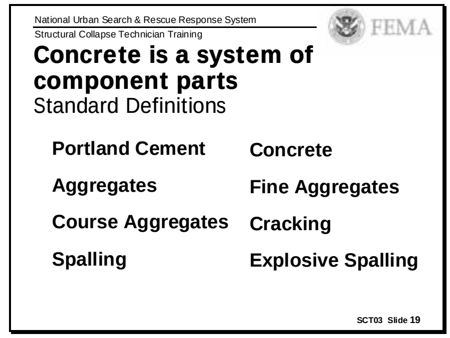
Concrete is made from many materials; The following are definitions that are standard within the industry.

- Portland Cement
  - A fine gray powder, it is mixed with water and aggregates to form concrete.
  - Portland Cement is the most commonly used cement, it is hydraulic cement, which means it hardens after the addition of water.
- Concrete
  - Is fire-retardant, watertight (if not cracked), and comparatively cheap to make
- Aggregates
  - Materials mixed with cement to make concrete, these may be fine or course
  - The type of rock can have an effect on the strength of concrete.
- Fine aggregates
  - Usually sand. The harder the sand the stronger the concrete
- Course aggregates
  - Crushed stone, gravel, cinders, shale, lava, pumice, vermiculite, etc.
  - Hard rock like granite or limestone produces the strongest concrete
  - Softer rock, found in old river bottoms produces weaker concrete that shrinks and cracks more.



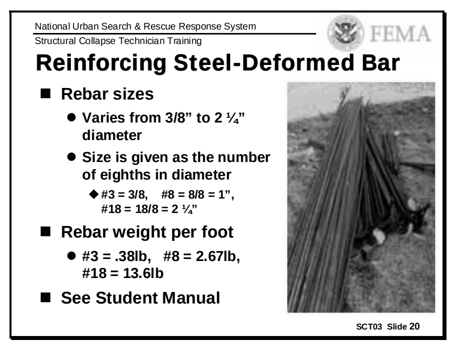
Definitions (continued)

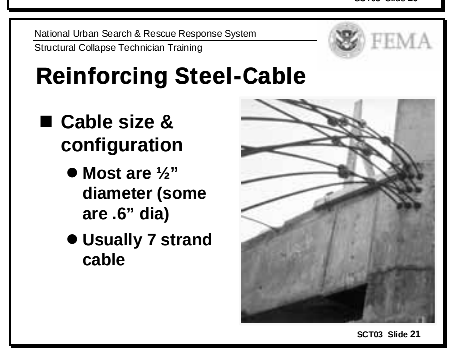
- Cracking (see detailed discussion in SCT01c, Part 4)
  - May be caused when concrete cures (dries) if too much water has been used
  - May be caused by extreme changes in temperature as concrete expands, then contracts.
  - Cracking is also caused by tension stresses that occur when concrete is exposed to extreme forces
- Spalling
  - The loss of surface material when concrete is subject to heat or the force of breaking and breaching. It may be due to the expansion of moisture in the concrete or improper consolidation during the pour.
- Explosive spalling
  - The violent projection of concrete. Heat or a portion of concrete being “sheared” by a tool may.



TYPES OF CONCRETE CONSTRUCTION

- Concrete can be used in a variety of structural members. The strength of the member is dependent upon construction. Obviously if you are expecting a portion of concrete to be used as a load bearing member it had better be engineered for the job. Depending upon the US&R mission you may be faced with a variety of different construction formats. Knowing how to identify each, what the properties of each are and establishing a best method scenario to breach and break provides you with a tactical edge.
- There are two types of reinforcement used in concrete systems. Rebar and Steel Cable. This is a composite material of steel (rebar) or steel cable and concrete. Steel provides the tensile strength that concrete alone lacks. In some cases, steel can add some compressive strength.
  - Rebar: these are low carbon steel bars that are similar to structural steel (beams, angles, etc). The bars have deformations that enhance the bond between the bar and the concrete. The bond is essential for the rebar and concrete to act together to resist loads
  - High strength cable (usually in a 7-wire twisted configuration) may be: bonded to the concrete, as in pre-cast pre-tensioned applications, or unbonded as in cast-in-place, post-tensioned applications. This will be discussed next



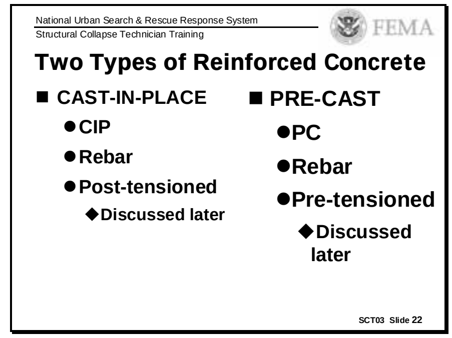


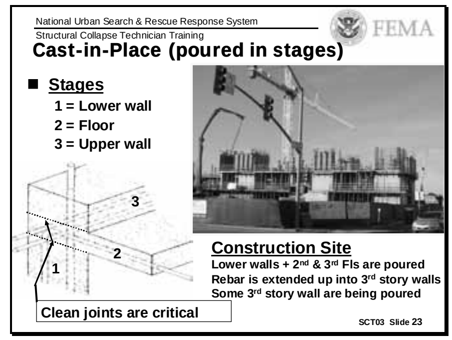
TYPES OF CONCRETE CONSTRUCTION (continued)

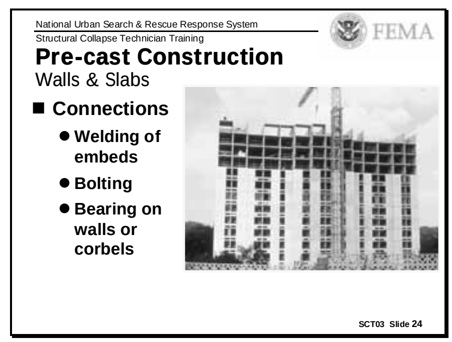
- Concrete construction can be broken down into the following two types.
  - **CAST IN PLACE**: This is concrete that has been poured in the location in which it is expected to remain. This could be a patio porch, a foundation for a house or the complete structure for a multi-story concrete building. For concrete buildings the concrete is poured in stages: walls and columns, then floor slabs and beams. This sequence is repeated at each story on multi-story construction. Cast in place concrete will often have rebar used as the reinforcing steel, and by the nature of its construction sequencing, it becomes a very well connected structure. Post-tensioned cables may be used in CIP concrete constructed (explained as follows)

    Post-tensioned: In this case high tensile strength steel cables or bars are encased in tubing (casing) and greased to prevent adhesion between steel and concrete, positioned in the forms and then the concrete is poured. After the concrete is set and reaches a specified strength the steel is stretched and anchored at the ends of the slab or structural member. Examples include floor slabs in concrete high-rise buildings and parking structures. Note that the grease also provides protection from rust, etc.
  - **PRECAST**: This is concrete, which has been cast at a location other than the place it is to remain. These could be at the construction site, as in tilt-up walls, or could be cast at an off-site pre-casting facility, and then trucked to the construction site. Precast concrete may be constructed with rebar or pre-tensioned reinforcing (or both). The inherent weakness of precast systems is their connections. Since most PC sections are heavy, their connections must be tough and ductile

    Pre-tensioned: High tensile strength steel strands (cable) are stretched inside the concrete member. Concrete is then placed into these very strong steel forms built around the strands. As the concrete sets it bonds to the tensioned steel. Pretensioning is done in a plant and the completed unit is shipped to the job site.

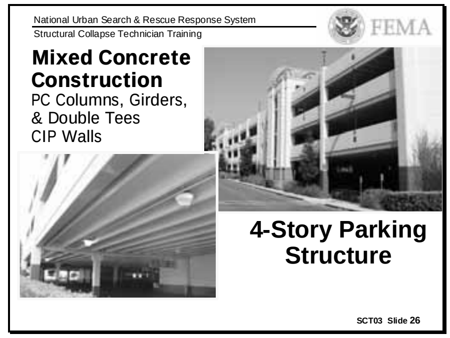


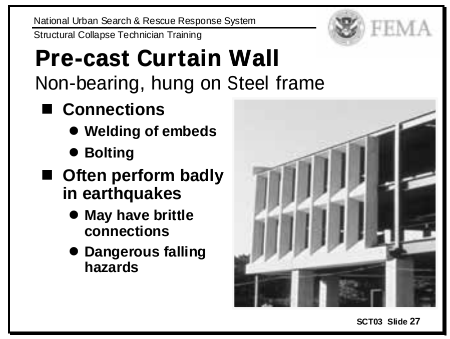


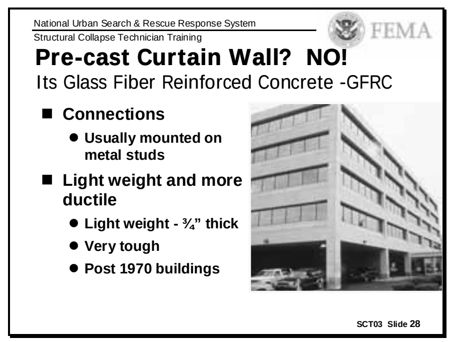


TYPES OF CONCRETE CONSTRUCTION (continued)

- Some structures may contain a mixture of precast and cast in place concrete. A common configuration is to erect precast columns and beams, and then cast in place the slab. These structures are usually better than all PC structures, since the CIP concrete tend to better tie them together
- Pre-cast curtain walls are used to provide the enclosure of steel and/or concrete frame type buildings. This type of facing wall has performed well in earthquakes, since many are installed with brittle connections. They are fairly rigid and without ductile connections, the earthquake shaking can overload the connections and cause the relatively heavy panels to fall.
- Some curtain walls, especially in earthquake prone areas may be made of Glass Fiber Reinforced Concrete. This material is light weight (3/4" thick) and very tough (like the hull of a fiberglass boat). The GFRC is mounted on metal studs in the factory and connections are easily made in the field.



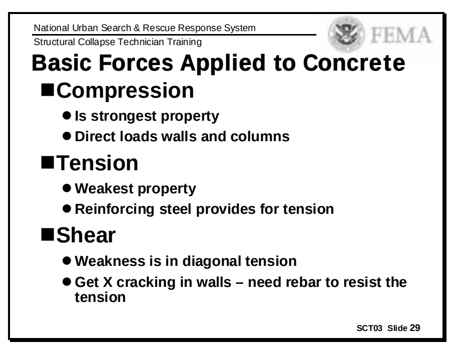




PROPERTIES OF CONCRETE

Weight

- Understanding of concrete weights is important to rescue personnel, both operationally and for your own safety. One should know the weights of the concrete that is being cut and lifted-out, and any piece that is being lifted.
  - Most reinforced concrete weighs about 150 lb (145 for concrete & 5 for rebar). Concrete wt = 150 pcf
  - Concrete Beams and Columns have a greater concentration of rebar, and may weigh up to 180 pcf. This must be taken into account when planning to lift the concrete, especially with a Crane. The US&R Structures Specialist should be asked to help with these calculations

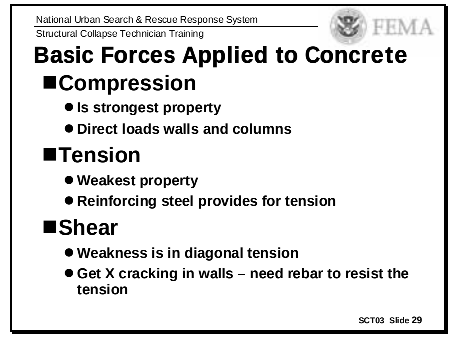


Strengths and Weaknesses

- Like all building materials, concrete has its strengths and weaknesses. Knowing these and taking advantage of the weaknesses while avoiding concrete's strengths will enable you to speed your breaching times and enable you to apply techniques suited to type of concrete you will be faced with.

Strengths and Weaknesses (continued

- There are three basic "forces" which we should be concerned about when dealing with concrete, tension, shear and compression.
- As discussed earlier concrete is actually a mixture of materials. This mixture provides its strengths and enables us to use it in different forms of construction. Concrete is strong in compression but weak in tension and shear. These general characteristics explain the need to add reinforcement to load bearing concrete components.
- A backyard concrete patio , with no or wire mesh reinforcement, is reasonable serviceable as long as its soil and drain-rock base are stable. It loaded with nominal loads that are delivered into its base. If we lift this slab up on blocks and jump up and down on it or strike it with a sledge hammer (placing it in tension and shear) it would fail.
- Concrete used in load bearing walls, floors, or columns requires the addition of materials, typically rebar to provide tensile strength and the ability of the concrete to withstand the forces of shear. If you were to remove or damage the reinforcement(s) you would effectively have nothing but dead weight. In this case, both elements are equally important failure of any element or removal of any element results in system failure.
- An example of using this knowledge to effectively breach is using a saw to create relief cuts or a breaker/drill to create “stitch” drill holes.



Effects of Environment and Chemicals on Concrete

- Any number of factors can effect concrete. Under these conditions concrete may be subject to early failure or weakening.
  - A harmful reaction between minerals in the aggregates
  - Exposure to groundwater, seawater, or industrial chemicals
  - Repeated cycles of freezing and thawing
  - Inferior concrete resulting from inferior materials, high water-cement ratio, low cement content, inadequate agitation, compaction, and lack of curing.

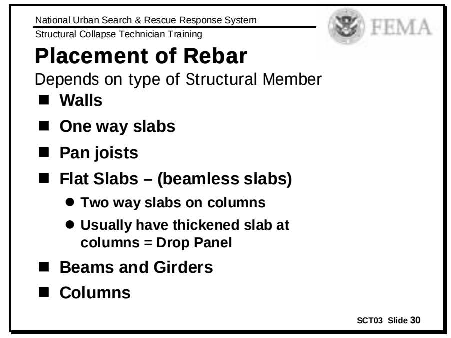
REBAR AND REINFORCING

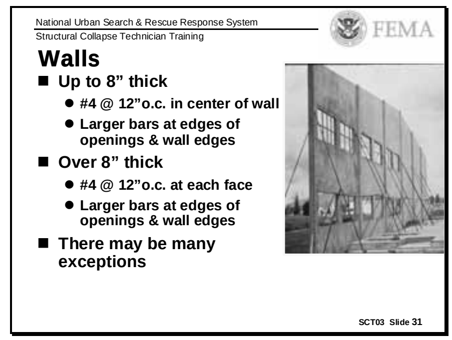
General Steel Properties

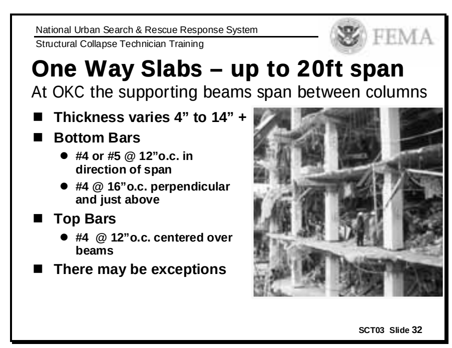
- Steel rebar and a variety of other steel products are used to provide reinforcing strength to concrete structures. Deformed round bars are the most common types to be found and range in sizes from 3/8" to 2 1/4" diameter.
- Rebar is found in almost all concrete used in construction as a method to provide shear and tensile strength. Failure or breaking away of the rebar by either mechanical forces or natural forces will result in failure of the concrete.

Placement of Rebar in Concrete Structures

- Rebar may generally be located in specific locations in certain types of construction. Not only can we predict the location but also the size and thickness of the rebar associated with each type of structural member.
- WALLS:
  - For thickness up to 8 inches will have one layer of bars, which will occur at the center of the wall. Spacing usually occurs from 8 to 16 inches each way. (vertical and horizontal). Bigger bars are normally added adjacent to the openings and will extend beyond edges of openings. There may even be diagonal bars at corners of openings.
  - Walls over 8 inches thick should have two layers of rebar, each about 1" clear of the surface. Spacing of each layer is 8" to 16" each way. Each bar will be 3/8" to 3/4" diameter.
- ONE-WAY SLABS:
  - These normally span 8 to 20 feet between parallel beams and are from 6 to 10 inches thick. Normally bars near top and bottom of the slabs occur about 1" clear in each case. Bars may vary from 1/2" to 3/4" in diameter. Bottom bars extend throughout the slabs each way. In the short direction they are spaced between 4" to 12". In the long direction they are spaced 10" to 18".



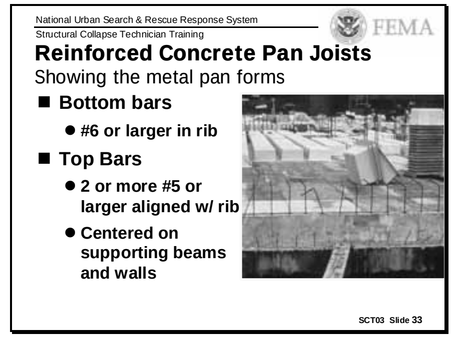




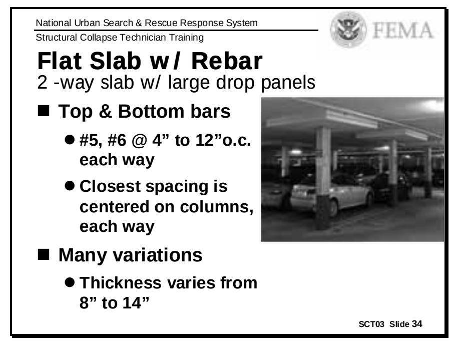
REBAR AND REINFORCING (continued)

Placement of Rebar in Concrete Structures (continued)

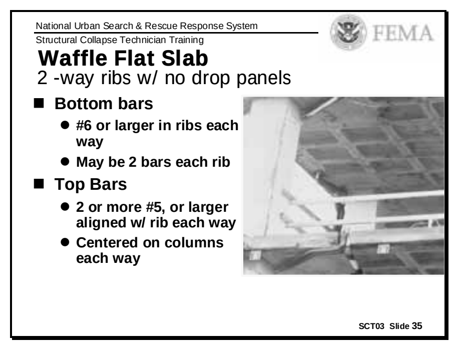
- PAN JOISTS:
  - These are deep concrete ribs that are usually about 6" wide and are spaced 24" to 36". The bottom bars may be two 1/2" or 1" diameter bars. The top bars are two or four 1/2" to 3/4" bars placed in the slab above the rib and parallel, these run about 4 inches or so apart and are 1/2" clear from the top.



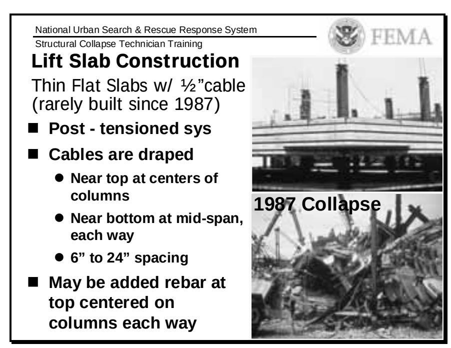
- TWO-WAY SLABS — FLAT SLABS (solid, two way slabs supported only by columns – beamless slabs):
  - These slabs most often have a drop panel (section of thicker concrete at each column, in order to reduce punching shear stress)
  - Normally these bars are similar to one way slabs except some top bars may extend through out the slab and will vary. Bars are usually 1" clear from the top and bottom of the slab. Bottom bars range from 1/2" to 3/4" diameter with spacing from 4" to 12". Top bars are most closely spaced over columns and have the same spacing in each direction.



- TWO-WAY SLAB — WAFFLE SLAB: (slabs that are poured over square, steel voids so that rips are formed in the concrete, The voids are omitted at and near the columns, in order to allow the full thickness of the concrete to resist punching shear stresses)
  - These are the same as two-way flat slabs except the bottom bars are found only within the ribs and about 1" from the bottom. The ribs are typically 6" wide and spaced between 24" and 48".



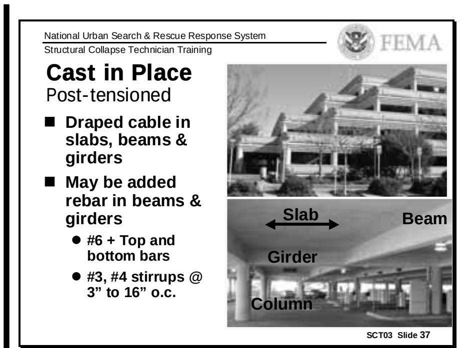
- TWO-WAY SLAB — LIFT SLABS: (slabs that are uniformly thick with no vertical projections)
  - This type of construction has lost favor since a spectacular collapse in 1987.
  - The slabs are all poured in a stack on the ground floor slab, cured, and then lifted into place by a series of jacks (one placed on each column)
  - These slabs most often were post-tensioned and the cables drape from near the top of slab over the columns to near the bottom at mid-span



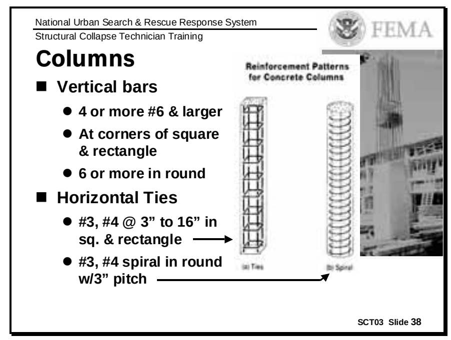
REBAR AND REINFORCING (continued)

Placement of Rebar in Concrete Structures (continued)

- BEAMS AND GIRDERS:
  - These usually are 12" to 24" wide and 18” to 36” deep. There are usually two to six bottom bars that are from 3/4" to 1 1/4" diameter and placed within 2" of the bottom. More bottom rebar occurs in the mid 2/3rds of the span. There may be two to eight top bars, also 3/4" to 1 1/4" diameter placed in the slab above the beam and parallel to it (usually 4" or so apart). Most top rebar will be within 10 feet of the support (one-forth of the span). You will also find vertical bars called stirrups, which extend from the top to the bottom of the beams. These range in size from 3/8" to 1/2" in diameter.

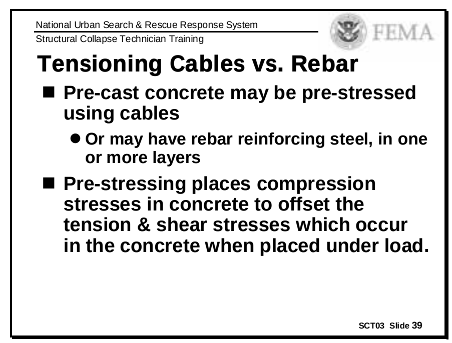


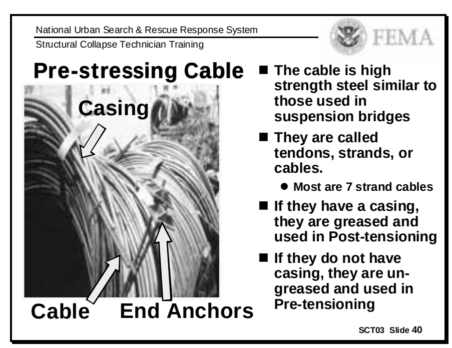
- COLUMNS:
  - Round, square or rectangular support members. Within columns are horizontal ties with usually occur about 1" from the surface and are usually shaped the same as the column. (Spiral for round columns and individual square ties for square columns, but you can find spiral ties in square columns)
  - Tie sizes range from 3/8" to 5/8" in diameter and the tie spacing of 2 to 6 inches for spiral and 6 to 18 inches for horizontal ties. Vertical rebar is usually placed more or less evenly around the periphery of the column. These “Verts” range in size from 5/8" to 1 1/4" in diameter. You will normally find from 4 to 8 vertical bars, but there may be as many as 18 Verts in very large columns.



Tensioning Cables vs. Steel Rebar

- As previously discussed, in some instances concrete will be pre-stressed by using high strength steel cables. Pre-stressing places calculate stresses in concrete to offset the tension and shear stresses, which occur in the concrete when it is placed under load.
  - The concrete may be precast and pre-tensioned, where the steel is bonded to the concrete, or
  - The concrete may be cast in place and post-tensioned, where the steel is not bonded to the concrete
  - The cables, similar to those used in suspension bridge. (called “tendons”, "strands," or "cables”).

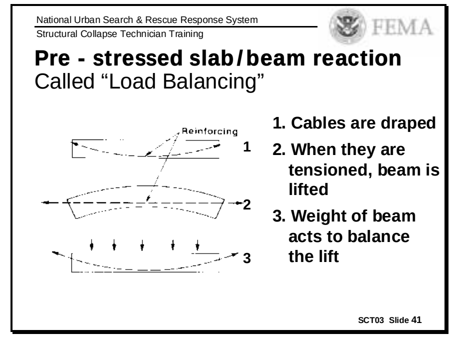


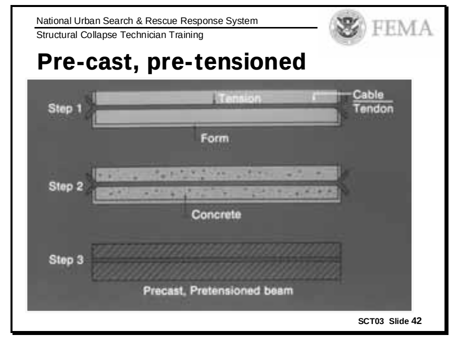


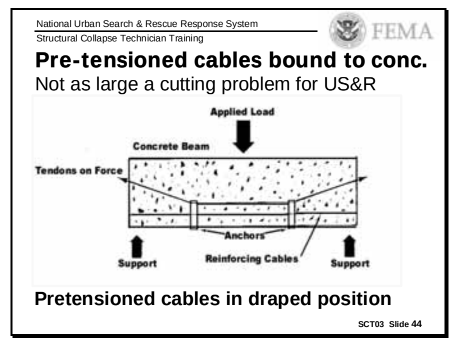
REBAR AND REINFORCING (continued)

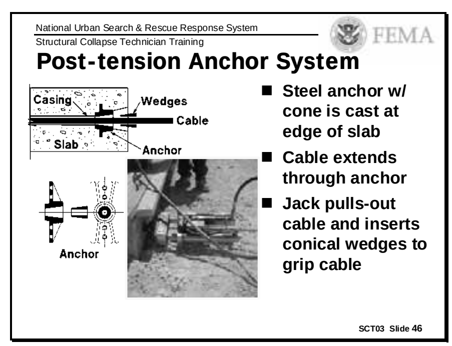
Tensioning Cables vs. Steel rebar (continued)

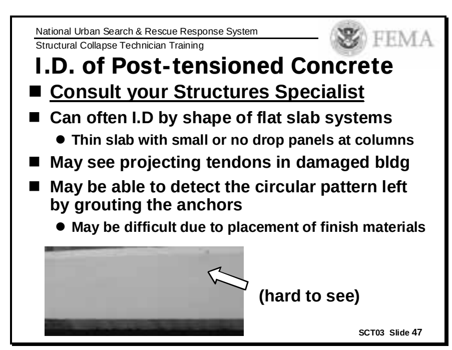
- Consider a row of books side by side. As a beam it will fail of its own weight without any added load due to the lack of shear resistance between the books. Drill a hole through the row of books laterally, pass a wire through the books and tighten the wire against the end books. The row of books would be compressed by putting tensile stress in the wire and compression in the books.
  - This beam could be placed across 2 chairs and loaded. The beam has been prestressed sufficiently to counteract the stresses placed on it by the load.
  - The prestress cable is normally placed in a draped configuration. The cables are proportioned so that they “balance” the weight of structure they support
  - This is similar to the way a suspension bridge cable is draped to carry the load of a large span
  - In precast, prestressed concrete the, the cables are “harped”, held down in two places, as shown in the adjacent slide, since this is the only way the pretensioned bar will not remain straight
- These cables need to be identified early to assure the rescue team can recognize the difference between the cables and rebar. Cutting of cables can result in the immediate failure of slabs or structural members in both Precast, Pre-tensioned Concrete and Cast in Place, Post Tensioned Concrete. The Structures Specialist should be consulted to help this I.D.
  - When post-tensioned cables are installed they have at least one end that must be stresses (pulled) using a special hydraulic jack.
  - Adjacent slides indicate what a typical end anchor looks like, before and during the stressing process.
  - After the cable is stressed and the conical wedges are inserted to “capture” the cable in the anchor cone, the cable is cut-of and a circular void space, about 3” deep is left in the edge of the concrete. This void space is normally filled with dry-pack grout , and one may “read” the difference in texture of the grout finish from the surrounding, CIP concrete
  - Recognize post-tensioned flat slabs by checking the drop panels (thickening of slat at column head). If they are 3 ft or less, square, or no drop is found, the slab is probably a post-tensioned slab









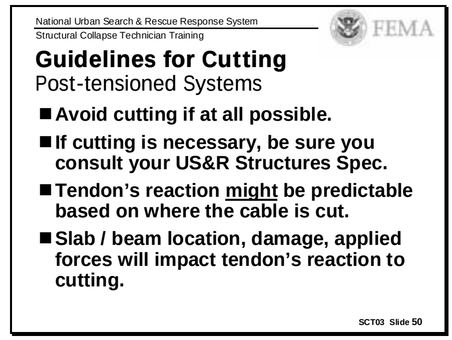


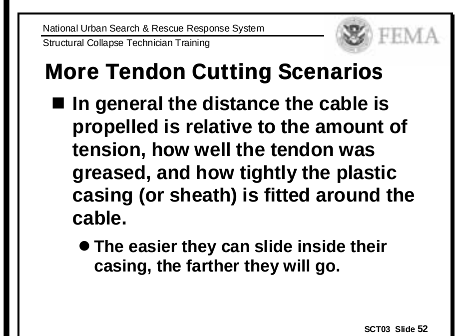
Cutting Cast in Place, Post-Tensioned Structure

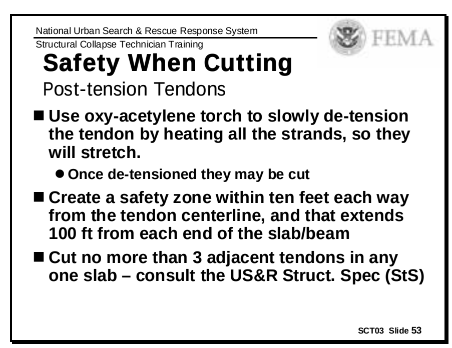
- This type of reinforcing cable usually consists of a greased, seven strand, 1/2" diameter wire in a plastic casing that is cast into the concrete. After the concrete is properly hardened, the cable is tensioned to about 25000 lb and then anchored at the exterior edges of the slab. Except in some bridges the cable is not bonded to the concrete and will rapidly un-tension if cut or one of the anchorages comes loose.
  - Post-tensioned cables can be found in beam and slab floors, flat slabs, and joist and girder floors.
- Following is known about cutting post-tensioned cables.
  - When the cable is cut near or at the end of the slab, the cable may pop out of the slab surface (above or below the slab) in the form of a loop that may be as high as three feet and as long as five feet or more.
  - When the cable is cut in the middle of the slab it will usually pop out of each end of the slab. It may extend only a few inches, but in extreme cases it may be propelled beyond the building.
  - In general the distance the cable is propelled is relative to the amount of tension, how tightly the plastic casing (sheath) is fitted around the cable, and how much grease was used.
  - It is possible that cables could pop out of the slab surface, as well as exit the end of the slab
- Generally rescue teams should not cut post-tensioned cables, unless absolutely necessary.
  - Cut them only under the direction of a US&R Structures Specialist (StS). The StS should be able to determine the location and type of cable, and if it is fully stressed
  - If you decide, to cut a cable there are two methods. (the first is preferred) After the concrete around the cable has carefully been removed, and its casing has been removed, locally:

    Method One (preferred) would be to use a torch to slowly heat the cable, so it will stretch and relax the tension stress. Then it can be cut more safely.

    Method Two would be to use carbide; circular saw to cut one strand at a time. In this process, since the strands are twisted, as one strand is cut its force is transferred to the uncut strands. Eventually a very few strands will be carrying all the force, and they may suddenly break, as the blade is engaged.







REBAR AND REINFORCING (continued)

Cutting of Post-Tensioned Structures (continued)

- To minimize the risk of injury from cutting tensioned cable during US&R operations, proceed as follows.
  - An area within ten feet each way of the centerline of the cable should be evacuated within the building.
  - The area outside the building at each end of the slab should be evacuated for a distance of one hundred feet, within ten feet of the centerline of the cable, and/or a barrier should be built at end of the slab to stop the cable's projection.
  - No more than two adjacent tendons should be cut in each direction unless the structure has been collapsed and is being supported more or less uniformity.
  - One normally may cut a few cables in several separate locations in a post-tensioned slab, however the StS should always be involved with making the decision

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Safety When Cutting

Post-tension Tendons

- **Use oxy-acetylene torch to slowly de-tension the tendon by heating all the strands, so they will stretch.**
  - **Once de-tensioned they may be cut**
- **Create a safety zone within ten feet each way from the tendon centerline, and that extends 100 ft from each end of the slab/beam**
- **Cut no more than 3 adjacent tendons in any one slab – consult the US&R Struct. Spec (StS)**

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Cutting of Precast, Pre-Tensioned Structural Members

- These members usually consist of Beams, Single and Double Tees, and Slabs. The steel is bonded to the concrete, but the stresses are usually very high near the steel. The following is a guide to cutting pre-tensioned members. (Discuss with your Structural Engineer)
  - AVOID cutting pre-tensioned Beams, or the Stems of Tees unless they have collapsed and are supported as part of the rubble pile. (Even in that case, AVOID cutting near the ends)
  - One may cut slabs, including the very thin slabs of Tees. Since these members are usually only about four feet wide, it is best to cut access holes centered on the joint between two adjacent pieces. In this way most of the steel can be avoided.

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Guidelines For Cutting

Pre-cast, Pre-tensioned Systems

- **If cutting is necessary consult StS**
- **Avoid cutting Beams and Stems of Single & Double Tees.**
  - **May carefully cut these when collapsed and are part of rubble pile.**
  - **Avoid cutting near the ends (all cases)**
- **May cut Slabs, including Slabs of Tees**
  - **Cut access holes, centered on the joint between two adjacent members**

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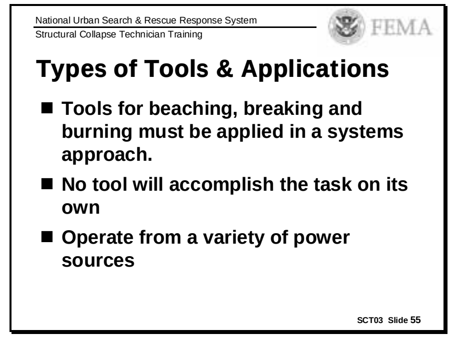
TYPES OF TOOLS AND USES

- Tools for breaching and breaking must be used in a "systems" approach. No tool will accomplish the task of breaching and breaking by itself. In order to accomplish any breaching and breaking task a team must identify the tools it will need in advance. Once identified they must be used in the appropriate manner to accomplish the operation as quickly and safely as possible.

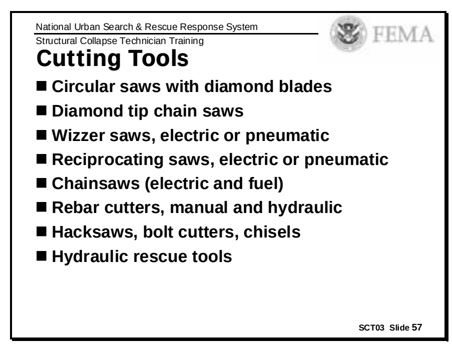
- These tools operate from a variety of power sources. They may be pneumatic, hydraulic, fuel driven, battery, electric or manually operated

- For our purposes we will categorize tools in the following manner.
  - Cutting
  - Breaking
  - Breaching
  - Torches
  - Support



Cutting Tools

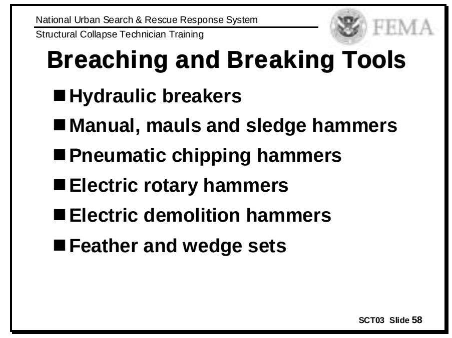
- These are tools, which are used to cut concrete, steel, wood or reinforcing bars. They come in a variety of forms and sizes with certain tools best suited for specific jobs. The following are tools that you will encounter during this course:
  - Circular saws with diamond segmented blades
  - Diamond-tip chain saws
  - Wizzer saws, electric or pneumatic
  - Reciprocating saws, electric or pneumatic
  - Chainsaws (electric and fuel)
  - Rebar cutters, manual and hydraulic
  - Hacksaws, bolt cutters, chisels
  - Hydraulic rescue tools



TYPES OF TOOLS AND USES (continued)

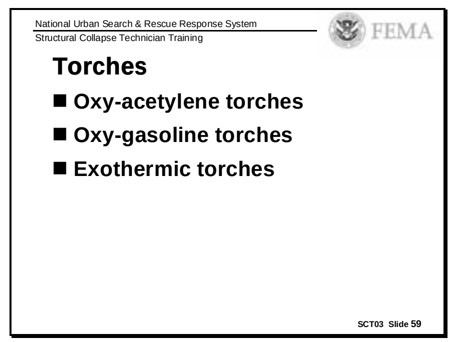
Breaking and Breaching Tools

- These tools are used to remove large or small section of concrete by removing it under tension or sheer. Breaking and breaching tools are most effective when some method of compression relief is provided for the concrete, such as relief cuts or stitch drilling.
  - Hydraulic breakers
  - Manual, mauls and sledge hammers
  - Pneumatic chipping hammers
  - Electric rotary hammers
  - Electric demolition hammers
  - Feather and wedge sets



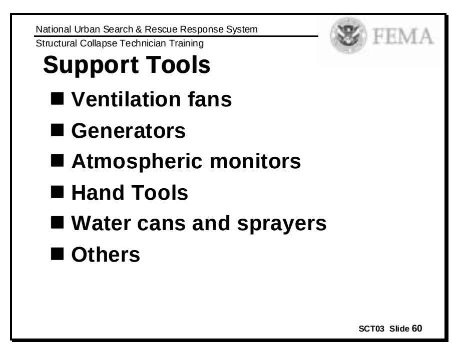
Torches

- These devices are used most appropriately to cut steel reinforcing, plates, beams or cables. They come in a variety of sizes and operate from a variety of different power sources. These may include the following:
  - Oxy-acetylene Torches
  - Exothermic Torches
  - Oxy-gasoline Torches



Support Tools

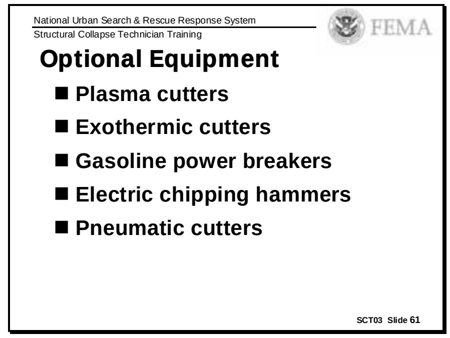
- These tools include all of the accessories you will need to accomplish your breaching and breaking. Without these tools your operation may not be as effective or safe. These may include:
  - Ventilation fans
  - Generators
  - Atmospheric monitors
  - Hand tools
  - Water cans, sprayers
  - Bolts
  - Lights and accessories
  - Cribbing
  - Fuel and repair tools
  - Webbing
  - Extinguishers
  - Mechanical advantage systems, and rope systems



TYPES OF TOOLS AND USES (continued)

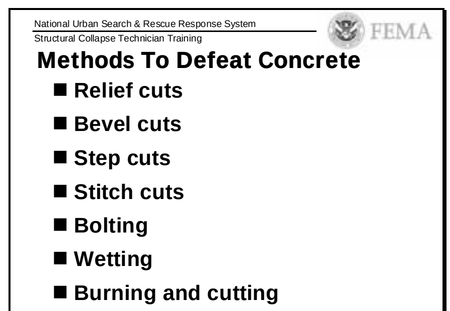
Other Optional Equipment

- There are other tools on the market or in the trades that can be used effectively at a rescue site. They may include the following:
  - Plasma cutters
  - Exothermic torches
  - Gasoline powered breakers
  - Electric chipping hammers
  - Pneumatic breakers



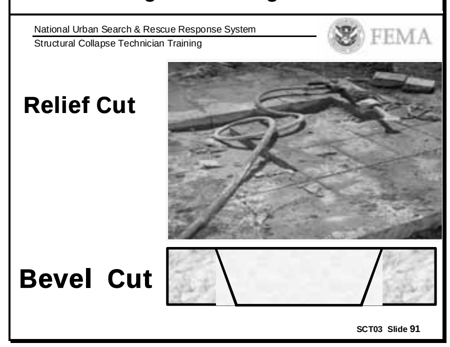
METHODS TO DEFEAT CONCRETE PROPERTIES

In order to effectively breach and break concrete you must know how to apply your tools using specific techniques. These techniques are designed to defeat the structural strengths of concrete based on its construction type. Listed below are several techniques, which used together, will enhance your operational capabilities. Prior to cutting, one needs to drill an inspection hole in order to assess the hidden side and account for victim location and safety.

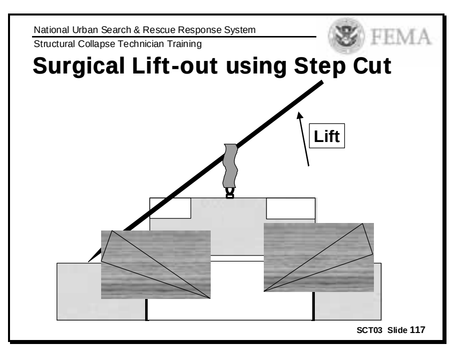


- RELIEF CUTS: (Tension & shear vs compression) These cuts are usually made with saws prevent the concrete, in which a "free edge" is being formed, from acting in compression. These may be square relief cuts, triangular or x shaped. The gap created by the relief allows you to attack an inherent weakness of concrete, which is its poor structural stability when placed in shear or tension. (shear failure in concrete is actually diagonal tension failure)

- BEVEL CUTS: This is an angled cut which is made during a "lift out" operation. The bevel cut allows the rescue team to cut deep within the concrete while limiting the possibility that the cut section will slip through the hole. These types of cuts are critical when cutting over the top of a victim(s).



- STEP CUTS: This is a cut which is used during a "lift out" operation, when the slab is thicker than what can be cut with one pass of the saw. Two cuts are made parallel to one another the width of the saw blade guard. The concrete is then chipped out between the two cuts forming a trench. This allows the saw to complete the cut through the full depth of concrete.



METHODS TO DEFEAT CONCRETE (cont.)

- STITCH DRILLS: These are bore holes which are partially or completely drilled thorough the concrete in a close stitch pattern within a predetermined area. These holes act very similar to the relief cut, allowing you to place the concrete in sheer or tension when applying a breaker.
- BOLTING: Bolting can be used in a variety of situations. Bolts can be permanent or re-usable. In most instances they are placed in the concrete as anchors to support either the slab portion being removed or to support a tool.
- WETTING: The application of water from tool attachments or from manual spray devices is often critical when using diamond saws. The application of water keeps blades and chains cool and lubricated. Which keeps the diamonds from becoming polished and ineffective. This also keeps down dust.
- BURNING AND CUTTING: Cutting with a torch is often an art and requires experience to become an accomplished burner. Oxy-acetylene and Oxy-gasoline requires the most knowledge while exothermic cutters can be used after only a few minutes of instruction and practice. ***<u>ALWAYS!!!</u>*** ***<u>Wear proper burners goggles</u>***. It only takes one piece of slag to end a career. In some instances cutting with a torch provides the most controllable method of cutting cables and rebar. When using any torch you must be aware of the fire hazard. You must also be aware of radiant heat transfer. <u>Before and during operations you must monitor the atmosphere to assure you are not in, or creating a hazardous atmosphere.</u>

  The most common method of cutting is to place the tip of the flame halfway over the edge, with the preheat flames 1/16 in. to 1/8 in. from the surface to be cut. When the flame starts to produce an orange color the metal has reached it's kindling point, slowly squeeze the oxygen-cutting lever and the process will begin. Once the cut has been started, the torch is moved with a smooth and steady motion maintaining a constant tip to work surface distance. Move the torch with a speed that will produce a light ripping sound and a smooth, steady stream of sparks.

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Stitch Drill

SCT03 Slide 118

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Burning and Cutting

- Often an art that requires experience
- Oxy-acetylene and Oxy-gasoline require the most knowledge, while exothermic cutters can be learned in a few moments.

SCT03 Slide 124

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Torch Safety

- Always wear proper burners goggles, one piece of slag can end your career
- Always be aware of the potential fire hazard
- Always be aware of heat transfer
- Monitor the atmosphere before,and during use

SCT03 Slide 125

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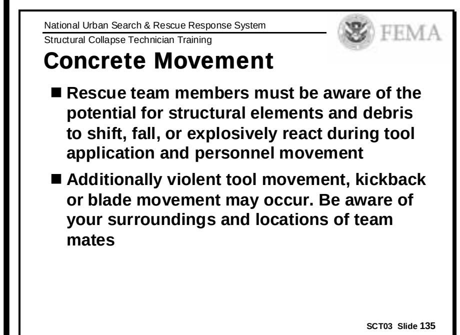
As A Cutter You Should:

- Understand the different torch functions
- Understand fuel and oxygen supply
- Understand torch heads and handle
- Select cutting tips
- Set up and cut using proper application
- Understand exothermic systems
- Set-up and cut with rods

SCT03 Slide 126

SAFETY ISSUES

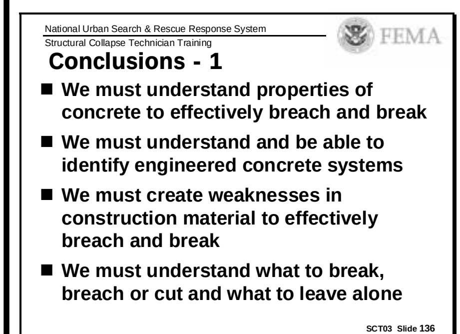
- The safety of the rescuers and support crews is critical to a successful operation. It is the responsibility of the Rescue Specialist to utilize all appropriate Personal Protective Equipment (PPE) for the task at hand. During breaching and breaking operations you may be confronted with a variety of hazards which may effect your operations. These may include but are not necessarily limited to the following:
  - Exposure to heat
  - Shifting or movement of large weights
  - Deficient or dangerous atmospheres
  - Confined spaces
  - Tool reaction
  - Materials reaction
  - Sharp objects, tools and blades
  - Trip and fall hazards

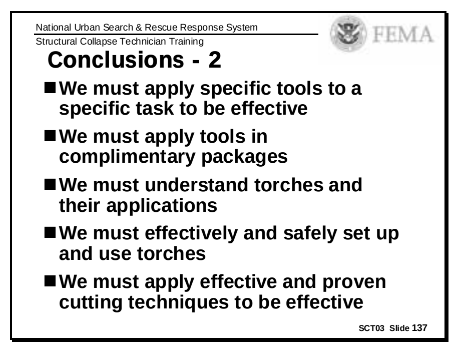


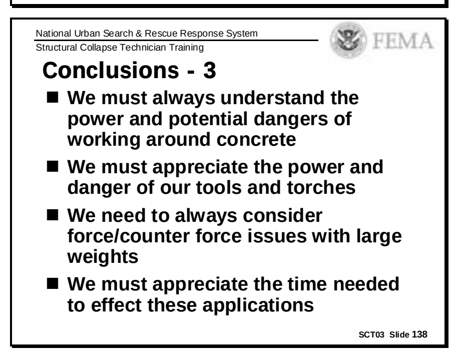
OTHER ISSUES

- Concrete movement during tool use
  - Rescuer must be aware of the ability of slabs to shift vertical lift out section to fall and the movement of concrete in large or small pieces as a result of tool reaction. You must also be aware of and anticipate tool reaction/torque during operation. The rescuer should be prepared for violent tool reactions during breaching and cutting operations.

- As in any cutting operation you must be aware and prepared for saw kickback and blade movement. During operations you must also be aware of your environment and fellow rescuers to assure you do not strike them with a running saw.







STUDENT MANUAL
MODULE 4 LIFTING AND MOVING

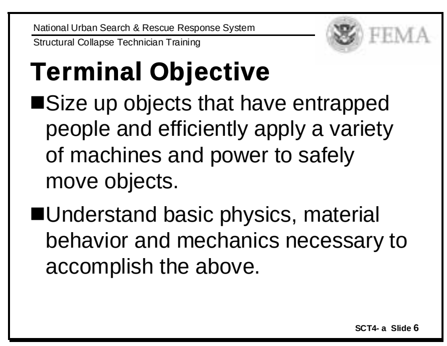
INTRODUCTION

A fire officer on a pumper was once asked why he ordered the pumper engineer to drive the 30,000 pound fire apparatus on a road that had a bridge with a 10,000 load limit. The officer responded to the question by saying that "it was an emergency". Rescue personnel often think that the physical laws of the universe do not apply when there is "an emergency". Gravity is one of the laws of the universe that applies to all earthly (rescue) environments. Rescuers deal with gravity every time they lift a patient, every time they move an object and every time they lower themselves on a rope.

Rescuers need to understand the relationship of gravity to basic tactical evolutions such as lifting, lowering, moving and stabilizing loads. Today even with the availability of powerful cranes, strong hydraulic winches and high pressure air bags there is a need for a knowledge of the basic concepts of leverage and gravity. It is the ability of the rescuer to make effective size ups in confined areas of collapsed buildings that often means the difference between life and death.

The rescuer also has a critical role to play when using the heavy lifting equipment such as cranes. All loads to be lifted or moved must be assessed for weight, stability and rigging points. The rescuer's knowledge of rigging equipment and its basic application will enhance the ability of the heavy equipment to perform.

This training module for the US&R Sructural Collapse Technician will look at levers, gravity, lifting and rescue rigging equipment.



TERMINAL OBJECTIVE

- Size-up objects that have entrapped people and efficiently apply a variety of machines and power to safely move these objects
- To understand the basic physics, material behavior and mechanics necessary to accomplish the above

ENABLING OBJECTIVES
At the conclusion of module the student should be able to:

For Part a
- Understand the basic physics as they relate to Weight, Gravity, and Center of Gravity.
- Explain the concepts of Energy, Work, and Power
- Describe what determines the efficiency of mechanical advantages.
- Explain the three classes of levers.
- Describe the efficiency of inclined planes.
- Describe the two types of pulley configurations.

For Part b
- Explain the effective use of high pressure air bags.
- Lifting & Stabilizing Loads and Cribbing
- Calculate the weights of common materials.

For Part c Explain use of proper sling angles to efficiently lift a load
- Explain the use of anchor systems, anchor failure considerations, and proper anchor spacing.
- Describe the proper use of swivel hoist ring, steel angle brackets, and concrete screws.
- Understand the proper use of wire ropes, wire rope fittings, end terminations, and tighteners.
- Explain the use of slings and sling arrangements.
- Describe the use of chains for rigging and lifting.
- Determine the effects of critical angles as the relate to lifting and moving objects.
- Identify and describe the advantages and disadvantages of the different types of cranes.
- Explain considerations for crane use, and demonstrate basic crane signals for rescue operations

PRIME RULE OF L&M
One should only Lift & Move an Object if there is no other viable alternative. Once in Motion, It is more Dangerous

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Enabling Objectives
- **Basic Laws of Physics**
- **Gravity & Weight**
- **Center of Gravity**
- **Mass & Equilibrium**
- **Friction**
- **Leverage**
- **Mechanics, energy, work & power**
- **Mechanical Advantage**
- **Simple-complex machines**

SCT4- a Slide 7

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Enabling Objectives
At the completion of this lesson the student shall have a working knowledge of:
- Inclined Planes
- Pulleys
- A-Frames
- Air bags
- Wedges & Cribbing
- Calculating weights
- Slings: wire, rope, chain & synthetic
- Consideration for crane use.
- Slings and sling attachments with cranes
- Crane hand signals
- Anchor systems & lifting devices

SCT4- a Slide 8

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Prime Rules of L&M
- If you can leave it, leave it.
- If you can't leave it, go around it.
- If you can't go around it, drag it.
- If you can't drag, roll it.
- If you can't roll it, lift it.
- If you have to lift it, STAY AWAY FROM IT…
- **IF IT FALLS DON'T BE UNDER IT!**

SCT4- a Slide 9

UNIVERSAL GRAVITATION and CENTER of GRAVITY

PRINCIPLE

- The Earth's Gravity exerts a Force on all objects on its surface called "Weight"

  - Gravity can help us move and/or stabilize objects
  - Gravity can be used as a movement engine
  - There is no exception to gravity.
  - All objects seek a state of equilibrium.
  - Gravity effects such evolutions as:
    - Lifting
    - Lowering
    - Moving
    - Stabilizing

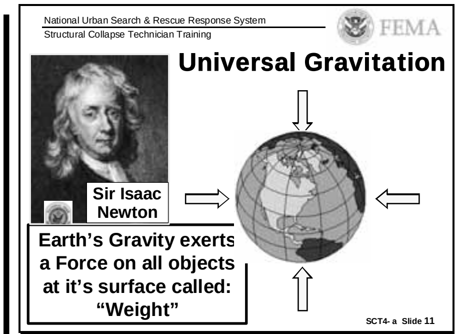
CENTER OF GRAVITY (CG) AND POSITION CHANGES

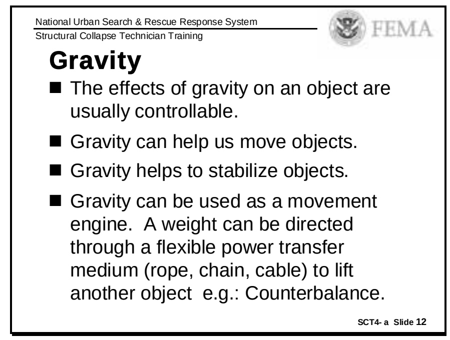
- Center of gravity: Point at which the whole weight of object is acting vertically downward = Balance Point.
- Load's weight is perfectly balanced or distributed around the center of gravity.
- If a load is suspended at its CG, it can be turned in any direction with little effort.
- If load is lifted to the right/left of CG, it will tilt at an angle.
- If a load is lifted below its center of gravity, the weight of the load will be above the lifting point, and the load will tip over.
- Important that loads be hoisted above the load's CG.
- CG of a solid object is located in three planes or directions:

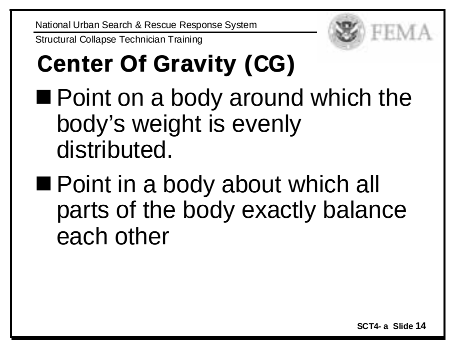
  - X axis = Horizontal, side to side
  - Y axis = Vertical axis
  - Z axis = Horizontal, front to back

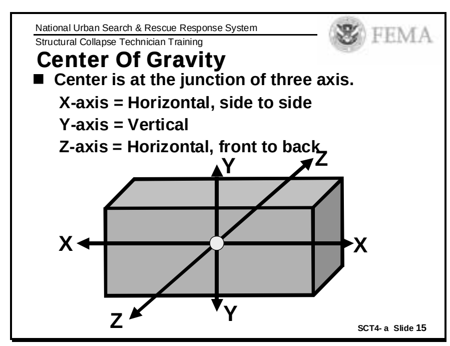
EXAMPLE OF CG:

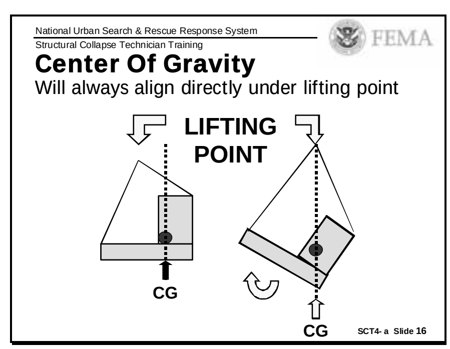
A solid piece of concrete that is 10ft long x 4ft wide x 6ft high has it's CG at a point that is 5ft from the end, 2ft from the front, and 3ft from the bottom











WEIGHT

- Force of the Earth's Gravity on a Mass sitting on its surface is called its "Weight"
  - The "Weight of the same Mass on the Moon would be 1/6 as much

EQUILIBRIUM

PRINCIPLE:

- Every object resting on earth is said to be "at rest" and in a state of Static Equilibrium. All objects seek a state of equilibrium.

CHANGING EQUILIBRIUM

- Small outside force/effort at the highest point on the object can change it's condition from static to unstable equilibrium:

  - Wind or a gentle push can move the object out this "balance point" of static equilibrium.
  - With applied force changes into a state of unstable equilibrium.
  - Object will move (fall over) into another position of static equilibrium.

FRICTION and RESISTANCE FORCE

PRINCIPLE:

- Force found in the location of the contact between two surfaces.
  - It depends on the type and roughness of the contact surfaces as well as the weight that is acting.

- Force acts parallel to those surfaces in a direction opposing the relative motion between them.

The greater the weight (force of gravity) of an object, the greater the friction force

Center of Gravity

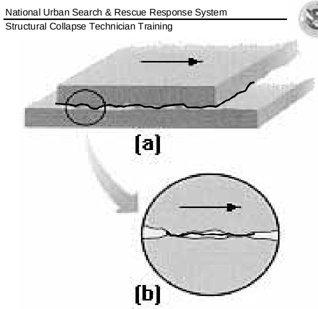
- The object:
  - Will not always have uniform density
  - Will not always have uniform shape
  - May have shifting loads; fluids in tanks, debris
- Intuitive Skill

Static Equilibrium

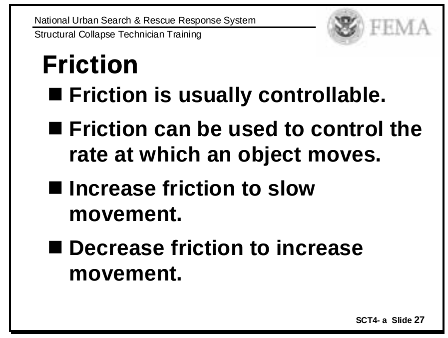
- An "at rest" object is in a state of static equilibrium.
- To move an object, you must overcome static equilibrium.
- Static equilibrium is effected by:
  - the object's weight
  - the object's frictional interface with other objects

Friction

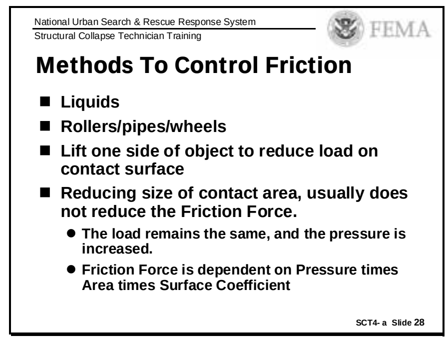
- A force tangential to the common boundary of two bodies in contact that resists motion of one relative to the other.
- The greater the weight, the greater the friction force
- A byproduct of friction is HEAT.



BASIC CONCEPTS RELATED TO FRICTION



- The smoother the two contact surfaces, the less the friction between those surfaces.
- Liquids can reduce the friction between two surfaces. (unless too much surfacetension is developed)
- Materials with rounded surfaces that break the contact between objects will generally reduce friction.
- Reducing the size of the surface area between two objects will, normally not reduce the Friction Force
  - Friction Force depends on the Vertical Load per square foot (pressure) and the Friction Factor (based on the surface type and roughness)
  - If the contact area for a given load becomes less, then the pressure increases proportionally, and therefore, the Friction Force remains the same.
- Lifting operations often involve lifting only one side of the object which reduces the weight on the contact surface and consequently decreases the friction force.

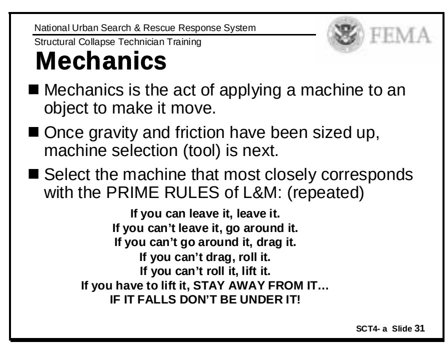


FRICTION AND EQUILIBRIUM

- Friction may be the outside force acting on a object creating equilibrium.
- The rescuer can change the amount of friction holding a object in place and allow the force of gravity to overcome the forces of friction:
  - Rocking motion
  - Making surface smaller (tilt lift)
  - Reducing the weight on the contact surface
- Friction holding an object in place can be overcome by the force of gravity when a object is on an inclined plane.

APPLICATION of MECHANICS to COLLAPSE RESCUE

Inappropriate or ineffective use of rescue tools is often a result of a lack of understanding of mechanical advantage. The following is an overview of mechanics of rescue:



- **Mechanics** is the branch of physics dealing with Force, Energy, Work, and Power in relation to physical bodies.
- **Leverage** is the practical application of the moment of force principle.

ENERGY

- Energy is the Work that a physical system is doing in changing from it's current configuration to another one.
- Both Energy and Work are measured in Foot-Pounds, but Energy and Work are different
- There are two types of physical Energy systems, Stored Energy and Kinetic (moving) Energy
  - An example of Stored Energy is the condition when a heave object is positioned or suspended above a place where it can move to a lower level.
  - If a Crane suspends a 100lb weight 100ft above the ground, the Stored Energy is 10,000 ft-lbs. Any tall building has millions of ft-lbs of Stored Energy that can be liberated during a collapse
  - A swiftly moving Train is an example of Kinetic Energy
- The basic principles of the Conservation of Energy are stated in the adjacent slide

WORK

- In a general dictionary definition, Work is the Physical or Mental effort directed toward the production or accomplishment of something.
  - Transfer of Energy from one physical state to another
- In our case Work is the physical effort in moving an object from one position to another. The application of a Force in moving an object some distance against a Resistance (Friction and Gravity)
- In the case of Work an object (pounds) will be moved a distance (feet)
- In the case of Energy an object (pounds) is elevated a distance (feet) above where it can eventually be moved

POWER

- Power is the Rate at which Work is done. Objects (pounds are moved Distance (feet) within a specific Time (minutes)
  - One Hoursepower is 33,000 ft-lbs per minute
- We need Work to produce the Power that will overcome Friction, Gravity, Wind Resistance over a specific Time period

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Energy & Work Concepts

The effective use of rescue tools is often determined by a good understanding of mechanical systems and their application in a given situation.

SCT4- a Slide 33

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Conservation of Energy

- **Energy is neither created or destroyed, it only changes forms.**
- **A falling body's energy may be changed to heat via a friction control device.**
- **A mechanical advantage system only exchanges the load into extended time and distance.**
- **The amount of energy required to do the job is EXACTLY (minus the friction) the same.**

SCT4- a Slide 36

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Conservation of Energy

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SCT4- a Slide 36

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Work & Power

- **Work is the result of a force moving an object some distance.**
- **Power is the rate at which work is done**

SCT4- a Slide 37

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Work & Power

- **Work = Force X Distance**
- **Force = Work / Distance**

SCT4- a Slide 38

MOVEMENT

- Moment of force about a point (always a point) is weight (or force) multiplied by the distance away from the turning point of that weight or force.
- **Foot-pound** means of describing a Moment of Force
  - foot = distance
  - pound= force
  - force = influence that can change an object's velocity.
- When a force is applied that will cause rotation around a fulcrum (pivot point) = moment of force = foot-pounds.

THE HUMAN MACHINE

- All machines require some energy source to apply the forces that will make them produce Work
- Humans can provide at Energy in the form of push and pull forces as well as applying their own weight in the downward direction
- Food is burned as the fuel in the body to create this bio-machine
- As noted in the adjacent slides The Rescue Squad can deliver a lot of Force that does the Work to produce Power

OVERVIEW OF MECHANICAL ADVANTAGE (MA)

- Ratio between the output force a machine exerts to the input force that is furnished to that machine to do work.
- Defines how efficient and effective a machine is.
- Mechanical advantage greater than one (1) means that the output force delivered by the machine exceeds the input force supplied to the machine.
- Mechanical advantage less than one (1) means that the output force delivered by the machine is smaller than the input force supplied to the machine.
- Applied to the relationship between the weight of a load being lifted and the power of the force required to lift/push/hold that load.

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Movement

- To obtain movement, these factors must come together:size-up of object being moved (weight, shape, obstructions, connection methods)
  - Mechanics (system to apply to the load)
  - Available energy (fuel, human machines)
  - Work, power, time

SCT4- a Slide 39

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The Human Machine

- All machines require some type of energy source to make them work.
- Humans are an excellent source of readily available energy.
- Food is burned as fuel by the body to create an extremely versatile bio-machine.

SCT4- a Slide 40

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The Human Machine

- The average human rescuer can apply approximately a 50 pound force (lbf) pushing or pulling an object at the rescue scene.
- A force equal to the rescuer's weight may be applied vertically.
- The human machine combined with the simple machine can move extremely heavy objects.
- A five person team applying force to a 5:1 mechanical advantage simple machine can deliver a 1250lb Force to an object:

5 (people) X 50 (lbf each) = 250 X 5 = 1250lbf

SCT4- a Slide 42

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Mechanical Advantage (MA) Definition

- Mechanical advantage is a force multiplier.
- The ratio between the output force a machine exerts to the input force that is furnished to that machine to do work, i.e.:
  - 5:1 pulley system, the human machine puts in one part and the anchor holds 4 parts (4 + 1 = 5).

SCT4- a Slide 44

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Mechanical Advantage & Conservation of Energy

- Mechanical (apply force to an object)
- Advantage (force multiplier) uses the same amount of energy to move an object as would moving the object with zero MA.
  - MA simply allows us to use less force to move an object by spreading the work out over time and distance.
- Example: a 5:1 pulley system takes 5 times as much rope to move the load as a 1:1 system would take.

SCT4- a Slide 45

OVERVIEW OF MECHANICAL ADVANTAGE (MA) (cont)

- Since all machines, including lifting devices, the efficiency of a machine is determined by calculating the Theoretical MA and subtracting Friction
  - In pulley systems the Friction Factor may be around 10%. That requires a 110lb force to lift a 100lb object
  - If a system has a mechanical advantage of 3 and friction factor or 10%, it will require about 55lb pull to lift the 100lb.
- There also may be secondary effects that reduce the efficiency of machines as listed in adjacent slide. Some of these are external (environmental) and some are internal to the machine (deflections caused by the applied forces)
- In all machines there may be a Point of Diminishing Return, such as being too big and heavy for hand use, or requiring an inordinate amount of fuel

SIMPLE MACHINES

- Consist of inclined planes, levers, pulley wheels, gears, ropes, belts, and/ or cams.
- Rigid or resistant bodies that have pre-defined motions.
- Capable of performing work.
- Energy applied to these mechanisms by a source that causes these mechanisms to perform useful motion.
- More efficient to perform work with machines than with muscle force only.
- We will now discuss Inclined Planes, Levers, Pulleys, and an advanced leverage application, the A-Frame

SIMPLE & COMPOUND MACHINES

- There will often be a trade-off, like time and distance when mechanical advantage is gained. However pulley systems with mechanical advantage, do allow the operator to move the load more slowly with better control.

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Theoretical vs. Actual
Mechanical Advantage

- **Theoretical MA (TMA) is the system with a complete lack of efficiency robbing friction.**
- **Actual MA (AMA) is the TMA minus the friction coefficient of the friction surface.**
- **If TMA = 5:1 and the Friction Coefficient (FC) of the system is 10%**
  AMA = 5.0-.5 = 4.5 to1

SCT4- a Slide 47

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Secondary MA Efficiency Factors
There are inherent secondary inefficiencies in any mechanical system.
Myriad of factors that influence efficiency:

- **Equipment condition**
- **Environmental conditions**
- **Material elongation**
- **Beam deflection**
- **Wood compression**
- **Torque in a shaft**
- **Interpersonal relationships**

SCT4- a Slide 48

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Point Of Diminishing Returns
Every machine has a point of diminishing returns:

- **Too big.**
- **Too complex.**
- **Too heavy.**
- **Material weakness.**
- **Too much fuel required.**

SCT4- a Slide 49

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Simple Machine

- **A simple machine accomplishes its task in a single movement.**
- **A COMPOUND machine combines two or more simple machines.**
- **Machines allow us to APPLY mechanical advantage to an object.**

SCT4- a Slide 50

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Simple & Compound Machines

- **Trade off of time and distance by placing the force required to move an object into our available power window.**
- **Nothing is free, the amount of energy expended is equal.**

(Conservation of Energy)

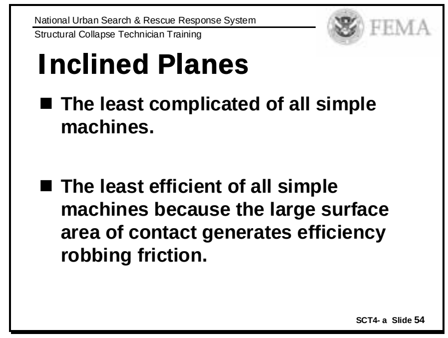
SCT4- a Slide 51

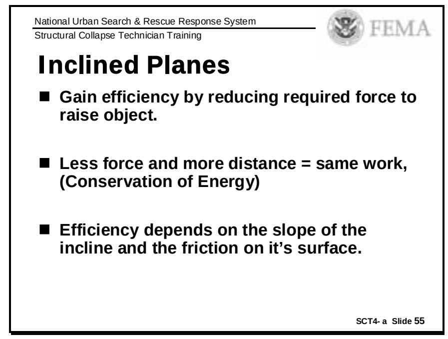
INCLINED PLANES

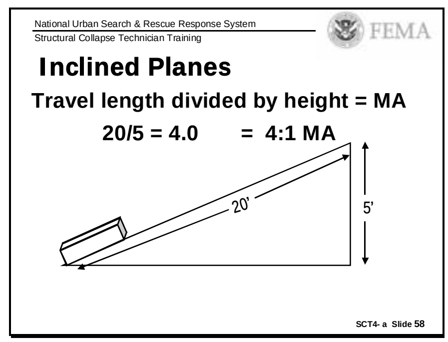
- Examples: Ramps, wooden wedge, screw thread
- Gains effectiveness of energy used based on distance traveled = mechanical advantage.
- Use of a gradual slope = less force to move an object a certain distance.
- **Percentage of load based on slope and grade**
  - When an object comes to rest on a slope, the rescuer must determine the percentage of the loads weight that needs to be managed during the stabilization process.
  - To estimate the load percentage first determine the amount of resistance the load surface has in relation to the object.
  - Discounting friction refer to the table below for approximate weight based on slope.

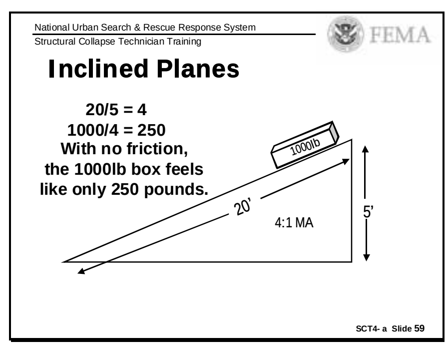
Slope/Grade	% of Load's Weight
45 degrees	71%
30 degrees	50%
20 degrees	34%
10 degrees	17%

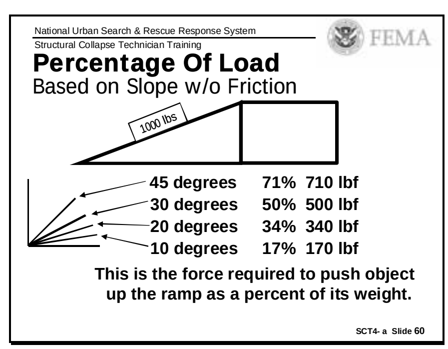
- However the friction force associated with sliding objects up ramps may be as high as 35%
  - In this case the Force that is requires to move the object up the ramp is greater as shown above and in adjacent slides
  - The Friction MAY be uses as a Break to keep the object from sliding back down the ramp when the slope is less than about 20 degrees











LEVERS

"Give me a place to stand and I will move the World" Archimedes

- Application of levers:
  - Move a load that is heavier than can be moved by manpower alone.
  - Pulling/hauling.
  - Raising.

- Leverage is the means of accomplishing work with levers:
  - Transfers force from one place to another.
  - Changes the force's direction.

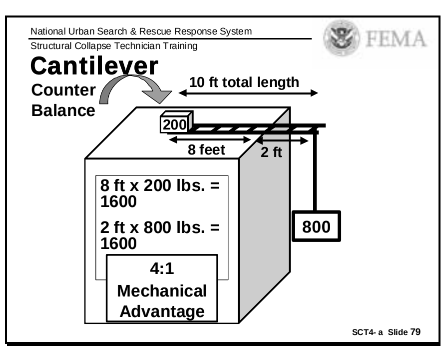
CLASSES OF LEVERS

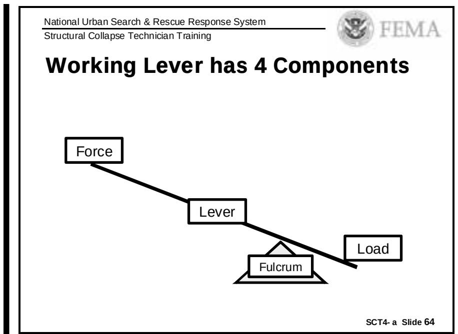
- **Class One Lever**
  - Fulcrum is placed between the force applied and weight (load).
  - MA: Used when a decided advantage is desired.
  - Examples: Crowbars, wrecking bars, pliers, scissors

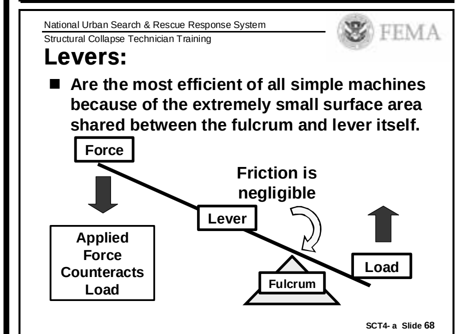
- **Class Two Lever:**
  - Weight (load) is placed between the force and the fulcrum.
  - MA: Used for advantage in moving heavy materials on a horizontal/near horizontal surface.
  - Examples: Wheelbarrows, furniture dollies

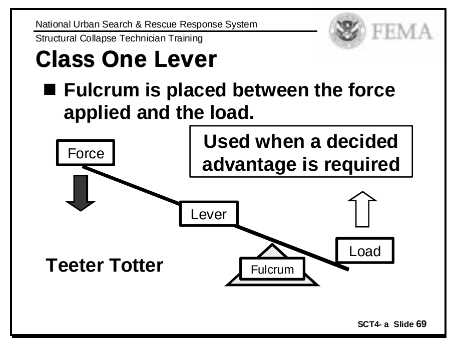
- **Class Three Lever:**
  - Force placed between the fulcrum and the load.
  - MA: used when force may be sacrificed for distance.
  - Examples: Brooms, shovels, baseball bat, tweezers

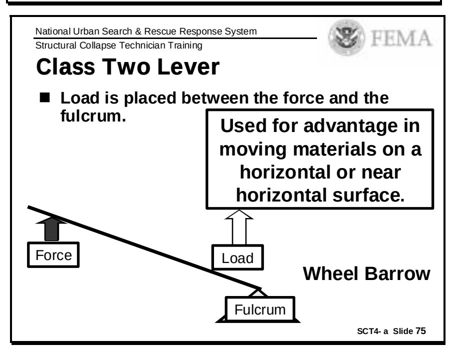
- The cantilever in the slide below is a special case of a Class One Lever

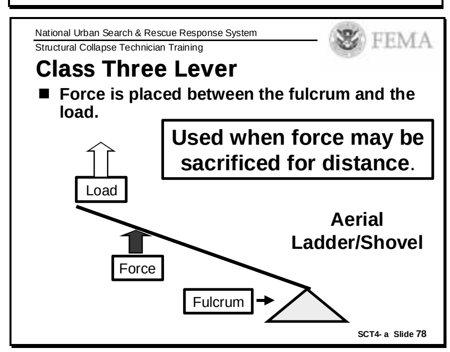








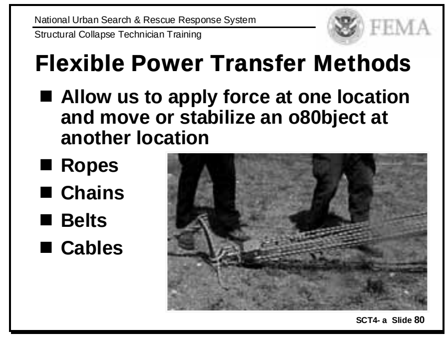




SCREW-TYPE MACHINES

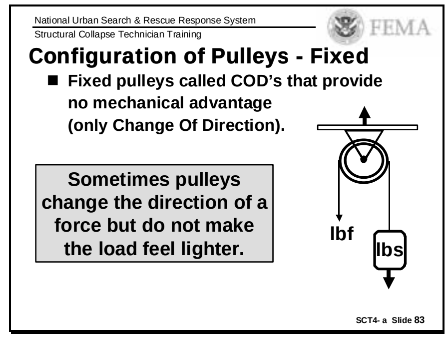
- Examples of screw-type machines: Worm gears, screw jacks and valves in fire hydrants.

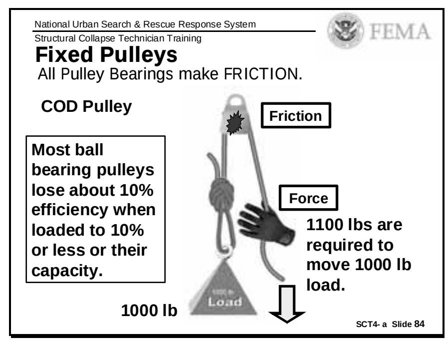
- Characteristics of these machines are:
  - Combination of a lever and an inclined plane.
  - Thread of a screw is an inclined plan encircling the stem of the screw.
  - Handle is the lever.
  - Thread works in a corresponding groove in the base.
  - Thread is forced to move under the load.
  - One rotation of the handle moves the thread through a distance equal to the distance between it and the thread below it.
  - Distance moved is call the pitch of the screw.



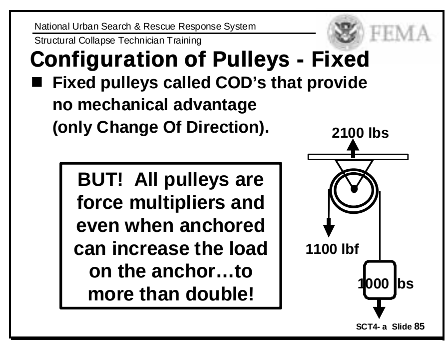
PULLEYS

- Application related to loads:
  - Lifting
  - Pulling
  - Moving
  - Change direction
  - Mechanical advantage
  - Reduce friction

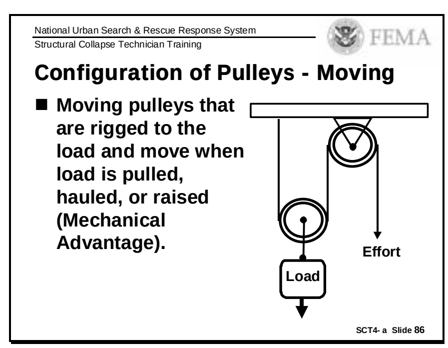




- Fixed Pulley - Change direction of effort:
  - Pulley is stationary: Does not change theoretical mechanical advantage



- Traveling Pulley - Gain mechanical advantage:
  - Pulley is moving: Changes mechanical advantage depending on use
  - Bitter end at the load — the simple system is odd
  - Bitter end at the anchor — the simple system is even



PULLEYS (continued)

- Calculating Pulley Mechanical Advantage (MA)
  - In general the system needs to have a Traveling pulley in order for there to be a MA
  - The number of rope lines (Parts of Line) coming from the Traveling Pulley determines the MA
  - The Load will travel the distance Traveled by the Pulled end of the line divided by the MA
  - As MA becomes greater the Anchor shares more Parts of Line

- In Simple pulley systems there is one set of Fixed pulleys and one set of Moving pulleys (Sheaves)
  - Add sheaves side by side to increase MA
  - On ODD numbered systems the Terminal end of the rope begins on the Load side of the system
  - For EVEN numbered systems the Terminal end of the rope begins at the Anchor End of the system

- In Compound pulley systems the pulleys are "**Stacked**" to gain MA, as shown in the adjacent slide
  - These systems have less Friction, use less rope and have a shorted Stroke

The difference between theoretical and actual mechanical advantage is "friction

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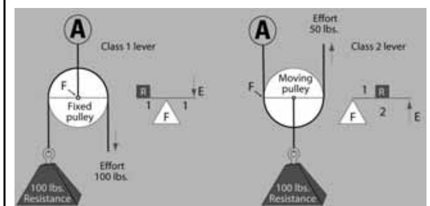
How Pulleys Work



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Sharing the load with our hero
The Anchor

- **The anchor shares progressively more "parts" of the load.**
- **On a 5:1 MA, the anchor carries 4 parts, and the force necessary to move the load only carries one part.**

SCT4- a Slide 91

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Simple Pulley Systems

- **Add sheaves (side by side) to gain advantage.**
- **On ODD numbered systems the terminal end of the rope begins on the LOAD side of the system.**
- **On EVEN numbered systems the terminal end of the rope begins on the ANCHOR side of the system.**

SCT4- a Slide 92

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Compound Pulley Systems

- **Multiply sheaves (stacked pulleys) to gain advantage.**
- **2 to the 2nd power = 4:1 C.**
- **2 to the 4th power = 16:1 C.**
- **Less friction, less rope,**
- **LESS STROKE!**

SCT4- a Slide 93

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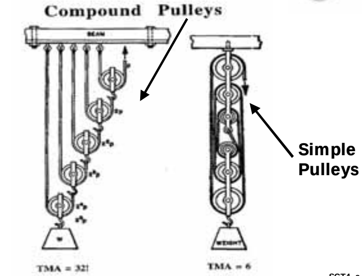
Structural Collapse Technician Training
FEMA

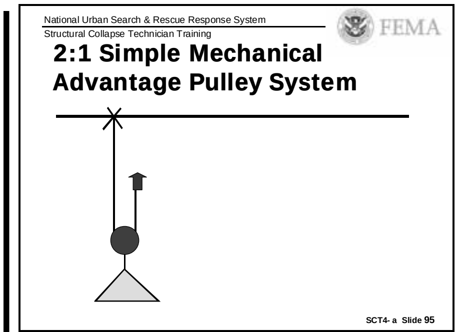
Compound Pulleys

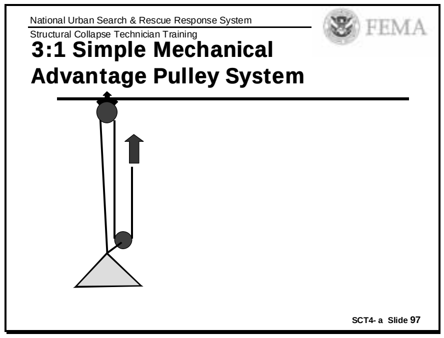


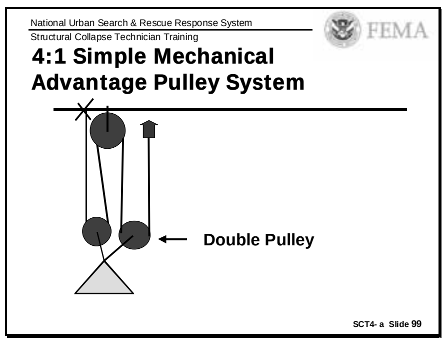
SCT4- a Slide 94

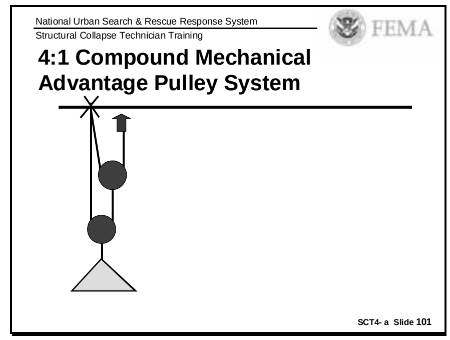
PULLEYS (continued)

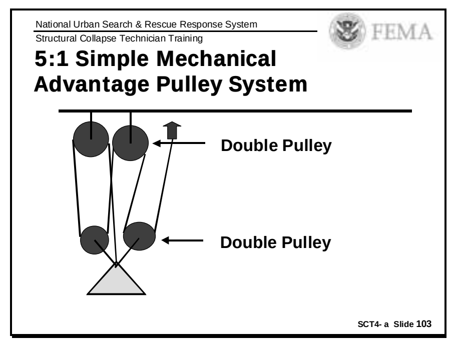
- **The adjacent slides provide examples of various pulley systems with different Mechanical Advantage, from 2 to 1 to 5 to 1**



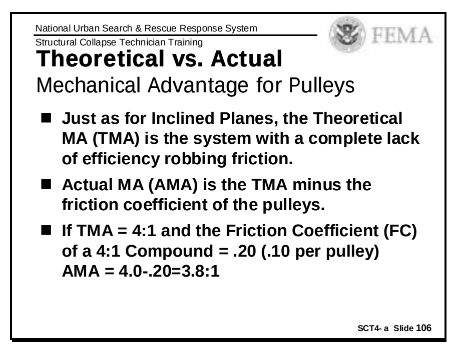






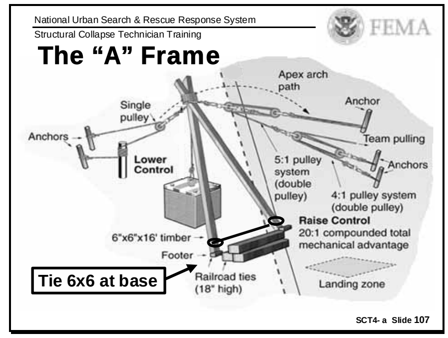


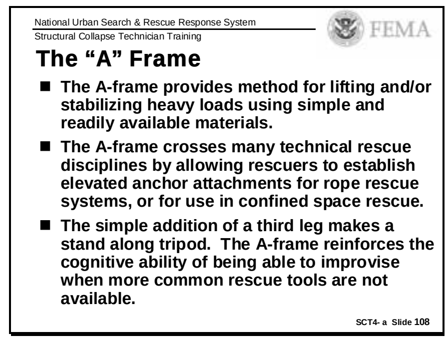
- **The difference between theoretical and actual mechanical advantage is "friction".**
  - **This is illustrated in adjacent slide**
  - **The pull required to move the load that is attached to the rope that runs over the pulley is the Load + Friction**

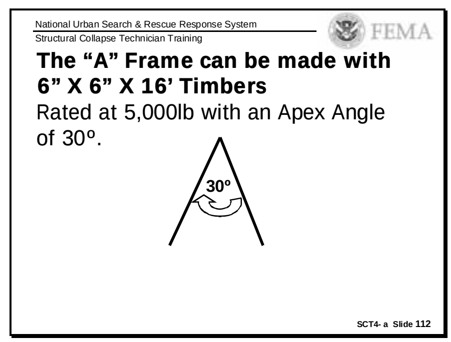


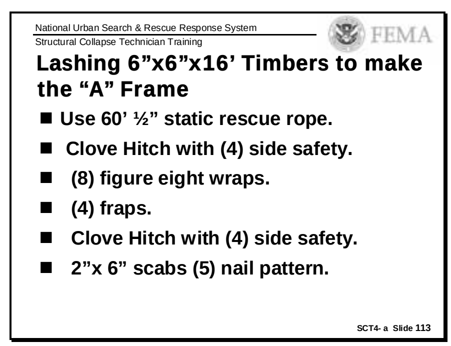
ADVANCED LEVERAGE APPLICATIONS A-Frame

- The A-Frame is a fairly complex application of leverage that involves floating an object in air between two horizontal points.
- The application for the A-Frame is most practical during collapse situations involving the movement of objects where there are no suitable overhead anchor points and crane access is not practical.
- The A- Frame may be made from two 6x6x14’-0” timbers that are lashed together at the top, or by using a pair of 12 ft long, aluminum rescue struts connected using special apex and foot connections.
  - The two lower ends of the A-Frame must be connected together, just above the ground, using a stout rope, webbing or chain.
  - The legs should be spaced from 10 to 12 feet apart at the ground.
- A 15:1 or 20:1 compounded mechanical advantage pulley system used for swinging the A-Frame is attached to the apex of the gantry and anchored to an appropriate bombproof anchors.
- The object (Load) is attached to the apex of the A-Frame using a short rigging strap, and a lowering control rope is connected opposite the mechanical advantage pulley system.
- As the A-Frame is tensioned and elevated, the load starts to rise. A hoist or come-along may also be used to initially suspend the load.
- The A-Frame apex must be rotated to be centered over the load, but the angle between the ground and the A-frame should not be less than 45 degrees.
  - At this angle the initial force on the hauling rope system is about 25% greater than the load, assuming that the hauling anchors are placed at least 30 feet from the base of the A-frame legs.
  - The force in each of the A-Frame legs will be about equal to the load as the lifting begins.





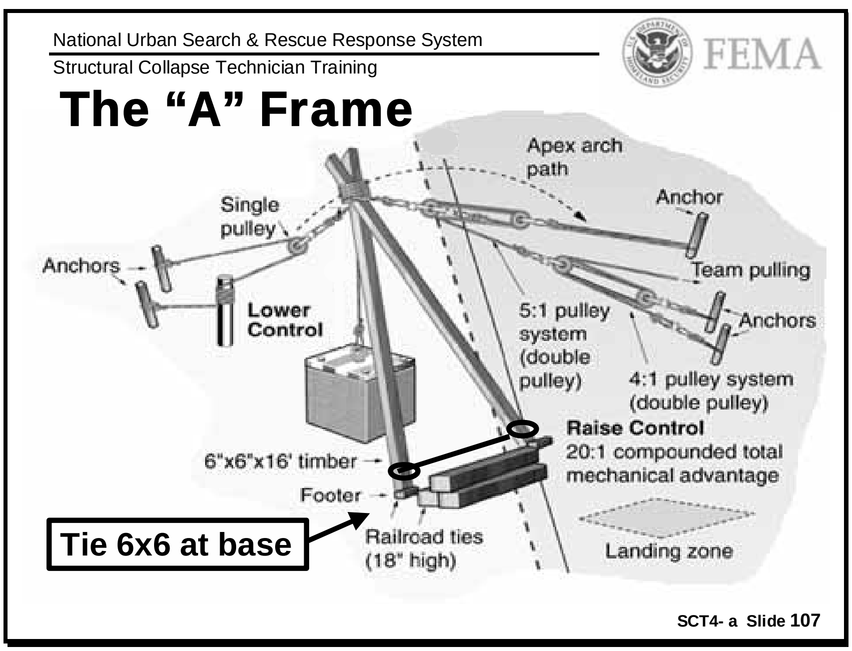




A-FRAME (continued)

- As lifting begins, forces are generated in the A-Frame legs
  - The horizontal force tending to move the base of each of the A frame legs away from the load will be about 2/3 of the load.
  - There will also be a vertical load acting into the ground at the frame base that is about equal to this horizontal force.
  - These forces need to be resisted by the ground, and/or some type of restraint system.
- The dimensions and forces for two A-Frame systems, using 45 and 60 degree initial angles are shown in the adjacent slides and on the following page.

DIAGRAM OF TIMBER A-FRAME



See SCT04 Appendix for a detailed description of the construction of an A-Frame using 6x6 timbers

DIAGRAM OF A-FRAME FORCES at 45 degree angle
(per 1000lb load. Suggested maximum Load = 4000lb

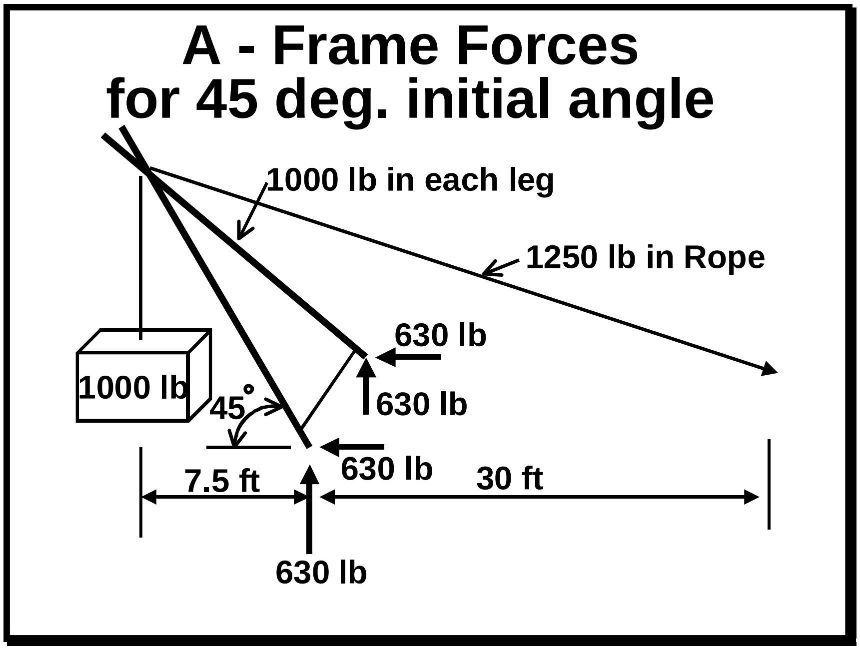
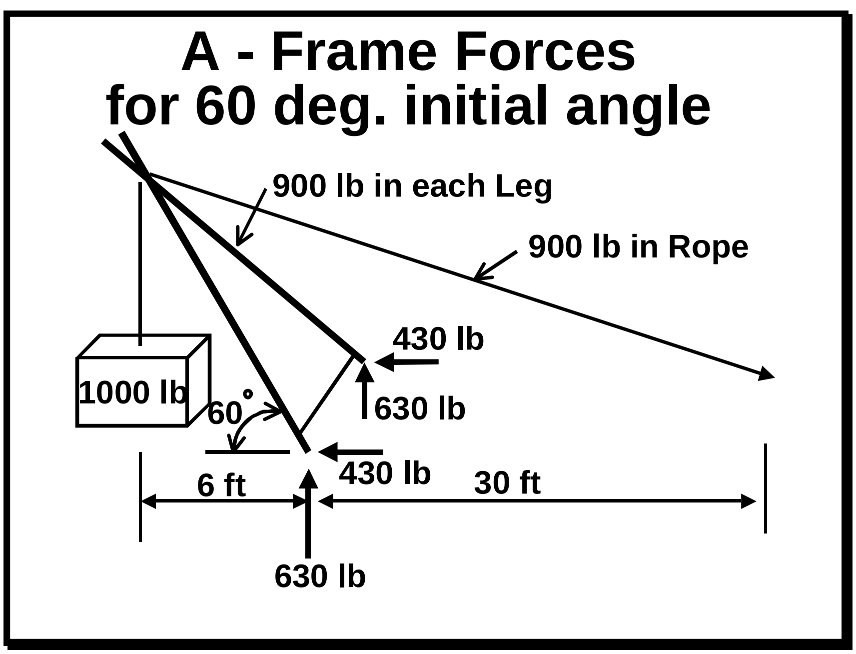


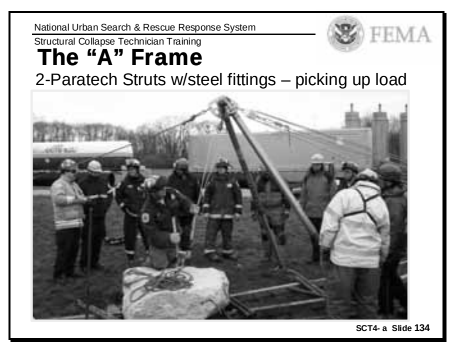
DIAGRAM OF A-FRAME FORCES at 60 degree angle
(per 1000lb load. Suggested maximum Load = 4000lb)



A-FRAME (continued)

- In most cases it is necessary to provide a footing/baseplate for each leg of the A-Frame.
  - In very firm ground, a shallow hole may provide enough resistance to the compression forces that are exerted when the A -Frame legs rotate.
    - The forces at the edges of the 6x6 will dig into the ground and create their own bearing surfaces.
  - In softer ground, it may be necessary to use a pair of 12" square plywood gussets to spread the load, and neoprene pads will be helpful in providing shaped bearings for the edges of the 6x6 as it rotates.
  - On concrete paving surfaces, it will be necessary to carefully restrain the 6x6 from slipping, and provide for the rotating bearing.
  - In the both the Airshore and Paratech Rescue Strut and A-Frame systems, a 12" square base plate that provides for the bearing and rotating leg.
    - This base plate must be properly restrained using rope, chain, or other mechanical anchors.

- As the A-Frame is arched over, the load elevates until the A-frame is straight up and the object being lifted is directly beneath apex.
  - As the load moves past 90 degrees, the pulley system becomes useless, and the lowering ropes take over the controlled lowering of the load.
- A-frame systems made by Rescue Strut Manufacturers
  - As mentioned above both Airshore and Paratech make fittings and bases that will allow their struts to be configured as an A-frame.
  - These systems are fairly expensive, so systems using 6x6 timpers may be more practical



SUMMARY of PART a

- We have discussed the basic principles of:
  - Gravity
  - Motion and Friction
  - Energy & Work
  - Simple Machines
  - A-Frames

TOPICS to be COVERED in PART b

- **Airbags**
- **Lifting Considerations & Stabilization**
- **Calculating Weights**

HIGH PRESSURE AIR BAGS

- Characteristics are:
  - Neoprene/butyl rubber — outer
  - Steel/Kevlar — reinforcement
  - Variety of sizes
  - Outer layer textured to reduce slippage
  - Capacity is calculated at 1" of lift
  - At maximum height, usable capacity typically is reduced to 50% of the rated capacity.
- Application:
  - Max. stack of two high (**bag centers must align)**
  - Lift capacity is that of the smaller bag
  - Lift height is increased
  - Ensure that the smallest bag has capacity for the lift
  - Place the large bag on the bottom
- Bags in tandem:
  - Bags side-by-side or at two points on a load
  - Maximum working capacities added together
  - Consider lift height as well as load weight
- Working area:
  - Flat surface
  - Solid cribbing bed under bag
  - Establish safe zones
  - Pressurize bags slowly and watch for load shift
  - If load is uncontrolled, stop the lift and reevaluate
  - Use solid cribbing or wedges under the load to stabilize
  - See mfr's manual for additional information
- Calculating lifting capabilities:
  - Maximum working pressure of individual bag
  - Surface area contact (is smaller than bag dimensions)
  - Working pressure of bag under load when in use
  - Maximum working capacity is the maximum contact surface area of the bag (**always smaller than bag dimensions**) times the maximum working pressure.
  - As the air bag lifts and "pillows," surface contact is reduced and the lift capacity is decreased

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High Pressure Air Bags

- Characteristics
  - Neoprene/butyl rubber
  - Steel kevlar reinforced
  - Variety of sizes
  - Maximum capacity is calculated at 1 inch of lift
  - Capacity reduced at max height

SCT4- b Slide 2

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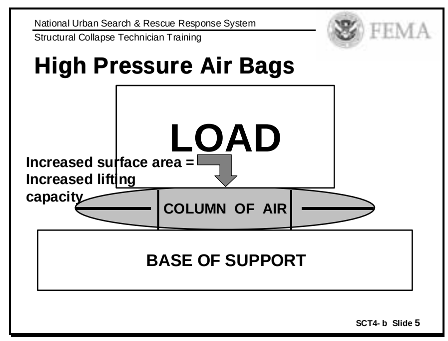
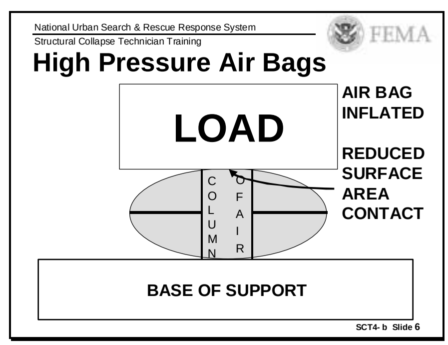
High Pressure Air Bags

- Application
  - Maximum stack of two high
  - Lift is limited to capacity of small bag
  - Larger bag on bottom
  - Centers of bags MUST be aligned

SCT4- b Slide 3





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High Pressure Air Bags

Dimension	Capacity	Lift Ht.	Weight
6"x 6"	1.5 Tons	3"	2 lbs
6"x 12"	3.2	3.5	3
10"x 10"	4.8	5	4
15"x 15"	12.0	8	10
15"x 21"	17.0	9	13
20"x 20"	21.8	11	16
24"x 24"	31.8	13	22
28"x 28"	43.8	16	30
36"x 36"	73.4	20	48

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HIGH PRESSURE AIR BAGS (continued)

EXAMPLE

- 10" x 10" air bag is 100 sq.in. in total area. The maximum working pressure is 118 PSI, and 100 sq.in. times 118 PSI = 11,800 lbs. of lift (5.9 tons) if full bag area was in surface contact. **From chart, actual capacity is 4.8 tons**.
- Check bag for **Identification Tag** that lists maximum pressure, load and lift height data.

High Pressure Air Bags
I.D. Tag is right on Bag

MAXIFORCE KPI 12
AIR LIFTING BAG SERIAL# 940492
MAXIMUM LIFTING CAPACITY 12TONS 10845 KG
MAXIMUM WORKING PRESSURE 118 PSI 8 BARS
MAXIMUM LIFTING HEIGHT 8 IN. 208 MM
MAXIMUM AIR CAPACITY 2.3 CU FT 65 LITERS
PARATECK INCORPORATED FRANKFORT, IL. U.S.A.
READ INSTRUCTIONS BEFORE OPERATING THIS EQUIPMENT

MECHANICS of LOAD STABILIZATION & MOVEMENT

- Four functions that need to be addresses before any load is stabilized, lifted, or moved:
  - Center of gravity
  - Load Stability including Shims, Wedges & Cribbing
  - Estimating Load Weight
  - Lifting Functions including Critical Angle Considerations

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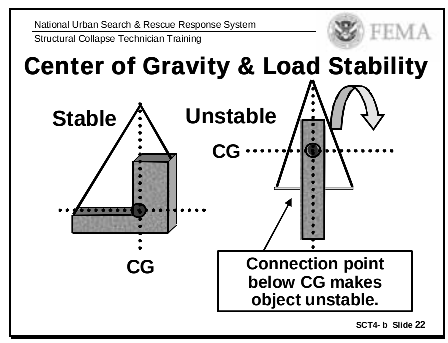
Structural Collapse Technician Training

Lifting Or Moving A Load
Functions to be addressed
- **Center of Gravity**
- **Load Stability**
  - **Wedges & cribbing**
- **Estimating Load Weight**
- **Lifting Functions**
  - **Critical angle**

SCT4- b Slide 21

CENTER OF GRAVITY

- **Center of gravity** is where any load's entire weight is concentrated.
- Loads will seek to have their center of gravity below the point of support.
- Moment of force (distance times weight) is created when the center of gravity moves around a fulcrum.
- Narrow base of support can rapidly become fulcrum (pivot point) for the load.
- The higher the center of gravity is located in the load, the wider and more stable the base of support needed to maintain the static equilibrium.
- A load with a relatively high estimated center of gravity and narrow base of support must be considered to be in a state of unstable equilibrium = moment of force of load's own weight (or external force) can cause the load to move into a state of equilibrium (i.e., fall over).
- Load rotation when the lifting point of the rigging is not directly above the center of gravity.



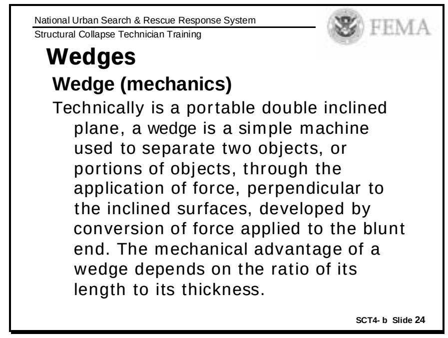
LOAD STABILIZATION

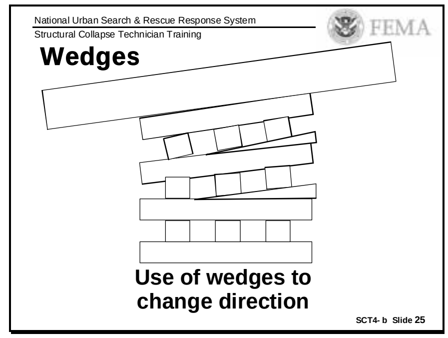
- Make load attachments above center of gravity when possible.
- Place attachments above and on either side of the estimated position of center of gravity to control load.
  - Wind or shaking from an earthquake (external force) can move a load with high estimated center of gravity and narrow base of support.
- Widen and extend the load base of support when:
  - Distance from base of support to estimated center of gravity is greater than the width of base of the support. Loads showing any signs of rocking or swaying = unstable equilibrium state. Consider that center of gravity may change:
  - Ground shaking changing position of internal load such as machinery in structure
  - Base of support shifting

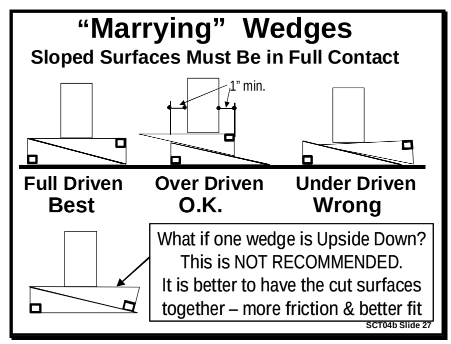
WEDGES / SHIMS / CRIBBING

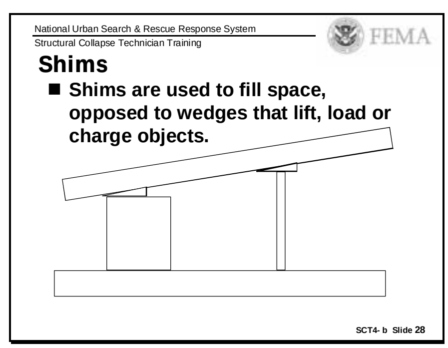
- Wedge Sets (always use Married Pairs)*
  - Snug up or tighten load.
  - Change of direction.
  - 2x wedges are more stable than 4x
  - For Shoring, Wedges will start to Cup when the Load reaches about 1.5 times the Allowable Load. This converts to a pressure of about 1000psi. This provides an Overload Indicator (Structure Fuse) for shoring.
  - If Cupping of Wedges occurs when Moving Objects, the process must be stopped Immediately, since it is too dangerous

  * = It is always best to place the Wedge Pairs so their Cut Surfaces are in Full contact with each other when moving objects. There will be more Friction and more complete contact . The Ends will also be Square for better Driving
- Shims (single wedge):
  - Stabilizing tools.
  - Incline plane (MA).
  - Take up void space.



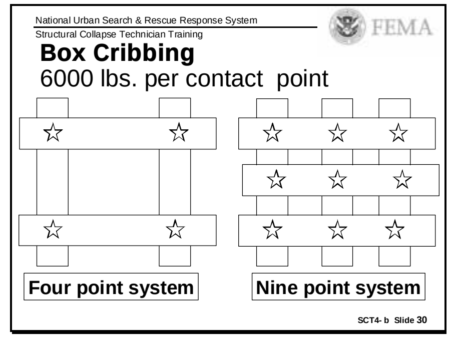


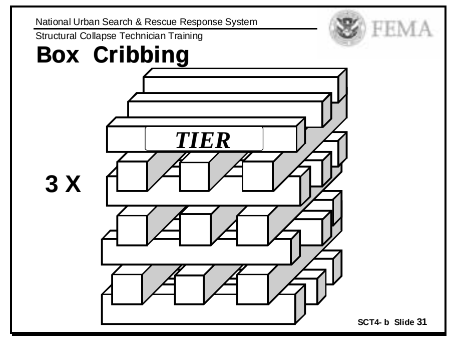


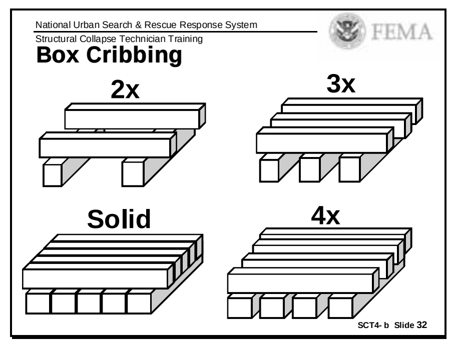


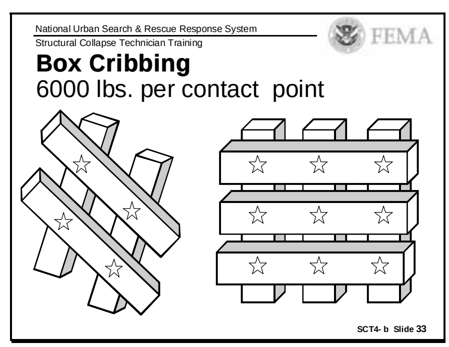
CRIBBING

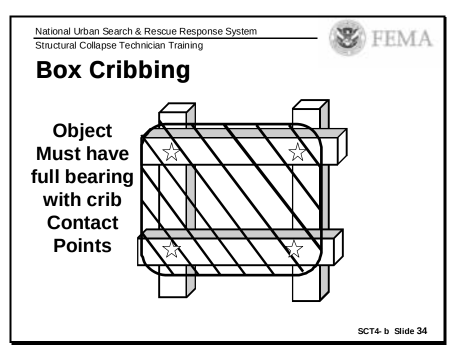
- Characteristics of Cribbing
  - Douglas Fir or Southern Pine are ”The Standard”, and there is no significant loss in strength when it has been pressure treated for decay
    - Oak is stronger, and is used in mines and for crane pads, but not available at local stores.
    - Hem-Fir and Spruce-Pine-Fir is a grading category that covers several; types of wood that may be used at a 15% reduction in strength.
    - Eastern Softwoods and Western Cedar are also grades that may be used, but with 25% reduction in strength
  - Tends to crush slowly
  - Provides advance warning of failure
  - 500 pounds per sq. inch (psi) max. load capacity
- Cribbing Types:
  - Box (2 x 2 Crib) : four points of contact
  - Crosstie (3 x 3 Crib) : 9 points of contact
  - Solid : entire surface area contact
- Cribbing strength is determined by figuring the surface area at each point of contact and multiplying by the design strength
  - Use 500 psi for Douglas Fir and Southern Pine, but is lower by 15% (425 psi) Hem-Fir & Spruce-Pine-Fir, and lower by 25% (375 psi) for softer woods
- Example:
  - 4x4 box cribbing is 3.5" x 3.5" = 12.25 X 500psi. = 6,125 lbs. per contact point. Use 6000 lbs
    - Total for Box Crib = 4 x 6000 = 24,000
    - Total for 3 x 3 Crib = 9 x 6000 = 54000
  - 6x6 box cribbing is 5.5" X 5.5" = 30.25 X 500 lbs. = 15,125 lbs. per contact point. Use 15,000 lbs
    - Total for Box Crib = 60,000 lbs
    - Total for Crib 3 x 3 = 135,000 lbs
- Cribbing performs best when it is uniformly load, since this means that all 4 corners will deflect the same under load (keeping the load level and the crib more stable.





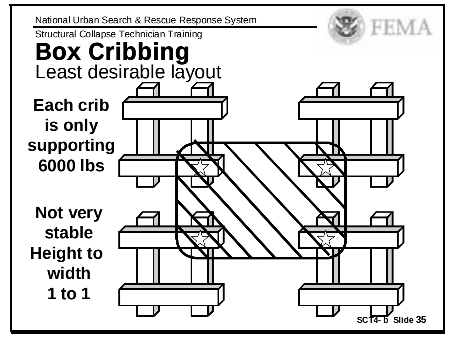


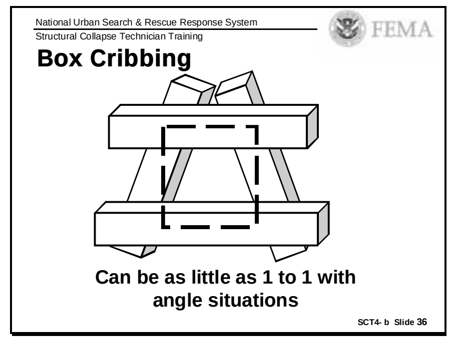


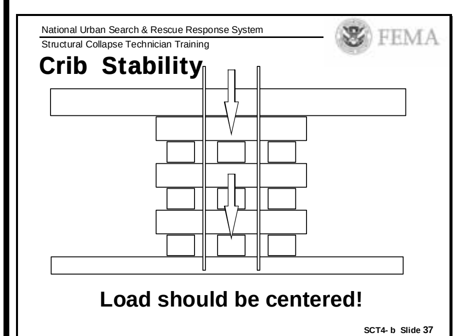


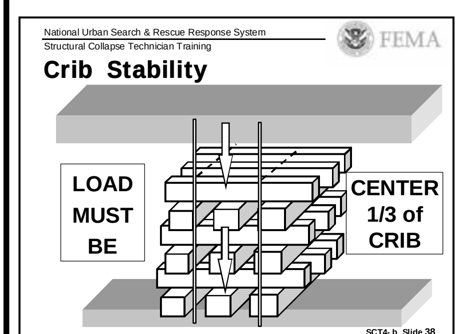
CRIBBING (continued)

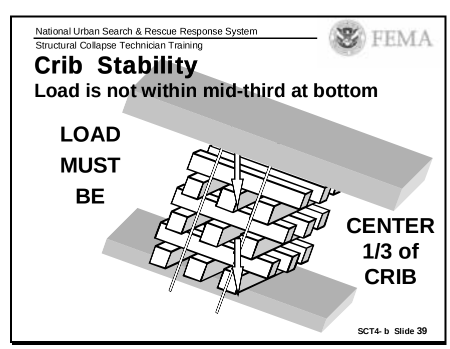
- Height of cribbing when used to stabilize loads to be moved should be limited to two times the width.
  - Support the load on the contact points (load to ground) as uniformly as possible.
  - When using cribbing to support collapsed structures the height may be increased to 3 times the width.
  - The maximum recommended height for 4x cribbing is 4 feet and 6x is 6 feet (for US&R Incidents)
  - Cribbing tends to deflect more than vertical shoring, since all the members are laid flat, and each layer can deflect a little.
    - This can add up to a significant amount of deflection, therefore, the recommended height of cribbing has been limited
    - The deflection for vertical shoring only occurs at the header and sole, since the posts do not deflect in the vertical direction
- Crib height should be limited to only 1 to 1 for conditions where the load is not centered and uniform.
  - For this case it is recommended that the maximum height be limited to 2 ft for 4x cribs and 3 feet for 6x cribs.
  - Also, one should de-rate the strength to half of normal for any case where the load is not centered
- When used for Moving Objects, the Center (or C.G.) of the Supported Load must be within the middle 1/3 of the Crib
  - The third of these Slides shows a Sloped Slab being supported by Cribbing.
  - The angle of the Slope to be allowed when Moving Loads needs to be limited to 10%
    (1 ft in 10 ft, same as 6 deg)
  - When using cribbing as shoring to support Sloped Slabs of Structures the angle is limited to 30%
    (3 ft in 10 ft, same as 15 deg)
    - In this case the load must be centered



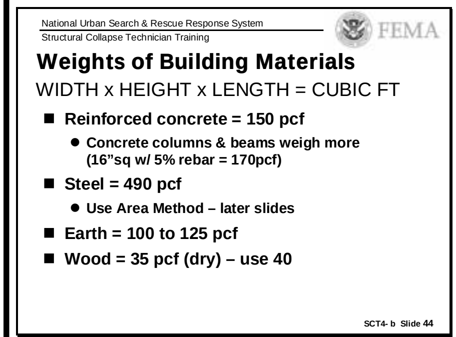






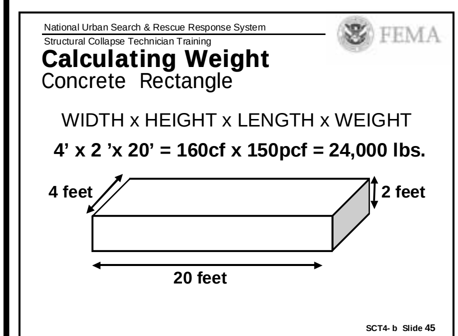


ESTIMATING LOAD WEIGHTS



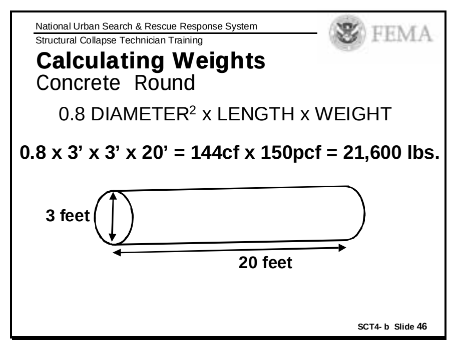
- Weight for material in pounds per cubic foot (pcf)
  - Reinforced concrete = 150 pcf **
  - Steel use 490 pcf (use 500)
  - Earth use 100 pcf
  - Wood use 40 pcf

** = This assumes that the concrete weighs 145 pcf and the reinforcing steel adds 5 pcf. However, Concrete Beams and Columns are often more heavily reinforced and may weigh as much as 175 pcf. This can be very important to know when lifting with a crane



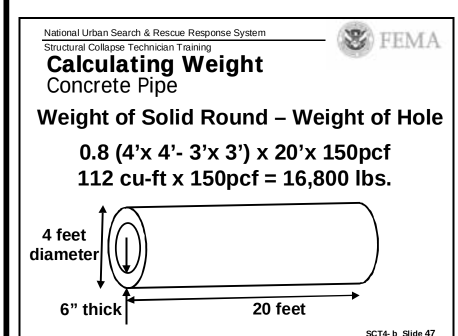
- For concrete and other thick, solid objects, calculate the volume of the object and multiply is by the weight per cubic foot (pcf)
  - For uniform thickness solid objects the total weight = Width x Height x Length x weight per cubic foot.

    Example: 4ft x 2ft x 2 ft concrete slab
    2 x 4 x 20 x 150 pcf = 24,000lbs =24 kips



  - For a solid cylinder the total weight = 0.8 Diameter^2 x Length x weight per cubic foot. (The exact number to use to determine the area of the round end is 0.785, but 0.8 is easier to remember and close enough)

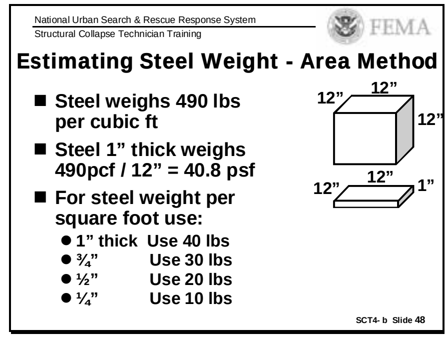
    Example: 3ft diameter x 20ft concrete column
    0.8 x 3ft x 3ft x 20 ft x 150 pcf = 21,600lbs



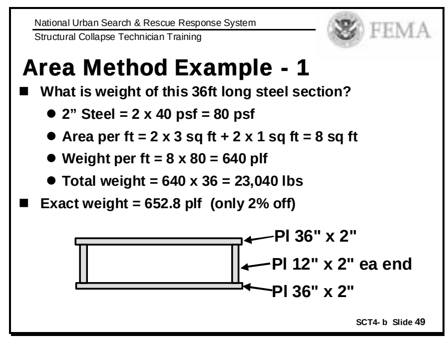
  - For a pipe the most accurate method is to find the volume of the solid and then subtract the volume of the hole, and multiply by the weight per cubic foot.

    Example: 4ft diameter x 20ft pipe w/ 3ft dia. Hole
    0.8 x (4x4 – 3x3) x 20ft x 150 pcf = 16,800lbs

ESTIMATING THE WEIGHT OF STEEL



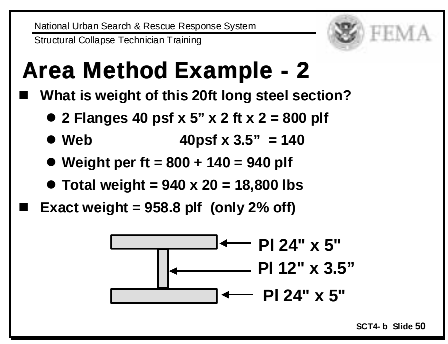
- Often rescue operations are needed when large steel beams & columns are present in a collapsed structure.
- Since these heavy objects will need to be moved, some of the first things to consider are the lifting capability of the available equipment, based on the distance to the objects initial and final positions.
  - The information regarding maximum lifting capacity will determine where to mark and cut the heavy steel members so that the weight requirements are met.
  - Most metal suppliers offer booklets that give information about the weight of steel by thickness, shape and dimension, usually on a per foot basis.
- There is a very simple way to calculate the weight of steel by using the known weight of a one square steel plate that is 1" thick. Called The Area Method
  - The exact weight is 40.8 psf, but 40 is close enough. Knowing this, we can say that:
    - ¾" thick plate = 30 psf
    - ½" thick plate = 20 psf
    - ¼" thick plate = 10 psf and so on
- Hear are two examples:



Area Method Example 1

The weight of the steel "box section" shown in adjacent slide can be easily calculated by noting that a 2" thick plate would weigh 80psf.

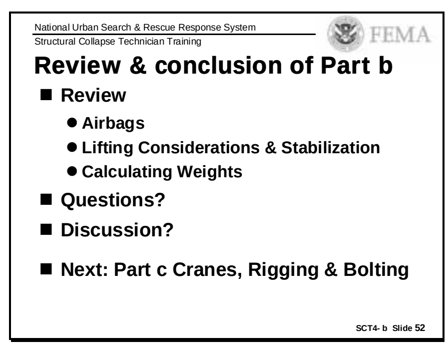
- Since the total area of 2" plate is 8 sqft per ft, the section weighs 8 x 80 = 640 pounds per foot (plf)
- Total weight if the section is 36ft long is 23,040 lbs This is only 2% less than the exact weight



Area Method Example 2

The adjacent slide shows an additional example, using a built-up so called W shape.

- Again, the calculation is simple, and the error is the same 2%
- The 2% is just the difference between the exact 40.8 psf and the easier to remember 40 psf for the 1" x one square foot steel plate



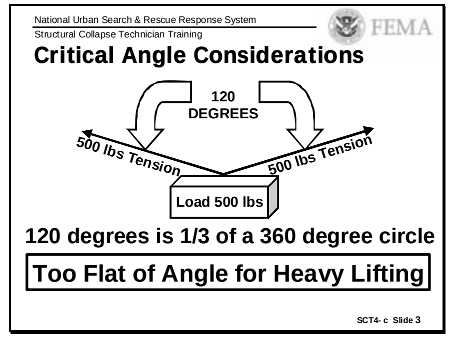
- Review of Part b: we have discussed the following:
  - Airbags
  - Lifting Considerations & Stabilization
  - Calculating Weights

TOPICS to be DISCUSSED in PART c

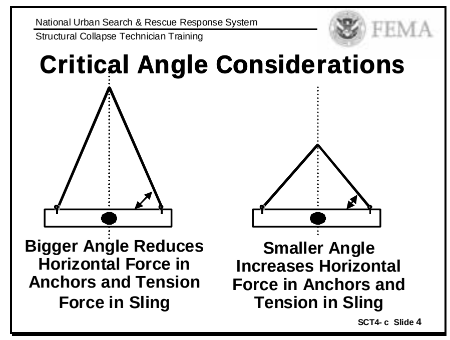
- **Critical Angles**
- **Concrete Anchor Systems**
- **Lifting Equipment & Techniques**
- **Cranes & Rigging**

CRITICAL ANGLE CONSIDERATIONS

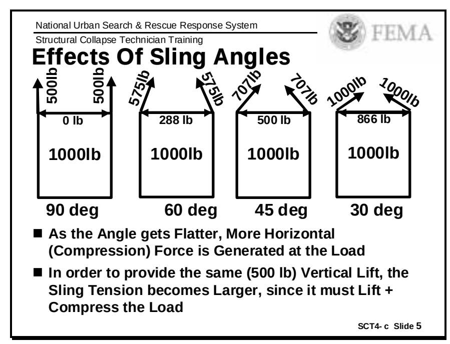
- The angle of a rigging strap/ cable attachment in relation to the lifting point greatly effects the vertical and horizontal forces placed on the anchor attachments as well as the forces in the strap/cable.
  - These forces are easily calculated, based on the properties of the triangle that is created.



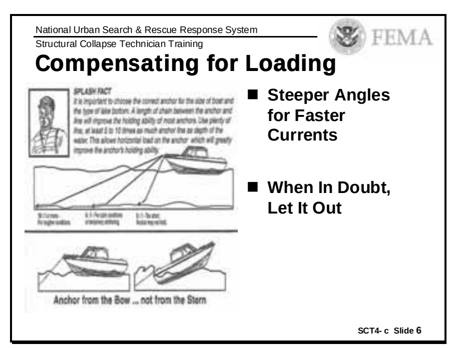
- A circle can be divided into three 120 degree sections.
  - If the included angle of the rope system is equal to 120 degrees, the force in the rope and it's attachment is equal to the supported load.
  - If the angle becomes greater by pulling the load line tighter, a greater force is placed on the rope and the anchors.
  - If the included angle is less, force in the rope is less.
  - In lifting systems the angle should be as small as possible, but a 120 deg angle, which translates to a 30 deg angle, measured up from the horizon, is the Largest Included Angle that is Allowed



- Applying this concept to rigging can be done by inverting the triangle.
  - The higher the point of attachment is over the objects CG the lesser the forces on the sling and it's attachments.
  - The flatter the angle, the greater the forces, as shown in the adjacent slide.
    - As the angle gets flatter, there is a greater compression force that is applied to the top of the load (or spreader bar), due to the angle of the force in the sling



  - Keep this in mind when you begin any lifting operation.
    - In some cases lifting a fairly light object with a flat lifting angle will create forces substatial enough to break the sling and/or blow-out the anchor points.
- The adjacent slide illustrates "If in Doubt, Let It Out". For Slings this means that the Longer the Sling, the Steeper the Horizontal Angle, and the Less Force in the Sling and its Anchors



CONCRETE ANCHOR SYSTEMS

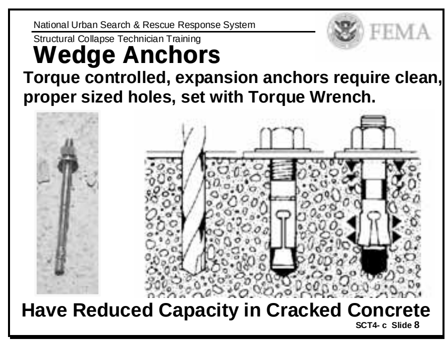
INTRODUCTION

- The purpose of this section is to provide information about safe and practical methods of anchoring to concrete when some other method (such as cable loops or chokers) is not available.
- Not all of the methods discussed may have useful application in US&R work.
  - The special equipment required for undercut anchors and the sensitivity of Adhesive anchors to vibration and heat, make both of little value in critical US&R situations.
- All the available methods are presented in order to give the student a more complete understanding of anchors

TYPES OF ANCHORS:

Most of these anchors require the drilling and cleaning of holes in concrete of the proper size and depth.

- Available types:
  - Wedge Anchors
  - Concrete Screws
  - Through Bolts
  - Undercut Anchor Bolts

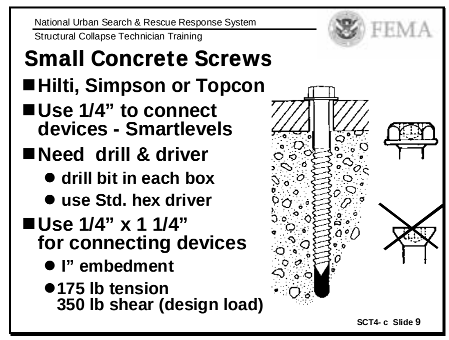


Wedge Anchors (most comenly used in US&R)

- Are torque controlled anchors that come in two types; Wedge Anchors and Sleeve Anchors. They both have an undercut shaft that is inserted into the hole and the wedge or sleeve device that expands as a cone at the bottom of the shaft is pulled through it when the fastener is tightened.
- Wedge Anchors have higher tension strength than sleeve anchors of the same size. However the sleeve anchor is the only anchor bolt (other than the through bolt) that can be safely used in hollow concrete block.
- Correct hole size (not too large) is very important since the wedge or sleeve must develop great friction against the sides of the hole.
  - The hole size is the same as the anchor. (½" hole for ½" anchor)
- Most of these anchors will develop more friction as they are loaded in tension, since more expansion occurs as the pull on the shaft causes the cone to spread the wedges or sleeve with greater force against the side of the hole.

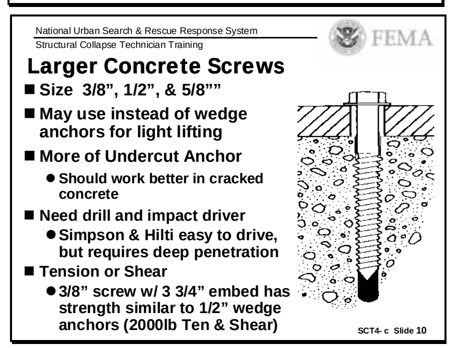
TYPES OF ANCHORS- Wedge Anchors (continued)

- Applying a setting torque with a calibrated wrench is essential to the reliable performance of this type of anchor, since doing so actually tests the installation.
- The proper failure mode for this type of anchor is either pull-through (where the conical part of the shaft pulls through the sleeve or wedge) or pull-out of a concrete cone.
  - The diameter of concrete cone that can be pulled is usually more than two times the depth of the embedment of the anchor, however, this assumes un-cracked concrete.
- Anchors of this type should not be used in badly cracked concrete.
- Expansion anchors may be used to anchor raker shores and in tieback systems, provided that the concrete into which they are set is relatively crack free.



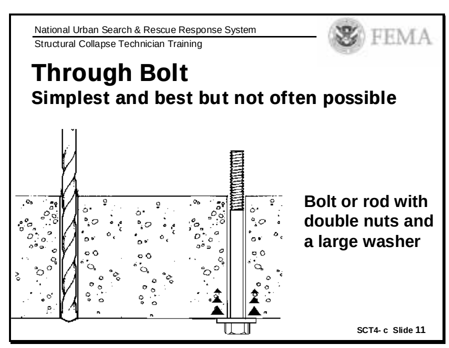
Concrete Screws

- The 1/4” diameters screws are used in US&R to fasten devices like the Electronic Level and other monitoring devices. They have a design strength of 300 lbs
- The 3/8” dia screws are similar in strength to ½” wedge anchors, and may be used to fasten Swivel Hoist Rings
- Screws are driven into a pre-drilled hole and the installation requires the use of the proper sized drill bit.
  - The 3/8” Simpson Titan Screw requires a 3/8” bit.
  - The 3/8 Hilti HUS-H Screw uses 5/16” bit.
- They can be installed in less than one minute and placed as close as one inch from the edge of the concrete, using an impact driver or a torque wrench



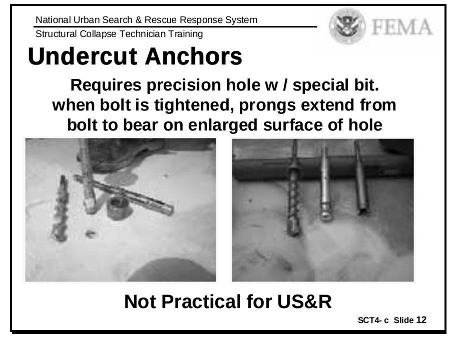
Through Bolts

- When both sides of a concrete slab are accessible, a standard machine bolt or piece of threaded rod can be extended completely through the concrete.
  - If a washer & bolt head/nut bears against the far side of a slab, a simple, reliable anchor is created.
- The allowable tension value for a through bolt would be the same as for an expansion bolt of the same size with embedment the same as the thickness of the slab.
- Through bolts require access to both sides of the concrete. Not much application in lifting concrete from debris piles.
- Through bolts are useful for anchoring to URM walls, or in tiebacks where concrete or URM walls are involved.



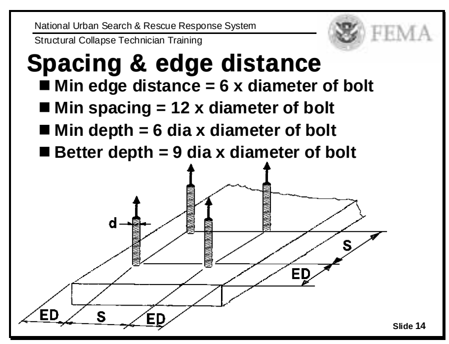
TYPES OF ANCHORS (continued)

Undercut Anchor Bolts (not used in US&R)

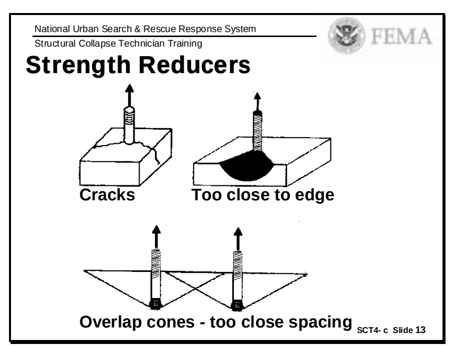


- Relatively complicated devices that require the cutting of a straight hole in the concrete and then inserting a special bit that enlarges the hole near its bottom.
- The undercut anchor bolt is then inserted and during the tightening process, prongs extend out from the body of the bolt that engage and bear on the surface of the enlarged hole.
- This produces a very positive anchor, since it does not have to depend on friction between the bolt and the hole as in the case of the other anchors presented here.
- The system requires the use of the special drill bit that undercuts the hole, and, therefore, would not be useful in most emergency situations.

ANCHOR APPLICATIONS



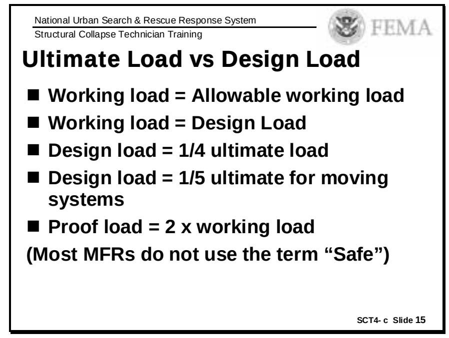
- Anchor Spacing & Edge Distance
  - Minimum spacing between anchors: 12 times the diameter of the anchor
  - Minimum distance to nearest concrete edge: 6 times the diameter of the anchor (9 times if load is acting towards the edge)
  - Minimum anchor depth in concrete: 6 times the diameter of the anchor
  - Anchor depth should be increased to 9 times the diameter of the anchor, since at ultimate load a more gradual failure will occur.
- One can increase tension values especially in lower strength concrete (2000 PSI) by increasing embedment and spacing to as much as double the minium listed strength values.



- Cracks in concrete near expansion bolts or shields can significantly reduce their strength.
  - Cracks do not significantly reduce the strength of Adhesive and Through Bolt anchors.

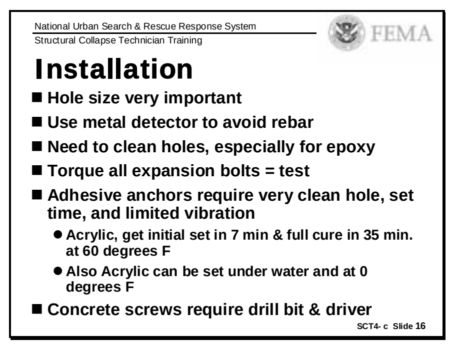
ULTIMATE LOAD VS WORKING LOAD

- The strength of these anchors has been determined by laboratory testing under “ideal” conditions, and is published as the Ultimate Strength.
  - If only the “strength” is listed without the word “Ultimate” one should assume that the value given is the Ultimate Strength and that the working load is about one fourth as much.
  - The Proof Load, which is 2 times the Working Load is load to which anchor installations are tested to assure proper installation
- The *Working Load* (sometimes called Allowable Working Load or Design Load) should be listed as not greater than one fourth the *ultimate strength*.
- The values given for most anchors are based on the ultimate crushing strength of the concrete into which they are inserted.
  - F'c=3000 PSI) means that a 6” diameter x 12” high cylinder made from the concrete will crush at 3000psi when tested 28 days after it was cast.
  - Most sound concrete can be assumed to have an *ultimate strength* of 3000 PSI.
  - Test it with a heavy blow from a framing hammer. It should ring and not be noticeably damaged, as long as its not hit on a corner.



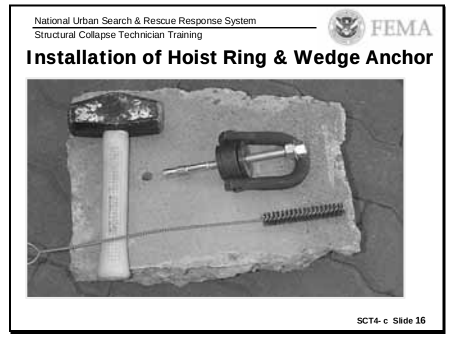
INSTALLATION OF ANCHORS

- Drilled holes should be the proper size and depth. Dull bits produce oversized holes which can lead to premature pull-out.
- A metal detector should be used to locate existing rebar, so that it can be avoided.
  - Hitting rebar with the bit will cause oversized holes, and a dull bit which will continue to produce oversized holes.
- Holes need to be cleaned of most all loose material.
  - One method to accomplish this is to drill the hole about one inch deeper than the insertion length, so that some of the loose material will drop to the bottom. (In thin slabs, drill completely through.
  - The pile of concrete powder that collects around the drill bit at top of slab should be carefully swept away.
  - In addition, one should lift-out the loose material by quickly pulling out the drill bit as it is rotating.
  - One should not use air to blow out the hole, and do not allow anyone to inhale any concrete dust – it is very damaging to the lungs



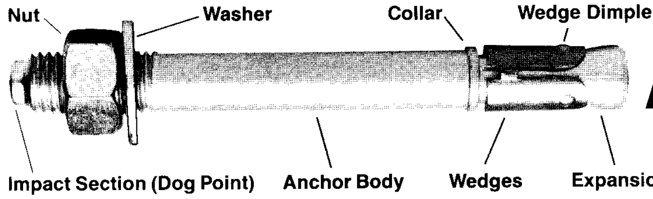
INSTALLATION OF ANCHORS (continued)

- Wedge Anchors need to be tightened with a calibrated torque wrench as previously discussed.
  - This tests and "preloads" the anchor, giving one reasonable confidence in the installation.
  - See table on following page for Anchor strength and required torque values.
  - Hole size is same as anchor size (½" hole for ½"anchor)
- Concrete screws are easily installed, provided the proper size drill bit is used.
  - Use 3/8" bit for 3/8" Simpson Titan Screw and 5/16" bit for 3/8" Hilti HUS-H Screw
  - They can be installed in less than one minute and placed as close as one inch from the edge of the concrete, using a hand, torque, or impact wrench
  - Drill the holes about one inch deeper than the insertion length. Then the holes need only need to be cleaned using the drill-bit to lift out the excess.
  - The screws can be driven (screwed) into the holes only once, since the threads cut their way into the concrete.
- Adhesive anchors are not normally used in US&R. Their installation requires very clean holes. If they are used, the following installation rules should be followed:
  - Adhesive anchors should be inserted into previously cleaned holes after the adhesive has filled the hole about 3/4 full. All dust needs to be removed by brushing and air blowing (Again to breathing of concrete dust is very harmful to the lungs
  - The adhesive should be placed using a coaxial cartridge dispenser with a long tube that reaches to the bottom of the hole.
  - Fill the hole from the bottom up, in order to minimize air pockets.
  - Insert the threaded rod with a twisting motion and work out all the bubbles.
  - Most epoxies require a minimum of 24 hours to fully cure at 60^{o} F (15^{o} C) and above. This time must be increased to about 48 hours at 40 degrees F (5^{o} C).
  - Acrylic adhesives can fully cure in as little as 1 hour at 60^{o} F (15^{o} C) and above
  - Most all adhesives used in Anchor Systems have a "Shelf Life" of one year or so, and, therefore, should not be kept in a US&R Cache for longer periods.



ALLOWABLE WORKING LOADS for WEDGE ANCHORS

SAFE WORKING LOADS



ANCH-6S

WEDGE ANCHORS • *KwikBolt, Wedge-All or Trubolt*

Allowable Tensile Loads (lbs)

Diameter	Embedment	Required Torque (ft-lb)	f'_c = 2000 psi	f'_c = 3000 psi
3/8″	1 5/8″ 2 1/2″ 4 1/4″	20 use 25 25	530 1130 1200	605 1210 1230
1/2″	2 1/4″ 3 1/2″ 6″	40 use 50 65	870 1750 1970	970 2000 2170
5/8″	2 3/4″ 4″ 7″	85 use 100 110	1430 2170 3000	1690 2670 3270
3/4″	3 1/4″ 4 3/4″ 8″	150 use 225 235	1850 2750 3750	2180 3630 4630
1″	4 1/2″ 6″ 9″	250 use 350 450	2930 4000 6070	3650 5310 7070

Allowable Shear Loads (lbs)

Diameter	Embedment	f'_c = 2000 psi	f'_c = 3000 psi
3/8″	1 5/8″ ≥ 2 1/2″ *	930 1100	970 1100
1/2″	2 1/4″ ≥ 3 1/2″ *	1810 1840	1840 1840
5/8″	2 3/4″ ≥ 4″ **	2880 3140	2880 3140
3/4″	3 1/4″ ≥ 4 3/4″ **	3880 4220	3880 4220
1″	4 1/2″ ≥ 6″	6620 8620	7120 8620

INCREASE TENSION & SHEAR VALUES 1.33x FOR WIND & EARTHQUAKE LOADING

TEN+SHEAR: $(P/P_{allow})^{5/3} + (V/V_{allow})^{5/3} \le 1$

SLEEVE ANCHORS

Carbon Steel Allowable Working Loads in Concrete (lbs.)

Sleeve Anchor Diameter	Bolt Diameter	Embedment Depth	Required Torque (ft-lb)	2000 PSI		4000 PSI	
				Tension	Shear	Tension	Shear
1/4″	3/16″	1″	5	275	235	275	240
5/16″	1/4″	1″	5	275	410	380	420
3/8″	5/16″	1 1/4″	10	425	680	580	945
1/2″	3/8″	1 1/2″	30	820	960	820	1340
5/8″	1/2″	2″	50	960	1270	960	1410
3/4″	5/8″	2″	90	1270	1900	1270	2350

Carbon Steel Allowable Working Loads in Hollow Concrete Block* (lbs)

Sleeve Anchor Size	Bolt Diameter	Tension (lbs)	Shear (lbs)
1/4″	3/16″	300	490
5/16″	1/4″	330	670
3/8″	5/16″	420	930
1/2″	3/8″	610	930

*ASTM Specification C90, Grade N, Type II.

ANCH-6S 03/02

ALLOWABLE WORKING LOADS for EPOXY ANCHORS

EPOXY ANCHORS

Allowable Loads ·Threaded Rod Anchors

Allowable Tensile Loads (lbs)							
Stud Dia	Drill Bit Dia	Min Embed Depth	Spa-cing	Edge Dist	Avg ult 2500 psi	Based on Bond Strength	
						fc = 2000	fc=2500
3/8″	1/2″	3 1/2″	4 1/2″	2 5/8″	8888	1985	2220
1/2″	5/8″	4 1/4″	6″	3 1/4″	10384	2320	2595
5/8″	3/4″	5″	7 1/2″	3 3/4″	17512	3915	4375
3/4″	7/8″	6 3/4″	9″	5″	27896	6235	6970
7/8″	1″	7 1/2″	10 1/2″	5 5/8″	32032	7160	8005
1″	1 1/8″	8 1/4″	12″	6 1/4″	41813	9350	10450

Allowable Shear Loads (lbs)				
Avg Ult 2500 psi	Based on Bond Strength			Based on Steel Strength
	fc = 2000	fc = 2500	fc = 3000	A 307
4096	910	1020	1750	1040
9664	2160	2415	3375	1870
13952	3115	3485	2965	2940
25920	5795	6480	4380	4250
24970	5580	6240	7275	6000
28746	6425	7185	7275	7820

Allowable tensile loads for ASTM A615 Gr 60 Reinforcing Bar

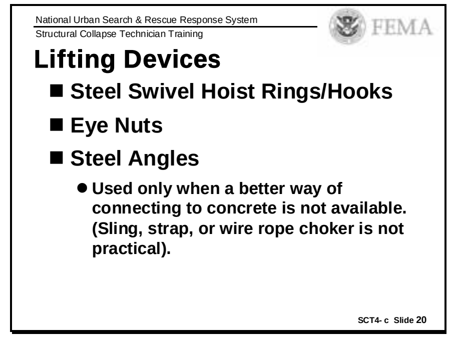
Rebar Dia.	Drill Bit Dia.	Minimum Embedment Depth	Concrete Compression Strength	
			fc = 2500	fc = 4500
No. 4	5/8″	4 1/4″	3055	3565
No. 6	7/8″	6 3/4″	7850	9070
No. 8	1 1/8″	8 1/4″	9065	10240

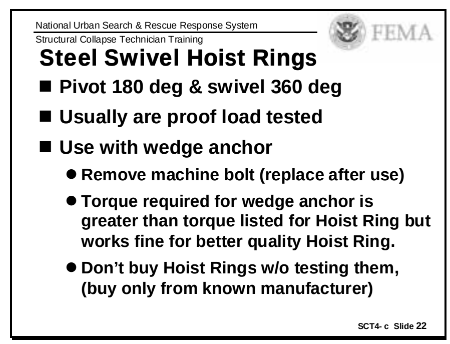
Minimum spacing = 12 bar diameters
Min. edge distance = 6 bar diameters

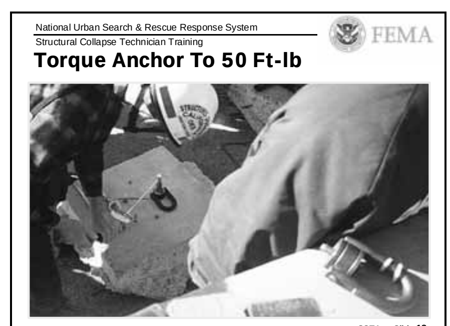
LIFTING DEVICES

Steel Swivel Hoist Rings

- These are devices that can be attached to concrete using, an expansion anchor, concrete screw, or through bolt.
- Since the ring's loop pivots 180 degrees and the ring's base swivels 360 degrees, the load will always be applied directly through the bolt into the concrete.
  - There is also no danger of the swiveling ring applying a de-torquing twist to the properly tightened, expansion anchor.
- These rings are available in sizes from 5/16" to 3". The ½" size is suggested as a minimum size, and it has a 2500 lb allowable working load which is greater than the 2000 lb of a ½" expansion anchor with 6" embedment.
  - The ½" Swivel Hoist Rings and Expansion Anchors are included in the FEMA US&R Cache List
- For larger loads, it is recommended that the 3/4" size be used. It has a 5000 lb allowable working load. A 3/4 expansion bold with 8" embedment has 4500 allowable working load. It is not in the FEMA US&R Cache
- Previous slides in this section illustrate the proper way to install the Hoist Ring using a ½" x 7" wedge anchor.
  - The hole may be cleaned by just lifting out the concrete dust with the bit a few times if the hole is made 1" deeper than the required 4 ½" embedment.
  - A 3/8" x 6 concrete screw (Simpson or Hilti) may also be used to attach the ½" Swivel Hoist Ring. Since the hoist ring is about 1 ¼" high, the screw will be embedded at least 4 ½".

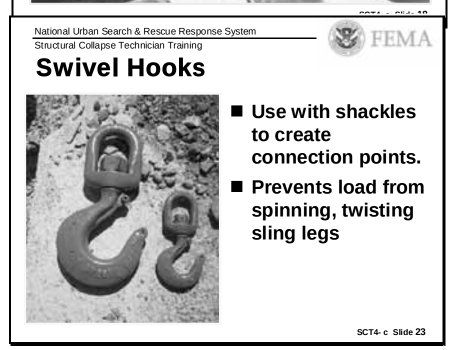






Swivel Hooks

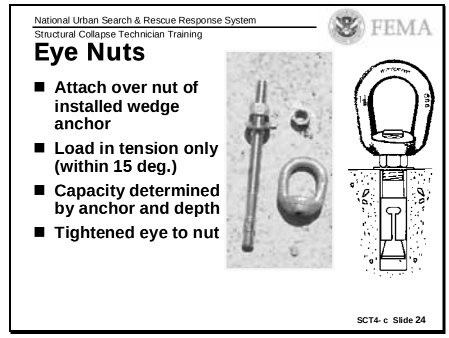
- These devices may be used to attach to a shackle, however most often a sling will be used between the load anchors and the Crane Hook
  - If these are used, the Load must be kept from spinning, and or the sling be kept from twisting.

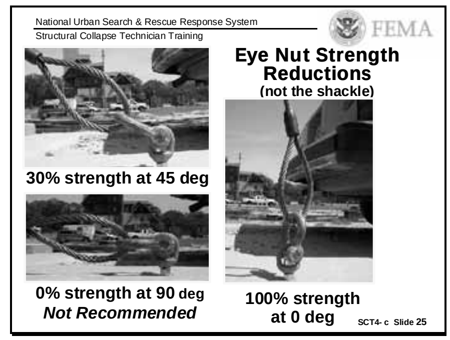


LIFTING DEVICES (continued)

Eye Nuts

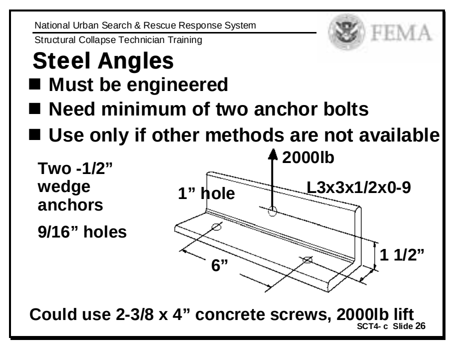
- Eye Nuts are drop forged and galvanized devices that can be attached to the exposed threads of an installed expansion bolt to produce a lifting device. ½" Eye Nuts are in the FEMA US&R Cache
- They have a lifting capacity slightly greater than the tension capacity of a wedge anchor, provided that the direction of the load is vertical, (or within 15 degrees of vertical) thereby, loading the anchor mostly in tension.
  - The adjacent slide shows what the eye nut looks like when attached to a ½" x 5" wedge anchor
  - The wedge anchor needs to be installed first; driven 4 inches into the ½" hole (with double nuts w/ washer just above the top end); then one of the nuts is removed, so the lower nut may be torqued to 50 ft-lb against the concrete: then the eye not is tightened on top of the bolt.
- ½" Eye Nuts with ½" wedge anchors have an allowable working load of about 2,000lb for a vertical pull.





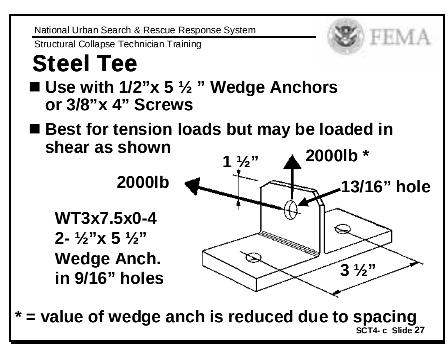
Steel Angles

- May be pre-fabricated to be used with wedge anchors, screws and /or through bolts, however, if not sized properly will cause the failure of the lifting system.
- To be useful an angle must be of sufficient thickness and length. A minimum of two bolts must be used with a single angle in order to assure that it will not spin.
- Due to the prying action of the vertical leg of the angle, it takes 2 expansion bolts to produce the same allowable working load as 1 bolt used with hoist rings.
- Use this angle only if a hoist ring is not available.



Steel Tees

- May be pre-fabricated to be used with ½" Wedge Anchors or 3/8" Concrete Screws
  - The 3/8"x 6" concrete screws have better resistance in cracked concrete, and have tested to be as strong as ½" wedge anchors.
- The T must be a sufficient size to allow for the required spacing of the fasteners, and have the thickness necessary to resist the bending stresses. For tension forces, there is no prying action.
- When the T is loaded in shear (parallel to the concrete surface) the T stem needs to be aligned with the direction of the pull. Use a 5/8" (min) shackle to connect to rigging



RIGGING TOOLS

SLINGS

- Commonly used material for the manufacture of slings
  - Wire rope
  - Chain
  - Synthetic Fibers

Rigging Definition: A length of rope / chain / webbing attached to a load to and/or an anchor for the purpose of stabilizing, lifting, pulling, or moving objects.

- **Wire Rope**
  - Very strong – suited for US&R enviroment
  - Strenght depends on size, grade,and core
  - Resistant to abrasion and crushing
  - Must keep from bending or kinking
  - Sharp bends and edges can cause damage

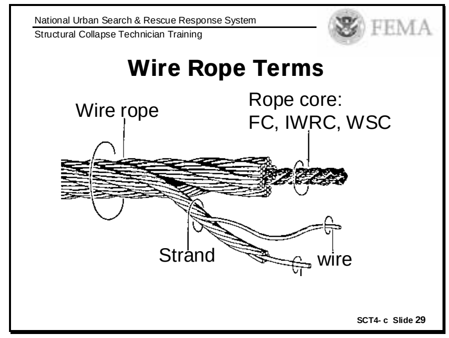
- **Wire rope components**
  - Core (Fiber Core or Independent Wire Rope Core)
  - Strand
  - Wire
  - Center

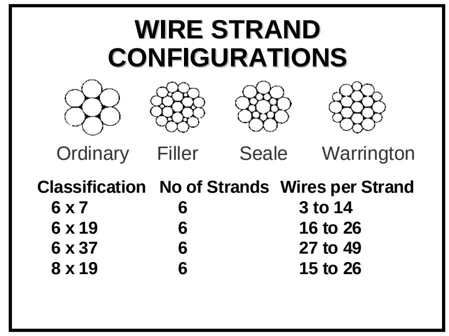
- **Wire rope safety factor**
  - Wire Rope Slings, Etc = 5 to 1
  - Lifts w/ Personnel = 10 to 1
  - Elevators = 20 to 1
  - Mobile Crane = 3 to 1 for standing ropes
  - Slings have greater factor of safety than for wire rope used on cranes due to likelihood of rough usage & wear

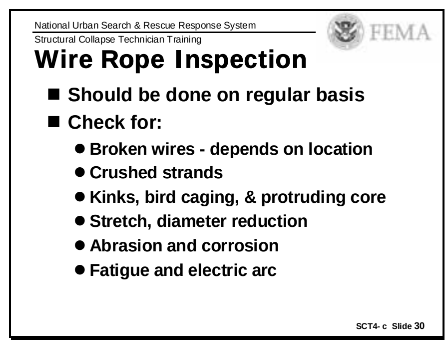
- Wire Rope Inspection should be done on a regular basis

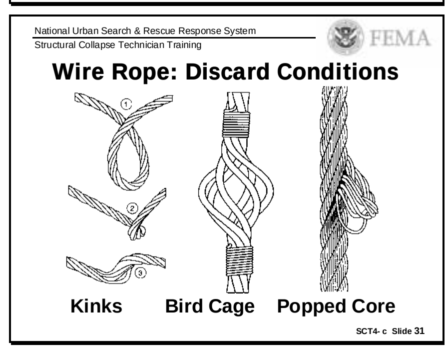
  - Need to check for conditions in adjacent slides

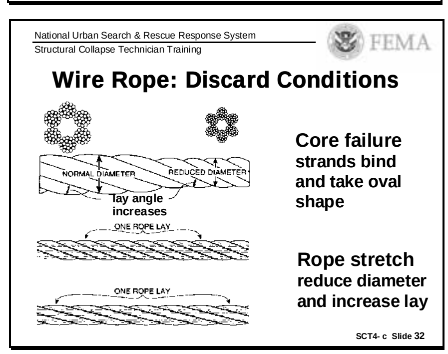
  - The following are wire rope discard conditions
    - Kinks
    - Bird cage
    - Core protrusions
    - Core failure
    - Rope stretch









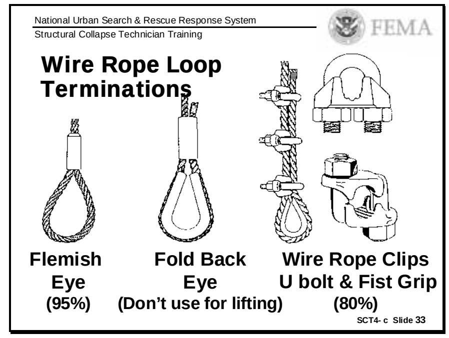


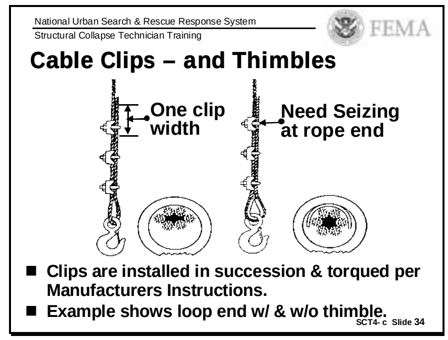
SLINGS (continued)

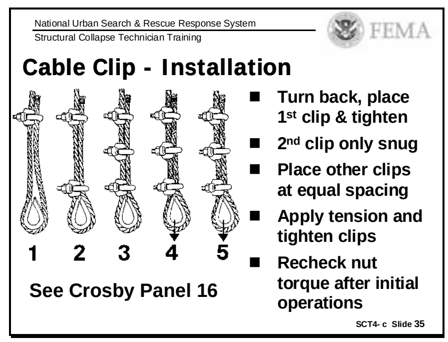
- Wire rope fittings and terminations are available in many designs. There are Socket Terminations and Loop Terminations as shown in adjacent slides
  - Swaged and Spelter Sockets
    - These sockets are normally found connecting the Standing lines (wire rope lines that do not move) on a Crane
  - Wedge socket
    - If properly manufactured and installed, will only reduce capacity by 10%
    - These normally occur at the connection of the Ball to the Whip line of a Crane. (Whip line is a single part line that extends from the Crane boom tip, just beyond the main sheaves)
  - Flemish eye
    - Most reliable and efficient termination. Must be done in a shop, and it does not reduce load capacity.
  - Fold back eye
    - Unreliable, do not use it.
  - Cable clips
    - During past US&R incidents it has been necessary to construct cable terminations using these clips.
    - All rescue personnel should become familiar with how to position and tighten these useful devices.
    - Reduce capacity by 20%

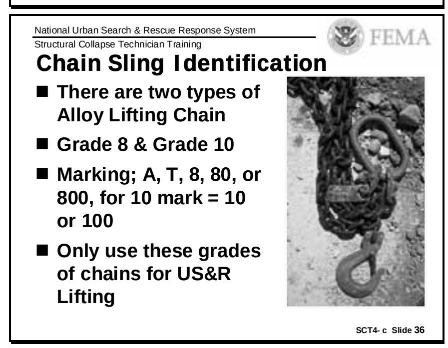
Chain and Chain Slings

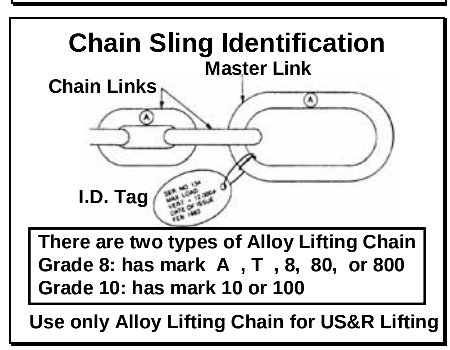
- Limited use due to weight.
- Links can break without warning
- Requires padding between chain and load to create better gripping surface.
- Should not be exposed to cold temperatures for long periods of time.
- Avoid kinking and twisting while under stress.
- Load must be seated in the hook.
- Avoid sudden jerks in lifting / lowering the load.
- Use padding (planks, heavy fabric) around sharp corners on the load to protect links from being cut.
- Cannot use for overhead lifting unless tagged by manufacturer.







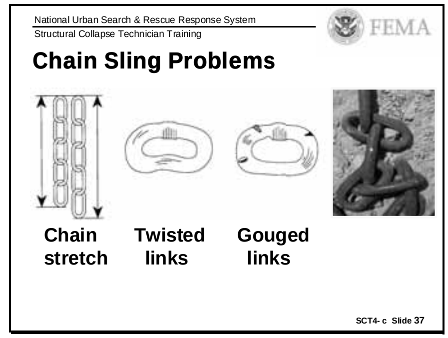




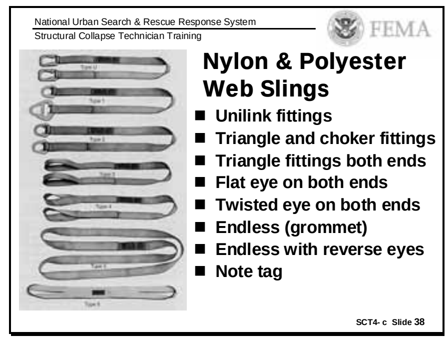
SLINGS (continued)

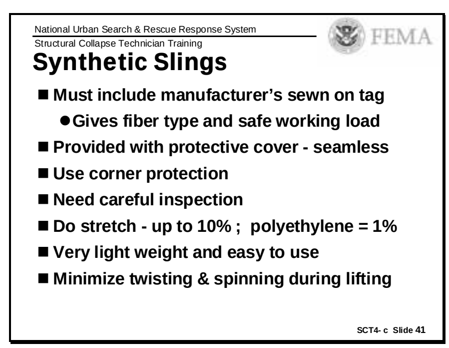
Chain and Chain Slings

- See chain sling discard conditions shown in adjacent slide.
  - Chain stretch
  - Twisted links
  - Gouged links



- **Synthetic slings:**
  - Tends to mold around the load adding additional holding power.
  - Do not rust and are non-sparking.
  - Are light weight making it easier and safer to rig, and carry on rubble pile
  - Have no sharp edges thereby reducing injury potential.
  - Are more elastic than chain or wire rope and can absorb shock loading better.
  - Are not effected by moisture and are resistant to many chemicals.
  - Are very susceptible to abrasion and catastrophic failure, especially in the collapse structure environment.





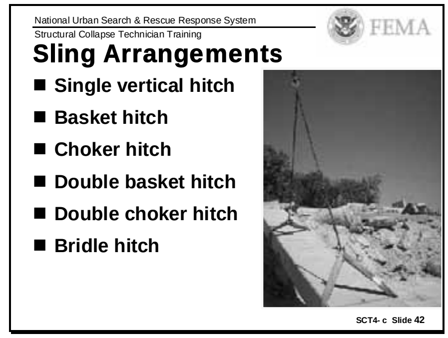
BASIC SLING ARRANGEMENTS

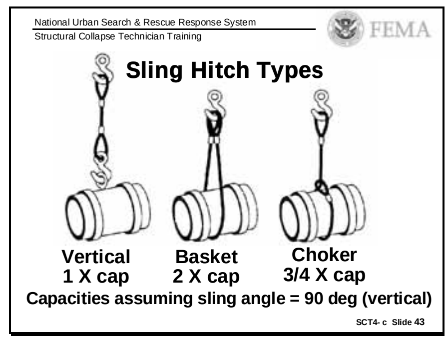
- **Single vertical / horizontal hitches:**
  - Supports load with single leg of rope / chain / webbing.
  - Full load carried by a single leg (one straight piece of chain / rope / webbing).
  - Should not be used when:
    - Load is hard to balance.
    - Center of gravity hard to establish.
    - Loads are loose.
    - Load extend past the point of attachment.

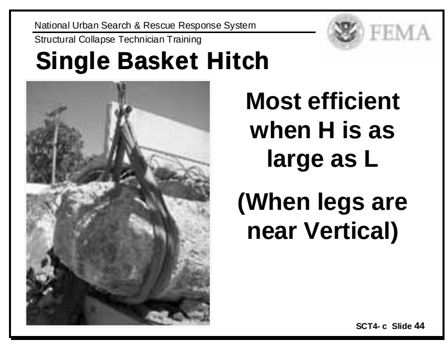
- **Basket hitches:**
  - Supports load by attaching one end of the sling to a hook.
  - Sling wrapped around the load.
  - Sling returns to the other end to attach to the same hook as the other side of the sling.
  - Presents problems related to keeping the load balanced or stabilized.

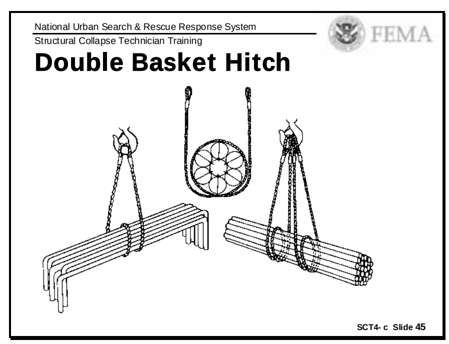
- **Double basket hitches:**
  - More stable than single basket hitch.
  - Uses 2 single slings wrapped at separate locations on the load in the same manner .
  - Allows for the locating of the center attachment hook over the estimated center of gravity.
  - Permits the wrapping of the slings to either side of the center of gravity.
  - Can use a "double wrap" basket hitch which makes contact all the way around the load surface for increased securing of loads (i.e., good for cylindrical loads).

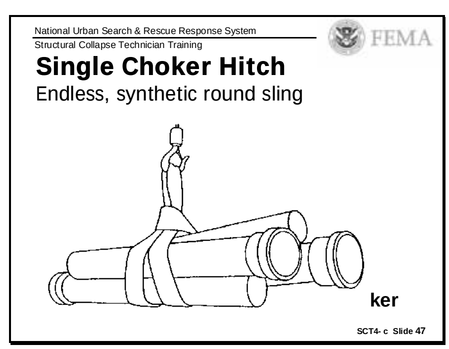
- **Single choker hitches:**
  - Loop a strap / rope around the load.
  - Pass 1 eye through shackle attached to other eye.
  - Pass the eye over the hook.
  - Sling should be wrapped around the load.
  - Sling is secured back onto itself.
  - Potential of having stability problems.
  - Creates a vise-like grip on load.
  - Choker has 75% capacity of single vertical sling



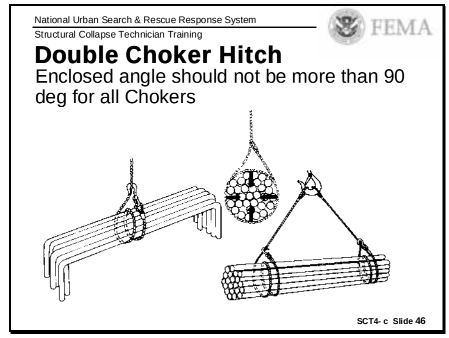






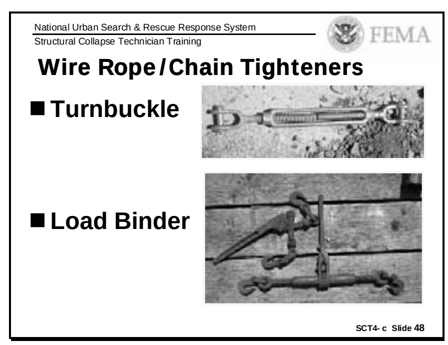


BASIC SLING ARRANGEMENTS (continued)



- **Double choker hitches:**
  - Has two single slings spread apart around the load.
  - Does not make full contact with the load surface.
  - Can be double wrapped to help control / hold the load.
  - Double choker with 2-points of wrap around the load provides better lifting / pulling / stabilizing / moving than single choker.
  - When using straps in pairs, hooks should be arranged on the straps so that they will pull from the opposite sides = better gripping action.
  - Creates a vise-like grip on load.
- **Bridle hitches:**
  - Uses 2 / 3 / 4 single slings -- each sling is called a "LEG."
  - Slings secured to a single point this is usually in line between the center of gravity and the anchor (lifting point).
  - Can provide very stable lifting, stabilizing, moving, pulling due to distribution of load onto the multiple slings.
  - Sling lengths must provide for even distribution of the load.
- Basic guideline for sling formations - make sure slings protected at all actual or potential sharp corners in contact with loads.

TIGHTENERS

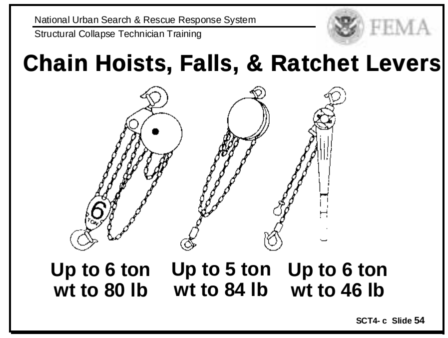


- **Wire rope tighteners** have been required during many US&R incidents.
  - They may be used for lifting light loads as well as tightening cable tiebacks and other rigging.
  - Care needs to be taken to not overload them. **DO NOT ADD CHEATER BARS TO THE HANDLES**
  - They are available in several configurations, and are included in the FEMA US&R Cache.

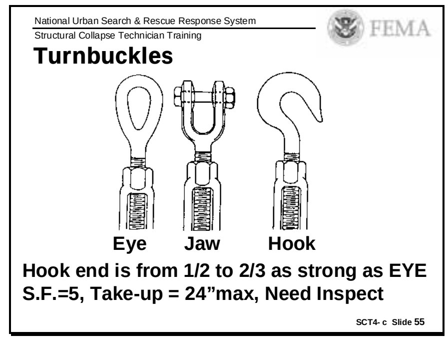
- **Cable winch**
  - The length of the handle and the strength of one person provides the Overload Limit. **DO NOT ADD TO LENGTH OF HANDLE.**
  - Take care in re-winding the cable, it can foul.
  - These devices are 2 to 3 feet long, therefore their use may be limited in confined spaces.
- **Load binder (most common with chain use)**
  - Use ratchet type for reliability, and must wire tie handle for safety.
  - Have 50 to 1 ratchet action, but only 8 inch take-up.

TIGHTENERS (continued)

- **Chain hoist**
  - Can lift up to 6 tons with 100lb pull. **DO NOT EXTEND HANDLES OR OVERPULL USING MORE THAN ONE PERSON.**
  - These tighteners have large take-up (up to 10 feet), and some only require only 12 inch clearance.

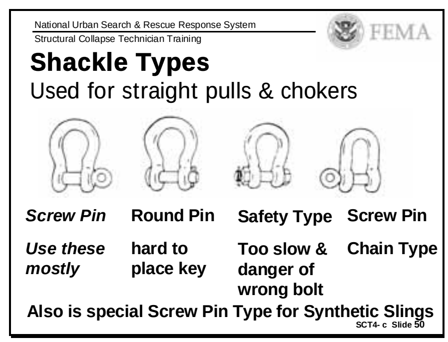


- **Turnbuckles**
  - Commonly used tightening device, and are in the US&R Cache
  - Can be used to do final tightening of tiebacks, and liberate Cable Winch to do other jobs.
  - The maximum take-up can vary from 8” to 24”, depending on what type is purchased.
  - They may be difficult to tighten at high loads, so keep the WD-40 handy.
  - HOOK ends are only 2/3 as strong as EYE or JAW ends

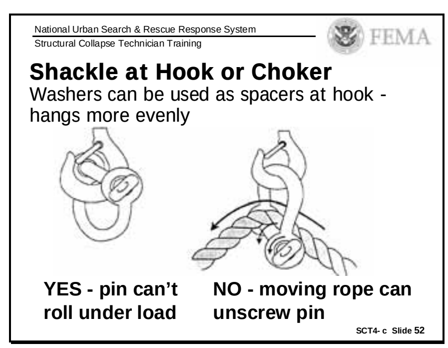


RIGGING FITTINGS

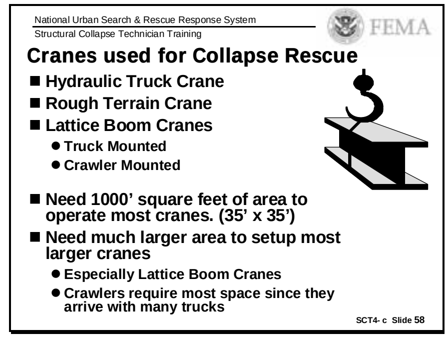
- Ring, hook, and shackle components of slings should be made from forged alloy steel.
- Basic components:
  - Hooks
  - Shackles
  - Eyes
- Provide means of hauling (lifting) loads without directly tying to the load.
  - Can be attached to wire or fiber rope, blocks, or chains.
  - Used when loads too heavy for hooks to handle.
  - Hooks need latch or mouse closing/securing device.



- **Mousing**
  - Process of closing the open section of a hook to keep slings / straps from slipping off the hook.
  - Can mouse hooks using rope yarn, seizing wire or shackle.
- **Shackles**
  - Check rating stamp and Working Load rating.
  - Pins not interchangeable with other shackles.
  - Screw pin in all the way and back off ¼ turn before loading.



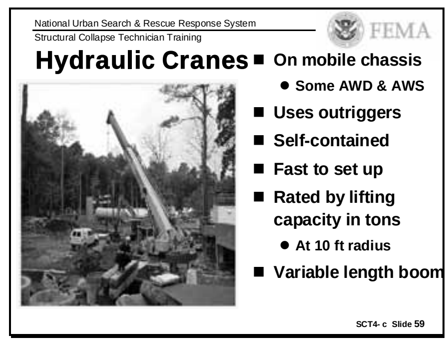
CRANES used for COLLAPSE RESCUE



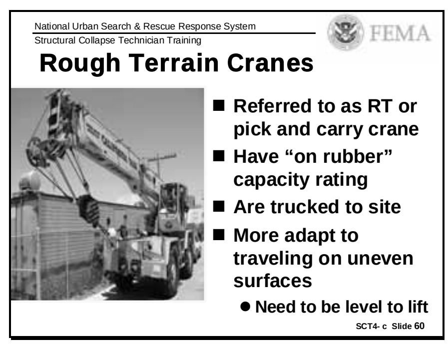
- Pre-incident information:
  - Develop and maintain listing of businesses with crane resources including crane equipment, crane operators and crane rigging equipment.
  - Develop telephone call-up list for crane resources.
  - Develop an identification and vendor call-back system for verification of incident needs and projected response time to the incident, as well as confirming on-scene contact person + their location.

TYPES OF MOBILE CRANES

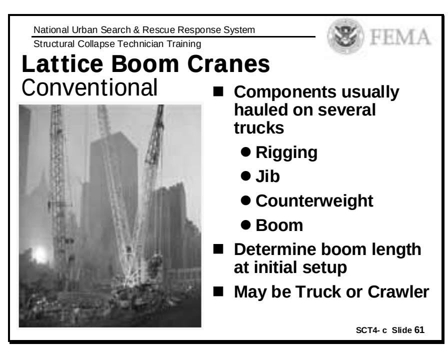
- **Hydraulic Cranes**



  - Mounted on mobile chassis. (some have AWD & AWS)
  - Have outriggers, which need to be set on firm bearings: some have "on rubber" lifting capacities.
  - Self-contained. (except for 120 Tons and greater)
  - Relatively fast to set up.
  - Rated by lifting capacity, in tons, at a distance of about 10 ft from the center of the crane .
  - The variable length boom makes them very useful in a US&R incident.
- **Rough Terrain (RT) Cranes**



  - Normally would be trucked to the site
  - "Pick and carry" capabilities – driving with loads
  - Rated for "on rubber"
  - More adaptable to rough terrain, but must be leveled to lift.
- **Lattice Boom Cranes (sometimes called conventional**



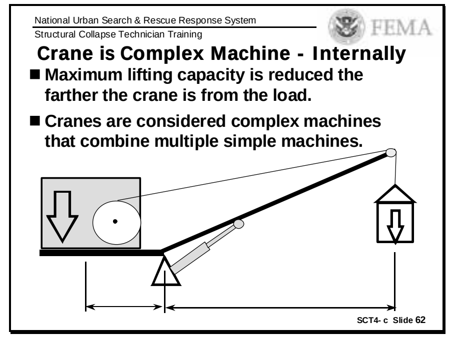
  - Lattice Boom Cranes may be **Truck Mounted** or **Crawler Mounted**
  - Normally requires more than one truck to haul the boom components, counter weights, and rigging.
  - **Crawler Cranes** usually require several trucks, since the crawlers may be trucked separately
  - Have a longer set-up time than the hydraulic crane
  - Rated by lifting capacity, in tons, at a distance of about 10 ft from the center of the crane .
  - Require more set-up area than the hydraulic crane.
  - Need to find a place to park all the trucks

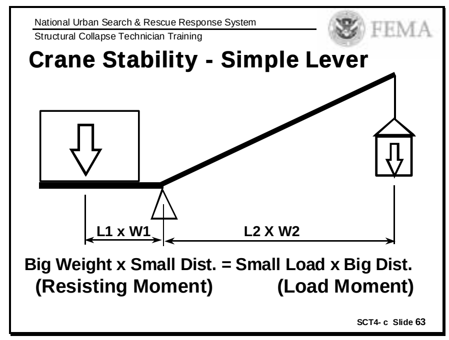
CRANES used for COLLAPSE RESCUE (continued)

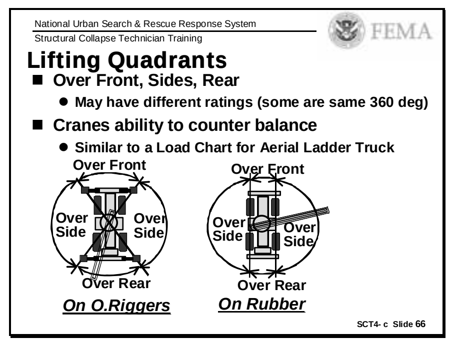
- Lifting capacity of all cranes is reduced the farther away the center of the cranes is from the load.
  - The ‘Rated Load” is what can be lifted at 10 to 12 ft from the Crane “Pin” (the Center of Rotation)
  - They are, essentially a very complicated 1st class lever

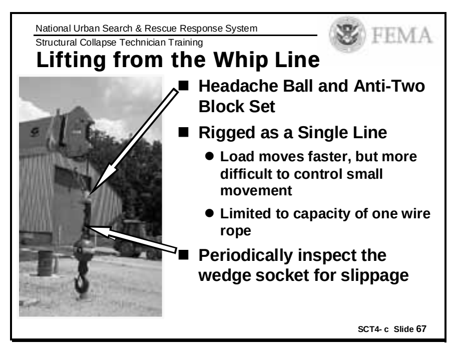
- **Areas of Operation**
  - All Cranes are required to carry Load Charts on board
  - Cranes may have different capacities for different Quadrants of Operation, as shown in adjacent slide
  - Some Cranes may Lift “on Rubber”, but most require their Out Riggers to be Fully Extended in order to operate safely.
  - Crawler Cranes are, of course an exception to the statement above, but some crawlers do have extendable tracks for greater lifting capacity

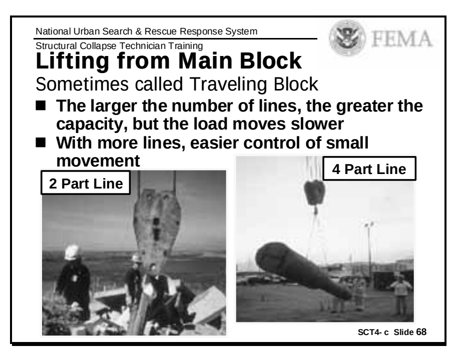
- **Crane Rigging**
  - Most Cranes have two separate Hook/Systems that they can lift from.
  - The Main Block will have more than one sheive so that its hook has the greatest capacity.
    - It may have several “Parts of Line”, which multiplies the strength of the wire rope that is connected to the Drum for lifting.
    - Often the capacity of each Part of Line is determined by the strength of the Brakes on the Drum. However the capacity of the wire rope, also must not be exceeded
  - The Ball (Headache Ball) and Hook normally drops over a single shieve at the tip of the Crane Boom
    - It most always has one “Part of Line”, but the Load moves much faster on this “Whip Line”.
    - Again the capacity of this line is often determined by the strength of the Brake at the Drum





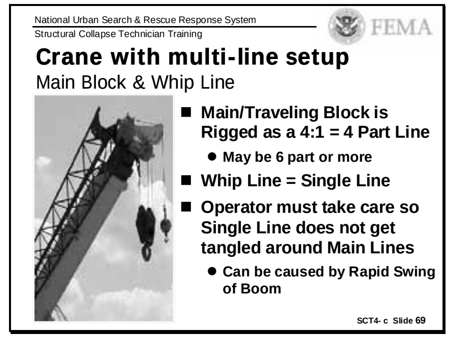


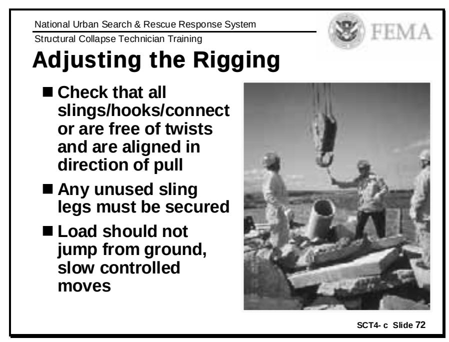


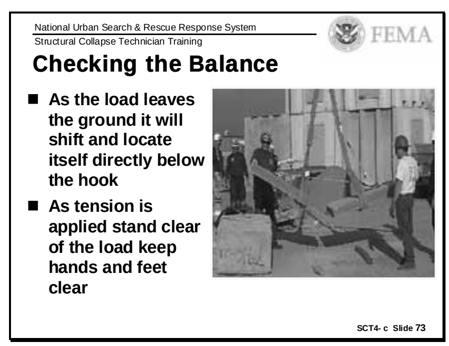


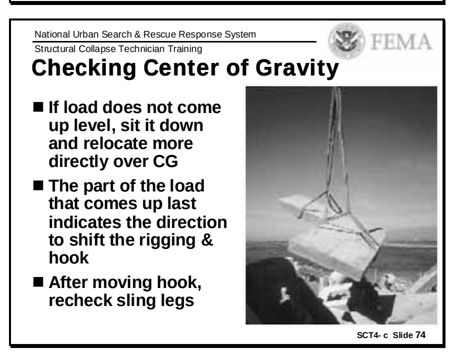
CRANES used for COLLAPSE RESCUE (continued)

- **Moving the Load & Moving Tatics**
  - **Securing the Load**
    - As stated in the adjacent slide, the type of Load and its weight + center of gravity must be known.
    - When Cranes are lifting near their maximum reach, have a very small Safety Factor for Tipping. A load the is underestimated by 20% can tip a Crane.
    - As previously discussed the Sling Angle should be made as steep as possible, although 45 deg is a reasonable place to start
  - **Adjusting the Rigging**
    - **Check all slings, hooks & connectors**
    - **All should be aligned and without twists, etc**
    - Load should be slowly lifted a short distance off the ground
    - Check balance and that all slings appear to be tight (one should note that for four leg slings it is very difficult to have more that three be tight. This is not a problem, since the Strength Rating of a Four Leg Sling is based on only 3 Legs
  - **Checking Center of Gravity (C.G.)**
    - If Load does not come up level, it means that the Rigging has not been correctly placed (Not Centered on the C.G.)
    - The Load will rotate until its C.G. is directly under the Lifting Hook
    - The Load, then, needs to be set down, and the rigging needs to be shifted towards the side of the Load that came up Last









CRANES used for COLLAPSE RESCUE (continued)

- **Sling Leg Adjustment**
  - One may need to change position of the Slings, or type of Hitch, in order to properly center the load
  - In some cases a pair of Slings may not be able to be positioned so the Load can be lifted without tilt
  - In such a case, another connection devise may need to be added, such as a Chain Hoist that is connected to the Load using an anchored Hoist Ring or Eye Nut
  - **Note that Edge Softeners are needed to preserve the integrety of Synthetic Slings, especially when lifting Broken Concrete**

Sling Leg Adjustment

- May need to change the type of hitch used to shorten or lengthen
- Use softeners as needed
- Change attachment points, by moving closer in or farther apart

■ Rules of Thumb

- The adjacent slide lists some common rules of thumb. They summarize what has been said on the preceeding pages, and are important considerations to be rememberred.

Rules of Thumb

- Leg of Sling 30 deg to flat, double the load
- Leg of Sling 45 deg to flat, 1 ½ time the load
- Choker de-rates sling 25%
- Lose 50% rating of rigging when bending rope around of equal or less than diameter
- Figure Multi-leg bridles to lift on no more than 2 legs
- Chains too brittle below 32 deg F
- Work from top to bottom, trace out Load Paths
- ***Crib around the victim***
- 20 Feet from Electric wires

■ **Common Rigging Considerations**

These are given in the adjacent slide, and will be discussed in order:

- Double T (also single T) Long span, precast concrete menbers are configured so that they may only be lifted from near the ends. (otherwise thy are likelt to break)
- Wood Trusses – are often mays using onlt 2x members and have little strength in other than the vertical direction.
- No Rapid Swing – the rapid swinging of a crane boom under load will induce side loading into the boom, which can cause it to buckle
- Using rigging as shoring – cables, shackles, turnbuckles etc., have been used in tiebacks to stabilize shored structures

Common Rigging Considerations

- Double "T"
- Wood Trusses
- No Rapid Swinging
- Using Rigging as Shoring
- Obtaining a gap for slings
- Don't Move a disaster from one spot to another, block load when landed

SUMMARY of SCT04 Part c

We have discussed the subjects listed in the adjacent slide. The student should be familiar with all of them

Summary

Lifting or Moving a Load

- Center of Gravity
- Load stability
  - Wedges, cribbing & ropes
- Estimating load weight
- Rating of rigging
- Place to land load
- Load clear to be lifted
- Load de-energized
- Shifting centers of gravity (fluids)
- Can the piece being lifted hold it's own weight?
- Can you stabilize load where it lands?
- Hands & Feet

REQUESTING THE APPROPRIATE CRANE

- Prepare for crane request by using standard US&R forms.
  - 20 questions & forms are on following pages

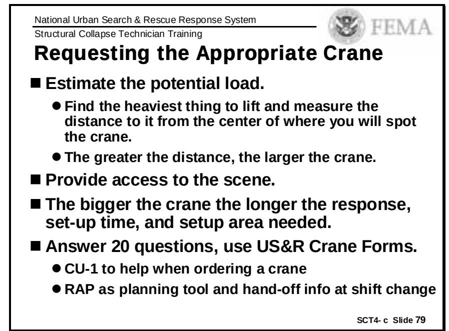
- Be sure to describe potential load weights and load materials so that the right size crane, the right rigging equipment, and the right personnel can be matched and sent to the incident.

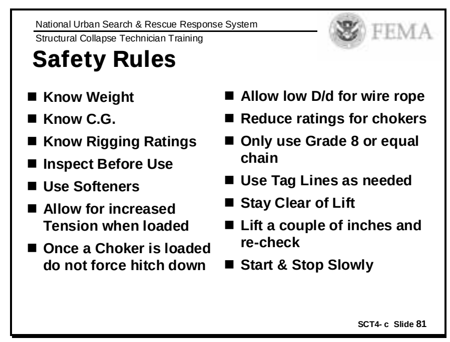
- Reach distance should be calculated from suitable crane lifting location or locations.
  - This assessment should be completed by identifying suitable location(s) that would accommodate aerial ladder operations
    - Distance is measured from the center pin on crane turntable to the center of gravity of the load.
  - Generally, the larger (either capacity or reach) the , the longer the response time and a larger area is required for effective operation.
  - Conventional cranes may require an area as large as 35ft x 200ft for boom assembly.

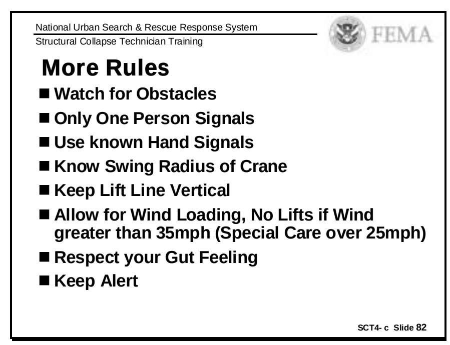
- Ensure sufficient access to the area before crane's arrival:
  - Access road condition and width.
  - Overhead clearance. (including power lines near site)
  - Room and conditions to maneuver around the site

- Rescue personnel must be assigned to facilitate crane operations:
  - Communicate with the crane operator
  - Assist the crane operator and riggers

- Rescuers should prepare for crane operations:
  - Anticipate the best location for crane operation & setup.
  - Initiate clearing activities prior to arrival of the crane.
  - Is surface sloped or level?
  - Is surface hard or soft?
  - Obstacles and hazards:
    - Buildings
    - Walls
    - Wires







20 QUESTIONS to ANSWER when ORDERING a CRANE

When you contact a rental source of heavy lift equipment, they will start asking questions to permit them to give you what you need. If you can have answers to their questions ready beforehand, you will speed the process considerably. If you have answers to the following questions, you will be well prepared for the rental agent's questions.

1. Who are you and what are you doing?
2. How quickly do you want a machine?
3. What do you intend for this machine to do?
   - Pick and swing
   - Pick and carry
   - Lift large objects at small distance
   - Lift small objects at large distance
4. Will multiple machines be needed? (Second machine to set up primary machine).
5. What are the capabilities of the onsite crew? (Are they qualified to assist with set up?)
6. If this machine is for a single task, what is the load weight and what is the load radius?
7. If this is for multiple tasks, what are several combinations of load and distance? Max load / min distance, max distance / min load, possible mid load/mid distance?
8. Will this task require pick and carry capability?
9. What are the limits of room available for operation of the machine? Overhead clearance, tail swing clearance, underground obstructions?
10. Is there a place to assemble boom (if lattice) and crane (counterweights)? Including room for assisting crane?
11. Are there limitations on delivery of crane or parts? Posted bridges, low clearances, underground utilities?
12. What areas of operation are anticipated? Over rear, Over side, Over front, On rubber?
13. Are two crane (simultaneous) picks anticipated?
14. Will work be performed on a continuous (24 hr) basis? Is auxiliary lighting available?
15. Will radio communication be required to control load? Are dedicated radios available?
16. How much boom is required? Are special boom features (offset, open-throat) needed?
17. What size hook block is needed? Are shackles to fit hook available?
18. Will jib be needed? Jib length? Offset? Load?
19. Are additional rigging components needed? Load cell, lift beams, slings, shackles?
20. Who is the contact person and who is the person directing the rigging operations?

US&R Crane Use Form CU-1

This form is intended to act as a check-list when ordering or planning for the use of a Crane. One form may be used for each Crane

The Sketch should show the approx position of crane and setup area, as well as where trucks for removal of debris should be staged. Also need to show locations of overhead and underground hazards **Get form on Disasterengineer.org**

US&R Rigging Action Plan - RAP

US&R Crane Use/Order Form CU-1 **By:** ______ **Date:** ______ **Page** ____ **of** ____

Situation Name:	**Date and Time of Lift:**
Rigging Task:	**Task Force Name:**
Weather Conditions:	**Task Force Leader:**
Load Description:	Crane Operator:
Load Weight:	Crane Make & Model:
Block Weight:	Crane Serial No:
Rigging Weight:	Boom Length:
Jib Weight:	Jib Length:
Jib Ball Weight:	Jib Position: ☐ Stowed ☐ Retracted ☐ Offset at ____
Hoist Line Weight:	Size of Counterweights Installed:
Other Weight:	Front Outrigger Installed: Yes No
Total Weight:	**Setup On:** ☐ Crawlers ☐ Outriggers ☐ Tires
Lift will be On: ☐ On Main Block ☐ On Jib	☐ Extended ☐ Retracted ☐ Other

Max. Intended Working Radius	Boom Angle:	Rated Capacity:	Percent of Capacity : (Total Load / Rated Capacity)
Over Rear:	Over Rear:	Over Rear:	Over Rear:
Over Side:	Over Side:	Over Side:	Over Side:
Over Front:	Over Front:	Over Front:	Over Front:

Hazards: ☐ Electrical ☐ Fire ☐ Underground ☐ Other ______ Are Crane Mats, Blocking Reqd: ______

SKETCH

US&R Rigging Action Plan - RAP

It is intended to be the planning tool and record of rigging ops during one operational period. It can then serve to hand-off the info to the on-coming shift. A copy should also get pack the the TF and/or IST Plans Unit

The HERS should number all significant loads, give dimensions & weight, indicate load Radius, indicate where the load is intended to go, and check-off if moved.

One page will work for 12 loads. Use as many pages as necessary. This form works best if a copy machine is located at the forward BoO. **Get form on Disasterengineer.org**

US&R Rigging Action Plan - RAP **Task Force:** ________ **Date:** ________ **Op Period** ______ **Page** ____ **of** ____

Situation Name:	**Crane Size & Type:**
HERS Name:	**Crane Supplier:**
RTM Name:	**Operator Name:**
StS Name:	**Oiler/Rigger Name:**
Squads Assigned:	**Boom Langth:**
Radio Frequency:	**Net Lift Cap @ 50ft:**
Operation Mode (circle one) **Rescue** **Recovery**	**Foot Print Dimen.:**

LOAD PATH HAZARDS

Overhead

Below Grade

Contanimation ☐ Biological ☐ Chemical ☐ Radiation ☐ Other

Debris Removal Effects

Chain of Evidence Needs:

Load No.	Weight & Size	Load Radius	Landing Zone	Completed Yes	Completed No

SKETCH:

National Urban Search & Rescue Response System
Structural Collapse Technician Training

Use Hand Signals to Guide Movement

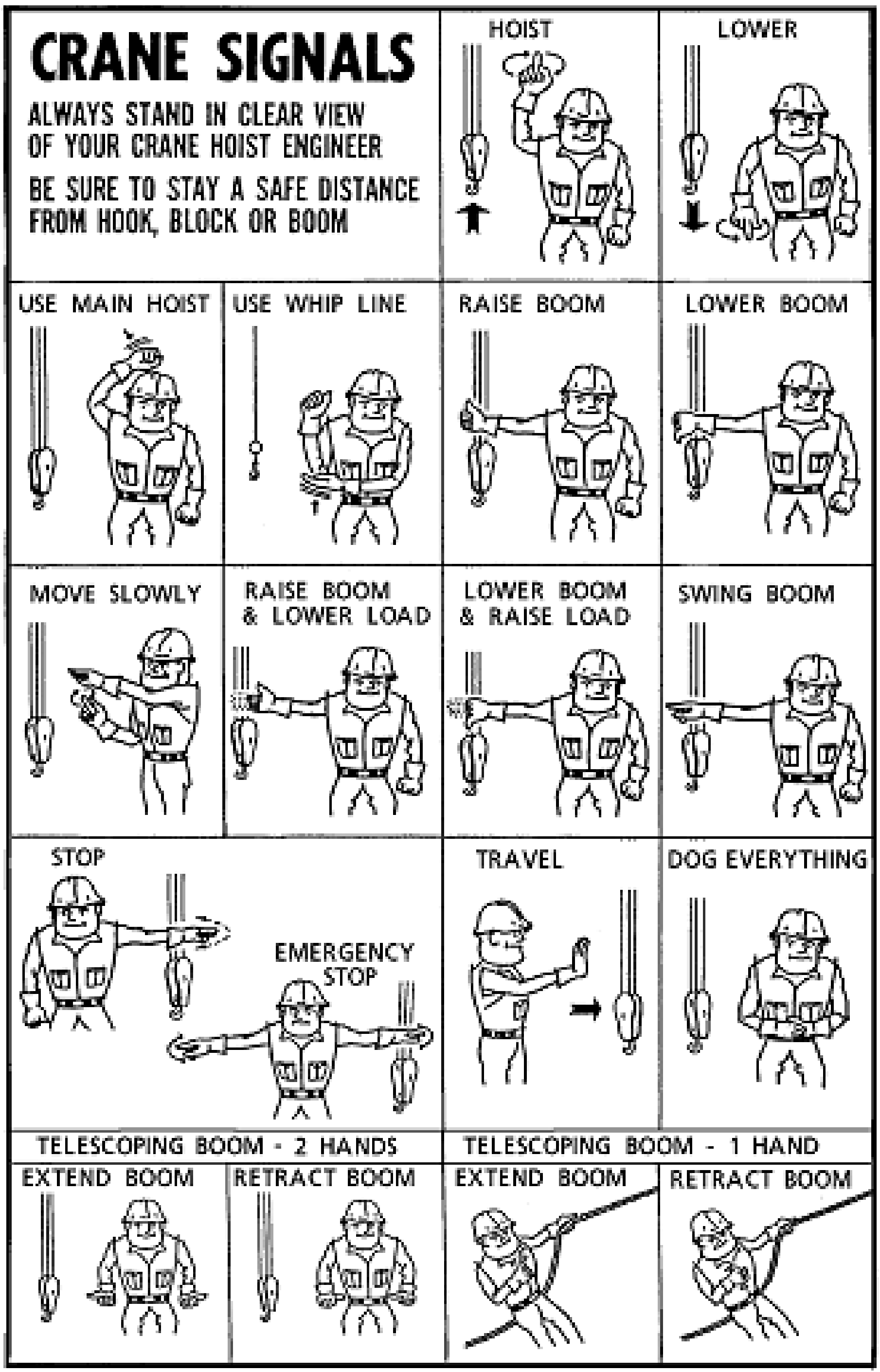
- Use of these hand signals in the positioning a Ladder Co's Aerial Ladder
- Raising & Lowering Loads with Rope
- Raising & Lowering Loads with Levers/air Bags
- Use Tag Lines to Control the Load
- Raise Load, Lower Load, Stop, Lock off,
- Extend Boom, Retract Boom

SCT4- c Slide 86

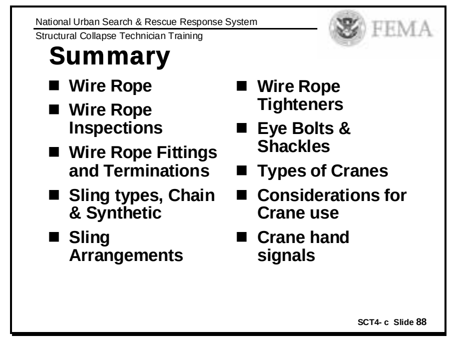
CRANE HAND SIGNALS

Rescue personnel must have a basic knowledge of hand signals normally used to communicate with the crane operator. These hand signals have been adopted as National Standards

At each incident, it will be up to the Heavy Equipment and Rigging Spec to determine if there are any exceptions to the standard hand signals that are being practiced locally



SUMMARY of SCT04
The two adjacent slides list the subjects that have been covered in this module. There are many and all should review the parts of this manual that need to be "refreshed"



REPEAT of ENABLING OBJECTIVES
Hopefully all have been able to:

<u>For Part a</u>

- Understand the basic physics as they relate to Weight, Gravity, and Center of Gravity.
- Explain the concepts of Energy, Work, and Power
- Describe what determines the efficiency of mechanical advantages.
- Explain the three classes of levers.
- Describe the efficiency of inclined planes.
- Describe the two types of pulley configurations.

<u>For Part b</u>

- Explain the effective use of high pressure air bags.
- Lifting & Stabilizing Loads and Cribbing
- Calculate the weights of common materials.

<u>For Part c</u>Explain use of proper sling angles to efficiently lift a load

- Explain the use of anchor systems, anchor failure considerations, and proper anchor spacing.
- Describe the proper use of swivel hoist ring, steel angle brackets, and concrete screws.
- Understand the proper use of wire ropes, wire rope fittings, end terminations, and tighteners.
- Explain the use of slings and sling arrangements.
- Describe the use of chains for rigging and lifting.
- Determine the effects of critical angles as the relate to lifting and moving objects.
- Identify and describe the advantages and disadvantages of the different types of cranes.
- Explain considerations for crane use, and demonstrate basic crane signals for rescue operations

National Urban Search & Rescue Response System
Structural Collapse Technician Training

The “A” Frame

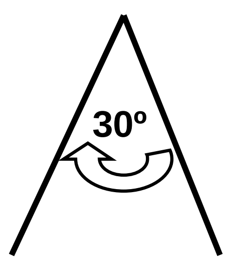
Pair of 6x6x14ft lashed at 12ft, A is set at 60 deg.

SCT4- a Slide 111

National Urban Search & Rescue Response System
Structural Collapse Technician Training

The “A” Frame can be made with 6” X 6” X 16’ Timbers

Rated at 5,000lb with an Apex Angle of 30º.



SCT4- a Slide 112

National Urban Search & Rescue Response System
Structural Collapse Technician Training

Lashing 6"x6"x16' Timbers to make the "A" Frame

- Use 60' ½" static rescue rope.
- Clove Hitch with (4) side safety.
- (8) figure eight wraps.
- (4) fraps.
- Clove Hitch with (4) side safety.
- 2"x 6" scabs (5) nail pattern.

SCT4- a Slide 113

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Structural Collapse Technician Training

Rigging the A Frame

Assemble listed equipment

Elevate and secure timbers

SCT4- a Slide 114

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3’ from the top of the timbers tie a clove hitch leaving 3’ of tail for the safety

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Wrap the 3’ tail around the clove hitch on each side of the 6X6

SCT4- a Slide 116

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Slack being taken out of friction hitch safety around clove hitch

SCT4- a Slide 117

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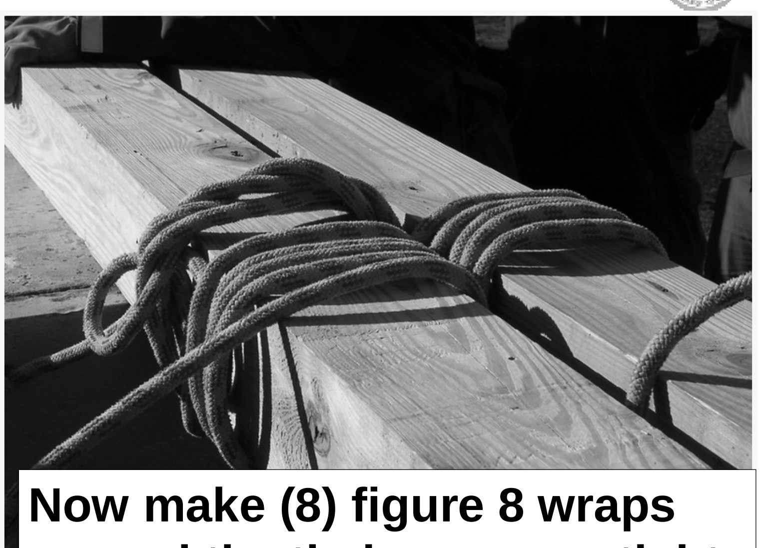
Structural Collapse Technician Training



Now make (8) figure 8 wraps around the timbers, snug tight

SCT4- a Slide 118

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Now make four fraps between the timbers snugging the (8) wraps tight

SCT4- a Slide 119

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After the fraps are tightened tie a clove hitch with friction hitch safety on the second (opposing) timber

SCT4- a Slide 120

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2x6 scab block nailed to timbers to prevent lashing slippage

SCT4- a Slide 121

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The A Frame is now ready to be raised
Use a flat ladder carry and raise

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FEMA

The A Frame is raised & scissored apart, 30 deg. is the desired apex angle

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Structural Collapse Technician Training

FEMA

- **The A Frame is raised and scissored apart**
- **30 degrees is the desired apex angle**
- **Legs should be tied and scabbed & placed in 6” holes**

SCT4- a Slide 124

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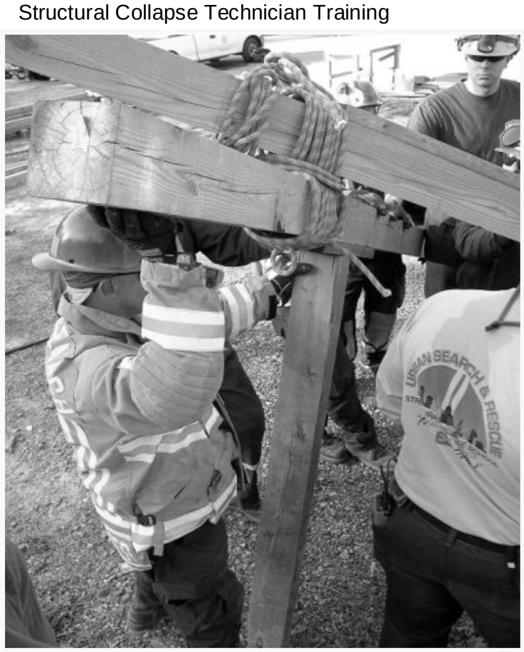
Structural Collapse Technician Training

Set A Frame on a 4' gin pole for application of raise/lower straps

SCT4- a Slide 125

National Urban Search & Rescue Response System
Structural Collapse Technician Training



The duplex nail heads help secure the temporary gin pole

SCT4- a Slide 126

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Structural Collapse Technician Training

6' rigging straps (loops) are added to each timber for raise/lower attachment

SCT4- a Slide 127

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Structural Collapse Technician Training

After attaching the raise/lower lines, the A Frame is raised into place

SCT4- a Slide 128

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Structural Collapse Technician Training

Erecting the "A" Frame

SCT4- a Slide 129

National Urban Search & Rescue Response System
Structural Collapse Technician Training

SCT4- a Slide 130

National Urban Search & Rescue Response System
Structural Collapse Technician Training

SCT4- a Slide 131

National Urban Search & Rescue Response System
Structural Collapse Technician Training

SCT4- a Slide 132

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Structural Collapse Technician Training

The "A" Frame

2-Airshore "Struts w/steel fittings, just past vertical

SCT4- a Slide 133

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Structural Collapse Technician Training

The "A" Frame

2-Paratech Struts w/steel fittings – picking up load

SCT4- a Slide 134

STUDENT MANUAL
STRUCTURAL COLLAPSE TECHNICIAN TRAINING
APPENDIX : A
TASK FORCE SEARCH CAPABILITIES

Unit Objective

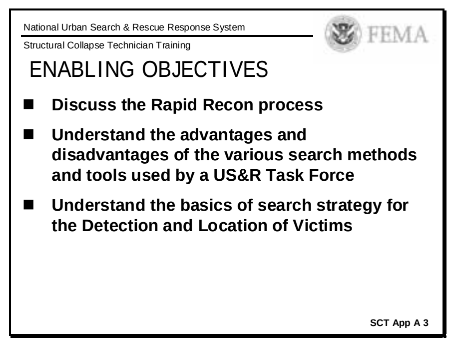
After completing this unit, you will understand the capabilities of the US&R Task Force Search Team

The Rescue Specialist should also be prepared to serve as part of the Search Team

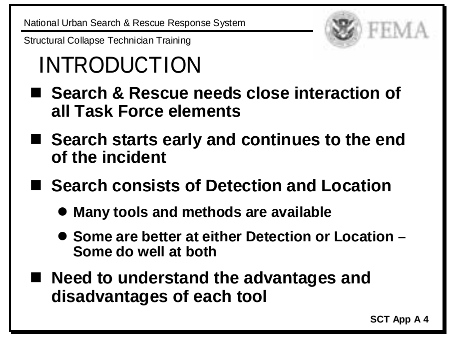
Enabling Objectives

You will:

- Discuss the Rapid Recon Process
- Understand the Advantages and Disadvantages of the various Search Methods and Tools that are used by a US&R Task Force
- Understand the basics of Search Strategy for the Detection and Location of Victims



I. Introduction



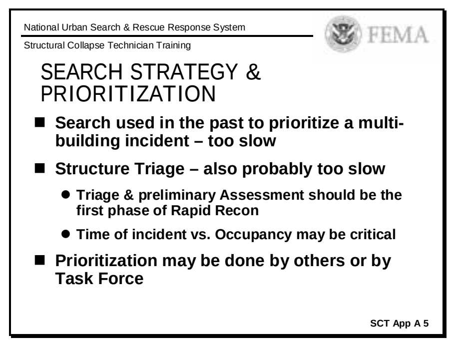
Search and Rescue operations in the urban disaster environment require close interaction of all task force elements for safe and successful victim extrications.

Search operations will be initiated early in the mission and could continue until stand-down, since as the structure is accessed, parts removed, etc., re-searching will be required.

Successful Search requires that the victims be **Detected** and then efficiently **Located.** There are many methods and types of equipment that can be used in the search, many can perform both of these functions. However, some are more efficient at **Detection** and some are most often used to **Locate** victims.

All members of the task force need to understand the advantages and disadvantages of each tool in order to enhance the functioning of all operations.

Search Strategy & Prioritization



In the past the search function has been used, at least partly, to initially prioritize a group of buildings. Since an adequate search may take several hours, it is essential to use some other logical method to prioritize the structures if a large number are involved.

The 2003 approach, based on Appendix TAM, FEMA US&R Response System, Operations Manual, is to use a simple, common sense, numerical method (Triage) to sort the buildings such that those that have the greatest chance of yielding positive results (most saves in shortest time) will be given highest priority.

This initial prioritization will probably have taken place prior to the arrival of the task force at a specified area.

The use of Triage by a US&R Task Force to pre-prioritize building would require too much time, so a new, Rapid Recon process has been developed in 2008

II. **Original Recon Team**

If some sort of initial prioritization was established, a task force (or task forces) could deploy one or both of it's 9 person search and recon teams, staffed as follows:

- **Search Team Manager** (1) - functions as search/reconn team supervisor, sketches and records information, and communicates details and recommendations back to the Task Force Leader.
- **Canine Search Specialists** (2) - conduct canine search operations and redundant verifications of alerts.
- **Technical Search Specialist** (1) - conduct electronic search operations including acoustic/seismic listening devices and/or electronic viewing equipment.
- **Medical Specialist** (1) - provide medical treatment for search/reconn team members and recovered victims..
- **Structure Specialist** (1) - provides advice regarding building stability, shoring, stabilization, access, victim location, hazard assessment and marking.
- **Hazardous Materials Specialists** (1) - monitors atmospheres in and around voids and confined spaces. Assesses, identifies and marks hazardous materials dangers. Works with Structural Specialist regarding hazard assessment and marking.
- **Rescue Specialists** (2) - provide assistance to the search/recon team including drilling/breaching for electronic viewing equipment and/or deployment of listening arrays.

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Structural Collapse Technician Training
FEMA

Original RECON TEAM

- **Search Team Manager**
- **Two Canine Search Specialists**
- **Technical Search Specialist**
- **Medical Specialist**
- **Structural Specialist**
- **Hazmat Specialist**
- **Two Rescue Specialists**

SCT App A 6

Rapid Recon – Concept of Operations

A segmented, rapid Recon Procedure has been proposed, in order to provide an additional deployment option for disaster situations where US&R Task Forces are overwhelmed by the size of the incident (great quake)

- The intent here is to speed-up the processes of using Triage to pre-prioritize the effected structures, followed by deploying Recon (in the order of the highest Triage Score)
- The assumption here is that, even though there may be many damaged structures involved, some could be initially judged low priority due to lack of occupancy at the time of the initial event.
- The need to rapidly find and rescue victims, requires an accelerated prioritization process

The personnel from the two, original, TF Recon Teams would be divided into three functional teams that would perform the following

- Rapid Triage/Assessment
- Rapid Victim Detection & detailed Hazard Assessment
- Victim Location & begin rescue
- All 3 teams would carry only the equipment that would be essential for their tasks, in order to maximize mobility

The Recon Team – contains the following Specialists.

- Hazmat, Structures, Tech Info (optional) & Search Team Manager (STM) (optional)

The Recon Team would begin by to rapidly assessing the first 3 or 4 structures and feed-back information to the Search Team Mgr

- The Hazmat Spec would be expected to make the appropriate test that would allow structure assessment to proceed
- The Struct Spec would be expected to use the concepts of triage and assessment to rapidly develop data that would determine relative priority.
- The Tech Info Spec would record information, document the process and communicate with the STM

NEW, RAPID RECON – 3 Phases

- **Assessment Team**
  - **Struct & Hazmat Spec + Tech Info Spec & Search Tm Mgr**
  - **Quick Assessment of a few buildings at a time**
  - **Initial prioritization**
- **Victim Detection Team**
  - **STM, 2 - K9 Teams, Tech Search, 2 - Rescue, Med Spec, Struct Spec, Hazmat Spec**
  - **Victim Detection & detailed Hazard Assessment**
- **Victim Location Team**
  - **STM, 2 – K9 Teams, Tech Search, 2 – Rescue, Med Spec, possibly Struct & Hazmat Spec (from detection Team)**
  - **Victim Location, Initial Treatment, & start rescue**

SCT App A 7

Rapid Recon – ConOp (continued)

The Victim Detection Team would, in turn, better define the highest priority structures.

The Victim Detection Team - the following Specialists.

- STM, 2 – K9 teams, Tech Search, 2 – Rescue Spec, Medical Spec, Struct & Hazmat Specs

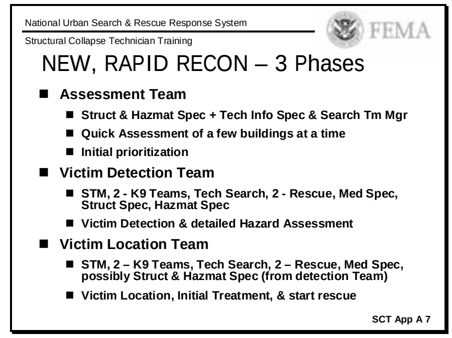
Their task would be to search the structures in the order, established by the Assessment Team

- The K9 and Tech Search would proceed, and be supported by Rescue and Medical
- The Struct & Hazmat Specs would complete a detailed assessment of each structure
- The STM would use search results would be used to re-prioritize the structures, and decide on the deployment of the Location Team, as well as the Detection Team

The Victim Location Team - the following Specialists.

- STM, 2 – K9 teams, Tech Search, 2 – Rescue, Medical, (possibly Struct & Hazmat Spec)

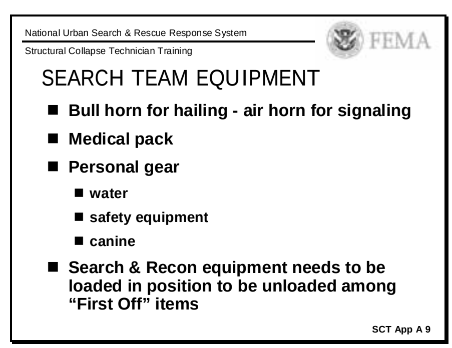
Their task would be to locate victims, starting with the highest priority as established be the Detection Team. Rescue would start immediately as victims were located, and this process would continue as long as there were structures that had not been investigated



Search Team Equipment

Specific equipment and materials are necessary to fully support a deployed recon team.

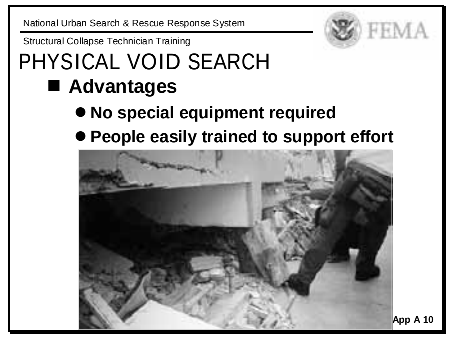
- This equipment should be segregated and receive priority consideration when a task force cache is being moved to an assigned location.
- It should be immediately available in order to deploy one or two search and recon teams in a timely manner.
- The equipment is listed on the two adjacent slides



III. Review of Search Tools and Operations

The following outlines the current tactics available for locating trapped victims (usually from collapsed buildings of reinforced concrete construction) and their corresponding **Advantages and Disadvantages**. No single tactic is sufficiently effective on its own to ensure that a complete search has been conducted. The most effective search strategy should blend all viable tactical capabilities into a logical plan of operation.

Physical Void Search (visual/vocal)



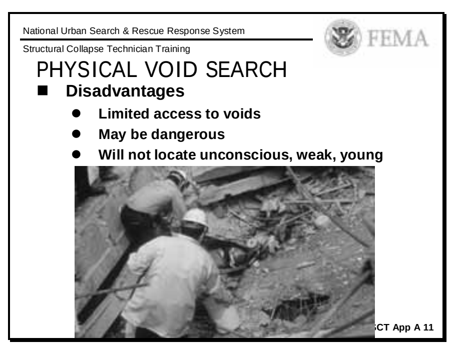
In some incidents a basic physical void search has been done by neighbors, passersby or first responders. To conduct a thorough physical search, the Task Force should be deployed in consistent pattern over the collapse site. They should make separate visual assessments in voids and confined space areas for any indication of victims. They may also be used in a coordinated fashion as an array of listeners. A bull-horn, or hailing device, could be used to provide direction to trapped victims. The area is then quieted and the personnel listen and attempt to pin-point the location of the noise.

This operation is less exacting then the others and poses a significant risk to the personnel involved in the operation.

Advantages - Physical Void Search

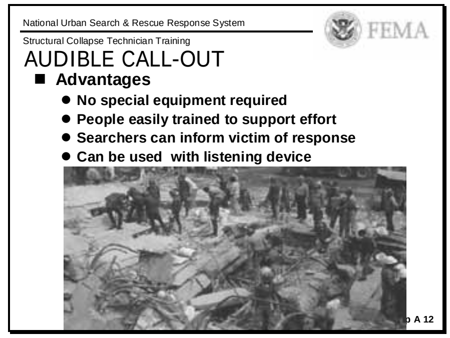
- Does not necessarily require specialists, canine, or sophisticated electronic equipment.
- People could quickly be trained to support the effort.

Disadvantages



- Limited access to all voids in building.
- Proximity required may be dangerous to search personnel.
- Will not locate unconscious, physically weak, or a very young victims

Audible Call-Out Method (rescue hailing method)

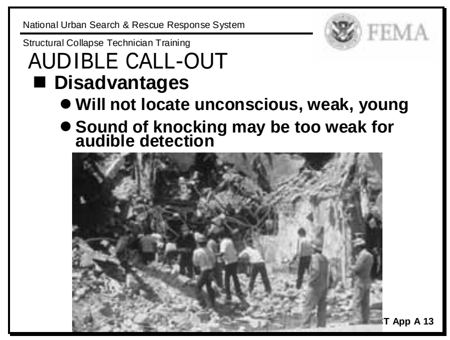


- Since frequently, the voice of the victim can not be heard, a method of calling out to them with a request for knocking may be successful. Again, an array of listeners in a grid pattern can be used to help point the victims location.

Advantages

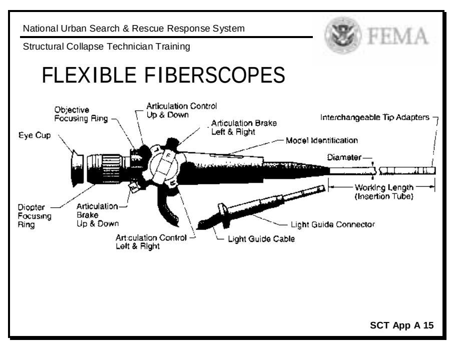
- Same as **Physical Void Search**
- Personnel can inform victim of expected response.
- This procedure can be modified and used in conjunction with listening devices.

Disadvantages



- Unconscious, physically weak, or a very young person cannot be detected.
- Sound of knocking is possibly too weak for audible detection.

Use Of Fiberoptics

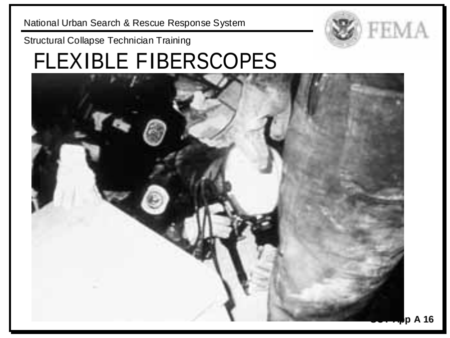


The flexibility and the small diameter of the fiber optics bundles makes the **<u>Flexible Fiberscopes</u>** very appealing in extremely tight spaces. The technology has been advanced primarily for precise medical applications. The picture resolution is limited by the number of fibers in the bundle. Light can be brought in and the picture will return through the same bundle. Eyepieces, camera, light sources, articulation are all available. Most Fiberscopes have four-way articulation of the tip. Diameters from 2.4 to 13 mm.

This equipment, especially when used with conjunction with concrete hammer/drills, is quite effective at pinpointing the exact **Location** of victims. However, it may also be used for general void searches within collapsed buildings. Prior experience has shown success, when rescue personnel have drilled an array of holes (in a floor space for example) and an operator(s) subsequently follows with the fiberoptic device(s) to make quick assessments through them.

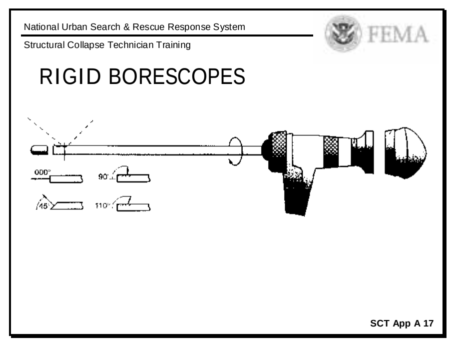
Flexable Fiberscopes

This equipment is simple to use once personnel are fully trained in its operation. The most difficult aspect to master is the determination of which direction one is viewing when the instrument is inserted into a drill hole or void opening. This requires consistent training. The equipment can also be considered as part of the rescue element's responsibility due to its ease of operation, and used when cutting/breaching near a victim.



Due to its actual visual indication of a victim, no redundant check is usually required. If the operator is required to move on for subsequent operations, the site should be marked with red tape to indicate a live victim. In addition, the specialist should sketch the general features of the structure/area being searched noting any significant information on the sketch for future reference.

Rigid Borescopes are An available alternate to the flexible fiberscope. These devices have been in use for many years. As the name implies - they are mainly used to explore, through bored holes, mechanical devices such as aircraft engines, castings, and pipes. These devices consist of straight tubes with lenses, mirrors or prisms on the ends. Because no fibers limit the resolution, picture quality is very high, cost is moderate. Limited articulation is available. Brightness, color and resolution are excellent especially when used with high intensity light sources. Tactics are similar to fiberoptic search, since this tool is used mostly to **Locate** victims



Advantages of Fiberoptics

- Provides the general position and condition of the victim.
- Can be used to verify other search tactics prior to commencing rescue operations.
- Can be used to monitor victim during rescue operation.

Disadvantages

- Extended or inaccessible voids (observation holes) cannot be viewed due to the flexible nature of the fiberoptic cable and the limited light source.

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FIBERSCOPES & BORESCOPES

- **Advantages**
  - **Finds position & condition of victim**
  - **Useful to verify other search tactics just prior to starting rescue operations**
  - **Used to monitor victim during rescue**
- **Disadvantages**
  - **Difficult to use in extended holes due to flexible cable, limited length of rigid scope, and limited light sources**

SCT App A 18

Search Cameras – Video Systems

These video systems use electronic components to capture and transmit images. Tactics used will make use of available holes and openings to look inside voids, or holes can be drilled to allow camera access. A video system requires three basic components:

- Video camera, Video cable, and Video display. (discussed below)

Video Camera

- The video camera is an electronic device that converts images into electronic signals.
- Almost all video cameras used today use charge-coupled devices (CCD) as the imaging sensor. The CCDs allow the camera to be very small and reliable.
- A CCD chip is made of small light-sensitive cells arranged into a grid pattern. When the image pattern strikes the sensor cells, the level of light registered on each cell captures the image. The number of pixels and the number of lines scanned control the quality of the image transmission.
- Each of the cells forms one picture element or pixel. These pixels are combined into horizontal lines representing the image. Since each line is "scanned" at a precise time interval, the picture can be reassembled line by line.

Video Cable

- The electrical cable allows the video signal to be transferred from the camera to the video display.
- Because the video signal is complex and any loss in the signal will result in loss of some portion of the video image, it is constructed coaxially. This type of construction helps to prevent signal loss and shields the video signal from outside electrical interference.
- A coaxial cable has two conductors, an inner center conductor that carries the signal and the outer, braided shield that is wrapped around the center conductor's insulation. All video cables must have a 75-Ohm impedance value.

Video Display

- The video display converts the signal transmitted from the camera and through the cable into the image that is viewed on its screen. There are several different types of video display designs, but the original type that was used in video search devices was the cathode ray tube.
- Another type of display is the Liquid Crystal Display (LCD). Images are created on the LCD via electric charges that are applied to liquid crystal molecules called TNs (twisted nematics).
  - ♦ A light source shines from behind two sets of transparent panels with a liquid crystal solution between them.
  - ♦ Each crystal either allows light to “twist” through or blocks the light., and the configuration of crystals forms the image.

Specific brands of US&R Search Cameras

The original **Search Cam™** had a pole mounted, 1.75" diameter camera specifically designed for urban search and rescue. The camera itself is remotely movable over a +/-90 deg.· angle. A CRT monitor, either black/white or color, displays a television like picture in front of the operator .

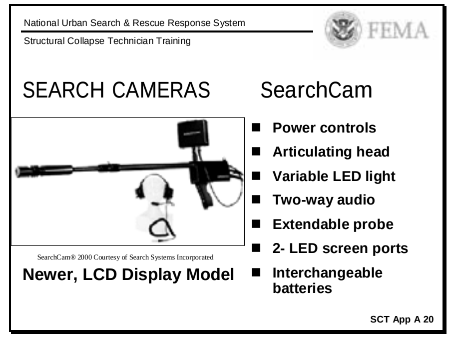
Typically a 2" hole is drilled into a void. The very light sensitive CCD camera is placed into the hole. A built-in light source will illuminate the interior of the void. Turning the telescoping pole and using the articulation allows viewing in all directions.

A microphone and speaker permit listening for sound and possibly communications with a victim. Depending on the distance to the objects to be viewed, the light source has to be adjusted carefully, so as not to wash out the picture. Unless there are obstructions that block the view, this is a very useful tool, not only during the search but also during extrication, where it can guide cutting ops.

This search camera has been replaced by smaller and more user friendly units that will be briefly discussed following:

Second generation – SearchCam – Properties

- Power controls
- Articulated head
- Variable LED light
- Two-way audio
- Extendable probe
- 2-LED screen ports
- Interchangeable batteries



Video Systems – Zistos WalkAbout

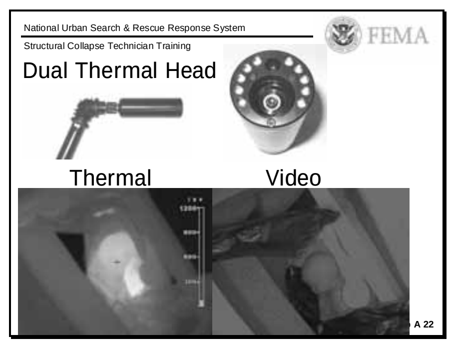
This is a another system that is very compact, and has the added benefit or coupling thermal imaging with the video

It accomplishes this by the use of a dual image head. The thermal image may be useful in initially locating the victim in a confined space, since when covered with concrete dust, they may blend into the background.

The properties and an example of the two types of images are shown in the next slide

Zistos WalkAbout - Properties

- Interchangeable heads
- Audio capable
- Thermal/video capabilities
- Secondary batteries
- Manual articulation
- Fiberoptic attachment

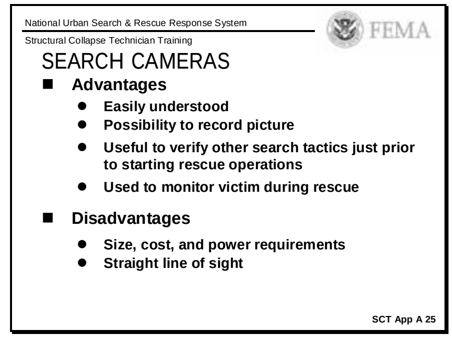


SnakeEye™ has 1¼" diameter CCD type camera, mounted on lightweight, rigid pole. The display is a (5") flat , high resolution, rotatable color TFT-LCD.

The camera head is mounted with a swivel that allows 90 deg. Vertical articulation, or the camera head may be removed from the wand, mounted on another device, or suspended by it's cable.

The camera head is waterproof, and, therefore, may be submerged to the length of the cable (100 ft max.). The display, connected only to the opposite end of the cable, is rugged and portable.

Search Cameras (continued)



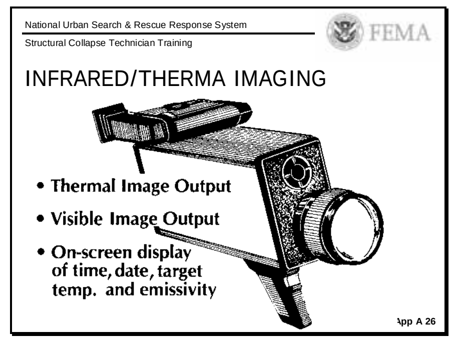
Advantages of Cameras

- Easily understood
- Possibility to record picture
- Remote viewing.

Disadvantages

- Size, cost, power requirement
- Has only straight line of sight

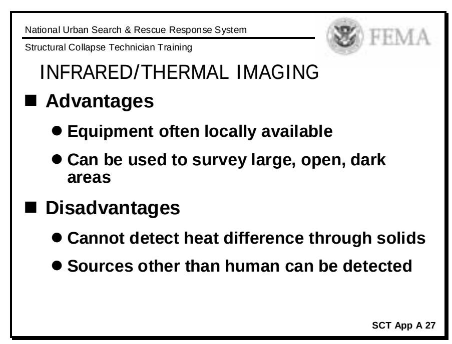
Infrared/Thermal Imaging



A unique way of seeing through smoke and dust is infrared. An infrared imaging system was used successfully in the very smoky environment of the World Trade Center incident.

- These cameras are fairly expensive.
- Some models are helmet mounted with a small TV display right in front of the eyes of the operator.
- Infrared vision also allows one to find hot spots inside of walls and sources of fire in very smoky environments
- Resolution is poorer than on a typical black and white TV picture, but they are useful when maneuvering around in unfamiliar surroundings.

Advantages InfraRed Imaging



- Equipment is sometimes readily available with some responding local organizations. Can be used to survey large, open, dark areas.

Disadvantages

- Unit cannot detect heat differential through solid mediums. Sources of heat other than persons buried under debris are also indicated which creates confusion in a search application.

Electronic Listening Devices

The advent of state-of-the-art electronic listening devices has added a new dimension to the search function. The latest electronic devices can extend the range of the search, (in case where the victim's scent may not reach the surface and therefore be inaccessible to canine) by detecting sounds from the victim. The task force staffing provides for two Technical Search Specialists, who will usually use the electronic acoustic/seismic listening devices as their primary tool.

Electronic search operations are usually more site-specific and longer in duration than canine search operations. Other task force personnel (preferably rescue personnel) should assist the Technical Search Specialist and also act in the overhead function to ensure overall safety. In addition, the specialist should sketch the general features of the structure/area being searched noting any significant information for future reference.

As shown in the adjacent slide, there are many ways to attach the sensors, and help from rescue is often needed.

The general application if the acoustic/seismic device involves the deployment of an array of two or more pick-up probes around the perimeter of a building or void area. A bull horn or other hailing device should be used to attempt to give direction to any conscious victim trapped within the structure.

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ELECTRONIC LISTENING DEVICES

- **All Task Forces have these devices**
- **Listen to acoustic or seismic vibration**
- **Normally deploy two or more sensors**
- **Hailing device used to get victim response**
- **Can Detect if live victim is in structure**

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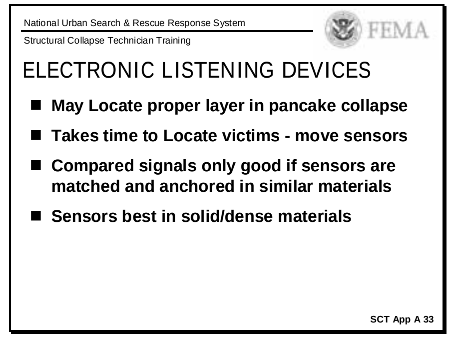
The victims should be directed to make a repetitive sound (i.e., "knock five times repeatedly"). The general area should be made as quiet as possible during this operation. the repetitive series will provide the operator with an identifiable sound to detect.

If victims are **Detected,** the different probes are assessed separately to determine which gives the strongest indication and should theoretically be closest to the source of the sound/victim.

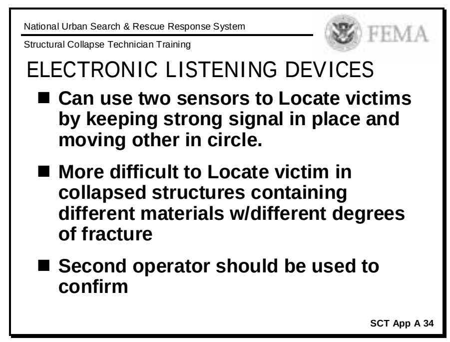
If necessary, the array of probes may then be redistributed (around the area of the original probe giving the strongest indication) to more precisely identify the victim's **Location.**

Electronic Listening Devices (continued)



The distance between probes or sensors will depend on the material of which the structure or rubble pile is made, and in what sections of material the structure-borne sound is expected to travel. Also of influence will be the presence of interfering signals, which may lead to a further reduction in sensor spacing. In any case, the sensor spacing should not exceed 25 feet (8 meters). Typically, a 15' (5 meter) spacing will cover the area well, even under more difficult circumstances.

For **Detection**, and as part of a hasty search, a single operator using one sensor may suffice. But for safety reasons, the search team should always comprise of at least 2 people.



Pin-pointing the **Location** of a victim using only one sensor will be difficult, because the signal amplitude and clarity would have to be remembered from sensor location to sensor location.

Being able to compare several sensors, and to switch from sensor to sensor quickly, will allow the operator to identify the sensor with the largest and/or clearest signal.

As a rule, if a signal is detected, it is advised to leave that sensor in its position and reposition the other sensors around it for more accurate determination of the location. The more sensors available, the larger is the area which can be searched and the quicker a victim location can be pin-pointed.

Comparison of signals is only meaningful if the sensors are matched in sensitivity and are of the same type and construction, covering the same frequency range. This may not be the case with all listening devices. Some use 2 types of sensors: one for high and one for low (seismic) waves.

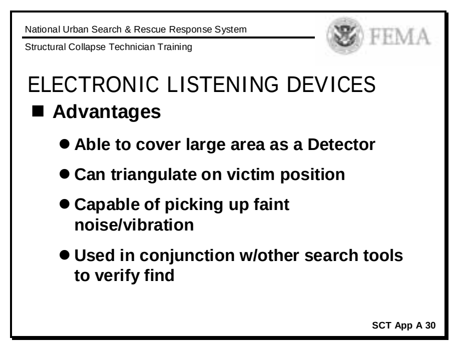
If two sensors are available and a signal is heard, the louder sensor again should be left in place. When the second sensor is moved step by step in a circular fashion around the first sensor, a direction toward the signal source may be obtained, when the movable sensor shows maximum signal.

Electronic Listening Devices (continued)

However, it should be kept in mind that the majority of collapsed sites will be made out of different materials: steel, concrete, brick, and wood may be found on one site, with each material having a different sound transmission capability. There will be breaks and fractures, large and small pieces, and overall inhomogeneous materials. It will be more important to access the larger structural parts and to try to place the sensor on similar materials rather than work with theoretical search patterns and assume equal sound distribution and attenuation. The "Stereo Effect" effective if homogenous materials are present. Eventually some type of modified grid search should be used to verify that no section of the site is overlooked.

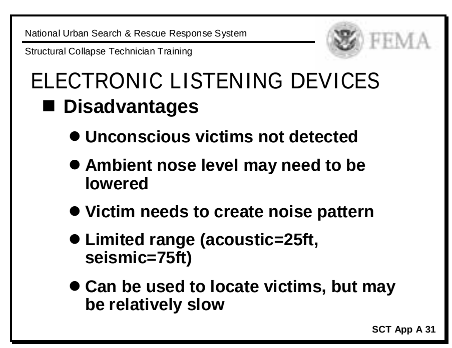
In the same manner as in searching with dogs, the second Technical Search Specialist should be used to confirm the initial find (certain brands of devices employ two separate headphones for this purpose). Should the second operator provide an indication of a find at the same location, this position should be marked with orange survey tape. This information would then be passed on to the Task Force leadership and the technical search would continue.

Advantages of Electronic Search.



- Able to cover large search areas and sometimes triangulate on victim position.
- Capable of picking up faint noises and vibrations.
- Can be used in conjunction with other search devices to verify find.

Disadvantages



- Unconscious person cannot be detected.
- Ambient site noise is intrusive.
- Victim must create a recognizable sound pattern.
- Range is limited (acoustic - 25 feet, seismic -75 feet).

IV. Canine Search

A well trained canine search team can search large areas in a relatively short time. The dogs use their keen sense of smell to **Detect and Locate** victims buried under the debris. The primary function of the canine is to find those victims that are alive. However, most canines will give subtle indications of the dead, and when ever possible these areas will be noted for future recovery.

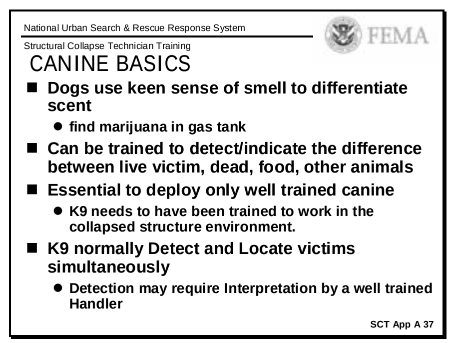
The search canine will indicate finding the scent of a buried human victim by focused barking and digging at the strongest scent source. The canine may also try to penetrate to the victim.

A canine team consists of a canine search specialist and a search canine. Two of these canine search specialist teams, a technical search specialist, and a search team manager will be assigned to search a site. The search team manager monitors handler safety, may be an observer, keeps track of and maps alerts, and coordinates the search operations.

Canine Basics

The canine's keen sense of smell allows them to differentiate scent. FEMA search K9 are trained to key on live, buried victims. During training they are conditioned to differentiate between sent from live humans and distractions, such as food and other animals (such as cats, rats, and other small critters).

The properly trained K9 will Detect and Locate a live victim simultaneously. They are trained to dig and bark at the victims location, and try to penetrate into the void space



Canine Training

The training that will enable to efficiently search a collapsed structure site is more extensive that normal Search & Rescue Training. The dig & bark alert system must be learned, and the K9 must be familiarized with the difficult collapsed structure environment.

To facilitate safe deployment on uneven and unstable surfaces, the K9 is taught to negotiate various types of obstacles. In addition, they are trained to respond to the handler's hand signals, that indicate the desired positioning of the K9 in a specific location

Canine Availability

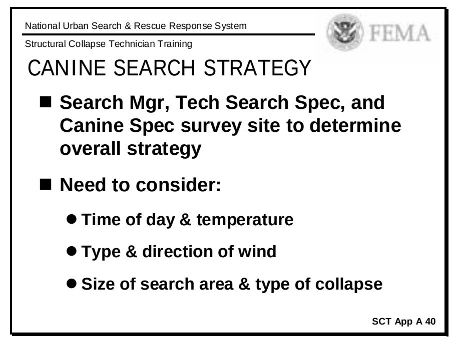
Each FEMA Task force is intended to have for certificated K9 that are ready to be deployed at any time. The desired number of K9 for each task force would be 4 x 3 = 12, and therefore, the total for the 28 FEMA Task Forces would be 336.

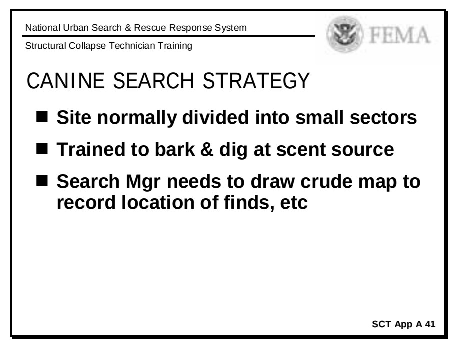
As of Jan 2008 there are a littler over 200 certificated K9 in the FEMA System, and evaluation sessions are schedule at the rate of ten per year

K9 Search Strategy

The search team manager, technical search specialist, and the canine search specialists (handlers) will survey the site and decide the best search strategy for the operation.

- They will factor in the time of day, the temperature, size of area to be searched, and the type of collapse.
- The site will usually be divided into small search sectors.
- The search team manager should sketch the general features of the structure/rubble area, labeling each search sector, and noting all significant information (land marks, etc) on the sketch for future reference

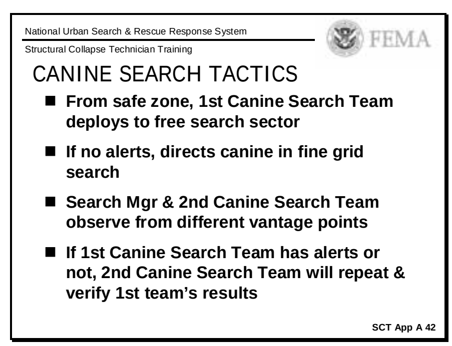




K9 Search Tactics

From a safe zone the handler will deploy canine #1 to free search the sector. If no alerts or areas of interest are indicated the handler will then direct the canine in a fine grid like search of the sector. While canine #1 is searching, canine #2 is nearby and resting. However, team two handler and possibly the team manager will be observing (spotting) canine #1 search. Each will watch from a different vantage point. These spotters provide the handler with very important information on how well the area has been covered, areas that need to be researched, and any subtle alerts on possible dead bodies, etc.

If canine #1 detects human scent and alerts, the handler will praise and reward the canine as they leave the area.



K9 Search Tactics (continued)

The area must be noted on the map and no flagging will be placed at this time. Canine #2 will be deployed into the general area of the alert. If the alert is confirmed by canine #2 it will be flagged and the search team manager will inform the task force leader of a find.

- If there are no finds, the canine teams will switch places after approximately 20-30 minutes of searching. Canine #2 will re-search the same sector. If possible, the handler will direct canine #2 to fine grid the sector in a different direction than canine #1 worked, such as north to south or east to west.
- When a search sector has been completely searched by both canines, the next sector will be started, and so on until the entire site has been searched. The canine team should continue to search around rescue operations that may be in progress, providing this doesn't endanger the rescuers.
- Scent channels around the solid slabs, large chunks of concrete, and canines will indicate where scent is emerging, not necessarily exactly where the victim is located.

Scent tends to raise /flow relatively evenly thru more broken rubble and lighter types of structures such as light frame, URM rubble with wood floor planes, and badly broken reinforced concrete and precast concrete buildings. Therefore, the canines will tend to indicate a more precise location of the scent source/victim in these lighter, more broken structures

- Continued re-searching of any structure, as it is penetrated by cutting and removal, is important in order to better locate the initial victim and provide information regarding additional victims.
- This is especially true for concrete structures with solid slabs, since the scent may be traveling back and forth across many solid layers/floor surfaces, and a true direction for victim location may not be indicated until the layers/floor level on which the victim rests is reached.

CANINE SEARCH TACTICS (continued)

- **Alert is marked only after confirmation by a 2nd team.**
- **Remaining sectors are searched & marked until entire are is covered.**
- **Scent channels around solid slabs, etc & canine will indicate where scent is emerging, not necessarily where victim is precisely located.**

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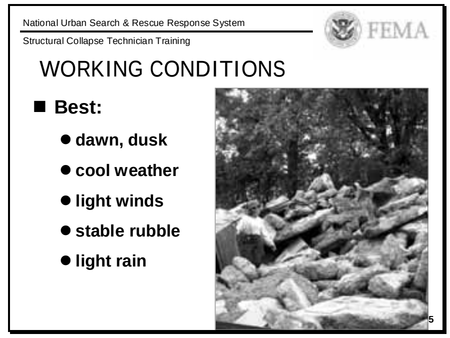
CANINE SEARCH TACTICS (continued)

- **Scent tends to raise evenly through broken rubble & lighter structures**
- **Continued re-searching of structure as it is accessed/uncovered will give best results**

SCT App A 44

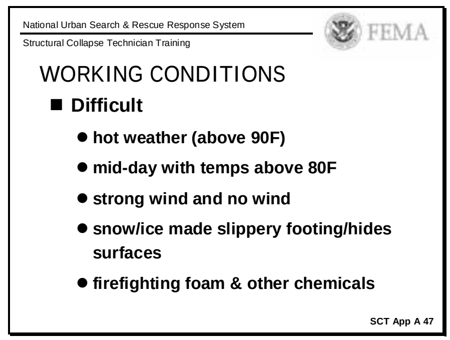
Best Working Conditions

- Dawn and dusk when scent is raising
- Cool weather, light winds (up to 20 MPH)
- Stable rubble that doesn't slide as canine traverses
- Light rain



Difficult Working Conditions

- Hot weather (above 90 degrees)
- Middle of day when temperatures are above 80 degrees
- Strong winds/no winds
- Snow makes surfaces more slippery/hides surface - safe footing unknown
- Fire fighting foam and other chemicals



Advantages in Canine Search

- Can search large areas in short period of time.
- Can traverse or gain access to voids and other opportunity sources.
- Can **Detect and Locate** unconscious victims

Disadvantages

- Short work period of 20-30 minutes, rest for 20-30 minutes, ready to work, etc.
- Need two canines to search same area, to check/confirm
- Performance may vary according to individual handler/canine capabilities.
- Scarce resource

Electronic Devices Working in Combo with Canine

Whenever possible dogs and electronic search should be employed together. Canines can and have successfully **Located** victims when Electronic **Detection** was first employed to sense structure borne sound/vibration.

- In Mexico City 1985 Quake, relatively crude seismic sensors were used in the quiet of late night to determine if live/conscious victims were present in pancaked, waffle slab structures. Canine teams were then deployed within the cavities of the building to pinpoint the **Location** of victims, leading to the successful rescue.
- With the more sensitive electronic detection currently available, a more efficient interaction between canine and seismic sensors should be initiated.
- For large, multi-story, pancaked concrete slab structures the electronic detectors could initially indicate, if conscious victims respond, even on which floor level they are trapped. Canine could then be more efficiently directed to search a specific floor area, even thru relatively thin voids
- During hot, day time hours, the electronic devices could be deployed to **Detect** numerous areas where victims are located . These area would then be searched at dusk by canine teams to confirm and pinpoint location.
- In buildings with unconscious victims or poor vibration transmission, characteristic of (badly broken structures of wood, brick, and even precast concrete), the initial search by canines may be the most effective.
- By contrast, in a large concrete and/or steel structures, Electronic **Detection** should be the most effective initial search tool.
- When both of these area search tools are available, they should be used to check/verify the finds of the other.

ELECTRONIC & CANINE SEARCH COMBINATION

- **Mexico City 1985 Quake had success using crude electronics with K9.**
- **Most common combo is to use electronics to Detect and K9 to Locate.**
- **In large pancake concrete collapse, electronic may be able to indicate which level contains victim, canine to pinpoint on that level.**

ELECTRONIC & CANINE SEARCH COMBINATION (continued)

- **During hot daytime canine do not work well & electronic may be able to direct canine to proper sector, etc.**
- **For badly broken structures, canine may be most effective for initial search.**
- **For structures w/large concrete slabs or steel structures, electronics may be most effective.**
- **If both search tools are available they should be used to confirm each other.**

Work Site Search Prioritization

Depending upon the situation, it may not be necessary to deploy a full search and recon team.

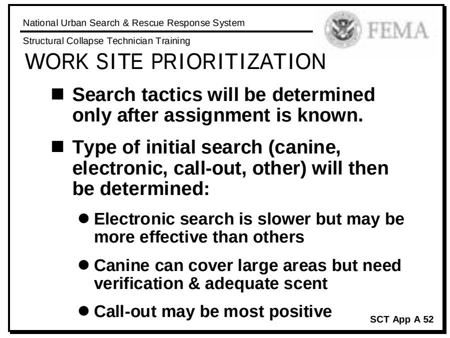
- Once a viable specific work area (i.e., group of buildings, single building, or separate section within a building) has been determined or assigned, the various search tactics should be determined.
- In many instances, the canine search can provide the most rapid assessment of a work site area.
- One search canine team can cover a significant area in short amount of time.
  - ♦ This capability is used, first to sweep an area for a general assessment of indications for victims.
  - ♦ The redundant check by the other canine is used to ensure the greatest degree of credibility.

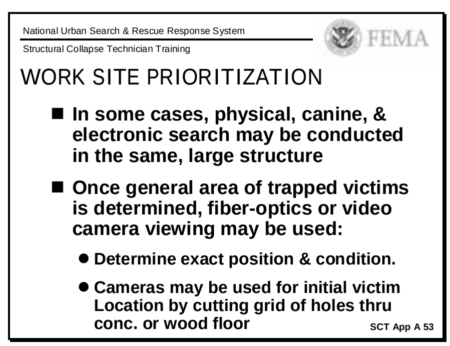
The electronic search capability may be used, prior to, in conjunction with the ongoing canine search, or afterward.

- The electronic search by it's nature will usually be slower and more time consuming.
- The specific selection of an electronic search site could result from the prior indications of the canine search teams or be based upon the types of construction/occupancies affected, as noted earlier.
- Once again, a redundant check by a second operator should be made after an initial find is identified and should also be marked if necessary

Prior to the location of any trapped victims, the task force rescue personnel present a significant search resource.

- They should be used to assist the canine and technical search personnel with safety assessments at collapse sites, gaining access to difficult areas, deploying equipment, etc.
- They also should conduct physical search operations, either separately, or in conjunction with the canine/electronic search operations.
  - ♦ Individual void inspections or combined listening operations can be conducted
  - ♦ Operations would be coordinated by the Rescue Team Manager and Rescue Squad Officers.

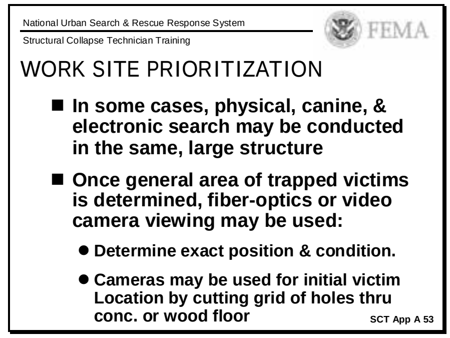




Work Site Search Prioritization (continued)

Once a reliable indication of the general location of a victim is made, the use of the fiberoptic viewing equipment (in conjunction with the concrete hammer/drills, if necessary) may prove useful in precisely determining the exact location and orientation of the victims.

- These tools may also prove to be the most effective method of performing a general sweep of a collapse area adjacent to an open, accessible area (such as basement or floor above a collapsed area).
- An array of inspections holes can be drilled and fiberoptic viewers can be inserted to make a general determination of the collapsed area.

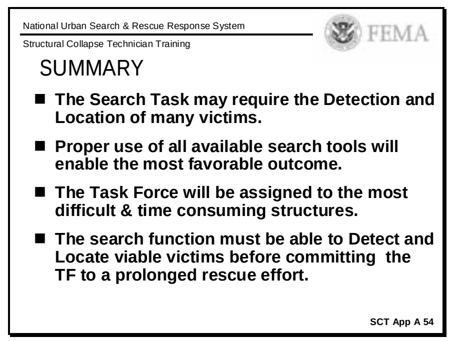


Summary

When the task force arrives at an area severely affected by an earthquake, they could possibly be faced with hundreds of persons trapped beneath the rubble.

The combined use of physical, canine and electronic search tactics will enable the task force to better establish priorities and focus emphasis on the most important rescue activities.

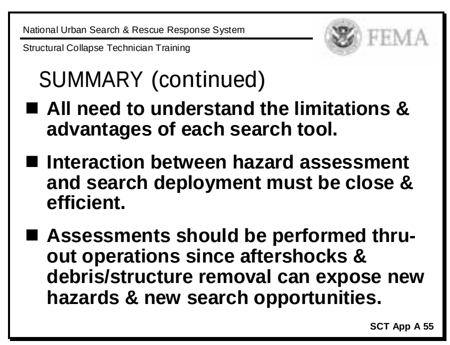
The task forces will be assigned the most difficult rescue situations. Depending on the complexity of the search and rescue activity, a great amount of time may be spent on each live extrication. The search function must locate viable victims before committing rescue resources to any prolonged operation



Accordingly, it is essential that all members of the task force understand the advantages and disadvantages of each search tool. The interdependence of the search and rescue function requires mutual respect and confidence, which can be best maintained by understanding that each has significant capability, and limitations.

There must be close interaction of the Assessment team with the search and rescue personnel during search operations. Assessments should include information regarding existing openings, probable victim location, in addition to hazard identification

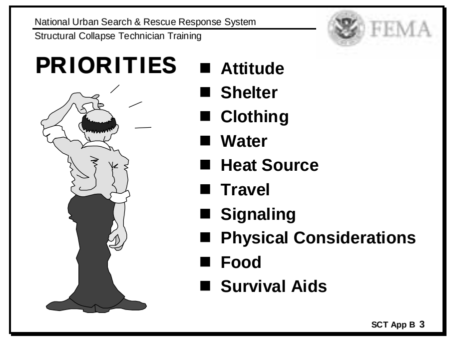
Recurring assessments should be performed throughout operations, since aftershocks and debris/structure removal can expose new hazards and new search opportunities



STUDENT MANUAL
STRUCTURAL COLLAPSE TECHNICIAN TRAINING
APPENDIX : B
SURVIVAL

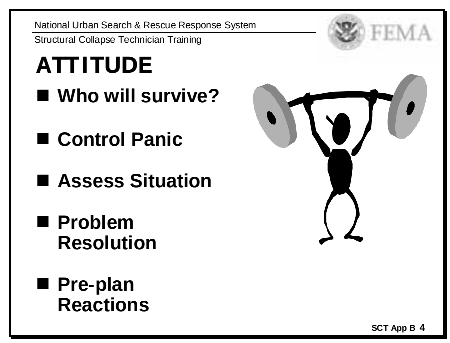
Unit Objective

The following is a guide to survival for a 24-48 hour period. If for any reason an individual or small group is isolated from your support system, this information may aid in their safe return. It is not comprehensive, nor is it intended to be. There are many books on the subject of survival for further study.



Survival priorities are listed in descending order with attitude topping the list.

ATTITUDE



- The will to survive and a positive attitude are the most important attributes in survival. The key is not to panic when confronted with separation or isolation. Keep calm, assess the situation, and do something, anything to positively affect your survival outcome.

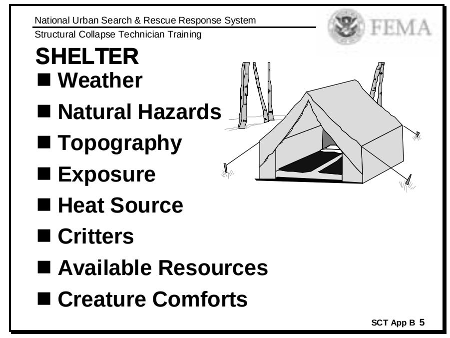
- Address only ONE survival problem at a time. If you were to look at everything at once, the task of surviving could seem overwhelming.

- Conserve strength, fluids, and heat. Prepare emergency signals, make shelter, inventory supplies, ration all food. Guard against infection and intestinal disorders. Do not travel in adverse weather; view the experience as a challenge.

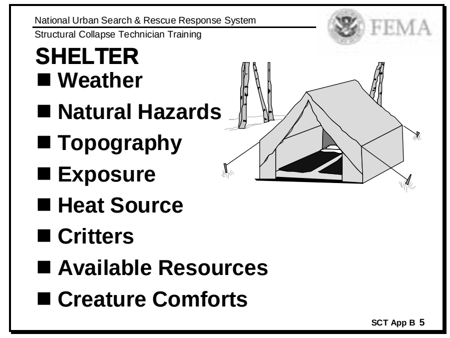
SHELTER

Shelter is the most critical necessity in a survival situation. You can live for days without water, weeks without food, but only a few hours exposed to a harsh environment. You can build a good shelter without the aid of knife, blanket, or anything but your bare hands almost anywhere on the continent.

- Protection from weather - Select a place away from wind, rain, snow, and glaring sun. Locate your shelter on the lee side of incoming weather systems.
- Protection from natural hazards - Keep an eye open for avalanche slopes, overhanging deal limbs, trees that might blow down in the wind, or rock formations that could collapse. Either break them down or select a new location.
- Dry, well drained area - Locate your shelter away from valleys, washes, troughs, and depressions.
- Open, southern exposure - Do not build in thick woods. Preferably build at the edge of a clearing with a southern exposure where the sun provides the longest lasting heat and light.
- Entryway facing east - Eastern exposure takes greater advantage of the warming rays of the sun.
- Fire safety - Locate your shelter away from cooking or signaling fire.
- Plant and animal hazards - Avoid everything from poison oak, to ant nests, to bear dens!
- Abundance of materials - pick an area with plenty of resources.
- Comfort - find an area free of sharp rocks or other debris.



SHELTER (continued)



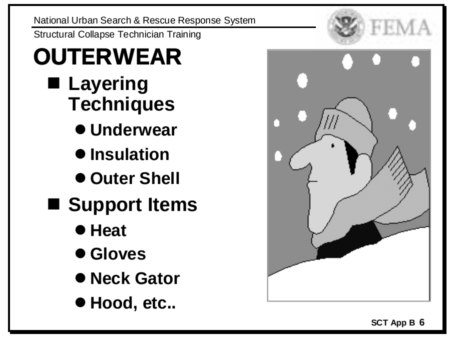
- Shelters are best built not too large. The main purpose of the shelter is to keep your body's internal fire burning with as little heat loss as possible. The smaller the shelter, the less energy it takes to keep it warm.

- Insulation between the ground and the body is essential for survival. Preventing heat from being conducted out of the body into the ground is important for anyone sitting or lying on the cold ground. Almost any light, dry, airy, soft debris laid out in a pile will do. Plastic sheeting can be used as a moisture barrier between the ground and the insulation.

- Any natural shelter will do to temporarily get you out of the weather. These are caves, rock outcroppings, or what ever you can squeeze into.

- The simplest shelter to build is the debris hut. Place one end of a large strong branch (ridgepole) on top of a tree stump, fallen log, or medium size rock. Prop other gathered branches along both sides of the ridgepole to create a wedge-shaped ribbing effect. The space created in-between should be large enough to accommodate your body, but steep enough to shed off moisture. Place finer sticks and brush crosswise to make a latticework that will keep junk from falling through the ribbing. Now heap on a pile of light, dry, airy, soft debris. To check thickness, work your arm through the debris to the ribbing. Debris should be to your armpit. In cold weather, add another foot or two of debris.

OUTERWEAR

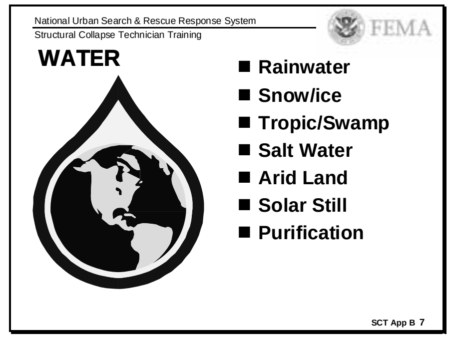


- Loose fitting clothing improves insulation, ventilation, and circulation. You can add insulation to clothing by stuffing them with dry grass or leaves. Sleeping in your clothes holds moisture and chills the body. You will not freeze to death in your sleep, the cold will awaken you.
- Layering the clothing is the best way to prepare for a variety of conditions. The three essential layers are underwear, insulation, and shell. Different combinations will enhance your comfort throughout changes in weather and exertion.
- The first layer is underwear. It should provide basic insulation and move moisture away from your skin, thus preventing chill when activity ceases.
- The second layer is insulation. These garments provide additional warmth. The weight of the material should be considered in relation to weather and activity.
- The third layer is the outer shell. This layer insulates against cold and protects against snow, wind, and rain. Shells can be wind and rain proof depending on need. Good fit is crucial. If you are wearing your shell in cold climates, allow room for your insulating clothing layers underneath. But if a parka is too big, heat loss can occur rapidly. Pay close attention to vents and closures, such as cuffs, hoods, and zippers. They should seal tight and open freely to allow you to adapt easily to changing conditions.
- Not all shells accomplish the same job. Coats made of Gore-Tex type material laminated to durable nylon are then treated for water repellency. The seams are sealed to make them waterproof. This type of shell is waterproof and allows your body to breath by wicking moisture away from your skin but retaining body heat.
- Remember to plan head to toe. Pants are just as important as a jacket for total warmth, and a hat is crucial for staying truly warm. Gloves, neck gaiters, balaclavas, hoods, and headbands further insulate you from the cold.

WATER

You can survive 10 days with no water at 50 degrees Fahrenheit. However, you need 3 to 4 pints a day to maintain good health. Most of this can come from food sources. There are a variety of additional sources where water can be found. In the desert at 120 degrees Fahrenheit in the shade, expected survival without water is only 1 to 2 days.

- Rainwater — Collect all you can. Set up plastic sheeting at an angle to catch rain and funnel to bottle, bucket, or cup. Spread out a blanket and wring out. Set out cups, buckets, anything to catch what ever you can. Look for standing water in depressions of rocks, etc. Water can be collected from dew in a similar fashion.
- Snow/Ice — Eating raw snow can cause dehydration. It takes 50% less fuel to melt ice. Ice is preferable to snow. Snow can be melted by holding it in your hand or packed in a can over the fire.
- Tropics/Swamp — Standing water is usually unfit to drink and the streams are too muddy. Dig a hole 1 to 6 feet from the shore, let the water filter in, strain and purify.
- Ocean — Salt water kills 1 to 2 days faster than no water at all from dehydration. At the beach, dig a hole below the high tide line and use the first water seeping in - deeper water is salty.
- Arid Lands — Avoid water holes where green vegetation doesn't grow. It is probably poison. Look for water where green vegetation does grow and low places in the outside bend of dry creeks (dig hole, wait 2 hours), base of cliffs, hills, mountains, canyon heads, rocky plates, and low places between dunes. All cactus in the world is safe. Mash the core to extract the liquid. Small barrel cactus and yucca are the best. PURIFY all arid land water.



WATER (Continued)

- Solar Still — Select an open, damp place. Dig a 3 foot deep hole. Place a cup or container capable of holding water in the center of the hole. Cover the hole with a 6 x 6 foot piece of plastic sheeting. Seal the edges of the plastic sheeting with rocks and dirt from the hole. Place a rock in the enter of the sheeting directly over the container. The sheeting should angle towards the container. Moisture from the ground is collected on the underside of the sheeting, runs toward the lowest point, and drops into the container. To help saturate the hole, add pieces of vegetation or urine. This method can collect about 1 quart in 2 hours. Make sure the container is large enough to collect all of the liquid. The water collected in this manner is safe to drink without any further purification.

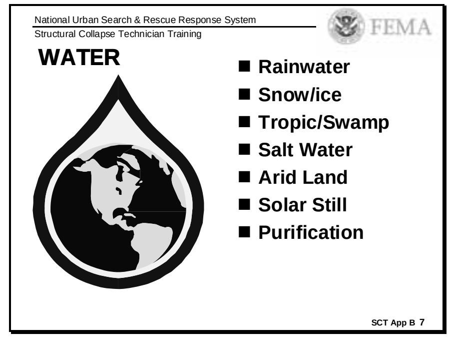
- Purification — According to the Federal Center for Disease Control and Prevention in Atlanta, no surface water in the world is guaranteed free of the microscopic cysts responsible for parasitic condition call giardiasis (Giardia). It is not fatal in healthy adults, but it is an unpleasant and debilitating illness. Another parasite, crystosporidium, similar to giardia is highly resistant to chlorine.

  - Symptoms of Giardia are a sudden onset of explosive diarrhea, nausea, vomiting, lack of appetite, headache, and a low grade fever. These occur 7 to 10 days after ingestion of the parasite

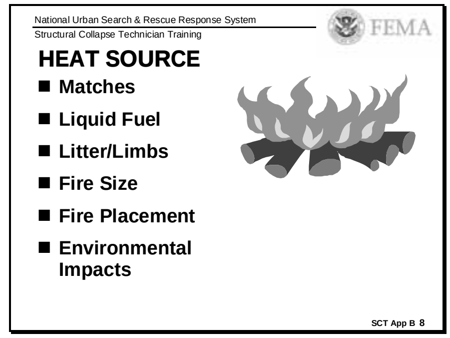
- Purification of collected water is a matter of your survival. Treat all back country surface water - streams, lakes, and waterfalls. Headwaters of streams are not even safe. Even treat municipal drinking water in developing countries.

  - Boil — 20 minutes and let stand for 30 minutes and strain. Boiling with charcoal helps remove the bad taste. It kills bacteria and cysts, but does not affect toxic chemicals or pesticides.

  - Filter — good filtration systems remove harmful bacteria, cocci, protozoa, cysts, fungi, and parasites. They are small, light weight, and effective

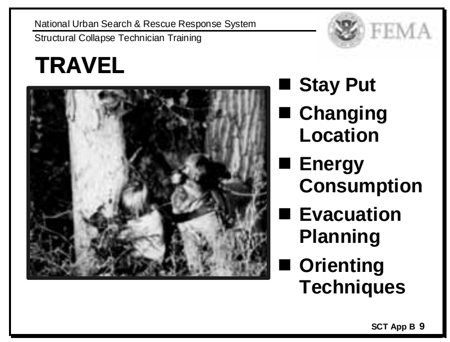


FIRE



- Build fires away from grass, trees, and overhead snow. Clear duff to bare mineral soil. Start with tinder - shaved, dry twigs, leaves, or needles. Once going, stack small fuels. As fire increases place larger fuels on top.
- Build a small fire, sit close. To keep warmer, sit between fire and a reflective surface (eg: large rock). Sleep with your feet toward fire.

TRAVEL



- Your best bet is to stay put. If you or your group is reported missing, the search will begin at your last known location.
  - Travel in the snow uses 5 to 10 times more energy than staying put.
  - Travel in the desert during the day rapidly dehydrates your body. In the desert, stay in the shade during the day and only travel at night when temperatures are lower.
  - Travel in the tropics only during the day.
- Follow ridge line trails and streams. But stay out of the streams, too many critters!
- Dense aerial canopy deadens sound, limits light, blocks radio waves, and renders signaling useless.
- Build shelters above ground.
- Straight line travel is best. Travel downhill along watershed may triple the distance. The use of a compass will aid in this endeavor.

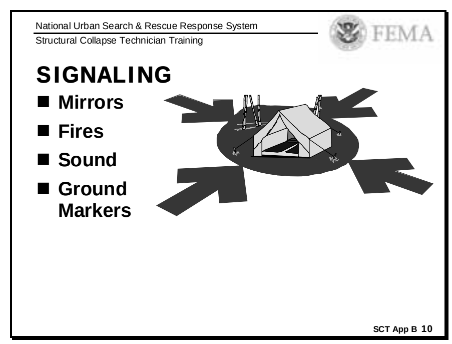
ORIENTING

- By Watch — Hold the watch level and point the hour hand at the sun. South is midway between the hour hand and the number twelve in the smallest angle. South of the equator, read with face down and the midline will point North.

- By Shadow — Put a long stick in the ground. Mark the tip of the shadow and mark the tip of the shadow an hour later. A line from the first point to the second points East.

- By Stars — Stars rise in the East and fall in the West. If a star is rising is on your right, you are facing North.

SIGNALING

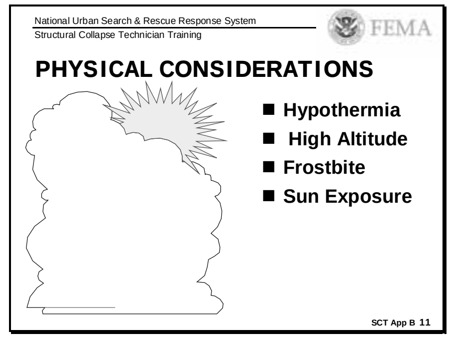


- Mirrors — Reflection is seen long distances. Signal even though you do not hear aircraft or vehicles, it may be spotted.

- Fires — In the daytime, make your fire very smoky. Use fuel oil, or wet fuels. In the nighttime, make your fire large and bright.

- Sound — Sound travels over great distance and further at night. Use whistles or other methods of making noise rather than yelling. Conserve as much energy as possible. Sound direction can be confusing as it seems to come from several directions when reflected off natural barriers.

PHYSICAL CONSIDERATIONS

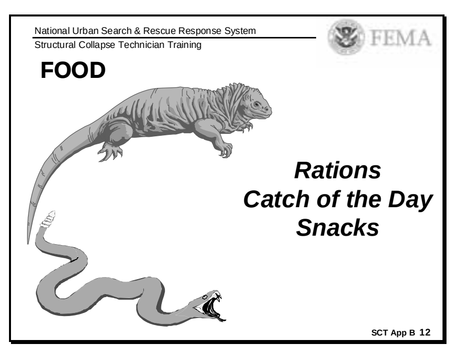


- HYPOTHERMIA — Individuals suffering from hypothermia will tend to lose consciousness. Awareness becomes clouded as body temperature approaches 90 degrees Fahrenheit and unconsciousness generally occurs at 86 degrees Fahrenheit. Pulse slows and becomes irregular. Skin is pale. Pupils are constricted and react poorly to light. Respiration is slow and labored. May appear intoxicated. Shivering becomes severe. Delay in treatment may cost a life.
  - Treatment consists of removing clothing, if wet, and replace with dry clothes. Warm rapidly, but do not burn or overheat. Victim should take nothing orally. Monitor respiration. Treat for shock. If available, administer intravenous fluids.

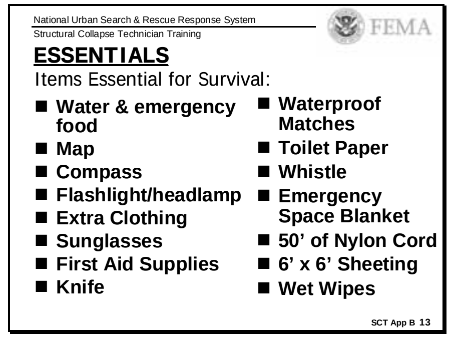
- HIGH ALTITUDE — The reduced amount of oxygen at high altitudes may have adverse effects on any pre-existing medical problems. Acute Mountain Sickness or AMS is a syndrome which can range from mild headache to incapacitating illness. Although it generally occurs when one sleeps at altitudes above 8,000 feet, it can develop some symptoms in some people at the 6,000 foot level. Symptoms are headache, nausea, insomnia, fatigue, lack of appetite, and light-headedness. Generally, symptoms

- DEHYDRATION — Dehydration occurs more frequently in areas where the humidity is very low. Dehydration depletes energy, causes headaches and affects performance. The rule of thumb is to drink enough fluid to cause urination at least every three hours. Take frequent water or fluid breaks during vigorous activities.

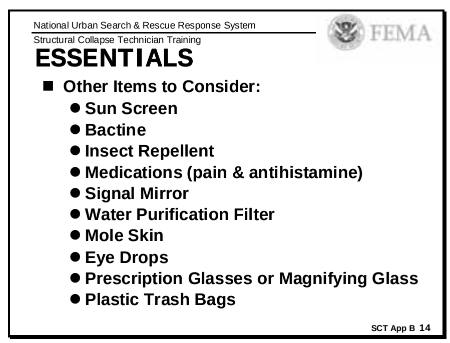
- OTHER — Avoid exposure to the cold resulting in frostbite and avoid exposure to the sun resulting in sunburn.
- FOOD — As this document provides some survival strategies for 24 to 48 hours, food should not be a factor. However, if your predicament lasts considerably longer, ALL healthy mammals, birds, fresh water fish, and insects are edible. Be sure to cook all flesh.



LIST OF ESSENTIALS

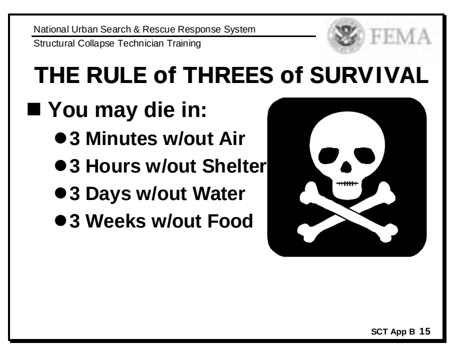


- Here are essentials to be carried in potential survival situations.
  - Water and emergency food
  - Map
  - Compass
  - Flashlight/headlamp with extra bulbs and batteries
  - Extra clothing (for season and location)
  - Sunglasses
  - First aid supplies
  - Knife
  - Waterproof matches or fire starter
  - Toilet paper
  - Whistle
  - Emergency space blanket
  - 50 ft. of nylon cord
  - 6' x 6' sheet of plastic
  - Wet wipes



- Other items to consider
  - Sun screen
  - Bactine
  - Insect repellent
  - Medications (pain and antihistamine)
  - Signal mirror
  - Water purification filter
  - Mole skin
  - Eye drops
  - Prescription glasses or magnifying glass
  - Plastic trash bags (large)

RULE OF 3'S IN SURVIVAL



- You may die in:
  - 3 minutes without AIR
  - 3 hours without SHELTER (hypothermia)
  - 3 day without WATER
  - 3 weeks without FOOD

STUDENT MANUAL

STRUCTURAL COLLAPSE TECHNICIAN TRAINING

APPENDIX C :

METAL BURN CUTTING OPERATIONS

Unit Objectives

The Student will understand the capabilities and limitations of all the types of burning equipment that can be used in US&R operations, and

Understand how to efficiently and safely cut and remove multiple pieces of steel from a debris pile

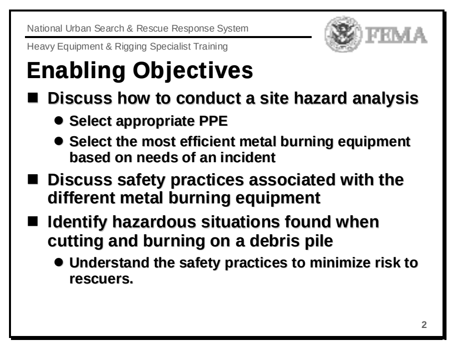
Acknowledgements

The majority of the information in this manual was provided by Robert Tooker, Captain, California Department of Forestry and CATF-3 Lead Metal Cutting Instructor, plus James Walker, Seattle Fire Department
Special Operations, WATF-1, Lead Metal Cutting Instr.

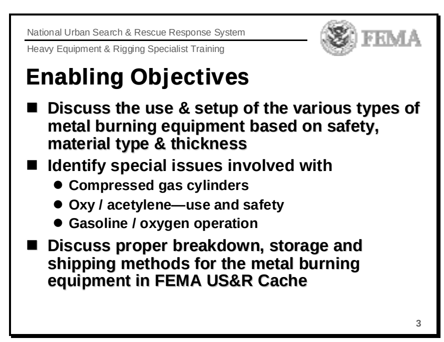
Enabling Objectives

We will:

- Discuss how to conduct a site hazard analysis
  - Select appropriate PPE
  - Select the most efficient metal burning equipment, based on needs of an incident
- Discuss safety practices associated with the different metal burning equipment
- Identify hazardous situations found when cutting and burning on a debris pile
  - Understand how to minimize risk to rescuers



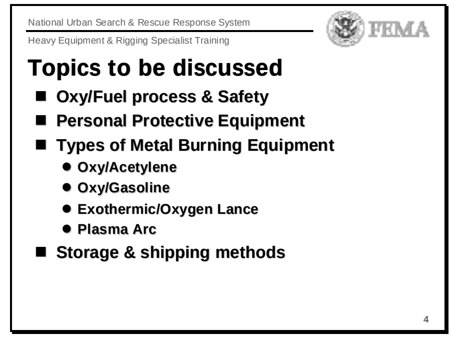
- Discuss the use & setup of the various types of metal burning equipment based on safety, material type & thickness
- Identify special issues involved with
  - Compressed gas cylinders
  - Oxy / acetylene—use and safety
  - Gasoline / oxygen operation
- Discuss proper breakdown, storage and shipping methods for the metal burning equipment in FEMA US&R Cache



I. Introduction & Topics to be discussed

We will discuss the following topics:

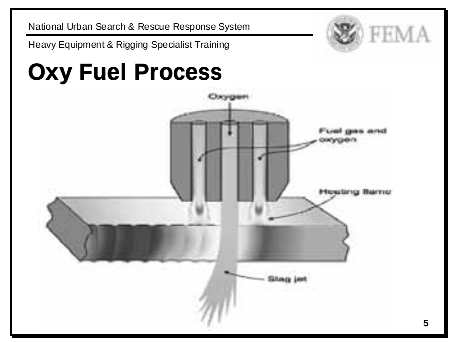
- Safety and the Oxy/Fuel Process
- Personal Protective Equipment that is required for metal cutting
- Types of Metal Cutting Equipment
  - Oxy/Acetylene
  - Oxy/Gasoline
  - Exothermic/Oxygen Lance
  - Plasma Arc
- Area Method for calculating the weight of steel objects of various shapes
- Storage and Shipping Methods



The Oxy/Fuel Process

Cutting with a torch is the process of burning metal with oxygen to effect separation. Wrought iron, steel, and cast iron are the metals cut by this process. Aluminum, brass, bronze, nickel, monel, and the other non-ferrous metals and alloys cannot at present be cut by the torch process

In oxyacetylene cutting of iron, steel, and cast iron, the metal is heated to the ignition temperature with preheating flames burning at the end of the tip. The preheating flames, usually four, are spaced around the cutting orifice in the center of the tip.



When the metal to be cut is heated to a bright red, the high-pressure oxygen jet is turned on, and the metal in the path is cut or burned away. Progressive movement of the torch results in cutting a narrow kerf similar to that made by a metal saw.

Acetylene is the most common fuel gas for the preheating flame, and oxygen is required both to burn the acetylene in the preheating flames and to effect cutting. However, the recently developed Petrogen System uses gasoline as the fuel gas, in combination with oxygen.

Both these cutting systems will be discussed in this manual

II. Safety

Metal burning operations require strict compliance to safety guidelines.

The two major causes of injury during burning operations are burns caused from hot materials or ultraviolet rays and injuries caused from breathing toxic materials and gases that can attack internal organs or the respiratory tract.

Full Personal Protective Equipment (PPE) must be worn at all times.

Respirators and air handling equipment should always be used in confined spaces or when material surface finishes such as paint or plating have been applied to metal.

Whenever possible, two-person teams should be assigned to burning assignments. One person should operate the burning equipment while a second person tends hoses and equipment. It is the second person's responsibility to look out for potential hazards and make sure the burner is aware of them.

Always pay strict attention to where the burn cutting is directed. (into or through) Flammable or explosive material or victims may be on the other side.

Always inspect cutting and burning equipment for leaks and proper setup before use.

Re-hydrate often. Because of the heavy protective clothing and the heat generated from the equipment and hot material, burning operations can be very hot work.

A pressurized or hand pump water extinguisher shall be on site at all times.

In order to minimize chance for injury, it is imperative to deploy a Safety Person that will have no other responsibility than the area where metal burn cutting is taking place.

This individual should watch for fires, and other hazards that may be created, and be aware of any other equipment that may be working in the area

The Metal Burning Team should be a minimum of Two persons, so that there is a second pair of eyes that are focused on the immediately surrounding area. The second person would observe the progress of the cut, and anticipate when and where to cut piece or pieces will fall

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General Safety Guidelines

- **Metal burning requires strict compliance with all manufacturer's safety guidelines**
- **Biggest causes of injury**
  - **Burns from hot material or ultraviolet rays**
  - **Breathing toxic materials**
- **Wear full PPE at ALL TIMES**
  - **Wear UV rated eye protection**
  - **Use proper respiratory protection**
- **Work in 2 person teams**

5

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General Safety Guidelines (contin.)

- **Inspect all equipment prior to use for damage and leaks**
- **Have a fire extinguisher or small hose line available for spot fires**
- **Hydrate often**
- **Consider the reaction of your actions before and while cutting a piece of steel or cable**

6

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Safety During Operations

- **Have a safety person watch the area for fire and other hazards**
  - **Be aware of heavy equipment and other people working above and below**
- **Two Person Team**
  - **The tender is the burner's second set of eyes because the person burning is focused on the progress of the cut**

7

Use of Proper PPE

In addition to “normal” US&R PPE, the metal cutting personnel must wear additional protection. This may vary, depending on what type of metal is being cut, but in most all cases one should be protected from the metal burning process. (listed in adjacent slide)

Coatings such as paint and galvanizing can create harmful gasses from which one needs protection.

Proper PPE

- Tinted eye protection
- Respirator (organic vapor)
  - Consider PAPR
- Helmet
- Leather gauntlet gloves
- Long sleeves
- Leather or heavy fire resistive jacket and chaps if needed

Level of protection will depend on Situation and type of Metal to be cut

Personal Accessory Equipment

Metal burn cutting requires specialty equipment and a tool belt to carry them.

Most of this equipment is listed on the adjacent slide

Extinguishing and ventilation equipment may be provided for an entire area of cutting operations, but should be immediately available for all that are involved .

Personal Equipment

- Crescent wrench
- Striker/spare flint
- Tool belt, Tape Measure & Soapstone
- Spare Tips & Tip cleaners
- Marking paint
- Side cutter pliers
- Water extinguisher
- Exhaust and ventilation equipment if needed

Special Cautions involved with Metal Burning

Do not operate welding or cutting equipment in the vicinity of chlorinated solvents or hydrocarbons.

The heat or arc rays can react with the chlorinated hydrocarbons to form phosgene or hydrogen chloride, which are highly toxic irritant gases.

CAUTION! Using Painted or Plated Metals

- Always inspect metal for protective surface finishes such as paint or plating before cutting.
- Metals that have been painted may contain lead or cadmium.
- Metals that have been plated may contain zinc (galvanize) or cadmium.
- Stainless steel contains nickel and chromium.
- Welding, cutting, and heating operations that involve or generate any of the substances listed at the right, require proper respiratory protection.

CAUTION!

- Using chlorinated solvents
- Using painted or plated metals
- Wear respiratory protection

Arsenic	Beryllium
Chromium	Cobalt
Copper	Lead
Manganese	Mercury
Nickel	Ozone
Selenium	Silver
Vanadium	Zinc

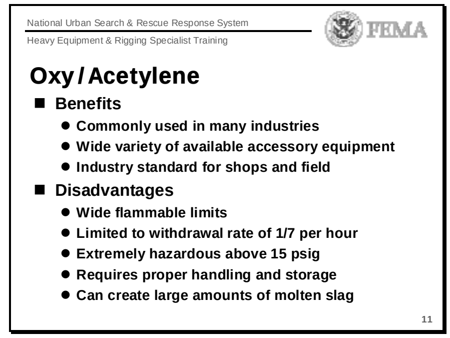
Internet Safety Articles

www.cdc.gov/elcosh/docs/hazard/chemical_metals.html

www.cdc.gov/elcosh/docs/hazard/chemical_welding.html

www.ccohs.ca/oshanswers/safety_haz/welding/fumes.html

III. Oxygen/Acetylene Burning Equipment



Oxygen/acetylene has been the most widely used metal burning technology in the industry for many years. It is very versatile and can be used for brazing, welding, and cutting carbon steel.

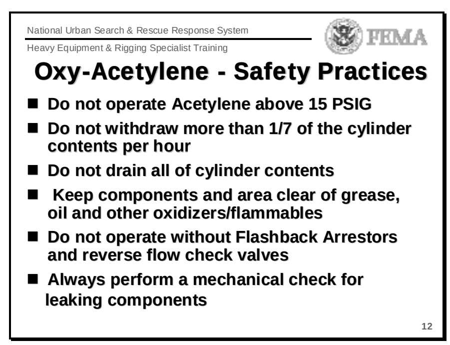
Benefits: There are a wide range of torches, accessories, and gasses available from most welding and gas suppliers.

- It is the industry standard used by most fabrication shops and at most construction or demolition sites.
- It can be used to weld items, unlike other systems that can only be used to cut.

Disadvantages: Acetylene has one of the widest flammable limits of any fuel gas (2.5 percent to 81 percent) and is extremely hazardous at pressures exceeding 15 psig.

- Acetylene gas requirements for proper handling, use, and storage must be followed at all times.
- The oxy/acetylene burning operation can create large amounts of molten slag when cutting thick steel.
  - ♦ This slag can fuse back into the cuts and cause problems for the burner if clean cuts are not made.
  - ♦ Slag will also ignite spot fires and can be a hazard to the burner.

Oxy/Acetylene Safety Practices



There are many safety practices to be followed, when using oxy/acetylene.

As listed on the adjacent slide, one must limit the pressure, limit the withdrawal rate, limit contaminants, use flashback arrestors and reverse flow valves, and perform checks for leaking components.

We will now discuss each of the components in this system

Acetylene Fuel Gas Cylinders

Acetylene cylinders are considered to below pressure, 200 to 250 psi.

Acetylene is a compound of carbon and hydrogen (C2H2). It is produced when calcium carbide is submerged in water or from petrochemical processes.

Acetylene becomes unstable when compressed in its gaseous state above 15 psig.

Acetylene gas requires a special cylinder; it has a porous core that is saturated with liquid acetone.

- Acetylene gas is pumped into the cylinder and is absorbed by the acetone, which keeps the gas stable while under pressure.

Acetylene cylinders must always be stored and used in an upright position to keep the liquid acetone properly contained.

The maximum safe delivery pressure for acetylene is 15 psig. **Never exceed regulated pressures above 15 psig or the acetylene gas will become very unstable.**

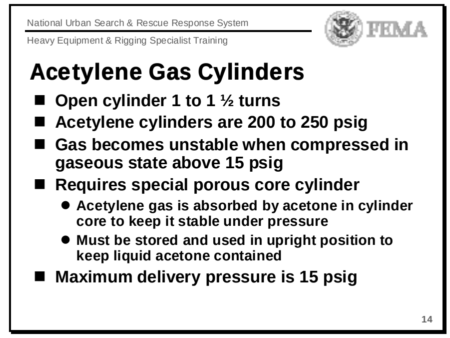
Only 1/7th of the total capacity of an acetylene cylinder should be withdrawn per hour, this is controlled by the tip size being used and regulated fuel gas pressure.

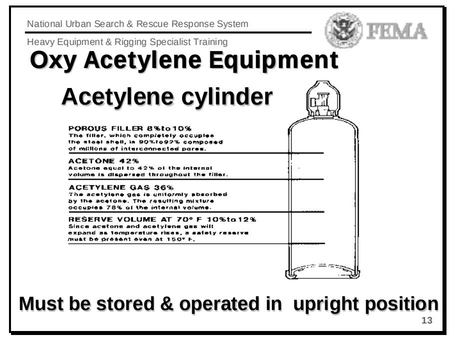
- If more than 1/7th of the total capacity is withdrawn from the cylinder, it may also withdraw the liquid acetone.

When not in use or being transported in a vehicle, acetylene cylinders must be capped and secured.

Most cylinders are equipped with pressure relief devices to prevent rupture of a normally pressurized cylinder when it is inadvertently exposed to fire or high temperatures.

- Never completely drain all of the gas out of the cylinder.
- Always change out your cylinders before they are completely empty, leaving some measurable amount of gas product in the cylinder.
- If you completely drain the cylinder, you may run the risk of contaminating the cylinder with mixed gases.





Example :
An acetylene cylinder with a total volume of 300 cubic ft may only be withdrawn at a rate of about 42 cubic ft per hour to not withdraw the acetone.

Acetylene Fuel Gas Cylinders (continued)

- Completely draining the cylinder may allow gas to travel down through the hose into the mixing chamber of the torch and then back down through the other hose into the empty cylinder, thereby contaminating it.
- If this goes unnoticed by the welding gas supplier, the next time the tank is filled, the cylinder will contain mixed gases that may be explosive.

Friction generated during filling or opening the high-pressure cylinder may cause the cylinder to explode. This is the reason for using one-way check valves and flashback arrestors on the regulators and torch.

Compressed Gas Oxygen Cylinders

Compressed gas oxygen cylinders are considered high pressure since they are rated at 2,250 psi.

They must be secured at all times; by law, they must be capped while being transported in a motor vehicle, or when not in use.

Grease and oil must never come in contact with any component of an oxygen system, cylinder, regulator, hose, or torch. They can combust and burn violently in the presence of pure oxygen.

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Compressed Gas Oxygen Cylinders

- High pressure—rated at 2,250 psi
- Must be secured at all times
  - By law must be capped to transport in motor vehicle or not in use
- Grease and oil must not come in contact with component of oxygen system
  - They can combust and burn violently in presence of pure oxygen

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Liquid Oxygen Tanks (DEWARS)

Dewars are large cryogenic tanks.

For large jobs, these liquid oxygen tanks (called Dewars) will be used instead of compressed gas oxygen cylinders.

- One GP45 Dewar holds 4,500 cubic feet of product, and One k-size compressed gas cylinder holds 249 cubic feet of product.

A manifold can be attached to the Dewar that will supply oxygen to many torch sets.

- Attachment of the manifold can save a lot of time and energy that would be wasted moving and changing out compressed gas cylinders.
- Dewars must be secured and handled with caution; they are heavy, and if knocked over, can be damaged.

The adjacent slide shows a large, compressed oxygen trailer that was used at the World Trade Center incident

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Alternate Oxygen Sources (Liquid Oxygen - Dewars)

- GP45 Dewars can evaporate 4500 Cu. Ft. of gas from a liquid contained in cylinder
  - External evaporator may be needed
  - Must be kept in an upright position
- The Green, K-Stile compressed gas cylinder holds about 250 cu ft of oxygen
- Both these tanks must be secured and handled with caution

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Compressed Oxygen Trailer

- Used when a large Demand is needed
- A tube style Trailer Cannot be easily moved around a site
- May not be readily available

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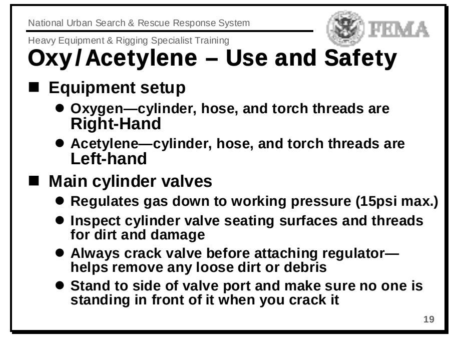
Oxy/Acetylene—Use and Safety

Equipment Set Up

- Oxygen/cylinder, hose, and torch threads are right hand.
- Acetylene/cylinder, hose, and torch threads are left hand.

Main Cylinder Valves

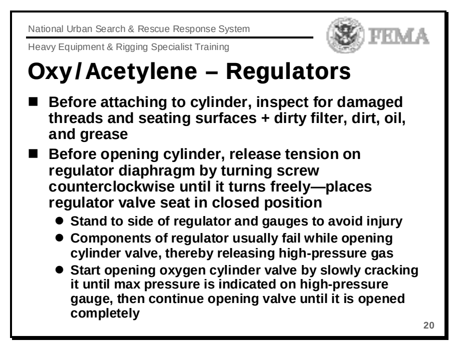
- Inspect the cylinder valve seating surfaces and threads for dirt or damage.
- If you notice the presence of oil or grease on the oxygen cylinder valve, do not use the cylinder; inform your gas supplier immediately.
- Always crack the valve before attaching a regulator; doing so helps remove any loose dirt or debris that might be in the valve.
    - ♦ Always stand to the side of the valve port and make sure nobody else is standing directly in front of the valve port when you crack it.



Regulators

The purpose of the regulator is to reduce the high pressure within the cylinder to a usable working pressure.

- Before attaching the regulator to the cylinder, inspect it for damaged threads, seating surfaces, dirty filter, or the presence of dirt, oil, or grease.
    - ♦ Regulators are attached to the cylinder or manifold by their inlet connections.
    - ♦ All inlet connections conform to specifications and standards set by the Compressed Gas Association (CGA) and are marked with an identifying CGA number.



- Before opening the cylinder, release the tension on the regulator diaphragm by turning the pressure adjustment screw counter clockwise until it turns freely. This places the valve seat of the regulator in a closed position.
  - ♦ When opening the tank cylinder valve, always stand to the side of the regulator and gauges to avoid injury.
  - ♦ If a gauge or other components of the regulator should malfunction or fail, they will usually do so while opening the cylinder valve and thereby release the high-pressure gas.

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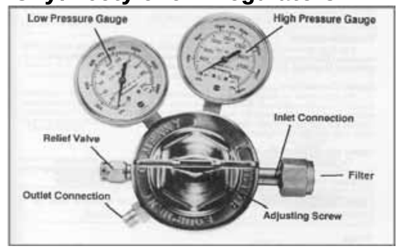
Oxy / Acetylene – Regulators



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Start opening the oxygen cylinder valve by slowly cracking it until maximum pressure is indicated on the high-pressure gauge, then continue opening the valve until it is opened completely.

Fuel Gas Cylinder Valves

- Do the same procedure with the **fuel gas cylinder valve**, but only open the cylinder valve a maximum of 1 to 1 1/2 turns.
  - ♦ Some acetylene cylinders use a regular hand wheel knob to open the cylinder and others use a special removable wrench or key.
  - ♦ If a removable wrench or key is used to open the valve, leave it attached to the cylinder valve so the fuel gas can be shut off quickly in the case of fire or other problems with the system.

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Oxy / Acetylene – Fuel Gas Cylinder Valves

- **Use similar to prior procedure to open fuel gas cylinder valve except only open cylinder valve 1 to 1½ turns**
- **Some acetylene cylinders use hand wheel knob to open; others use special, removable wrench or key**
- **If removable wrench or key is used to open valve, leave it attached to valve for quick shut off**

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Check Valves

- Check valves permit the gas to flow in only one direction—from the regulator to the torch.

Quick Connections

- Quick connections can be installed on regulators, hoses, and torches.
- They make setup plus extending and/or changing equipment more efficient.
- Each quick connect has a check valve built into it.

Flashback Arrestors

- Flashback arrestors are designed to prevent the flame from flashing into the hose and regulators.

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Oxy / Acetylene – Connection Parts

- **Check valves**
  - **Permits gas to flow in only one direction—from regulator to torch**
- **Quick connectors**
  - **Can be installed on regulators, hoses, and torch**
  - **Make extending or changing equipment more efficient**
  - **Quick connectors have check valve built-in**
- **Flashback arrestors**
  - **Designed to stop flame from flashing into hose and regulators**

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Hoses

Make sure the hoses are rated for the fuel gas being used and that they are large enough to deliver the required volume for the tip size that has been selected.

- Welding hoses are often exposed to severe abuse and must be inspected for cracks, crushed areas, burns, cuts, and other damage.
- They must be kept clean and free of oil or grease and should be repaired or replaced if found to be damaged.
- The hoses are color-coded and threaded differently:
  - ♦ (Oxygen—green with right-hand threads),
  - ♦ (Fuel gas—red with left-hand threads),
  - ♦ The fuel gas hose nuts also have a V groove on the outside to indicate left-hand threads.
- Purge both hoses at about 3 psi to clear any foreign objects before attaching torch.

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Oxy/Acetylene – Hoses

- Hoses are color-coded and threaded differently
  - Oxygen is green with Right-Hand threads
  - Fuel gas is red with Left-Hand threads
  - Fuel gas hose nuts have a V-Groove on outside to indicate Left-Hand threads
- Make sure rated for gas being used and tip size
- Hoses often exposed to abuse and must be inspected for cracks, burns, etc.
- Keep clean and free from oil or grease
- Purge both hoses at about 3 psi to clear any foreign objects before attaching torch

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Torches

- Torches come in a variety of brands, models, and sizes.
  - ♦ There are 1-piece and universal 2-piece styles.
- Long torches work well when the burner needs extended reach or is burning thick steel with a large size tip and needs extra distance from the heat.
- Long torches can be very awkward and heavy, which cause additional fatigue to the operator.
- Short torches are lighter and more maneuverable, especially in confined spaces.
- Remember, the size of the tip determines the thickness of the steel that can be burned, not the size of the torch.
- Some newer style torches have anti-reverse-flow check valves built into the main torch body; as such, additional accessory check valves may not be necessary.
  - ♦ The valves are marked OC or FC with an arrow to indicate the direction of flow.
  - ♦ If you are using an older style torch or a brand not having one-way check valves, you should install them.

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Oxy/Acetylene - Torches

- Many models and sizes
- Long ones work well for extended reach and when cutting thick steel
  - May be awkward and cause operator fatigue
  - Size of tip determines thickness that may be cut
- Some newer torches have anti-reverse flow check valves built-in to main torch body
  - Marked OC or FC with arrow to indicate flow direction

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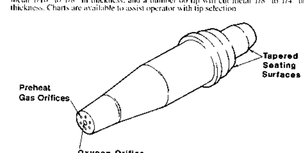
Cutting Tip

Cutting tips are available in a wide variety of configurations and sizes. Cutting tips keep the preheat gas mixture and cutting oxygen stream separated and provide flame characteristics needed for a particular cutting application. Tips are sized according to the thickness of metal they can cut. For instance, a number 000 tip is designed to cut metal 1/16" to 1/8" in thickness, and a number 00 tip will cut metal 1/8" to 1/4" in thickness. Charts are available to assist operator with tip selection



⚠CAUTION Always make sure your equipment is rated for the size tip you have selected. A tip with too much capacity for the equipment can starve or choke the tip. This causes overheating of the head and a flashback may result. Use only genuine VICTOR tips, welding nozzles and multi-flame nozzles to ensure leak-free connections and balanced equipment.

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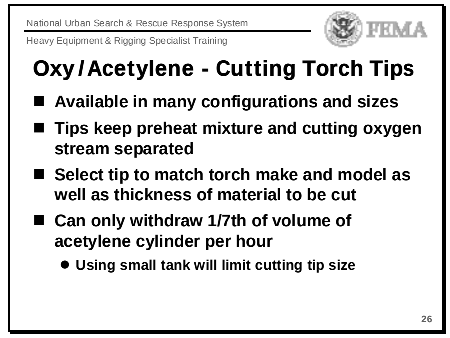
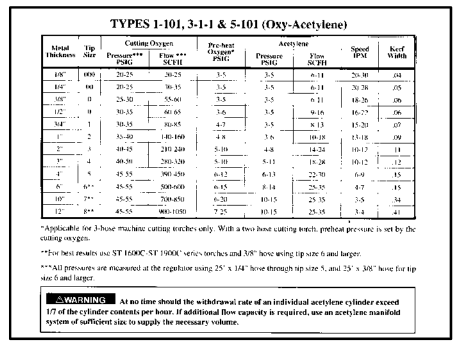
Cutting Torch Tips

- Cutting tips are available in a wide variety of configurations and sizes.
- Cutting tips keep the preheat gas mixture and cutting oxygen stream separated and provide flame characteristics needed for a particular cutting application.
- Select the proper size torch tip to match the make and model torch you are using and the thickness of the material you will be burning.



Selection of the proper size tip can be aided by using a tip chart.

- Remember, you can only withdraw 1/7th of the total volume of an acetylene cylinder per hour.
- If you are using a small acetylene cylinder, the size of the tank will dictate or limit the cutting tip size that can be used.



TYPES 1-101, 3-1-1 & 5-101 (Oxy-Acetylene)

Metal Thickness	Tip Size	Cutting Oxygen Pressure*** PSIG	Cutting Oxygen Flow *** SCFH	Pre-heat Oxygen* PSIG	Acetylene Pressure PSIG	Acetylene Flow SCFH	Speed IPM	Kerf Width
1/8"	000	20-25	20-25	3-5	3-5	6-11	20-30	.04
1/4"	00	20-25	30-35	3-5	3-5	6-11	20-28	.05
3/8"	0	25-30	55-60	3-5	3-5	6-11	18-26	.06
1/2"	0	30-35	60-65	3-6	3-5	9-16	16-22	.06
3/4"	1	30-35	80-85	4-7	3-5	8-13	15-20	.07
1"	2	35-40	140-160	4-8	3-6	10-18	13-18	.09
2"	3	40-45	210-240	5-10	4-8	14-24	10-12	.11
3"	4	40-50	280-320	5-10	5-11	18-28	10-12	.12
4"	5	45-55	390-450	6-12	6-13	22-30	6-9	.15
6"	6**	45-55	500-600	6-15	8-14	25-35	4-7	.15
10"	7**	45-55	700-850	6-20	10-15	25-35	3-5	.34
12"	8**	45-55	900-1050	7-25	10-15	25-35	3-4	.41

*Applicable for 3-hose machine cutting torches only. With a two hose cutting torch, preheat pressure is set by the cutting oxygen.

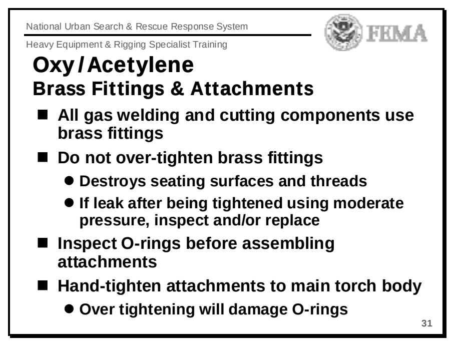
**For best results use ST 1600C-ST 1900C series torches and 3/8" hose using tip size 6 and larger.

***All pressures are measured at the regulator using 25' x 1/4" hose through tip size 5, and 25' x 3/8" hose for tip size 6 and larger.

⚠WARNING At no time should the withdrawal rate of an individual acetylene cylinder exceed 1/7 of the cylinder contents per hour. If additional flow capacity is required, use an acetylene manifold system of sufficient size to supply the necessary volume.

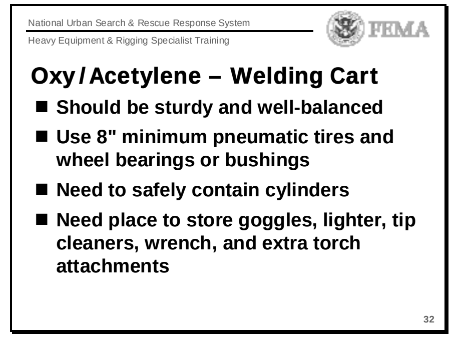
Brass Fittings and Attachments

- All gas-welding components use **<u>brass</u>** compression type fittings.
- When assembling welding components, remember not to over tighten them, or you will destroy the brass seating surfaces and threads.
  - ♦ You should only have to tighten them snugly with a short wrench.
  - ♦ If they leak after being tightened with moderate pressure, check for damage or defects and repair or replace.
- Always inspect O-rings before assembling welding and cutting attachments (welding tips, cutting attachment and/or heating attachment, multi-flame or rose bud).
  - ♦ If damaged O-Rings are found, do not use the torch until they are replaced.
- When mating attachments to the main torch body, only tighten them hand tight.
  - ♦ Over tightening with a wrench will only damage the O-rings and cause them to fail.



Welding Cart

- The welding cart should be of sturdy construction and be well balanced.
- Pneumatic rubber tires 8” tall or larger with bearings or bushings should be used to ensure ease of movement on broken or uneven ground.
    - ♦ Small hard rubber or steel wheels will stop or bind when used on rough or rocky surfaces.
- The cart should be of the proper size to accommodate and contain cylinders safely.
- There should also be a place to store safety goggles, spark lighter, tip cleaners, a wrench, and extra torch attachments

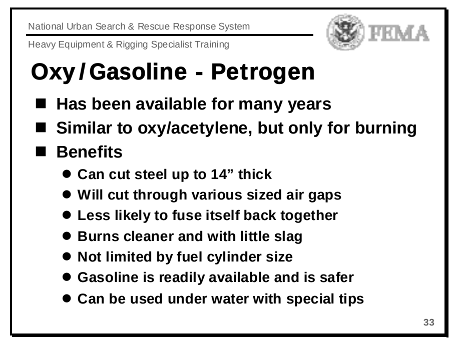


IV. Oxygen/Gasoline - Petrogen

The Petrogen gasoline/oxygen system operates somewhat differently from its oxy/acetylene cousin that most torch operators are accustomed to.

- It uses all of the same oxygen components and safety guidelines.
- The torch looks and operates in much the same way on the outside but is totally different on the inside.
- The gasoline stays liquid throughout the system until it reaches the cutting tip where it is heated and turned into a vapor in much the same way a Coleman stove or lantern does.

Petrogen system has many advantages as listed on the adjacent slide

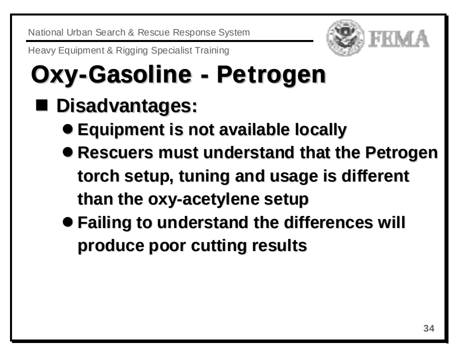


Petrogen Disadvantages

As previously mentioned Oxy/Acetylene is used by many industries, including construction.

Petrogen’s use is limited to cutting metal, and may not be available in many locations where disasters may occur.

The Petrogen Torches may look very similar to ones using Oxyacetylene, but all must remember that they operate differently

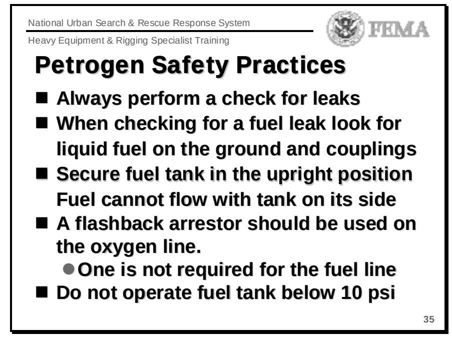


Petrogen Safety Practices

As with all burn cutting, the use of Petrogen equipment entails significant and special risks.

Fuel leaks are critical

- Perform leak checks after assembly and prior to lighting
- Look for liquid fuel on the ground and at couplings
- Secure fuel tank in the upright position, since the fuel cannot flow with tank on its side
- A flashback arrestor should be used on the oxygen line, but one is not required for the fuel line



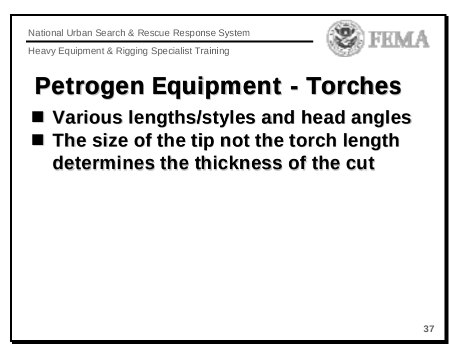
The 2.5-gallon ASTM certified Petrogen fuel tank is equivalent to a 250-cubic foot acetylene tank.

- It has a fast-flow check valve located inside the tank shut-off valve that is designed to shut off the fuel in the event that the fuel hose is ever cut or severed.
- For the fast-flow check valve to operate properly, the pressure in the gasoline fuel tank should never be allowed to drop below 10 psig.
- The tank shutoff valve should be opened slowly when setting up the torch for operation so that the fast-flow check valve will not engage and shut off the fuel.
- The tank pressure should normally be between 10 to 20 psig during normal operations when using the hand pump.
- Higher pressures may be used when using the optional compressed air carry tank.

Petrogen Torches

Torches cone in various configurations

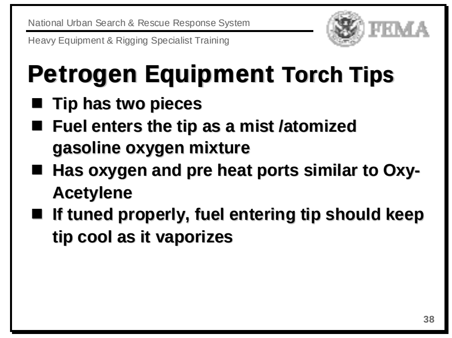
- Torches are available in 14”, 20”, 27” 36,” and 48” lengths.
- Available head angles are 75, 90 and, 180 degrees.
- The size of the tip, and not the torch length determines the thickness of the cut



Petrogen Torch Tips

The tip is a 2-piece assembly, with an inner brass core and an outer copper shell. The liquid fuel is vaporized, directed down to the base of the core, and then re-directed out the tip through the flutes of the core.

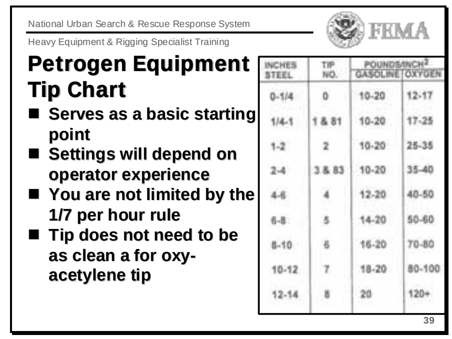
- As gasoline changes from liquid to vapor, its volume increases almost 200 times. This rapid expansion provides a large force to the pre-heat flame.
- Because gasoline vaporizes inside the tip, and evaporation is a cooling process, the tip runs cool.



Petrogen Tip Chart

The chart shows the cutting range of each tip, and suggests gasoline and oxygen pressures.

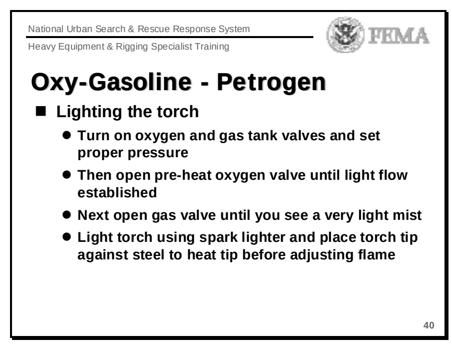
- The range of each tip is extended by higher pressures, but the quality may be reduced.
- The best combination of tip and pressures depends on operator technique, type and size of steel, desired cutting speed, and quality of cut



INCHES STEEL	TIP NO.	POUNDS/INCH² GASOLINE	OXYGEN
0-1/4	0	10-20	12-17
1/4-1	1 & 81	10-20	17-25
1-2	2	10-20	25-35
2-4	3 & 83	10-20	35-40
4-6	4	12-20	40-50
6-8	5	14-20	50-60
8-10	6	16-20	70-80
10-12	7	18-20	80-100
12-14	8	20	120+

Lighting the Torch

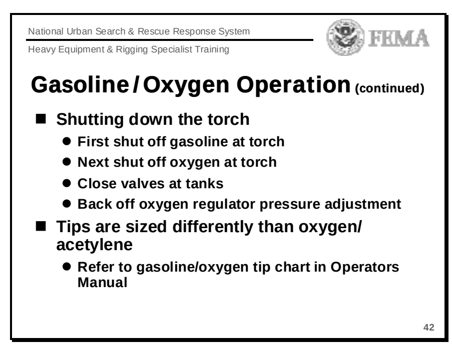
- Lighting the torch is done by first turning on the oxygen and the gasoline tank valves and setting the proper pressures.
- Open the pre-heat oxygen valve at the torch until a light flow is established.
- Next, open the gasoline valve until you see a very light mist.
- Using a spark lighter, light the torch and adjust the flame.
- Place the torch tip against the steel to heat the tip. Then re-adjust and you are ready to burn.



To Shut Down the Torch

- First, shut off the gasoline, then the oxygen at the torch.
- Close the valves at the tanks and back off the oxygen regulator pressure adjustment.
- The tips are sized a little differently from oxy/acetylene tips.

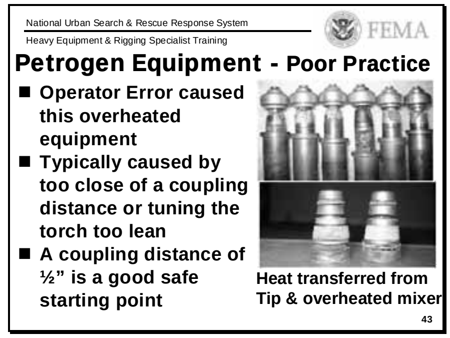
Refer to the gasoline/oxygen tip chart that is posted on the side of the fuel tank or in the operators manual



Petrogen – Poor Practice

The adjacent slide shows the damage to torch tips that can be caused by operator error.

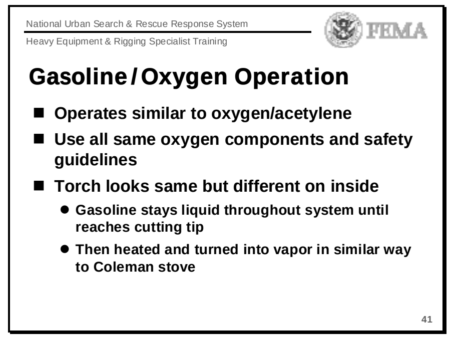
- This type of damage is usually caused by having the coupling distance too short, or
- By turning the torch too lean
- One should start with a coupling distance of ½"



Petrogen Operation

To summarize, Petrogen operates very similar to Oxy/Acetylene.

- One needs to use the same oxygen components and guidelines
- The torches look the same but they are different inside.
- The gasoline stays in liquid for until it reaches the cutting tip. Liquid gasoline is NOT flammable



V. Other Metal Burning Tools

Exothermic

The exothermic technology came to us from the U.S. Navy. They designed this equipment for burning through bulkheads in submarines.

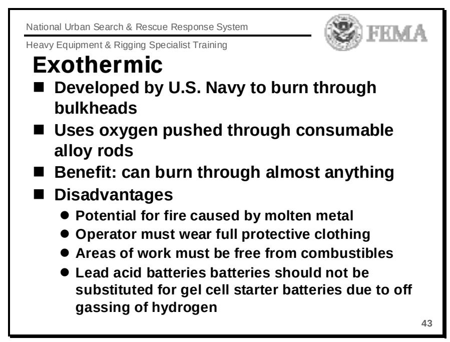
This technology uses oxygen pushed through consumable alloy rods, which burn at a very high temperature.

The arc is started by shorting out the consumable rod, which is attached to a gel-cell battery and to a grounding plate (or by using a burning punk).

Benefits: This system can burn through almost anything, including:

- Ferrous and nonferrous metals,
- Stainless steel,
- Concrete,
- Glass,
- Cast iron, or

(Just about anything else you can think of).



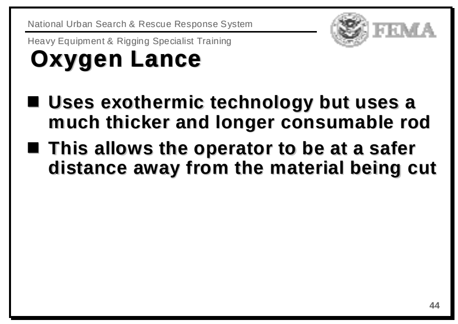
Disadvantages: The main disadvantage is fire!

- This system throws large amounts of molten material.
- The operator must be wearing full PPE to prevent serious burns.
- The area where the work is performed must be free from combustible materials, and water extinguishers must be available at all times.
- Gel-cell starter batteries should not be substituted for lead acid automotive batteries because they may give off hydrogen gas and can explode.

Oxygen Lance

The Oxygen Lance uses a carbon steel, consumable pipe, fed with oxygen to burn cut other substances.

The **Thermolance** uses a steel pipe that is packed with a combination of wire inserts, also fed with oxygen. It burns at a higher temperature than the Oxygen Lance, and will melt anything from concrete to stainless steel. It is, also, more effective and controllable



Plasma Arc

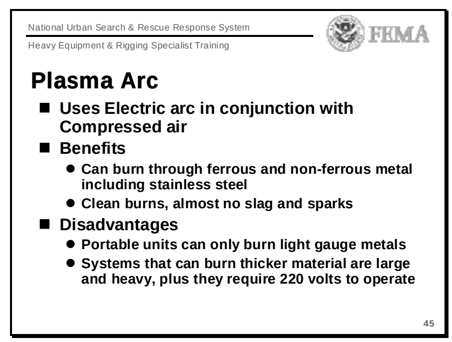
This technology uses an electric arc in conjunction with compressed air. It works very well but is best suited for fabrication work.

Benefits: Plasma systems do an excellent job and can burn through both ferrous and nonferrous metals, including stainless steel.

- They are able to make very clean, precise cuts with very little slag and light sparks.

Disadvantages: Only small units that are limited to burning light gauge metals are portable.

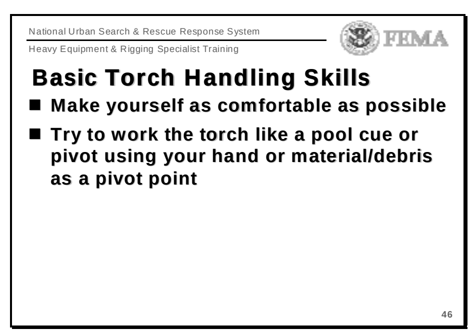
- The larger systems that can burn thicker material are large, heavy and require 220 volts to operate.



Basic Torch Handling

As with any physical task that will last for significant time, one needs to assume a reasonably comfortable position.

- One should use a longer torch rather than reaching with a shorter one.
- It is best to balance the torch on a pivot point like a pool cue.
- It is worth the time to set-up one's work space in order to remove stress from the arms and back.



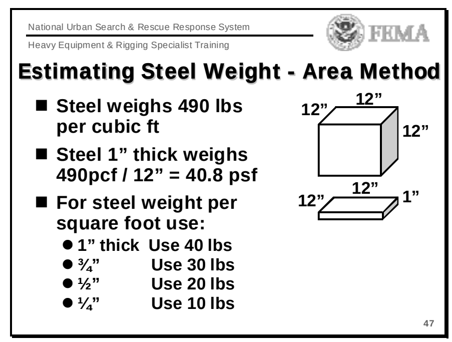
VI. Estimating the Weight of Steel

Often burning operations are needed when large steel beams and columns are present in a collapsed structure.

Since these heavy objects will need to be moved, some of the first things to consider are the lifting capability of the available equipment, based on the distance to the object's initial and final positions.

- The information regarding maximum lifting capacity will determine where to mark and cut the heavy steel members so that the weight requirements are met.
- Most metal suppliers offer booklets that give information about the weight of steel by thickness, shape, and dimension, usually on a per-foot basis.

There is an easy way to quickly estimate the weight of steel, by remembering that a one square foot, one inch thick steel plate weighs 40.8 pounds per square foot (psf).



The 40.8 psf is based on the fact that steel weighs 490 pounds per cubic foot (12"x 12"x12"). One may cut 12 – one inch slices, one square foot each, from a cubic foot.

Therefore, 1" thick, sq ft plate weighs 490/12=40.8 lbs

In order to easily remember, we round off to 40 and use the following weights for one sq ft steel plates:

1" thick = 40 psf

¾"thick = 30 psf

½" thick = 20 psf

¼" thick = 10 psf

One can easily calculate the weights of steel plates to the eight or sixteenth of an inch (3/8" = 15psf)

Note that this Area Method can be used to estimate the weight of concrete slabs.
Reinforced concrete weighs about 150 lbs per cubic ft, and we can use the following weights per sq foot

12" slab = 150 psf

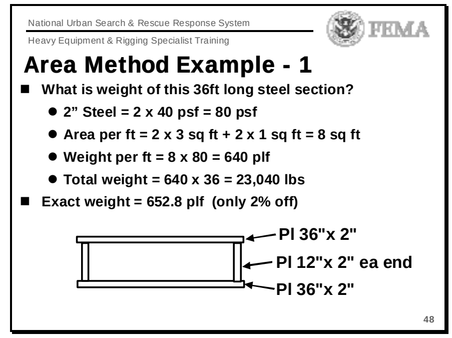
8" slab = 100psf

6" slab = 75psf & 4" slab = 50psf

Area Method Example 1

The weight of the steel "box section" shown in adjacent slide can be easily calculated by noting that a 2" thick plate would weigh 80psf.

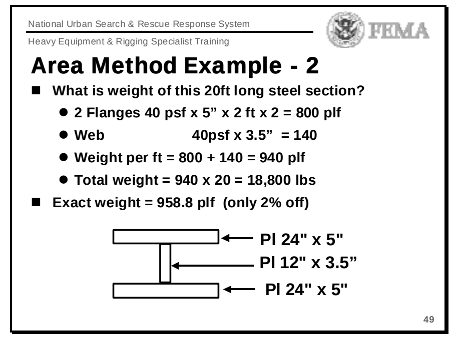
- Since the total area of 2" plate is 8 sqft per ft, the section weighs 8 x 80 = 640 pounds per foot (plf)
- Total weight if the section is 36ft long is 23,040 lbs
- This is only 2% less than the exact weight



Area Method Example 2

The adjacent slide shows an additional example, using a built-up so called W shape.

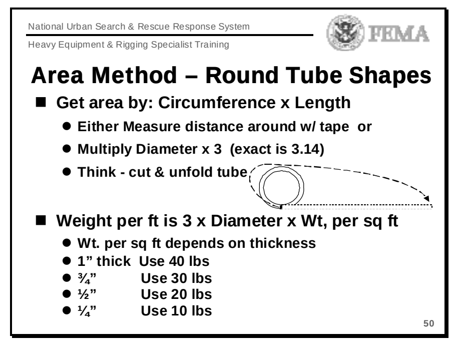
- Again, the calculation is simple, and the error is the same 2%
- The 2% is just the difference between the exact 40.8 psf and the easier to remember 40 psf for the 1" x one square foot steel plate



Area Method for Round Tube/Pipe Shapes

For round tubes, one may imagine a flat plate, made from cutting the tube length-wise and laying it flat.

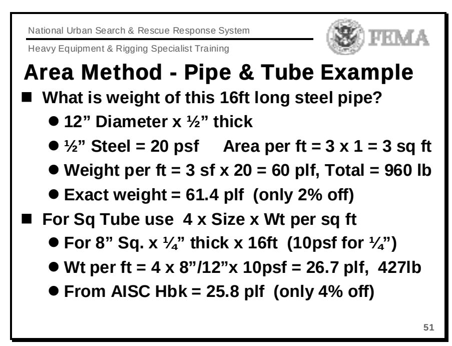
- The width of this imaginary plate is the circumference of the round shape, which is the diameter x 3.14 (Phi).
- The easy to remember value is 3, which is about 5% less, but close enough.



Area Method – Pipe & Tube Example

In the adjacent slide there is an example for estimating the weight for a 12" diameter x ½" steel pipe and a 8" square x ¼" square tube, using the Area Method.

One can see that this method yields results that are within 5% of the actual weight in both cases



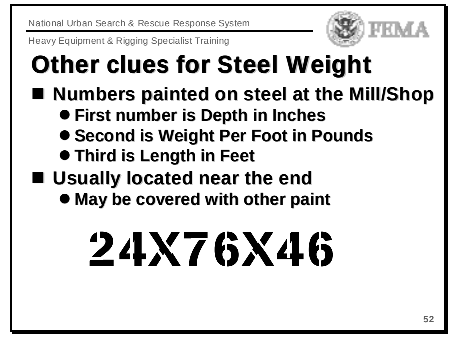
Additional methods for calculating weights of both concrete and steel will be presented in a later HERS Training Module. The student is encouraged to use whatever method is easiest for them to remember.

Other Clues of Steel Weight

In order to identify steel sections and aid with erection, the steel mill, and/or shop may paint-on indications of the section/s weight.
The standard method is:

- First numbers are the section depth
- Second number is the weight per foot
- Third number is the approximate length in feet

One may or may not be able to find these numbers for any specific piece, since it may be cut from something longer, and/or may be covered by some sort of primer or finish paint/coating

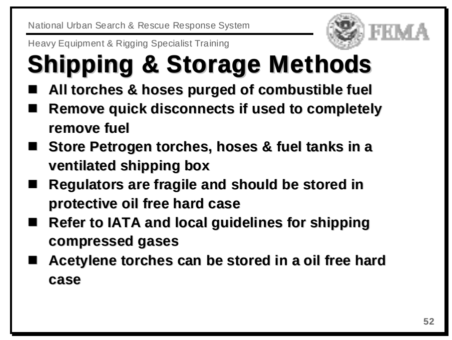


Shipping & Storage Methods

To be stored, all torches & hoses must be completely purged of fuel. In order to do this, one must remove quick disconnects.

Acetylene torches should may be stored in a oil free, hard case
Petrogen torches, hoses, and fuel tanks must be stored in ventilated shipping boxes

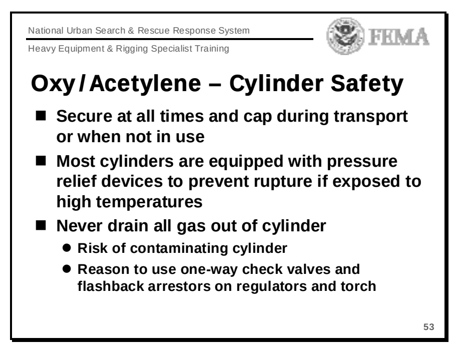
Since regulators are relatively fragile, they should be stored and/or shipped in oil free, padded hard cases.
Refer to IATA and local guidelines for shipping compressed gas



Cylinder Safety

Cylinders must be secured and capped during transport and when not in use

- Since most cylinders are equipped with pressure relief devices, there is little chance of rupture, due to high temperature.
- One should never drain all gas out of a cylinder due to the risk of contaminating it



Review Unit Objectives

The Student will understand the capabilities and limitations of all the types of burning equipment that can be used in US&R operations, and

Understand how to efficiently and safely cut and remove multiple pieces of steel from a debris pile