For SI: °C = [(°F) - 32] / 1.8.

FIGURE 704.7
EQUIVALENT OPENING FACTOR

704.8 Allowable area of openings. The maximum area of unprotected or protected openings permitted in an exterior wall in any story shall not exceed the values set forth in Table 704.8. Where both unprotected and protected openings are located in the exterior wall in any story, the total area of the openings shall comply with the following formula:

$$\frac{A}{a}+\frac{A_u}{A_u} \leq 1.0 \qquad \text{(Equation 7-2)}$$

where:

A = Actual area of protected openings, or the equivalent area of protected openings, A_e (see Section 704.7).

a = Allowable area of protected openings.

A_u = Actual area of unprotected openings.

a_u = Allowable area of unprotected openings.

704.8.1 Automatic sprinkler system. In buildings equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1, the maximum allowable area of unprotected openings in occupancies other than Groups H-1, H-2 and H-3 shall be the same as the tabulated limitations for protected openings.

704.8.2 First story. In occupancies other than Group H, unlimited unprotected openings are permitted in the first story of exterior walls facing a street that have a fire separation distance of greater than 15 feet (4572 mm) or facing an unoccupied space. The unoccupied space shall be on the same

lot or dedicated for public use, shall not be less than 30 feet (9144 mm) in width, and shall have access from a street by a posted fire lane in accordance with the *International Fire Code*.

704.9 Vertical separation of openings. Openings in exterior walls in adjacent stories shall be separated vertically to protect against fire spread on the exterior of the buildings where the openings are within 5 feet (1524 mm) of each other horizontally and the opening in the lower story is not a protected opening in accordance with Section 715.4.8. Such openings shall be separated vertically at least 3 feet (914 mm) by spandrel girders, exterior walls or other similar assemblies that have a fire-resistance rating of at least 1 hour or by flame barriers that extend horizontally at least 30 inches (762 mm) beyond the exterior wall. Flame barriers shall also have a fire-resistance rating of at least 1 hour. The unexposed surface temperature limitations specified in ASTM E 119 shall not apply to the flame barriers or vertical separation unless otherwise required by the provisions of this code.

Exceptions:

1. This section shall not apply to buildings that are three stories or less in height.

2. This section shall not apply to buildings equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1 or 903.3.1.2.

3. Open parking garages.

TABLE 704.8
MAXIMUM AREA OF EXTERIOR WALL OPENINGS[a]

CLASSIFICATION OF OPENING	FIRE SEPARATION DISTANCE (feet)							
	0 to 3[e,h]	Greater than 3 to 5[b]	Greater than 5 to 10[d,f]	Greater than 10 to 15[c,d,f]	Greater than 15 to 20[c,f]	Greater than 20 to 25[c,f]	Greater than 25 to 30[c,f]	Greater than 30
Unprotected	Not Permitted[g]	Not Permitted[b,g]	10%[g]	15%[g]	25%[g]	45%[g]	70%[g]	No Limit
Protected	Not Permitted	15%	25%	45%	75%	No Limit	No Limit	No Limit

For SI: 1 foot = 304.8 mm.

a. Values given are percentage of the area of the exterior wall.
b. For occupancies in Group R-3, as applicable in Section 101.2, the maximum percentage of unprotected and protected exterior wall openings shall be 25 percent.
c. The area of openings in an open parking structure with a fire separation distance of greater than 10 feet shall not be limited.
d. For occupancies in Group H-2 or H-3, unprotected openings shall not be permitted for openings with a fire separation distance of 15 feet or less.
e. For requirements for fire walls for buildings with differing roof heights, see Section 705.6.1.
f. The area of unprotected and protected openings is not limited for occupancies in Group R-3, as applicable in Section 101.2, with a fire separation distance greater than 5 feet.
g. Buildings whose exterior bearing wall, exterior nonbearing wall and exterior structural frame are not required to be fire-resistance rated shall be permitted to have unlimited unprotected openings.
h. Includes accessory buildings to Group R-3 as applicable in Section 101.2.

704.10 Vertical exposure. For buildings on the same lot, approved protectives shall be provided in every opening that is less than 15 feet (4572 mm) vertically above the roof of an adjoining building or adjacent structure that is within a horizontal fire separation distance of 15 feet (4572 mm) of the wall in which the opening is located.

Exception: Opening protectives are not required where the roof construction has a fire-resistance rating of not less than 1 hour for a minimum distance of 10 feet (3048 mm) from the adjoining building and the entire length and span of the supporting elements for the fire-resistance-rated roof assembly has a fire-resistance rating of not less than 1 hour.

704.11 Parapets. Parapets shall be provided on exterior walls of buildings.

Exceptions: A parapet need not be provided on an exterior wall where any of the following conditions exist:

1. The wall is not required to be fire-resistance rated in accordance with Table 602 because of fire separation distance.

2. The building has an area of not more than 1,000 square feet (93 m²) on any floor.

3. Walls that terminate at roofs of not less than 2-hour fire-resistance-rated construction or where the roof, including the deck and supporting construction, is constructed entirely of noncombustible materials.

4. One-hour fire-resistance-rated exterior walls that terminate at the underside of the roof sheathing, deck or slab, provided:

   4.1. Where the roof/ceiling framing elements are parallel to the walls, such framing and elements supporting such framing shall not be of less than 1-hour fire-resistance-rated construction for a width of 4 feet (1220 mm) measured from the interior side of the wall for Groups R and U and 10 feet (3048 mm) for other occupancies.

   4.2. Where roof/ceiling framing elements are not parallel to the wall, the entire span of such framing and elements supporting such framing shall not be of less than 1-hour fire-resistance-rated construction.

   4.3. Openings in the roof shall not be located within 5 feet (1524 mm) of the 1-hour fire-resistance-rated exterior wall for Group R and U and 10 feet (3048 mm) for other occupancies.

   4.4. The entire building shall be provided with not less than a Class B roof covering.

5. In occupancies of Groups R-2 and R-3 as applicable in Section 101.2, both provided with a Class C roof covering, the exterior wall shall be permitted to terminate at the roof sheathing or deck in Type III, IV and V construction provided:

   5.1. The roof sheathing or deck is constructed of approved noncombustible materials or of fire-retardant-treated wood, for a distance of 4 feet (1220 mm); or

   5.2. The roof is protected with 0.625-inch (15.88 mm) Type X gypsum board directly beneath the underside of the roof sheathing or deck, supported by a minimum of nominal 2-inch (51 mm) ledgers attached to the sides of the roof framing members, for a minimum distance of 4 feet (1220 mm).

6. Where the wall is permitted to have at least 25 percent of the exterior wall areas containing unprotected openings based on fire separation distance as determined in accordance with Section 704.8.

704.11.1 Parapet construction. Parapets shall have the same fire-resistance rating as that required for the supporting wall, and on any side adjacent to a roof surface, shall have noncombustible faces for the uppermost 18 inches (457 mm), including counterflashing and coping materials.

The height of the parapet shall not be less than 30 inches (762 mm) above the point where the roof surface and the wall intersect. Where the roof slopes toward a parapet at a slope greater than two units vertical in 12 units horizontal (16.7-percent slope), the parapet shall extend to the same height as any portion of the roof within a fire separation distance where protection of wall openings is required, but in no case shall the height be less than 30 inches (762 mm).

704.12 Opening protection. Windows required to be protected in accordance with Section 704.8, 704.9, or 704.10 shall comply with Section 715.4.8. Other openings required to be protected with fire doors or shutters in accordance with Sections 704.8, 704.9 and 704.10 shall comply with Section 715.3.

> **Exception:** Fire protective assemblies are not required where the building is protected throughout by an automatic sprinkler system and the exterior openings are protected by an approved water curtain using automatic sprinklers approved for that use. The sprinklers and the water curtain shall be installed in accordance with NFPA 13.

> **704.12.1 Unprotected openings.** Where protected openings are not required by Section 704, windows and doors shall be constructed of any approved materials. Glazing shall conform to the requirements of Chapters 24 and 26.

704.13 Joints. Joints made in or between exterior walls required by this section to have a fire-resistance rating shall comply with Section 713.

> **Exception:** Joints in exterior walls that are permitted to have unprotected openings.

> **704.13.1 Voids.** The void created at the intersection of a floor/ceiling assembly and an exterior curtain wall assembly shall be protected in accordance with Section 713.4.

704.14 Ducts and air transfer openings. Penetrations by air ducts and air transfer openings in fire-resistance-rated exterior walls required to have protected openings shall comply with Section 716.

> **Exception:** Foundation vents installed in accordance with this code are permitted.

SECTION 705
FIRE WALLS

705.1 General. Each portion of a building separated by one or more fire walls that comply with the provisions of this section shall be considered a separate building. The extent and location of such fire walls shall provide a complete separation. Where a fire wall also separates groups that are required to be separated by a fire barrier wall, the most restrictive requirements of each separation shall apply. Fire walls located on lot lines shall also comply with Section 503.2. Such fire walls (party walls) shall be constructed without openings.

705.2 Structural stability. Fire walls shall have sufficient structural stability under fire conditions to allow collapse of construction on either side without collapse of the wall for the duration of time indicated by the required fire-resistance rating.

705.3 Materials. Fire walls shall be of any approved noncombustible materials.

> **Exception:** Buildings of Type V construction.

705.4 Fire-resistance rating. Fire walls shall have a fire-resistance rating of not less than that required by Table 705.4.

TABLE 705.4
FIRE WALL FIRE-RESISTANCE RATINGS

GROUP	FIRE-RESISTANCE RATING (hours)
A, B, E, H-4, I, R-1, R-2, U	3[a]
F-1, H-3[b], H-5, M, S-1	3
H-1, H-2	4[b]
F-2, S-2, R-3, R-4	2

a. Walls shall be not less than 2-hour fire-resistance rated where separating buildings of Type II or V construction.

b. For Group H-1, H-2 or H-3 buildings, also see Sections 415.4 and 415.5.

705.5 Horizontal continuity. Fire walls shall be continuous from exterior wall to exterior wall and shall extend at least 18 inches (457 mm) beyond the exterior surface of exterior walls.

> **Exceptions:**
> 1. Fire walls shall be permitted to terminate at the interior surface of combustible exterior sheathing or siding provided the exterior wall has a fire-resistance rating of at least 1 hour for a horizontal distance of at least 4 feet (1220 mm) on both sides of the fire wall. Openings within such exterior walls shall be protected by fire assemblies having a fire-protection rating of not less than ³⁄₄ hour.
> 2. Fire walls shall be permitted to terminate at the interior surface of noncombustible exterior sheathing, exterior siding or other noncombustible exterior finishes provided the sheathing, siding, or other exterior noncombustible finish extends a horizontal distance of at least 4 feet (1220 mm) on both sides of the fire wall.
> 3. Fire walls shall be permitted to terminate at the interior surface of noncombustible exterior sheathing where the building on each side of the fire wall is protected by an automatic sprinkler system installed in accordance with Section 903.3.1.1 or 903.3.1.2.

705.5.1 Exterior walls. Where the fire wall intersects the exterior walls, the fire-resistance rating for the exterior walls on both sides of the fire wall shall have a 1-hour fire-resistance rating with ³⁄₄-hour opening protection where opening protection is required. The fire-resistance rating of the exterior wall shall extend a minimum of 4 feet (1220 mm) on each side of the intersection of the fire wall to exterior wall. Exterior wall intersections at fire walls that form an angle equal to or greater than 180 degrees (3.14 rad) do not need exterior wall protection.

705.5.2 Horizontal projecting elements. Fire walls shall extend to the outer edge of horizontal projecting elements

705.8 Openings. Each opening through a fire wall shall be protected in accordance with Section 715.3 and shall not exceed 120 square feet (11 m²). The aggregate width of openings at any floor level shall not exceed 25 percent of the length of the wall.

Exceptions:

1. Openings are not permitted in party walls constructed in accordance with Section 503.2.

2. Openings shall not be limited to 120 square feet (11 m²) where both buildings are equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.1.

705.9 Penetrations. Penetrations through fire walls shall comply with Section 712.

705.10 Joints. Joints made in or between fire walls shall comply with Section 713.

705.11 Ducts and air transfer openings. Ducts and air transfer openings shall not penetrate fire walls.

Exception: Penetrations by ducts and air transfer openings of fire walls that are not on a lot line shall be allowed provided the penetrations comply with Sections 712 and 716. The size and aggregate width of all openings shall not exceed the limitations of Section 705.8.

SECTION 706
FIRE BARRIERS

706.1 General. Fire barriers used for separation of shafts, exits, exit passageways, horizontal exits or incidental use areas, to separate different occupancies, to separate a single occupancy into different fire areas, or to separate other areas where a fire barrier is required elsewhere in this code or the *International Fire Code*, shall comply with this section.

706.2 Materials. The walls and floor assemblies shall be of materials permitted by the building type of construction.

706.3 Fire-resistance rating. The fire-resistance rating of the walls and floor assemblies shall comply with this section.

706.3.1 Shaft enclosures. The fire-resistance rating of the fire barrier separating building areas from a shaft shall comply with Section 707.4.

706.3.2 Exit enclosures. The fire-resistance rating of the fire barrier separating building areas from an exit shall comply with Section 1019.1.

706.3.3 Exit passageway. The fire-resistance rating of the separation between building areas and an exit passageway shall comply with Section 1020.1.

706.3.4 Horizontal exit. The fire-resistance rating of the separation between building areas connected by a horizontal exit shall comply with Section 1021.1.

706.3.5 Incidental use areas. The fire barrier separating incidental use areas shall have a fire-resistance rating of not less than that indicated in Table 302.1.1.

706.3.6 Separation of mixed occupancies. Where the provisions of Section 302.3.2 are applicable, the fire barrier separating mixed occupancies shall have a fire-resistance

rating of not less than that indicated in Section 302.3.2 based on the occupancies being separated.

706.3.7 Single-occupancy fire areas. The fire barrier separating a single occupancy into different fire areas shall have a fire-resistance rating of not less than that indicated in Table 706.3.7.

TABLE 706.3.7
FIRE-RESISTANCE RATING REQUIREMENTS FOR FIRE BARRIER ASSEMBLIES BETWEEN FIRE AREAS

OCCUPANCY GROUP	FIRE-RESISTANCE RATING (hours)
H-1, H-2	4
F-1, H-3, S-1	3
A, B, E, F-2, H-4, H-5, I, M, R, S-2	2
U	1

706.4 Continuity of fire barrier walls. Fire barrier walls shall extend from the top of the floor/ceiling assembly below to the underside of the floor or roof slab or deck above and shall be securely attached thereto. These walls shall be continuous through concealed spaces such as the space above a suspended ceiling. The supporting construction for fire barrier walls shall be protected to afford the required fire-resistance rating of the fire barrier supported except for 1-hour fire-resistance-rated incidental use area separations as required by Table 302.1.1 in buildings of Type IIB, IIIB and VB construction. Hollow vertical spaces within the fire barrier wall shall be firestopped at every floor level.

Exceptions:

1. The maximum required fire-resistance rating for assemblies supporting fire barriers separating tank storage as provided for in Section 415.7.2.1 shall be 2 hours, but not less than required by Table 601 for the building construction type.

2. Shaft enclosure shall be permitted to terminate at a top enclosure complying with Section 707.12.

706.5 Horizontal fire barriers. Horizontal fire barriers shall be constructed in accordance with Section 711.

706.6 Exterior walls. Where exterior walls serve as a part of a required fire-resistance-rated enclosure, such walls shall comply with the requirements of Section 704 for exterior walls and the fire-resistance-rated enclosure requirements shall not apply.

Exception: Exterior walls required to be fire-resistance rated in accordance with Section 1022.6.

706.7 Openings. Openings in a fire barrier wall shall be protected in accordance with Section 715. Openings shall be limited to a maximum aggregate width of 25 percent of the length of the wall, and the maximum area of any single opening shall not exceed 120 square feet (11 m²). Openings in exit enclosures shall also comply with Section 1019.1.1.

Exceptions:

1. Openings shall not be limited to 120 square feet (11 m²) where adjoining fire areas are equipped throughout with an automatic sprinkler system in accordance with Section 903.3.1.1.

TABLE 715.3
FIRE DOOR AND FIRE SHUTTER FIRE PROTECTION RATINGS

TYPE OF ASSEMBLY	REQUIRED ASSEMBLY RATING (hours)	MINIMUM FIRE DOOR AND FIRE SHUTTER ASSEMBLY RATING (hours)
Fire walls and fire barriers having a required fire-resistance rating greater than 1 hour	4 3 2 1½	3 3[a] 1½ 1½

Fire barriers having a required fire-resistance rating of 1 hour:
  Shaft, exit enclosure and exit
    passageway walls
  Other fire barriers
	
	1
	1
		
		1
		3/4

Fire partitions:
  Corridor walls
 	
  Other fire partitions
	
	1
	0.5
	1
		
		1/3[b]
		1/3[b]
		3/4

Exterior walls	3 2 1	1½ 1½ 3/4

a. Two doors, each with a fire protection rating of 1½ hours, installed on opposite sides of the same opening in a fire wall, shall be deemed equivalent in fire protection rating to one 3-hour fire door.

b. For testing requirements, see Section 715.3.3.

715.3.1 Side-hinged or pivoted swinging doors.
Side-hinged and pivoted swinging doors shall be tested in accordance with NFPA 252 or UL 10C. After 5 minutes into the NFPA 252 test, the neutral pressure level in the furnace shall be established at 40 inches (1016 mm) or less above the sill.

715.3.2 Other types of doors. Other types of doors, including swinging elevator doors, shall be tested in accordance with NFPA 252 or UL 10B. The pressure in the furnace shall be maintained as nearly equal to the atmospheric pressure as possible. Once established, the pressure shall be maintained during the entire test period.

715.3.3 Door assemblies in corridors and smoke barriers. Fire door assemblies required to have a minimum fire protection rating of 20 minutes where located in corridor walls or smoke barrier walls having a fire-resistance rating in accordance with Table 715.3 shall be tested in accordance with NFPA 252 or UL 10C without the hose stream test. If a 20-minute fire door assembly contains glazing material, the glazing material in the door itself shall have a minimum fire protection rating of 20 minutes and be exempt from the hose stream test. Glazing material in any other part of the door assembly, including transom lites and sidelites, shall be tested in accordance with NFPA 257, including the hose stream test, in accordance with Section 715.4. Fire door assemblies shall also meet the requirements for a smoke- and draft-control door assembly tested in accordance with UL 1784 with an artificial bottom seal installed across the full width of the bottom of the door assembly. The air leakage rate of the door assembly shall not exceed 3.0 cfm per square foot (0.01524 m³/s · m²) of door opening at 0.10 inch (24.9 Pa) of water for

both the ambient temperature and elevated temperature tests. Louvers shall be prohibited.

Exceptions:

1. View ports that require a hole not larger than 1 inch (25 mm) in diameter through the door, have at least an 0.25-inch-thick (6.4 mm) glass disc and the holder is of metal that will not melt out where subject to temperatures of 1,700°F (927°C).

2. Corridor door assemblies in occupancies of Group I-2 shall be in accordance with Section 407.3.1.

3. Unprotected openings shall be permitted for corridors in multitheater complexes where each motion picture auditorium has at least one-half of its required exit or exit access doorways opening directly to the exterior or into an exit passageway.

715.3.4 Doors in vertical exit enclosures and exit passageways. Fire door assemblies in vertical exit enclosures and exit passageways shall have a maximum transmitted temperature end point of not more than 450°F (232°C) above ambient at the end of 30 minutes of standard fire test exposure.

Exception: The maximum transmitted temperature end point is not required in buildings equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.1 or 903.3.1.2.

715.3.4.1 Glazing in doors. Fire-protection-rated glazing in excess of 100 square inches (0.065 m²) shall be permitted in fire door assemblies when tested in accordance with NFPA 252 as components of the door assemblies and not as glass lights, and shall have a maximum transmitted temperature end point of 450°F (232°C) in accordance with Section 715.3.4.

Exception: The maximum transmitted temperature end point is not required in buildings equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.1 or 903.3.1.2.

715.3.5 Labeled protective assemblies. Fire door assemblies shall be labeled by an approved agency. The labels shall comply with NFPA 80, and shall be permanently affixed to the door or frame.

715.3.5.1 Fire door labeling requirements. Fire doors shall be labeled showing the name of the manufacturer, the name of the third-party inspection agency, the fire protection rating and, where required for fire doors in exit enclosures by Section 715.3.4, the maximum transmitted temperature end point. Smoke and draft control doors complying with UL 1784 shall be labeled as such. Labels shall be approved and permanently affixed. The label shall be applied at the factory or location where fabrication and assembly are performed.

715.3.5.2 Oversized doors. Oversized fire doors shall bear an oversized fire door label by an approved agency or shall be provided with a certificate of inspection furnished by an approved testing agency. When a certificate of inspection is furnished by an approved testing agency, the certificate shall state that the door conforms to the re-

TABLE 715.4
FIRE WINDOW ASSEMBLY FIRE PROTECTION RATINGS

TYPE OF ASSEMBLY	REQUIRED ASSEMBLY RATING (hours)	MINIMUM FIRE WINDOW ASSEMBLY RATING (hours)
Interior walls:		
Fire walls	All	NP[a]
Fire barriers and fire partitions	>1	NP[a]
	1	$3/4$
Smoke barriers	1	$3/4$
Exterior walls	>1	$1^1/_2$
	1	$3/4$
Party walls	All	NP[a]

a. Not permitted except as specified in Section 715.2.

715.4.1 Testing under positive pressure. NFPA 257 shall evaluate fire-protection-rated glazing under positive pressure. Within the first 10 minutes of a test, the pressure in the furnace shall be adjusted so at least two-thirds of the test specimen is above the neutral pressure plane, and the neutral pressure plane shall be maintained at that height for the balance of the test.

715.4.2 Nonsymmetrical glazing systems. Nonsymmetrical fire-protection-rated glazing systems in fire partitions, fire barriers or in exterior walls with a fire separation of 5 feet (1524 mm) or less pursuant to Section 704 shall be tested with both faces exposed to the furnace, and the assigned fire protection rating shall be the shortest duration obtained from the two tests conducted in compliance with NFPA 257.

715.4.3 Wired glass. Steel window frame assemblies of 0.125-inch (3.2 mm) minimum solid section or of not less than nominal 0.048-inch-thick (1.2 mm) formed sheet steel members fabricated by pressing, mitering, riveting, interlocking or welding and having provision for glazing with $1/_4$-inch (6.4 mm) wired glass where securely installed in the building construction and glazed with $1/_4$-inch (6.4 mm) labeled wired glass shall be deemed to meet the requirements for a $3/_4$-hour fire window assembly. Wired glass panels shall conform to the size limitations set forth in Table 715.4.3.

TABLE 715.4.3
LIMITING SIZES OF WIRED GLASS PANELS

OPENING FIRE PROTECTION RATING	MAXIMUM AREA (square inches)	MAXIMUM HEIGHT (inches)	MAXIMUM WIDTH (inches)
3 hours	0	0	0
$1^1/_2$-hour doors in exterior walls	0	0	0
1 and $1^1/_2$ hours	100	33	10
$3/_4$ hour	1,296	54	54
20 minutes	Not Limited	Not Limited	Not Limited
Fire window assemblies	1,296	54	54

For SI: 1 inch = 25.4 mm, 1 square inch = 645.2 mm^2.

715.4.4 Nonwired glass. Glazing other than wired glass in fire window assemblies shall be fire-protection-rated glazing installed in accordance with and complying with the size limitations set forth in NFPA 80.

715.4.5 Installation. Fire-protection-rated glazing shall be in the fixed position or be automatic-closing and shall be installed in approved frames.

715.4.6 Window mullions. Metal mullions that exceed a nominal height of 12 feet (3658 mm) shall be protected with materials to afford the same fire-resistance rating as required for the wall construction in which the protective is located.

715.4.7 Interior fire window assemblies. Fire-protection-rated glazing used in fire window assemblies located in fire partitions and fire barriers shall be limited to use in assemblies with a maximum fire-resistance rating of 1 hour in accordance with this section.

715.4.7.1 Where permitted. Fire-protection-rated glazing shall be limited to fire partitions designed in accordance with Section 708 and fire barriers utilized in the applications set forth in Sections 706.3.5 and 706.3.6 where the fire-resistance rating does not exceed 1 hour.

715.4.7.2 Size limitations. The total area of windows shall not exceed 25 percent of the area of a common wall with any room.

715.4.8 Exterior fire window assemblies. Exterior openings, other than doors, required to be protected by Section 704.12, where located in a wall required by Table 602 to have a fire-resistance rating of greater than 1 hour, shall be protected with an assembly having a fire protection rating of not less than $1^1/_2$ hours. Exterior openings required to be protected by Section 704.8, where located in a wall required by Table 602 to have a fire-resistance rating of 1 hour, shall be protected with an assembly having a fire protection rating of not less than $3/_4$ hour. Exterior openings required to be protected by Section 704.9 or 704.10 shall be protected with an assembly having a fire protection rating of not less than $3/_4$ hour. Openings in nonfire-resistance-rated exterior wall assemblies that require protection in accordance with Section 704.8, 704.9 or 704.10 shall have a fire protection rating of not less than $3/_4$ hour.

715.4.9 Labeling requirements. Fire-protection-rated glazing shall bear a label or other identification showing the name of the manufacturer, the test standard, and the fire protection rating. Such label or identification shall be issued by an approved agency and shall be permanently affixed.

SECTION 716
DUCTS AND AIR TRANSFER OPENINGS

716.1 General. The provisions of this section shall govern the protection of ducts and air transfer openings in fire-resistance-rated assemblies.

716.1.1 Ducts and air transfer openings without dampers. Ducts and air transfer openings that penetrate fire-resistance-rated assemblies and are not required by this section to have dampers shall comply with the requirements of Section 712.

716.2 Installation. Fire dampers, smoke dampers, combination fire/smoke dampers and ceiling dampers located within air distribution and smoke control systems shall be installed in ac-

cordance with the requirements of this section, the manufacturer's installation instructions and listing.

716.2.1 Smoke control system. Where the installation of a fire damper will interfere with the operation of a required smoke control system in accordance with Section 909, approved alternative protection shall be utilized.

716.2.2 Hazardous exhaust ducts. Fire dampers for hazardous exhaust duct systems shall comply with the *International Mechanical Code.*

716.3 Damper testing and ratings. Dampers shall be listed and bear the label of an approved testing agency indicating compliance with the standards in this section. Fire dampers shall comply with the requirements of UL 555. Only fire dampers labeled for use in dynamic systems shall be installed in heating, ventilation and air-conditioning systems designed to operate with fans on during a fire. Smoke dampers shall comply with the requirements of UL 555S. Combination fire/smoke dampers shall comply with the requirements of both UL 555 and UL 555S. Ceiling radiation dampers shall comply with the requirements of UL 555C.

716.3.1 Fire protection rating. Fire dampers shall have the minimum fire protection rating specified in Table 716.3.1 for the type of penetration.

TABLE 716.3.1
FIRE DAMPER RATING

TYPE OF PENETRATION	MINIMUM DAMPER RATING (hours)
Less than 3-hour fire-resistance-rated assemblies	1.5
3-hour or greater fire-resistance-rated assemblies	3

716.3.1.1 Fire damper actuating device. The fire damper actuating device shall meet one of the following requirements:

1. The operating temperature shall be approximately 50°F (10°C) above the normal temperature within the duct system, but not less than 160°F (71°C).

2. The operating temperature shall be not more than 286°F (141°C) where located in a smoke control system complying with Section 909.

3. Where a combination fire/smoke damper is located in a smoke control system complying with Section 909, the operating temperature rating shall be approximately 50°F (10°C) above the maximum smoke control system designed operating temperature, or a maximum temperature of 350°F (177°C). The temperature shall not exceed the UL 555S degradation test temperature rating for a combination fire/smoke damper.

716.3.2 Smoke damper ratings. Smoke damper leakage ratings shall not be less than Class II. Elevated temperature ratings shall not be less than 250°F (121°C).

716.3.2.1 Smoke damper actuation methods. The smoke damper shall close upon actuation of a listed smoke detector or detectors installed in accordance with

Section 907.10 and one of the following methods, as applicable:

1. Where a damper is installed within a duct, a smoke detector shall be installed in the duct within 5 feet (1524 mm) of the damper with no air outlets or inlets between the detector and the damper. The detector shall be listed for the air velocity, temperature and humidity anticipated at the point where it is installed. Other than in mechanical smoke control systems, dampers shall be closed upon fan shutdown where local smoke detectors require a minimum velocity to operate.

2. Where a damper is installed above smoke barrier doors in a smoke barrier, a spot-type detector listed for releasing service shall be installed on either side of the smoke barrier door opening.

3. Where a damper is installed within an unducted opening in a wall, a spot-type detector listed for releasing service shall be installed within 5 feet (1524 mm) horizontally of the damper.

4. Where a damper is installed in a corridor wall, the damper shall be permitted to be controlled by a smoke detection system installed in the corridor.

5. Where a total-coverage smoke detector system is provided within areas served by a heating, ventilation and air-conditioning (HVAC) system, dampers shall be permitted to be controlled by the smoke detection system.

716.4 Access and identification. Fire and smoke dampers shall be provided with an approved means of access, large enough to permit inspection and maintenance of the damper and its operating parts. The access shall not affect the integrity of fire-resistance-rated assemblies. The access openings shall not reduce the fire-resistance rating of the assembly. Access points shall be permanently identified on the exterior by a label having letters not less than 0.5 inch (12.7 mm) in height reading: SMOKE DAMPER or FIRE DAMPER. Access doors in ducts shall be tight fitting and suitable for the required duct construction.

716.5 Where required. Fire dampers, smoke dampers, combination fire/smoke dampers and ceiling radiation dampers shall be provided at the locations prescribed in this section. Where an assembly is required to have both fire dampers and smoke dampers, combination fire/smoke dampers or a fire damper and a smoke damper shall be required.

716.5.1 Fire walls. Ducts and air transfer openings permitted in fire walls in accordance with Section 705.11 shall be protected with approved fire dampers installed in accordance with their listing.

716.5.2 Fire barriers. Ducts and air transfer openings in fire barriers shall be protected with approved fire dampers installed in accordance with their listing.

Exception: Fire dampers are not required at penetrations of fire barriers where any of the following apply:

1. Penetrations are tested in accordance with ASTM E 119 as part of the fire-resistance-rated assembly.

TABLE 720.1(1)
MINIMUM PROTECTION OF STRUCTURAL PARTS BASED ON TIME PERIODS
FOR VARIOUS NONCOMBUSTIBLE INSULATING MATERIALS[m]

STRUCTURAL PARTS TO BE PROTECTED	ITEM NUMBER	INSULATING MATERIAL USED	MINIMUM THICKNESS OF INSULATING MATERIAL FOR THE FOLLOWING FIRE-RESISTANCE PERIODS (inches)			
			4 hour	3 hour	2 hour	1 hour
1. Steel columns and all of primary trusses	1-1.1	Carbonate, lightweight and sand-lightweight aggregate concrete, members 6″ × 6″ or greater (not including sandstone, granite and siliceous gravel).[a]	$2^1/_2$	2	$1^1/_2$	1
	1-1.2	Carbonate, lightweight and sand-lightweight aggregate concrete, members 8″ × 8″ or greater (not including sandstone, granite and siliceous gravel).[a]	2	$1^1/_2$	1	1
	1-1.3	Carbonate, lightweight and sand-lightweight aggregate concrete, members 12″ × 12″or greater (not including sandstone, granite and siliceous gravel).[a]	$1^1/_2$	1	1	1
	1-1.4	Siliceous aggregate concrete and concrete excluded in Item 1-1.1, members 6″ × 6″ or greater.[a]	3	2	$1^1/_2$	1
	1-1.5	Siliceous aggregate concrete and concrete excluded in Item 1-1.1, members 8″ × 8″ or greater.[a]	$2^1/_2$	2	1	1
	1-1.6	Siliceous aggregate concrete and concrete excluded in Item 1-1.1, members 12″ × 12″ or greater.[a]	2	1	1	1
	1-.2.1	Clay or shale brick with brick and mortar fill.[a]	$3^3/_4$	—	—	$2^1/_4$
	1-3.1	4″ hollow clay tile in two 2″ layers; $^1/_2$″ mortar between tile and column; $^3/_8$″ metal mesh 0.046″ wire diameter in horizontal joints; tile fill.[a]	4	—	—	—
	1-3.2	2″ hollow clay tile; $^3/_4$″ mortar between tile and column; $^3/_8$″metal mesh 0.046″ wire diameter in horizontal joints; limestone concrete fill;[a] plastered with $^3/_4$″ gypsum plaster.	3	—	—	—
	1-3.3	2″ hollow clay tile with outside wire ties 0.08″ diameter at each course of tile or $^3/_8$″ metal mesh 0.046″ diameter wire in horizontal joints; limestone or trap-rock concrete fill[l] extending 1″ outside column on all sides	—	—	3	—
	1-3.4	2″ hollow clay tile with outside wire ties 0.08″ diameter at each course of tile with or without concrete fill; $^3/_4$″ mortar between tile and column.	—	—	—	2
	1-4.1	Cement plaster over metal lath wire tied to $^3/_4$″ cold-rolled vertical channels with 0.049″ (No. 18 B.W. gage) wire ties spaced 3″ to 6″ on center. Plaster mixed 1:2 $^1/_2$ by volume, cement to sand.	—	—	$2^1/_2$[b]	$^7/_8$
	1-5.1	Vermiculite concrete, 1:4 mix by volume over paperbacked wire fabric lath wrapped directly around column with additional 2″ × 2″ 0.065″/0.065″ (No. 16/16 B.W. gage) wire fabric placed $^3/_4$″ from outer concrete surface. Wire fabric tied with 0.049″ (No. 18 B.W. gage) wire spaced 6″ on center for inner layer and 2″ on center for outer layer.	2	—	—	—
	1-6.1	Perlite or vermiculite gypsum plaster over metal lath wrapped around column and furred $1^1/_4$″ from column flanges. Sheets lapped at ends and tied at 6″ intervals with 0.049″ (No. 18 B.W. gage) tie wire. Plaster pushed through to flanges.	$1^1/_2$	1	—	—
	1-6.2	Perlite or vermiculite gypsum plaster over self-furring metal lath wrapped directly around column, lapped 1″ and tied at 6″ intervals with 0.049″ (No. 18 B.W. gage) wire.	$1^3/_4$	$1^3/_8$	1	—
	1-6.3	Perlite or vermiculite gypsum plaster on metal lath applied to $^3/_4$″ cold-rolled channels spaced 24″ apart vertically and wrapped flatwise around column.	$1^1/_2$	—	—	—
	1-6.4	Perlite or vermiculite gypsum plaster over two layers of $^1/_2$″ plain full-length gypsum lath applied tight to column flanges. Lath wrapped with 1″ hexagonal mesh of No. 20 gage wire and tied with doubled 0.035″ diameter (No. 18 B.W. gage) wire ties spaced 23″ on center. For three-coat work, the plaster mix for the second coat shall not exceed 100 pounds of gypsum to $2^1/_2$ cubic feet of aggregate for the 3-hour system.	$2^1/_2$	2	—	—

(continued)

TABLE 720.1(1)—continued
MINIMUM PROTECTION OF STRUCTURAL PARTS BASED ON TIME PERIODS
FOR VARIOUS NONCOMBUSTIBLE INSULATING MATERIALS^m

STRUCTURAL PARTS TO BE PROTECTED	ITEM NUMBER	INSULATING MATERIAL USED	MINIMUM THICKNESS OF INSULATING MATERIAL FOR THE FOLLOWING FIRE-RESISTANCE PERIODS (inches)			
			4 hour	3 hour	2 hour	1 hour
1. Steel columns and all of primary trusses (continued)	1-6.5	Perlite or vermiculate gypsum plaster over one layer of $^1/_2''$ plain full-length gypsum lath applied tight to column flanges. Lath tied with doubled 0.049″ (No. 18 B.W. gage) wire ties spaced 23″ on center and scratch coat wrapped with 1″ hexagonal mesh 0.035″ (No. 20 B.W. gage) wire fabric. For three-coat work, the plaster mix for the second coat shall not exceed 100 pounds of gypsum to $2^1/_2$ cubic feet of aggregate.	—	2	—	—
	1-7.1	Multiple layers of $^1/_2''$ gypsum wallboard^c adhesively^d secured to column flanges and successive layers. Wallboard applied without horizontal joints. Corner edges of each layer staggered. Wallboard layer below outer layer secured to column with doubled 0.049″ (No. 18 B.W. gage) steel wire ties spaced 15″ on center. Exposed corners taped and treated.	—	—	2	1
	1-7.2	Three layers of $^5/_8''$ Type X gypsum wallboard.^{c} First and second layer held in place by $^1/_8''$ diameter by $1^3/_8''$ long ring shank nails with $^5/_{16}''$ diameter heads spaced 24″ on center at corners. Middle layer also secured with metal straps at mid-height and 18″ from each end, and by metal corner bead at each corner held by the metal straps. Third layer attached to corner bead with 1″ long gypsum wallboard screws spaced 12″ on center.	—	—	$1^7/_8$	—
	1-7.3	Three layers of $^5/_8''$ Type X gypsum wallboard,^{c} each layer screw attached to $1^5/_8''$ steel studs 0.018″ thick (No. 25 carbon sheet steel gage) at each corner of column. Middle layer also secured with 0.049″ (No. 18 B.W. gage) double-strand steel wire ties, 24″ on center. Screws are No. 6 by 1″ spaced 24″ on center for inner layer, No. 6 by $1^5/_8''$ spaced 12″on center for middle layer and No. 8 by $2^1/_4''$ spaced 12″ on center for outer layer.	—	$1^7/_8$	—	—
	1-8.1	Wood-fibered gypsum plaster mixed 1:1 by weight gypsum-to-sand aggregate applied over metal lath. Lath lapped 1″ and tied 6″ on center at all end, edges and spacers with 0.049″ (No. 18 B.W. gage) steel tie wires. Lath applied over $^1/_2''$ spacers made of $^3/_4''$ furring channel with 2″ legs bent around each corner. Spacers located 1″ from top and bottom of member and a maximum of 40″ on center and wire tied with a single strand of 0.049″ (No. 18 B.W. gage) steel tie wires. Corner bead tied to the lath at 6″ on center along each corner to provide plaster thickness.	—	—	$1^5/_8$	—
2. Webs or flanges of steel beams and girders	2-1.1	Carbonate, lightweight and sand-lightweight aggregate concrete (not including sandstone, granite and siliceous gravel) with 3″ or finer metal mesh placed 1″ from the finished surface anchored to the top flange and providing not less than 0.025 square inch of steel area per foot in each direction.	2	$1^1/_2$	1	1
	2-1.2	Siliceous aggregate concrete and concrete excluded in Item 2-1.1 with 3″ or finer metal mesh placed 1″ from the finished surface anchored to the top flange and providing not less than 0.025 square inch of steel area per foot in each direction.	$2^1/_2$	2	$1^1/_2$	1
	2-2.1	Cement plaster on metal lath attached to $^3/_4''$ cold-rolled channels with 0.049″ (No. 18 B.W. gage) wire ties spaced 3″ to 6″ on center. Plaster mixed 1:2 $^1/_2$ by volume, cement to sand.	—	—	$2^1/_2^b$	$^7/_8$
	2-3.1	Vermiculite gypsum plaster on a metal lath cage, wire tied to 0.165″ diameter (No. 8 B.W. gage) steel wire hangers wrapped around beam and spaced 16″ on center. Metal lath ties spaced approximately 5″ on center at cage sides and bottom.	—	$^7/_8$	—	—

(continued)

TABLE 720.1(1)—continued
MINIMUM PROTECTION OF STRUCTURAL PARTS BASED ON TIME PERIODS
FOR VARIOUS NONCOMBUSTIBLE INSULATING MATERIALS[m]

STRUCTURAL PARTS TO BE PROTECTED	ITEM NUMBER	INSULATING MATERIAL USED	MINIMUM THICKNESS OF INSULATING MATERIAL FOR THE FOLLOWING FIRE-RESISTANCE PERIODS (inches)			
			4 hour	3 hour	2 hour	1 hour
2. Webs or flanges of steel beams and girders (continued)	2-4.1	Two layers of $5/8''$ Type X gypsum wallboard[c] are attached to U-shaped brackets spaced 24" on center. 0.018" thick (No. 25 carbon sheet steel gage) $1^5/8''$ deep by 1" galvanized steel runner channels are first installed parallel to and on each side of the top beam flange to provide a $1/2''$ clearance to the flange. The channel runners are attached to steel deck or concrete floor construction with approved fasteners spaced 12" on center. U-shaped brackets are formed from members identical to the channel runners. At the bent portion of the U-shaped bracket, the flanges of the channel are cut out so that $1^5/8''$ deep corner channels can be inserted without attachment parallel to each side of the lower flange. As an alternate, 0.021" thick (No. 24 carbon sheet steel gage) $1'' \times 2''$ runner and corner angles may be used in lieu of channels, and the web cutouts in the U-shaped brackets may be omitted. Each angle is attached to the bracket with $1/2''$-long No. 8 self-drilling screws. The vertical legs of the U-shaped bracket are attached to the runners with one $1/2''$ long No. 8 self-drilling screw. The completed steel framing provides a $2^1/8''$ and $1^1/2''$ space between the inner layer of wallboard and the sides and bottom of the steel beam, respectively. The inner layer of wallboard is attached to the top runners and bottom corner channels or corner angles with $1^1/4''$-long No. 6 self-drilling screws spaced 16" on center. The outer layer of wallboard is applied with $1^3/4''$-long No. 6 self-drilling screws spaced 8" on center. The bottom corners are reinforced with metal corner beads.	—	—	$1^1/4$	—
	2-4.2	Three layers of $5/8''$ Type X gypsum wallboard[c] attached to a steel suspension system as described immediately above utilizing the 0.018" thick (No. 25 carbon sheet steel gage) $1'' \times 2''$ lower corner angles. The framing is located so that a $2^1/8''$ and 2" space is provided between the inner layer of wallboard and the sides and bottom of the beam, respectively. The first two layers of wallboard are attached as described immediately above. A layer of 0.035" thick (No. 20 B.W. gage) 1" hexagonal galvanized wire mesh is applied under the soffit of the middle layer and up the sides approximately 2". The mesh is held in position with the No. 6 $1^5/8''$-long screws installed in the vertical leg of the bottom corner angles. The outer layer of wallboard is attached with No. 6 $2^1/4''$-long screws spaced 8" on center. One screw is also installed at the mid-depth of the bracket in each layer. Bottom corners are finished as described above.	—	$1^7/8$	—	—
3. Bonded pretensioned reinforcement in prestressed concrete[e]	3-1.1	Carbonate, lightweight, sand-lightweight and siliceous[f] aggregate concrete Beams or girders Solid slabs[h]	4^g	3^g 2	$2^1/2$ $1^1/2$	$1^1/2$ 1

4. Bonded or unbonded post-tensioned tendons in prestressed concrete[e, i]	4-1.1	Carbonate, lightweight, sand-lightweight and siliceous[f] aggregate concrete
		Unrestrained members:
		   Solid slabs[h]
		   Beams and girders[j]
		     8" wide
		     greater than 12" wide
			—
			
			3
				2
				
				$4^1/2$
				$2^1/2$
					$1^1/2$
					
					$2^1/2$
					2
						—
						
						$1^3/4$
						$1^1/2$

	4-1.2	Carbonate, lightweight, sand-lightweight and siliceous aggregate
		Restrained members:[k]
		   Solid slabs[h]
		   Beams and girders[j]
		     8" wide
		     greater than 12" wide
			$1^1/4$
			
			$2^1/2$
			2
				1
				
				2
				$1^3/4$
					$3/4$
					
					$1^3/4$
					$1^1/2$
						—
						
						—
						—

(continued)

TABLE 720.1(1)—continued
MINIMUM PROTECTION OF STRUCTURAL PARTS BASED ON TIME PERIODS
FOR VARIOUS NONCOMBUSTIBLE INSULATING MATERIALS[m]

STRUCTURAL PARTS TO BE PROTECTED	ITEM NUMBER	INSULATING MATERIAL USED	MINIMUM THICKNESS OF INSULATING MATERIAL FOR THE FOLLOWING FIRE-RESISTANCE PERIODS (inches)			
			4 hour	3 hour	2 hour	1 hour
5. Reinforcing steel in reinforced concrete columns, beams girders and trusses	5-1.1	Carbonate, lightweight and sand-lightweight aggregate concrete, members 12″ or larger, square or round. (Size limit does not apply to beams and girders monolithic with floors.)	$1^1/_2$	$1^1/_2$	$1^1/_2$	$1^1/_2$
		Siliceous aggregate concrete, members 12″ or larger, square or round. (Size limit does not apply to beams and girders monolithic with floors.)	2	$1^1/_2$	$1^1/_2$	$1^1/_2$
6. Reinforcing steel in reinforced concrete joists[l]	6-1.1	Carbonate, lightweight and sand-lightweight aggregate concrete.	$1^1/_4$	$1^1/_4$	1	$^3/_4$
	6-1.2	Siliceous aggregate concrete.	$1^3/_4$	$1^1/_2$	1	$^3/_4$
7. Reinforcing and tie rods in floor and roof slabs[l]	7-1.1	Carbonate, lightweight and sand-lightweight aggregate concrete.	1	1	$^3/_4$	$^3/_4$
	7-1.2	Siliceous aggregate concrete.	$1^1/_4$	1	1	$^3/_4$

For SI: 1 inch = 25.4 mm, 1 square inch = 645.2 mm^2, 1 cubic foot = 0.0283 m^3.

a. Reentrant parts of protected members to be filled solidly.

b. Two layers of equal thickness with a $^3/_4$-inch airspace between.

c. For all of the construction with gypsum wallboard described in Table 720.1(1), gypsum base for veneer plaster of the same size, thickness and core type shall be permitted to be substituted for gypsum wallboard, provided attachment is identical to that specified for the wallboard and the joints on the face layer are reinforced, and the entire surface is covered with a minimum of $^1/_{16}$-inch gypsum veneer plaster.

d. An approved adhesive qualified under ASTM E 119.

e. Where lightweight or sand-lightweight concrete having an oven-dry weight of 110 pounds per cubic foot or less is used, the tabulated minimum cover shall be permitted to be reduced 25 percent, except that in no case shall the cover be less than $^3/_4$ inch in slabs or $1^1/_2$ inches in beams or girders.

f. For solid slabs of siliceous aggregate concrete, increase tendon cover 20 percent.

g. Adequate provisions against spalling shall be provided by U-shaped or hooped stirrups spaced not to exceed the depth of the member with a clear cover of 1 inch.

h. Prestressed slabs shall have a thickness not less than that required in Table 720.1(3) for the respective fire resistance time period.

i. Fire coverage and end anchorages shall be as follows: Cover to the prestressing steel at the anchor shall be $^1/_2$ inch greater than that required away from the anchor. Minimum cover to steel-bearing plate shall be 1 inch in beams and $^3/_4$ inch in slabs.

j. For beam widths between 8 inches and 12 inches, cover thickness shall be permitted to be determined by interpolation.

k. Interior spans of continuous slabs, beams and girders shall be permitted to be considered restrained.

l. For use with concrete slabs having a comparable fire endurance where members are framed into the structure in such a manner as to provide equivalent performance to that of monolithic concrete construction.

m. Generic fire-resistance ratings (those not designated as PROPRIETARY* in the listing) in GA 600 shall be accepted as if herein listed.

TABLE 720.1(2)
RATED FIRE-RESISTANCE PERIODS FOR VARIOUS WALLS AND PARTITIONS [a,o,p]

MATERIAL	ITEM NUMBER	CONSTRUCTION	MINIMUM FINISHED THICKNESS FACE-TO-FACE[b] (inches)			
			4 hour	3 hour	2 hour	1 hour
1. Brick of clay or shale	1-1.1	Solid brick of clay or shale[c]	6	4.9	3.8	2.7
	1-1.2	Hollow brick, not filled.	5.0	4.3	3.4	2.3
	1-1.3	Hollow brick unit wall, grout or filled with perlite vermiculite or expanded shale aggregate.	6.6	5.5	4.4	3.0
	1-2.1	4″ nominal thick units at least 75 percent solid backed with a hat-shaped metal furring channel $^3/_4$″ thick formed from 0.021″ sheet metal attached to the brick wall on 24″ centers with approved fasteners, and $^1/_2$″ Type X gypsum wallboard attached to the metal furring strips with 1″-long Type S screws spaced 8″ on center.	—	—	5[d]	—
2. Combination of clay brick and load-bearing hollow clay tile	2-1.1	4″ solid brick and 4″ tile (at least 40 percent solid).	—	8	—	—
	2-1.2	4″ solid brick and 8″ tile (at least 40 percent solid).	12	—	—	—
3. Concrete masonry units	3-1.1[f,g]	Expanded slag or pumice.	4.7	4.0	3.2	2.1
	3-1.2[f,g]	Expanded clay, shale or slate.	5.1	4.4	3.6	2.6
	3-1.3[f]	Limestone, cinders or air-cooled slag.	5.9	5.0	4.0	2.7
	3-1.4[f,g]	Calcareous or siliceous gravel.	6.2	5.3	4.2	2.8
4. Solid concrete[h,i]	4-1.1	Siliceous aggregate concrete.	7.0	6.2	5.0	3.5
		Carbonate aggregate concrete.	6.6	5.7	4.6	3.2
		Sand-lightweight concrete.	5.4	4.6	3.8	2.7
		Lightweight concrete.	5.1	4.4	3.6	2.5
5. Glazed or unglazed facing tile, nonload-bearing	5-1.1	One 2″ unit cored 15 percent maximum and one 4″ unit cored 25 percent maximum with $^3/_4$″ mortar-filled collar joint. Unit positions reversed in alternate courses.	—	$6^3/_8$	—	—
	5-1.2	One 2″ unit cored 15 percent maximum and one 4″ unit cored 40 percent maximum with $^3/_4$″ mortar-filled collar joint. Unit positions side with $^3/_4$″ gypsum plaster. Two wythes tied together every fourth course with No. 22 gage corrugated metal ties.	—	$6^3/_4$	—	—
	5-1.3	One unit with three cells in wall thickness, cored 29 percent maximum.	—	—	6	—
	5-1.4	One 2″ unit cored 22 percent maximum and one 4″ unit cored 41 percent maximum with $^1/_4$″ mortar-filled collar joint. Two wythes tied together every third course with 0.030″ (No. 22 galvanized sheet steel gage) corrugated metal ties.	—	—	6	—
	5-1.5	One 4″ unit cored 25 percent maximum with $^3/_4$″ gypsum plaster on one side.	—	—	$4^3/_4$	—
	5-1.6	One 4″ unit with two cells in wall thickness, cored 22 percent maximum.	—	—	—	4
	5-1.7	One 4″ unit cored 30 percent maximum with $^3/_4$″ vermiculite gypsum plaster on one side.	—	—	$4^1/_2$	—
	5-1.8	One 4″ unit cored 39 percent maximum with $^3/_4$″ gypsum plaster on one side.	—	—	—	$4^1/_2$

(continued)

TABLE 720.1(2)—continued
RATED FIRE-RESISTANCE PERIODS FOR VARIOUS WALLS AND PARTITIONS [a,o,p]

MATERIAL	ITEM NUMBER	CONSTRUCTION	MINIMUM FINISHED THICKNESS FACE-TO-FACE[b] (inches)			
			4 hour	3 hour	2 hour	1 hour
6. Solid gypsum plaster	6-1.1	$^3/_4''$ by 0.055" (No. 16 carbon sheet steel gage) vertical cold-rolled channels, 16" on center with 2.6-pound flat metal lath applied to one face and tied with 0.049" (No. 18 B.W. Gage) wire at 6" spacing. Gypsum plaster each side mixed 1:2 by weight, gypsum to sand aggregate.	—	—	—	2^d
	6-1.2	$^3/_4''$ by 0.055" (No. 16 carbon sheet steel gage) cold-rolled channels 16" on center with metal lath applied to one face and tied with 0.049" (No. 18 B.W. gage) wire at 6" spacing. Perlite or vermiculite gypsum plaster each side. For three-coat work, the plaster mix for the second coat shall not exceed 100 pounds of gypsum to $2^1/_2$ cubic feet of aggregate for the 1-hour system.	—	—	$2^1/_2{}^d$	2^d
	6-1.3	$^3/_4''$ by 0.055" (No. 16 carbon sheet steel gage) vertical cold-rolled channels, 16" on center with $^3/_8''$ gypsum lath applied to one face and attached with sheet metal clips. Gypsum plaster each side mixed 1:2 by weight, gypsum to sand aggregate.	—	—	—	2^d
	6-2.1	Studless with $^1/_2''$ full-length plain gypsum lath and gypsum plaster each side. Plaster mixed 1:1 for scratch coat and 1:2 for brown coat, by weight, gypsum to sand aggregate.	—	—	—	2^d
	6-2.2	Studless with $^1/_2''$ full-length plain gypsum lath and perlite or vermiculite gypsum plaster each side.	—	—	$2^1/_2{}^d$	2^d
	6-2.3	Studless partition with $^3/_8''$ rib metal lath installed vertically adjacent edges tied 6" on center with No. 18 gage wire ties, gypsum plaster each side mixed 1:2 by weight, gypsum to sand aggregate.	—	—	—	2^d
7. Solid perlite and portland cement	7-1.1	Perlite mixed in the ratio of 3 cubic feet to 100 pounds of portland cement and machine applied to stud side of $1^1/_2''$ mesh by 0.058-inch (No. 17 B.W. gage) paper-backed woven wire fabric lath wire-tied to 4"-deep steel trussed wire[j] studs 16" on center. Wire ties of 0.049" (No. 18 B.W. gage) galvanized steel wire 6" on center vertically.	—	—	$3^1/_8{}^d$	—
8. Solid neat wood fibered gypsum plaster	8-1.1	$^3/_4''$ by 0.055-inch (No. 16 carbon sheet steel gage) cold-rolled channels, 12" on center with 2.5-pound flat metal lath applied to one face and tied with 0.049" (No. 18 B.W. gage) wire at 6" spacing. Neat gypsum plaster applied each side.	—	—	2^d	—
9. Solid wallboard partition	9-1.1	One full-length layer $^1/_2''$ Type X gypsum wallboard[e] laminated to each side of 1" full-length V-edge gypsum coreboard with approved laminating compound. Vertical joints of face layer and coreboard staggered at least 3".	—	—	2^d	—
10. Hollow (studless) gypsum wallboard partition	10-1.1	One full-length layer of $^5/_8''$ Type X gypsum wallboard[e] attached to both sides of wood or metal top and bottom runners laminated to each side of 1" × 6" full-length gypsum coreboard ribs spaced 24" on center with approved laminating compound. Ribs centered at vertical joints of face plies and joints staggered 24" in opposing faces. Ribs may be recessed 6" from the top and bottom.	—	—	—	$2^1/_4{}^d$
	10-1.2	1" regular gypsum V-edge full-length backing board attached to both sides of wood or metal top and bottom runners with nails or $1^5/_8''$ drywall screws at 24" on center. Minimum width of runors $1^5/_8''$. Face layer of $^1/_2''$ regular full-length gypsum wallboard laminated to outer faces of backing board with approved laminating compound.	—	—	$4^5/_8{}^d$	—

(continued)

TABLE 720.1(2)—continued
RATED FIRE-RESISTANCE PERIODS FOR VARIOUS WALLS AND PARTITIONS [a,o,p]

MATERIAL	ITEM NUMBER	CONSTRUCTION	MINIMUM FINISHED THICKNESS FACE-TO-FACE[b] (inches)			
			4 hour	3 hour	2 hour	1 hour
11. Noncombustible studs—interior partition with plaster each side	11-1.1	$3^{1}/_{4}'' \times 0.044''$ (No. 18 carbon sheet steel gage) steel studs spaced 24″ on center. $^{5}/_{8}''$ gypsum plaster on metal lath each side mixed 1:2 by weight, gypsum to sand aggregate.	—	—	—	$4^{3}/_{4}$[d]
	11-1.2	$3^{3}/_{8}'' \times 0.055''$ (No. 16 carbon sheet steel gage) approved nailable[k] studs spaced 24" on center. $^{5}/_{8}''$ neat gypsum wood-fibered plaster each side over $^{3}/_{8}''$ rib metal lath nailed to studs with 6d common nails, 8″ on center. Nails driven $1^{1}/_{4}''$ and bent over.	—	—	$5^{5}/_{8}$	—
	11-1.3	$4'' \times 0.044''$ (No. 18 carbon sheet steel gage) channel-shaped steel studs at 16″ on center. On each side approved resilient clips pressed onto stud flange at 16″ vertical spacing, $^{1}/_{4}''$ pencil rods snapped into or wire tied onto outer loop of clips, metal lath wire-tied to pencil rods at 6″ intervals, 1″ perlite gypsum plaster, each side.	—	$7^{5}/_{8}$[d]	—	—
	11-1.4	$2^{1}/_{2}'' \times 0.044''$ (No. 18 carbon sheet steel gage) steel studs spaced 16″ on center. Wood fibered gypsum plaster mixed 1:1 by weight gypsum to sand aggregate applied on $^{3}/_{4}$-pound metal lath wire tied to studs, each side. $^{3}/_{4}''$ plaster applied over each face, including finish coat.	—	—	$4^{1}/_{4}$[d]	—
12. Wood studs interior partition with plaster each side	12-1.1[l, m]	$2'' \times 4''$ wood studs 16″ on center with $^{5}/_{8}''$ gypsum plaster on metal lath. Lath attached by 4d common nails bent over or No. 14 gage by $1^{1}/_{4}''$ by $^{3}/_{4}''$ crown width staples spaced 6″ on center. Plaster mixed $1:1^{1}/_{2}$ for scratch coat and 1:3 for brown coat, by weight, gypsum to sand aggregate.	—	—	—	$5^{1}/_{8}$
	12-1.2[l]	$2'' \times 4''$ wood studs 16″ on center with metal lath and $^{7}/_{8}''$ neat wood-fibered gypsum plaster each side. Lath attached by 6d common nails, 7″ on center. Nails driven $1^{1}/_{4}''$ and bent over.	—	—	$5^{1}/_{2}$[d]	—
	12-1.3[l]	$2'' \times 4''$ wood studs 16″ on center with $^{3}/_{8}''$ perforated or plain gypsum lath and $^{1}/_{2}''$ gypsum plaster each side. Lath nailed with $1^{1}/_{8}''$ by No. 13 gage by $^{19}/_{64}''$ head plasterboard blued nails, 4″ on center. Plaster mixed 1:2 by weight, gypsum to sand aggregate.	—	—	—	$5^{1}/_{4}$
	12-1.4[l]	$2'' \times 4''$ wood studs 16″ on center with $^{3}/_{8}''$ Type X gypsum lath and $^{1}/_{2}''$ gypsum plaster each side. Lath nailed with $1^{1}/_{8}''$ by No. 13 gage by $^{19}/_{64}''$ head plasterboard blued nails, 5″ on center. Plaster mixed 1:2 by weight, gypsum to sand aggregate.	—	—	—	$5^{1}/_{4}$
13.Noncumbustible studs—interior partition with gypsum wallboard each side	13-1.1	0.018″ (No. 25 carbon sheet steel gage) channel-shaped studs 24″ on center with one full-length layer of $^{5}/_{8}''$ Type X gypsum wallboard[e] applied vertically attached with 1″ long No. 6 drywall screws to each stud. Screws are 8″ on center around the perimeter and 12″ on center on the intermediate stud. The wallboard may be applied horizontally when attached to $3^{5}/_{8}''$ studs and the horizontal joints are staggered with those on the opposite side. Screws for the horizontal application shall be 8″ on center at vertical edges and 12″ on center at intermediate studs.	—	—	—	$2^{7}/_{8}$[d]
	13-1.2	0.018″ (No. 25 carbon sheet steel gage) channel-shaped studs 25″ on center with two full-length layers of $^{1}/_{2}''$ Type X gypsum wallboard[e] applied vertically each side. First layer attached with 1″-long, No. 6 drywall screws, 8″ on center around the perimeter and 12″ on center on the intermediate stud. Second layer applied with vertical joints offset one stud space from first layer using $1^{5}/_{8}''$ long, No. 6 drywall screws spaced 9″ on center along vertical joints, 12″ on center at intermediate studs and 24″ on center along top and bottom runners.	—	—	$3^{5}/_{8}$[d]	—
	13-1.3	0.055″ (No. 16 carbon sheet steel gage) approved nailable metal studs[e] 24″ on center with full-length $^{5}/_{8}''$ Type X gypsum wallboard[e] applied vertically and nailed 7″ on center with 6d cement-coated common nails. Approved metal fastener grips used with nails at vertical butt joints along studs.	—	—	—	$4^{7}/_{8}$

(continued)

TABLE 720.1(2)—continued
RATED FIRE-RESISTANCE PERIODS FOR VARIOUS WALLS AND PARTITIONS [a,o,p]

MATERIAL	ITEM NUMBER	CONSTRUCTION	MINIMUM FINISHED THICKNESS FACE-TO-FACE[b] (inches)			
			4 hour	3 hour	2 hour	1 hour
14. Wood studs—interior partition with gypsum wallboard each side	14-1.1[h,m]	$2'' \times 4''$ wood studs $16''$ on center with two layers of $3/8''$ regular gypsum wallboard[e] each side, 4d cooler[n] or wallboard[n] nails at $8''$ on center first layer, 5d cooler[n] or wallboard[n] nails at $8''$ on center second layer with laminating compound between layers, joints staggered. First layer applied full length vertically, second layer applied horizontally or vertically	—	—	—	5
	14-1.2[l,m]	$2'' \times 4''$ wood studs $16''$ on center with two layers $1/2''$ regular gypsum wallboard[e] applied vertically or horizontally each side[k], joints staggered. Nail base layer with 5d cooler[n] or wallboard[n] nails at $8''$ on center face layer with 8d cooler[n] or wallboard[n] nails at $8''$ on center.	—	—	—	$5^1/_2$
	14-1.3[l,m]	$2'' \times 4''$ wood studs $24''$ on center with $5/8''$ Type X gypsum wallboard[e] applied vertically or horizontally nailed with 6d cooler[n] or wallboard[n] nails at $7''$ on center with end joints on nailing members. Stagger joints each side.	—	—	—	$4^3/_4$
	14-1.4[l]	$2'' \times 4''$ fire-retardant-treated wood studs spaced $24''$ on center with one layer of $5/8''$ Type X gypsum wallboard[e] applied with face paper grain (long dimension) parallel to studs. Wallboard attached with 6d cooler[n] or wallboard[n] nails at $7''$ on center.	—	—	—	$4^3/_4$[d]
	14-1.5[l,m]	$2'' \times 4''$ wood studs $16''$ on center with two layers $5/8''$ Type X gypsum wallboard[e] each side. Base layers applied vertically and nailed with 6d cooler[n] or wallboard[n] nails at $9''$ on center. Face layer applied vertically or horizontally and nailed with 8d cooler[n] or wallboard[n] nails at $7''$ on center. For nail-adhesive application, base layers are nailed $6''$ on center. Face layers applied with coating of approved wallboard adhesive and nailed $12''$ on center.	—	—	6	—
	14-1.6[l]	$2'' \times 3''$ fire-retardant-treated wood studs spaced $24''$ on center with one layer of $5/8''$ Type X gypsum wallboard[e] applied with face paper grain (long dimension) at right angles to studs. Wallboard attached with 6d cement-coated box nails spaced $7''$ on center.	—	—	—	$3^5/_8$[d]
15. Exterior or interior walls	15-1.1[l,m]	Exterior surface with $3/4''$ drop siding over $1/2''$ gypsum sheathing on $2'' \times 4''$ wood studs at $16''$ on center, interior surface treatment as required for 1-hour-rated exterior or interior $2'' \times 4''$ wood stud partitions. Gypsum sheathing nailed with $1^3/_4''$ by No. 11 gage by $7/_{16}''$ head galvanized nails at $8''$ on center. Siding nailed with 7d galvanized smooth box nails.	—	—	—	Varies
	15-1.2[l,m]	$2'' \times 4''$ wood studs $16''$ on center with metal lath and $3/4''$ cement plaster on each side. Lath attached with 6d common nails $7''$ on center driven to $1''$ minimum penetration and bent over. Plaster mix 1:4 for scratch coat and 1:5 for brown coat, by volume, cement to sand.	—	—	—	$5^3/_8$
	15-1.3[l,m]	$2'' \times 4''$ wood studs $16''$ on center with $7/8''$ cement plaster (measured from the face of studs) on the exterior surface with interior surface treatment as required for interior wood stud partitions in this table. Plaster mix 1:4 for scratch coat and 1:5 for brown coat, by volume, cement to sand.	—	—	—	Varies
	15-1.4	$3^5/_8''$ No. 16 gage noncombustible studs $16''$ on center with $7/8''$ cement plaster (measured from the face of the studs) on the exterior surface with interior surface treatment as required for interior, nonbearing, noncombustible stud partitions in this table. Plaster mix 1:4 for scratch coat and 1:5 for brown coat, by volume, cement to sand.	—	—	—	Varies[d]

(continued)

TABLE 720.1(2)—continued
RATED FIRE-RESISTANCE PERIODS FOR VARIOUS WALLS AND PARTITIONS [a,o,p]

MATERIAL	ITEM NUMBER	CONSTRUCTION	MINIMUM FINISHED THICKNESS FACE-TO-FACE[b] (inches)			
			4 hour	3 hour	2 hour	1 hour
15. Exterior or interior walls (continued)	15-1.5[m]	$2^{1}/_{4}'' \times 3^{3}/_{4}''$ clay face brick with cored holes over $^{1}/_{2}''$ gypsum sheathing on exterior surface of $2'' \times 4''$ wood studs at $16''$ on center and two layers $^{5}/_{8}''$ Type X gypsum wallboard[e] on interior surface. Sheathing placed horizontally or vertically with vertical joints over studs nailed $6''$ on center with $1^{3}/_{4}'' \times$ No. 11 gage by $^{7}/_{16}''$ head galvanized nails. Inner layer of wallboard placed horizontally or vertically and nailed $8''$ on center with 6d cooler[n] or wallboard[n] nails. Outer layer of wallboard placed horizontally or vertically and nailed $8''$ on center with 8d cooler[n] or wallboard[n] nails. All joints staggered with vertical joints over studs. Outer layer joints taped and finished with compound. Nail heads covered with joint compound. 0.035 inch (No. 20 galvanized sheet gage) corrugated galvanized steel wall ties $^{3}/_{4}''$ by $6^{5}/_{8}''$ attached to each stud with two 8d cooler[n] or wallboard[n] nails every sixth course of bricks.	—	—	10	—
	15-1.6[l, m]	$2'' \times 6''$ fire-retardant-treated wood studs $16''$ on center. Interior face has two layers of $^{5}/_{8}''$ Type X gypsum with the base layer placed vertically and attached with 6d box nails $12''$ on center. The face layer is placed horizontally and attached with 8d box nails 8" on center at joints and $12''$ on center elsewhere. The exterior face has a base layer of $^{5}/_{8}''$ Type X gypsum sheathing placed vertically with 6d box nails $8''$ on center at joints and $12''$ on center elsewhere. An approved building paper is next applied, followed by self-furred exterior lath attached with $2^{1}/_{2}''$, No. 12 gage galvanized roofing nails with a $^{3}/_{8}''$ diameter head and spaced $6''$ on center along each stud. Cement plaster consisting of a $^{1}/_{2}''$ brown coat is then applied. The scratch coat is mixed in the proportion of 1:3 by weight, cement to sand with 10 pounds of hydrated lime and 3 pounds of approved additives or admixtures per sack of cement. The brown coat is mixed in the proportion of 1:4 by weight, cement to sand with the same amounts of hydrated lime and approved additives or admixtures used in the scratch coat.	—	—	$8^{1}/_{4}$	—
	15-1.7[l, m]	$2'' \times 6''$ wood studs $16''$ on center. The exterior face has a layer of $^{5}/_{8}''$ Type X gypsum sheathing placed vertically with 6d box nails $8''$ on center at joints and $12''$ on center elsewhere. An approved building paper is next applied, followed by $1''$ by No. 18 gage self-furred exterior lath attached with 8d by $2^{1}/_{2}''$ long galvanized roofing nails spaced $6''$ on center along each stud. Cement plaster consisting of a $^{1}/_{2}''$ scratch coat, a bonding agent and a $^{1}/_{2}''$ brown coat and a finish coat is then applied. The scratch coat is mixed in the proportion of 1:3 by weight, cement to sand with 10 pounds of hydrated lime and 3 pounds of approved additives or admixtures per sack of cement. The brown coat is mixed in the proportion of 1:4 by weight, cement to sand with the same amounts of hydrated lime and approved additives or admixtures used in the scratch coat. The interior is covered with $^{3}/_{8}''$ gypsum lath with $1''$ hexagonal mesh of 0.035 inch (No. 20 B.W. gage) woven wire lath furred out $^{5}/_{16}''$ and $1''$ perlite or vermiculite gypsum plaster. Lath nailed with $1^{1}/_{8}''$ by No. 13 gage by $^{19}/_{64}''$ head plasterboard glued nails spaced $5''$ on center. Mesh attached by $1^{3}/_{4}''$ by No. 12 gage by $^{3}/_{8}''$ head nails with $^{3}/_{8}''$ furrings, spaced $8''$ on center. The plaster mix shall not exceed 100 pounds of gypsum to $2^{1}/_{2}$ cubic feet of aggregate.	—	—	$8^{3}/_{8}$	—
	15-1.8[l, m]	$2'' \times 6''$ wood studs $16''$ on center. The exterior face has a layer of $^{5}/_{8}''$ Type X gypsum sheathing placed vertically with 6d box nails $8''$ on center at joints and $12''$ on center elsewhere. An approved building paper is next applied, followed by $1^{1}/_{2}''$ by No. 17 gage self-furred exterior lath attached with 8d by $2^{1}/_{2}''$ long galvanized roofing nails spaced $6''$ on center along each stud. Cement plaster consisting of a $^{1}/_{2}''$ scratch coat, and a $^{1}/_{2}''$ brown coat is then applied. The plaster may be placed by machine. The scratch coat is mixed in the proportion of 1:4 by weight, plastic cement to sand. The brown coat is mixed in the proportion of 1:5 by weight, plastic cement to sand. The interior is covered with $^{3}/_{8}''$ gypsum lath with $1''$ hexagonal mesh of No. 20 gage woven wire lath furred out $^{5}/_{16}''$ and $1''$ perlite or vermiculite gypsum plaster. Lath nailed with $1^{1}/_{8}''$ by No. 13 gage by $^{19}/_{64}''$ head plasterboard glued nails spaced $5''$ on center. Mesh attached by $1^{3}/_{4}''$ by No. 12 gage by $^{3}/_{8}''$ head nails with $^{3}/_{8}''$ furrings, spaced $8''$ on center. The plaster mix shall not exceed 100 pounds of gypsum to $2^{1}/_{2}$ cubic feet of aggregate.	—	—	$8^{3}/_{8}$	—

(continued)

TABLE 720.1(2)—continued
RATED FIRE-RESISTANCE PERIODS FOR VARIOUS WALLS AND PARTITIONS [a,o,p]

MATERIAL	ITEM NUMBER	CONSTRUCTION	MINIMUM FINISHED THICKNESS FACE-TO-FACE[b] (inches)			
			4 hour	3 hour	2 hour	1 hour
15. Exterior or interior walls (continued)	15-1.9	4″ No. 18 gage, nonload-bearing metal studs, 16″ on center, with 1″ portland cement lime plaster [measured from the back side of the $^3/_4$-pound expanded metal lath] on the exterior surface. Interior surface to be covered with 1″ of gypsum plaster on $^3/_4$-pound expanded metal lath proportioned by weight—1:2 for scratch coat, 1:3 for brown, gypsum to sand. Lath on one side of the partition fastened to $^1/_4$″ diameter pencil rods supported by No. 20 gage metal clips, located 16" on center vertically, on each stud. 3″ thick mineral fiber insulating batts friction fitted between the studs.	—	—	$6^1/_2$[d]	—
	15-1.10	Steel studs 0.060" thick, 4″ deep or 6" at 16" or 24″ centers, with $^1/_2$″ Glass Fiber Reinforced Concrete (GFRC) on the exterior surface. GFRC is attached with flex anchors at 24″ on center, with 5″ leg welded to studs with two $^1/_2$″-long flare-bevel welds, and 4″ foot attached to the GFRC skin with $^5/_8$″ thick GFRC bonding pads that extend $2^1/_2$″ beyond the flex anchor foot on both sides. Interior surface to have two layers of $^1/_2$″ Type X gypsum wallboard.[e] The first layer of wallboard to be attached with 1″-long Type S buglehead screws spaced 24″ on center and the second layer is attached with $1^5/_8$″-long Type S screws spaced at 12″ on center. Cavity is to be filled with 5″ of 4 pcf (nominal) mineral fiber batts. GFRC has $1^1/_2$″ returns packed with mineral fiber and caulked on the exterior.	—	—	$6^1/_2$	—
	15-1.11	Steel studs 0.060″ thick, 4″ deep or 6″ at 16″ or 24″ centers, respectively, with $^1/_2$″ Glass Fiber Reinforced Concrete (GFRC) on the exterior surface. GFRC is attached with flex anchors at 24″ on center, with 5″ leg welded to studs with two $^1/_2$″-long flare-bevel welds, and 4″ foot attached to the GFRC skin with $^5/_8$″-thick GFRC bonding pads that extend $2^1/_2$″ beyond the flex anchor foot on both sides. Interior surface to have one layer of $^5/_8$″ Type X gypsum wallboard[e], attached with $1^1/_4$″-long Type S buglehead screws spaced 12″ on center. Cavity is to be filled with 5″ of 4 pcf (nominal) mineral fiber batts. GFRC has $1^1/_2$″ returns packed with mineral fiber and caulked on the exterior.	—	—	—	$6^1/_8$
	15-1.12[q]	2″ × 6″ wood studs at 16″ with double top plates, single bottom plate; interior and exterior sides covered with $^5/_8$″ Type X gypsum wallboard, 4′ wide, applied horizontally or vertically with vertical joints over studs, and fastened with $2^1/_4$″ Type S drywall screws, spaced 12″ on center. Cavity filled with $5^1/_2$″ mineral wool insulation.	—	—	—	$6^3/_4$
	15-1.13[q]	2″ × 6″ wood studs at 16″ with double top plates, single bottom plate; interior and exterior sides covered with $^5/_8$″ Type X gypsum wallboard, 4′ wide, applied horizontally or vertically with vertical joints over studs, and fastened with $2^1/_4$″ Type S drywall screws, spaced 7″ on center. Cavity to be filled with $5^1/_2$″ mineral wool insulation minimum 2.58 pcf (nominal).	—	—	—	$6^3/_4$
	15-1.14[q]	2″ × 4″ wood studs at 16″ with double top plates, single bottom plate; interior and exterior sides covered with $^5/_8$″ Type X gypsum wallboard and sheathing, respectively, 4′ wide, applied horizontally or vertically with vertical joints over studs, and fastened with $2^1/_4$″ Type S drywall screws, spaced 12″ on center. Cavity to be filled with $3^1/_2$″ mineral wool insulation.	—	—	—	$4^3/_4$
	15-1.15[q]	2″ × 4″ wood studs at 16″ with double top plates, single bottom plate; interior sides covered with $^5/_8$″ Type X gypsum wallboard, 4′ wide, applied horizontally unblocked, and fastened with $2^1/_4$″ Type S drywall screws, spaced 12″ on center, wallboard joints covered with paper tape and joint compound, fastener heads covered with joint compound. Exterior covered with $^3/_8$″ wood structural panels (oriented strand board), applied vertically, horizontal joints blocked and fastened with 6d common nails (bright)—12″ on center in the field, 6″ on center panel edges. Cavity to be filled with $3^1/_2$″ mineral wool insulation. Rating established for exposure from interior side only.	—	—	—	$4^1/_2$

(continued)

TABLE 720.1(2)—continued
RATED FIRE-RESISTANCE PERIODS FOR VARIOUS WALLS AND PARTITIONS [a,o,p]

MATERIAL	ITEM NUMBER	CONSTRUCTION	MINIMUM FINISHED THICKNESS FACE-TO-FACE[b] (inches)			
			4 hour	3 hour	2 hour	1 hour
15. Exterior or interior walls (continued)	15-1.16[q]	2" × 6" (51mm x 152 mm) wood studs at 16 " centers with double top plates, single bottom plate; interior side covered with $5/8$" Type X gypsum wallboard, 4' wide, applied horizontally or vertically with vertical joints over studs and fastened with $2^1/4$" Type S drywall screws, spaced 12" on center, wallboard joints covered with paper tape and joint compound, fastener heads covered with joint compound, exterior side covered with $7/16$" wood structural panels (oriented strand board) fastened with 6d common nails (bright) spaced 12" on center in the field and 6" on center along the panel edges. Cavity to be filled with $5^1/2$" mineral wool insulation. Rating established from the gypsum-covered side only.	—	—	—	$6^9/16$
	15-1.17[q]	2" × 6" wood studs at 24" centers with double top plates, single bottom plate; interior and exterior side covered with two layers of $5/8$" Type X gypsum wallboard, 4' wide, applied horizontally with vertical joints over studs. Base layer fastened with $2^1/4$" Type S drywall screws, spaced 24" on center, and face layer fastened with Type S drywall screws, spaced 8" on center, wallboard joints covered with paper tape and joint compound, fastened heads covered with joint compound. Cavity to be filled with $5^1/2$" mineral wool insulation.	—	—	$7^3/4$	—
16. Exterior walls rated for fire resistance from the inside only in accordance with Section 704.5.	16-1.1[q]	2" × 4" wood studs at 16" centers with double top plates, single bottom plate; interior side covered with $5/8$" Type X gypsum wallboard, 4' wide, applied horizontally unblocked, and fastened with $2^1/4$" Type S drywall screws, spaced 12" on center, wallboard joints covered with paper tape and joint compound, fastener heads covered with joint compound. Exterior covered with $3/8$" wood structural panels (oriented strand board), applied vertically, horizontal joints blocked and fastened with 6d common nails (bright) — 12" on center in the field, and 6" on center panel edges. Cavity to be filled with $3^1/2$" mineral wool insulation. Rating established for exposure from interior side only.	—	—	—	$4^1/2$

For SI: 1 inch = 25.4 mm, 1 square inch = 645.2 mm^2, 1 cubic foot = 0.0283 m^3.

a. Staples with equivalent holding power and penetration shall be permitted to be used as alternate fasteners to nails for attachment to wood framing.

b. Thickness shown for brick and clay tile are nominal thicknesses unless plastered, in which case thicknesses are net. Thickness shown for concrete masonry and clay masonry is equivalent thickness defined in Section 721.3.1 for concrete masonry and Section 721.4.1.1 for clay masonry. Where all cells are solid grouted or filled with silicone-treated perlite loose-fill insulation; vermiculite loose-fill insulation; or expanded clay, shale or slate lightweight aggregate, the equivalent thickness shall be the thickness of the block or brick using specified dimensions as defined in Chapter 21. Equivalent thickness may also include the thickness of applied plaster and lath or gypsum wallboard, where specified.

c. For units in which the net cross-sectional area of cored brick in any plane parallel to the surface containing the cores is at least 75 percent of the gross cross-sectional area measured in the same plane.

d. Shall be used for nonbearing purposes only.

e. For all of the construction with gypsum wallboard described in this table, gypsum base for veneer plaster of the same size, thickness and core type shall be permitted to be substituted for gypsum wallboard, provided attachment is identical to that specified for the wallboard, and the joints on the face layer are reinforced and the entire surface is covered with a minimum of $1/16$-inch gypsum veneer plaster.

f. The fire-resistance time period for concrete masonry units meeting the equivalent thicknesses required for a 2-hour fire-resistance rating in Item 3, and having a thickness of not less than $7^5/8$ inches is 4 hours when cores which are not grouted are filled with silicone-treated perlite loose-fill insulation; vermiculite loose-fill insulation; or expanded clay, shale or slate lightweight aggregate, sand or slag having a maximum particle size of $3/8$ inch.

g. The fire-resistance rating of concrete masonry units composed of a combination of aggregate types or where plaster is applied directly to the concrete masonry shall be determined in accordance with ACI 216.1/TMS 216. Lightweight aggregates shall have a maximum combined density of 65 pounds per cubic foot.

h. See also Note b. The equivalent thickness shall be permitted to include the thickness of cement plaster or 1.5 times the thickness of gypsum plaster applied in accordance with the requirements of Chapter 25.

i. Concrete walls shall be reinforced with horizontal and vertical temperature reinforcement as required by Chapter 19.

j. Studs are welded truss wire studs with 0.18 inch (No. 7 B.W. gage) flange wire and 0.18 inch (No. 7 B.W. gage) truss wires.

k. Nailable metal studs consist of two channel studs spot welded back to back with a crimped web forming a nailing groove.

l. Wood structural panels shall be permitted to be installed between the fire protection and the wood studs on either the interior or exterior side of the wood frame assemblies in this table, provided the length of the fasteners used to attach the fire protection are increased by an amount at least equal to the thickness of the wood structural panel.

m. The design stress of studs shall be reduced to 78 percent of allowable F'_c with the maximum not greater than 78 percent of the calculated stress with studs having a slenderness ratio l/d of 33.

n. For properties of cooler or wallboard nails, see ASTM C 514, ASTM C 547 or ASTM F 1667.

o. Generic fire-resistance ratings (those not designated as PROPRIETARY* in the listing) in the GA 600 shall be accepted as if herein listed.

p. NCMA TEK 5-8, shall be permitted for the design of fire walls.

q. The design stress of studs shall be equal to a maximum of 100 percent of the allowable F'_c calculated in accordance with Section 2306.

TABLE 720.1(3)
MINIMUM PROTECTION FOR FLOOR AND ROOF SYSTEMS[a,q]

FLOOR OR ROOF CONSTRUCTION	ITEM NUMBER	CEILING CONSTRUCTION	THICKNESS OF FLOOR OR ROOF SLAB (inches)				MINIMUM THICKNESS OF CEILING (inches)			
			4 hour	3 hour	2 hour	1 hour	4 hour	3 hour	2 hour	1 hour
1. Siliceous aggregate concrete	1-1.1	Slab (no ceiling required). Minimum cover over nonprestressed reinforcement shall not be less than $^3/_4$ inch.[b]	7.0	6.2	5.0	3.5	—	—	—	—
2. Carbonate aggregate concrete	2-1.1		6.6	5.7	4.6	3.2	—	—	—	—
3. Sand-lightweight concrete	3-1.1		5.4	4.6	3.8	2.7	—	—	—	—
4. Lightweight concrete	4-1.1		5.1	4.4	3.6	2.5	—	—	—	—
5. Reinforced concrete	5-1.1	Slab with suspended ceiling of vermiculite gypsum plaster over metal lath attached to $^3/_4''$ cold-rolled channels spaced 12″ on center. Ceiling located 6″ minimum below joists.	3	2	—	—	1	$^3/_4$	—	—
	5-2.1	$^3/_8''$ Type X gypsum wallboard[c] attached to 0.018 inch (No. 25 carbon sheet steel gage) by $^7/_8''$ deep by $2^5/_8''$ hat-shaped galvanized steel channels with 1″-long No. 6 screws. The channels are spaced 24″ on center, span 35″ and are supported along their length at 35″ intervals by 0.033-inch (No. 21 galvanized sheet gage) galvanized steel flat strap hangers having formed edges that engage the lips of the channel. The strap hangers are attached to the side of the concrete joists with $^5/_{32}''$ by $1^1/_4''$ long power-driven fasteners. The wallboard is installed with the long dimension perpendicular to the channels. All end joints occur on channels and supplementary channels are installed parallel to the main channels, 12″ each side, at end joint occurrences. The finished ceiling is located approximately 12″ below the soffit of the floor slab.	—	—	$2^1/_2$	—	—	—	$^5/_8$	—
6. Steel joists constructed with a poured reinforced concrete slab on metal lath forms or steel form units[d,e]	6-1.1	Gypsum plaster on metal lath attached to the bottom cord with single No. 16 gage or doubled No. 18 gage wire ties spaced 6″ on center. Plaster mixed 1:2 for scratch coat, 1:3 for brown coat, by weight, gypsum-to-sand aggregate for 2-hour system. For 3-hour system plaster is neat.	—	—	$2^1/_2$	$2^1/_4$	—	—	$^3/_4$	$^5/_8$
	6-2.1	Vermiculite gypsum plaster on metal lath attached to the bottom chord with single No.16 gage or doubled 0.049-inch (No. 18 B.W. gage) wire ties 6″ on center.	—	2	—	—	—	$^5/_8$	—	—
	6-3.1	Cement plaster over metal lath attached to the bottom chord of joists with single No. 16 gage or doubled 0.049-inch (No. 18 B.W. gage) wire ties spaced 6″ on center. Plaster mixed 1:2 for scratch coat, 1:3 for brown coat for 1-hour system and 1:1 for scratch coat, 1:1 $^1/_2$ for brown coat for 2-hour system, by weight, cement to sand.	—	—	—	2	—	—	—	$^5/_8$[f]
	6-4.1	Ceiling of $^5/_8''$ Type X wallboard[c] attached to $^7/_8''$ deep by $2^5/_8''$ by 0.021 inch (No. 25 carbon sheet steel gage) hat-shaped furring channels 12″ on center with 1″ long No. 6 wallboard screws at 8″ on center. Channels wire tied to bottom chord of joists with doubled 0.049 inch (No. 18 B.W. gage) wire or suspended below joists on wire hangers.[g]	—	—	$2^1/_2$	—	—	—	$^5/_8$	—
	6-5.1	Wood-fibered gypsum plaster mixed 1:1 by weight gypsum to sand aggregate applied over metal lath. Lath tied 6″ on center to $^3/_4''$ channels spaced $13^1/_2''$ on center. Channels secured to joists at each intersection with two strands of 0.049 inch (No. 18 B.W. gage) galvanized wire.	—	—	$2^1/_2$	—	—	—	$^3/_4$	—

(continued)

TABLE 720.1(3)—continued
MINIMUM PROTECTION FOR FLOOR AND ROOF SYSTEMS[a,q]

FLOOR OR ROOF CONSTRUCTION	ITEM NUMBER	CEILING CONSTRUCTION	THICKNESS OF FLOOR OR ROOF SLAB (inches)				MINIMUM THICKNESS OF CEILING (inches)			
			4 hour	3 hour	2 hour	1 hour	4 hour	3 hour	2 hour	1 hour
7. Reinforced concrete slabs and joists with hollow clay tile fillers laid end to end in rows $2^1/_2''$ or more apart; reinforcement placed between rows and concrete cast around and over tile.	7-1.1	$^5/_8''$ gypsum plaster on bottom of floor or roof construction.	—	—	8^h	—	—	—	$^5/_8$	—
	7-1.2	None	—	—	—	$5^1/_2{}^i$	—	—	—	—
8. Steel joists constructed with a reinforced concrete slab on top poured on a $^1/_2''$ deep steel deck.[e]	8-1.1	Vermiculite gypsum plaster on metal lath attached to $^3/_4''$ cold-rolled channels with 0.049″ (No. 18 B.W. gage) wire ties spaced 6″ on center.	$2^1/_2{}^j$	—	—	—	$^3/_4$	—	—	—
9. 3″ deep cellular steel deck with concrete slab on top. Slab thickness measured to top.	9-1.1	Suspended ceiling of vermiculite gypsum plaster base coat and vermiculite acoustical plaster on metal lath attached at 6″ intervals to $^3/_4''$ cold-rolled channels spaced 12″ on center and secured to $1^1/_2''$ cold-rolled channels spaced 36″ on center with 0.065″ (No. 16 B.W. gage) wire. $1^1/_2''$ channels supported by No. 8 gage wire hangers at 36″ on center. Beams within envelope and with a $2^1/_2''$ airspace between beam soffit and lath have a 4-hour rating.	$2^1/_2$	—	—	—	$1^1/_8{}^k$	—	—	—
10. $1^1/_2''$-deep steel roof deck on steel framing. Insulation board, 30 pcf density, composed of wood fibers with cement binders of thickness shown bonded to deck with unified asphalt adhesive. Covered with a Class A or B roof covering.	10-1.1	Ceiling of gypsum plaster on metal lath. Lath attached to $^3/_4''$ furring channels with 0.049″ (No. 18 B.W. gage) wire ties spaced 6″ on center. $^3/_4''$ channel saddle tied to 2″ channels with doubled 0.065″ (No. 16 B.W. gage) wire ties. 2″ channels spaced 36″ on center suspended 2″ below steel framing and saddle-tied with 0.165″ (No. 8 B.W. gage) wire. Plaster mixed 1:2 by weight, gypsum-to-sand aggregate.	—	—	$1^7/_8$	1	—	—	$^3/_4{}^l$	$^3/_4{}^l$
11. $1^1/_2''$-deep steel roof deck on steel-framing wood fiber insulation board, 17.5 pcf density on top applied over a 15-lb asphalt-saturated felt. Class A or B roof covering.	11-1.1	Ceiling of gypsum plaster on metal lath. Lath attached to $^3/_4''$ furring channels with 0.049″ (No. 18 B.W. gage) wire ties spaced 6″ on center. $^3/_4''$ channels saddle tied to 2″ channels with doubled 0.065″ (No. 16 B.W. gage) wire ties. 2″ channels spaced 36″ on center suspended 2″ below steel framing and saddle tied with 0.165″ (No. 8 B.W. gage) wire. Plaster mixed 1:2 for scratch coat and 1:3 for brown coat, by weight, gypsum-to-sand aggregate for 1-hour system. For 2-hour system, plaster mix is 1:2 by weight, gypsum-to-sand aggregate.	—	—	$1^1/_2$	1	—	—	$^7/_8{}^g$	$^3/_4{}^l$

(continued)

TABLE 720.1(3)—continued
MINIMUM PROTECTION FOR FLOOR AND ROOF SYSTEMS[a,q]

FLOOR OR ROOF CONSTRUCTION	ITEM NUMBER	CEILING CONSTRUCTION	THICKNESS OF FLOOR OR ROOF SLAB (inches)				MINIMUM THICKNESS OF CEILING (inches)			
			4 hour	3 hour	2 hour	1 hour	4 hour	3 hour	2 hour	1 hour
12. 1$\frac{1}{2}$" deep steel roof deck on steel-framing insulation of rigid board consisting of expanded perlite and fibers impregnated with integral asphalt waterproofing; density 9 to 12 pcf secured to metal roof deck by $\frac{1}{2}$" wide ribbons of waterproof, cold-process liquid adhesive spaced 6" apart. Steel joist or light steel construction with metal roof deck, insulation, and Class A or B built-up roof covering.[e]	12-1.1	Gypsum-vermiculite plaster on metal lath wire tied at 6" intervals to $\frac{3}{4}$" furring channels spaced 12" on center and wire tied to 2" runner channels spaced 32" on center. Runners wire tied to bottom chord of steel joists.	—	—	1	—	—	—	$\frac{7}{8}$	—
13. Double wood floor over wood joists spaced 16" on center.[m,n]	13-1.1	Gypsum plaster over $\frac{3}{8}$" Type X gypsum lath. Lath initially applied with not less than four 1$\frac{1}{8}$" by No. 13 gage by $\frac{19}{64}$" head plasterboard blued nails per bearing. Continuous stripping over lath along all joist lines. Stripping consists of 3" wide strips of metal lath attached by 1$\frac{1}{2}$" by No. 11 gage by $\frac{1}{2}$" head roofing nails spaced 6" on center. Alternate stripping consists of 3" wide 0.049" diameter wire stripping weighing 1 pound per square yard and attached by No.16 gage by 1$\frac{1}{2}$" by $\frac{3}{4}$" crown width staples, spaced 4" on center. Where alternate stripping is used, the lath nailing may consist of two nails at each end and one nail at each intermediate bearing. Plaster mixed 1:2 by weight, gypsum-to-sand aggregate.	—	—	—	—	—	—	—	$\frac{7}{8}$
	13-1.2	Cement or gypsum plaster on metal lath. Lath fastened with 1$\frac{1}{2}$" by No. 11 gage by $\frac{7}{16}$" head barbed shank roofing nails spaced 5" on center. Plaster mixed 1:2 for scratch coat and 1:3 for brown coat, by weight, cement to sand aggregate.	—	—	—	—	—	—	—	$\frac{5}{8}$
	13-1.3	Perlite or vermiculite gypsum plaster on metal lath secured to joists with 1$\frac{1}{2}$" by No. 11 gage by $\frac{7}{16}$" head barbed shank roofing nails spaced 5" on center.	—	—	—	—	—	—	—	$\frac{5}{8}$
	13-1.4	$\frac{1}{2}$" Type X gypsum wallboard[c] nailed to joists with 5d cooler[o] or wallboard[o] nails at 6" on center. End joints of wallboard centered on joists.	—	—	—	—	—	—	—	$\frac{1}{2}$
14. Plywood stressed skin panels consisting of $\frac{5}{8}$"-thick interior C-D (exterior glue) top stressed skin on 2" × 6"nominal (minimum) stringers. Adjacent panel edges joined with 8d common wire nails spaced 6" on center. Stringers spaced 12" maximum on center.	14-1.1	$\frac{1}{2}$"-thick wood fiberboard weighing 15 to 18 pounds per cubic foot installed with long dimension parallel to stringers or $\frac{3}{8}$" C-D (exterior glue) plywood glued and/or nailed to stringers. Nailing to be with 5d cooler[o] or wallboard[o] nails at 12" on center. Second layer of $\frac{1}{2}$" Type X gypsum wallboard[c] applied with long dimension perpendicular to joists and attached with 8d cooler[o] or wallboard[o] nails at 6" on center at end joints and 8" on center elsewhere. Wallboard joints staggered with respect to fiberboard joints.	—	—	—	—	—	—	—	1

(continued)

TABLE 720.1(3)—continued
MINIMUM PROTECTION FOR FLOOR AND ROOF SYSTEMS[a,q]

FLOOR OR ROOF CONSTRUCTION	ITEM NUMBER	CEILING CONSTRUCTION	THICKNESS OF FLOOR OR ROOF SLAB (inches)				MINIMUM THICKNESS OF CEILING (inches)			
			4 hour	3 hour	2 hour	1 hour	4 hour	3 hour	2 hour	1 hour
15. Vermiculite concrete slab proportioned 1:4 (portland cement to vermiculite aggregate) on a $1^1/_2$″-deep steel deck supported on individually protected steel framing. Maximum span of deck 6′-10″ where deck is less than 0.019 inch (No. 26 carbon steel sheet gage) or greater. Slab reinforced with 4″ × 8″ 0.109/0.083″ (No. $^{12}/_{14}$ B.W. gage) welded wire mesh.	15-1.1	None	—	—	—	3^j	—	—	—	—
16. Perlite concrete slab proportioned 1:6 (portland cement to perlite aggregate) on a $1^1/_4$″-deep steel deck supported on individually protected steel framing. Slab reinforced with 4″ × 8″ 0.109/0.083″ (No. $^{12}/_{14}$ B.W. gage) welded wire mesh.	16-1.1	None	—	—	—	$3^1/_2{}^j$	—	—	—	—
17. Perlite concrete slab proportioned 1:6 (portland cement to perlite aggregate) on a $^9/_{16}$″-deep steel deck supported by steel joists 4′ on center. Class A or B roof covering on top.	17-1.1	Perlite gypsum plaster on metal lath wire tied to $^3/_4$″ furring channels attached with 0.065-inch (No. 16 B.W. gage) wire ties to lower chord of joists.	—	2^p	2^p	—	—	$^7/_8$	$^3/_4$	—
18. Perlite concrete slab proportioned 1:6 (portland cement to perlite aggregate) on $1^1/_4$″-deep steel deck supported on individually protected steel framing. Maximum span of deck 6′-10″ where deck is less than 0.019″ (No. 26 carbon sheet steel gage) and 8′-0″ where deck is 0.019″ (No. 26 carbon sheet steel gage) or greater. Slab reinforced with 0.042″ (No. 19 B.W. gage) hexagonal wire mesh. Class A or B roof covering on top.	18-1.1	None	—	$2^1/_4{}^p$	$2^1/_4{}^p$	—	—	—	—	—

(continued)

TABLE 720.1(3)—continued
MINIMUM PROTECTION FOR FLOOR AND ROOF SYSTEMS[a,q]

FLOOR OR ROOF CONSTRUCTION	ITEM NUMBER	CEILING CONSTRUCTION	THICKNESS OF FLOOR OR ROOF SLAB (inches)				MINIMUM THICKNESS OF CEILING (inches)			
			4 hour	3 hour	2 hour	1 hour	4 hour	3 hour	2 hour	1 hour
19. Floor and beam construction consisting of 3″-deep cellular steel floor unit mounted on steel members with 1:4 (proportion of portland cement to perlite aggregate) perlite-concrete floor slab on top.	19-1.1	Suspended envelope ceiling of perlite gypsum plaster on metal lath attached to $^3/_4''$ cold-rolled channels, secured to $1^1/_2''$ cold-rolled channels spaced 42″ on center supported by 0.203 inch (No. 6 B.W. gage) wire 36″ on center. Beams in envelope with 3″ minimum airspace between beam soffit and lath have a 4-hour rating.	2[p]	—	—	—	1[l]	—	—	—
20. Perlite concrete proportioned 1:6 (portland cement to perlite aggregate) poured to $^1/_8$-inch thickness above top of corrugations of $1^5/_{16}''$-deep galvanized steel deck maximum span 8′-0″ for 0.024-inch (No. 24 galvanized sheet gage) or 6′ 0″ for 0.019-inch (No. 26 galvanized sheet gage) with deck supported by individually protected steel framing. Approved polystyrene foam plastic insulation board having a flame spread not exceeding 75 (1″ to 4″ thickness) with vent holes that approximate 3 percent of the board surface area placed on top of perlite slurry. A 2′ by 4′ insulation board contains six $2^3/_4''$ diameter holes. Board covered with $2^1/_4''$ minimum perlite concrete slab.	20-1.1	None	—	—	Varies	—	—	—	—	—

(continued)

TABLE 720.1(3)—continued
MINIMUM PROTECTION FOR FLOOR AND ROOF SYSTEMS[a,q]

FLOOR OR ROOF CONSTRUCTION	ITEM NUMBER	CEILING CONSTRUCTION	THICKNESS OF FLOOR OR ROOF SLAB (inches)				MINIMUM THICKNESS OF CEILING (inches)			
			4 hour	3 hour	2 hour	1 hour	4 hour	3 hour	2 hour	1 hour
(continued) 20. Slab reinforced with mesh consisting of 0.042 inch (No. 19 B.W. gage) galvanized steel wire twisted together to form 2″ hexagons with straight 0.065 inch (No. 16 B.W. gage) galvanized steel wire woven into mesh and spaced 3″. Alternate slab reinforcement shall be permitted to consist of 4″ × 8″, 0.109/0.238-inch (No. 12/4 B.W. gage), or 2″ × 2″, 0.083/0.083-inch (No. 14/14 B.W. gage) welded wire fabric. Class A or B roof covering on top.	20-1.1	None	—	—	Varies	—	—	—	—	—
21. Wood joists, floor trusses and flat or pitched roof trusses spaced a maximum 24″ o.c. with 1/2″ wood structural panels with exterior glue applied at right angles to top of joist or top chord of trusses with 8d nails. The wood structural panel thickness shall not be less than nominal 1/2″ less than required by Chapter 23.	21-1.1	Base layer 5/8″ Type X gypsum wallboard applied at right angles to joist or truss 24″ o.c. with 1 1/4″ Type S or Type W drywall screws 24″ o.c. Face layer 5/8″ Type X gypsum wallboard or veneer base applied at right angles to joist or truss through base layer with 1 7/8″ Type S or Type W drywall screws 12″ o.c. at joints and intermediate joist or truss. Face layer Type G drywall screws placed 2″ back on either side of face layer end joints, 12″ o.c.	—	—	—	Varies	—	—	—	1 1/4
22. Steel joists, floor trusses and flat or pitched roof trusses spaced a maximum 24″ o.c. with 1/2″ wood structural panels with exterior glue applied at right angles to top of joist or top chord of trusses with No. 8 screws. The wood structural panel thickness shall not be less than nominal 1/2″ nor less than required by Chapter 23.	22-1.1	Base layer 5/8″ Type X gypsum board applied at right angles to steel framing 24″ on center with 1″ Type S drywall screws spaced 24″ on center. Face layer 5/8″ Type X gypsum board applied at right angles to steel framing attached through base layer with 1 5/8″ Type S drywall screws 12″ on center at end joints and intermediate joints and 1 1/2″ Type G drywall screws 12 inches on center placed 2″ back on either side of face layer end joints. Joints of the face layer are offset 24″ from the joints of the base layer.	—	—	—	Varies	—	—	—	1 1/4
23. Wood I-joist (minimum joist depth 9 1/4″ with a minimum flange depth of 1 5/16″ and a minimum flange cross-sectional area of 2.3 square inches) at 24″ o.c. spacing with 1 × 4 (nominal) wood furring strip spacer applied parallel to and covering the bottom of the bottom flange of each member, tacked in place. 2″ mineral fiber insulation, 3.5 pcf (nominal) installed adjacent to the bottom flange of the I-joist and supported by the 1 × 4 furring strip spacer.	23-1.1	1/2″ deep single leg resilient channel 16″ on center (channels doubled at wallboard end joints), placed perpendicular to the furring strip and joist and attached to each joist by 1 7/8″ Type S drywall screws. 5/8″ Type C gypsum wallboard applied perpendicular to the channel with end joints staggered at least 4′ and fastened with 1 1/8″ Type S drywall screws spaced 7″ on center. Wallboard joints to be taped and covered with joint compound.	—	—	—	Varies	—	—	—	—

Table 720.1(3) Notes.

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm, 1 pound = 0.454 kg, 1 cubic foot = 0.0283 m³,
1 pound per square inch = 6.895 kPa = 1 pound per lineal foot = 1.4882 kg/m.

a. Staples with equivalent holding power and penetration shall be permitted to be used as alternate fasteners to nails for attachment to wood framing.

b. When the slab is in an unrestrained condition, minimum reinforcement cover shall not be less than 1⁵/₈ inches for 4-hour (siliceous aggregate only); 1¹/₄ inches for 4- and 3-hour; 1 inch for 2-hour (siliceous aggregate only); and ³/₄ inch for all other restrained and unrestrained conditions.

c. For all of the construction with gypsum wallboard described in this table, gypsum base for veneer plaster of the same size, thickness and core type shall be permitted to be substituted for gypsum wallboard, provided attachment is identical to that specified for the wallboard, and the joints on the face layer are reinforced and the entire surface is covered with a minimum of ¹/₁₆-inch gypsum veneer plaster.

d. Slab thickness over steel joists measured at the joists for metal lath form and at the top of the form for steel form units.

e. (a) The maximum allowable stress level for H-Series joists shall not exceed 22,000 psi.
   (b) The allowable stress for K-Series joists shall not exceed 26,000 psi, the nominal depth of such joist shall not be less than 10 inches and the nominal joist weight shall not be less than 5 pounds per lineal foot.

f. Cement plaster with 15 pounds of hydrated lime and 3 pounds of approved additives or admixtures per bag of cement.

g. Gypsum wallboard ceilings attached to steel framing shall be permitted to be suspended with 1¹/₂-inch cold-formed carrying channels spaced 48 inches on center, which are suspended with No. 8 SWG galvanized wire hangers spaced 48 inches on center. Cross-furring channels are tied to the carrying channels with No. 18 SWG galvanized wire hangers spaced 48 inches on center. Cross-furring channels are tied to the carrying channels with No. 18 SWG galvanized wire (double strand) and spaced as required for direct attachment to the framing. This alternative is also applicable to those steel framing assemblies recognized under Note q.

h. Six-inch hollow clay tile with 2-inch concrete slab above.

i. Four-inch hollow clay tile with 1¹/₂-inch concrete slab above.

j. Thickness measured to bottom of steel form units.

k. Five-eighths inch of vermiculite gypsum plaster plus ¹/₂ inch of approved vermiculite acoustical plastic.

l. Furring channels spaced 12 inches on center.

m. Double wood floor shall be permitted to be either of the following:
   (a) Subfloor of 1-inch nominal boarding, a layer of asbestos paper weighing not less than 14 pounds per 100 square feet and a layer of 1-inch nominal tongue-and-groove finished flooring; or
   (b) Subfloor of 1-inch nominal tongue-and-groove boarding or ¹⁵/₃₂-inch wood structural panels with exterior glue and a layer of 1-inch nominal tongue-and-groove finished flooring or ¹⁹/₃₂-inch wood structural panel finish flooring or a layer of Type I Grade M-1 particleboard not less than ⁵/₈-inch thick.

n. The ceiling shall be permitted to be omitted over unusable space, and flooring shall be permitted to be omitted where unusable space occurs above.

o. For properties of cooler or wallboard nails, see ASTM C 514, ASTM C 547 or ASTM F 1667.

p. Thickness measured on top of steel deck unit.

q. Generic fire-resistance ratings (those not designated as PROPRIETARY* in the listing) in the GA 600 shall be accepted as if herein listed.

721.2 Concrete assemblies. The provisions of this section contain procedures by which the fire-resistance ratings of concrete assemblies are established by calculations.

721.2.1 Concrete walls. Cast-in-place and precast concrete walls shall comply with Section 721.2.1.1. Multiwythe concrete walls shall comply with Section 721.2.1.2. Joints between precast panels shall comply with Section 721.2.1.3. Concrete walls with gypsum wallboard or plaster finish shall comply with Section 721.2.1.4.

721.2.1.1 Cast-in-place or precast walls. The minimum equivalent thicknesses of cast-in-place or precast concrete walls for fire-resistance ratings of 1 hour to 4 hours are shown in Table 721.2.1.1. For solid walls with flat vertical surfaces, the equivalent thickness is the same as the actual thickness. The values in Table 721.2.1.1 apply to plain, reinforced or prestressed concrete walls.

TABLE 721.2.1.1
MINIMUM EQUIVALENT THICKNESS OF CAST-IN-PLACE OR PRECAST CONCRETE WALLS, LOAD-BEARING OR NONLOAD-BEARING

CONCRETE TYPE	MINIMUM SLAB THICKNESS (inches) FOR FIRE-RESISTANCE RATING OF				
	1-hour	1¹/₂-hour	2-hour	3-hour	4-hour
Siliceous	3.5	4.3	5.0	6.2	7.0
Carbonate	3.2	4.0	4.6	5.7	6.6
Sand-Lightweight	2.7	3.3	3.8	4.6	5.4
Lightweight	2.5	3.1	3.6	4.4	5.1

For SI: 1 inch = 25.4 mm.

721.2.1.1.1 Hollow-core precast wall panels. For hollow-core precast concrete wall panels in which the cores are of constant cross section throughout the length, calculation of the equivalent thickness by dividing the net cross-sectional area (the gross cross section minus the area of the cores) of the panel by its width shall be permitted.

721.2.1.1.2 Core spaces filled. Where all of the core spaces of hollow-core wall panels are filled with loose-fill material, such as expanded shale, clay, or slag, or vermiculite or perlite, the fire-resistance rating of the wall is the same as that of a solid wall of the same concrete type and of the same overall thickness.

721.2.1.1.3 Tapered cross sections. The thickness of panels with tapered cross sections shall be that determined at a distance 2t or 6 inches (152 mm), whichever is less, from the point of minimum thickness, where t is the minimum thickness.

721.2.1.1.4 Ribbed or undulating surfaces. The equivalent thickness of panels with ribbed or undulating surfaces shall be determined by one of the following expressions:

For $s \geq 4t$, the thickness to be used shall be t

For $s \leq 2t$, the thickness to be used shall be t_e

For $4t > s > 2t$, the thickness to be used shall be

$$t + \left(\frac{4t}{s} - 1\right)\left(t_e - t\right)$$

(Equation 7-3)

where:

s = Spacing of ribs or undulations.

t = Minimum thickness.

t_e = Equivalent thickness of the panel calculated as the net cross-sectional area of the panel divided by the width, in which the maximum thickness used in the calculation shall not exceed $2t$.

721.2.1.2 Multiwythe walls. For walls that consist of two wythes of different types of concrete, the fire-resistance ratings shall be permitted to be determined from Figure 721.2.1.2.

721.2.1.2.1 Two or more wythes. The fire-resistance rating for wall panels consisting of two or more wythes shall be permitted to be determined by the formula:

$$R = (R_1^{0.59} + R_2^{0.59} + ... + R_n^{0.59})^{1.7} \quad \text{(Equation 7-4)}$$

where:

R = The fire endurance of the assembly, minutes.

R_1, R_2 and R_n = The fire endurances of the individual wythes, minutes. Values of $R_n^{0.59}$ for use in Equation 7-4 are given in Table 721.2.1.2(1). Calculated fire-resistance ratings are shown in Table 721.2.1.2(2).

721.2.1.2.2 Foam plastic insulation. The fire-resistance ratings of precast concrete wall panels consisting of a layer of foam plastic insulation sandwiched between two wythes of concrete shall be permitted to be determined by use of Equation 7-4. Foam plastic insulation with a total thickness of less than 1 inch (25 mm) shall be disregarded. The R_n value for thickness of foam plastic insulation of 1 inch (25 mm) or greater, for use in the calculation, is 5 minutes; therefore $R_n^{0.59} = 2.5$.
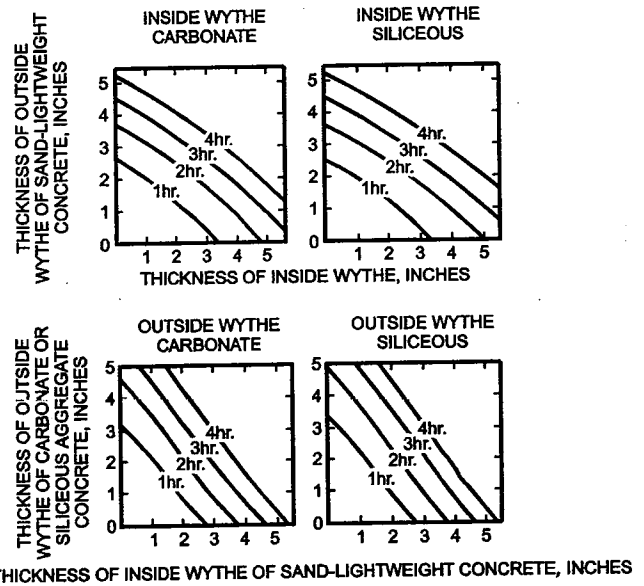
For SI: 1 inch = 25.4 mm.

FIGURE 721.2.1.2
FIRE-RESISTANCE RATINGS OF
TWO-WYTHE CONCRETE WALLS

721.2.1.3 Joints between precast wall panels. Joints between precast concrete wall panels which are not insulated as required by this section shall be considered as openings in walls. Uninsulated joints shall be included in determining the percentage of openings permitted by Table 704.8. Where openings are not permitted or are required by this code to be protected, the provisions of this section shall be used to determine the amount of joint insulation required. Insulated joints shall not be considered

TABLE 721.2.1.2(1)
VALUES OF $R_n^{0.59}$ FOR USE IN EQUATION 7-4

TYPE OF MATERIAL	THICKNESS OF MATERIAL (inches)											
	$1^1/_2$	2	$2^1/_2$	3	$3^1/_2$	4	$4^1/_2$	5	$5^1/_2$	6	$6^1/_2$	7
Siliceous aggregate concrete	5.3	6.5	8.1	9.5	11.3	13.0	14.9	16.9	18.8	20.7	22.8	25.1
Carbonate aggregate concrete	5.5	7.1	8.9	10.4	12.0	14.0	16.2	18.1	20.3	21.9	24.7	27.2[c]
Sand-lightweight concrete	6.5	8.2	10.5	12.8	15.5	18.1	20.7	23.3	26.0[c]	Note c	Note c	Note c
Lightweight concrete	6.6	8.8	11.2	13.7	16.5	19.1	21.9	24.7	27.8[c]	Note c	Note c	Note c
Insulating concrete[a]	9.3	13.3	16.6	18.3	23.1	26.5[c]	Note c	Note c	Note c	Note c	Note c	Note c
Airspace[b]	—	—	—	—	—	—	—	—	—	—	—	—

For SI: 1 inch = 25.4 mm, 1 pound per cubic foot = 16.02 kg/m³.

a. Dry unit weight of 35 pcf or less and consisting of cellular, perlite or vermiculite concrete.
b. The $R_n^{0.59}$ value for one $^1/_2''$ to 3 $^1/_2''$ airspace is 3.3. The $R_n^{0.59}$ value for two $^1/_2''$ to 3 $^1/_2''$ airspaces is 6.7.
c. The fire-resistance rating for this thickness exceeds 4 hours.

openings for purposes of determining compliance with the allowable percentage of openings in Table 704.8.

TABLE 721.2.1.2(2)
FIRE-RESISTANCE RATINGS BASED ON $R^{0.59}$

R^a, MINUTES	$R^{0.59}$
60	11.20
120	16.85
180	21.41
240	25.37

a. Based on Equation 7-4.

721.2.1.3.1 Ceramic fiber joint protection. Figure 721.2.1.3.1 shows thicknesses of ceramic fiber blankets to be used to insulate joints between precast concrete wall panels for various panel thicknesses and for joint widths of $^3/_8$ inch (9.5 mm) and 1 inch (25 mm) for fire-resistance ratings of 1 hour to 4 hours. For joint widths between $^3/_8$ inch (9.5 mm) and 1 inch (25 mm), the thickness of ceramic fiber blanket is allowed to be determined by direct interpolation. Other tested and labeled materials are acceptable in place of ceramic fiber blankets.

721.2.1.4 Walls with gypsum wallboard or plaster finishes. The fire-resistance rating of cast-in-place or precast concrete walls with finishes of gypsum wallboard or plaster applied to one or both sides shall be permitted to be calculated in accordance with the provisions of this section.

721.2.1.4.1 Nonfire-exposed side. Where the finish of gypsum wallboard or plaster is applied to the side of the wall not exposed to fire, the contribution of the finish to the total fire-resistance rating shall be determined as follows: The thickness of the finish shall first be corrected by multiplying the actual thickness of the finish by the applicable factor determined from Table 721.2.1.4(1) based on the type of aggregate in the concrete. The corrected thickness of finish shall then be added to the actual or equivalent thickness of concrete and fire-resistance rating of the concrete and finish determined from Table 721.2.1.1, Figure 721.2.1.2 or Table 721.2.1.2(1).

721.2.1.4.2 Fire-exposed side. Where gypsum wallboard or plaster is applied to the fire-exposed side of the wall, the contribution of the finish to the total fire-resistance rating shall be determined as follows: The time assigned to the finish as established by Table 721.2.1.4(2) shall be added to the fire-resistance rating determined from Table 721.2.1.1 or Figure 721.2.1.2, or Table 721.2.1.2(1) for the concrete alone, or to the rating determined in Section 721.2.1.4.1 for the concrete and finish on the nonfire-exposed side.

721.2.1.4.3 Nonsymmetrical assemblies. For a wall having no finish on one side or different types or thicknesses of finish on each side, the calculation procedures of Sections 721.2.1.4.1 and 721.2.1.4.2 shall be performed twice, assuming either side of the wall to be the fire-exposed side. The fire-resistance rating of the wall shall not exceed the lower of the two values.

Exception: For an exterior wall with more than 5 feet (1524 mm) of horizontal separation, the fire shall be assumed to occur on the interior side only.
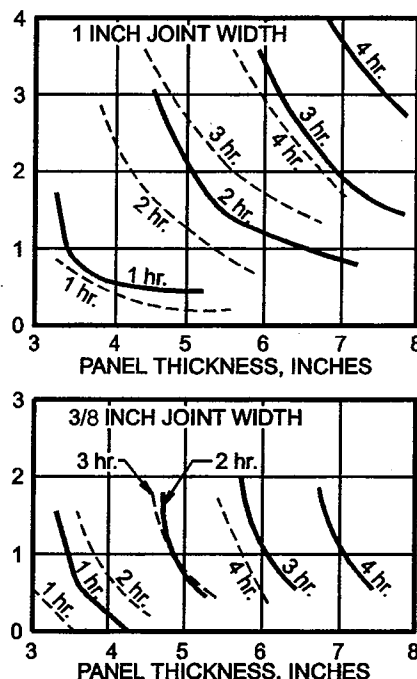
For SI: 1 inch = 25.4 mm.
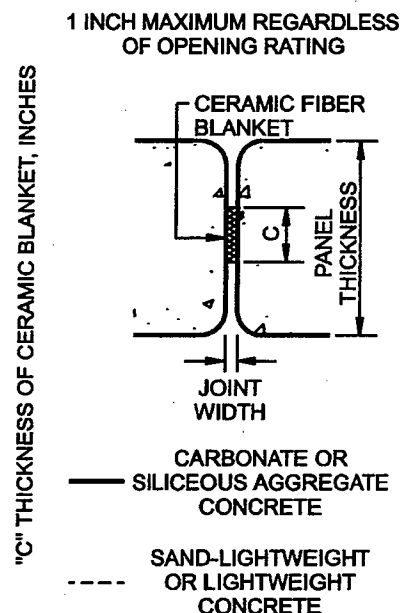
FIGURE 721.2.1.3.1
CERAMIC FIBER JOINT PROTECTION

TABLE 721.2.1.4(1)
MULTIPLYING FACTOR FOR FINISHES ON NONFIRE-EXPOSED SIDE OF WALL

TYPE OF FINISH APPLIED TO MASONRY WALL	TYPE OF AGGREGATE USED IN CONCRETE OR CONCRETE MASONRY			
	Concrete: siliceous or carbonate Masonry: siliceous or calcareous gravel	Concrete: sand lightweight concrete Masonry: limestone, cinders or unexpected slag	Concrete: lightweight concrete Masonry: expanded shale, clay or slate	Concrete: pumice, or expanded slag
Portland cement-sand plaster	1.00	0.75[a]	0.75[a]	0.50[a]
Gypsum-sand plaster or gypsum wallboard	1.25	1.00	1.00	1.00
Gypsum-vermiculite or perlite plaster	1.75	1.50	1.50	1.25

For SI: 1 inch = 25.4 mm.
a. For portland cement-sand plaster $^5/_8$ inch or less in thickness and applied directly to the masonry on the nonfire-exposed side of the wall, the multiplying factor shall be 1.00.

721.2.1.4.4 Minimum concrete fire-resistance rating. Where finishes applied to one or both sides of a concrete wall contribute to the fire-resistance rating, the concrete alone shall provide no less than one-half of the total required fire-resistance rating. Additionally, the contribution to the fire resistance of the finish on the nonfire-exposed side of a load-bearing wall shall not exceed one-half the contribution of the concrete alone.

TABLE 721.2.1.4(2)
TIME ASSIGNED TO FINISH MATERIALS ON FIRE-EXPOSED SIDE OF WALL

FINISH DESCRIPTION	TIME (minute)
Gypsum wallboard	
$^3/_8$ inch	10
$^1/_2$ inch	15
$^5/_8$ inch	20
2 layers of $^3/_8$ inch	25
1 layer $^3/_8$ inch, 1 layer $^1/_2$ inch	35
2 layers $^1/_2$ inch	40
Type X gypsum wallboard	
$^1/_2$ inch	25
$^5/_8$ inch	40
Portland cement-sand plaster applied directly to concrete masonry	See Note a
Portland cement-sand plaster on metal lath	
$^3/_4$ inch	20
$^7/_8$ inch	25
1 inch	30
Gypsum sand plaster on $^3/_8$-inch gypsum lath	
$^1/_2$ inch	35
$^5/_8$ inch	40
$^3/_4$ inch	50
Gypsum sand plaster on metal lath	
$^3/_4$ inch	50
$^7/_8$ inch	60
1 inch	80

For SI: 1 inch = 25.4 mm.
a. The actual thickness of portland cement-sand plaster, provided it is $^5/_8$ inch or less in thickness, shall be permitted to be included in determining the equivalent thickness of the masonry for use in Table 721.3.2.

721.2.1.4.5 Concrete finishes. Finishes on concrete walls that are assumed to contribute to the total fire-resistance rating of the wall shall comply with the installation requirements of Section 721.3.2.5.

721.2.2 Concrete floor and roof slabs. Reinforced and prestressed floors and roofs shall comply with Section 721.2.2.1. Multicourse floors and roofs shall comply with Sections 721.2.2.2 and 721.2.2.3, respectively.

721.2.2.1 Reinforced and prestressed floors and roofs. The minimum thicknesses of reinforced and prestressed concrete floor or roof slabs for fire-resistance ratings of 1 hour to 4 hours are shown in Table 721.2.2.1.

TABLE 721.2.2.1
MINIMUM SLAB THICKNESS (inches)

CONCRETE TYPE	FIRE-RESISTANCE RATING (hour)				
	1	1$^1/_2$	2	3	4
Siliceous	3.5	4.3	5.0	6.2	7.0
Carbonate	3.2	4.0	4.6	5.7	6.6
Sand-lightweight	2.7	3.3	3.8	4.6	5.4
Lightweight	2.5	3.1	3.6	4.4	5.1

For SI: 1 inch = 25.4 mm.

721.2.2.1.1 Hollow-core prestressed slabs. For hollow-core prestressed concrete slabs in which the cores are of constant cross section throughout the length, the equivalent thickness shall be permitted to be obtained by dividing the net cross-sectional area of the slab including grout in the joints, by its width.

721.2.2.1.2 Slabs with sloping soffits. The thickness of slabs with sloping soffits (see Figure 721.2.2.1.2) shall be determined at a distance 2t or 6 inches (152 mm), whichever is less, from the point of minimum thickness, where t is the minimum thickness.

DETERMINE THICKNESS HERE

2t OR 6 INCHES, WHICHEVER IS LESS
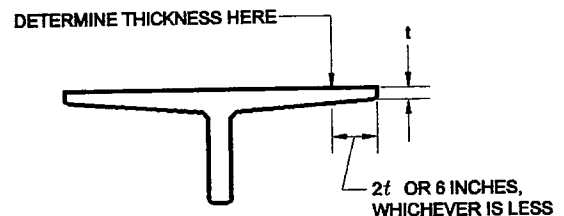
For SI: 1 inch = 25.4 mm.

FIGURE 721.2.2.1.2
DETERMINATION OF SLAB THICKNESS FOR SLOPING SOFFITS

721.2.2.1.3 Slabs with ribbed soffits. The thickness of slabs with ribbed or undulating soffits (see Figure 721.2.2.1.3) shall be determined by one of the following expressions, whichever is applicable:

For $s \geq 4t$, the thickness to be used shall be t

For $s \leq 2t$, the thickness to be used shall be t_e

For $4t > s > 2t$, the thickness to be used shall be

$$t + \left(\frac{4t}{s} - 1\right)\left(t_e - t\right) \qquad \text{(Equation 7-5)}$$

where:

s = Spacing of ribs or undulations.

t = Minimum thickness.

t_e = Equivalent thickness of the slab calculated as the net area of the slab divided by the width, in which the maximum thickness used in the calculation shall not exceed $2t$.
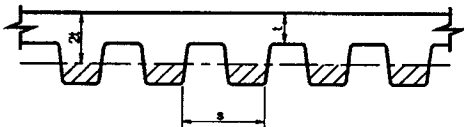
NEGLECT SHADED AREA IN CALCULATION OF EQUIVALENT THICKNESS
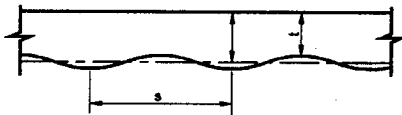
For SI: 1 inch = 25.4 mm.

FIGURE 721.2.2.1.3
SLABS WITH RIBBED OR UNDULATING SOFFITS

721.2.2.2 Multicourse floors. The fire-resistance ratings of floors that consist of a base slab of concrete with a topping (overlay) of a different type of concrete shall comply with Figure 721.2.2.2.

721.2.2.3 Multicourse roofs. The fire-resistance ratings of roofs which consist of a base slab of concrete with a topping (overlay) of an insulating concrete or with an insulating board and built-up roofing shall comply with Figures 721.2.2.3(1) and 721.2.2.3(2).

721.2.2.3.1 Heat transfer. For the transfer of heat, three-ply built-up roofing contributes 10 minutes to the fire-resistance rating. The fire-resistance rating for concrete assemblies such as those shown in Figure 721.2.2.3(1) shall be increased by 10 minutes. This increase is not applicable to those shown in Figure 721.2.2.3(2).

721.2.2.4 Joints in precast slabs. Joints between adjacent precast concrete slabs need not be considered in calculating the slab thickness provided that a concrete topping at least 1 inch (25 mm) thick is used. Where no
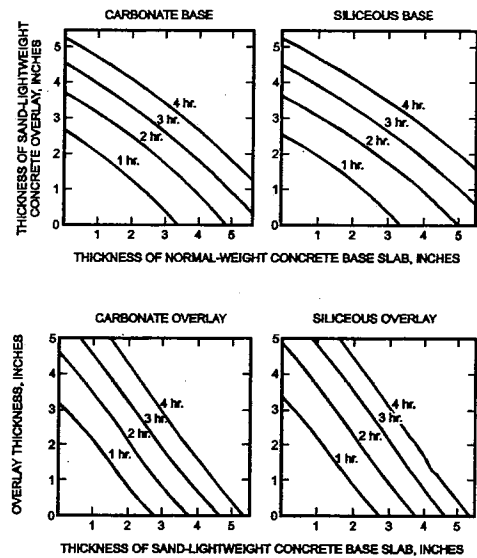
For SI: 1 inch = 25.4 mm.

FIGURE 721.2.2.2
FIRE-RESISTANCE RATINGS FOR TWO-COURSE
CONCRETE FLOORS
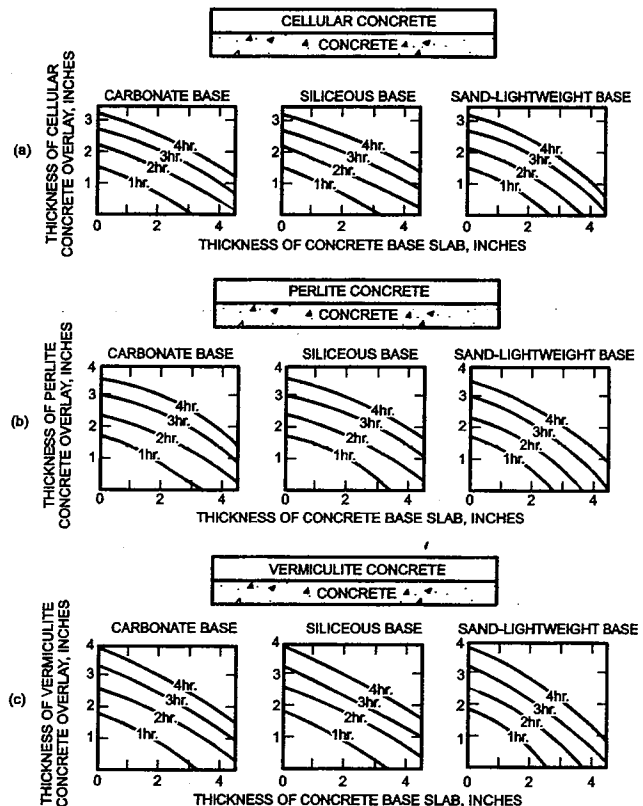
For SI: 1 inch = 25.4 mm.

FIGURE 721.2.2.3(1)
FIRE-RESISTANCE RATINGS FOR CONCRETE
ROOF ASSEMBLIES
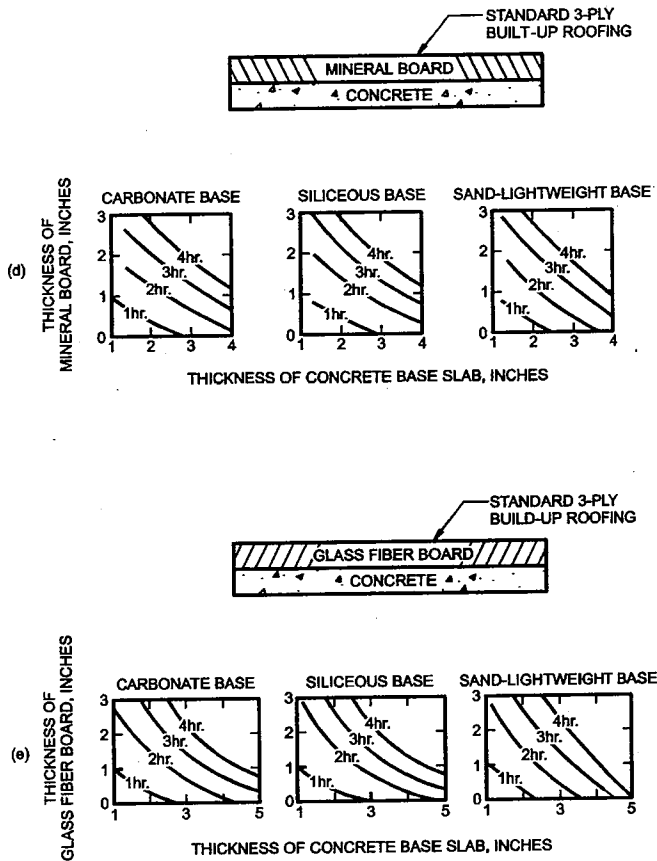
FIGURE 721.2.2.3(2)
FIRE-RESISTANCE RATINGS FOR CONCRETE ROOF ASSEMBLIES

For SI: 1 inch = 25.4 mm.

concrete topping is used, joints must be grouted to a depth of at least one-third the slab thickness at the joint, but not less than 1 inch (25 mm), or the joints must be made fire resistant by other approved methods.

721.2.3 Concrete cover over reinforcement. The minimum thickness of concrete cover over reinforcement in concrete slabs, reinforced beams and prestressed beams shall comply with this section.

721.2.3.1 Slab cover. The minimum thickness of concrete cover to the positive moment reinforcement shall comply with Table 721.2.3(1) for reinforced concrete and Table 721.2.3(2) for prestressed concrete. These tables are applicable for solid or hollow-core one-way or two-way slabs with flat undersurfaces. These tables are applicable to slabs that are either cast in place or precast. For precast prestressed concrete not covered elsewhere, the procedures contained in PCI MNL 124 shall be acceptable.

721.2.3.2 Reinforced beam cover. The minimum thickness of concrete cover to the positive moment reinforcement (bottom steel) for reinforced concrete beams is shown in Table 721.2.3(3) for fire-resistance ratings of 1 hour to 4 hours.

721.2.3.3 Prestressed beam cover. The minimum thickness of concrete cover to the positive moment prestressing tendons (bottom steel) for restrained and unrestrained prestressed concrete beams and stemmed units shall comply with the values shown in Tables 721.2.3(4) and 721.2.3(5) for fire-resistance ratings of 1 hour to 4 hours. Values in Table 721.2.3(4) apply to beams 8 inches (203 mm) or greater in width. Values in Table 721.2.3(5) apply to beams or stems of any width, provided the cross-section area is not less than 40 square inches (25 806 mm²). In case of differences between the values determined from Table 721.2.3(4) or 721.2.3(5), it is permitted to use the smaller value. The concrete cover shall be calculated in accordance with Section 721.2.3.3.1. The minimum concrete cover for nonprestressed reinforcement in prestressed concrete beams shall comply with Section 721.2.2.2.

721.2.3.3.1 Calculating concrete cover. The concrete cover for an individual tendon is the minimum thickness of concrete between the surface of the tendon and the fire-exposed surface of the beam, except that for ungrouped ducts, the assumed cover thickness is the minimum thickness of concrete between the surface of the duct and the fire-exposed surface of the beam. For beams in which two or more tendons are used, the cover is assumed to be the average of the minimum cover of the individual tendons. For corner tendons (tendons equal distance from the bottom and side), the minimum cover used in the calculation shall be one-half the actual value. For stemmed members with two or more prestressing

TABLE 721.2.3(1)
COVER THICKNESS FOR REINFORCED CONCRETE FLOOR OR ROOF SLABS (inches)

CONCRETE AGGREGATE TYPE	FIRE-RESISTANCE RATING (hours)									
	Restrained					Unrestrained				
	1	1¹/₂	2	3	4	1	1¹/₂	2	3	4
Siliceous	³/₄	³/₄	³/₄	³/₄	³/₄	³/₄	³/₄	1	1¹/₄	1⁵/₈
Carbonate	³/₄	³/₄	³/₄	³/₄	³/₄	³/₄	³/₄	³/₄	1¹/₄	1¹/₄
Sand-lightweight or lightweight	³/₄	³/₄	³/₄	³/₄	³/₄	³/₄	³/₄	³/₄	1¹/₄	1¹/₄

For SI: 1 inch = 25.4 mm.

TABLE 721.2.3(2)
COVER THICKNESS FOR PRESTRESSED CONCRETE FLOOR OR ROOF SLABS (inches)

CONCRETE AGGREGATE TYPE	FIRE-RESISTANCE RATING (hours)									
	Restrained					Unrestrained				
	1	$1^1/_2$	2	3	4	1	$1^1/_2$	2	3	4
Siliceous	$^3/_4$	$^3/_4$	$^3/_4$	$^3/_4$	$^3/_4$	$1^1/_8$	$1^1/_2$	$1^3/_4$	$2^3/_8$	$2^3/_4$
Carbonate	$^3/_4$	$^3/_4$	$^3/_4$	$^3/_4$	$^3/_4$	1	$1^3/_8$	$1^5/_8$	$2^1/_8$	$2^1/_4$
Sand-lightweight or lightweight	$^3/_4$	$^3/_4$	$^3/_4$	$^3/_4$	$^3/_4$	1	$1^3/_8$	$1^1/_2$	2	$2^1/_4$

For SI: 1 inch = 25.4 mm.

TABLE 721.2.3(3)
MINIMUM COVER FOR MAIN REINFORCING BARS OF REINFORCED CONCRETE BEAMS[c]
(APPLICABLE TO ALL TYPES OF STRUCTURAL CONCRETE)

RESTRAINED OR UNRESTRAINED[a]	BEAM WIDTH[b] (inches)	FIRE-RESISTANCE RATING (hours)				
		1	$1^1/_2$	2	3	4
Restrained	5	$^3/_4$	$^3/_4$	$^3/_4$	1^a	$1^1/_4{}^a$
	7	$^3/_4$	$^3/_4$	$^3/_4$	$^3/_4$	$^3/_4$
	≥ 10	$^3/_4$	$^3/_4$	$^3/_4$	$^3/_4$	$^3/_4$
Unrestrained	5	$^3/_4$	1	$1^1/_4$	—	—
	7	$^3/_4$	$^3/_4$	$^3/_4$	$1^3/_4$	3
	≥ 10	$^3/_4$	$^3/_4$	$^3/_4$	1	$1^3/_4$

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm.

a. Tabulated values for restrained assemblies apply to beams spaced more than 4 feet on center. For restrained beams spaced 4 feet or less on center, minimum cover of $^3/_4$ inch is adequate for ratings of 4 hours or less.

b. For beam widths between the tabulated values, the minimum cover thickness can be determined by direct interpolation.

c. The cover for an individual reinforcing bar is the minimum thickness of concrete between the surface of the bar and the fire-exposed surface of the beam. For beams in which several bars are used, the cover for corner bars used in the calculation shall be reduced to one-half of the actual value. The cover for an individual bar must be not less than one-half of the value given in Table 721.2.3(3) nor less than $^3/_4$ inch.

TABLE 721.2.3(4)
MINIMUM COVER FOR PRESTRESSED CONCRETE BEAMS 8 INCHES OR GREATER IN WIDTH

RESTRAINED OR UNRESTRAINED[a]	CONCRETE AGGREGATE TYPE	BEAM WIDTH[b] (inches)	FIRE-RESISTANCE RATING (hours)				
			1	$1^1/_2$	2	3	4
Restrained	Carbonate or siliceous	8	$1^1/_2$	$1^1/_2$	$1^1/_2$	$1^3/_4{}^a$	$2^1/_2{}^a$
	Carbonate or siliceous	≥ 12	$1^1/_2$	$1^1/_2$	$1^1/_2$	$1^1/_2$	$1^7/_8{}^a$
	Sand lightweight	8	$1^1/_2$	$1^1/_2$	$1^1/_2$	$1^1/_2$	2^a
	Sand lightweight	≥ 12	$1^1/_2$	$1^1/_2$	$1^1/_2$	$1^1/_2$	$1^5/_8{}^a$
Unrestrained	Carbonate or siliceous	8	$1^1/_2$	$1^3/_4$	$2^1/_2$	5^c	—
	Carbonate or siliceous	≥ 12	$1^1/_2$	$1^1/_2$	$1^7/_8{}^a$	$2^1/_2$	3
	Sand lightweight	8	$1^1/_2$	$1^1/_2$	2	$3^1/_4$	—
	Sand lightweight	≥ 12	$1^1/_2$	$1^1/_2$	$1^5/_8$	2	$2^1/_2$

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm.

a. Tabulated values for restrained assemblies apply to beams spaced more than 4 feet on center. For restrained beams spaced 4 feet or less on center, minimum cover of $^3/_4$ inch is adequate for 4-hour ratings or less.

b. For beam widths between 8 inches and 12 inches, minimum cover thickness can be determined by direct interpolation.

c. Not practical for 8-inch-wide beam but shown for purposes of interpolation.

TABLE 721.2.3(5)
MINIMUM COVER FOR PRESTRESSED CONCRETE BEAMS OF ALL WIDTHS

RESTRAINED OR UNRESTRAINED[a]	CONCRETE AGGREGATE TYPE	BEAM AREA[b] A (square inches)	FIRE-RESISTANCE RATING (hours)				
			1	1 1/2	2	3	4
Restrained	All	40 ≤ A ≤ 150	1 1/2	1 1/2	2	2 1/2	—
	Carbonate or siliceous	150 < A ≤ 300	1 1/2	1 1/2	1 1/2	1 3/4	2 1/2
		300 < A	1 1/2	1 1/2	1 1/2	1 1/2	2
	Sand lightweight	150 < A	1 1/2	1 1/2	1 1/2	1 1/2	2
Unrestrained	All	40 ≤ A ≤ 150	2	2 1/2	—	—	—
	Carbonate or siliceous	150 < A ≤ 300	1 1/2	1 3/4	2 1/2	—	—
		300 < A	1 1/2	1 1/2	2	3[c]	4[c]
	Sand lightweight	150 < A	1 1/2	1 1/2	2	3[c]	4[c]

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm.

a. Tabulated values for restrained assemblies apply to beams spaced more than 4 feet on center. For restrained beams spaced 4 feet or less on center, minimum cover of 3/4 inch is adequate for 4-hour ratings or less.

b. The cross-sectional area of a stem is permitted to include a portion of the area in the flange, provided the width of the flange used in the calculation does not exceed three times the average width of the stem.

c. U-shaped or hooped stirrups spaced not to exceed the depth of the member and having a minimum cover of 1 inch shall be provided.

tendons located along the vertical centerline of the stem, the average cover shall be the distance from the bottom of the member to the centroid of the tendons. The actual cover for any individual tendon shall not be less than one-half the smaller value shown in Tables 721.2.3(4) and 721.2.3(5) or 1 inch (25 mm), whichever is greater.

721.2.4 Concrete columns. Concrete columns shall comply with this section.

TABLE 721.2.4
MINIMUM DIMENSION OF CONCRETE COLUMNS (inches)

TYPES OF CONCRETE	FIRE-RESISTANCE RATING (hours)				
	1	1 1/2	2[a]	3[a]	4[b]
Siliceous	8	9	10	12	14
Carbonate	8	9	10	11	12
Sand-lightweight	8	8 1/2	9	10 1/2	12

For SI: 1 inch = 25 mm.

a. The minimum dimension is permitted to be reduced to 8 inches for rectangular columns with two parallel sides at least 36 inches in length.

b. The minimum dimension is permitted to be reduced to 10 inches for rectangular columns with two parallel sides at least 36 inches in length.

721.2.4.1 Minimum size. The minimum overall dimensions of reinforced concrete columns for fire-resistance ratings of 1 hour to 4 hours shall comply with Table 721.2.4.

721.2.4.2 Minimum cover for R/C columns. The minimum thickness of concrete cover to the main longitudinal reinforcement in columns, regardless of the type of aggregate used in the concrete, shall not be less than 1 inch (25 mm) times the number of hours of required fire resistance or 2 inches (51 mm), whichever is less.

721.2.4.3 Columns built into walls. The minimum dimensions of Table 721.2.4 do not apply to a reinforced

concrete column that is built into a concrete or masonry wall provided all of the following are met:

1. The fire-resistance rating for the wall is equal to or greater than the required rating of the column;

2. The main longitudinal reinforcing in the column has cover not less than that required by Section 721.2.4.2; and

3. Openings in the wall are protected in accordance with Table 715.4.

Where openings in the wall are not protected as required by Section 715.4, the minimum dimension of column required to have a fire-resistance rating of 3 hours or less shall be 8 inches (203 mm) and 10 inches (254 mm) for columns required to have a fire-resistance rating of 4 hours, regardless of the type of aggregate used in the concrete.

721.2.4.4 Precast cover units for steel columns. See Section 721.5.1.4.

721.3 Concrete masonry. The provisions of this section contain procedures by which the fire-resistance ratings of concrete masonry are established by calculations.

721.3.1 Equivalent thickness. The equivalent thickness of concrete masonry construction shall be determined in accordance with the provisions of this section.

721.3.1.1 Concrete masonry unit plus finishes. The equivalent thickness of concrete masonry assemblies, T_{ea}, shall be computed as the sum of the equivalent thickness of the concrete masonry unit, T_e, as determined by Section 721.3.1.2, 721.3.1.3, or 721.3.1.4, plus the equivalent thickness of finishes, T_{ef}, determined in accordance with Section 721.3.2:

$T_e = V_n / LH =$ Equivalent thickness of concrete masonry unit (inch) (mm).

where:

V_n = Net volume of masonry unit (inch³) (mm³).

L = Specified length of masonry unit (inch) (mm).

H = Specified height of masonry unit (inch) (mm).

721.3.1.2 Ungrouted or partially grouted construction. T_e shall be the value obtained for the concrete masonry unit determined in accordance with ASTM C 140.

721.3.1.3 Solid grouted construction. The equivalent thickness, T_e, of solid grouted concrete masonry units is the actual thickness of the unit.

721.3.1.4 Airspaces and cells filled with loose-fill material. The equivalent thickness of completely filled hollow concrete masonry is the actual thickness of the unit when loose-fill materials are: sand, pea gravel, crushed stone, or slag that meet ASTM C 33 requirements; pumice, scoria, expanded shale, expanded clay, expanded slate, expanded slag, expanded fly ash, or cinders that comply with ASTM C 331; or perlite or vermiculite meeting the requirements of ASTM C 549 and ASTM C 516, respectively.

721.3.2 Concrete masonry walls. The fire-resistance rating of walls and partitions constructed of concrete masonry units shall be determined from Table 721.3.2. The rating shall be based on the equivalent thickness of the masonry and type of aggregate used.

721.3.2.1 Finish on nonfire-exposed side. Where plaster or gypsum wallboard is applied to the side of the wall not exposed to fire, the contribution of the finish to the total fire-resistance rating shall be determined as follows: The thickness of gypsum wallboard or plaster shall be corrected by multiplying the actual thickness of the finish by applicable factor determined from Table 721.2.1.4(1). This corrected thickness of finish shall be added to the equivalent thickness of masonry and the fire-resistance rating of the masonry and finish determined from Table 721.3.2.

721.3.2.2 Finish on fire-exposed side. Where plaster or gypsum wallboard is applied to the fire-exposed side of the wall, the contribution of the finish to the total fire-resistance rating shall be determined as follows: The time assigned to the finish as established by Table 721.2.1.4(2) shall be added to the fire-resistance rating determined in Section 721.3.2 for the masonry alone, or in Section 721.3.2.1 for the masonry and finish on the nonfire-exposed side.

721.3.2.3 Nonsymmetrical assemblies. For a wall having no finish on one side or having different types or thicknesses of finish on each side, the calculation procedures of this section shall be performed twice, assuming either side of the wall to be the fire-exposed side. The fire-resistance rating of the wall shall not exceed the lower of the two values calculated.

> **Exception:** For exterior walls with more than 5 feet (1524 mm) of horizontal separation, the fire shall be assumed to occur on the interior side only.

721.3.2.4 Minimum concrete masonry fire-resistance rating. Where the finish applied to a concrete masonry wall contributes to its fire-resistance rating, the masonry alone shall provide not less than one-half the total required fire-resistance rating.

721.3.2.5 Attachment of finishes. Installation of finishes shall be as follows:

1. Gypsum wallboard and gypsum lath applied to concrete masonry or concrete walls shall be secured to wood or steel furring members spaced not more than 16 inches (406 mm) on center (o.c.).

2. Gypsum wallboard shall be installed with the long dimension parallel to the furring members and shall have all joints finished.

3. Other aspects of the installation of finishes shall comply with the applicable provisions of Chapters 7 and 25.

TABLE 721.3.2
MINIMUM EQUIVALENT THICKNESS (inches) OF BEARING OR NONBEARING CONCRETE MASONRY WALLS[a,b,c,d]

TYPE OF AGGREGATE	FIRE-RESISTANCE RATING (hours)														
	1/2	3/4	1	1 1/4	1 1/2	1 3/4	2	2 1/4	2 1/2	2 3/4	3	3 1/4	3 1/2	3 3/4	4
Pumice or expanded slag	1.5	1.9	2.1	2.5	2.7	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.5	4.7
Expanded shale, clay or slate	1.8	2.2	2.6	2.9	3.3	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8	4.9	5.1
Limestone, cinders or unexpanded slag	1.9	2.3	2.7	3.1	3.4	3.7	4.0	4.3	4.5	4.8	5.0	5.2	5.5	5.7	5.9
Calcareous or siliceous gravel	2.0	2.4	2.8	3.2	3.6	3.9	4.2	4.5	4.8	5.0	5.3	5.5	5.8	6.0	6.2

For SI: 1 inch = 25.4 mm.

a. Values between those shown in the table can be determined by direct interpolation.

b. Where combustible members are framed into the wall, the thickness of solid material between the end of each member and the opposite face of the wall, or between members set in from opposite sides, shall not be less than 93 percent of the thickness shown in the table.

c. Requirements of ASTM C 55, ASTM C 73 or ASTM C 90 shall apply.

d. Minimum required equivalent thickness corresponding to the hourly fire-resistance rating for units with a combination of aggregate shall be determined by linear interpolation based on the percent by volume of each aggregate used in manufacture.

721.3.3 Multiwythe masonry walls. The fire-resistance rating of wall assemblies constructed of multiple wythes of masonry materials shall be permitted to be based on the fire-resistance rating period of each wythe and the continuous airspace between each wythe in accordance with the following formula:

$$R_A = (R_1^{0.59} + R_2^{0.59} + \ldots + R_n^{0.59} + A_1 + A_2 + \ldots + A_n)^{1.7}$$

(Equation 7-7)

where:

R_A = Fire endurance rating of the assembly (hours).

$R_1, R_2, \ldots R_n$ = Fire endurance rating of wythes for 1, 2, n (hours), respectively.

$A_1, A_2, \ldots, A_n$ = 0.30, factor for each continuous airspace for 1, 2, ...n, respectively, having a depth of $^1/_2$ inch (12.7 mm) or more between wythes.

721.3.4 Concrete masonry lintels. Fire-resistance ratings for concrete masonry lintels shall be determined based upon the nominal thickness of the lintel and the minimum thickness of concrete masonry or concrete, or any combination thereof covering the main reinforcing bars, as determined according to Table 721.3.4, or by approved alternate methods.

TABLE 721.3.4
MINIMUM COVER OF LONGITUDINAL
REINFORCEMENT IN FIRE-RESISTANCE-RATED
REINFORCED CONCRETE MASONRY LINTELS (inches)

NOMINAL WIDTH OF LINTEL (inches)	FIRE-RESISTANCE RATING (hours)			
	1	2	3	4
6	$1^1/_2$	2	—	—
8	$1^1/_2$	$1^1/_2$	$1^3/_4$	3
10 or greater	$1^1/_2$	$1^1/_2$	$1^1/_2$	$1^3/_4$

For SI: 1 inch = 25.4 mm.

721.3.5 Concrete masonry columns. The fire-resistance rating of concrete masonry columns shall be determined based upon the least plan dimension of the column in accordance with Table 721.3.5 or by approved alternate methods.

TABLE 721.3.5
MINIMUM DIMENSION OF
CONCRETE MASONRY COLUMNS (inches)

FIRE-RESISTANCE RATING (hours)			
1	2	3	4
8	10	12	14

For SI: 1 inch = 25.4 mm.

721.4 Clay brick and tile masonry. The provisions of this section contain procedures by which the fire-resistance ratings of clay brick and tile masonry are established by calculations.

721.4.1 Masonry walls. The fire-resistance rating of masonry walls shall be based upon the equivalent thickness as calculated in accordance with this section. The calculation shall take into account finishes applied to the wall and airspaces between wythes in multiwythe construction.

721.4.1.1 Equivalent thickness. The fire-resistance ratings of walls or partitions constructed of solid or hollow clay masonry units shall be determined from Table 721.4.1(1) or 721.4.1(2). The equivalent thickness of the clay masonry unit shall be determined by Equation 7-8 when using Table 721.4.1(1). The fire-resistance rating determined from Table 721.4.1(1) shall be permitted to be used in the calculated fire-resistance rating procedure in Section 721.4.2.

$$T_e = V_n / LH$$

(Equation 7-8)

where:

T_e = The equivalent thickness of the clay masonry unit (inches).

V_n = The net volume of the clay masonry unit (in.^{3}).

L = The specified length of the clay masonry unit (inches).

H = The specified height of the clay masonry unit (inches).

721.4.1.1.1 Hollow clay units. The equivalent thickness, T_e, shall be the value obtained for hollow clay units as determined in accordance with ASTM C67.

TABLE 721.4.1(1)
FIRE-RESISTANCE PERIODS OF CLAY MASONRY WALLS

MATERIAL TYPE	MINIMUM REQUIRED EQUIVALENT THICKNESS FOR FIRE RESISTANCE[a,b,c] (inches)			
	1 hour	2 hour	3 hour	4 hour
Solid brick of clay or shale[d]	2.7	3.8	4.9	6.0
Hollow brick or tile of clay or shale, unfilled	2.3	3.4	4.3	5.0
Hollow brick or tile of clay or shale, grouted or filled with materials specified in Section 721.4.1.1.3	3.0	4.4	5.5	6.6

For SI: 1 inch = 25.4 mm.

a. Equivalent thickness as determined from Section 721.4.1.1.

b. Calculated fire resistance between the hourly increments listed shall be determined by linear interpolation.

c. Where combustible members are framed in the wall, the thickness of solid material between the end of each member and the opposite face of the wall, or between members set in from opposite sides, shall not be less than 93 percent of the thickness shown.

d. For units in which the net cross-sectional area of cored brick in any plane parallel to the surface containing the cores is at least 75 percent of the gross cross-sectional area measured in the same plane.

TABLE 721.4.1(2)
FIRE-RESISTANCE RATINGS FOR BEARING STEEL FRAME
BRICK VENEER WALLS OR PARTITIONS

WALL OR PARTITION ASSEMBLY	PLASTER SIDE EXPOSED (hours)	BRICK FACED SIDE EXPOSED (hours)
Outside facing of steel studs: $1/_2''$ wood fiberboard sheathing next to studs, $3/_4''$ airspace formed with $3/_4'' \times 1\,5/_8''$ wood strips placed over the fiberboard and secured to the studs; metal or wire lath nailed to such strips, $3^3/_4''$ brick veneer held in place by filling $3/_4''$ airspace between the brick and lath with mortar. Inside facing of studs: $3/_4''$ unsanded gypsum plaster on metal or wire lath attached to $5/_{16}''$ wood strips secured to edges of the studs.	1.5	4
Outside facing of steel studs: $1''$ insulation board sheathing attached to studs, $1''$ airspace, and $3^3/_4''$ brick veneer attached to steel frame with metal ties every 5th course. Inside facing of studs: $7/_8''$ sanded gypsum plaster (1:2 mix) applied on metal or wire lath attached directly to the studs.	1.5	4
Same as above except use $7/_8''$ vermiculite—gypsum plaster or $1''$ sanded gypsum plaster (1:2 mix) applied to metal or wire.	2	4
Outside facing of steel studs: $1/_2''$ gypsum sheathing board, attached to studs, and $3^3/_4''$ brick veneer attached to steel frame with metal ties every 5th course. Inside facing of studs: $1/_2''$ sanded gypsum plaster (1:2 mix) applied to $1/_2''$ perforated gypsum lath securely attached to studs and having strips of metal lath 3 inches wide applied to all horizontal joints of gypsum lath.	2	4

For SI: 1 inch = 25.4 mm.

721.4.1.1.2 Solid grouted clay units. The equivalent thickness of solid grouted clay masonry units shall be taken as the actual thickness of the units.

721.4.1.1.3 Units with filled cores. The equivalent thickness of the hollow clay masonry units is the actual thickness of the unit when completely filled with loose-fill materials of: sand, pea gravel, crushed stone, or slag that meet ASTM C 33 requirements; pumice, scoria, expanded shale, expanded clay, expanded slate, expanded slag, expanded fly ash, or cinders in compliance with ASTM C 331, or perlite or vermiculite meeting the requirements of ASTM C 549 and ASTM C 616, respectively.

721.4.1.2 Plaster finishes. Where plaster is applied to the wall, the total fire-resistance rating shall be determined by the formula:

$$R = (R_n^{0.59} + pl)\,1.7 \qquad \text{(Equation 7-9)}$$

where:

R = The fire endurance of the assembly (hours).

R_n = The fire endurance of the individual wall (hours).

pl = Coefficient for thickness of plaster.

Values for $R_n^{0.59}$ for use in Equation 7-9 are given in Table 721.4.1(3). Coefficients for thickness of plaster shall be selected from Table 721.4.1(4) based on the actual thickness of plaster applied to the wall or partition and whether one or two sides of the wall are plastered.

721.4.1.3 Multiwythe walls with airspace. Where a continuous airspace separates multiple wythes of the wall or partition, the total fire-resistance rating shall be determined by the formula:

$$R = (R_1^{0.59} + R_2^{0.59} + ... + R_n^{0.59} + as)^{1.7} \qquad \text{(Equation 7-10)}$$

where:

R = The fire endurance of the assembly (hours).

R_1, R_2 and R_n = The fire endurance of the individual wythes (hours).

as = Coefficient for continuous airspace.

Values for $R_n^{0.59}$ for use in Equation 7-10 are given in Table 721.4.1(3). The coefficient for each continuous airspace of $1/_2$ inch to $3^1/_2$ inches (12.7 to 89 mm) separating two individual wythes shall be 0.3.

721.4.1.4 Nonsymmetrical assemblies. For a wall having no finish on one side or having different types or thicknesses of finish on each side, the calculation procedures of this section shall be performed twice, assuming either side to be the fire-exposed side of the wall. The fire resistance of the wall shall not exceed the lower of the two values determined.

Exception: For exterior walls with more than 5 feet (1524 mm) of horizontal separation, the fire shall be assumed to occur on the interior side only.

TABLE 721.4.1(3)
VALUES OF $R_n^{0.59}$

$R_n^{0.59}$	R (hours)
1	1.0
2	1.50
3	1.91
4	2.27

TABLE 721.4.1(4)
COEFFICIENTS FOR PLASTER, pl [a]

THICKNESS OF PLASTER (inch)	ONE SIDE	TWO SIDE
$^1/_2$	0.3	0.6
$^5/_8$	0.37	0.75
$^3/_4$	0.45	0.90

For SI: 1 inch = 25.4 mm.
a. Values listed in table are for 1:3 sanded gypsum plaster.

TABLE 721.4.1(5)
REINFORCED MASONRY LINTELS

NOMINAL LINTEL WIDTH (inches)	MINIMUM LONGITUDINAL REINFORCEMENT COVER FOR FIRE RESISTANCE (inch)			
	1 hour	2 hour	3 hour	4 hour
6	$1^1/_2$	2	NP	NP
8	$1^1/_2$	$1^1/_2$	$1^3/_4$	3
10 or more	$1^1/_2$	$1^1/_2$	$1^1/_2$	$1^3/_4$

For SI: 1 inch = 25.4 mm.
NP = Not permitted.

TABLE 721.4.1(6)
REINFORCED CLAY MASONRY COLUMNS

COLUMN SIZE	FIRE-RESISTANCE RATING (hour)			
	1	2	3	4
Minimum column dimension (inches)	8	10	12	14

For SI: 1 inch = 25.4 mm.

721.4.2 Multiwythe walls. The fire-resistance rating for walls or partitions consisting of two or more dissimilar wythes shall be permitted to be determined by the formula:

$$R = (R_1^{0.59} + R_2^{0.59} + \ldots + R_n^{0.59})^{1.7} \qquad \text{(Equation 7-11)}$$

where:

R = The fire endurance of the assembly (hours).

R_1, R_2 and R_n = The fire endurance of the individual wythes (hours).

Values for $R_n^{0.59}$ for use in Equation 7-11 are given in Table 721.4.1(3).

721.4.2.1 Multiwythe walls of different material. For walls that consist of two or more wythes of different materials (concrete or concrete masonry units) in combination with clay masonry units, the fire-resistance rating of the different materials shall be permitted to be determined from Table 721.3.1.1 for concrete, Table 721.3.2 for concrete masonry units or Table 721.4.1(1) or 721.4.1(2) for clay and tile masonry units.

721.4.3 Reinforced clay masonry lintels. Fire-resistance ratings for clay masonry lintels shall be determined based on the nominal width of the lintel and the minimum covering for the longitudinal reinforcement in accordance with Table 721.4.1(5).

721.4.4 Reinforced clay masonry columns. The fire-resistance rating shall be determined based on the least plan dimension of the column in accordance with Table 721.4.1(6). The minimum cover for longitudinal reinforcement shall be 2 inches (51 mm).

721.5 Steel assemblies. The provisions of this section contain procedures by which the fire-resistance ratings of steel assemblies are established by calculations.

721.5.1 Structural steel columns. The fire-resistance ratings of steel columns shall be based on the size of the element and the type of protection provided in accordance with this section.

721.5.1.1 General. These procedures establish a basis for determining the fire resistance of column assemblies as a function of the thickness of fire-resistant material and, the weight, W, and heated perimeter, D, of steel columns. As used in these sections, W is the average weight of a structural steel column in pounds per linear foot. The heated perimeter, D, is the inside perimeter of the fire-resistant material in inches as illustrated in Figure 721.5.1(1).

721.5.1.1.1 Nonload-bearing protection. The application of these procedures shall be limited to column assemblies in which the fire-resistant material is not designed to carry any of the load acting on the column.

721.5.1.1.2 Embedments. In the absence of substantiating fire-endurance test results, ducts, conduit, piping, and similar mechanical, electrical, and plumbing installations shall not be embedded in any required fire-resistant materials.

721.5.1.1.3 Weight-to-perimeter ratio. Table 721.5.1(1) contains weight-to-heated-perimeter ratios (W/D) for both contour and box fire-resistant profiles, for the wide flange shapes most often used as columns.
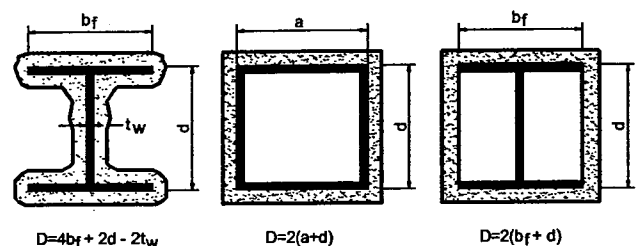

FIGURE 721.5.1(1)
DETERMINATION OF THE HEATED PERIMETER OF STRUCTURAL STEEL COLUMNS

SNAP-LOCK   PITTSBURGH SEAM   LAP

No.8x1/2" SHEET STEEL SCREWS SPACED 12"o.c.

5/8"

3/8"

3/8"

5/16" MIN.
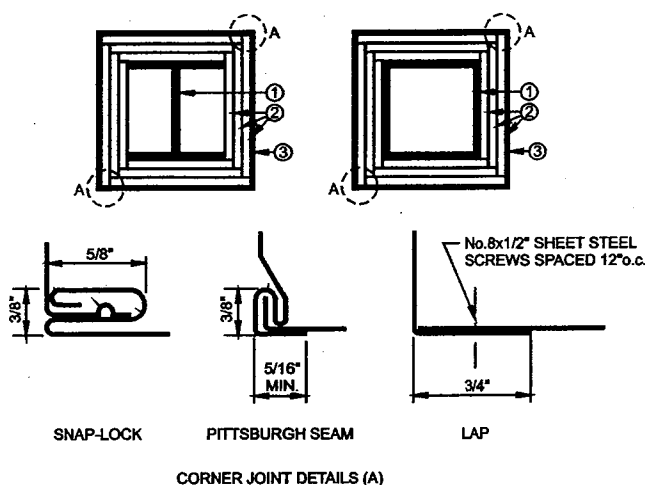
3/4"

CORNER JOINT DETAILS (A)

FIGURE 721.5.1(2)
GYPSUM WALLBOARD PROTECTED STRUCTURAL STEEL COLUMNS WITH SHEET STEEL COLUMN COVERS

For SI: 1 inch = 25.4 mm, 1 foot = 305 mm.

1. Structural steel column, either wide flange or tubular shapes.

2. Type X gypsum wallboard in accordance with ASTM C 36. For single-layer applications, the wallboard shall be applied vertically with no horizontal joints. For multiple-layer applications, horizontal joints are permitted at a minimum spacing of 8 feet, provided that the joints in successive layers are staggered at least 12 inches. The total required thickness of wallboard shall be determined on the basis of the specified fire-resistance rating and the weight-to-heated-perimeter ratio (*W/D*) of the column. For fire-resistance ratings of 2 hours or less, one of the required layers of gypsum wallboard may be applied to the exterior of the sheet steel column covers with 1-inch long Type S screws spaced 1 inch from the wallboard edge and 8 inches on center. For such installations, 0.0149-inch minimum thickness galvanized steel corner beads with $1^1/_2$-inch legs shall be attached to the wallboard with Type S screws spaced 12 inches on center.

3. For fire-resistance ratings of 3 hours or less, the column covers shall be fabricated from 0.0239-inch minimum thickness galvanized or stainless steel. For 4-hour fire-resistance ratings, the column covers shall be fabricated from 0.0239-inch minimum thickness stainless steel. The column covers shall be erected with the Snap Lock or Pittsburgh joint details.

For fire-resistance ratings of 2 hours or less, column covers fabricated from 0.0269-inch minimum thickness galvanized or stainless steel shall be permitted to be erected with lap joints. The lap joints shall be permitted to be located anywhere around the perimeter of the column cover. The lap joints shall be secured with $^1/_2$-inch-long No. 8 sheet metal screws spaced 12 inches on center.

The column covers shall be provided with a minimum expansion clearance of $^1/_8$ inch per linear foot between the ends of the cover and any restraining construction.

For different fire-resistant protection profiles or column cross sections, the weight-to-heated-perimeter ratios (*W/D*) shall be determined in accordance with the definitions given in this section.

721.5.1.2 Gypsum wallboard protection. The fire resistance of structural steel columns with weight-to-heated-perimeter ratios (*W/D*) less than or equal to 3.65 and which are protected with Type X gypsum wallboard shall be permitted to be determined from the following expression:

$$R = 130\left[\frac{h(W'/D)}{2}\right]^{.75}$$ **(Equation 7-12)**

where:

A
1 LAYER = 5/8" OR 1/2"

B
2 LAYERS = 1 1/4" OR 1"

C
3 LAYERS = 1 7/8" OR 1 1/2"

D
4 LAYERS = 2 1/2" OR 2"
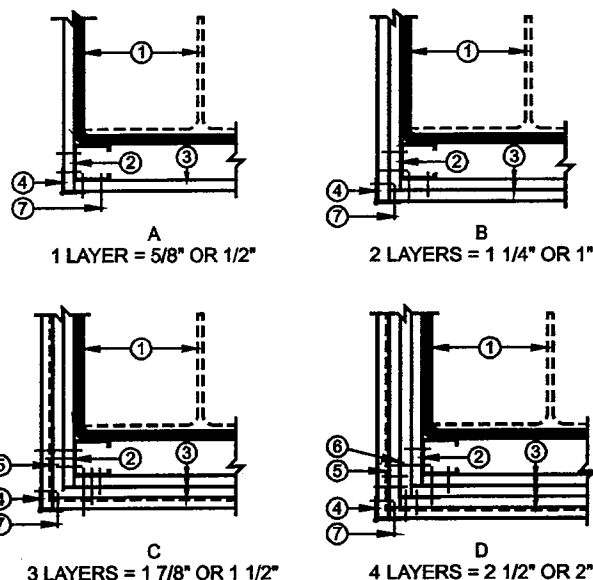
FIGURE 721.5.1(3)
GYPSUM WALLBOARD PROTECTED STRUCTURAL STEEL COLUMNS WITH STEEL STUD/SCREW ATTACHMENT SYSTEM

For SI: 1 inch = 25.4 mm, 1 foot = -305 mm.

1. Structural steel column, either wide flange or tubular shapes.

2. $1^5/_8$-inch deep studs fabricated from 0.0179-inch minimum thickness galvanized steel with $1^5/_{16}$ or $1^7/_{16}$-inch legs. The length of the steel studs shall be $^1/_2$ inch less than the height of the assembly.

3. Type X gypsum wallboard in accordance with ASTM C 36. For single-layer applications, the wallboard shall be applied vertically with no horizontal joints. For multiple-layer applications, horizontal joints are permitted at a minimum spacing of 8 feet, provided that the joints in successive layers are staggered at least 12 inches. The total required thickness of wallboard shall be determined on the basis of the specified fire-resistance rating and the weight-to-heated-perimeter ratio (*W/D*) of the column.

4. Galvanized 0.0149-inch minimum thickness steel corner beads with $1^1/_2$-inch legs attached to the wallboard with 1-inch-long Type S screws spaced 12 inches on center.

5. No. 18 SWG steel tie wires spaced 24 inches on center.

6. Sheet metal angles with 2-inch legs fabricated from 0.0221-inch minimum thickness galvanized steel.

7. Type S screws, 1 inch long, shall be used for attaching the first layer of wallboard to the steel studs and the third layer to the sheet metal angles at 24 inches on center. Type S screws $1^3/_4$-inch long shall be used for attaching the second layer of wallboard to the steel studs and the fourth layer to the sheet metal angles at 12 inches on center. Type S screws $2^1/_4$ inches long shall be used for attaching the third layer of wallboard to the steel studs at 12 inches on center.

R = Fire resistance (minutes).

h = Total thickness of gypsum wallboard (inches).

D = Heated perimeter of the structural steel column (inches).

W' = Total weight of the structural steel column and gypsum wallboard protection (pounds per linear foot).

W' = $W + 50hD/144$.

721.5.1.2.1 Attachment. The gypsum wallboard shall be supported as illustrated in either Figure 721.5.1(2) for fire resistance ratings of 4 hours or less, or Figure 721.5.1(3) for fire resistance ratings of 3 hours or less.
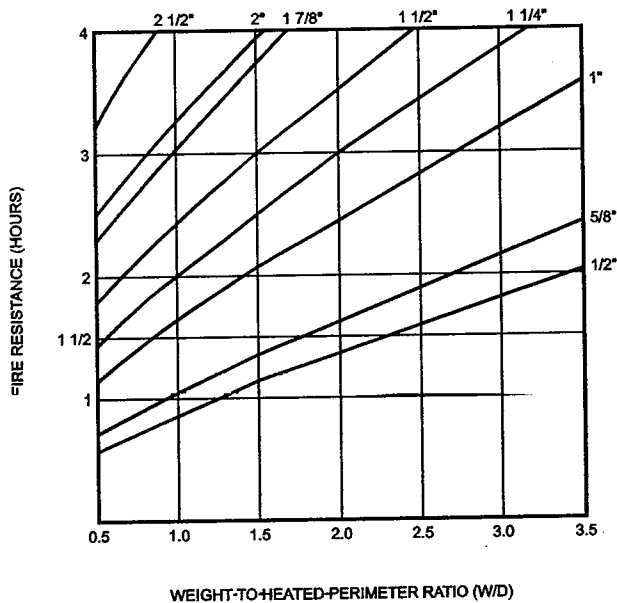
For SI: 1 inch = 25.4 mm, 1 pound per linear foot/inch = 0.059 kg/m/mm.

FIGURE 721.5.1(4)
FIRE RESISTANCE OF STRUCTURAL STEEL COLUMNS
PROTECTED WITH VARIOUS THICKNESSES OF
TYPE X GYPSUM WALLBOARD

a. The W/D ratios for typical wide flange columns are listed in Table 721.5.1(1). For other column shapes, the W/D ratios shall be determined in accordance with Section 720.5.1.1.

721.5.1.2.2 Gypsum wallboard equivalent to concrete. The determination of the fire resistance of structural steel columns from Figure 721.5.1(4) is permitted for various thicknesses of gypsum wallboard as a function of the weight-to-heated-perimeter ratio (W/D) of the column. For structural steel columns with weight-to-heated-perimeter ratios (W/D) greater than 3.65, the thickness of gypsum wallboard required for specified fire-resistance ratings shall be the same as the thickness determined for a W14 × 233 wide flange shape.

721.5.1.3 Spray-applied fire-resistant materials. The fire resistance of wide-flange structural steel columns protected with spray-applied fire-resistant materials, as illustrated in Figure 721.5.1(5), shall be permitted to be determined from the following expression:

$$R = [C_1 (W/D) + C_2] h \qquad \text{(Equation 7-13)}$$

where:

R = Fire resistance (minutes).

h = Thickness of spray-applied fire-resistant material (inches).

D = Heated perimeter of the structural steel column (inches).

C_1 and C_2 = Material-dependent constants.

W = Weight of structural steel column (pounds per linear foot).
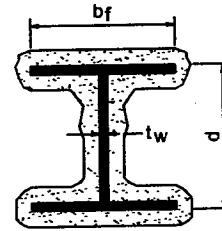
FIGURE 721.5.1(5)
WIDE FLANGE STRUCTURAL STEEL COLUMNS WITH
SPRAY-APPLIED FIRE-RESISTANT MATERIALS

721.5.1.3.1 Material-dependent constants. The material-dependent constants, C_1 and C_2, shall be determined for specific fire-resistant materials on the basis of standard fire endurance tests in accordance with Section 703.2. Unless evidence is submitted to the building official substantiating a broader application, this expression shall be limited to determining the fire resistance of structural steel columns with weight-to-heated-perimeter ratios (W/D) between the largest and smallest columns for which standard fire-endurance test results are available.

721.5.1.3.2 Spray-applied identification. Spray-applied fire-resistant materials shall be identified by density and thickness required for a given fire-resistance rating.

721.5.1.4 Concrete-protected columns. The fire resistance of structural steel columns protected with concrete, as illustrated in Figure 721.5.1(6) (a) and (b), shall be permitted to be determined from the following expression:

$$R = R_o (1 + 0.03m) \qquad \text{(Equation 7-14)}$$

where:

$$R_o = 10 (W/D)^{0.7} + 17 (h^{1.6}/k_c^{0.2}) \times (1 + 26 (H/p_c c_c h (L + h))^{0.8})$$

As used in these expressions:

R = Fire endurance at equilibrium moisture conditions (minutes).

R_o = Fire endurance at zero moisture content (minutes).

m = Equilibrium moisture content of the concrete by volume (percent).

W = Average weight of the steel column (pounds per linear foot).

D = Heated perimeter of the steel column (inches).

h = Thickness of the concrete cover (inches).

k_c = Ambient temperature thermal conductivity of the concrete (Btu/hr ft °F).

H = Ambient temperature thermal capacity of the steel column = 0.11W (Btu/ ft °F).

p_c = Concrete density (pounds per cubic foot).

c_c = Ambient temperature specific heat of concrete (Btu/lb °F).

L = Interior dimension of one side of a square concrete box protection (inches).

721.5.1.4.1 Reentrant space filled. For wide-flange steel columns completely encased in concrete with all reentrant spaces filled [Figure 721.5.1(6)(c)], the thermal capacity of the concrete within the reentrant spaces shall be permitted to be added to the thermal capacity of the steel column, as follows:

$$H = 0.11W + (p_c c_c / 144)(b_f d - A_s) \quad \text{(Equation 7-15)}$$

where:

b_f = Flange width of the steel column (inches).

d = Depth of the steel column (inches).

A_s = Cross-sectional area of the steel column (square inches).

721.5.1.4.2 Concrete properties unknown. If specific data on the properties of concrete are not available, the values given in Table 721.5.1(2) are permitted.

721.5.1.4.3 Minimum concrete cover. For structural steel column encased in concrete with all reentrant spaces filled, Figure 721.5.1(6)(c) and Tables 721.5.1(7) and 721.5.1(8) indicate the thickness of concrete cover required for various fire-resistance ratings for typical wide-flange sections. The thicknesses of concrete indicated in these tables also apply to structural steel columns larger than those listed.

721.5.1.4.4 Minimum precast concrete cover. For structural steel columns protected with precast concrete column covers as shown in Figure 721.5.1(6)(a), Tables 721.5.1(9) and 721.5.1(10) indicate the thickness of the column covers required for various fire-resistance ratings for typical wide-flange shapes. The thicknesses of concrete given in these tables also apply to structural steel columns larger than those listed.

721.5.1.4.5 Masonry protection. The fire resistance of structural steel columns protected with concrete masonry units or clay masonry units as illustrated in Figure 721.5.1(7) shall be permitted to be determined from the following expression:

$$R = 0.17 (W/D)^{0.7} + [0.285 (T_e^{1.6}/K^{0.2})]$$
$$[1.0 + 42.7 \{ (A_s/d_m T_e) / (0.25p + T_e) \}^{0.8}] \quad \text{(Equation 7-16)}$$

where

R = Fire-resistance rating of column assembly (hours).

W = Average weight of steel column (pounds per foot).

D = Heated perimeter of steel column (inches) [see Figure 721.5.1(7)].

T_e = Equivalent thickness of concrete or clay masonry unit (inches) (see Table 721.3.2 Note a or Section 721.4.1).

K = Thermal conductivity of concrete or clay masonry unit (Btu/hr ft °F) [see Table 721.5.1(3)].

A_s = Cross-sectional area of steel column (square inches).

d_m = Density of the concrete or clay masonry unit (pounds per cubic foot).

p = Inner perimeter of concrete or clay masonry protection (inches) [see Figure 721.5.1(7)].

721.5.1.4.6 Equivalent concrete masonry thickness. For structural steel columns protected with concrete masonry, Table 721.5.1(5) gives the equivalent thickness of concrete masonry required for various fire-resistance ratings for typical column shapes. For structural steel column protected with clay masonry, Table 721.5.1(6) gives the equivalent thickness of concrete masonry required for various fire-resistance ratings for typical column shapes.

(a)
PRECAST
CONCRETE
COLUMN
COVERS

(b)
CONCRETE
ENCASED
STRUCTURAL
TUBE

(c)
CONCRETE
ENCASED
WIDE-FLANGE
SHAPE
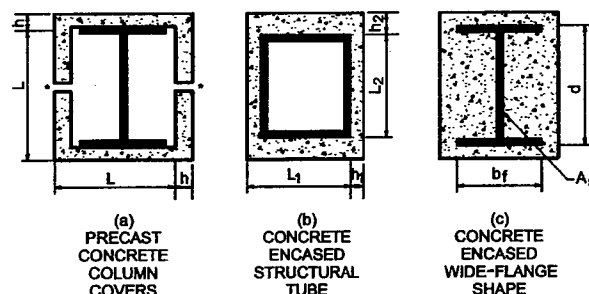
FIGURE 721.5.1(6)
CONCRETE PROTECTED STRUCTURAL STEEL COLUMNS[a]

a. When the inside perimeter of the concrete protection is not square, L shall be taken as the average of L_1 and L_2. When the thickness of concrete cover is not constant, h shall be taken as the average of h_1 and h_2.

b. Joints shall be protected with a minimum 1 inch thickness of ceramic fiber blanket but in no case less than one-half the thickness of the column cover (see Section 720.2.1.3).

$D = 2(w+d) + 2(w - t_{web})$

$D = \pi d$

$D = 2w + 2d$

W SHAPE COLUMN   STEEL PIPE COLUMN   STRUCTURAL TUBE COLUMN
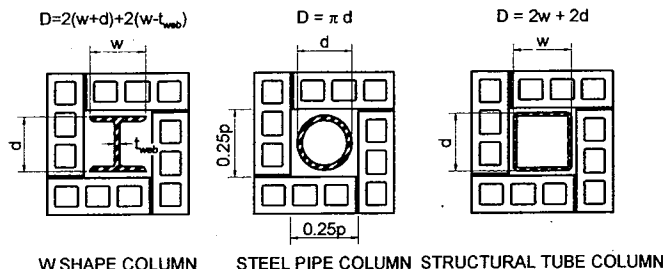
For SI: 1 inch = 25.4 mm.

FIGURE 721.5.1(7)
CONCRETE OR CLAY MASONRY PROTECTED
STRUCTURAL STEEL COLUMNS

d = Depth of a wide flange column, outside diameter of pipe column, or outside dimension of structural tubing column (inches).

t_{web} = Thickness of web of wide flange column (inches).

w = Width of flange of wide flange column (inches).

TABLE 721.5.1(1)
***W/D* RATIOS FOR STEEL COLUMNS**

STRUCTURAL SHAPE	CONTOUR PROFILE	BOX PROFILE	STRUCTURAL SHAPE	CONTOUR PROFILE	BOX PROFILE
W14 × 233	2.49	3.65	W10 × 112	1.78	2.57
× 211	2.28	3.35	× 100	1.61	2.33
× 193	2.10	3.09	× 88	1.43	2.08
× 176	1.93	2.85	× 77	1.26	1.85
× 159	1.75	2.60	× 68	1.13	1.66
× 145	1.61	2.39	× 60	1.00	1.48
× 132	1.52	2.25	× 54	0.91	1.34
× 120	1.39	2.06	× 49	0.83	1.23
× 109	1.27	1.88	× 45	0.87	1.24
× 99	1.16	1.72	× 39	0.76	1.09
× 90	1.06	1.58	× 33	0.65	0.93
× 82	1.20	1.68			
× 74	1.09	1.53	W8 × 67	1.34	1.94
× 68	1.01	1.41	× 58	1.18	1.71
× 61	0.91	1.28	× 48	0.99S	1.44
× 53	0.89	1.21	× 40	0.83	1.23
× 48	0.81	1.10	× 35	0.73	1.08
× 43	0.73	0.99	× 31	0.65	0.97
			× 28	0.67	0.96
W12 × 190	2.46	3.51	× 24	0.58	0.83
× 170	2.22	3.20	× 21	0.57	0.77
× 152	2.01	2.90	× 18	0.49	0.67
× 136	1.82	2.63			
× 120	1.62	2.36	W6 × 25	0.69	1.00
× 106	1.44	2.11	× 20	0.56	0.82
× 96	1.32	1.93	× 16	0.57	0.78
× 87	1.20	1.76	× 15	0.42	0.63
× 79	1.10	1.61	× 12	0.43	0.60
× 72	1.00	1.48	× 9	0.33	0.46
× 65	0.91	1.35			
× 58	0.91	1.31	W5 × 19	0.64	0.93
× 53	0.84	1.20	× 16	0.54	0.80
× 50	0.89	1.23			
× 45	0.81	1.12	W4 × 13	0.54	0.79
× 40	0.72	1.00			

For SI: 1 pound per linear foot per inch = 0.059 kg/m/mm.

TABLE 721.5.1(2)
PROPERTIES OF CONCRETE

PROPERTY	NORMAL WEIGHT CONCRETE	STRUCTURAL LIGHTWEIGHT CONCRETE
Thermal conductivity (k_c)	0.95 Btu/hr ft °F	0.35 Btu/hr ft °F
Specific heat (c_c)	0.20 Btu/lb °F	0.20 Btu/lb °F
Density (P_c)	145 lb/ft^3	110 lb/ft^3
Equilibrium (free) moisture content (m) by volume	4%	5%

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm, 1 lb/ft^3 = 16.0185 kg/m^3, Btu/hr ft °F = 1.731 W/(m · K)

TABLE 721.5.1(3)
THERMAL CONDUCTIVITY OF CONCRETE OR CLAY
MASONRY UNITS

DENSITY (d_m) OF UNITS (lb/ft^3)	THERMAL CONDUCTIVITY (K) OF UNITS (Btu/hr ft °F)
Concrete Masonry Units	
80	0.207
85	0.228
90	0.252
95	0.278
100	0.308
105	0.340
110	0.376
115	0.416
120	0.459
125	0.508
130	0.561
135	0.620
140	0.685
145	0.758
150	0.837
Clay Masonry Units	
120	1.25
130	2.25

For SI: 1 pound per cubic foot = 16.0185 kg/m^3, Btu per hour foot °F = 1.731 W/(m · K).

TABLE 721.5.1(4)
WEIGHT-TO-HEATED-PERIMETER RATIOS (*W/D*)
FOR TYPICAL WIDE FLANGE BEAM AND GIRDER SHAPES

STRUCTURAL SHAPE	CONTOUR PROFILE	BOX PROFILE	STRUCTURAL SHAPE	CONTOUR PROFILE	BOX PROFILE
W36 × 300	2.47	3.33	× 68	0.92	1.21
× 280	2.31	3.12	× 62	0.92	1.14
× 260	2.16	2.92	× 55	0.82	1.02
× 245	2.04	2.76			
× 230	1.92	2.61	W21 × 147	1.83	2.60
× 210	1.94	2.45	× 132	1.66	2.35
× 194	1.80	2.28	× 122	1.54	2.19
× 182	1.69	2.15	× 111	1.41	2.01
× 170	1.59	2.01	× 101	1.29	1.84
× 160	1.50	1.90	× 93	1.38	1.80
× 150	1.41	1.79	× 83	1.24	1.62
× 135	1.28	1.63	× 73	1.10	1.44
			× 68	1.03	1.35
W33 × 241	2.11	2.86	× 62	0.94	1.23
× 221	1.94	2.64	× 57	0.93	1.17
× 201	1.78	2.42	× 50	0.83	1.04
× 152	1.51	1.94	× 44	0.73	0.92
× 141	1.41	1.80			
× 130	1.31	1.67	W18 × 119	1.69	2.42
× 118	1.19	1.53	× 106	1.52	2.18
			× 97	1.39	2.01
W30 × 211	2.00	2.74	× 86	1.24	1.80
× 191	1.82	2.50	× 76	1.11	1.60
× 173	1.66	2.28	× 71	1.21	1.59
× 132	1.45	1.85	× 65	1.11	1.47
× 124	1.37	1.75	× 60	1.03	1.36
× 116	1.28	1.65	× 55	0.95	1.26
× 108	1.20	1.54	× 50	0.87	1.15
× 99	1.10	1.42	× 46	0.86	1.09
			× 40	0.75	0.96
W27 × 178	1.85	2.55	× 35	0.66	0.85
× 161	1.68	2.33			
× 146	1.53	2.12	W16 × 100	1.56	2.25
× 114	1.36	1.76	× 89	1.40	2.03
× 102	1.23	1.59	× 77	1.22	1.78
× 94	1.13	1.47	× 67	1.07	1.56
× 84	1.02	1.33	× 57	1.07	1.43
			× 50	0.94	1.26
			× 45	0.85	1.15
W24 × 162	1.85	2.57	× 40	0.76	1.03
× 146	1.68	2.34	× 36	0.69	0.93
× 131	1.52	2.12	× 31	0.65	0.83
× 117	1.36	1.91	× 26	0.55	0.70
× 104	1.22	1.71			
× 94	1.26	1.63	W14 × 132	1.83	3.00
× 84	1.13	1.47	× 120	1.67	2.75
× 76	1.03	1.34	× 109	1.53	2.52

(continued)

TABLE 721.5.1(4)—continued
WEIGHT-TO-HEATED-PERIMETER RATIOS (*W/D*)
FOR TYPICAL WIDE FLANGE BEAM AND GIRDER SHAPES

STRUCTURAL SHAPE	CONTOUR PROFILE	BOX PROFILE	STRUCTURAL SHAPE	CONTOUR PROFILE	BOX PROFILE
× 99	1.39	2.31	× 30	0.79	1.12
× 90	1.27	2.11	× 26	0.69	0.98
× 82	1.41	2.12	× 22	0.59	0.84
× 74	1.28	1.93	× 19	0.59	0.78
× 68	1.19	1.78	× 17	0.54	0.70
× 61	1.07	1.61	× 15	0.48	0.63
× 53	1.03	1.48	× 12	0.38	0.51
× 48	0.94	1.35			
× 43	0.85	1.22	W8 × 67	1.61	2.55
× 38	0.79	1.09	× 58	1.41	2.26
× 34	0.71	0.98	× 48	1.18	1.91
× 30	0.63	0.87	× 40	1.00	1.63
× 26	0.61	0.79	× 35	0.88	1.44
× 22	0.52	0.68	× 31	0.79	1.29
			× 28	0.80	1.24
W12 × 87	1.44	2.34	× 24	0.69	1.07
× 79	1.32	2.14	× 21	0.66	0.96
× 72	1.20	1.97	× 18	0.57	0.84
× 65	1.09	1.79	× 15	0.54	0.74
× 58	1.08	1.69	× 13	0.47	0.65
× 53	0.99	1.55	× 10	0.37	0.51
× 50	1.04	1.54			
× 45	0.95	1.40	W6 × 25	0.82	1.33
× 40	0.85	1.25	× 20	0.67	1.09
× 35	0.79	1.11	× 16	0.66	0.96
× 30	0.69	0.96	× 15	0.51	0.83
× 26	0.60	0.84	× 12	0.51	0.75
× 22	0.61	0.77	× 9	0.39	0.57
× 19	0.53	0.67			
× 16	0.45	0.57	W5 × 19	0.76	1.24
× 14	0.40	0.50	× 16	0.65	1.07
W10 × 112	2.14	3.38	W4 × 13	0.65	1.05
× 100	1.93	3.07			
× 88	1.7	2.75			
× 77	1.52	2.45			
× 68	1.35	2.20			
× 60	1.20	1.97			
× 54	1.09	1.79			
× 49	0.99	1.64			
× 45	1.03	1.59			
× 39	0.94	1.40			
× 33	0.77	1.20			

For SI: Pounds per linear foot per inch = 0.059 kg/m/mm.

TABLE 721.5.1(5)
FIRE RESISTANCE OF CONCRETE MASONRY PROTECTED STEEL COLUMNS

COLUMN SIZE	CONCRETE MASONRY DENSITY POUNDS PER CUBIC FOOT	MINIMUM REQUIRED EQUIVALENT THICKNESS FOR FIRE-RESISTANCE RATING OF CONCRETE. MASONRY PROTECTION ASSEMBLY T_e, (inches)				COLUMN SIZE	CONCRETE MASONRY DENSITY POUNDS PER CUBIC FOOT	MINIMUM REQUIRED EQUIVALENT THICKNESS FOR FIRE-RESISTANCE RATING OF CONCRETE. MASONRY PROTECTION ASSEMBLY T_e, (inches)			
		1-hour	2-hour	3-hour	4-hour			1-hour	2-hour	3-hour	4-hour
W14 × 82	80	0.74	1.61	2.36	3.04	W10 × 68	80	0.72	1.58	2.33	3.01
	100	0.89	1.85	2.67	3.40		100	0.87	1.83	2.65	3.38
	110	0.96	1.97	2.81	3.57		110	0.94	1.95	2.79	3.55
	120	1.03	2.08	2.95	3.73		120	1.01	2.06	2.94	3.72
W14 × 68	80	0.83	1.70	2.45	3.13	W10 × 54	80	0.88	1.76	2.53	3.21
	100	0.99	1.95	2.76	3.49		100	1.04	2.01	2.83	3.57
	110	1.06	2.06	2.91	3.66		110	1.11	2.12	2.98	3.73
	120	1.14	2.18	3.05	3.82		120	1.19	2.24	3.12	3.90
W14 × 53	80	0.91	1.81	2.58	3.27	W10 × 45	80	0.92	1.83	2.60	3.30
	100	1.07	2.05	2.88	3.62		100	1.08	2.07	2.90	3.64
	110	1.15	2.17	3.02	3.78		110	1.16	2.18	3.04	3.80
	120	1.22	2.28	3.16	3.94		120	1.23	2.29	3.18	3.96
W14 × 43	80	1.01	1.93	2.71	3.41	W10 × 33	80	1.06	2.00	2.79	3.49
	100	1.17	2.17	3.00	3.74		100	1.22	2.23	3.07	3.81
	110	1.25	2.28	3.14	3.90		110	1.30	2.34	3.20	3.96
	120	1.32	2.38	3.27	4.05		120	1.37	2.44	3.33	4.12
W12 × 72	80	0.81	1.66	2.41	3.09	W8 × 40	80	0.94	1.85	2.63	3.33
	100	0.91	1.88	2.70	3.43		100	1.10	2.10	2.93	3.67
	110	0.99	1.99	2.84	3.60		110	1.18	2.21	3.07	3.83
	120	1.06	2.10	2.98	3.76		120	1.25	2.32	3.20	3.99
W12 × 58	80	0.88	1.76	2.52	3.21	W8 × 31	80	1.06	2.00	2.78	3.49
	100	1.04	2.01	2.83	3.56		100	1.22	2.23	3.07	3.81
	110	1.11	2.12	2.97	3.73		110	1.29	2.33	3.20	3.97
	120	1.19	2.23	3.11	3.89		120	1.36	2.44	3.33	4.12
W12 × 50	80	0.91	1.81	2.58	3.27	W8 × 24	80	1.14	2.09	2.89	3.59
	100	1.07	2.05	2.88	3.62		100	1.29	2.31	3.16	3.90
	110	1.15	2.17	3.02	3.78		110	1.36	2.42	3.28	4.05
	120	1.22	2.28	3.16	3.94		120	1.43	2.52	3.41	4.20
W12 × 40	80	1.01	1.94	2.72	3.41	W8 × 18	110	1.22	2.20	3.01	3.72
	100	1.17	2.17	3.01	3.75		100	1.36	2.40	3.25	4.01
	110	1.25	2.28	3.14	3.90		110	1.42	2.50	3.37	4.14
	120	1.32	2.39	3.27	4.06		120	1.48	2.59	3.49	4.28

(continued)

TABLE 721.5.1(5)—continued
FIRE RESISTANCE OF CONCRETE MASONRY PROTECTED STEEL COLUMNS

NOMINAL TUBE SIZE (inches)	CONCRETE MASONRY DENSITY, POUNDS PER CUBIC FOOT	MINIMUM REQUIRED EQUIVALENT THICKNESS FOR FIRE-RESISTANCE RATING OF CONCRETE. MASONRY PROTECTION ASSEMBLY T_e, (inches)				NOMINAL PIPE SIZE (inches)	CONCRETE MASONRY DENSITY, POUNDS PER CUBIC FOOT	MINIMUM REQUIRED EQUIVALENT THICKNESS FOR FIRE-RESISTANCE RATING OF CONCRETE. MASONRY PROTECTION ASSEMBLY T_e, (inches)			
		1-hour	2-hour	3-hour	4-hour			1-hour	2-hour	3-hour	4-hour
4 × 4 × 1/2 wall thickness	80	0.93	1.90	2.71	3.43	4 double extra strong 0.674 wall thickness	80	0.80	1.75	2.56	3.28
	100	1.08	2.13	2.99	3.76		100	0.95	1.99	2.85	3.62
	110	1.16	2.24	3.13	3.91		110	1.02	2.10	2.99	3.78
	120	1.22	2.34	3.26	4.06		120	1.09	2.20	3.12	3.93
4 × 4 × 3/8 wall thickness	80	1.05	2.03	2.84	3.57	4 extra strong 0.337 wall thickness	80	1.12	2.11	2.93	3.65
	100	1.20	2.25	3.11	3.88		100	1.26	2.32	3.19	3.95
	110	1.27	2.35	3.24	4.02		110	1.33	2.42	3.31	4.09
	120	1.34	2.45	3.37	4.17		120	1.40	2.52	3.43	4.23
4 × 4 × 1/4 wall thickness	80	1.21	2.20	3.01	3.73	4 standard 0.237 wall thickness	80	1.26	2.25	3.07	3.79
	100	1.35	2.40	3.26	4.02		100	1.40	2.45	3.31	4.07
	110	1.41	2.50	3.38	4.16		110	1.46	2.55	3.43	4.21
	120	1.48	2.59	3.50	4.30		120	1.53	2.64	3.54	4.34
6 × 6 × 1/2 wall thickness	80	0.82	1.75	2.54	3.25	5 double extra strong 0.750 wall thickness	80	0.70	1.61	2.40	3.12
	100	0.98	1.99	2.84	3.59		100	0.85	1.86	2.71	3.47
	110	1.05	2.10	2.98	3.75		110	0.91	1.97	2.85	3.63
	120	1.12	2.21	3.11	3.91		120	0.98	2.02	2.99	3.79
6 × 6 × 3/8 wall thickness	80	0.96	1.91	2.71	3.42	5 extra strong 0.375 wall thickness	80	1.04	2.01	2.83	3.54
	100	1.12	2.14	3.00	3.75		100	1.19	2.23	3.09	3.85
	110	1.19	2.25	3.13	3.90		110	1.26	2.34	3.22	4.00
	120	1.26	2.35	3.26	4.05		120	1.32	2.44	3.34	4.14
6 × 6 × 1/4 wall thickness	80	1.14	2.11	2.92	3.63	5 standard 0.258 wall thickness	80	1.20	2.19	3.00	3.72
	100	1.29	2.32	3.18	3.93		100	1.34	2.39	3.25	4.00
	110	1.36	2.43	3.30	4.08		110	1.41	2.49	3.37	4.14
	120	1.42	2.52	3.43	4.22		120	1.47	2.58	3.49	4.28
8 × 8 × 1/2 wall thickness	80	0.77	1.66	2.44	3.13	6 double extra strong 0.864 wall thickness	80	0.59	1.46	2.23	2.92
	100	0.92	1.91	2.75	3.49		100	0.73	1.71	2.54	3.29
	110	1.00	2.02	2.89	3.66		110	0.80	1.82	2.69	3.47
	120	1.07	2.14	3.03	3.82		120	0.86	1.93	2.83	3.63
8 × 8 × 3/8 wall thickness	80	0.91	1.84	2.63	3.33	6 extra strong 0.432 wall thickness	80	0.94	1.90	2.70	3.42
	100	1.07	2.08	2.92	3.67		100	1.10	2.13	2.98	3.74
	110	1.14	2.19	3.06	3.83		110	1.17	2.23	3.11	3.89
	120	1.21	2.29	3.19	3.98		120	1.24	2.34	3.24	4.04
8 × 8 × 1/4 wall thickness	80	1.10	2.06	2.86	3.57	6 standard 0.280 wall thickness	80	1.14	2.12	2.93	3.64
	100	1.25	2.28	3.13	3.87		100	1.29	2.33	3.19	3.94
	110	1.32	2.38	3.25	4.02		110	1.36	2.43	3.31	4.08
	120	1.39	2.48	3.38	4.17		120	1.42	2.53	3.43	4.22

For SI: 1 inch = 25.4 mm, 1 pound per cubic feet = 16.02 kg/m³.

Note: Tabulated values assume 1-inch air gap between masonry and steel section.

TABLE 721.5.1(6)
FIRE RESISTANCE OF CLAY MASONRY PROTECTED STEEL COLUMNS

COLUMN SIZE	CLAY MASONRY DENSITY, POUNDS PER CUBIC FOOT	MINIMUM REQUIRED EQUIVALENT THICKNESS FOR FIRE-RESISTANCE RATING OF CLAY. MASONRY PROTECTION ASSEMBLY T_e, (inches)				COLUMN SIZE	CLAY MASONRY DENSITY, POUNDS PER CUBIC FOOT	MINIMUM REQUIRED EQUIVALENT THICKNESS FOR FIRE-RESISTANCE RATING OF CLAY MASONRY PROTECTION ASSEMBLY T_e, (inches)			
		1-hour	2-hour	3-hour	4-hour			1-hour	2-hour	3-hour	4-hour
W14 × 82	120	1.23	2.42	3.41	4.29	W10 × 68	120	1.27	2.46	3.26	4.35
	130	1.40	2.70	3.78	4.74		130	1.44	2.75	3.83	4.80
W14 × 68	120	1.34	2.54	3.54	4.43	W10 × 54	120	1.40	2.61	3.62	4.51
	130	1.51	2.82	3.91	4.87		130	1.58	2.89	3.98	4.95
W14 × 53	120	1.43	2.65	3.65	4.54	W10 × 45	120	1.44	2.66	3.67	4.57
	130	1.61	2.93	4.02	4.98		130	1.62	2.95	4.04	5.01
W14 × 43	120	1.54	2.76	3.77	4.66	W10 × 33	120	1.59	2.82	3.84	4.73
	130	1.72	3.04	4.13	5.09		130	1.77	3.10	4.20	5.13
W12 × 72	120	1.32	2.52	3.51	4.40	W8 × 40	120	1.47	2.70	3.71	4.61
	130	1.50	2.80	3.88	4.84		130	1.65	2.98	4.08	5.04
W12 × 58	120	1.40	2.61	3.61	4.50	W8 × 31	120	1.59	2.82	3.84	4.73
	130	1.57	2.89	3.98	4.94		130	1.77	3.10	4.20	5.17
W12 × 50	120	1.43	2.65	3.66	4.55	W8 × 24	120	1.66	2.90	3.92	4.82
	130	1.61	2.93	4.02	4.99		130	1.84	3.18	4.28	5.25
W12 × 40	120	1.54	2.77	3.78	4.67	W8 × 18	120	1.75	3.00	4.01	4.91
	130	1.72	3.05	4.14	5.10		130	1.93	3.27	4.37	5.34

	Steel tubing						Steel pipe				
Nominal tube size (inches)	Clay masonry density, pounds per cubic foot	Minimum required equivalent thickness for fire-resistance rating of clay. Masonry protection assembly T_e, (inches)				Nominal pipe size (inches)	Clay masonry density, pounds per cubic foot	Minimum required equivalent thickness for fire-resistance rating of clay. Masonry protection assembly T_e, (inches)			
		1-hour	2-hour	3-hour	4-hour			1-hour	2-hour	3-hour	4-hour
4 × 4 × 1/2 wall thickness	120	1.44	2.72	3.76	4.68	4 double extra strong 0.674 wall thickness	120	1.26	2.55	3.60	4.52
	130	1.62	3.00	4.12	5.11		130	1.42	2.82	3.96	4.95
4 × 4 × 3/8 wall thickness	120	1.56	2.84	3.88	4.78	4 extra strong 0.337 wall thickness	120	1.60	2.89	3.92	4.83
	130	1.74	3.12	4.23	5.21		130	1.77	3.16	4.28	5.25
4 × 4 × 1/4 wall thickness	120	1.72	2.99	4.02	4.92	4 standard 0.237 wall thickness	120	1.74	3.02	4.05	4.95
	130	1.89	3.26	4.37	5.34		130	1.92	3.29	4.40	5.37
6 × 6 × 1/2 wall thickness	120	1.33	2.58	3.62	4.52	5 double extra strong 0.750 wall thickness	120	1.17	2.44	3.48	4.40
	130	1.50	2.86	3.98	4.96		130	1.33	2.72	3.84	4.83
6 × 6 × 3/8 wall thickness	120	1.48	2.74	3.76	4.67	5 extra strong 0.375 wall thickness	120	1.55	2.82	3.85	4.76
	130	1.65	3.01	4.13	5.10		130	1.72	3.09	4.21	5.18
6 × 6 × 1/4 wall thickness	120	1.66	2.91	3.94	4.84	5 standard 0.258 wall thickness	120	1.71	2.97	4.00	4.90
	130	1.83	3.19	4.30	5.27		130	1.88	3.24	4.35	5.32
8 × 8 × 1/2 wall thickness	120	1.27	2.50	3.52	4.42	6 double extra strong 0.864 wall thickness	120	1.04	2.28	3.32	4.23
	130	1.44	2.78	3.89	4.86		130	1.19	2.60	3.68	4.67
8 × 8 × 3/8 wall thickness	120	1.43	2.67	3.69	4.59	6 extra strong 0.432 wall thickness	120	1.45	2.71	3.75	4.65
	130	1.60	2.95	4.05	5.02		130	1.62	2.99	4.10	5.08
8 × 8 × 1/4 wall thickness	120	1.62	2.87	3.89	4.78	6 standard 0.280 wall thickness	120	1.65	2.91	3.94	4.84
	130	1.79	3.14	4.24	5.21		130	1.82	3.19	4.30	5.27

TABLE 721.5.1(7)
MINIMUM COVER (inch) FOR STEEL COLUMNS
ENCASED IN NORMAL-WEIGHT CONCRETE[a]
[FIGURE 721.5.1(6)(c)]

STRUCTURAL SHAPE	FIRE-RESISTANCE RATING (hours)				
	1	1½	2	3	4
W14 × 233				1½	2
× 176			1		
× 132		1			2½
× 90	1			2	
× 61			1½		
× 48					3
× 43		1½		2½	
W12 × 152			1		2½
× 96		1		2	
× 65	1				
× 50			1½		3
× 40		1½		2½	
W10 × 88	1			2	
× 49					3
× 45	1	1½	1½		
× 39				2½	3½
× 33			2		
W8 × 67		1			3
× 58			1½		
× 48	1			2½	
× 31		1½			3½
× 21			2		
× 18				3	4
W6 × 25		1½	2		3½
× 20				3	
× 16	1	2			4
× 15					
× 9	1½		2½	3½	

For SI: 1 inch = 25.4 mm.
a. The tabulated thicknesses are based upon the assumed properties of normal-weight concrete given in Table 721.5.1(2).

TABLE 721.5.1(8)
MINIMUM COVER (inch) FOR STEEL COLUMNS
ENCASED IN STRUCTURAL LIGHTWEIGHT CONCRETE[a]
[FIGURE 721.5.1(6)(c)]

STRUCTURAL SHAPE	FIRE-RESISTANCE RATING (HOURS)				
	1	1½	2	3	4
W14 × 233				1	1½
× 193					
× 74	1	1	1	1½	2
× 61					
× 43			1½	2	2½
W12 × 65				1½	2
× 53	1	1	1		
× 40			1½	2	2½
W10 × 112					2
× 88	1		1	1½	
× 60		1			
× 33			1½	2	2½
W8 × 35					2½
× 28	1	1		2	
× 24			1½		3
× 18		1½		2½	

For SI: 1 inch = 25.4 mm.
a. The tabulated thicknesses are based upon the assumed properties of structural lightweight concrete given in Table 721.5.1(2).

TABLE 721.5.1(9)
MINIMUM COVER (inch) FOR STEEL COLUMNS
IN NORMAL-WEIGHT PRECAST COVERS[a]
[FIGURE 721.5.1(6)(a)]

STRUCTURAL SHAPE	FIRE-RESISTANCE RATING (hours)				
	1	1½	2	3	4
W14 × 233					3
× 211			1½	2½	
× 176					3½
× 145		1½	2		
× 109	1½			3	
× 99					
× 61					4
× 43		2	2½	3½	4½
W12 × 190			1½	2½	3½
× 152					
× 120		1½	2		
× 96				3	
× 87	1½				4
× 58					
× 40		2	2½	3½	4½
W10 × 112					3½
× 88		1½	2	3	
× 77	1½				4
× 54		2	2½	3½	
× 33					4½
W8 × 67		1½	2	3	
× 58					4
× 48	1½	2	2½	3½	
× 28					4½
× 21					
× 18		2½	3	4	
W6 × 25		2	2½	3½	
× 20	1½				4½
× 16			3		
× 12	2	2½		4	
× 9					5

For SI: 1 inch = 25.4 mm.
a. The tabulated thicknesses are based upon the assumed properties of normal-weight concrete given in Table 721.5.1(2).

TABLE 721.5.1(10)
MINIMUM COVER (inch) FOR STEEL COLUMNS
IN STRUCTURAL LIGHTWEIGHT PRECAST COVERS[a]
[FIGURE 721.5.1(6)(a)]

STRUCTURAL SHAPE	FIRE-RESISTANCE RATING (hours)				
	1	1½	2	3	4
W14 × 233					2½
× 176				2	
× 145			1½		
× 132					3
× 109	1½	1½			
× 99				2½	
× 68			2		
× 43				3	3½
W12 × 190					2½
× 152				2	
× 136			1½		
× 106					3
× 96	1½	1½		2½	
× 87					
× 65			2		
× 40				3	3½
W10 × 112				2	
× 100		1½			3
× 88					
× 77	1½	1½		2½	
× 60			2		
× 39				3	3½
× 33		2			–
W8 × 67			1½	2½	3
× 48		1½			
× 35	1½		2		3½
× 28				3	
× 18		2	2½		4
W6 × 25			2	3	3½
× 15	1½	2			4
× 9			2½	3½	

For SI: 1 inch = 25.4 mm.
a. The tabulated thicknesses are based upon the assumed properties of structural lightweight concrete given in Table 721.5.1(2).

721.5.2 Structural steel beams and girders. The fire-resistance ratings of steel beams and girders shall be based upon the size of the element and the type of protection provided in accordance with this section.

D = 3b$_f$ + 2d -2t$_w$

D = 2d + b$_f$
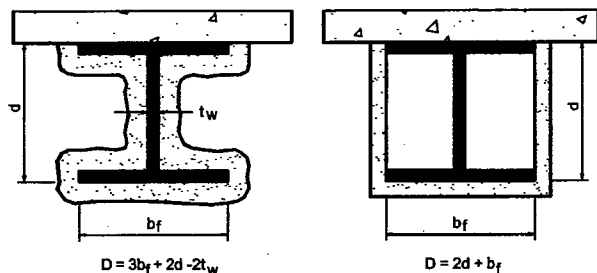
FIGURE 721.5.2
DETERMINATION OF THE HEATED PERIMETER
OF STRUCTURAL STEEL BEAMS AND GIRDERS

721.5.2.1 Determination of fire resistance. These procedures establish a basis for determining resistance of structural steel beams and girders which differ in size from that specified in approved fire-resistance-rated assemblies as a function of the thickness of fire-resistant material and the weight (W) and heated perimeter (D) of the beam or girder. As used in these sections, W is the average weight of a structural steel member in pounds per linear foot (plf). The heated perimeter, D, is the inside perimeter of the fire-resistant material in inches as illustrated in Figure 721.5.2.

721.5.2.1.1 Weight-to-heated perimeter. The weight-to-heated-perimeter ratios (W/D), for both contour and box fire-resistant protection profiles, for the wide flange shapes most often used as beams or girders are given in Table 721.5.1(4). For different shapes, the weight-to-heated-perimeter ratios (W/D) shall be determined in accordance with the definitions given in this section.

721.5.2.1.2 Beam and girder substitutions. Except as provided for in Section 721.5.2.2, structural steel beams in approved fire-resistance-rated assemblies shall be considered the minimum permissible size. Other beam or girder shapes shall be permitted to be substituted provided that the weight-to-heated-perimeter ratio (W/D) of the substitute beam is equal to or greater than that of the beam specified in the approved assembly.

721.5.2.2 Spray-applied fire-resistant materials. The provisions in this section apply to unrestrained structural steel beams and girders protected with spray-applied fire-resistance-rated materials. Larger or smaller unrestrained beam and girder shapes shall be permitted to be substituted for beams specified in approved unrestrained or restrained fire-resistance-rated assemblies provided that the thickness of the fire-resistant material is adjusted in accordance with the following expression:

$$h_2 = \left[\frac{(W_1 / D_1) + 0.60}{(W_2 / D_2) + 0.60} \right] h_1$$

(Equation 7-17)

where:

h = Thickness of spray-applied fire-resistant material in inches.

W = Weight of the structural steel beam or girder in pounds per linear foot.

D = Heated perimeter of the structural steel beam or girder in inches.

Subscript 1 refers to the beam and fire-resistant material thickness in the fire-resistance-rated assembly.

Subscript 2 refers to the substitute beam or girder and the required thickness of fire-resistant material.

721.5.2.2.1 Minimum thickness. Equation 7-17 is limited to beams with a weight-to-heated-perimeter ratio (W/D) of 0.37 or greater. The minimum thickness of fire-resistant material shall not be less than ³/₈ inch (9.5 mm).

721.5.2.3 Structural steel trusses. The fire resistance of structural steel trusses protected with fire-resistant material spray applied to each of the individual truss elements shall be permitted to be determined in accordance with this section. The thickness of the fire-resistant material shall be determined in accordance with Section 721.5.1.3. The weight-to-heated-perimeter ratio (W/D) of truss elements that can be simultaneously exposed to fire on all sides shall be determined on the same basis as columns as specified in Section 721.5.1.1. The weight-to-heated-perimeter ratio (W/D) of truss elements that directly support floor or roof construction shall be determined on the same basis as beams and girders, as specified in Section 721.5.2.1.

721.6 Wood assemblies. The provisions of this section contain procedures by which the fire-resistance ratings of wood assemblies are established by calculation.

721.6.1 General. This section contains procedures for calculating the fire-resistance ratings of walls, floor/ceiling and roof/ceiling assemblies based in part on the standard method of testing referenced in Section 703.2.

721.6.1.1 Maximum fire-resistance rating. Fire-resistance ratings calculated using the procedures in this section shall be used only for 1-hour rated assemblies.

721.6.1.2 Dissimilar membranes. Where dissimilar membranes are used on a wall assembly, the calculation shall be made from the least fire-resistant (weaker) side.

721.6.2 Walls, floors and roofs. These procedures apply to both load-bearing and nonload bearing assemblies.

721.6.2.1 Fire-resistance rating of wood frame assemblies. The fire-resistance rating of a wood frame assembly is equal to the sum of the time assigned to the membrane on the fire-exposed side, the time assigned to the framing members and the time assigned for additional contribution by other protective measures such as insulation. The membrane on the unexposed side shall not be included in determining the fire resistance of the assembly.

721.6.2.2 Time assigned to membranes. Table 721.6.2(1) indicates the time assigned to membranes on the fire-exposed side.

721.6.2.3 Exterior walls. For an exterior wall having more than 5 feet (1524 mm) of horizontal separation, the wall is assigned a rating dependent on the interior membrane and the framing as described in Tables 721.6.2(1) and 721.6.2(2). The membrane on the outside of the nonfire-exposed side of exterior walls having more than 5 feet (1524 mm) of horizontal separation may consist of sheathing, sheathing paper, and siding as described in Table 721.6.2(3).

721.6.2.4 Floor and roofs. In the case of a floor or roof, the standard test provides only for testing for fire exposure from below. Except as noted in Section 703.3, Item 5, floor or roof assemblies of wood framing shall have an upper membrane consisting of a subfloor and finished floor conforming to Table 721.6.2(4) or any other membrane that has a contribution to fire resistance of at least 15 minutes in Table 721.6.2(1).

721.6.2.5 Additional protection. Table 721.6.2(5) indicates the time increments to be added to the fire resistance where glass fiber, rock wool, slag mineral wool, or cellulose insulation is incorporated in the assembly.

721.6.2.6 Fastening. Fastening of wood frame assemblies and the fastening of membranes to the wood framing members shall be done in accordance with Chapter 23.

TABLE 721.6.2(1)
TIME ASSIGNED TO WALLBOARD MEMBRANES[a,b,c,d]

DESCRIPTION OF FINISH	TIME[e] (minutes)
$^3/_8$-inch wood structural panel bonded with exterior glue	5
$^{15}/_{32}$-inch wood structural panel bonded with exterior glue	10
$^{19}/_{32}$-inch wood structural panel bonded with exterior glue	15
$^3/_8$-inch gypsum wallboard	10
$^1/_2$-inch gypsum wallboard	15
$^5/_8$-inch gypsum wallboard	30
$^1/_2$-inch Type X gypsum wallboard	25
$^5/_8$-inch Type X gypsum wallboard	40
Double $^3/_8$-inch gypsum wallboard	25
$^1/_2$- + $^3/_8$-inch gypsum wallboard	35
Double $^1/_2$-inch gypsum wallboard	40

For SI: 1 inch = 25.4 mm.

a. These values apply only when membranes are installed on framing members which are spaced 16 inches o.c.

b. Gypsum wallboard installed over framing or furring shall be installed so that all edges are supported, except $^5/_8$-inch Type X gypsum wallboard shall be permitted to be installed horizontally with the horizontal joints staggered 24 inches each side and unsupported but finished.

c. On wood frame floor/ceiling or roof/ceiling assemblies, gypsum board shall be installed with the long dimension perpendicular to framing members and shall have all joints finished.

d. The membrane on the unexposed side shall not be included in determining the fire resistance of the assembly. When dissimilar membranes are used on a wall assembly, the calculation shall be made from the least fire-resistant (weaker) side.

e. The time assigned is not a finished rating.

TABLE 721.6.2(2)
TIME ASSIGNED FOR CONTRIBUTION OF WOOD FRAME[a,b,c]

DESCRIPTION	TIME ASSIGNED TO FRAME (minutes)
Wood studs 16 inches o.c.	20
Wood floor and roof joists 16 inches o.c.	10

For SI: 1 inch = 25.4 mm.

a. This table does not apply to studs or joists spaced more than 16 inches o.c.

b. All studs shall be nominal 2 × 4 and all joists shall have a nominal thickness of at least 2 inches.

c. Allowable spans for joists shall be determined in accordance with Sections 2308.8, 2308.10.2 and 2308.10.3

TABLE 721.6.2(3)
MEMBRANE[a] ON EXTERIOR FACE OF WOOD STUD WALLS

SHEATHING	PAPER	EXTERIOR FINISH
$^5/_8$-inch T & G lumber $^5/_{16}$-inch exterior glue plywood $^1/_2$-inch gypsum wallboard $^5/_8$-inch gypsum wallboard $^1/_2$-inch fiberboard	Sheathing paper	Lumber siding Wood shingles and shakes $^1/_4$-inch wood structural panels—exterior type $^1/_4$-inch hardboard Metal siding Stucco on metal lath Masonry veneer
None	—	$^3/_8$-inch exterior-grade wood structural panels

For SI: 1 pound/cubic feet = 16.0185 kg/m^2.

a. Any combination of sheathing, paper, and exterior finish is permitted.

TABLE 721.6.2(4)
FLOORING OR ROOFING OVER WOOD FRAMING[a]

ASSEMBLY	STRUCTURAL MEMBERS	SUBFLOOR OR ROOF DECK	FINISHED FLOORING OR ROOFING
Floor	Wood	$^{15}/_{32}$-inch wood structural panels or $^{11}/_{16}$ inch T & G softwood	Hardwood or softwood flooring on building paper resilient flooring, parquet floor felted-synthetic fiber floor coverings, carpeting, or ceramic tile on $^{3}/_{8}$-inch-thick panel-type underlay Ceramic tile on $1^{1}/_{4}$-inch mortar bed
Roof	Wood	$^{15}/_{32}$-inch wood structural panels or $^{11}/_{16}$ inch T & G softwood	Finished roofing material with or without insulation

For SI: 1 inch = 25.4 mm.

a. This table applies only to wood joist construction. It is not applicable to wood truss construction.

TABLE 721.6.2(5)
TIME ASSIGNED FOR ADDITIONAL PROTECTION

DESCRIPTION OF ADDITIONAL PROTECTION	FIRE RESISTANCE (minutes)
Add to the fire-resistance rating of wood stud walls if the spaces between the studs are completely filled with glass fiber mineral wool batts weighing not less than 2 pounds per cubic foot (0.6 pound per square foot of wall surface) or rockwool or slag material wool batts weighing not less than 3.3 pounds per cubic foot (1 pound per square foot of wall surface), or cellulose insulation having a nominal density not less than 2.6 pounds per cubic foot.	15

For SI: 1 pound/cubic foot = 16.0185 kg/m^3.

721.6.3 Design of fire-resistant exposed wood members.
The fire-resistance rating, in minutes, of timber beams and columns with a minimum nominal dimension of 6 inches (152 mm) is equal to:

Beams: $2.54Zb$ (4 -2(b/d)) for beams which may be exposed to fire on four sides.
(Equation 7-18)

$2.54Zb$ (4 -(b/d)) for beams which may be exposed to fire on three sides.
(Equation 7-19)

Columns: $2.54Zd$ (3 -(d/b)) for columns which may be exposed to fire on four sides
(Equation 7-20)

$2.54Zd$ (3 -$(d/2b)$) for columns which may be exposed to fire on three sides.
(Equation 7-21)

where:

b = The breadth (width) of a beam or larger side of a column before exposure to fire (inches).

d = The depth of a beam or smaller side of a column before exposure to fire (inches).
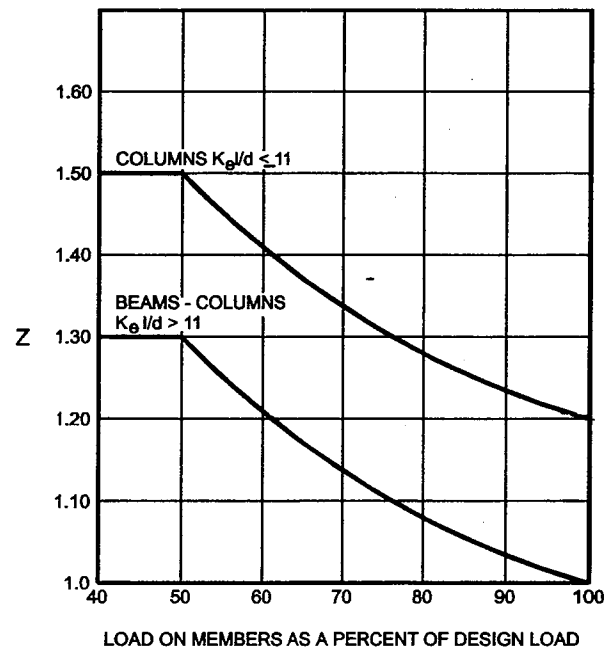
Z = Load factor, based on Figure 720.6.3(1)

FIGURE 721.6.3(1)
LOAD FIGURE

K_e = The effective length factor as noted in Figure 721.6.3(2).

l = The unsupported length of columns (inches).

BUCKLING MODES						
THEORETICAL K_e VALUE	0.5	0.7	1.0	1.0	2.0	2.0
RECOMMENDED DESIGN K_e WHEN IDEAL CONDITIONS APPROXIMATED	0.65	0.80	1.2	1.0	2.10	2.4
END CONDITION CODE	ROTATION FIXED, TRANSLATION FIXED					
	ROTATION FREE, TRANSLATION FIXED					
	ROTATION FIXED, TRANSLATION FREE					
	ROTATION FREE, TRANSLATION FREE					

FIGURE 721.6.3(2)
EFFECTIVE LENGTH FACTORS

721.6.3.1 Equation 7-21. Equation 7-21 applies only where the unexposed face represents the smaller side of the column. If a column is recessed into a wall, its full dimension shall be used for the purpose of these calculations.

721.6.3.2 Allowable loads. Allowable loads on beams and columns are determined using design values given in ANSI/AF&PA NDS.

721.6.3.3 Fastener protection. Where minimum 1-hour fire resistance is required, connectors and fasteners shall be protected from fire exposure by 1 1/2 inches (38 mm) of wood, or other approved covering or coating for a 1-hour rating. Typical details for commonly used fasteners and connectors are shown in AITC Technical Note 7.

721.6.3.4 Minimum size. Wood members are limited to dimensions of 6 inches (152 mm) nominal or greater. Glued laminated timber beams utilize standard laminating combinations except that a core lamination is removed. The tension zone is moved inward and the equivalent of an extra nominal 2-inch-thick (51 mm) outer tension lamination is added.

721.7 Other reference documents. Refer to Section 703.3, Item 1, and NBS BMS 71 and NBS STRBM-44 for fire-resistance ratings of materials and assemblies.