COMMONWEALTH OF MASSACHUSETTS
DEPARTMENT OF TRANSPORTATION
STANDARD SPECIFICATIONS

for Highways and Bridges

2024 Edition

DIVISION III

massDOT
Massachusetts Department of Transportation
Highway Division

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SECTION M: MATERIALS

Approval and Acceptance.

All materials must be approved prior to incorporation in the work. Approval of materials shall be in accordance with the applicable requirements of Subsection 5.03: Conformity with Plans and Specifications and Section 6.00: Control of Materials. Materials may be approved at the source of manufacture or at the project site. Information regarding the origin, composition and/or manufacture of any material shall be furnished if requested by the Engineer.

Approval and acceptance of any material intended for use in the work of the Department is contingent upon the particular material conforming to a designated specification. All questions relating to materials will be resolved by RMS or its duly authorized representative.

The Department maintains a QCML of commonly used materials that meet these specifications.

Sampling and Testing.

Materials will be sampled and tested in accordance with the designated Standards. The applicable edition of the Standard shall be as stipulated in Subsection 1.03: Defined Terms.

Sampling of materials will be performed by Department personnel, personnel authorized by the Department or personnel under Department supervision.

Certification.

Materials accepted on certification as stipulated in Subsection 6.01: Source of Supply and Quality fall into two categories:

1. Those accepted on a particular certification and sampling frequency.
2. Those accepted on certification alone.

A listing of materials falling into one or the other of the above categories will be furnished upon request to RMS.

SECTION M1: SOILS AND BORROW MATERIALS

M1.00.0: General

All Soils and borrow materials shall conform to the requirements of the specifications as designated hereinafter.

M1.01.0: Ordinary Borrow

Ordinary Borrow shall consist of a material satisfactory to the Engineer and not specified as gravel borrow, sand borrow, special borrow material or other particular kind of borrow.

This material shall have the physical characteristics of soils designated as group A-1, A-2-4 or A-3 under AASHTO M 145. It shall have properties such that it may be readily spread and compacted for the formation of embankments.

The use of PGA meeting the requirements of M2.01.8: Processed Glass Aggregate may be homogeneously blended with the borrow material up to an addition rate of 10 % by mass in areas that will not be exposed, providing the AASHTO M 145 physical characteristics are maintained.

M1.02.0: Special Borrow

Special Borrow shall consist of one of the following:

a) A native in-situ soil that is classified under AASHTO M 145 as A-3, or that portion of A-1 and A-2 with less than 12% passing the No. 200 sieve as determined by AASHTO T 311.
b) A crushed rock, either obtained from ledge excavation on the project or other approved sources, that meets the following requirements:

Percent of wear LA abrasion test ..... 50% Maximum
Plasticity Index ..... 6% Maximum

Table M1.02.0-1: Gradation Requirements for Special Borrow

Sieve Designation	Percent Passing
6 in.	100
2 in.	90-100
No. 4 mesh	20-65
No. 200 mesh	0-12

The use of PGA meeting the requirements of M2.01.8: Processed Glass Aggregate may be blended with either special borrow material outlined above. An addition rate of 10% by mass in areas where the borrow will not be exposed will be allowed, providing the physical characteristics are maintained. The PGA will be blended so as to produce a homogeneous borrow material.

M1.03.0: Gravel Borrow

Gravel Borrow shall consist of inert material that is hard, durable stone and coarse sand, free from loam and clay, surface coatings, and deleterious materials.

Gradation requirements for gravel shall be determined by AASHTO T 311 and shall conform to the following:

Table M1.03.0-1: Gradation Requirements for Gravel Borrow

Sieve Designation	Percent Passing
½ in.	50-85
No. 4	40-75
No. 50	8-28
No. 200	0-10

Maximum size of stone in gravel shall be as follows:

M1.03.0 Type a..... 6 in. largest dimension
M1.03.0 Type b ..... 3 in. largest dimension
M1.03.0 Type c..... 2 in. largest dimension
M1.03.0 Type d ..... 1.5 in. largest dimension

The gradation for Gravel Borrow for Bridge Foundations shall have at least 70% passing the ¾-in. sieve.

The use of PGA meeting the requirements of M2.01.8: Processed Glass Aggregate may be homogeneously blended with the processed gravel up to an addition rate of 10% by mass, providing the subbase material will not be exposed. The resulting blend will meet the physical requirements of gravel borrow types a, b, c and d specified above.

M1.03.1: Processed Gravel for Subbase

This specification covers the quality and gradation for subbase material of crusher run gravel.

Gravel shall consist of inert material that is hard, durable stone and coarse sand, free from loam and clay, surface coatings and deleterious materials.

The coarse aggregate shall have a percentage of wear, by the Los Angeles Abrasion Test, of not more than 50.

The gradation shall meet the following requirements:

Table M1.03.1-1: Gradation Requirements for Processed Gravel for Subbase

Sieve Designation	Percent Passing
3 in.	100
1 ½ in.	70-100
¾ in.	50-85
No. 4	30-60
No. 200	0-10

The approved source of bank-run gravel material shall be processed by mechanical means. The equipment for producing crushed gravel shall be of adequate size and with sufficient adjustments

to produce the desired materials. The processed material shall be stockpiled in such a manner to minimize segregation of particle sizes. All processed gravel shall come from approved stockpiles.

The use of PGA meeting the requirements of M2.01.8: Processed Glass Aggregate may be homogeneously blended with the processed gravel up to an addition rate of 10% by mass, providing the subbase material will not be exposed. The resulting blend will meet the physical requirements of processed gravel specified above.

M1.04.0: Sand Borrow

Sand Borrow shall consist of clean inert, hard, durable grains of quartz or other hard durable rock, free from loam or clay, surface coatings and deleterious materials. The allowable amount of material passing a No. 200 sieve as determined by AASHTO T 11 shall not exceed 10% by weight.

The maximum particle size for Sand Borrow shall be as follows:

M1.04.0 Type a..... ¼ in.
M1.04.0 Type b ..... ⅜ in.

The use of PGA meeting the requirements of M2.01.8: Processed Glass Aggregate will be allowed at an addition rate of 10% mass to type b sand borrow. This addition is allowed providing the material will not be exposed, that the blended material is homogeneous and that the physical requirements specified for Sand Borrow above are maintained.

M1.04.1: Sand Borrow for Subdrains

Sand for use in subdrain installations shall conform to the requirements of M1.04.0: Sand Borrow with the following grading limitations, as determined by AASHTO T 311:

Table M1.04.1-1: Gradation Limitations for Sand Borrow for Use in Subdrains

Sieve Size	Minimum Percent by Weight Passing Through	Maximum Percent by Weight Passing Through
½ in.	100	
⅜ in.	85	100
No. 4	60	100
No. 16	35	80
No. 50	10	55
No. 100	2	10

M1.05.0: Loam

Loam shall be fertile, friable soil obtained from naturally well-drained areas or shall be the product of a commercial sand and gravel processing facility. It shall be uncontaminated by salt water, foreign matter, or substances harmful to plant growth. Loam shall be free of debris rocks, clods, and any other extraneous matter. Loam for Roadsides shall have no material greater than 1 in. in diameter. Loam for Lawns shall have no material greater than ½ in. in diameter.

Loam shall have the following mechanical analysis:

Table M1.05.0-1: Gradation Requirements for Loam

Sieve Size	Percent Passing
No. 10	85-100
No. 40	35-85
No. 200	10-35
<20 µm	<5

Testing shall be on material that has passed the No. 10 sieve. Loam shall contain 4% to 10% organic matter as determined by the loss on ignition of oven-dried samples. Lawn areas shall have an organic content of at least 4%. Organic content for lawn areas shall be at least 4%; for woody plantings, organic content shall be 7% to 10%. Salinity (electrical conductivity) shall be less than 0.1 S/m as determined by a 1:2 (by volume) soil-to-water mix. Salt test samples shall not be oven-dried. The acidity range of the Loam shall be pH 5.5 to 7.0.

The Contractor shall provide testing submittals as follows:

- One 25-lb representative sample per source of loam
- For sources providing >1,000 yd^3, one additional 25-lb representative sample for each 1,000 yd^3 unit of soil

In addition, five random representative 25-lb samples of on-site stockpiles of delivered loam shall be collected and packaged in the presence of the Engineer.

The Contractor shall deliver samples to testing laboratories and shall have the testing report sent directly to the Engineer.

Testing and analysis will be at the Contractor's expense. Soil samples shall be dry. Tests for particle gradation, organic content, and pH shall be performed by an Agricultural Experiment Station testing laboratory or other testing laboratory approved by the Engineer. Soil analysis tests shall show recommendations for soil additives to correct soils deficiencies, and for additives necessary to accomplish particular planting objectives noted. University of Massachusetts Agricultural Extension Service methods for soil and soil additive analysis shall be used.

No Loam shall be delivered to the site until the review and approval of loam test results by the Engineer.

M1.06.0: Compost

The Contractor shall submit for approval a written list of all vendors of manufactured compost that will be used on the project, including locations of compost facilities and feedstock materials. All vendors shall submit certified results of regular periodic testing by an approved testing facility. Certification shall be per US Composting Council Seal of Testing Assurance (STA) Program .

In addition, the Contractor shall provide representative 1-gallon samples from each proposed source for testing and analysis. The Contractor shall deliver samples to testing laboratories and shall have the testing report sent directly to the Engineer. Compost tests shall be performed by STA-certified laboratory. (https://www.compostingcouncil.org/page/CertifiedLabs)

Compost shall be a well-decomposed humus material derived from the aerobic decomposition of biodegradable matter, free of viable weed seeds and other plant propagules (except airborne weed species), foreign debris such as glass, plastic, etcetera and substances toxic to plants. Compost shall be suitable for use as a soil amendment and shall support the growth of ornamental nursery stock and turf establishment. Compost shall be in a shredded or granular form and free from hard lumps.

Food and agriculture residues, animal manure are acceptable source materials. Biosolids and peat are not acceptable as source materials.

Composted material with an unpleasant odor, such as that of ammonia or fecal material shall be rejected by the Engineer.

Compost shall have the following properties:

Table M1.06.0-1: Compost Properties by Type of Compost

Parameter	Units	Type 1 Organic Amendment to Loam	Type 2 Compost Blanket and Compost for Modified Rock	Type 3 Compost Filter Berm	Type 4 Sediment Barrier Media
pH	pH Scale Range	6.0-8.5	6.0-8.5	6.0-8.5	5.0-8.5
Soluble Salt Concentration (Electrical Conductivity)	dS/m	Max 10	Max 5	Max 5	Max 10
Moisture Content	%, wet weight	30-60	30-60	30-60	< 60
Organic Matter Content	%, dry weight	30-65	25-65	25-65	25-100
Particle Size % passing a selected mesh size, dry weight basis	3 in.	-	100	100	100
	2 in.				99-100
	1 in.	-	90-100	90-100	-
	¾ in.	-	65-100	70-100	
	⅜ in.	95	-	-	0-50
	¼ in.	95	0-75	30-75 (no more than 60% passing in high rainfall/flow rate situations)	-
	Particle length	Max. 6 in.	Max. 6 in.	Max. 6 in.	Max. 2 in.
Stability (Carbon Dioxide Evolution Rate)	mg CO2-C per g OM per day	< 4	< 4	< 4	< 8
Maturity (plant bioassay)	%, germination and vigor	> 80 / 80	> 80 / 80	N/A	N/A
Physical Contaminants (Man-made inert materials)	%, dry weight	< 0.5% (0.25% film plastic)	< 0.5 (0.25 film plastic)	< 0.5 (0.25 film plastic)	< 0.5 (0.25) film plastic)

M1.08.0: Impervious Soil Borrow

Impervious Soil shall have the physical characteristics of one of the following, under AASHTO M 145:

1. A-4, A-5, A-6, A-7 soils;
2. A-2 soils containing more than 20% by weight passing the No. 200 sieve; or
3. Peats and other highly organic soils.

The Impervious Soil shall be reasonably free of stumps, brush, and stones larger than 3 in. in diameter.

Material excavated near salt water to be used as impervious soil will be tested for salt content. The maximum soluble salt index shall be 100.

M1.09.0: Reclaimed Pavement Borrow Material

Reclaimed Pavement Borrow material shall consist of crushed asphalt pavement and/or crushed cement concrete, and gravel borrow meeting M1.03.0: Gravel Borrow. The material shall be free of loam, clay, and deleterious materials such as brick, reinforcing steel, wood, paper, plaster, lathing, and building rubble, etc.

The coarse aggregate shall have a percentage of wear not greater than 50 as measured by the Los Angeles Abrasion Test.

Gradation requirements shall be determined by AASHTO T 311 except the material shall not be oven dried. It shall be air dried, fan dried at low speed, or other low temperature heat so as not to liquefy the asphalt or cause the asphalt to adhere to the sieves. Water used for the No. 200 sieve analysis shall be cold tap water.

The gradation shall meet the following requirements:

Table M1.09.0-1: Gradation Requirements for Reclaimed Pavement Borrow

Sieve Designation	Percent Passing
3 in.	100
1 ½ in.	70-100
¾ in.	50-85
No. 4	30-60
No. 50	8-24
No. 200	0-10

The portion of materials passing the No. 40 sieve shall have a liquid limit not greater than 25 and a plasticity index not greater than 6. The reclaimed pavement borrow shall be compacted to a minimum of 95% of AASHTO T 180 proctor density. Liquid limits shall be determined by AASHTO T 90.

Reclaimed pavement borrow material shall be processed by mechanical means and blended to form a homogeneous material. The equipment for producing crushed material shall be of adequate size and have sufficient adjustments to produce the desired materials. Blended materials that are

stockpiled for more than 3 months shall be reworked to a uniform material and retested prior to use however, the Engineer may require additional testing any time the materials appear excessively hard, wet and/or segregated. The processed materials shall be stockpiled in such a manner as to minimize segregation of particle sizes. All reclaimed pavement borrow material shall come from approved sources and stockpiles.

The amount of combined crushed asphalt pavement and crushed cement concrete shall not exceed 50% by volume as determined by visual inspection, and/or by laboratory tests required by the Engineer.

M1.10.0: Pavement Milling Mulch

Pavement milling mulch shall consist of recently milled asphalt concrete pavement. The milled material shall meet the following gradation requirements as determined by AASHTO T 311:

Table M1.10.0-1: Gradation Requirements for Pavement Milling Mulch

Square Opening Sieve	Percent Passing by Weight
1 ½ in.	100
1 in.	85-100
½ in.	10-98
No. 4	0-70
No. 200	0-12

SECTION M2: AGGREGATES AND RELATED MATERIALS

M2.01.0: Crushed Stone

Crushed stone shall consist of one or the other of the following materials:

1. Durable crushed rock consisting of the angular fragments obtained by breaking and crushing solid or shattered natural rock, and free from a detrimental quantity of thin, flat, elongated* or other objectionable pieces. A detrimental quantity will be considered as any amount in excess of 15% of the total weight.
2. Durable crushed gravel stone obtained by artificial crushing of gravel boulders or fieldstone with a minimum diameter before crushing of 8 in.

*Thin or elongated pieces are defined as follows: Thin stones shall be considered to be such stones whose average width exceeds 4 times their average thickness. Elongated stones shall be considered to be such stones whose average length exceeds 4 times their average width.

The crushed stone shall be reasonably free from clay, loam or deleterious material and not more than 1.0% of satisfactory material passing a No. 200 sieve will be allowed to adhere to the crushed stone. Where crushed stone is to be used for surfacing, this requirement shall be not more than 0.5% of satisfactory material passing a No. 200 sieve.

The crushed stone shall have a maximum percentage of wear as determined by the Los Angeles Abrasion Test (AASHTO T 96) as follows:

1. For Hot Mix Asphalt ..... 30% **
2. For Cement Concrete Aggregate ..... 45% ***
3. Crushed Stone for Subbase 45%
4. Special Borrow Ledge 45%

**Crushed stone for this use shall consist of crushed or shattered natural rock only. Crushed gravel stone will not be permitted.

***Except for 5,000 psi or greater cement concrete and prestressed concrete which shall be 30%.

The crushed stone shall be uniformly blended according to the grading requirements for the respective stone sizes shown in Table M2.01.0-1.

Table M2.01.0-1: Tabulation of Stone Sizes
Percent by Weight Passing Through

Square Opening Sieve	M2.01.1 & M2.02.2	M2.01.3	M2.01.4	M2.01.5	M2.01.6
	1 ½ in.	**1 ¼ in.**	**¾ in.**	**½ in.**	**⅜ in.**
2 ½ in.					
2 in.	100				
1 ½ in.	95-100	100			
1 ¼ in.		85-100			
1 in.	35-70		100		
¾ in.	0-25	10-40	90-100		
⅝ in.				100	
½ in.		0-8	10-50	85-100	100
⅜ in.			0-20	15-45	85-100
No. 4			0-5	0-15	20-50
No. 8				0-5	0-15
No. 16					0-5

M2.01.7: Dense Graded Crushed Stone for Sub-base

This Specification covers the quality and gradation requirements for a sub-base material combining crusher-run coarse aggregates of crushed stone (trap only, meeting M2.01.0,1), and fine aggregates uniformly premixed with a predetermined quantity of water.

Coarse aggregate shall consist of hard, durable particles of fragments of stone. Materials that break up when alternately frozen and thawed or wetted and dried shall not be used.

Coarse aggregate shall have a percentage of wear, by the Los Angeles test, of not more than 45.

Fine aggregate shall consist of natural or crushed sand.

The composite material shall be free from clay, loam or other plastic material, and shall conform to the following grading requirements:

Table M2.01.7-1, Gradation Requirements for Dense Graded Crushed Stone for Sub-base

Sieve Designation	Percentage by Weight Passing Square Mesh Sieves
2 in.	100
1 ½ in.	70-100
¾ in.	50-85
No. 4	30-55
No. 50	8-24
No. 200	3-10

Testing shall be in accordance with AASHTO T 311.

The use of PGA meeting the requirements of M2.01.8: Processed Glass Aggregate will be allowed at a maximum addition rate of 10% mass, providing the blended material is homogeneous and the physical requirements of dense graded crushed stone are maintained.

M2.01.8: Processed Glass Aggregate

PGA shall be manufactured from an approved supplier of crushed cullet. The material shall consist of recycled glass food or beverage containers free of debris such as paper, metals, fabrics, toxins, clay, loam, or other materials that would be associated with the glass recycling process. A maximum of 5% mass of the material may be produced from china dishes, ceramics, plate glass or other glass products. The material will have a nominal aggregate size of ⅜ in. and meet the following gradation requirements.

Table M2.01.8-1: Gradation Requirements for Processed Glass Aggregate

Sieve Designation	Percent by Mass Passing
⅜ in.	100
No. 4	70-100
No. 8	35-88
No. 16	15-40
No. 50	4-12
No. 200	0-5

The percent wear as determined by the Los Angeles Abrasion Test, Class C or D will be a maximum of 40%.

M2.02.0: Riprap

Riprap shall be sound, durable rock which is angular in shape. Rounded stones, boulders, sandstone or similar soft stone or relatively thin slabs will not be acceptable. Each stone shall weigh not less than 50 lb and at least 75% of the volume shall consist of stones weighing not less than 500 lb each. The remainder of the stones shall be so graded that when placed with the larger stones the entire mass will be compact.

M2.02.1: Rockfill

Stone for rockfill shall be sound, angular in shape, free from structural defects and comparatively free of chemical decay. From 50% to 70% of the stones shall weigh not less than 500 lb each and remainder shall weigh not less than 50 lb each.

M2.02.2: Dumped Riprap

Stone used for dumped riprap shall be hard, durable, angular in shape, resistant to weathering and shall meet the gradation requirement specified. Neither breadth nor thickness of a single stone should be less than one-third its length. Rounded stone or boulders will not be accepted.

Stone shall be free from overburden, spoil, shale, and organic material and shall meet the following gradation requirement specified:

Table M2.02.2-1: Gradation Requirements for Dumped Riprap

Size of Stone (lb)	Maximum Percent of Total Weight Smaller Than Given Size
400	100
300	80
200	50
*25	10
*No more than 5% by weight shall pass a 2 in. sieve.	

Each load of riprap shall be reasonably well graded from the smallest to the maximum size specified. Stones smaller than the specified 10% size and spalls will not be permitted in an amount exceeding 10% by weight of each load.

Control of gradation will be by visual inspection. The Contractor shall provide at the locations specified a mass of rock of at least 5 tons meeting the gradation for the class specified. The sample at the construction site may be a part of the finished riprap covering. At the quarry, an additional sample shall be provided. These samples shall be used as a frequent reference for judging the gradation of the riprap supplied. Any difference of opinion between the Engineer and the Contractor shall be resolved by dumping and checking the gradation of two random truckloads of stone. Mechanical equipment, a sorting site and labor needed to assist in checking gradation shall be provided by the Contractor at no additional cost to the Department.

M2.02.3: Stone for Pipe Ends

Stone for pipe ends shall be sound, durable rock which is angular in shape. Rounded stones, boulders, sandstone or similar stone or relatively thin slabs will not be acceptable. Each stone shall weigh not less than 50 lb not more than 125 lb and at least 75% of the volume shall consist of stones weighing not less than 75 lb each. The remainder of the stones shall be so graded that when placed with the larger stones the entire mass will be compact.

M2.02.4: Modified Rockfill

Modified rockfill shall consist of hard, durable angular shaped stones which are the product of the primary crushing of a stone crusher. Rounded stone, boulders, sandstone and similar soft stone or relatively thin slabs will not be acceptable.

Stone shall be free from overburden, spoil, shale, organic material and meet the following gradation requirements:

Table M2.02.4-1: Gradation Requirements for Modified Rockfill

Size of Stone (in.)	Passing Percentages
8	95-100
4	0-25
2 ½	0-5

M2.03.0: Granite Rubble Block

Rubble pavement blocks shall be granite, basically light grey in color, free from seams and other structural imperfections or flaws which would impair its structural integrity, and of a smooth splitting appearance. Natural color variations characteristic of the deposit from which the paving blocks are obtained will be permitted.

Rubble pavement blocks shall be not less than 4 in. nor more than 12 in. in length, not less than 3.5 in. nor more than 4.5 in. in width and depth. Rubble blocks shall be rectangular in shape with one good face.

Opposite faces of rubble blocks shall be approximately parallel and adjoining faces shall be approximately at right angles to each other. Blocks shall be dressed so that they may be laid with 1 in. to 1.5 in. joints.

M2.04.0: Aggregate for Sand Blasting

Aggregate to be used for sand blasting shall be an approved material currently used in the industry. It shall be graded to produce the profile requirements of the material being cleaned and shall meet the applicable requirements of OSHA, EPA, and DEP.

M2.05.0: Stone Screenings

Stone Screenings shall be that product from a stone crusher that completely passes a No. 4 sieve and not less than 40% passes a No. 8 sieve.

M2.06.0: Slope Paving

Stone for slope paving shall be sound, angular in shape and free from structural defects. Each stone shall have one reasonably flat face and a thickness perpendicular to the face of not less than 6 in., which shall be the least dimension of the stone.

Approximately 60% of the stones shall vary from 2 ft^3 to 3 ft^3 each in volume and the remainder of the stones shall each be from 1 ft^3 to 2 ft^3 in volume.

M2.06.1: Special Slope Paving Under Bridge (Quarry Stone).

Quarry stone shall consist of granite or other similar durable stone. The exposed surface of the stones shall range from roughly square to rectangular shape, with split or quarry face finish and uniform in color. The stones shall be from 12 in. to 28 in. long, 10 in. to 14 in. wide and from 3 in. to 6 in. thick.

M2.06.2: Channel Paving

Stones for Channel Paving and Grouted Channel Paving shall be sound, approved quality angular blocks, as nearly rectangular or cubical as practicable. Rounded stones or relatively thin slabs will not be acceptable. At least 75% of the volume shall consist of stones weighing at least 200 lb each. The remainder of the stones shall be so graded that when placed with the larger stones a compact mass will result.

SECTION M3: ASPHALTIC MATERIALS

M3.00.0: General

Asphaltic materials (also referred to as bituminous materials) include liquid asphalts as well as Hot Mix Asphalt (HMA) mixtures and other related materials. All asphaltic materials shall conform to the requirements of the specifications as designated hereinafter.

The sampling of liquid asphalt materials shall be in accordance with AASHTO R 66.

The following procedure shall be followed in obtaining liquid asphalt samples from pressure distributors or tankers used for the transport of liquid asphalt materials:

1. Distributors and tankers shall be equipped with approved sampling valves. The sampling valves on tankers shall be installed in the rear bulkhead approximately ⅓ of the height from the bottom. The sampling valves on pressure distributors may be located in the side of the tank somewhere in the middle third of the tank depth.
2. At least 1 gal of material shall be drained off through the sampling valve and discarded before the sample is obtained.
3. Sample containers shall be new, clean and sealed with a tight-fitting cap. Washing of sample containers with solvents or water will not be permitted.

M3.01.0: Performance Graded Asphalt Binder

Performance Graded Asphalt Binder (PGAB) delivered to a project or to an HMA plant must be accompanied by a Bill of Lading (BOL) signed by the asphalt binder Supplier's authorized representative in accordance with AASHTO R 26. Shipments of material not accompanied by a BOL will not be accepted for use in the work.

The PGAB Supplier and the Contractor shall perform random Quality Control (QC) sampling and testing of PGAB as specified in 450.65: Quality Control Sampling and Testing Requirements, Part F(1). The Contractor shall furnish, to the Engineer, the PGAB Supplier's BOL for each truckload of asphalt binder shipped to the project or HMA plant. The Contractor shall also submit to the Engineer the Supplier's Certificate of Compliance (COC) along with copies of the Certificate of Analysis (COA) showing the certified AASHTO M 320 test results for each Supplier Lot of PGAB. The COA shall meet the requirements of AASHTO R 26. The Contractor shall maintain a copy of the COA for each Lot of PGAB used, with a copy attached to each sample obtained for testing.

The Contractor shall assist the Engineer in obtaining random Department Acceptance samples of PGAB from the HMA plant in accordance with AASHTO R 66 and as specified in 450.74: Acceptance Sampling & Testing, Part C. Each sample shall be labeled with the PGAB grade, Supplier source and Lot number, sampling location, quantity represented, project name, plant, date, and the sampling inspector. When the PGAB is used for HMA production under Subsection 450: Hot Mix Asphalt Pavement the sample shall be obtained from an in-line sample valve located between the asphalt tanks and mixing chamber at a sampling location downstream of all additive injection ports.

The Engineer will test the Department Acceptance samples for verification of the PGAB grade. The material shall conform to the specification requirements for the applicable performance grade as specified herein. Material not conforming to specification requirements shall be subject to corrective action, production suspension, rejection, or removal as determined by the Engineer.

The blending of binder of different grades or binder from different Suppliers at the HMA plants is strictly prohibited without the Engineer's approval. Contractors may switch to another approved source of binder, upon written notification to the Engineer, and by certifying that the tank to be utilized has been drained to an un-pumpable condition. The binder tanks at the HMA production facility shall be managed in a manner which prevents contamination. The Contractor shall not switch binder suppliers in the middle of a production Lot as defined in 450.20: Quality Assurance, Part B.

Contractors who modify, blend PG binders, or add additives to the PGAB at the HMA production facility will be reclassified as a Supplier and shall be required to certify the binder in accordance with AASHTO R 26.

A copy of the COA for each Lot shall be provided in accordance with AASHTO R 26. The data reported shall meet the requirements of the specific binder specification:

1. For AASHTO M 320 – Table 1
2. For AASHTO M 332 – Table 1
3. For Crumb Rubber Modified Asphalt ASTM D6114-09 – Table 1

M3.01.1: Standard Asphalt Binder Grade

The asphalt binder for HMA mixtures shall be a PGAB which meets the specification requirements of AASHTO M 320. PGAB shall be provided by an Approved Supplier in accordance with AASHTO R 26. Approved Suppliers shall be listed on the QCML.

The standard PGAB Grade of PG64-28 shall be used.

M3.01.2: Modified Asphalt Binder Grades

When specified by the contract documents, the PGAB shall be modified in accordance with the following:

A. Polymer Modified Asphalt Binder

The polymer modified asphalt binder shall be a PGAB which meets the specification requirements of AASHTO M 332, however "E" grades will not be subject to the $J_{nr\text{diff}}$ difference requirement. PGAB shall be provided by an approved Supplier in accordance with the AASHTO R 26. The modified PGAB Grade of PG64E-28 shall be used.

B. Crumb Rubber Modified Asphalt Binder

The modified binder shall be in accordance with ASTM D6114-09, Type II. Virgin PGAB for the crumb rubber modified asphalt shall be a PG 58-28 or PG 64-28 provided by an approved Supplier in accordance with the AASHTO R 26. The grade selected shall be based on laboratory testing by the asphalt-rubber Manufacturer.

The granulated rubber shall be vulcanized rubber product from the ambient temperature processing of scrap, pneumatic tires. The granulated rubber shall meet the gradation found in Table M3.01.2-1.

Table M3.01.2-1: Crumb Rubber Gradation

Sieve Size	Percent by Weight Passing
No. 10	100
No. 16	90-100
No. 30	25-100
No. 80	0-20

The use of crumb rubber of multiple types from multiple sources is acceptable provided that the overall blend of crumb rubber meets the gradation requirements. The length of the individual rubber particles shall not exceed ⅛ in. The rubber shall be certified by the crumb rubber Manufacturer.

The percent of crumb rubber shall be a minimum of 15% by weight of binder. The temperature of the asphalt shall be between 350°F and 400°F at the time of addition of the granulated crumb rubber. The asphalt and crumb rubber shall be combined and mixed together in a blender unit and reacted in the distributor for a period of time as required by design. The temperature of the asphalt-rubber mixture shall be above 325°F during the reaction for a period of one hour.

M3.01.3: Asphalt Binder Grade for Recycled Asphalt Materials

For any HMA mixture containing recycled asphalt materials, a binder that is softer than the standard asphalt binder shall be utilized in the mixture to account for the amount and stiffness of the recycled binder in accordance with Table M3.01.3-1.

If greater than 25% Reclaimed Asphalt Pavement (RAP) or any quantity of Recycled Asphalt Shingles (RAS) are used in an asphalt mixture, the virgin PGAB grade when blended with the RAP binder shall meet the binder grade specified by the project. The resulting final PGAB grade shall be in accordance with Table M3.01.3-1. Only PGABs meeting the requirements of AASHTO M 320 or M 323 will be used.

The type and amount of virgin asphalt binder to be used in the HMA mixture shall be included as part of the Laboratory Trial Mix Formula (LTMF). The Contractor shall submit certified test results from an AASHTO accredited laboratory showing the testing of the individual binders and the blending.

Table M3.01.3-1: PGAB Grades for HMA Containing RAP/RAS

Amount of RAP in Mixture	Virgin PGAB Grade	Resulting PGAB Grade
≤25% RAP by Weight of Mixture	Project Specified Grade	Project Specified Grade
>25% to 40% RAP by Weight of Mixture	Follow AASHTO M 323 Appendix X1	Project Specified Grade
≤5% RAS by Weight of Mixture	Follow AASHTO PP 78	Project Specified Grade

M3.01.4: Warm Mix Asphalt Additive

All HMA shall be modified using a WMA additive. The WMA additive shall be listed on the QCML. No WMA foaming technology which requires the mechanical injection of steam or water into the liquid asphalt will be permitted.

For HMA placed on bridge decks, the WMA additive shall not be used to lower the mixing and compaction temperatures. The mixing and compaction temperatures specified for the binder prior to addition of the WMA additive shall be used.

The WMA additive must be compatible with polyphosphoric acid modified binders, polymer modified binders, and anti-stripping agents. The WMA additive shall be introduced in accordance with the Manufacturer's dosing rates and approved blending methods.

The HMA mixture design shall incorporate the requirements of AASHTO R 35 Appendix X2: Special Mixture Design Considerations and Practices for Warm Mix Asphalt (WMA). Laboratory mixing and compaction temperatures shall be reduced per the WMA Manufacturer's recommendations, however, the optimum laboratory compaction temperature for unmodified asphalt binders shall be less than 260°F. Target laboratory mixing and compaction temperatures shall be submitted to the RMS for review prior to performing a mix design.

When the asphalt binder is modified with the WMA additive at the HMA plant, all WMA additive equipment shall be fully automated and integrated into the plant controls and shall record actual dosage rates on the plant printouts. The Contractor's QSM shall provide mixture production and placement alterations due to the WMA additive and shall incorporate the modification of asphalt binders when the WMA additive is blended with the asphalt binder at the plant. This plan shall specifically address WMA metering requirements, tolerances and other QC measures.

M3.01.5: Asphalt Anti-Stripping Additive

An anti-stripping additive may be required in a HMA mixture to increase the resistance of the asphalt binder coating to stripping in the presence of water. An anti-stripping additive may be a liquid anti-strip or hydrated lime.

The Engineer may verify the effectiveness of the anti-strip used in a HMA mixture. When added at the dosage rate recommended by the Manufacturer to a HMA mixture showing moisture susceptibility, the anti-strip shall cause an improvement to the mixture's moisture susceptibility. This shall be determined by testing specimens with and without the anti-strip additive in accordance with AASHTO T 324. If the antistrip does not show an improvement in the moisture susceptibility the additive will not be permitted for use.

The Manufacturer shall certify that the material is in accordance with this specification. The Manufacturer shall submit a COC for each Lot in accordance with Division 1 Section 6.0. The COC shall also include the:

1. Brand name and designation.
2. Composition or description of the anti-strip additive.
3. Manner in which the material will be identified on the containers.

A. Hydrated Lime

The hydrated lime for HMA shall conform to the requirements of AASHTO M 303.

B. Liquid Anti-Strip

The anti-strip Manufacture shall submit product documentation, including the recommended dosage rate, to RMS for approval. Approved anti-strip additives shall be listed on the QCML.

Anti-stripping additives shall be an organic chemical compound free from inorganic mineral salts or inorganic mineral soaps. The anti-strip additive shall be chemically inert to asphalt binder and shall not appreciably alter the specified characteristics of the asphalt binder. When blended with asphalt binder, it shall be stable and withstand storage at a temperature of 400°F for extended periods without loss of effectiveness.

M3.01.6: Asphalt Release Agents

Approved asphalt release agents shall be tested in accordance with AASHTO T 383 and be listed on the QCML. The asphalt release agent shall not be detrimental to the HMA and shall not dissolve asphalt binder when applied to the truck bed. Dilution by diesel or other petroleum products will not be permitted.

M3.02.0: Cutback Asphalts

These materials shall be blends of asphalt cements and suitable solvents. They shall be homogeneous, free from water and conform to the requirements of AASHTO M 81 for the rapid curing type and AASHTO M 82 for the medium curing type.

M3.03.0: Asphalt Emulsions

Approved asphalt emulsions suppliers will be on the QCML.

M3.03.1: Anionic Emulsified Asphalt

These materials shall conform to the requirements of AASHTO M 140. Anionic emulsion used for tack coat shall be grade RS-1h.

When HMA paving takes place between November 1st and March 31st the use of RS-1 is acceptable.

When supplied in 5-gallon buckets the anionic emulsion used for tack coat shall be grade RS-1.

M3.03.2: Cationic Emulsified Asphalt

This material shall conform to the requirements of AASHTO M 208. Cationic asphalt emulsion used for tack coat shall be grade CRS-1h.

When HMA paving takes place between November 1st and March 31st the use of CRS-1 is acceptable.

When supplied in 5-gallon buckets the cationic emulsion used for tack coat shall be grade CRS-1.

M3.03.3: Polymer Modified Emulsified Asphalt

This material shall conform to the requirements of AASHTO M 316. Polymer modified asphalt emulsion used for tack coat shall be grade CRS-1P.

M3.05.0: Pavement Crack Sealers and Joint Adhesives

The material shall pour readily and penetrate a ¼ inch pavement crack or joint to a depth of at least 1 inch when the application temperature of the fully reacted mixture is 350°F and the air temperature is 35°F or higher.

The material, when placed with conventional field installation equipment, shall readily melt to a pumping consistency after being heated to 400°F for a maximum of 2 hr. The mixture shall remain

in a pumping consistency when the temperature of the field installation equipment is reduced to the normal operating temperature range of 300°F to 350°F.

M3.05.1: Chemically Modified Crumb Rubber Crack Sealer

Chemically modified crumb rubber crack sealer (CMFR) shall be a polymer modified performance graded asphalt binder which also incorporates crumb rubber and fibers.

1. The asphalt binder shall consist of a blend of performance graded asphalt binder and crumb rubber that meets the following specifications:
    - The SBS and Rubber modified binder shall meet a grade of PG64E-28 with a JnR3.2 < 0.5.
    - The PGAB utilized in the CMCR shall be a PG58-28 and shall comply with the requirements of M3.01.0: Performance Graded Asphalt Binder.
    - The modified binder shall contain a minimum of 3% SBS polymer.
    - The modified binders shall contain a minimum of 7% 80 mesh crumb rubber.
    - The asphalt binder supplier shall provide testing for the base asphalt binder and modified asphalt binder in accordance with AASHTO M 320 and M 332.
2. Fiber reinforcing materials shall be short-length polyester fibers having properties listed in Table M3.05.1-1.
3. The asphalt-fiber blend shall consist of 8% fiber by weight of asphalt binder.
4. Blending of the fibers with the modified asphalt binder shall be in accordance with the recommendations of the manufacturer of the fibers.

Table M3.05.1-1: Polyester Fiber Requirements

Characteristic	Test Method	Requirement
Length (See Note 1)		0.25 in.+0.02
Elongation at break	ASTM D2256	38%
Melting point	ASTM D3418	> 475°F
Crimps per inch	ASTM D3937	None
Cross Section		Round
Denier	ASTM D1577	4.5 Nominal dpf
Tensile Strength	ASTM D2256	>70,000 psi
Diameter		0.0008 in. (See Note 2)
Specific Gravity	ASTM D792	1.32 to 1.40

1. At temperature ranging from ambient to maximum finished product mix temperature.
2. Subject to normal variations.

M3.05.2: Hot Applied Crack Sealer

This sealer shall meet the requirements of ASTM D6690 Type II. Products shall be listed on the QCML.

M3.05.3: Asphalt-Fiber Crack Sealer

Asphalt-fiber crack sealer shall be a performance graded asphalt binder blended with fibers.

1. The PGAB utilized in the asphalt-fiber crack sealer shall be a PG64-28 and shall comply with the requirements of M3.01.0: Performance Graded Asphalt Binder.
2. Fiber reinforcing materials shall be short-length polyester fibers having properties listed in Table M3.05.1-1.
3. The asphalt-fiber blend shall consist of 7-8% fiber by weight of asphalt binder.

M3.05.4: Hot Applied Pavement Joint Adhesive

This material shall be a hot applied asphaltic product designed to adhere and seal HMA construction joints. The material shall meet the requirements of Table M3.05.4-1.

Table M3.05.4-1 Hot Applied Pavement Joint Adhesive

Property	Test Method	Requirement
Flash Point	AASHTO T 48	> 410°F
Ductility (See Note 1)	AASHTO T 51	> 300 mm
Ductility (See Note 2)	AASHTO T 51	> 300 mm
Softening Point	AASHTO T 53	> 170°F
Viscosity (See Note 3)	ASTM D3236	4,000 – 10,000 cp
Asphalt Compatibility	ASTM D5329	Pass
Cone Penetration (See Note 1)	ASTM D5329	60 – 100 mm
Resilience (See Note 1)	ASTM D5329	> 30 %
Tensile Adhesion (See Note 1)	ASTM D5329	> 500 %

1. Test to be conducted at 77°F.
2. Test to be conducted at 39°F.
3. Test to be conducted at 400°F

The manufacturer must supply all current product literature, including technical data sheets and Safety Data Sheets (SDS). This shall include information relevant to the material's use, its limitations, material properties, instructions for storage, mixing, and application.

As part of the evaluation, the Department will review the submitted laboratory test results. Qualified products will be listed on MassDOT's QCML.

M3.05.5: Preformed Bituminous Joint Filler for Concrete

This material shall be a non-extruding and resilient bituminous type preformed expansion joint filler. It shall conform to the requirements of AASHTO M 213.

M3.06.0: Hot Mix Asphalt

M3.06.1: General

All HMA mixtures shall meet the requirements of the Superpave volumetric mix design system as well as the following. Asphalt mixtures shall be composed of the following:

1. Mineral aggregate
2. Mineral filler (if required)
3. PGAB

The use of recycled materials shall be at the Contractor's option in accordance with these specifications. And as permitted, recycled materials shall be limited to:

1. RAP
2. RAS
3. PGA

Each HMA pavement course placed shall be compromised of one of the mixture types listed in Table 450.10-1.

M3.06.2: Aggregate for Hot Mix Asphalt

A. Coarse Aggregate

The coarse mineral aggregate shall be clean, hard, durable, crushed rock consisting of the angular fragments obtained by breaking and crushing shattered natural rock, reasonably free from thin and/or elongated pieces, free from dirt or other objectionable materials. It shall be surface dry and shall have a moisture content of not more than 0.5 percent after drying. Aggregates from multiple sources of supply shall not be mixed or stored in the same stockpile.

B. Fine Aggregate

The fine aggregate shall consist of one of the following:

1. 100% Natural Sand.
2. 100% Stone Sand.
3. A blend of sand and stone screenings, the proportions of which shall be approved by the Engineer.
4. A blend of natural sand and stone sand.

Natural sand shall consist of inert, hard, durable grains of quartz or other hard, durable rock, free from topsoil or clay, surface coatings, organic matter or other deleterious materials.

Stone sand shall be a processed material prepared from stone screenings to produce a consistently graded material conforming to specification requirements.

Stone screenings shall be the product of a secondary crusher and shall be free from dirt, clay, organic matter, excess fines or other deleterious material.

C. Consensus Properties

Aggregates utilized in HMA mixtures, including RAP if used in the mixture, shall be tested for conformance with the Consensus Property requirements outlined in AASHTO M 323 Sections 6.2 to 6.6 and Table M3.06.2-1 below.

Table M3.06.2-1: Aggregate Consensus Property Requirements

Traffic Level	Design ESALs (Millions) (See Note 1)	Fractured Faces, Coarse Aggregate % Minimum (See Note 2)		Uncompacted Content of Fine Aggregate % Minimum		Sand Equivalent % Minimum	Flat and Elongated % Maximum (See Note 2)
		All Courses (except Base Course)	Base Course	All Courses (except Base Course)	Base Course		
1	<0.3	55/--	--/--	-- (See Note 4)	--	40	--
2	0.3 to <10	85/80 (See Note 3)	60/--	45	40	45	10
3	≥10	95/90	80/75	45	40	45	10

1. The anticipated project traffic level expected on the design lane over a 20-year period. Regardless of the actual design life of the roadway, determine the design ESALs for 20 years.
2. This criterion does not apply to #4 nominal maximum size mixtures.
3. 85/80 denotes that 85% of the coarse aggregate has one fractured face and 80% has two or more fractured faces.
4. For #4 nominal maximum size mixtures designed for traffic levels below 0.3 million ESALs, the minimum Uncompacted Void Content is 40.

D. Source Properties

The coarse aggregate utilized in asphalt mixtures shall be clean, crushed rock consisting of the angular fragments obtained by breaking and crushing shattered natural rock. It shall be free from dirt or other objectionable materials. The coarse aggregate, including RAP if used in the mixture, shall be tested for conformance with the requirements indicated in Table M3.06.2-2. The specific gravity of each aggregate component shall be determined as specified in Table M3.06.2-3 below.

To determine the bulk specific gravity of RAP aggregate the method outlined in FHWA Publication Number FHWA-HRT-11-021 “Reclaimed Asphalt Pavement in Asphalt Mixtures: State of the Practice” shall be used. The following excerpt is the method to be followed:

If the source of RAP is known and original construction records are available, the bulk specific gravity (BSG) value of the virgin aggregate from the construction records may be used as the BSG value of the RAP aggregate. However, if original construction records are not available, the recommended procedure for estimating BSG of the RAP aggregate is a simple three-step process as follows:

1. Determine the maximum theoretical specific gravity of the RAP mixture, G_{mm}^{RAP}, according to AASHTO T 209.
2. Calculate the effective specific gravity of the RAP aggregate, G_{se}^{RAP}, using G_{mm}^{RAP}, the asphalt content of the RAP mixture (P_b) and an assumed asphalt specific gravity (G_b) as follows:

$$G_{se}^{RAP} = \frac{100 - P_b}{{100}/{G_{mm}} - {P_b}/{G_b}}$$

Where: $G_b = 1.030$

3. The asphalt absorption, P_{ba}, shall be assumed to be 0.5%. Use this value to estimate the BSG of the RAP aggregate, G_{sb}^{RAP}, from the calculated G_{se}^{RAP}.

$$G_{sb}^{RAP} = {G_{se}^{RAP}}\Big/{\left(\frac{P_{ba} \times G_{se}^{RAP}}{100 G_B} + 1\right)}$$

Table M3.06.2-2: Aggregate Source Property Requirements

Source Property Test	Test Method	Limit
Toughness	AASHTO T 96	Maximum Loss < 30%
Soundness (See Note 1)	AASHTO T 104	Maximum Loss < 10%
Deleterious Materials	AASHTO T 112	Maximum Permissible < 0.5%
1. 5 cycles using Sodium Sulfate solution.		

Table M3.06.2-3: Aggregate Specific Gravity Test Method

Aggregate Type	Test Method
Coarse	AASHTO T 85
Fine	AASHTO T 84 or ASTM D7370
Mineral Filler	AASHTO T 100
RAP	From FHWA-HRT-11-021

E. Recycled Asphalt Pavement

RAP shall meet the requirements of M3.06.2: Aggregate for Hot Mix Asphalt, Paragraphs C and D as well as the following. RAP shall consist of the material obtained from state highways or streets by crushing or milling existing HMA pavements. This material shall be transported to the HMA production facility yard and processed through an appropriate crusher so that the resulting material will contain no particles larger than the maximum aggregate size of the HMA mixture in which it will be used.

The RAP shall be stockpiled on a free draining base and kept separate from the other aggregates. RAP stockpiles shall be covered by a framed structure which prevents the intrusion of water but also allows the flow of air to promote drying of the stockpile. The structure shall be capable of storing a minimum of 500 tons of RAP. The RAP stockpiles shall have a reasonably uniform gradation from fine to coarse and shall not be contaminated by foreign materials. The RAP used in

the HMA mix production shall have a moisture content such that the final HMA contains no more than 0.5% moisture.

The proportion of RAP to virgin aggregate shall be in accordance with Table M3.06.2-4 and M3.01.3: Asphalt Binder Grade for Recycled Asphalt Materials.

Table M3.06.2-4: Maximum Allowed RAP Content by Mix Type

Mix Type	Maximum Amount of RAP Allowed (%)	Maximum Amount of RAS Allowed (%) (see Note 1)
Friction Course (OGFC)	0	0
Friction Course (ARGG)	10	0
Surface Course	15	0
Leveling Course	15	5
Bridge Surface Course	15	0
Bridge Protective Course	15	0
Intermediate Course	40	5
Base Course	40	5

1. When RAS is used in HMA mixtures containing RAP or other recycled materials, the RAS will be considered as part of the overall allowable weight of recycled materials in the mixture.

F. Recycled Asphalt Shingles

RAS shall consist of only the by-product materials obtained from the roofing shingle manufacturing process. Post-consumer shingle waste and re-roofing shingle scrap will not be allowed. The Contractor or the plant shall provide certification from the roofing shingle manufacturer that RAS material provided is a by-product of the shingle manufacturing process. This material shall be transported to the HMA production facility yard and processed through an appropriate crusher so that the resulting material will contain no particles larger than 0.5 in. The material shall be stockpiled on a free draining base and kept separate from the other aggregates. The material contained in the processed stockpile shall not be contaminated by foreign materials. RAS stockpiles shall be covered in a manner that prevents the intrusion of water but also allows the flow of air.

RAS may be used in HMA leveling courses, HMA intermediate courses, and HMA base courses at a maximum rate of 5% by weight. When RAS is used in HMA mixtures containing RAP or other recycled materials, the RAS will be considered as part of the overall allowable weight of recycled materials in the mixture.

G. PGA

The use of PGA meeting the requirements of M2.01.8: Processed Glass Aggregate may be added at a maximum addition rate of 10% by weight. This addition will only be allowed in base and intermediate mixtures. PGA in mixes containing RAP will be considered as part of the overall allowable mass of RAP in the mix. If PGA is used in the mix, a separate aggregate bin shall be used and the use of lime as an anti-stripping agent shall be required.

M3.06.3: Performance Graded Asphalt Binder

The PGAB utilized in the HMA mixture shall be specified by the Contract and shall comply with the requirements of M3.01.0: Performance Graded Asphalt Binder.

M3.06.4: Hot Mix Asphalt Mixture Design

The Contractor shall be responsible for development of all HMA mixture designs. All HMA surface courses, intermediate courses, base courses, leveling courses, bridge surface courses, and bridge protective courses shall be supported by volumetric mixture designs using the Superpave mixture design system. All Superpave HMA designs shall be developed in accordance with the following AASHTO standards, as modified herein:

1. AASHTO M 323
2. AASHTO R 35
3. AASHTO T 312

OGFC and ARGG mixtures shall be designed in accordance with Subsections M3.06.4: Hot Mix Asphalt Mixture Design, Parts G and H, respectively

A. Development of LTMF

The Contractor shall develop and submit a LTMF for each HMA mixture type, which is to be proposed as a JMF, a minimum of 60 days prior to HMA production. Each LTMF shall be submitted with supporting documentation and adequate amount of blended aggregate material and PGAB in order to verify the LTMF.

Once verified by the Department, the LTMF may become the JMF for a project. Two or more JMFs per HMA type may be approved for a particular plant, however, only mixture conforming to one JMF is permitted to be produced and placed on any given day.

B. Estimated Design Traffic

The estimated traffic level to be used for HMA mix designs shall be specified by the contract. The traffic level shall be expressed in Equivalent Single Axle Loads (ESALs) for the design travel lane over a 20-year period in million 18-kip ESALs.

C. Specific Gravity Requirements

The individual aggregate specific gravities shall be included with the LTMF. The Contractor shall provide samples of each aggregate material a minimum of 60 days prior to production for each LTMF to the Department for verification specific gravity of each stockpile.

D. Superpave Aggregate Gradation Requirements

The combined aggregate blend for each Superpave HMA mixture shall conform to the Gradation Control Point requirements specified in Table M3.06.4-1. The results of the selected optimum design aggregate structure shall be plotted on a 0.45 power chart and included with the LTMF.

The combined aggregate gradation shall be classified as coarse-graded when it passes below the Primary Control Sieve (PCS) control point as defined in Table M3.06.4-2. All other gradations shall be classified as fine graded.

When a Superpave Surface Course - 19.0 (SSC - 19.0) is specified in the contract, the LTMF aggregate gradation shall provide a fine-graded HMA mixture as defined in Table M3.06.4-2.

E. Gyratory Compaction Criteria

Each asphalt mixture shall be designed and controlled during production using an approved gyratory compactor which meets the requirements of AASHTO T 312. Compaction shall be in accordance with the requirements of AASHTO T 312. The density of each HMA mixture shall be evaluated at the initial number of gyrations ($N_{initial}$), the design number of gyrations (N_{design}), and the maximum number of gyrations (N_{max}). The gyratory-compacted specimens for each LTMF shall meet the density requirements specified in Table M3.06.4-3 below.

F. Superpave Volumetric Design Requirements.

Each Superpave HMA mixture shall be designed in accordance with the volumetric mixture design specifications contained in AASHTO M 323 and procedures contained in AASHTO R 35, as modified herein. Each HMA mixture LTMF shall be tested for conformance with the following volumetric properties:

1. Air Voids at N_{design} (V_a)
2. Voids in the Mineral Aggregate at N_{design} (VMA)
3. Voids Filled with Asphalt at N_{design} (VFA)
4. Fines to Effective Asphalt Ratio ($P_{0.075}$ / P_{be})

The volumetric property test results shall be submitted with the LTMF for each Superpave HMA mixture. The required minimum or maximum criteria for each of the volumetric property tests are specified in Table M3.06.4-3, Table M3.06.4-4, and Table M3.06.4-5.

Table M3.06.4-1: Superpave Aggregate Gradation Control Points

	Nominal Maximum Aggregate Size – Control Points (% Passing)											
Sieve	#4		⅜ in.		½ in.		¾ in.		1 in.		1 ½ in.	
(in.)	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
2											100	
1.5									100		90	100
1							100		90	100		90
¾					100		90	100		90		
½	100		100		90	100		90				
⅜	95	100	90	100		90						
#4	90	100		90								
#8			32	67	28	58	23	49	19	45	15	41
#16	30	55										
#30												
#50												
#100												
#200	6	13	2	10	2	10	2	8	1	7	0	6

Table M3.06.4-2: Gradation Classification

PCS Control Point for Mixture Nominal Maximum Aggregate Size (% Passing)					
Nominal maximum aggregate size	⅜ in.	½ in.	¾ in.	1 in.	1 ½ in.
Primary Control Sieve	#8	#8	#4	#4	⅜ in.
PCS control point, % passing	47	39	47	40	47

Table M3.06.4-3: Superpave Asphalt Mixture Design Laboratory Compaction Requirements

Traffic Level	**Design ESALs (millions)**	**Number of Gyrations**			**Percent Density of G_{mm} from Asphalt Mixture Gyratory Specimen**		
		N_{ini}	N_{des}	N_{max}	N_{ini}	N_{des}	N_{max}
1	<0.3	6	50	74	≤91.5	96.0	≤98.0
2	0.3 to <10	7	75	115	≤90.5	96.0	≤98.0
3	≥10	8	100	160	≤89.0	96.0	≤98.0

Table M3.06.4-4: Superpave Volumetric Requirements

	Nominal Maximum Aggregate Size					
	#4	⅜ in.	½ in.	¾ in.	1 in.	1 ½ in.
P_b	LTMF Value					
G_{mb}						
G_{mm}						
V_a	4.0					
VMA	≥17.0	≥16.0	≥15.0	≥14.0	≥13.0	≥12.0
VFA	See Table M3.06.4-5					
Dust/P_{be} (See Note 1)	0.9 to 2.0	0.6 to 1.2	0.6 to 1.2	0.6 to 1.2	0.6 to 1.2	0.6 to 1.2
Mixture Temp. (See Note 2)	Unmodified PGAB ≤325°F Modified PGAB ≤350°F					

1. If the aggregate gradation passes beneath the PCS Control Point specified in M 323 Table 5, the dust-to-binder ratio range may be increased from 0.6-1.2 to 0.8-1.6 at the Engineer's discretion.
2. Laboratory mixing and compaction temperatures shall be based on the PGAB COA. When additives such as WMA, polymers, and rubber are introduced the mixing and compaction temperatures may be modified from the PGAB COA. Temperature modifications shall be recommended by the binder Supplier and approved at the Engineer's discretion.

Table M3.06.4-5: Superpave Asphalt Mixture VFA Requirements

Traffic Level	**Design ESALs (millions)**	**Voids Filled with Asphalt (VFA) Based on Nominal Maximum Aggregate Size**					
		#4	⅜ in.	½ in.	¾ in.	1 in.	1 ½ in.
1	<0.3	70 to 80	70 to 80	70 to 80	70 to 80	67 to 80	64 to 80
2	0.3 to <10	65 to 78	65 to 78	65 to 78	65 to 78	65 to 78	64 to 78
3	≥10	75 to 78	73 to 76	65 to 75	65 to 75	65 to 75	64 to 75

G. OGFC Design Requirements

Each OGFC asphalt mixture shall be designed in accordance with AASHTO R 113, as modified herein. The combined aggregate gradation shall conform to Table M3.06.4-6 and the mixture shall conform to Table M3.06.4-7.

1. OGFC-P will utilize asphalt binder meeting the requirements of M3.01.2: Modified Asphalt Binder Grades, Part A.
2. OGFC-AR will utilize asphalt binder meeting the requirements of M3.01.2: Modified Asphalt Binder Grades, Part B.

Table M3.06.4-6: OGFC Aggregate Gradation Control Points

Sieve	⅜ in. OGFC Control Points (% Passing)	
In.	Min	Max
1	-	-
¾	-	-
½	100	-
⅜	85	100
#4	20	30
#8	5	15
#200	0	4

Table M3.06.4-7: OGFC Mixture Requirements

Property	Requirement
N_{des}, gyrations	50
P_b, % (Polymer)	≥6.5
P_b, % (Asphalt Rubber)	≥7.5
V_a, %	18 to 22
VCA_{mix}, %	$<VCA_{DRC}$
Draindown, % (See Note 1)	≤0.3
Abrasion Loss, % (See Note 2)	≤15
Moisture Susceptibility, % (See Note 3)	≥70
Permeability, in/sec (See Note 4)	≥0.0178

1. Draindown shall be tested in accordance with AASHTO T 305 at the production temperature.
2. Abrasion loss shall be tested in accordance with AASHTO T 401.
3. Moisture susceptibility shall be tested in accordance with AASHTO T 283.
4. Permeability shall be performed in accordance with the procedure outlined by RMS.

H. ARGG Design Requirements

Each ARGG asphalt mixture shall be designed in accordance with the AASHTO M 323 and procedures contained in AASHTO R 35, as modified herein. The combined aggregate gradation shall conform to Table M3.06.4-8 and the mixture shall conform to Table M3.06.4-9.

ARGG will utilize asphalt binder meeting the requirements of M3.01.2: Modified Asphalt Binder Grades, Part B.

Table M3.06.4-8: ARGG Aggregate Gradation Control Points

Sieve	**⅜ in. ARGG Control Points (% Passing)**		**½ in. ARGG Control Points (% Passing)**	
Inches	Min	Max	Min	Max
1	-	-	-	-
¾	-	-	100	-
½	100	-	90	100
#30	90	100	83	87
#50	38	52	28	42
#100	22	30	14	22
#200	-	-	0	6

Table M3.06.4-9: ARGG Mixture Requirements

Property	**Requirement ⅜ in.**	**Requirement ½ in.**
N_{des}, gyrations	75	100
P_b, % (Asphalt Rubber)	≥7.6	≥7.6
V_a, %	3 to 5	3 to 5
VMA, %	18 to 23	18 to 23
Draindown % (See note 1)	≤0.3	≤0.3

1. Draindown shall be tested in accordance with AASHTO T 305 at the production temperature.

M3.06.5: Verification of Laboratory Trial Mix Formula

The Contractor shall submit an LTMF in accordance with M3.06.4: Hot Mix Asphalt Mixture Design. The Engineer will perform laboratory verification of each LTMF.

If the Engineer is unable to verify the Contractor's LTMF in accordance with the applicable LTMF Verification Limits in Table M3.06.5-1, Table M3.06.5-2, or Table M3.06.5-3, then the Engineer will work with the Contractor to resolve the verification issue(s). The Contractor shall not proceed with production and placement of a Control Strip under Subsection 450: Hot Mix Asphalt Pavement until the LTMF is verified by the Engineer.

Table M3.06.5-1: Superpave LTMF Verification Limits

Properties	Test Method	LTMF Verification Limit
Asphalt Binder Content (P_b)	AASHTO T 308	Target ± 0.3%
Gradation Passing #4 and Larger Sieves	AASHTO T 30	Target ± 6.0%
Gradation Passing #8 Sieve	AASHTO T 30	Target ± 5.0%
Gradation Passing #16 to #50 Sieve	AASHTO T 30	Target ± 3.0%
Gradation Passing #100 Sieve	AASHTO T 30	Target ± 2.0%
Gradation Passing #200 Sieve	AASHTO T 30	Target ± 1.0%
Bulk Specific Gravity (G_{mb})	AASHTO T 166	Target ± 0.022
Max. Theo. Specific Gravity (G_{mm})	AASHTO T 209	Target ± 0.020
Air Voids (V_a)	AASHTO R 35	Target ± 1.0%
Voids in Mineral Aggregate (VMA)	AASHTO R 35	Target ± 1.0%
Voids Filled with Asphalt (VFA)	AASHTO R 35	Target ± 5.0%
Rutting and Moisture Susceptibility	AASHTO T 324	See Table M3.06.5-4

Table M3.06.5-2: OGFC LTMF Verification Limits

Properties	Test Method	LTMF Verification Limit
Asphalt Binder Content (P_b)	AASHTO T 308	Target ± 0.3%
Gradation Passing #4 and Larger Sieves	AASHTO T 30	Target ± 6.0%
Gradation Passing #8 Sieve	AASHTO T 30	Target ± 4.0%
Gradation Passing #16 to #50 Sieve	AASHTO T 30	Target ± 4.0%
Gradation Passing #100 Sieve	AASHTO T 30	Target ± 2.0%
Gradation Passing #200 Sieve	AASHTO T 30	Target ± 1.0%
Bulk Specific Gravity (G_{mb})	AASHTO T 331	Target ± 0.022
Max. Theo. Specific Gravity (G_{mm})	AASHTO T 209	Target ± 0.020
Air Voids (V_a)	AASHTO R 35	Target ± 2.0%
Voids in Mineral Aggregate (VMA)	AASHTO R 35	Target ± 2.0%
Voids Filled with Asphalt (VFA)	AASHTO R 35	Target ± 5.0%
Draindown	AASHTO T 401	≤0.3%
Abrasion Loss	AASHTO T 283	≤15%
Tensile Strength Ratio		≥70%

Table M3.06.5-3: ARGG LTMF Verification Limits

Properties	Test Method	LTMF Verification Limit
Asphalt Binder Content (P_b)	AASHTO T 308	Target ± 0.3%
Gradation Passing ¾ in. Sieve	AASHTO T 30	Target ± 0.0%
Gradation Passing #4 to ½ in. Sieve	AASHTO T 30	Target ± 6.0%
Gradation Passing #8 Sieve	AASHTO T 30	Target ± 5.0%
Gradation Passing #16 to #50 Sieve	AASHTO T 30	Target ± 3.0%
Gradation Passing #100 Sieve	AASHTO T 30	Target ± 2.0%
Gradation Passing #200 Sieve	AASHTO T 30	Target ± 1.0%
Bulk Specific Gravity (G_{mb})	AASHTO T 166	Target ± 0.022
Max. Theo. Specific Gravity (G_{mm})	AASHTO T 209	Target ± 0.020
Air Voids (V_a)	AASHTO R 35	Target ± 1.0%
Voids in Mineral Aggregate (VMA)	AASHTO R 35	Target ± 1.0%
Voids Filled with Asphalt (VFA)	AASHTO R 35	Target ± 5.0%
Draindown	AASHTO T 305	≤0.3%
Rutting and Moisture Susceptibility	AASHTO T 324	See Table M3.06.5-4

Evaluation of Rutting and Moisture Sensitivity

Each HMA mixture, with the exception of Base Courses and OGFC, shall be tested by RMS for rutting and moisture sensitivity in accordance with the requirements of AASHTO T 324 using the Hamburg Wheel-Tracking Device (HWTD).

The Engineer may also require that mixtures meet the requirements of AASHTO T 283 with a minimum tensile strength ratio of 80%.

Table M3.06.5-4: Hamburg Wheel Tracking Device Requirements

Traffic Level	Maximum Rut Depth (in.)	Minimum number of passes before Stripping Inflection Point is observed
1	½	10,000
2	½	15,000
3	½	15,000

M3.07.0: HMA for Driveways, Sidewalks, Berm, and Curb

HMA mixtures for driveways, sidewalks, berm, and curb shall conform to the master ranges in Table M3.06.6-1. The PGAB shall conform to M3.01.1: Standard Asphalt Binder Grade. The aggregate shall conform to M3.06.2: Aggregate for Hot Mix Asphalt. The Contractor shall submit a JMF prior to production which shows the target aggregate gradation and PG asphalt binder content for each HMA mixture for driveways, sidewalks, berm, and curb.

With the approval of the Engineer, the Contractor may substitute a MassDOT approved 9.5 mm or 12.5 mm Superpave Surface Course mixture (Traffic Level 1 or 2) for Driveways and Sidewalks.

The composition limits in Table M3.07.0-1 are HMA mix design master ranges for aggregate gradation and asphalt binder content. The JMF for each HMA mixture type shall establish a single percentage of aggregate passing each required sieve size, and a single percentage of asphalt binder material to be added to the aggregate.

The JMF shall be submitted in writing by the Contractor to the Engineer at least 30 days prior to the start of paving operations and shall include the following as a minimum:

1. Source of materials
2. Percent of each aggregate stockpile
3. Percent passing each sieve size
4. Combined aggregate specific gravity
5. Percent of asphalt binder
6. Performance grading test results and Certificate of Compliance certifying the PG grade
7. Mixing temperature
8. Compaction temperature
9. Temperature of mix when discharged from the mixer
10. Maximum theoretical specific gravity of the mixture

AASHTO T 195 (Ross Count) with a coating factor of 98% will be used when necessary to evaluate proper mixing time.

The use of recycled materials will be permitted at the option of the Contractor and provided that the end product is in conformance with the designated JMF. The proportion of reclaimed materials (including RAP, PGA, and RAS) in the total mix shall be limited to a maximum of 15%.

All HMA JMFs for sidewalks, pedestrian curb ramps, driveways, and berm will be submitted to the Engineer for approval.

The JMF for each mixture shall be in effect until modified in writing by the Contractor and approved by the Engineer. Should a change in sources of materials be made, a new JMF must be approved by the Engineer before the new material is used.

Table M3.07.0-1: Master Ranges for HMA for Driveways, Sidewalks, Berm, and Curb

	Control Points (% Passing)			
Mix Type	Driveways, Sidewalks, and Berm		Berm and Curb Only	
Sieve (in.)	Min	Max	Min	Max
1	-	-	-	-
¾	100	-	-	-
½	95	100	100	-
⅜	87	93	87	93
#4	57	69	62	73
#8	41	45	52	55
#16	30	36	40	45
#30	21	25	28	34
#50	14	17	18	23
#100	9	12	10	14
#200	4	5	6	6
P_b, %	6.0	6.6	7.4	7.6

M3.08.0: Cold Patch for Temporary Patching

When HMA is not available due to seasonal limitations the Contractor shall use stockpiled cold patch mixtures approved by the Research & Materials Section.

M3.10.0: Surface Preservation Treatment

M3.10.2: Stress Absorbing Membrane & Stress Absorbing Membrane Interlayer

All Stress Absorbing Membrane (SAM) and Stress Absorbing Membrane Interlayer (SAMI) mixtures shall meet the requirements as specified below. SAM & SAMI mixtures shall be composed of the following:

1. Mineral aggregate
2. Performance Graded Asphalt Binder

A. Aggregate.

The aggregate shall conform to M3.06.2: Aggregate for Hot Mix Asphalt. Crushed gravel stone will not be permitted. The aggregate shall be pre-heated to a temperature between 200°F and 300°F, and be pre-coated with 0.4% to 0.8% asphalt binder (by weight of aggregate) prior to application. The aggregate shall meet the requirements in Tables M3.10.2-1 and M3.10.22.

Table M3.10.2-1: SAM & SAMI Aggregate Control Points

	Nominal Maximum Aggregate Size – Control Points (% Passing)					
Type	**⅜ in.**	**⅜ in.**	**½ in.**	**½ in.**	**⅜ in. (SAMI only)**	**⅜ in. (SAMI only)**
Sieve	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
⅝ in.	100	-	100	-	100	-
½ in.	100	-	90	100	100	-
⅜ in.	85	100	25	65	85	100
#4	0	8	0	8	0	30
#8	0	4	0	4	0	5
#200	0	2	0	2	0	2

Table M3.10.2-2: SAM & SAMI Aggregate Source Property Requirements

Source Property Test	**Test Method**	**Limit**
Toughness	AASHTO T 96	<30%
Flakiness Index (for SAM)	TEX-224-F (see note 1)	<20%
Flakiness Index (for SAMI)	TEX-224-F (see note 1)	<30%

1. Determined following TxDOT's Test Procedure for Determining Flakiness Index.

B. Performance Graded Asphalt Binder.

The PGAB binder to be applied to the pavement shall be in conformance with M3.01.2: Modified Asphalt Binder Grades, Part B. Asphalt binder that is pre-coated onto the aggregate shall be in conformance with M3.01.1: Standard Asphalt Binder Grade.

M3.10.5: Ultrathin Bonded Overlay

All Ultrathin Bonded Overlay (UTBO) mixtures shall meet the requirements as specified below. UTBO mixtures shall be composed of the following:

1. Mineral aggregate
2. Mineral filler (if required)
3. PGAB

The use of recycled materials will not be permitted.

A. Coarse Aggregate.

Coarse aggregate shall meet the requirement of M3.06.2: Aggregate for Hot Mix Asphalt, Part A as well as the following. Where coarse aggregates for these mixes are from more than one source or of more than one type of material, they shall be proportioned and blended to provide a uniform mixture.

Table M3.10.5-1: Coarse Aggregate Requirements

Source Property Test	Test Method	Limit
Flat and Elongated, 3:1	ASTM D4791	<25%
Crushed Particles, Two Faced	AASHTO T 335	>90%
Water Absorption	AASHTO T 85	≤3.0%

B. Fine Aggregate.

Fine aggregate shall meet the requirement of M3.06.2: Aggregate for Hot Mix Asphalt, Part B as well as one of the following. Fine aggregate shall be 100% crushed and consist of one of the following:

1. 100% stone sand
2. A blend of stone sand and stone screenings

Table M3.10.5-2: Fine Aggregate Consensus Property Requirements

Source Property Test	Test Method	Limit
Fine Aggregate Angularity	AASHTO T 304	>40%
Methylene Blue	AASHTO T 330	≤10 mg/g
Water Absorption	AASHTO T 84	≤3.0%

C. Mineral Filler.

Hydrated lime, fly ash, and baghouse fines are acceptable as mineral filler. The material shall conform to the following:

- Lime – AASHTO M 303
- Fly Ash – AASHTO M 295
- Baghouse fines – AASHTO M 17

Typical acceptable gradation:

- #30 - 100% passing
- #200 - 75-100% passing

D. Performance Graded Asphalt Binder.

The PGAB utilized in the HMA mixture shall be specified by the Contract and shall comply with the requirements of M3.01.2: Modified Asphalt Binder Grades.

E. UTBO Mixture Design.

The Contractor shall be responsible for development of all UTBO mixture designs. All UTBO designs shall be developed in accordance with the requirements specified below.

F. Development of Laboratory Trial Mix Formula.

The Contractor shall develop and submit an LTMF for each UTBO mixture type, which is to be proposed as a JMF, a minimum of 60 days prior to UTBO production. Each LTMF shall be submitted

with supporting documentation and adequate amount of blended aggregate material and PGAB in order to verify the LTMF. Once verified by the Department, the LTMF may become JMF for a project.

G. Specific Gravity Requirements.

The individual aggregate, mineral filler, and PGAB specific gravities shall be included with the LTMF. The Contractor shall provide samples of each material a minimum of 60 days prior to production for each LTMF to the Department for verification specific gravity of each stockpile.

H. UTBO Aggregate Gradation and Binder Requirements.

The combined aggregate blend for each UTBO mixture shall conform to the Gradation Control Point requirements specified in Table M3.10.5-3. The results of the selected optimum design aggregate structure shall be plotted on a 0.45 power chart and included with the LTMF.

Table M3.10.5-3: UTBO Aggregate Control Points

	Nominal Maximum Aggregate Size – Control Points (% Passing)					
	Type 1	**Type 1**	**Type 2 (see Note 1)**	**Type 2 (see Note 1)**	**Type 3 (see Note 1)**	**Type 3 (see Note 1)**
Sieve	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
¾ in.	100	-	100	-	100	-
½ in.	100	-	92	100	85	100
⅜ in.	85	100	55	90	45	85
#4	24	40	24	41	24	41
#8	21	32	21	33	21	33
#16	16	26	15	26	15	26
#30	12	20	11	20	11	20
#50	8	16	8	16	8	16
#100	5	10	5	10	5	10
#200	5	7	4	7	4	7
Pb, % (Polymer)	4.8	5.2	4.7	5.2	4.6	5.2
Pb, % (Asphalt Rubber) (See note 2)	-	-	5.7	6.2	5.6	6.2

1. When asphalt rubber is specified the gradation master ranges may be modified with the prior approval from the Research & Materials Section.
2. Type 1 UTBO shall not use asphalt rubber

I. UTBO Mixture Requirements.

The combined mixture for each UTBO mixture shall conform to the mixture requirements specified in Table M3.10.5-4. The results of the selected optimum design shall be included with the LTMF.

Table M3.10.5-4: UTBO Mixture Requirements

Property	Requirement
Unit Weight	Per LTMF
Draindown, % (see Note 2)	≤0.1
Moisture Susceptibility, % (see Note 3)	≥80

1. Draindown shall be tested in accordance with AASHTO T 305 at the production temperature.
2. The mixture shall be compacted according to AASHTO T 312 and tested in accordance with AASHTO T 283.

The tensile strength ratio, TSR, shall meet or exceed 80% when tested in accordance with AASHTO T 283. Specimens for T 283 shall be 6 in. in diameter by 3 ¾ ± ¼ in. in height and compacted in accordance with AASHTO T 312, except the specimens shall be compacted to 100 gyrations and resultant air voids reported for information purposes only. The compaction temperatures shall be 300 ± 10°F or as recommended by the binder supplier.

Follow T 283 with the following exceptions:

1. Condition the mixture for 2 hours in accordance with AASHTO R 30, Section 7.1.
2. Compact the Superpave Gyratory Compactor, SGC, specimens to 100 gyrations.
3. Extrude the samples as soon as possible without damage to the sample.
4. Use AASHTO T 269 to determine the air void content.
5. Record the air void content of the specimens.
6. If less than 55% saturation is achieved, the procedure does not need to be repeated unless the difference in tensile strength between duplicate specimens is greater than 25 lb/in.^{2}.

J. Verification of Laboratory Trial Mix Formula.

The Contractor shall submit an LTMF in accordance with Subsections M3.10.5, Part A to Part I. The Engineer will perform laboratory verification of each LTMF.

If the Engineer is unable to verify the Contractor's LTMF in accordance with the applicable LTMF Verification Limits in Table M3.10.5-4, then the Engineer will work with the Contractor to resolve the verification issue(s). The Contractor shall not proceed with production and placement of a Control Strip until the LTMF is verified by the Engineer.

Table M3.10.5-4: UTBO LTMF Verification Limits

Properties	Test Method	LTMF Verification Limit
Asphalt Binder Content (P_b)	AASHTO T 308	Target ± 0.3%
Gradation Passing ¾ in. Sieve	AASHTO T 30	Target ± 0.0%
Gradation Passing #4 and Larger Sieves	AASHTO T 30	Target ± 6.0%
Gradation Passing #8 Sieve	AASHTO T 30	Target ± 5.0%
Gradation Passing #16 to #50 Sieve	AASHTO T 30	Target ± 3.0%
Gradation Passing #100 Sieve	AASHTO T 30	Target ± 2.0%
Gradation Passing #200 Sieve	AASHTO T 30	Target ± 1.0%
Draindown	AASHTO T 305	≤0.1%
Moisture Susceptibility	AASHTO T 283	≥80%

M3.12.0: Hot Mix Asphalt Production Facility

All facilities producing HMA must be approved on an annual basis by the Department. All sources of materials used for the production of HMA must be approved by the Department prior to their use. Such materials shall include:

1. Coarse aggregate
2. Fine aggregate
3. Mineral filler
4. Performance graded asphalt binder
5. Modifiers and/or additives

HMA production operations shall follow industry accepted best management practices including:

1. Aggregate handling and stockpile management
2. Recycled asphalt pavement handling and stockpile management
3. PGAB storage
4. Plant process controls
5. Silo loading
6. Truck loading

The plant shall meet the requirements of AASHTO M 156 as well as the following provisions. HMA plants meeting these requirements and which have been approved by RMS shall be listed on the QCML.

An adequate quantity of each size aggregate, mineral filler and asphalt binder shall be maintained at the HMA plant site at all times while the plant is in operation to ensure that the plant can continuously produce mixtures that meet these specifications. The quantity of such materials shall never be less than one day's production capacity.

A. Production Facility Quality Control System

The production facility shall provide a Quality Control System (QC System) adequate to ensure that all materials and workmanship meet the required quality levels for each specified Quality Characteristic. The QC System shall be documented in a Quality System Manual (QSM). The Contractor shall provide qualified QC personnel and QC laboratory facilities and perform Quality Control inspection, sampling, testing, data analysis, corrective action (when necessary), and documentation.

The QSM shall conform to the requirements of AASHTO R 38 and the MassDOT Model QSM. The pages of the QSM shall be sequentially numbered and shall address, in sufficient detail, the specific information requested under each section and subsection contained in the MassDOT Model QSM.

B. Scales

Plant and truck scales shall be certified:

1. At the start of each construction season, prior to use for MassDOT projects.
2. At intervals of not more than 90 calendar days.
3. Whenever the plant changes location.
4. At any time as requested by the Engineer.

C. Calibration of Plant Equipment

The plant's systems shall be calibrated:

1. At the start of each construction season, prior to use for MassDOT projects.
2. Whenever there is a significant change to the material.
3. Whenever a plant component supply system affecting the ingredient proportions has been repaired, replaced, or adjusted.
4. At any time as requested by the Engineer.

D. Automatic Recordation

Recordation equipment shall be provided. Each recorder shall include an automatic printer system. The printer shall be so positioned that the digital display and the printer can be readily observed within the plant's control room by the Engineer and the plant operator, simultaneously. The delivery ticket shall be printed with an original and at least one copy. The original shall be furnished to the Engineer at the paving site and the copy to the Engineer at the plant. The delivery ticket format shall be approved by RMS and will include the following information:

1. Company / plant location.
2. MassDOT contract number and/or distinct project name.
3. MassDOT mix ID number and/or distinct mix description.
4. Percentage of RAP in the mixture.
5. Percentage of asphalt binder in the mixture.
6. Date and time of loading.
7. Sequential load number for the contract for a 24-hour period.
8. Total weight of mix in truck (pay weight).

The following mixture production information shall also be provided:

For Batch Plants

1. Date mixed.
2. Time of batching.
3. Tare weight of aggregate weigh box.
4. Tare weight of PGAB weigh bucket.
5. Moisture content of recycled materials.
6. Target and actual cumulative or net weights as batched for each bin with a batch total for all net ingredients.
7. Target and actual weight of PGAB.
8. Total weight of mix in truck (pay weight).

Note: This information shall be included on the delivery ticket when the mix is batched directly into a truck. When the mix is batched and stored in a silo the information may be separate from the delivery ticket however it must be provided to the Engineer at the plant.

For Drum Plants

1. Percent of mixture as well as the target and actual production rate for each individual mix component including:
    a. Aggregate
    b. Mineral Filler
    c. PGAB
    d. Recycled materials
    e. Additives
2. Moisture content of aggregates and recycled materials.
3. PGAB temperature.
4. Target and actual mix temperature.
5. Target and actual mix production rate.

Note: This information is not required to be included on the delivery ticket however it must be provided to the Engineer at the plant.

E. Surge and Storage Silo Holding Time

The mixtures shall not be stored in surge and storage bins longer than the following:

1. Unheated and not insulated ..... 2 hours
2. Unheated and insulated with heated gate ..... 15 hours
3. Insulated and heated ..... 24 hours

Note: In order to prevent excessive draindown, OGFC shall not be stored in a surge or storage bin for longer than 2 hours. ARGG shall not be stored for more than 6 hours.

F. Asphalt Release Agents

The plant shall have a method of applying MassDOT approved asphalt release agents to the haul units in accordance with the Manufacturer's recommendations. Spray systems may either be manual or automated but application of the release agent must be at the rate specified by the Manufacturer.

G. Air Quality

The plant shall be designed and operated to meet all current Federal and State air quality requirements.

H. Equipment Failure

If at any time the automatic proportioning or recording system becomes inoperative, the plant will cease all HMA production. Work will only be allowed to restart once all automatic controls and recording systems are functional.

M3.12.1: HMA Plant Facility Inspection

The Engineer shall have access at any time to all parts of the plant for:

1. Inspections of the conditions and operations of the plant.
2. Confirmation of the adequacy of the equipment in use.
3. Verification of the character and proportions of the mixture.
4. Determination of temperatures being maintained in the preparation of the mixture.
5. Inspection of incidental related procedures.

M3.13.0: Hot Mix Asphalt Materials Testing Laboratory and Equipment

M3.13.1: Contractor Quality Control Laboratory

All Contractor QC testing shall be performed in laboratories that are approved by RMS and qualified through the NETTCP LQP or accredited through the AAP. All laboratories shall maintain a QSM in accordance with the outline maintained by RMS.

1. Laboratories that perform HMA mix designs or QC testing under Subsection 450: Hot Mix Asphalt Pavement shall at a minimum be qualified as a NETTCP LQP Category 2 laboratory.
2. Laboratories performing only QC testing shall be qualified as a NETTCP LQP Category 3 laboratory.

Contractors who do not produce mixtures under Subsection 450: Hot Mix Asphalt Pavement will not be required to have their own laboratory at the production facility but will be required to either test at their central laboratory or hire a consultant testing company to perform the QC testing required in the specification. The Contractor will still be required to maintain a QSM.

The Contractor’s QC laboratory shall be qualified to perform all testing required by Table M3.13.2-1 as well as contract specifications.

Laboratories meeting these requirements, and which have been approved by the RMS, shall be listed on the QCML.

The Contractor's QC Manager shall have overall responsibility for ensuring that all laboratories utilized for QC are in compliance with the requirements of the NETTCP LQP. This includes providing required AASHTO, ASTM, and NETTCP reference documents and ensuring that all required equipment and tools are properly functioning and calibrated.

The Engineer shall be permitted unrestricted access to inspect and review the Contractor’s laboratory facility.

Along with the required testing capabilities the laboratory facilities shall meet the following:

1. Be kept clean and all equipment shall be maintained in proper working condition.
2. Provide adequate environmental control to the satisfaction of the Engineer and must be able to maintain an inside temperature of 68°F to 86°F during working hours.
3. Adequate ventilation to remove dust and fumes from the laboratory.
4. Hot and cold potable water.
5. First aid kit and emergency eye wash station.
6. Multi-class ABC fire extinguisher.
7. A restroom shall also be made available within 500 ft of the laboratory during all work shifts. The restroom facilities shall be enclosed in a separate room with proper ventilation and comply with applicable sanitary codes as well as:
    a. A flush toilet.
    b. A sink with hot and cold running water.
    c. A sewer or septic tank with connections.
    d. Adequate rest room supplies.
    e. Maintained environmental control and cleanliness.

M3.13.2: Department Acceptance Laboratory at HMA Production Facility

The Engineer shall be provided laboratory working space meeting the requirements of M3.13.1: Contractor Quality Control Laboratory as well as the following. A desk must be located in close proximity to the laboratory but be separated from the ovens, sieve shakers, and anything else that can cause poor air and sound quality. The Engineer's desk and laboratory space will not be shared with any other entity.

Contractors who do not produce mixtures under Subsection 450: Hot Mix Asphalt Pavement will not be required to have a Department Acceptance Laboratory at the production facility, but will be required to allow the Engineer to perform Acceptance testing at their central laboratory or Consultant testing company laboratory. These laboratories are still required to meet M3.13.1: Contractor Quality Control Laboratory.

If the Engineer is unable to perform their duties either due to lack of working space, poor working conditions, or access to equipment it will be considered a laboratory facility deficiency. The Engineer will advise the Contractor in writing of any noted deficiencies concerning the laboratory facility, equipment, supplies, or testing personnel and procedures. Deficiencies shall be grounds for the Engineer to order an immediate stoppage of work until the deficiencies are corrected.

The plant, silos, and sample rack shall be in view of laboratory when performing testing under Subsection 450: Hot Mix Asphalt Pavement.

The Engineer shall be provided with the following:

A. Computer

For plants producing HMA in accordance with Subsection 450: Hot Mix Asphalt Pavement, the Engineer shall be furnished with a computer with high speed internet access which conforms to the requirements determined by RMS. The minimum requirements shall include:

1. The Engineer is required to have 1 computer at the laboratory.

2. Computers shall be required to have the latest MS Office Professional with all security updates, Antivirus software with all current security updates maintained, and any other software required by RMS.
3. A laser printer with the capability to also scan and copy. The printer shall be compatible and connected to the laboratory's computer.

B. Testing Equipment

The Contractor shall supply the Engineer with the following equipment. This equipment shall only be utilized by the Engineer and shall be labeled as such. It shall be the Contractor's responsibility to maintain and replace equipment as needed.

1. For T 27 and T 30:
    a. 12-in. sieve stack (2 in. to #200) with cover and pan.
    b. Mechanical sieve shaker (only for Subsection 450: Hot Mix Asphalt Pavement Category A Lots).
    c. Electronic balance (only for Subsection 450: Hot Mix Asphalt Pavement Category A Lots).
2. For T 166 and T 209: Complete setup (only for Subsection 450: Hot Mix Asphalt Pavement).
3. For T 312: Gyratory mold.
4. For T 308:
    a. Ignition oven sample basket.
    b. Ignition oven and 2 sample baskets (only for Subsection 450: Hot Mix Asphalt Pavement Category A Lots).
5. Miscellaneous equipment such as sample buckets, scoops, pans, brushes, thermometers, etc.
6. Oven which meets AASHTO R 30 and is capable of storing the sample buckets for 3 samples (only for Subsection 450: Hot Mix Asphalt Pavement Category A Lots).
7. Supply of sample boxes.
8. Sample rack which is a suitable sampling platform from which the Engineer is able to stand and sample the material in the truck bed adequately and safely. The rack shall:
    a. Be of sturdy construction.
    b. Be able to safely accommodate at least two people at a time (minimum standing area of 4 ft x 4 ft).
    c. Have a safe stairway that is attached to the sampling platform.
    d. Be at a height which allows the Technician the ability to reach the HMA in the bed of any size truck safely and efficiently.
    e. Have a mounted spotlight to allow for sampling at night.
    f. Be within 100 ft of the laboratory and visible from the laboratory.
    g. Meet applicable OSHA standards.

Table M3.13.2-1: Required Test Methods by Laboratory

Test Method	Description	Mix Design Laboratory	QC Laboratory	Department Acceptance Laboratory
AASHTO M 323	Superpave Volumetric Mix Design	X		
AASHTO R 30 (See note 1)	Mixture Conditioning of HMA	X		
AASHTO R 35	Superpave Volumetric Design for Asphalt Mixtures	X		
AASHTO R 47	Reducing Samples of HMA to Testing Size	X	X	X
AASHTO R 66	Sampling of Asphalt Materials		X	
AASHTO R 76	Reducing Samples of Aggregate to Testing Size	X	X	
AASHTO R 79 (See note 3)	Vacuum Drying Compacted HMA Specimens		X	
AASHTO R 90	Sampling of Aggregate		X	
AASHTO R 97	Sampling of Bituminous Paving Mixtures		X	X
AASHTO T 11	Material Finer Than #200 Sieve by Washing	X	X	X
AASHTO T 27	Sieve Analysis of Fine and Coarse Aggregates	X	X	X
AASHTO T 30	Sieve Analysis of Extracted Aggregate	X	X	X
AASHTO T 84	Specific Gravity and Absorption of Fine Aggregate	X		
AASHTO T 85	Specific Gravity and Absorption of Coarse Aggregates	X		
AASHTO T 96	Coarse Aggregate L.A. Abrasion	X		
AASHTO T 104	Soundness of Aggregates	X		
AASHTO T 166	Bulk Specific gravity of HMA	X	X	X
AASHTO T 176	Sand Equivalence	X		
AASHTO T 209	Theoretical Maximum Specific Gravity of HMA	X	X	X
AASHTO T 255	Moisture Contents of Aggregates		X	
AASHTO T 283 (See note 4)	Resistance of Compacted Asphalt Mixtures to Moisture-Induced Damage	X		
AASHTO T 304	Un-compacted Void Content of Fine Aggregate	X		

Test Method	Description	Mix Design Laboratory	QC Laboratory	Department Acceptance Laboratory
AASHTO T 305 (See note 3)	Draindown in Uncompacted Asphalt Mixtures	X		
AASHTO T 308	Asphalt Binder Content by Ignition Oven		X	X
AASHTO T 312	Density of HMA by Superpave Gyratory	X	X	X
AASHTO T 329	Moisture Control of HMA		X	X
AASHTO T 331 [4]	Bulk Specific Gravity and Density of Compacted Asphalt Mixtures Using Automatic Vacuum Sealing	X	X	X
AASHTO T 335	Determining the Percentage of Fracture in Coarse Aggregate	X		
ASTM D3549	Thickness of Compacted HMA Specimens		X	
ASTM D4791	Flat & Elongated Particles in Coarse Aggregate	X		
ASTM D7370 (See note 2)	Relative Density and Absorption of Aggregate Using Combined Vacuum Saturation and Rapid Submersion	X		

1. Two ovens shall be required; one to heat binder, aggregate, and mixing tools to mixing temperature and one to condition the loose mixture at the compaction or conditioning temperature.
2. Optional test.
3. Required for OGFC and ARGG.
4. Required for OGFC.

SECTION M4: CEMENT AND CEMENT CONCRETE MATERIALS

M4.00.00: General

All cement, cement concrete, and related materials shall be sampled and tested in accordance with the applicable AASHTO, ASTM or other designated methods. Cement as defined in this specification shall mean cementitious material as specified in the following sections.

M4.01.0: Portland Cement

Portland Cement shall conform to the requirements of AASHTO M 85.

M4.01.1: Blended Hydraulic Cements

Blended hydraulic cements shall conform to the requirements of AASHTO M 240M/M 240.

M4.01.2: Fly Ash

Fly ash shall conform to AASHTO M 295.

M4.02.00: Cement Concrete

Producers shall report proposed mix design formulations onto the Department issued mix design sheet in its entirety and submit to the Department for review. Mix design formulations shall meet the requirements specified in the construction standard specifications, contract document special provisions, design plans, and herein. Mix design formulations shall be approved by the Department prior to construction.

Mix design formulations shall be designed with precise proportions of constituent materials, yielding 27.0 ft^3 (1 cubic yard) of cement concrete. All required mix design targets shall be reported on the Department issued mix design sheet for each proposed mix design. Mill certifications and technical data sheets of the constituent materials incorporated into the proposed mix design formulation shall accompany the mix design formulation submission.

Cement concrete shall be classified and reported according to the mix design formulation's 28-day compressive strength (f'_c), nominal maximum aggregate size (NMAS), total cementitious content (lb), air content (%), water-cementitious (w/cm) ratio, paste content (%), paste content-void content (PC/VC) ratio, slump (in.), unit weight (lb/ft^3), and mix type. Nominal maximum aggregate size (NMAS) shall be determined from the combined aggregate system of the proposed mix design formulation and is defined as the sieve size immediately above the first sieve size that cumulatively retains more than 10% by mass.

Table M4.02.00-1: Classifications of Concrete Mixes

Class 28-Day Compressive Strength	Minimum Total Cementitious Content (Pounds per Cubic Yard of Concrete)		
	1-½ in.	¾ in.	⅜ in.
2,500 psi	425	470	520
3,000 psi	470	520	565
3,500 psi	520	565	610
4,000 psi	565	610	660
5,000 psi	660	705	760

M4.02.01: Cement

Cement for concrete shall be the kind and type designated on the plans or in the specifications for the particular work. If no type is specified either Type I, IA, IP, IP-A or Type II, IIA shall be furnished except that cement for exposed bridge deck concrete or concrete exposed to sea water shall be Type II or IIA.

Cement shall not exhibit a flash set or cause an abnormal initial rise of temperature when mixed with water. It shall maintain its full plasticity and fluidity during the period required for placing the concrete.

The temperature of the cement at the time of mixing shall not exceed 150°F.

When tested at the mill, no cement shall be shipped to the work until it has passed the 7-day test. At least 12 days from the time of sampling shall be allowed to the completion of the required 7-day test.

Each shipment, regardless of quantity, shall be accompanied by a certified Mill Test Report, three copies of which shall be furnished to the Engineer before the cement may be incorporated in the work. Cement furnished without a current Mill Analysis Report shall not be used in the work until the Engineer has had sufficient time to make appropriate tests and has approved the cement for use. A current Certificate of Compliance for concrete admixtures, fly ash, silica fume, and slag based on test results shall be available for the inspector prior to production.

Cement of a uniform color shall be used in all exposed concrete of any structure.

M4.02.02: Aggregates

Aggregate shall exhibit acceptable quality characteristics and material properties, including particle size distribution, shape, surface texture, absorption, compressibility, effect on modulus of elasticity of concrete, moisture-related volume changes, coefficient of thermal expansion, wetting and drying, and resistance to abrasion, alkali aggregate reaction, and d-cracking, popouts, and sulfate attack due to freezing, thawing, and de-icing. Aggregate shall be sufficiently limited of potentially deleterious amounts of constituents that may negatively affect cement concrete performance, including workability, setting, hardening, aggregate-cement bond, strength, color, long-term durability, and other properties.

Aggregate sources with limited historical field and test data shall be subjected to ASTM C295 Petrographic Examination for Potential Akali Aggregate Reactive Constituents and Deleterious Materials in Aggregate. Examinations and reporting shall be conducted by accredited independent laboratories. The Producer shall submit ASTM C295 examination reports to the Department for review.

A. Fine Aggregates

Fine aggregate shall meet AASHTO M 6 Standard Specification for Fine Aggregate for Hydraulic Cement Concrete.

B. Coarse Aggregates

Coarse aggregate shall meet AASHTO M 80 Standard Specification for Coarse Aggregate for Hydraulic Cement Concrete and AASHTO M 43 Sizes of Aggregate for Road and Bridge Construction.

M4.02.03: Lightweight Aggregates

Lightweight aggregates for Structural Concrete shall meet AASHTO M 195.

M4.02.04: Water

Water for use in cement concrete shall be clean, clear and free from deleterious amount of oil, acid, alkali, salts and organic matter.

The water shall exhibit no deleterious effect upon the strength, setting, or soundness of the cement. It shall conform to the following requirements:

1. pH: 3.0 to 11.7
2. Total Solids.
    a. Organics: 0.01% Maximum
    b. Inorganics: 0.10% Maximum
    c. Sulphate: 0.05% Maximum

Testing of the water shall be in accordance with AASHTO T 26.

M4.02.05: Chemical Admixtures

Chemical admixtures shall be defined as constituent materials in both liquid or powder form that are incorporated into the material immediately prior or during mixing, to enhance mix properties and maintain consistency during mixing, transporting, placing, finishing, and curing. Chemical admixtures shall be considered any ingredient added to a concrete mixture other than cement, supplementary cementitious materials (SCMs), aggregate, water, and fiber reinforcement. Chemical admixtures shall exhibit acceptable quality characteristics and material properties, including chemical composition, performance, and uniformity. Chemical admixtures shall be listed on the QCML as of the date of placement and meet the requirements specified herein.maintain valid listing on the Department Qualified Construction Materials List (QCML) and meet the requirements specified herein.

A. Standard Admixtures.

Standard admixtures shall meet AASHTO M 194 Standard Specification for Chemical Admixtures for Concrete.

B. Air-Entraining Admixtures.

Air-entraining admixtures shall meet AASHTO M 154 Standard Specification for Air-Entraining Admixtures for Concrete.

C. Corrosion Inhibiting Admixtures.

Corrosion inhibiting admixtures shall meet ASTM C1582 Standard Specification for Admixtures to Inhibit Chloride-Induced Corrosion of Reinforcing Steel in Concrete.

M4.02.06: Proportioning

Concrete shall be proportioned with the specified minimum cement content for each class and shall be mixed to the required consistency as determined by standard slump test AASHTO T 119M/T 119.

A. Proportioning by Weight.

Cement and aggregates shall be proportioned by weight in an approved manner. Scales shall be calibrated and sealed by the proper authority within the preceding year, or following any reassembly, or as the Engineer may direct.

B. Scope of Control for Proportioning.

The responsibility of the Department is confined to the inspection of the following four factors controlling the mix:

1. Minimum Cement Content and Minimum Strength.

The cement proportion is subject to adjustment and approval by the Engineer in order to insure compliance with minimum strength requirements. Standard field test specimens (AASHTO T 23) shall be taken on the job and the Contractor shall be required to add additional cement as directed by the Engineer if the test specimens fail to meet the requirements of M4.02.13: Test Specimens.

No claims shall be allowed for extra cement or extra concrete due to variations in materials, proportioning, dimensions, shrinkage, waste and similar causes. The Contractor is advised to anticipate a normal loss in yield of 1% or 2% due to the foregoing causes.

The volume of plastic concrete in a given batch shall be determined from the total weight of the batch divided by the actual weight per cubic foot of the concrete. The total weight of the batch shall be calculated as the sum of the weights of all materials including water. The weight per cubic foot shall be determined in accordance with the Method of Test for Weight per Cubic Foot Yield and Air Content (Gravimetric) of Concrete (AASHTO T 121M/T 121).

2. Consistency.

The Contractor shall uniformly regulate the consistency of the mix to the slump directed by the Engineer. The slump target shall be identified on the approved cement concrete mix design sheet. For approved slump targets less than or equal to 3 in., slump test results shall not exceed the allowable tolerance of ±1.0 in. from the approved target. For approved slump targets greater than 3 in., slump test results shall not exceed the allowable tolerance of ±1.5 in. from the approved target.

Modifications to the approved slump target shall be prohibited. If slump test results are not within the specified design target ranges, the Contractor is permitted to request for Department review and approval, on-site adjustments of chemical admixture dosages and the use of water held back at the plant. The Engineer may reject non-conforming batches and the Contractor shall receive no additional compensation.

3. Workability.

The Engineer may vary the proportion of fine aggregate in order to regulate the workability or density of the mix, making an equivalent change in the coarse aggregate to keep the yield constant.

4. Air Content.

The air void system shall contain a stabilized air bubble distribution and promote quality concrete properties, including enhanced workability, cohesion, strength, and resistance to freezing, thawing, de-icing, and sulfate reaction. Cement concrete shall meet the air content targets identified in Table M4.02.06-1. A tolerance of ±1.5% in the percentages will be allowed.

Table M4.02.06-1: Air Content Target

Nominal Maximum Aggregate Size (in.)	Reinforced Concrete (%)[1]	Non-Reinforced Concrete (%)[1]
⅜	7.5	7.5
½	7.0	7.0
¾	6.0	7.0
1	6.0	6.5
1½	5.5	6.5

[1]A 1.0% reduction from the air content target is permitted for $f'_c \geq 5000$ psi.

C. Automatic Proportioning Plants.

All plants shall be equipped with an approved automatic weighing, cycling and monitoring system installed as part of the batching equipment. Each plant shall include equipment for accurate proportioning batches containing the various components by weight or by volume for admixtures and water in the proper sequence and for controlling the sequence and timing of mixing operation. The automatic proportioning system shall be capable of consistently delivering each constituent within the tolerances indicated in M4.02.07: Measuring Materials. Interlocks shall be provided which will hold or delay the automatic batch cycling whenever the batched quantity of any component is not within the specific weight tolerance, when any aggregate bin becomes empty or when there is a malfunction in any portion of the control system. The weight setting and time controls shall be so equipped that they may be locked when directed by the Engineer.

The weighing equipment shall be so arranged that the batch plant operator can conveniently observe all scales from their operation station.

The Controls shall be set so that:

1. The batcher inlet gates cannot be opened while the discharge gates are open.

2. The batcher discharge gates cannot be opened:
    a. Until the full batch weights are registered on the scales;
    b. While the weigh hopper is being filled;
    c. If batch weights are over or under the delivery tolerances specified on M4.02.07: Measuring Materials.
3. A new batch cannot be weighed until the hopper is entirely empty of the previous batch and all scales have returned to zero.

Discharge chutes shall be so arranged that they are not suspended from any part of the weighing system and so that no materials will lodge therein or be lost on discharge.

Each weighing unit shall include a springless dial which shall indicate the scale load at all stages of the weighing operation from zero to full capacity.

If at any time the automatic proportioning system becomes inoperative, the plant will be allowed to batch materials manually for a period not in excess of 2 working days. Manual batching for longer periods will require written permission of the Engineer. All plant scales shall be tested at the expense of the producer by a competent scale technician as follows:

1. Annually prior to use in Department work.
2. At any time ordered by the Engineer.

D. Admixture Dispensing Systems.

Plants shall be equipped with a separate dispensing system necessary to incorporate each of the required admixtures into the concrete. At least two admixture dispensing systems shall be required for plants supplying structural concrete.

E. Recording the Batching.

All concrete batching plants equipped with automatic proportion systems shall have digital recording instruments approved by the Engineer which shall be so located as to be readily accessible and readable to the operator from their normal work station. The recording instruments shall be designed to record the quantities of each aggregate component, cement, fly ash (when used), water and the presence of admixture for each batch of concrete produced. All records of batches shall show the batch number, the day, the month, year, and time of day to the nearest minute for each batch and they shall be imprinted on the record so that each batch may be permanently identified. The Department shall be provided with a clear and legible copy of all batch records.

Cement, fly ash, and aggregate component weight quantities shall be recorded separately. Water may be recorded by weight or volume.

Weights and/or volumes shall be recorded as indicated on the batching scale or meter within an accuracy of ±1 scale or meter gradation. The minimum recorder resolution shall be equivalent to or less than minimum gradation on the scale or meter. When the automation system is capable of producing other than standard size batches (full, half or quarter cubic yard increments), the recordation requirements shall be in accordance with written directives from the Engineer.

Each plant site shall be equipped with an approved instrument capable of automatically applying a time-date stamp to each delivery ticket as the delivery vehicle departs from the plant site.

M4.02.07: Measuring Materials

Materials shall be measured in accordance with AASHTO M 157, Section 8, with the following exceptions:

All wash water shall be removed from truck mixers and truck agitators prior to charging with a fresh load.

Water may be held back at the plant by up to 5.0 gallons per cubic yard of concrete mixed. The use of this water on the project is at the direction of the Engineer and must be verified through sight glass increments or in-line meter readings and then the amount will be written on the ticket. Absolutely no additional water may be utilized on site for slump adjustment purposes. If after placing all the allowable hold-back water and mixing the proper time, the concrete mixture still does not attain the proper slump, the Engineer will reject the truckload.

M4.02.08: Plant and Equipment

The plant and equipment shall be subject to approval by the Engineer to insure satisfactory prosecution of the work without delay.

A. Batching Plant.

1. Bins with adequate separate compartments for fine aggregates and for each required size of coarse aggregate shall be provided in the batching plant. Each compartment shall be designed to discharge efficiently and freely into the weighing hopper. Means of control shall be provided so that, as the quantity desired in the weighing hopper is being approached, the material may be added slowly and shut off with precision. Weighing hoppers shall be constructed so as to eliminate accumulation of tare materials and to discharge fully.
2. Fly ash shall be stored at the batch plant in a separate storage or holding bin and it shall be protected from rain and moisture.
3. Scales for weighing aggregates and cement shall be of either the springless-dial type or the load cell type and shall indicate the load at all stages of the weighing operation from zero to full capacity. They shall conform to the applicable sections of the current edition of the National Bureau of Standards Handbook 44, Specifications, Tolerances and other Measuring Devices, except as may be otherwise specified. They shall be accurate within one half of 1 % under operating conditions. Ten 50-lb weights shall be available at the plant at all times for checking accuracy. All exposed fulcrums, clevises, and similar working parts of scales shall be kept clean. When beam-type scales are used, provisions shall be made for indicating to the operator that the required load in the weighing hopper is being approached; the device shall indicate within the last 200 lb of load and within 50 lb overload. All weighing and indicating devices shall be in full view of the operator while charging the hopper and the operator shall have convenient access to all controls.
4. The materials, including admixtures, shall be proportioned by automatic proportioning devices, approved by the Engineer. The automatic proportioning equipment shall be installed in an area enclosed for protection against dust and inclement weather.

B. Testing Facilities.

A weatherproof building or room shall be furnished at the site of the producing plant suitable for the housing and use of equipment necessary to carry on the various tests required and for

recording and processing test results. This building shall be for the exclusive use of the Engineer or their representative for testing and recording purposes. The building or room shall have a least dimension of 7 ft and a minimum of 220 ft². Windows and doors shall be adequately screened and satisfactory lighting and heating shall be provided for a 24 hour day and be supplied with water. The room shall have adequate ventilation and be air conditioned in the warm months to provide a minimum of 75°F. A table, chairs, desk, work bench, file cabinet, electronic calculator, and a minimum of two 5-lb fire extinguishers shall be provided.

If the Engineer permits, the testing facility may be part of another building in which case it shall be entirely partitioned off from the remainder of such building.

Testing equipment conforming to current AASHTO standards and meeting the approval of the Engineer shall be furnished as follows and installed in the building for use in testing the materials (and mixtures) supplied by the Plant for the work:

- 1 Fine Aggregate Sieve Shaker, power driven, for 8-in. minimum diameter sieves.
- 1 Each of the following standard 8-in. minimum diameter square opening sieves: No. 4, No. 8, No. 16, No. 30, No. 50, No. 100, and No. 200, with pan and cover.
- 1 Sample Splitter with a minimum capacity of 1 ft³. It shall be of the clam shell type and the chute width shall be adjustable from a minimum of ½ in. up to 2 in.
- 1 Solution Balance, 20-kg capacity, weighing directly to 1 g, with two weighing beams and a taring beam; tare capacity to be 2 kg; weight beams to read 1,000 g by 100 g divisions and 100 g by 1 g divisions. Additional matching weights (one 1-kg, two 2-kg, one 5-kg, and one 10-kg) shall be provided to fulfill the capacity of 20 kg. The platform to be 11-in. diameter. An electronic, direct reading, top loading, 20-kg minimum capacity, balance with a precision of 0.1 g may be substituted for the solution balance.
- 1 Approved Scale with a minimum capacity of 2,000 g and with a sensitivity of 0.50 g. An electronic, top-loading, balance, with a capacity of 2,000 g minimum, and reading to 0.1 g may be used in place of the scale.
- 1 Approved Dial Thermometer, range of 50°F to 500°F.
- 1 Approved Hot Plate.

Approval of a plant will be contingent upon approval of the aforementioned requirements for Plant Laboratory, including the building and appurtenances, furnishings, facilities including heat, light, power and water, the testing equipment and any other incidentals.

M4.02.09: Mixers and Agitators

A. Mixers may be stationary mixers or truck mixers. Agitators may be truck mixers or truck agitators. Each mixer and agitator shall have attached thereto, in a prominent place by the manufacturer, a metal plate or plates on which is plainly marked the various uses for which the equipment is designed, the volume of the drum, the capacity of the drum or container in terms of the volume of mixed concrete and the speed of rotation of the mixing drum or blades. Stationary mixers shall be equipped with an acceptable timing device that will not permit the batch to be discharged until the specified mixing time has elapsed. Truck mixers shall be equipped with counters by which the number of revolutions of the drum or blades may readily be verified. The counters shall be read at the time of starting and ending of mixing at mixing speeds.

B. The truck mixer when loaded with concrete shall not contain more than 63 % of the gross volume of the drum. The mixer shall be capable of combining the ingredients of the concrete into a thoroughly mixed and uniform mass and of discharging the concrete with a satisfactory degree of uniformity.
C. The stationary mixer, when loaded at the manufacturer's guaranteed mixing capacity, and the concrete mixed for the time prescribed, shall be capable of combining the ingredients of the concrete into a thoroughly mixed and uniform mass and discharging the concrete with satisfactory uniformity.
D. The agitator, when loaded not to exceed 80% of gross drum volume, shall be capable of maintaining the mixed concrete in a thoroughly mixed and uniform mass and of discharging the concrete with a satisfactory degree of uniformity.

M4.02.10: Mixing and Delivery

A. Ready-mixed concrete shall be mixed and delivered to the point designated by the Engineer by means of one of the following combinations of operations.
    1. Mixed completely in a stationary mixer and the mixed concrete transported to the point of delivery in a truck agitator or in a truck mixer operating at agitator speed or in non-agitating equipment when approved by the Engineer.
    2. Mixed completely in a truck-mixer at the point of delivery under the supervision of the Engineer, who shall certify on a delivery slip that they observed the complete mixing of the concrete.
B. Truck mixers and truck agitators shall be operated within a capacity not to exceed 63% or 80% respectively of the gross volume of the drum and at a speed of rotation for mixing or agitating as designated by the manufacturer of the equipment. A truck mixer or truck agitator used for transporting concrete that has been completely mixed in a stationary mixer shall be operated within the limits of capacity and speed of rotation designated by the manufacturer for agitating, except that the agitator capacity in no event exceed 80% of the gross drum volume.
C. When a stationary mixer is used for the complete mixing of the concrete, the mixing time for mixers having a capacity of 10 yd^3 or less shall be not less than 60 seconds. For mixers of more than 10 yd^3 capacity, the mixing time shall be determined by the Engineer. The time is valid provided mixer efficiency tests prove the concrete is satisfactory for uniformity and strength. Mixing time shall be measured from the time all cement and aggregates are in the drum. The batch shall be so charged into the mixer that some water will enter in advance of cement and aggregates, and all water shall be in the drum by the end of the first one-fourth of the specified mixing time.
D. When a truck mixer is used for complete mixing, each batch of concrete shall be mixed for not less than 70 nor more than 100 revolutions of the drum or blades at the rate of rotation designated by the manufacturer of the equipment on the metal plate on the mixer as mixing speed. Additional mixing, if any, shall be at the speed designated by the manufacturer of the equipment as agitating speed. All materials including mixing water shall be in the mixer drum before actuating the revolution counter for determination of number of revolutions of mixing.
E. When a truck mixer or truck agitator is used for transporting central-mixed concrete, or when all ingredients including water have been added to the truck mixer at the batching plant, the drum shall be constantly rotated at the agitating speed designated by the

manufacturer of the equipment, both during transport and while on the project prior to discharge, except during the period required for mixing.

F. When a truck mixer or truck agitator is used for transporting concrete, the concrete shall be delivered to the site of the work and discharge shall be completed within 90 minutes after the addition of the cement to the aggregates. Each batch of concrete delivered at the job site shall be accompanied by a time slip issued at the batching plant, bearing the time of charging of the mixer drum with cement and aggregates. In hot weather or under conditions contributing to quick stiffening of the concrete or when the temperature of the concrete is 85°F or above, the time between the introduction of the cement to the aggregates and discharge shall not exceed 1 hour. When a truck mixer is used for the complete mixing of the concrete, the mixing operation shall begin within 30 minutes after the cement has been added to the aggregate.

   When it is determined that more than 90 minutes will be required to batch and completely discharge the load, an alternate method of delivery and mixing will be permitted. The truck mixer will be charged at the batching plant with reasonably dry aggregates and cement but no mixing water. The required amount of mixing water shall be carefully introduced into the truck mixer at the job site and the batch of concrete mixed as outlined above. Under such conditions one hour shall be allowed for the discharge of the load, computed from the time the mixing water has been added to the batch and the mixing begun.

   The concrete when discharged from truck mixers and truck agitators, shall be of the consistency and workability required for the job. The rate of discharge of the plastic concrete from the mixer drum shall be controlled by the speed of rotation of the drum in the discharge direction with the discharge gate fully open.

   All wash water shall be removed from truck mixers and truck agitators prior to charging with a fresh load.

G. When approved by the Engineer, central-mixed concrete which is designed for the purpose may be transported in suitable non-agitating equipment.
   1. When non-agitating equipment is used for transportation of concrete:
      a) Bodies of equipment shall be smooth, water-tight, metal containers equipped with gates that will permit control of the discharge of the concrete. Covers meeting the approval of the Engineer shall be provided for protection against the weather.
      b) The concrete shall be delivered to the site of the work in a thoroughly mixed and uniform mass and discharged with a satisfactory degree of uniformity. Slump tests of representative samples taken during the discharge shall not differ by more than 2 in. Discharge shall be completed within 30 minutes after introduction of the mixing water to the cement and aggregates.
   2. Concrete delivered in outdoor temperatures lower than 40°F shall arrive at the work having a temperature not less than 60°F nor greater than 90°F.

H. Concrete may be tempered only once before the initial set with the permission of the Engineer and only with an approved superplasticizer to bring the slump back to within the specification. The concrete shall be mixed thoroughly according to the manufacturer's recommendation. Concrete shall not be re-tempered by adding water. Any batch of concrete that does not conform to the specification with respect to delivery time, temperature, slump or entrained air content shall be rejected.

M4.02.11: Storage and Handling of Materials

All materials shall be stored and handled in an approved manner.

A. Cement.

Cement shall be fully protected against moisture and any cement damaged by exposure shall not be used.

Cement shall be emptied directly from the shipping packages into the skip of the mixer, except when bulk cement is used. The cement discharge chute at the aggremeter shall be so arranged that there will be no possibility of loss of cement in passing through it.

B. Aggregates.

Aggregates in stockpiles shall be placed on firm well-drained ground. The piles shall be of such shape and size that materials may be handled and stored without becoming dirty or mixed with deleterious substances. Aggregates from different sources or of different grading shall be kept in separate stockpiles.

Coarse aggregate will be handled and stored to produce minimum segregation of sizes. Fine aggregate will be handled in such a way as to prevent the loss of fines. Aggregate shall be induced into the aggremeter in an approved manner complying with required gradation.

Storage and handling of aggregates shall be done in a manner to ensure a uniform moisture content satisfactory for proper control of the consistency of the mix. Frozen aggregates shall not be used.

Aggregates shall be taken continuously from one source in filling the compartments of the batcher bin, and no change of source of any of the aggregates shall be permitted without the consent of the Engineer.

The Department reserves the right to prohibit the use of aggregates from any plant, pit quarry or deposit where the character of the material method of operation or rate of production is inadequate.

When aggregate is proportioned in the batching plants and transported by trucks to the paving mixer, the compartments in the trucks shall be of sufficient size to prevent spilling from one compartment to another either in transit or when emptying the load into the skip of mixer.

M4.02.13: Test Specimens

A. Samples of concrete shall be obtained in accordance with AASHTO R 60. Slump, air content and temperature shall be measured and recorded when concrete cylinders are fabricated.
B. For the purpose of determining the flexural or compressive strength of concrete, the Engineer reserves the right to cast test beams or cylinders as they deem necessary.

   The Contractor shall furnish concrete and such assistance as the Engineer may require.

   After the fabrication of concrete cylinders by the Engineer, the concrete cylinders shall be protected and cured on the project by the Contractor in accordance with AASHTO T 23 and as directed by the Engineer without additional compensation. The Contractor shall furnish and maintain, without extra compensation, a protected environment to provide initial curing of all concrete cylinders at the project. The protective environment shall be available

at each site where concrete is placed and then maintained by the Contractor until such time that all concrete cylinders have been transported to the laboratory for testing. The Engineer shall approve each protective environment prior to the beginning of any project concrete placement.

The protective environment shall be shielded from direct sunlight and radiant heating devices. The protective environment shall be capable of maintaining the temperature for the stored concrete cylinders in the range between 60°F and 80°F and loss of moisture from the cylinders shall be prevented.

When moving the concrete cylinders into the protective environment, precautions shall be taken to avoid any damage to the freshly made concrete cylinders. If the top surface is marred during movement to the protective environment, refinish immediately.

The protective environment for the concrete cylinders shall consist of tightly constructed, firmly braced wooden boxes, damp sandpits, temporary building at construction sites, wet burlap covered in plastic in favorable weather, or heavyweight closed plastic bags. Other suitable methods may be used, upon approval by the Engineer, provided that the foregoing requirements limiting concrete cylinder temperature and moisture loss are met.

Storage temperature shall be regulated by means of ventilation, or thermostatically controlled cooling devices, or by using heating devices such as stoves, light bulbs, or thermostatically controlled heating elements. A temperature record of the concrete cylinders shall be established by means of maximum-minimum thermometers.

After finishing the concrete cylinders, they shall be covered and placed immediately into the protective environment where they will remain undisturbed for the initial curing period.

Concrete cylinders that are to be transported to the laboratory for standard curing before 48 hours shall remain in the molds in a moist environment until they are received in the laboratory, demolded and placed in standard curing. Concrete cylinders that will be transported to the laboratory for standard curing after 48 hours age may be cured in the protective environment provided that the loss of moisture is prevented until the time of transportation and testing. Concrete cylinders shall be demolded no later than 48 hours.

28-day and 56-day concrete cylinders shall be transported to the laboratory for standard curing and testing by the Department personnel within six days of the time of cylinder fabrication. 7-day cylinders shall be transported to the laboratory as soon as possible but not until at least 8 hours after final set (Setting Time may be measured by AASHTO T 197M/T 197).

When the sequence of the construction operation is dependent upon the development of strength in concrete previously placed the specimens taken for this purpose shall be further cured after 24 hours as required in Section 9 of AASHTO T 23 by the Contractor, without additional compensation, under the direction of the Engineer.

C. Consistency tests shall be made when designated by the Engineer. Determination of air content shall be made as designated by the Engineer if air-entraining cement or an air-entraining admixture is used. If the measured consistency or air-content falls outside the

limits specified, a check test shall be made. In the event of a second failure, the Engineer may refuse to permit the use of the load of concrete represented.

D. Methods of testing ready-mixed concrete shall be in accordance with the following AASHTO methods:
    1. Sampling Fresh Concrete (AASHTO T 141).
    2. Weight Per Cubic Foot, Yield and Air Content (Gravimetric) of Concrete (AASHTO T 121M/T 121).
    3. Flexural Strength of Concrete (Using Simple Beam with Third Point Loading) (AASHTO T 97).
    4. Compressive Strength of Molded Concrete Cylinders (AASHTO T 22).
    5. Making and Curing Concrete Compression and Flexure Test Specimens in the Field (AASHTO T 23).
    6. Slump Test for Portland Cement Concrete (AASHTO T 119M/T 119).
    7. Air Content of Freshly Mixed Concrete by the Pressure Method (AASHTO T 152).
    8. Air Content of Freshly Mixed Concrete by the Volumetric Method (AASHTO T 196M/T 196).
E. Strength tests will be performed to determine concrete strength compliance for the project. The concrete cylinders must be fabricated in accordance with the sampling schedule as specified in the Materials Manual; the number of concrete cylinders fabricated will depend on the number of ages at which they are to be tested. Test cylinders shall be cured under controlled conditions as described in Article 9.3 of AASHTO T 23 and tested at the age of 28 days and/or other ages as specified. A test is defined as the average strength of two concrete cylinders of the same age, fabricated from a sample taken from a single batch of concrete.
F. Individual strength tests shall not fall below the specified strength (f́c) by more than 500 psi. If the 28-day cylinder breaks fail to meet the specified strength, 56-day cylinder breaks shall be accepted as proof of reasonably close conformity with the specification. If the 56-day cylinder breaks fail to meet the specified strength, the Contractor may request permission to core the concrete to verify its strength. Coring may only be done with the permission of the Department, at locations chosen by the Department and within 2 weeks of being notified that the 56-day cylinder breaks have failed. The Department shall specify a minimum of 3 core locations. Core results shall be evaluated in accordance with ACI procedures whereby the average of all core breaks must exceed 85% of the specified design strength and no single core break may be less than 75% of the specified design strength. The Contractor may request permission to core the concrete immediately after the failure of 28-day cylinder breaks, rather than waiting for 56-day cylinder tests, if waiting for later tests will compromise the project's schedule. All concrete represented by the compression test that indicates a compressive strength of more than 500 psi below the specified 28-day strength will be rejected and shall be removed and replaced with acceptable concrete. However, the Contractor may, at their own expense, obtain and submit evidence as outlined below, acceptable to the Engineer, that the strength and quality of the concrete placed in the work is acceptable, then the concrete will be permitted to remain in place and the contractor will be paid at a reduced price as outlined below.
G. If three consecutive standard concrete cylinders tests (AASHTO T 22) taken on the jobs from the same plant for the same mix design of concrete fail to meet the strength requirement, the plant shall submit remedial actions for all future production until the

source of the problem can be identified and corrected, or new trial batches can be performed. When the average of three consecutive tests, falls to less than 150 psi above the specified strength or any single test falls more than 200 psi below the specified strength, the plant shall make corrective changes in the materials, mix proportions or in the concrete manufacturing procedures before placing additional concrete of the same mix design. Such changes shall be subjected to the approval of the Engineer prior to use.

H. Evaluation and Acceptance of Concrete. The strength of the concrete will be considered satisfactory provided that the average of all sets of three consecutive test results of the same concrete mix equal to or exceed the required specified strength fć, and no individual test result falls below the specified strength fć by more than 500 psi.

Non-destructive testing will not be permitted in lieu of compressive strength tests of concrete cylinders, air content tests by the pressure method, slump or other test for evaluation and acceptance on concrete placed on the projects. Coring is the only acceptance method to determine the in-situ characteristics of concrete. The size of the core shall be 4-in. finished diameter for concrete with ¾-in. or less aggregate and 6-in. finished diameter for concrete with aggregate greater than ¾ in. The length of the concrete core, when capped, shall be as nearly as practicable twice its diameter and a strength correction factor in accordance with AASHTO T 24 must be determined based on the ratio of Length to Diameter (L/D). Cores with L/D ratio less than 1 shall not be tested. Wipe off the surface of the drilled cores and allow the remaining surface moisture to evaporate. When the surfaces appear dry but not more than an hour after drilling, place cores in separate plastic bags or non-absorbent containers and seal to prevent moisture loss. Allow the cores to remain in the sealed plastic bags or non-absorbent containers for at least 5 days after last being wetted before making the compression test.

A request for strength analysis by coring shall be approved by the Engineer prior to beginning the work. Coring will not be permitted if the Department determines it would be harmful to the integrity of the structure, Cores shall be obtained by the Contractor and witnessed by the Engineer in accordance with AASHTO T 24M/T 24 and delivered to RMS for testing in accordance with AASHTO T 22. The test results will be considered proof of in-situ concrete strength and will supersede all other strength data for the concrete represented by that placement. Cores shall be obtained no later than two weeks after the 56 day cylinder breaks have failed. All reinforcing steel shall be located with a pachometer around the proposed coring locations prior to the coring operation. The Department shall approve the location to be cored. And all cost associated with the coring operation including the repair of cored area shall be the responsibility of the contractor. The Contractor shall patch the core holes with low slump mortar, similar to that used in the concrete, immediately after coring, to the satisfaction of the Engineer. Acceptance by core method requires that the average compressive strength of three cores from the same concrete placement exceeds 85 percent of the specified design strength with no single core less than 75% of the specified design strength.

These cores may be subjected to petrographic analysis, if deemed necessary by the Engineer and at the expense of the Contractor, to determine if there is microscopy evidence that identifies the constituents of concrete, possible reasons for the strength deficiency of the in-situ concrete, if any, and to provide a basis for assessing the quality and long term durability of the in-situ concrete. The results of the petrographic analysis will be considered in conjunction with the results of concrete cylinders to determine if the concrete can remain in place or has to be removed.

Concrete that meets the strength requirements through the 28-day, the 56-day break or the core break shall be considered in reasonably close conformance with the specifications and no credit shall be taken.

Concrete with cylinder or core compressive strength (fc) which fails to meet acceptance level requirements shall be evaluated for structural adequacy at the Contractors' expense. The Department shall review all production records, the concrete test records, petrographic analysis report, field notes, and the placement records for the concrete in question. If the Engineer determines the material is found to be adequate to remain in place, payment shall be adjusted in accordance with the following formula:

$$P = \frac{2(fc - f\acute{c})(UP)(Q)}{f\acute{c}}$$

Where: $P = pay\ adjustment\ for\ substandard\ concrete$
$f\acute{c} = specified\ minimum\ compressive\ strength\ at\ 28\ days$
$fc = substandard\ concrete\ cylinder\ compressive\ strength\ at\ 28\ days$
$or\ compressive\ strength\ of\ concrete\ cores\ determined\ by\ AASHTO\ T\ 22$
$Q = quantity\ of\ concrete\ represented\ by\ the\ acceptance\ cylinders\ tested$
$UP = unit\ contract\ price\ or\ the\ lump\ sum\ breakdown\ price\ per\ cubic\ yard$
$for\ the\ class\ of\ concrete\ involved\ complete\ in\ place$

M4.02.14: Precast Concrete Highway Units

The following Precast Concrete Highway Units shall meet the requirements specified herein:

(a) Standard Temporary Barriers
(b) Standard Permanent Barriers
(c) Box Culverts (Spans ≤ 10 ft)
(d) Catch Basins
(e) Drainage Pipes (Non-Dry Cast)
(f) Manholes
(g) Retaining Wall Systems
(h) Traffic Light Pole Bases
(i) Luminaire Bases

A. Materials.

Materials shall meet the requirements specified in Section M4: Cement and Cement Concrete Materials, the following Subsections of Division III, Materials, and specified herein:

1. Cement Concrete Mix Design Formulation.

Fabricators shall report proposed mix design formulations onto the Department issued mix design sheet in its entirety and submit to the Department for evaluation. Mix design formulations shall be designed with precise proportions of constituent materials, yielding 27.0 ft^3 (1 cubic yard) of cement concrete. All required mix design targets shall be reported on the Department issued mix design sheet for each proposed mix design.

Cement concrete mix designs shall be classified and reported according to the specified compressive strength of the concrete structure (f'_c), nominal maximum aggregate size (NMAS), and mix type. The specified compressive strength of the concrete structure (f'_c) shall be identified from the construction standard specifications, contract document special provisions, and design plans. Nominal maximum aggregate size (NMAS) shall be determined from the combined aggregate system of the proposed mix design formulation and is defined as the sieve size immediately above the first sieve size that cumulatively retains more than 10% by mass.

Proposed mix design formulations will be evaluated for quality and conformance to the requirements specified herein.

a. High Performance Cement Concrete for Precast Concrete Barrier.

Precast concrete barrier shall be fabricated with cement concrete meeting M4.06.1: High Performance Concrete.

b. Self-Consolidating Concrete.

Precast concrete highway units fabricated with self-consolidating concrete shall meet M4.02.17: Self-Consolidating Concrete for Precast Concrete Products.

2. Cement Concrete Mix Design Verification Testing.

Upon Department Acceptance of the mix design evaluation, Fabricators proposing new mix design formulations shall select an AASHTO accredited independent laboratory to conduct mix design verification testing. The sampling and testing conducted by the independent laboratory shall be witnessed by the Department. Fabricators shall report the source, type, quantity, and design target for each constituent material incorporated into the proposed mix design onto batch tickets meeting AASHTO M 157. Fabricators shall provide Batch tickets to the Department for review. Mix design verification test results shall be within the limits specified in Table M4.02.14-1. Proposed mix design formulations for high performance concrete shall meet the additional requirements specified in M4.06.1: High Performance Concrete and self-consolidating concrete shall meet the additional requirements specified in M4.02.17: Self-Consolidating Concrete for Precast Concrete Products.

Table M4.02.14-1: Mix Design Verification Testing Requirements

Property	Method	Quality Characteristic		Limits	
				Min.	**Max.**
Uniformity	T 119[1]	Slump (in.)	< 4 in.	Target -1.0	Target +1.0
			4 – 8 in.	Target -1.5	Target +1.5
	T 121[1]	Unit Weight (lb/ft^3)		For Information	
Workability	T 119[2]	Segregation Resistance		Pass	
Thermal	T 309	Concrete Temperature (°F)		50	90
Strength	T 22[1][3][4]	Compressive Strength (psi)	3 Days	–	–
			7 Days	–	–
			28 Days	f'_c	–
			56 Days	–	–
Durability	T 358[3]	Surface Chloride Ion Penetration Resistance (kΩ-cm)	7 Days	–	–
			28 Days	15	–
	T 121[1] T 152[1] T 196[1]	Freezing, Thawing, and De-Icing Resistance: Air Content (%)		Target -1.0	Target +1.0
	C 1567	Alkali Silica Reaction Resistance: Expansion of Accelerated Mortar Bar (%)	14 Days	M4.02.00	

[1] Prior to mix design verification testing, the Cement Concrete Producer shall identify and report the proposed mix design targets onto the Department issued cement concrete mix design sheet. Any adjustments made to the proposed mix design targets shall be based on the verification test results, and are subject to Department approval and the requirements specified herein.
[2] Testing for segregation resistance shall be performed while the concrete is being discharged and during AASHTO T 119 Standard Method of Test for Slump of Hydraulic Cement Concrete. Visual signs of segregation include coarse particles advancing in front of or behind the fine particles and mortar and a tendency for coarse aggregate to separate from the mortar, particularly when the mixture is being consolidated.
[3] Three (3) 4 x 8 in. cylinders shall be cast for each set specified for maximum aggregate size less than 1-½ inches. Two (2) 6 x 12 in. cylinders shall be cast for each set specified for maximum aggregate size greater than 1 inch.

3. Reinforcement for Precast Concrete Barrier.

Reinforcement for precast concrete barrier shall meet M8.01.7: Epoxy Coated Reinforcing Bars or M8.01.8: Galvanized Reinforcing Bars, and Grade 60 of the AASHTO M 31. The 1-in. plain dowel bars shall conform to ASTM A36 and shall be galvanized according to AASHTO M 111M/M 111.

B. Fabrication Methods.

Precast Concrete Highway Units shall be fabricated by a Department approved precast or prestressed concrete Fabricator, under the controlled settings of the approved Fabricator's facility, with a Department approved mix design formulation, as specified herein. Fabricators and concrete

mix design formulations shall maintain valid listing on the QCML. Precast Concrete Highway Units shall be fabricated in conformance with:

(a) MassDOT Standard Details and Drawings
(b) Approved Shop Drawings
(c) Latest edition of the American Association of State Highway and Transportation Officials (AASHTO) LRFD Bridge Construction Specifications
(d) Latest edition of the National Precast Concrete Association (NPCA) Quality Control Manual for Precast Concrete Plants
(e) Latest edition of the Precast Concrete Institute (PCI) MNL-116 Manual for Quality Control for Plants and Production of Structural Precast Concrete Products
(f) Requirements specified herein

Circular vertical precast reinforced concrete manholes and structures used in sewer, drainage, and water works shall meet AASHTO M 199. Reinforced concrete draingage pipes intended to be used for the conveyance of sewage, industrial wastes, and storm water shall meet AASHTO M 170.

1. Standard Drawings and Details.

Prior to fabrication of precast concrete highway units, the Fabricator shall prepare shop drawings in accordance with:

(a) MassDOT Construction Standard Details
(b) Traffic Standard Drawings for Traffic Signals and highway Lighting
(c) Signal Structure and Foundation Standard Drawings
(d) Standard Drawings for Signs and Supports

2. Shop Drawings.

Prior to fabrication of non-standard precast concrete highway units, the Fabricator shall prepare shop drawings in accordance with the relevant provisions of 5.02: Plans and Detail Drawings and shall, at a minimum, contain the following, where applicable:

(a) Fabricator’s name and address on each sheet
(b) Category and Type of Product, Unit Identification Number
(c) Overall length, width, and height
(d) Location, size, and geometry of all steel reinforcement, including mechanical reinforcing bar splicers to be used for connecting products together in the field (if called for on plans).
(e) Location and details of all inserts, anchors, vertical adjustment assemblies, and any other items required to be cast into the product (whether detailed on the plans by the Engineer of Record or provided for the Contractor's convenience).
(f) Locations and details of the lifting devices, including supporting calculations, type and amount of any additional reinforcing required for lifting. The Fabricator shall design all lifting devices based on the no cracking criteria in the latest edition of the PCI Design Handbook.
(g) The minimum concrete compressive strength required prior to handling the product.
(h) Specified concrete design compressive strength (f'_c), Nominal Maximum Aggregate Size (NMAS), and Mix Type.

Proposed shop drawings shall be drawn to scale and submitted to the Engineer of Record for review and approval. The shop drawings shall not include procedures for placement, finishing, and curing of concrete. These details shall be included in the Fabricator's Quality Control Plan as specified herein.

3. Control, Handling, and Storage of Constituent Materials

Fabricators shall verify the conformance of the constituent materials to specifications from Quality Control testing and Manufacturer certificates of compliance and meet the control, handling, and storage of constituent materials requirements specified herein.

a. Hydraulic Cement and Supplementary Cementitious Materials.

Hydraulic cement and supplementary cementitious materials shall be sufficiently controlled, handled, and stored through prevention of moisture absorption, cement caking, and contamination. Hydraulic cement and supplementary cementitious materials shall be stored in weathertight, sufficiently ventilated structures to prevent absorption of moisture. The interior of a cement silo shall be smooth, with a minimum bottom slope of 50 degrees from the horizontal for a circular silo and 55 to 60 degrees for a rectangular silo. Silos shall be equipped with non-clogging air-diffuser flow pads through which small quantities of dry, oil-free, low-pressure air can be introduced intermittently at approximately 3 to 5 psi to loosen cement that has settled tightly in the silos. Storage silos shall be drawn down once per month to prevent cement caking. Each bin compartment from which cement is batched shall include a separate gate, screw conveyor, air slide, rotary feeder, or other conveyance that allows both constant flow and precise cutoff to obtain accurate batching of cement.

Sources of contamination include incorrect sources placed into storage structures and dust contaminants. Storage structures shall be sufficiently labeled to avoid contamination. Contamination shall be sufficiently monitored and controlled during loading and transferring.

b. Aggregate.

Aggregate shall be sufficiently controlled, handled, and stored through prevention of gradation variation due to segregation and undersized particles, moisture content variation, contamination, degradation, and fracture.

(1) Variation in Gradation.

Aggregate gradation shall be sufficiently monitored to maintain control of the mix design. Aggregate shall be stockpiled in thin horizontal layers of uniform thickness to limit segregation. Storing aggregate in large conical stockpiles causes segregation and shall be prohibited. Segregation is limited when the coarse aggregate is further divided into several different sized sub-groupings with smaller ranges to be batched separately. Segregation in the coarse aggregate is controlled when the maximum aggregate size to the minimum aggregate size for a given aggregate size grouping is limited to a 4 to 1 ratio for maximum aggregate size less than 1 in. and is limited to a 2 to 1 ratio for maximum aggregate size greater than or equal to 1 in.

Undersized particles for a given coarse aggregate size grouping is defined as material passing the sieve size with an opening ⅝ of the nominal minimum size of the coarse aggregate size grouping. Coarse aggregate shall be rescreened as it is charged to the bins to remove undersized particles and

undesirable fines if handling and storage methods are unsatisfactory and variations in gradation exceed allowable tolerances.

Storage bins (hoppers) shall be circular or nearly square and their bottoms shall slope more than 50 degrees from the horizontal on all sides to a center outlet. During bin loading, the aggregate shall be discharged directly above and fall vertically into the center of the bin. Discharging aggregate against the side of the bin or baffle wall causes segregation and shall be prohibited. Baffle plates or dividers can minimize segregation. Bins shall be filled to limit variation in gradation caused by withdrawal of material, segregation, and breakage of aggregate particles. Dry fine aggregate when dropped from buckets or conveyors shall be sufficiently shielded from wind and other external forces to prevent loss of fines. Fine aggregate may require dampening to prevent segregation of material.

(2) Variation in Moisture Content.

Aggregate moisture content shall be sufficiently monitored to maintain control of the mix design. Coarse aggregate shall be wetted to keep the aggregate in a constantly saturated condition, to compensate for aggregate absorption, and to provide cooling. Aggregate shall be sufficiently dewatered and drained to form a uniform moisture content and to prevent transfer of excessive free water to the bins. Fine aggregate, due to its surface area, contributes the largest amount of free water added to the mix design. Moisture meters can indicate variations in the moisture of aggregate and moisture compensators can be used for rapid batch weight adjustments, to limit moisture variations in the aggregate. Aggregates washed to remove contaminants shall be stockpiled well before use so that they can drain to a uniform moisture content.

(3) Contamination.

Sources of contamination include overlapping of different aggregate sizes from adjacent stockpiles, aggregate leakage through or around bulkheads in storage bins, underlying soil, dislodged clay lumps and other contaminants from transporting unit, leaves and vegetation, freezing aggregate, incorrect delivery from aggregate manufacturer, and incorrect aggregate size placed into a bin or stockpile. Stockpiles shall be placed on a hard base with sufficient drainage to prevent contamination from underlying material. Bulkheads, dividers, and partitions with sufficient height and ample spacing between piles shall be utilized to avoid cross-contamination and overlapping of different aggregate sources, types, and size groupings between stockpiles. Storage areas shall be sufficiently labeled to avoid contamination. Clay lumps or clay balls shall be removed from the aggregate by placing a scalping screen over the batch plant bin. Aggregate may require washing to remove contaminants. During cold temperatures, bins shall be covered or underground to prevent the freezing of aggregate. Frozen aggregate shall be prohibited from use. Aggregates may require heating to maintain an acceptable aggregate temperature and prevent freezing. Trucks, loaders, dozers, and other heavy transport equipment shall not be operated on the stockpiles due to the potential for aggregate particle fracture and contamination of track dirt onto the piles. Additional measures, including storage area coverings, shall be instituted in cases where storage areas are subject to other sources of contamination.

c. Mixing Water.

Mixing water shall be sufficiently controlled, handled, and stored through prevention of contamination.

d. Chemical Admixtures.

Chemical admixtures shall be sufficiently controlled, handled, and stored through prevention of contamination. Sources of contamination include freezing, evaporation, sunlight, and incorrect chemical admixture sources placed into chemical admixture tanks. Chemical admixtures shall be stored in heated environments to prevent freezing. Frozen chemical admixtures shall be reblended. Long-term storage of liquid admixtures in vented tanks shall be prohibited due to evaporation of the liquid negatively affecting the performance of the mix design. Certain chemical admixtures are prone to sunlight and shall be sufficiently protected in the storage tanks. Storage tanks shall be sufficiently labeled to avoid contamination. Chemical admixtures shall be stored in accordance with the chemical admixture manufacturer's recommendations.

4. Temperature Control.

Concrete shall be batched, mixed, delivered, placed, finished, and cured with ambient temperatures greater than or equal to 40°F and less than or equal to 85°F. The temperature of plastic concrete shall be greater than or equal to 50°F and less than or equal to 90°F. At no point shall the temperature of the concrete exceed 158°F.

Temperature measuring devices shall record and report to the nearest 1°F. The Fabricator shall continuously monitor, record, and report the ambient temperatures surrounding the concrete without interruption, at a minimum frequency of once per hour, until 100% of f'c is attained. The Fabricator shall confirm all temperature requirements meet the specifications herein. Fabricator temperature monitoring records shall be provided to the Department upon request.

5. Protection from Adverse Conditions.

The concrete shall be protected from all adverse conditions, including precipitation, cold conditions, and hot conditions, until 100% of f'_c is attained, as specified 901.64: Protection from Adverse Weather.

6. Batching and Mixing.

Equipment, measurement, tolerances, procedures, sequencing, and batch ticketing used for the batching and mixing of cement concrete shall meet the applicable standards of AASHTO M 157, Concrete Plant Manufacturers Bureau (CPMB), Truck Mixer Manufacturers Bureau (TMMB), National Institute of Standards and Technology (NIST), and the requirements specified herein.

Weigh batch equipment shall be categorized as manual, partially automatic, semiautomatic, and fully automatic. Scales and volumetric devices for measuring quantities of constituent materials shall be calibrated for accuracy through certified field standard weights and product substitute loading. Scales shall be accurate to the greater of ±0.15% of the scale capacity or ±0.4% of the applied test load in all quarters of the scale capacity through its range of use. The accuracy of scales and batching equipment shall be inspected routinely and adjusted when necessary. Equipment shall be isolated from plant vibration. Automatic controls shall be protected from dust and weather. Scale and beam pivot points shall be routinely inspected and cleaned. Equipment shall operate within the specified batch-weight tolerances specified in Table M4.02.14-2. Equipment shall be made accessible to the Department for inspection.

Table M4.02.14-2: Allowable Batching Tolerances of Mix Design Target Weights

Specification	Constituent Material	Batch Weights > 30% of Scale Capacity		Batch Weights ≤ 30% of Scale Capacity	
		Individual Batching Tolerances	Cumulative Batching Tolerances	Individual Batching Tolerances	Cumulative Batching Tolerances
M 157	Hydraulic Cement (%)	±1.0 or ±0.3% of scale capacity, whichever is greater		Not less than required weight or 4% more than required weight	
	Hydraulic Cement + Supplementary Cementitious Materials (%)	±1.0 or ±0.3% of scale capacity, whichever is greater		Not less than required weight or 4% more than required weight	
	Aggregate (%)	±2.0	±1.0	±2.0	±3.0 or ±0.3% of scale capacity whichever is less
	Mixing Water (%)	±1.0	Prohibited	±1.0	Prohibited
	Chemical Admixtures (%)	±3.0	Prohibited	±3.0	Prohibited

Cement concrete shall be mixed by stationary mixers, truck mixers, volumetric (continuous) mixers, or portable mixers. Cement concrete shall be mixed thoroughly until the constituent materials are uniformly distributed. Mixers shall be adequately designed with blade or fin arrangements and drum shapes that ensure an end-to-end exchange of materials parallel to the axis of rotation or a rolling, folding, and spreading movement of the batch over itself as it is being mixed. Mixing blades shall be free of wear and hardened concrete.

Modifications to Department approved mix design formulations, including source of constituent materials, design quantities, mix type, combined aggregate system targets, paste system targets, slump targets, air content targets, and compressive strength targets shall be prohibited. However, if slump or air content test results are not within the specified design target ranges, the Fabricator is permitted to submit to the Department a request to review and approve proposed adjustments of chemical admixture dosages. At no point shall the total water or water-cementitious (w/cm) ratio exceed the approved mix design formulation targets. The Producer shall report the adjustments onto the batch ticket. Chemical admixture adjustments without Department approval shall be prohibited. Department approval is subject to performance at the plant, as well as conformance to the requirements specified herein.

7. Formwork.

Precast Concrete Highway Units shall meet 901.61: Forms, Falsework, and Centering and PCI Manual 116-21, Section 2.4 Forms/Molds. Precast concrete barrier shall be cast with the forms in a 180° inverted position and compacted with an approved vibrator.

8. Reinforcement.

Precast Concrete Highway Units shall meet 901.62: Reinforcement and the reinforcement materials requirements specified herein.

9. Handling and Placing of Concrete.

Precast Concrete Highway Units shall meet 901.63: Handling and Placing Concrete.

10. Finishing.

As-cast formed surface finishes shall be acceptable in appearance, color, and texture. Exposed unformed surface finishes shall be finished by screeding or floating, unless otherwise noted. Under no circumstances shall bleed water or initial curing materials be worked into the surface. The addition of water, spreading of cement, or the use of unacceptable tools, including steel trowels and fresnos to the surface of the concrete shall be prohibited. The concrete shall not be overworked, to prevent premature degradation from excess water and fine material rising to surface. Defects shall be addressed per M4.02.14: Precast Concrete Highway Units, B.15: Repairs and Replacement.

11. Final Curing.

Final curing materials, methods, and procedures shall be applied to all exposed cement concrete surfaces immediately after the completion of finishing operations and final set to prevent the loss of moisture and surface drying. Exposed surfaces from form removal shall be wetted immediately and kept moist until final curing materials are applied.

Final curing materials applied to the concrete shall allow the concrete to mature sufficiently to achieve its designed and desired properties, including strength, volume stability, permeability, durability, and resistance to freezing, thawing, and de-icing cycles. Curing water shall be free of deleterious impurities, causing staining and deterioration. The potential staining ability of curing water shall be evaluated by means of US Army Corps of Engineers CRD-C401 Method of Test For The Staining Properties of Water for instances where curing water quality is questioned.

The Fabricator shall maintain a continuous application of moisture or moisture retention throughout the entire duration of the final curing method cycle and meet the minimum sustained ambient temperature, concrete temperature, duration, and strength requirements as specified herein. Controlled, gradual, and uniform termination of the final curing method cycle shall begin only after all specified conditions are met. The concrete temperature shall be reduced at a rate not to exceed 36°F per hour until the concrete temperature is within 20°F of the ambient temperature.

Termination of final curing methods shall not occur until both the duration and compressive strength requirements are met, as specified in Table M4.02.14-2.

Table M4.02.14-3: Termination of Final Curing Method

Product Categories	Methods	Duration	Compressive Strength
Precast Concrete Highway Products (Excluding Barrier)	Form Cure[1]	–	≥ 70% of f'_c
Precast Concrete Barrier	Liquid Membrane-Forming Compounds[2] Saturated Covers Sheet Materials	≥ 3 Days	≥ 80% of f'_c
	Curing Water Nozzles	≥ 5 Days	

[1] Final curing materials, methods, and procedures shall be applied to all exposed surfaces not being cured by the form.
[2] If the liquid membrane-forming compound is to be removed due to compatibility or bonding concerns, removal shall not take place until the specified application duration is met.

Concrete cured by way of curing water nozzles, saturated covers, sheet materials, or liquid membrane-forming compounds shall be cured with sustained ambient temperatures greater than or equal to 40°F and less than or equal to 85°F.

Curing water shall not exceed a temperature differential of more than 20°F from the internal concrete temperature, to prevent cracking due to temperature gradients causing strain that exceeds the strain capacity of concrete. Curing water shall remain above freezing temperatures throughout the duration of the curing cycle. Compressive strength cylinders for termination of curing cycle shall be cast and field cured with the same environmental conditions that the concrete is subjected to throughout the entire duration of the curing cycle.

All procedures, operations, materials, and equipment required for adequate curing shall be present and ready for use prior to concrete production.

a. Curing Water Nozzles.

Curing water nozzles shall provide the surface of cement concrete with a continuous fine spray of water.

b. Saturated Covers.

Saturated covers shall meet AASHTO M 182, Class 3. Saturated covers shall be in good condition, free from holes, tears, or other defects that would render it unsuitable for curing cement concrete. Saturated covers shall be dried to prevent mildew when storing. Saturated covers shall be of sufficient thickness to maximize moisture retention. Saturated covers shall be free of harmful substances that are deleterious or cause discoloration to cement concrete and cementitious materials. Saturated covers shall have the ability to retain sufficient moisture from continuous watering so that a film of water remains on the surface of cement concrete.

Prior to application, saturated covers shall be thoroughly rinsed in water and free of harmful substances that are deleterious or cause discoloration to cement concrete. The Fabricator shall maintain sufficient moisture with continuous watering so that a film of water remains on the surface of the cement concrete throughout the entire duration of the final curing method cycle. Saturated covers shall be properly positioned, secured, and maintained on the surface of the

concrete to maximize moisture retention and to prevent moisture loss. The Fabricator shall prohibit saturated covers from drying out and prevent the absorption of curing water from the surface of the concrete. Polyethylene film may be applied over the saturated cover to limit the amount of continuous watering required for sufficient moisture retainage.

c. Sheet Materials.

Sheet materials shall meet ASTM C171. Sheet materials shall inhibit moisture loss and reduce temperature rise in concrete exposed to radiation from the sun. Adjoining sheet materials shall overlap not less than 12 in. All edges of the sheet materials shall be secured to maintain a moist environment.

(1) Polyethylene Film.

Polyethylene film shall be clear, white, or black in color and consist of a single sheet manufactured from polyethylene resins, be free of visible defects, including tears, wrinkles, and discontinuity. The film shall prohibit mottling and uneven spots from appearing on the surface of concrete, due to variations in temperature, moisture content, or both. Polyethylene film shall accommodate concrete surfaces with constant contact without damage. White polyethylene film shall minimize heat gain caused by absorption of solar radiation. Clear and black polyethylene films shall inhibit absorption of solar radiation and be exclusively applied during cold conditions.

The Fabricator shall prohibit mottling and uneven spots from appearing on the surface of concrete, due to variations in temperature, moisture content, or both. Application of additional curing water under the film or application of a polyethylene film bonded to absorbent fabric to the concrete surface may be required to prevent mottling and to retain and evenly distribute the moisture. The Polyethylene film shall be applied to concrete surfaces with constant contact without damage. The film shall extend beyond the edges of the concrete surface. Edges of adjacent polyethylene film shall overlap a minimum of 6 in. and be tightly sealed with the use of sand, wood planks, pressure-sensitive tape, mastic, or glue to maintain close contact with the concrete surface, retain moisture, and prevent the formation of air pockets.

(2) White Burlap-Polyethylene Sheeting.

White burlap-polyethylene sheeting shall be securely bonded to the burlap so to avoid separation of the materials during handling and curing of the concrete.

(3) Reinforced Impervious Paper.

Reinforced impervious paper shall be white in color, consist of two sheets of kraft paper cemented together with a bituminous adhesive, and reinforced with embedded cords or strands of fiber running in both directions. Reinforced impervious paper shall be free of holes, tears, and pin holes from deterioration of the paper through repeated use. Reinforced impervious paper shall be treated to prevent tearing when wetted and dried. Reuse of reinforced impervious paper shall be permitted so long as it is able to retain moisture on the surface of concrete. The paper shall be discarded and prohibited from use when moisture is no longer retained in the material.

d. Liquid Membrane-Forming Compounds.

Liquid membrane-forming compounds, including compounds with curing properties and compounds with both curing and sealing properties, shall maintain valid listing on the QCML and meet the requirements specified herein.

Compounds shall form a continuous, non-yellowing, and durable film with quality moisture-retention properties. Compounds shall maintain the relative humidity of the concrete surface above 80% for greater than or equal to 3 days to sustain cement hydration. Compounds shall not affect the original color of the concrete surface. Compounds shall not degrade due to exposure to ultraviolet light from direct sunlight. Compounds shall meet the local and federal allowable Volatile Organic Compound (VOC) content limits.

Liquid membrane-forming compounds shall be applied per the Manufacturer's instructions and recommendations as specified herein. Prior to use, compounds shall be thoroughly mixed, stirred, and agitated. Compounds shall be applied immediately after final finishing and the disappearance of the surface water sheen, but before the free water on the surface has evaporated, to prevent the formation of cracks and loss of moisture at the surface. Careful considerations shall be made by the Fabricator to determine if the evaporation rate is exceeding the rate of bleeding, thus causing the surface to appear dry even though bleeding is still occurring. To diagnose and prevent this condition, the Fabricator shall place a transparent plastic sheet over a test area of the uncured and unfinished concrete surface and shall determine if any bleed water accumulates under the plastic. Under such conditions, the application of liquid membrane-forming compounds to the concrete surface shall be delayed to prevent bleed water from being sealed below the concrete surface, map cracking of the membrane films, reduction in moisture-retention capability, and the need for reapplication of the compound.

When using compounds to reduce moisture loss from formed surfaces, the exposed surface shall be wetted immediately after form removal and kept moist until the compound is applied. The concrete shall be allowed to reach a uniformly damp appearance with no free water on the surface, and then application of the compound shall begin at once. Delayed application resulting in surface drying, absorption of the compound into the concrete, and forming of a discontinuous membrane shall be prohibited.

The concrete surface shall be damp when the compound is applied. Power-driven spray equipment shall be used for uniform application of compounds on large paving projects. Spray nozzles recommended by the compound Manufacturer and use of windshields shall be arranged by the Fabricator to prevent wind-blown loss of compound and to ensure proper coverage application rates are achieved. The compound shall be applied by power sprayer, using appropriate wands and nozzles with pressures between 25 and 100 psi. The Fabricator shall fill the power sprayer with curing compound from the Manufacturer's original container in the presence of the Engineer. Any dilution as recommended by the Manufacturer shall take place in the presence of the Engineer. For very small areas such as repairs, the compound shall be applied with a wide, soft-bristled brush or paint roller.

The Fabricator shall verify the application rate and procedures are in accordance with the Manufacturer's instructions and recommendations. At least one uniform coat shall be applied at a rate of 150 to 200 ft^2/gallon. On very deeply textured surfaces, the surface area to be treated shall be at least twice the surface area of the surface. In such cases, two separate applications may be

needed, each at 200 ft^2/gallon or greater if specified by the Manufacturer to achieve the desired moisture retention rate, with the first being allowed to become tacky before the second is applied. If two coats are necessary to ensure complete coverage, for effective protection the second coat should be applied at right angles to the first. Complete coverage of the surface shall be attained due to the potential for formation of small pinholes in the membrane, which will result in loss of moisture from the concrete. Compounds shall not sag, run off peaks, or collect in grooves.

Compounds and procedures shall be compatible with concrete surfaces receiving subsequent applications or placements of concrete, overlays, coatings, paints, sealers, finishes or other toppings to ensure acceptable bonding to the concrete. Testing to establish compatibility among the curing compound, subsequent surface treatments, concrete moisture content and the actual finished surface texture of the concrete shall be conducted when compatibility is not known. The compound Manufacturer shall be consulted by the Fabricator to determine the compatibility of the application. Compounds shall not be applied to concrete surfaces where bonding of subsequent applications or placements is incompatible or is of concern. The use of wax-based curing compounds shall be prohibited in instances where concrete surfaces are subject to additional toppings and vehicular, pedestrian, or other traffic.

Deliberate removal of compounds in the presence of the Engineer and in accordance with Manufacturer's instructions and recommendations shall be conducted as an alternative to compatibility testing, incompatibility, or in instances where bonding is of concern. Bonding of subsequent materials may still be inhibited by the presence of the compound even after the moisture retention characteristics of the compound have diminished.

White-pigmented compounds shall be used in instances where solar-heat gain is concern to the concrete surface. White-pigmented compounds shall be agitated in the container prior to application to prevent pigment from settling out resulting in non-uniform overage and ineffective curing.

(1) Liquid Membrane-Forming Compounds for Curing.

Liquid membrane-forming compounds for curing shall meet ASTM C309 and the requirements specified herein.

Table M4.02.14-4: Types

Type	Description
Type 1	Clear or translucent without dye
Type 1-D	Clear or translucent with fugitive dye
Type 2	White pigmented

Table M4.02.14-5: Composition Classification

Type	Description
Class A	Unrestricted composition, generally wax-based products
Class B	ASTM D883 resin-based products

(2) Liquid Membrane-Forming Compounds for Curing and Sealing.

Liquid membrane-forming compounds for curing and sealing shall meet ASTM and the requirements specified herein. The protective sealing requirements specified in M4.02.14: Precast Concrete Highway Units, B.16 do not apply to cement concrete surfaces previously applied with liquid membrane-forming compounds for curing and sealing.

In addition to moisture-retention capabilities compounds shall exhibit specific properties, including alkali resistance, acid resistance, adhesion-promoting quality, and resistance to degradation by ultraviolet light.

Table M4.02.14-6: Types

Type	Description
Type I	Clear or translucent
Type II	White pigmented

Table M4.02.14-7: Classification

Type	Description
Class A	Non-yellowing

12. Form Removal.

The Fabricator shall not remove forms from the concrete until compressive strength cylinders attain 70% of f'_c. Compressive strength cylinders for removal of forms shall be cast and field cured with the same environmental conditions that the concrete is subjected to throughout the entire duration of the operation. Immediately following form removal, all exposed concrete surfaces shall be prepared and cured per the requirements specified in.

13. Handling and Storage of Concrete Products.

Precast Concrete Highway Units shall not be handled until form removal strength has been attained. Concrete products shall be lifted at the designated points by approved lifting devices embedded in the concrete and in accordance with proper lifting and handling procedures. Storage areas shall be smooth and well compacted to prevent damage due to differential settlement. Concrete products shall be supported on the ground by means of continuous blocking, in conformance with the approved dunnage plan. The concrete shall be protected from all adverse conditions, including precipitation, cold conditions, and hot conditions, until 100% of f'_c is attained, as specified 901.64: Protection from Adverse Weather.

14. Primer and Damp-Proofing of Precast Concrete Drainage Structures.

The Fabricator shall apply primer and damp-proofing materials, methods, and procedures to the outside surface of the tapered or cone section of precast concrete drainage structures. Precast concrete drainage structures shall be damp-proofed in accordance with 970: Damp-Proofing.

15. Repairs and Replacement.

Defects identified during inspection shall be classified in the following categories and a non-conformance report (NCR) shall be initiated if required. The NCR shall be submitted to the

Department for review and approval of the Fabricator's proposed NCR disposition. Defects shall be repaired per the approved NCR disposition, with approved materials listed on the QCML, according to the PCI Northeast Region Guidelines for Resolution of Non-Conformances in Precast Concrete Bridge Elements, Report Number PCINE-18-RNPCBE, at the expense of the Contractor. Defects requiring Non-Conformance Report (NCR) submission shall be repaired in the presence of Department personnel. All defects regardless of category shall be documented by Quality Control personnel and made available to the Department upon request.

a. Category 1 Surface Defects.

Category 1 defects do not require repair or Non-Conformance Report (NCR) submission. However, documentation of the identified defects is required by the Fabricator. Surface defects are defined as the following:

(a) Surface voids or bug holes that are less than 0.625 in. in diameter and less than 0.250 in. in depth, except when classified as Category 3
(b) Cracks less than or equal to 0.006 in. in width

b. Category 2 Minor Defects.

Category 2 defects shall be documented. Repairs shall be documented, however, NCR submission is not required by the Fabricator. Minor defects are defined as the following:

(a) Spalls, honeycombing, surface voids that are less than 2 inches in depth and have no dimension greater than 12 in.
(b) Cracks greater than 0.006 in. and less than or equal to 0.060 in. in width (cracks shall be sealed according to the PCI Repair Procedure #14 in PCINE-18-RNPCBE)
(c) Broken or spalled corners without exposed reinforcing steel

c. Category 3 Rejectable Defects.

Category 3 defects may be cause for rejection, as determined by the Engineer. Category 3 defects shall be documented and reported on the NCR and submitted to the Department. The Fabricator may include proposed repair procedures on the submitted NCR for Department review. However, if the proposed repair procedures are not accepted by the Department, the Precast Concrete Highway Unit shall be rejected. If accepted, proposed repair procedures shall not takeplace prior to Department approval. Rejectable defects are defined as the following, including, but not limited to:

(a) Surface defects on more than 5% of the surface area
(b) Minor defects that in total make up more than 5% of the surface area of the unit
(c) Concentrated area of defects consisting of four or more Category 2 Defects within a 4-square foot area.
(d) Exposed reinforcing steel
(e) Spalls, honeycombing and surface voids that are deeper than 2 in. or have any dimension greater than 12 in., when measured along a straight line
(f) Cracks greater than 0.060 in. in width
(g) Elements fabricated outside of the specified tolerances
(h) Compressive strength that does not meet f'_c

16. Protective Sealing Compounds for Precast Concrete Barrier.

The protective sealing requirements specified herein do not apply to cement concrete surfaces previously applied with liquid membrane-forming compounds for curing and sealing.

Protective sealing compounds meeting M9.15.0: Liquid Penetrant/Sealant shall be applied to precast concrete barrier per the Manufacturer's instructions and recommendations as specified herein. Protective sealing compounds shall not be applied to concrete while conditions meeting 901.64: Protection from Adverse Weather are present.

Curing materials, methods, and procedures shall be applied to the concrete prior to the application of protective sealing compounds. The surface shall be sufficiently prepared, clean, and dry for at least 24 hours with ambient temperatures exceeding 60°F. Protective sealing compounds shall not be applied to the concrete for a minimum of 28 days after the concrete is poured, unless otherwise noted in the manufacturer's instructions and recommendations. Periodic re-application shall be required for protective sealing compounds requiring multiple applications and for concrete surfaces exhibiting wear to ensure long-term protection of the concrete surface.

17. Prior to Loading.

Prior to loading the concrete product onto the truck for shipping, the Fabricator shall provide the MassDOT Plant Inspector and RMS a minimum seven-day notice of the Fabricator's intent to load the concrete product. Inspection by the MassDOT Plant Inspector shall take place while the element is still on dunnage in the yard. The unit shall not be loaded onto the truck until the MassDOT Plant Inspector has performed the inspection.

18. Loading.

Concrete products shall be loaded on a trailer with continuous blocking, in accordance with the approved dunnage plan. Shock-absorbing cushioning material shall be used at all bearing points. Blocking shall be provided at all locations of tie-down straps. Concrete products shall not be subjected to damaging torsional or impact stresses.

19. Shipping.

Prior to shipment, the Fabricator shall perform the following actions and provide the required documentation to the MassDOT Plant Inspector:

(a) Precast Concrete Highway Units shall remain at the Fabricator's plant for a minimum of 7 days after cast date.
(b) QC Inspection Reports shall be signed by the Quality Control Manager and provided to the MassDOT Plant Inspector.
(c) QC Compressive Strength Test Report Forms attaining Design Strength, f'_c for the Precast Concrete Highway Unit's representative Sublot shall be generated by the Fabricator and provided to the MassDOT Plant Inspector.
(d) Certificate of Compliance shall be generated by the Fabricator as described under the Fabricator Quality Control section and provided to the MassDOT Plant Inspector.
(e) All Department approved Corrective Actions submitted on the Non-Conformance Reports (NCR), shall be verified to have been completed by the MassDOT Plant Inspector and Quality Control Manager.

(f) All NCRs shall be signed off by the Quality Control Manager and the Department Inspector and/or MassDOT RMS.
(g) QC Inspection Stamp shall be applied to each unit after loading.

20. Delivery.

Upon Delivery, the following documentation shall be provided to the Engineer:

(a) QC Compressive Strength Test Report Forms attaining Design Strength, f'_c for the Precast Concrete Highway Unit's representative Sublot.
(b) Certificate of Compliance generated by the Fabricator as described under the Fabricator Quality Control section.
(c) QC Inspection Reports signed by the Quality Control Manager.

The Contractor shall inspect the concrete product upon receipt at the site. Concrete products damaged during delivery shall be repaired or replaced per the Department direction, at the Contractor's expense.

C. Quality Assurance.

Quality Assurance is the planned and systematic actions necessary to provide confidence that a product or facility will perform satisfactorily in service. The Quality Assurance Program is comprised of the six core elements including Contractor Quality Control, Department Acceptance, Independent Assurance, Dispute Resolution, Laboratory Accreditation and Qualification, Personnel Qualification and Certification. The Fabricator shall conduct Quality Control (QC) and the Department will conduct Acceptance throughout the fabrication process, independently from one another.

The quality of the material or product shall be determined through quality measurements from sampling, testing, and inspection. The sampling population for quality measurements shall be comprised of lots and sublots. A lot shall be defined as a specific quantity of material from a single source which is assumed to be produced or placed by the same controlled process. Lots shall be used to represent the population of the produced material and constructed product. The lot size shall be the specified quantity of material produced and placed. A sublot shall be defined as a subdivision of a lot. Sublots shall be used to assess the inspection attributes and quality characteristics of the lot. The sublot size shall be the specified subdivision of quantity for a given lot.

The sampling population for testing and inspection shall be randomly sampled in accordance with ASTM D3665. Random sampling is defined as a small quantity of material or measurement obtained from a lot or sublot, whereby each sample obtained from the lot or sublot has an equal probability of being selected. Selective (non-random) sampling may also be conducted to provide supplemental information to assist in maintaining control of all production and placement processes. Selective sampling shall not replace random sampling and shall not be used in the Department Acceptance decision.

1. Fabricator Quality Control.

Quality Control (QC) shall be established, maintained, and performed by the Fabricator to monitor, assess, and adjust manufacturing, production, fabrication, and construction processes, to maintain continuous control of the process, and to ensure that the final material or product will meet the specified level of quality, through:

(a) Implementation of the Department approved Quality System Manual (QSM)
(b) Proper Quality Control organization
(c) Qualified Production Personnel, including equipment operators and craftsmen incorporated into the manufacturing, production, fabrication, and construction operations
(d) Certified Quality Control Technicians and Quality Control Managers
(e) Qualified Quality Control laboratory through the NETTCP Laboratory Qualification Program or accredited through the AASHTO Accreditation Program (AAP)
(f) Routine QC inspection of equipment, environmental conditions, materials, and workmanship
(g) Routine QC sampling and testing of material quality characteristics and properties
(h) Timely analysis of QC results, through statistical analysis (mean, standard deviation, etc), control charts, and conformance to allowable limits
(i) Immediate initiation of non-conformance reporting and corrective action for non-conforming inspection results, uncontrolled processes, and materials with test results not within allowable limits
(j) Retention of QC records
(k) Conformance to specifications

a. Quality Control Operating Documents.

Quality Control operating documents shall be prepared, implemented, and maintained by the Fabricator and submitted to the Department for review and approval prior to the start of fabrication. The Fabricator shall adhere to all policies, practices, procedures, and activities identified in the following Department approved Quality Control operating documents.

(1) Quality System Manual.

The Fabricator shall submit a Quality System Manual (QSM) for Department review and approval. The QSM shall document the overall internal Quality Control operating procedures of the Producer's Quality Control System and meet AASHTO R 18, AASHTO R 38, and the requirements specified by the Department.

(2) Quality Control Plans for Contract Work Items.

When applicable, a Quality Control Plan (QCP) shall be prepared for each contract work item by the Fabricator to document all Quality Control personnel and procedures utilized to maintain control of all production and placement processes. The Quality Control Plan for each contract work item shall meet the NorthEast Transportation Training and Certification Program (NETTCP) Model Quality Control Plan standard format and requirements specified by the Department.

b. Fabricator Plant Certification.

At a minimum, the Fabricator shall maintain an active National Precast Concrete Association (NPCA) Plant Certification or Precast/Prestressed Concrete (PCI) Plant Certification.

c. Quality Control Laboratory.

The Fabricator shall have all required sampling, testing, and inspection equipment on site and available for use during all phases of fabrication. The equipment shall meet all applicable AASHTO

or ASTM standards, maintain required calibration schedules, and be in acceptable working condition.

The Fabricator shall provide a room of sufficient size to house all equipment and to adequately perform all required testing. The room shall include a desk and file cabinet for proper record keeping and have good lighting and ventilation. This room shall be kept for testing and quality control and not used for any other purpose. An additional desk and file cabinet shall be provided for exclusive use of the Engineer.

d. Quality Control Organization.

The Fabricator's Quality Control organization shall be comprised of trained, experienced, and qualified Production Personnel, Quality Control Technicians, and Quality Control Managers at the Fabricator's plant, per NPCA and/or PCI and as specified herein. Production Personnel, Quality Control Technicians, and Quality Control Managers shall maintain continuous communication to ensure conformance to specification requirements and to dictate corrective action for non-conformance.

(1) Production Personnel.

Production Personnel that are directly responsible for the fabrication of Precast Concrete Highway Units shall be comprised of sufficiently trained, qualified, and experienced craftsmen, equipment operators, foremen, and superintendents. Best practices meeting Department recognized standards, organizations, and programs and requirements specified herein shall be performed by Production Personnel throughout the entire fabrication process.

In addition to the fabrication activities, Production Personnel shall perform continuous self-inspection throughout the entire construction operation, to ensure quality workmanship is performed, through observation and verification of:

(a) Proper tools and equipment are utilized to perform the work
(b) Routine maintenance, calibration, and cleaning of tools and equipment is performed
(c) Proper procedures for shipping, handling, and storage of materials are performed
(d) Best practices for workmanship are incorporated throughout the construction operation
(e) Quality appearance of finished material or product

Production Personnel shall be capable of identifying unacceptable materials and products prior to completing the construction operation and shall notify potential non-conformances to the Quality Control Technicians and Quality Control Manager. The Fabricator shall provide continual education, training, and qualification opportunities to Production Personnel to promote quality workmanship practices.

(2) Quality Control Technicians.

Each Quality Control Technician shall be sufficiently trained, qualified, and certified through Department recognized qualification and certification programs or through relevant experience acceptable to the Department.

The Fabricator's Quality Control organization shall include an acceptable number of experienced, trained, and qualified Quality Control Technicians at the Production Facility. The number of Quality Control Technicians shall be determined according to the size of the production operation and the

volume of material or product manufactured, produced, or fabricated for each work item. The principle responsibilities of each Production Facility Quality Control Technician include:

(a) Performing Quality Control sampling, testing, and inspection at the production facility
(b) Preparing and signing standard Quality Control test and inspection report forms
(c) Providing routine feedback based on sampling, testing, and inspection results to the Production Personnel, Production Facility Quality Control Manager, and Prime Contractor Quality Control Manager

At a minimum, Quality Control Technicians shall maintain an active American Concrete Institute (ACI) Concrete Field Testing Technician – Grade I certification and Concrete Strength Testing Technician certification. Quality Control Technicians shall be on site and present during all phases of fabrication.

(3) Quality Control Manager.

The principal responsibilities of each Quality Control Manager shall include:

(a) Establishing the Quality Control system in accordance with the company's Quality System Manual (QSM)
(b) Preparing Quality Control Plans (if applicable)
(c) Managing and monitoring the activities of Quality Control technicians
(d) Communicating routinely with production personnel
(e) Initiating work suspension and corrective action in instances where materials or products are non-conforming or a process is not in control.
(f) Ensuring proper Quality Control documentation and records retention

At a minimum, the Fabricator's Quality Control Manager shall meet the following requirements:

(a) Maintain an active ACI Concrete Field Testing Technician – Grade I Certification
(b) Maintain an active NETTCP Quality Assurance Technician Certification
(c) A minimum of 6 months continuous experience in the fabrication of precast concrete highway products

Quality Control Managers shall be employed full-time (or engaged consultants), on site, and present during all phases of fabrication.

e. Quality Control Inspection.

Quality Control inspection shall be performed by qualified Production Personnel and Quality Control Technicians to visually inspect equipment, environmental conditions, materials, and workmanship, per the Department approved Quality Control documents and specified herein. The results and findings of QC inspection shall be documented on the Fabricator's Inspection Report Forms (IRFs). The Fabricator shall conduct immediate initiation of non-conformance reporting and corrective action for non-conforming inspection results and uncontrolled processes.

f. Quality Control Sampling and Testing.

Quality Control sampling and testing shall be performed and reported by qualified Quality Control Technicians, to provide measurement of properties and quality characteristics of the material, to determine the degree of uniformity or the measured variability of materials or products, to monitor

the quality and acceptability of the material or product, and to evaluate the control during the production or placement process, per the Department approved Quality Control documents and specified herein. The minimum QC sampling and testing activities shall be in accordance with the requirements specified herein. The results and findings of QC sampling and testing shall be documented on the Fabricator's Test Report Forms (TRFs). The Fabricator shall conduct immediate initiation of non-conformance reporting and corrective action for materials with test results not within allowable limits.

(1) Aggregate Sampling and Testing.

The Fabricator shall conduct routine Quality Control sampling and testing of aggregate quality characteristics and properties, to ensure uniformity and consistency of the material per the requirements specified herein.

Table M4.02.14-8: QC Sampling and Testing Requirements for Aggregate

Method	Quality Characteristic
T 27	Particle Size Distribution
T 84 T 85	Bulk Specific Gravity Dry
	Bulk Specific Gravity SSD
	Apparent Specific Gravity
	Absorption (%)
T 19	Unit Weight (lb / ft^3)
	Aggregate Void Content (%)
T 255	Moisture Content (%)

(2) Concrete Production Sampling and Testing.

Quality Control sampling and testing shall be conducted during production per the minimum requirements specified herein. Production test results shall be within the limits specified herein.

Table M4.02.14-9: QC Sampling and Testing Frequency During Concrete Production

Lot Size	Sublot Size	Frequency
Total quantity of concrete (cy) produced in a year, per approved mix design formulation	50 cy	1 per sublot or fraction thereof, minimum 1 per day

Table M4.02.14-10: QC Sampling and Testing Requirements During Production

Property	Method	Quality Characteristic		Limits	
				Min.	Max.
Uniformity	M 157[1]	Batching Quantities of Constituent Materials		Table M4.07.0-4	
	T 119[2][3]	Slump (in.)	< 4 in.	Target -1.0	Target +1.0
			4 – 8 in.	Target -1.5	Target +1.5
	T 121[2]	Unit Weight (lb/ft^3)		For Information	
Workability	T 119[4]	Segregation Resistance		Pass	
Filling Ability	T 347[2][5]	Slump Flow (in.)	22.0 – 29.0 in.[6]	Target -2.0	Target +2.0
Thermal	T 309	Concrete Temperature (°F)		50	90
Strength	T 22[2][7]	Compressive Strength (psi)	Form Removal	70% of f'_c[8][9]	–
			Storage in Adverse Conditions	f'_c[8]	–
			28 Days	f'_c[8]	–
			56 Days	f'_c[8][9]	–
Durability	T 121[2] T 152[2] T 196[2]	Air Content (%)		Target -1.5	Target +1.5

[1] Batch tickets shall be provided to the Department by the Producer. Producers shall report the source, type, quantity, and design target for each constituent material incorporated into the proposed mix design onto batch tickets meeting AASHTO M 157.
[2] Mix design target shall be identified on the Department issued cement concrete mix design sheet.
[3] Required for non-self-consolidating concrete (SCC).
[4] Required for non-self-consolidating concrete (SCC). Testing for segregation resistance shall be performed while the concrete is being discharged and during AASHTO T 119. Visual signs of segregation include coarse particles advancing in front of or behind the fine particles and mortar and a tendency for coarse aggregate to separate from the mortar, particularly when the mixture is being consolidated.
[5] Required for Self-Consolidating Concrete (SCC).
[6] Mix design target and production test results shall meet the specified range.
[7] Three (3) 4 x 8 in. cylinders shall be cast and tested for each set specified for maximum aggregate size less than 1-½ in. Two (2) 6 x 12 in. cylinders shall be cast and tested for each set specified for maximum aggregate size greater than 1 in.
[8] The specified compressive strength (f'c) is defined as the minimum compressive strength required to be attained at a specified age for a given concrete structure, as specified in construction standard specifications, contract document special provisions, and design plans.
[9] In instances where the 28-Day test results do not meet the specified limits, 56-Day test results shall meet the 28-Day limits.

g. Quality Control Records, Documentation, and Analysis.

The Fabricator shall organize, maintain, and retain Quality Control documentation, including the Quality System Manual, Quality Control Plans for contract work items, plant certification records,

personnel qualification and certification records, laboratory accreditation and certification records, daily diaries, record books, databases, Department and Contractor correspondence, random sampling location report forms, test report forms, inspection report forms, certificates of compliance, non-conformance report forms, corrective actions, control charts, quality level analysis, Quality Control test result summary sheets, material quantities produced or placed by lot and sublot, and other Quality Control documentation per the Department Approved Quality System Manual, Quality Control Plan, and specified herein.

At a minimum, the Fabricator shall maintain a filing system for the following QC records and documentation:

(a) Plant Certification
(b) QC Laboratory NETTCP Qualification or AASHTO Accreditation
(c) Qualifications and Certifications for QC Manager(s) and QC Technician(s)
(d) Approved Quality System Manual (QSM)
(e) Approved Quality Control Plan (if applicable)
(f) MassDOT Approved Mix Design Sheet(s) and Approval Letter(s)
(g) MassDOT Standard Shop Drawings
(h) MassDOT Approved Shop Drawings
(i) Manufacturer's Technical Data Sheet for each chemical admixture
(j) Manufacturer's Mill Certification for hydraulic cement, supplementary cementitious materials, and steel reinforcement
(k) Batch tickets
(l) QC Inspection Report Forms (IRFs) for each fabricated concrete product
(m) QC Test Report Forms (TRFs)
(n) Non-Conformance Reports (NCRs)
(o) Documentation of Repairs (if applicable)
(p) Fabricator Certificate of Compliance (Subsection 6.01: Source of Supply and Quality) for each fabricated concrete product
(q) QC and Production equipment calibrations, verifications, and maintenance documentation.

All QC records and documentation shall be made available upon the request of the Department.

2. Department Acceptance.

Acceptance shall be performed by the Department, including consultants under direct contract with the Department independent of the Fabricator, to evaluate the degree of compliance with contract requirements, to monitor the Fabricator's Quality Control activities, to determine the corresponding value for a given product and the acceptability of all material produced and placed through Department acceptance sampling, testing, inspection, evaluation, and documentation.

a. Acceptance of Quality Control Operating Documents.

The Department will review all Quality Control operating documents, including the Quality System Manual and Quality Control Plans for contract work items submitted by the Fabricator. Department approval shall be subject to conformance with the requirements specified herein.

b. Monitoring Fabricator Quality Control.

The Department will monitor the adequacy of the Fabricator Quality Control System, to ensure Fabricator compliance to all items identified in Quality Control documents, including the Fabricator Quality System Manual and Quality Control Plans for contract work items. Failure to comply with these Quality Control documents may result in work suspension.

c. Acceptance Inspection.

Acceptance inspection will be performed and reported by qualified Department (or designee) Acceptance Technicians, to visually inspect equipment, environmental conditions, materials, and workmanship, per the requirements specified herein. The results and findings of Acceptance inspection will be documented on the Department's Inspection Report Forms (IRFs). The Department will conduct immediate initiation of non-conformance reporting for non-conforming inspection results and uncontrolled processes.

d. Acceptance Sampling and Testing.

Acceptance sampling and testing will be performed and reported by qualified Department (or designee) Acceptance Technicians, to provide quality characteristic data used for Department Acceptance determination, per the requirements specified herein. The results and findings of Acceptance sampling and testing will be documented on the Department's Test Report Forms (TRFs). The Department will conduct immediate initiation of non-conformance reporting and corrective action for materials with test results not within allowable limits.

(1) Concrete Production Sampling and Testing.

Acceptance sampling and testing will be conducted during production per the minimum requirements specified herein. Production test results shall be within the limits specified herein.

Table M4.02.14-11: Acceptance Sampling and Testing Frequency During Concrete Production

Lot Size	Sublot Size	Frequency
Total quantity of concrete (cy) produced in a year, per approved mix design formulation	50 cy	1 per sublot or fraction thereof, minimum 1 per day

Table M4.02.14-12: Acceptance Sampling and Testing Requirements During Production

Property	Method	Quality Characteristic		Limits	
				Min.	Max.
Uniformity	M 157[1]	Batching Quantities of Constituent Materials		Table M4.08.0-1	
	T 119[2][3]	Slump (in.)	< 4 in.	Target -1.0	Target +1.0
			4 – 8 in.	Target -1.5	Target +1.5
	T 121[2]	Unit Weight (lb/ft^3)		For Information	
Workability	T 119[4]	Segregation Resistance		Pass	
Filling Ability	T 347[2][5]	Slump Flow (in.)	22.0 – 29.0 in.[6]	Target -2.0	Target +2.0
Thermal	T 309	Concrete Temperature (°F)		50	90
Strength	T 22[2][7]	Compressive Strength (psi)	7 Days	–	–
			28 Days	f'_c[8]	–
			56 Days	f'_c[8][9]	–
Durability	T 121[2] T 152[2] T 196[2]	Air Content (%)		Target -1.5	Target +1.5

[1] Batch tickets shall be provided to the Department by the Cement Concrete Producer. Producers shall report the source, type, quantity, and design target for each constituent material incorporated into the proposed mix design onto batch tickets meeting AASHTO M 157.
[2] Mix design target shall be identified on the Department issued cement concrete mix design sheet.
[3] Required for non-self-consolidating concrete (SCC).
[4] Required for non-self-consolidating concrete (SCC). Testing for segregation resistance shall be performed while the concrete is being discharged and during AASHTO T. Visual signs of segregation include coarse particles advancing in front of or behind the fine particles and mortar and a tendency for coarse aggregate to separate from the mortar, particularly when the mixture is being consolidated.
[5] Required for Self-Consolidating Concrete (SCC).
[6] Mix design target and production test results shall meet the specified range.
[7] Three (3) 4 x 8 in. cylinders shall be cast for each set specified for maximum aggregate size less than 1-½ in. Two (2) 6 x 12 in. cylinders shall be cast for each set specified for maximum aggregate size greater than 1 in.
[8] The specified compressive strength (f'_c) is defined as the minimum compressive strength required to be attained at a specified age for a given concrete structure, as specified in construction standard specifications, contract document special provisions, and design plans.
[9] In instances where the 28-Day test results do not meet the specified limits, 56-Day test results shall meet the 28-Day limits.

M4.02.15: Cement Mortar

Mortar shall be composed of 1 part Portland cement and 2 parts of sand by volume with sufficient water to form a workable mixture. Cement, sand and water shall conform to M4.01.0: Portland Cement, M4.02.02: Aggregates, Paragraph A, and M4.02.04: Water respectively.

M4.02.17: Self-Consolidating Concrete for Precast Concrete Products

Self-Consolidating Concrete (SCC) may be used at the Fabricator's discretion. SCC is a non-segregating concrete that is sufficiently flowable to fill formwork, spread into place, and encapsulate reinforcing steel, requiring minimal or no mechanical vibration to avoid segregation of the plastic concrete mixture. The following provision shall apply in addition to the other requirements specified in Section M4: Cement and Cement Concrete Materials.

A. Fine Aggregates.

The fine aggregate portion of a given mix shall not exceed 50% by weight of the total aggregate in the mix.

B. Chemical Admixtures.

Chemical admixtures shall be selected from the QCML, shall be used in accordance with manufacturer's recommendations, and shall be compatible with all mix components. Any type of chemical admixture that is not included in the QCML (such as shrinkage reducing admixtures) shall be used in accordance with the manufacturer's recommendations, shall be compatible with all mix components and shall conform to AASHTO M 194M/M 194 and the following:

1. Air entraining admixtures shall comply with AASHTO M 154M/M 154.
2. VMA shall comply with the ASTM C 494 Type S.
3. High-range water-reducing admixtures (HRWRA) shall comply with the requirements of ASTM C 494 Type F (water-reducing, high range) or G (water-reducing, high range, and retarding) or ASTM C 1017. Such HRWRA can be used in combination with regular water-reducing admixtures or mid-range water-reducing admixtures. High-Range Water-Reducing Admixture (HRWR).
4. All corrosion inhibitors shall comply with AASHTO M 194M/M 194.

C. SCC Mix Design.

Prior to concrete production, the Contractor shall submit a copy of the SCC mix design to RMS for review and approval.

SCC Compressive strength specimens shall be fabricated in accordance to ASTM C1758. Multiple samples from the same batch shall be made simultaneously. Prior to testing for compressive strength, the de-molded cylinders shall be visually examined for evidence of segregation. The results of the observations shall be reported as part of the strength results.

In addition to the testing provided in M4.02.00: Cement Concrete, the following tests shall be performed by qualified staff, in the presence of the Engineer and submitted to RMS for the prequalification of the SCC mix design;

Table M4.02.17-1: Additional Material Acceptance Criteria for SCC Trial Batch Testing

Property	Test Method	Target Value
Filling Ability	Slump Flow (AASHTO T 347)	22 to 29 in.
Passing Ability	Slump Flow (AASHTO T 347) J-Ring Flow (AASHTO T 345)	The measured difference between the Slump Flow and the J-Ring Flow shall be <2 in.
Static Stability	Column Segregation (ASTM C1610)	Percent static segregation (S) ≤15%
	Visual Stability Index (AASHTO T 351)	0 or 1
Note: Slump flow values outside of the above range will be considered, provided mock-ups performed during the trial batch process demonstrate full consolidation of concrete without segregation as approved by the Engineer.		

D. Production Sampling and Testing.

In addition to production sampling and testing defined in M4.02.00: Cement Concrete, the following testing shall be performed during production. These tests shall apply whether performed by MassDOT for acceptance or by the Contractor for QC. Sampling and testing requirements shall be performed in accordance with the specifications for the precast concrete unit.

Table M4.02.17-2: Additional Material Criteria for SCC Production Testing

Property	Test Method	Target Value	Testing Frequency
Filling Ability	Slump Flow (AASHTO T 347)	±2 in. of Trial Batch Slump Flow Target Value and within Range of 22 to 29 in	1 per Sublot
Static Stability	Visual Stability Index (AASHTO T 351)	0 or 1	1 per Sublot

M4.03.0: Concrete Produced by Volumetric Mixers

Concrete produced by volumetric mixers shall meet AASHTO M 241 and the Volumetric Mixer Manufacturers Bureau (VMMB) Certification program.

Quality Control (QC) shall be established, maintained, and performed by the Contractor (and/or Sub-Contractor Producer) to monitor, assess, and adjust manufacturing, production, fabrication, and construction processes, to maintain continuous control of the process, and to ensure that the final material or product will meet the specified level of quality, through:

a) Implementation of the Department approved Quality System Manual (QSM)
b) Proper Quality Control organization
c) Qualified Production Personnel, including equipment operators and craftsmen incorporated into the manufacturing, production, and construction operations
d) Certified Quality Control Technicians and Quality Control Managers
e) Qualified Quality Control laboratory through the NETTCP Laboratory Qualification Program or accredited through the AASHTO Accreditation Program (AAP)
f) Routine QC inspection of equipment, environmental conditions, materials, and workmanship

g) Routine QC sampling and testing of material quality characteristics and properties
h) Timely analysis of QC results, through statistical analysis (mean, standard deviation, etc), control charts, and conformance to allowable limits
i) Immediate initiation of non-conformance reporting and corrective action for non-conforming inspection results, uncontrolled processes, and materials with test results not within allowable limits
j) Retention of QC records
k) Conformance to specifications

1. Quality Control Operating Documents.

Quality Control operating documents shall be prepared, implemented, and maintained by the Producer and submitted to the Department for review and approval at a minimum of 30 days prior to the start of construction. The Producer shall adhere to all policies, practices, procedures, and activities identified in the following Department approved Quality Control operating documents.

a) Quality System Manual.

The Producer shall submit a Quality System Manual (QSM) to the Department for review and approval on an annual basis. The Quality System Manual (QSM) shall document the overall internal Quality Control operating procedures of the Producer's Quality Control System and meet AASHTO R 18, AASHTO R 38, and the requirements of this section.

b) Quality Control Plan.

At a minimum of 30 days prior to construction, the Contractor shall submit a contract-specific Quality Control Plan (QCP) for each applicable contract work item to the Department for review and approval. The QCP shall document all Quality Control personnel and procedures utilized to maintain control of all production and placement processes. The QCP for each contract work item shall meet the NETTCP Model Quality Control Plan standard format and requirements specified by the Department.

2. Quality Control Laboratory.

The Contractor's Quality Control Laboratory shall maintain active qualification through the NETTCP Laboratory Qualification Program or accreditation through the AASHTO Accreditation Program (AAP).

The Contractor shall have all required sampling, testing, and inspection equipment on site and available for use during all phases of production. The equipment shall meet all applicable AASHTO or ASTM standards, maintain required calibration schedules, and be in acceptable working condition.

3. Quality Control Organization.

The Contractor's Quality Control organization shall be comprised of trained, experienced, and qualified Production Personnel, Quality Control Technicians, and Quality Control as specified herein. Production Personnel, Quality Control Technicians, and Quality Control Managers shall maintain continuous communication to ensure conformance to specification requirements and to dictate corrective action for non-conformance.

4. Quality Control Records, Documentation, and Analysis.

The Contractor shall organize, maintain, and retain Quality Control documentation, including the Quality System Manual, Quality Control Plans for contract work items, plant certification records, personnel qualification and certification records, laboratory accreditation and certification records, daily diaries, record books, databases, Department and Contractor correspondence, random sampling location report forms, test report forms, inspection report forms, certificates of compliance, non-conformance report forms, corrective actions, control charts, quality level analysis, Quality Control test result summary sheets, material quantities produced or placed by lot and sublot, and other Quality Control documentation per the Department Approved Quality System Manual, Quality Control Plan, and specified herein. All QC records and documentation shall be made available upon the request of the Department.

At a minimum, the Contractor shall maintain a filing system for the following QC records and documentation:

a) Volumetric Mixer Certification
b) QC Laboratory NETTCP Qualification or AASHTO Accreditation
c) Qualifications and Certifications for QC Manager(s) and QC Technician(s)
d) Approved Quality System Manual (QSM)
e) Approved Quality Control Plan
f) MassDOT Approved Mix Design Sheet(s) and Approval Letter(s)
g) Manufacturer's Technical Data Sheet for each chemical admixture
h) Manufacturer's Mill Certification for hydraulic cement, supplementary cementitious materials, and steel reinforcement
i) Batch tickets
j) QC Inspection Report Forms (IRFs)
k) QC Test Report Forms (TRFs)
l) Non-Conformance Reports (NCRs)
m) Deficiency Reports (DRs)
n) QC and Production equipment calibrations, verifications, and maintenance documentation.

M4.04.0: Mortar for Prestressed Concrete Deck Beams

The mortar shall conform to the following specification:

General.

The purpose of this specification is to describe a 2-component, polymer-modified, cementitious, fast-setting, free flow mortar for filling keyways between adjacent box beams.

Materials.

The polymer-modified cementitious system shall consist of a factory pre-proportioned, 2-component system whose components conform to the following requirements:

a) Component A shall be a liquid polymer emulsion of an acrylic copolymer base and additives. This acrylic copolymer shall have the following properties:

pH ..... 4.5 to 6.5
Minimum film forming temperature ..... Approximately 68°F
Tear Strength ..... Approximately 990 psi to 1,420 psi
Elongation at break ..... 500% to 900%
Particle size range ..... Less than 0.1 micron

b) Component B shall be a blend of a selected Portland Cement. specially graded aggregates, organic accelerator, and admixtures for controlling setting time, water reducers for workability and a corrosion inhibiter.
c) The component ratio A:B shall be 1:7.2 by weight. The system shall not contain chlorides, nitrates, added gypsum, added lime, or high alumna cements. The system shall be non-combustible, either before or after cure.

Typical Properties of Mixed Components.

a) Application Time (Working Time): ..... 15 minutes after components have been mixed
b) Finishing Time: ..... 20 to 60 minutes after combining components
c) Color: ..... Concrete Gray
d) Flow Test: ..... 100% to 200%

Typical Properties of Cured System.

a) Abrasion Resistance: ..... 6 times greater than Control
b) Bond Strength (Pulloff method): ..... 100% concrete substrate failure
c) Modulus of Elasticity ..... 4.5×10^6
d) Surface Scaling (Deicing salt freeze/thaw): ..... No deterioration after 120 cycles
e) Compressive Strength (4 hours 50% RH): ..... 100 psi minimum
f) Compressive Strength (28 days 50% RH): ..... 5,300 psi minimum
g) Flexural Strength (28 days 50% RH): ..... 1,200 psi minimum
h) System shall conform to EPA/USPHS Standards for surface contact with potable water.
i) The system shall not produce a vapor barrier.
j) The system shall be thoroughly compatible with concrete.

M4.05.0: Cement Concrete Brick

Cement concrete brick shall be machine made solid segments conforming to the requirements of ASTM C139, except that the minimum average compressive strength for 5 representative bricks shall be 3,000 psi. The minimum compressive strength for one individual brick shall be 2,500 psi. Dimensional requirements shall be the same as for M4.05.2: Clay Brick.

M4.05.1: Cement Concrete Blocks

Cement concrete blocks shall be machine made solid segments, conforming to the requirements for Concrete Masonry Units for Construction of Catch Basins and Manholes. ASTM C139, supplemented by the following requirements:

The blocks shall be 6 in. in width for basins and manholes of 9 ft or less in depth, 8 in. in width below a depth of 9 ft when used in structures having a depth greater than 9 ft.

The permissible dimensional variation for nominal size shall be in accordance with ASTM C139. The inside and outside surfaces of the blocks shall be carved to the necessary radius and so designed that the interior surfaces of the structures shall be cylindrical, except the top batter courses which shall be designed to reduce uniformly the inside section of the structure to the required top size and shape. The blocks used in the top courses shall be designed to produce a surface 8 in. in width upon which to seat the frame, and the curb inlet when one is used. Blocks shall be so designed that only full-length units are required to lay any one course.

Blocks shall be sampled and tested in accordance with ASTM C140. The minimum average compressive strength for 5 representative blocks shall be 3,000 psi. The minimum compressive strength for one individual block shall be 2,500 psi.

M4.05.2: Clay Brick

Clay brick shall conform to the requirements of ASTM C32 with the following exceptions:

The size of brick furnished shall be 7.75 in. long by 3.75 in. wide by 2.25 in. deep.

All dimensions shall be nominal.

The average of the absorption of 5 representative samples shall not exceed 15% and the individual absorption of any one sample shall not exceed 17.5%. The average compressive strength of 5 representative samples shall not be less than 3,000 psi and the compressive strength of any one sample shall not be less than 2,500 psi.

M4.05.3: Precast Concrete Block for Slope Paving

Precast blocks shall be solid segments, conforming to requirements for Concrete Masonry Units for Construction of Catch Basins and Manholes, ASTM-Cl39, supplemented by the following requirements:

The thickness shall be 4 in., the width shall be 12 in., and the length 16 in. Blocks shall be sampled and tested in accordance with ASTM C140. Dimensional tolerances shall be in accordance with ASTM C139.

M4.05.4: Sidewalk Brick

Sidewalk brick shall conform to the requirements of ASTM C902 except that the absorption shall be 5% maximum when subjected to 5 hours of submersion in boiling water.

M4.05.5: Epoxy-Resin Base Bonding System for Concrete

This specification covers two-component, epoxy-resin bonding systems for application to Portland cement concrete. The materials shall meet AASHTO M 235M/M 235 Type III, IV, or V. The Type, Grade and Class shall be specified for each individual application.

M4.06.1: High Performance Concrete

High Performance (HP) Concrete shall meet the requirements of M4: Cement and Cement Concrete Materials and the requirements specified herein. HP Concrete shall be designed and produced with precise proportions of constituent materials to form a homogenous composition with a well distributed, spaced, and sized air void system and quality concrete properties. HP Concrete shall exhibit acceptable quality characteristics and material properties, including uniformity, workability, bleeding and settlement, setting, thermal effects, shrinkage control, strength, modulus of elasticity, aesthetics, long-term durability, and resistance to premature deterioration due to freezing, thawing, and de-icing cycles, alkali silica reaction, corrosion of steel reinforcement, abrasion, erosion, sulfate reaction, salt crystallization, acid disintegration, carbonation reaction, delayed ettringite formation, and marine environments for the expected service life of the structure.

The Contractor may elect to use fly ash, slag cement, silica fume, or a combination thereof provided that the dosage limits, permeability, and strength provisions contained herein are satisfied and the MassDOT Research and Materials Section (RMS) has approved the trial batches and mix design. Changing the mix design shall not be accepted and approved by RMS without the preparing, testing, and approval of trial batches for the revised mix design. HP Concrete shall meet AASHTO M 157.

Table M4.06.1-1: Classifications of HP Concrete

28 Day Compressive Strength	Nominal Maximum Coarse Aggregate Size (in.)	Maximum Total Cementitious Content (lb per yd³)
5,000 psi	¾	685
5,000 psi	⅜	710
6,500 psi	⅜, ½, ¾	–
8,000 psi	⅜, ½, ¾	–

Prior to concrete placement, the Contractor shall develop and forward a copy of the HP Concrete design mix to the Department for review and approval. Approval of the design mix must be obtained prior to placement of concrete. The mix design sent to the Department must be accompanied with trial batch information. Trial batches shall be performed in accordance with procedures outlined by the Department.

Trial batch testing will be performed on samples of the same contents and proportions as the HP Concrete to be used in the proposed structures. AASHTO T 358 or AASHTO TP 119 shall be conducted and meet the requirements specified in Table M4.06.1-2.

Table M4.06.1-2: Durability Requirements

Property	Method	Quality Characteristic		Limits	
				Min.	Max.
Durability	T 358[1][2][3]	Surface Chloride Ion Penetration Resistance (kΩ-cm)	7 Days	Informational	
			28 Days	21	–
	Or				
	TP 119[1][2][3]	Uniaxial Chloride Ion Penetration Resistance (kΩ-cm)	7 Days	Informational	
			28 Days	10.4	–

[1] Three 4 x 8 in. cylinders shall be cast for each set specified.

[2] This test method has been known to have compatibility issues with mix designs containing calcium nitrite chemical admixtures or steel fibers. As a result, inclusion of these materials into the test specimens may negatively affect test results. An additional set of cylinders shall be cast and tested without the noted materials. The calcium nitrite shall be replaced by an equivalent quantity of water. A correction factor shall be determined by the following equation:

$$CF = PR_{REMOVED} / PR_{MIX\ DESIGN}$$

where $PR_{REMOVED}$ = Penetration Resistivity with noted materials removed, $PR_{MIX\ DESIGN}$ = Penetration Resistivity of original mix design with noted materials included, and CF = Correction Factor. The correction factor established during the mix design verification shall be applied to the penetration resistivity test results to compensate for the noted materials. The corrected penetration resistivity ($PR_{CORRECTED}$) shall be determined by the following equation and meet the specified limits identified in the table:

$$PR_{CORRECTED} = PR_{MIX\ DESIGN} * CF$$

[3] Specimens shall be moist cured in accordance with AASHTO T 22 and shall be in saturated surface dry (SSD) condition during testing.

A. **Supplementary Cementitious Materials.**

High Performance Concrete shall meet the supplementary cementitious materials (SCM) requirements specified in Section M4: Cement and Cement Concrete Materials and the content target requirements specified in Table M4.06.1-3. SCMs shall be incorporated into the mix design formulation to successfully mitigate alkali silica reaction (ASR) without exceeding the SCM content requirements. High Performance Concrete shall meet the ASR requirements specified in M4.02.00: Cement Concrete. SCM content is defined as the percent by mass replacement of hydraulic cement.

Table M4.06.1-3: SCM Content Target

Supplementary Cementitious Material	SCM Content
Blended Hydraulic Cement Content[1]	[2]
Fly Ash (Class F) Content	15 – 30
Slag Content	20 – 50
Silica Fume Content	7 – 15
Total Fly Ash and Silica Fume Content	≤ 35
Total SCM Content	≤ 50

[1] The SCM content of blended hydraulic cement shall be identified on the Manufacturer's certified mill test report.
[2] SCMs in blended hydraulic cement shall meet the total cementitious material requirements for fly ash, slag, and silica fume specified in the table.

B. **Water-Cementitious Ratio.**

The water-cementitious ratio shall be 0.40 maximum. The water content of all additives shall be included in the water-cementitious ratio.

C. **Air Content.**

Cement concrete shall meet the air content targets specified in M4.02.00: Cement Concrete, Table M4.02.06-1: Air Content Target.

D. **Chemical Admixtures.**

Chemical admixtures incorporated into cement concrete shall meet M4.02.05: Chemical Admixtures and be precisely dosed per admixture manufacturer recommendations to meet the required properties of HP Concrete.

HP Concrete shall be formulated with 3.0 gal of corrosion inhibiting admixture per yd^3 of concrete in order to increase the active corrosion threshold to 9.9 lb of chloride per yd^3 of concrete at the reinforcing bar level. Acceptance will depend upon the material's conformance, as documented by certified test results, to all applicable sections of AASHTO M 194M/M 194. The calcium nitrite solution shall contain 30 ± 2% calcium nitrite by weight. The calcium nitrite material shall have neutral set characteristics.

E. **Paste and Void Content.**

HP Concrete shall be designed with a paste content that decreases the tendency of shrinkage cracking, while also adequately filling the voids of the concrete to provide sufficient separation and effective bonding between the aggregate particles. HP Concrete shall meet Table M4.06.1-4.

Table M4.06.1-4: Paste and Void Content Target

Property	Design Parameter	Target
Shrinkage Resistance	Paste Content Target (%)	≤ 30[1][2]
Workability	Paste Content to Void Content (PC/VC) Ratio	1.1 – 1.75[2]

[1] Not applicable to mix design formulations incorporating sufficiently designed dosages of S-SRA Shrinkage Reducing or Type S-CRA Crack Reducing chemical admixtures meeting M4.05.0: Cement Concrete Brick.
[2] Not applicable to specialized mix design formulations, including self-consolidating concrete.

M4.06.2: High Early Strength Concrete

High Early Strength Concrete shall meet the requirements of Section M4: Cement and Cement Concrete Materials and the requirements specified herein. High Early Strength Concrete shall meet the requirements specified in Table M4.06.2-1.

Table M4.06.2-1: Verification Testing Requirements

Property	Method	Quality Characteristic		Limits	
				Min.	Max.
Strength	AASHTO T 22[1]	Compressive Strength (psi)	12 Hours	Informational	
			24 Hours	2500	–
			3 Days	4000	–
			7 Days	5000	–
			28 Days	Informational	
	AASHTO T 97[2]	Flexural Strength (psi)	12 Hours	Informational	
			24 Hours	400	–
			3 Days	550	–
			7 Days	650	–
			28 Days	Informational	
	ASTM C882[3]	Slant Sheared Bond Strength (psi)	24 Hours	1200	–
			7 Days	1900	–
			28 Days	2200	–
Setting	AASHTO T 197	Initial Set (min.)		Informational	
		Final Set (min.)		Informational	
Shrinkage Cracking Resistance [5]	AASHTO T 160[4]	Unrestrained Volume Change (με)	28 Days	–	420
	ASTM C1581[6]	Restrained Shrinkage	28 Days	No Cracking[7]	
	Or				
	AASHTO T 363[8]	Restrained Shrinkage (psi)	7 Days	–	0.6T[9]

Table M4.06.2-1: Verification Testing Requirements (cont.)

Property	Method	Quality Characteristic		Limits	
				Min.	Max.
Durability	AASHTO T 358[1][10]	Surface Chloride Ion Penetration Resistance (kΩ-cm)	7 Days	Informational	
			28 Days	21	–
	Or				
	AASHTO TP 119[1][10]	Uniaxial Chloride Ion Penetration Resistance (kΩ-cm)	7 Days	Informational	
			28 Days	10.4	–

[1] Three (3) 4 x 8 in. cylinders shall be cast and tested for each age specified for maximum aggregate size less than 1-½ in. Two (2) 6 x 12 in. cylinders shall be cast and tested for each age specified for maximum aggregate size greater than 1 in.
[2] For applications where the concrete is subject to flexural stresses: Two (2) 6 x 6 x 20 in. beams shall be cast for each age specified.
[3] For applications where bond strength is desired.
[4] For applications where the concrete is not subject to restraining stresses.
[5] Not applicable to mix design formulations incorporating sufficiently designed dosages of Type S-SRA Shrinkage Reducing or Type S-CRA Crack Reducing chemical admixtures meeting M4.02.05: Chemical Admixtures.
[6] For nominal maximum aggregate sizes less than or equal to ½ in. and for applications where the concrete is subject to restraining stresses.
[7] Cracking is defined as the sudden decrease in compressive strain greater than 30 με.
[8] For any nominal maximum aggregate size and for applications where the concrete is subject to restraining stresses.c The circumferential residual stress in the specimen at the inner face of the specimen (σθ(RIC)) shall be calculated according to AASHTO T 363.
[9] The splitting tensile strength (T) at 28 days shall be determined by AASHTO T 198.
[10] Specimens shall be moist cured in accordance with AASHTO T 22 and shall be in saturated surface dry (SSD) condition during testing.

M4.06.3: Rapid Hardening Concrete

Rapid Hardening Concrete shall meet the requirements of Section M4: Cement and Cement Concrete Materials and the requirements specified herein. Rapid Hardening Concrete shall meet the requirements specified in Table M4.06.3-1.

Table M4.06.3-1: Verification Testing Requirements

Property	Method	Quality Characteristic		Limits	
				Min.	Max.
Strength	AASHTO T 22[1]	Compressive Strength (psi)	2 Hours	Informational	
			4 Hours	2500	–
			6 Hours	Informational	
			24 Hours	4000	–
			7 Days	5000	–
			28 Days	Informational	
	AASHTO T 97[2]	Flexural Strength (psi)	2 Hours	Informational	
			4 Hours	400	–
			6 Hours	Informational	
			24 Hours	550	–
			7 Days	650	–
			28 Days	Informational	
	ASTM C882[3]	Slant Sheared Bond Strength (psi)	24 Hours	1200	–
			7 Days	1900	–
			28 Days	2200	–
Setting	AASHTO T 197	Initial Set (min.)		Informational	
		Final Set (min.)		Informational	
Shrinkage Cracking Resistance	AASHTO T 160[4]	Unrestrained Volume Change (με)	28 Days	–	420
	ASTM C1581[5]	Restrained Shrinkage	28 Days	No Cracking[6]	
	Or				
	AASHTO T 363[7]	Restrained Shrinkage (psi)	7 Days	–	0.6T[8

Table M4.06.3-1: Verification Testing Requirements (cont.)

Property	Method	Quality Characteristic		Limits	
				Min.	Max.
Durability	AASHTO T 358[1][9]	Surface Chloride Ion Penetration Resistance (kΩ-cm)	7 Days	Informational	
			28 Days	21	–
	Or				
	AASHTO TP 119[1][9]	Uniaxial Chloride Ion Penetration Resistance (kΩ-cm)	7 Days	Informational	
			28 Days	10.4	–

[1] Three (3) 4 x 8 in. cylinders shall be cast and tested for each age specified for maximum aggregate size less than 1-½ in. Two (2) 6 x 12 in. cylinders shall be cast and tested for each age specified for maximum aggregate size greater than 1 in.
[2] For applications where the concrete is subject to flexural stresses: Two (2) 6 x 6 x 20 in. beams shall be cast for each age specified.
[3] For applications where bond strength is desired.
[4] For applications where the concrete is not subject to restraining stresses.
[5] For nominal maximum aggregate sizes less than or equal to ½ in. and for applications where the concrete is subject to restraining stresses.
[6] Cracking is defined as the sudden decrease in compressive strain greater than 30 με.
[7] For any nominal maximum aggregate size and for applications where the concrete is subject to restraining stresses. The circumferential residual stress in the specimen at the inner face of the specimen ($\sigma\theta(RIC)$) shall be calculated according to AASHTO T 363.
[8] The splitting tensile strength (T) at 28 days shall be determined by AASHTO T 198.
[9] Specimens shall be moist cured in accordance with AASHTO T 22 and shall be in saturated surface dry (SSD) condition during testing.

M4.06.4: Lightweight Concrete

Lightweight Concrete shall meet the requirements of Section M4: Cement and Cement Concrete Materials and the requirements specified herein. Lightweight Concrete shall be formulated with lightweight aggregate meeting M4.02.03: Lightweight Aggregates. Lightweight Concrete shall meet the requirements specified in Table M4.06.4-1.

Table M4.06.4-1: Verification Testing Requirements

Property	Method	Quality Characteristic	Limits	
			Min.	Max.
Unit Weight	ASTM C567	Calculated Equilibrium Density, E_c (lb/ft^3)[1]	–	115.0

[1] Measured Oven Dry Density (O_m) shall be used for Calculated Equilibrium Density (E_c).

M4.07.0: Elastomeric Concrete

Elastomeric concrete for use in strip seal bridge joint systems, shall consist of a two-component polyurethane material that shall be mixed and placed at the job site. The cured elastomeric concrete shall have the following physical properties:

Table M4.07.0-1: Physical Properties of Elastomeric Concrete

Property	Test Method	Requirement
Compressive Stress @ 5% deflection	ASTM D 695	800 psi minimum
Resilience @ 5% deflection	ASTM D695	70% minimum
Impact Resistance @ -20°F, 32°F and 158°F	ASTM D3209	No cracks

M4.08.0: Controlled Low-Strength Materials

Controlled Low Strength Materials shall meet the requirements of Section M4: Cement and Cement Concrete Materials and the requirements specified herein.

Controlled Low Strength Materials (CLSM) shall be designed and produced with precise proportions of hydraulic cement, supplementary cementitious materials (SCM), aggregate, mixing water, air-entrainment, and chemical admixtures to form a self-compacting, self-leveling, flowable, excavatable or non-excavatable, low strength, rigid setting, and unshrinkable material.

Controlled Low Strength Materials mix design formulations shall be classified and reported according to the 90-day ultimate compressive strength target, nominal maximum aggregate size (NMAS), and CLSM mix type. Classification is subject to meeting the requirements specified herein.

Table M4.08.0-1: Classification

Type	90-Day Ultimate Compressive Strength Target (psi)
CLSM – Manual Excavatable[1][2]	0 – 100
CLSM – Mechanical Excavatable[1][2]	101 – 300
CLSM – Structural Non-Excavatable[1][3]	> 300

[1] In addition to the ultimate compressive strength target requirements, the Controlled Low Strength Materials shall meet the removability modulus (RE) requirements specified in Table M4.08.0-2.
[2] The coarse aggregate content of the mix design shall also be considered. Mixtures using high coarse aggregate quantities may be difficult to excavate.
[3] Structural non-excavatable Controlled Low Strength Materials are intended for permanent installation.

Controlled Low Strength Materials shall meet the requirements specified in Table M4.08.0-2.

Table M4.08.0-2: Minimum Verification Testing Requirements

Property	Method	Quality Characteristic			Limits	
					Min.	Max.
Uniformity	ASTM D6023[1]	Unit Weight (lb/ft^3)			Target - 2.0	Target +2.0
		Air Content (%)			Target - 2.0	Target +2.0
	ASTM D6103[1]	Slump Flow (in.)		≥ 8 in.	Target - 2.0	Target +2.0
Workability	ASTM D6103[2]	Visual Inspection for Segregation			Pass	
Thermal	AASHTO T 309	Concrete Temperature (°F)			50	90
Excavatability	ASTM D4832[1][3]	Ultimate Compressive Strength (psi)	Manual Excavatable	28 Days	Informational	
				56 Days	Informational	
				90 Days	–	100
			Mechanical Excavatable	28 Days	Informational	
				56 Days	Informational	
				90 Days	101	300
			Structural Non-Excavatable	28 Days	Informational	
				56 Days	Informational	
				90 Days	301	–
	ACI 229R ASTM D4832	Removability Modulus (RE)[4]	Excavatable		–	1.0
			Non-Excavatable		1.1	–
Permeability[5]	ASTM D5084	Coefficient of Water Conductivity (cm/s)			0.004	–

[1] Prior to mix design verification testing, the Cement Concrete Producer shall identify and report the proposed mix design targets onto the Department issued cement concrete mix design sheet. Any adjustments made to the proposed mix design targets shall be based on the verification test results, and are subject to Department approval and the requirements specified herein.

[2] Visual inspection for segregation shall be performed while the CLSM is being discharged and during ASTM D6103. Visual signs of segregation include coarse particles advancing in front of or behind the fine particles and mortar and a tendency for coarse aggregate to separate from the mortar, particularly when the mixture is being consolidated.

[3] Two (2) 6 x 12 in. cylinders shall be cast and tested for each age specified.

[4] The Removability Modulus is determined by the equation $RE = [(W^{1.5} \times 104 \times C^{0.5}) / 10^6]$, where RE = Removability Modulus, W = Hardened Unit Weight (lb/ft^3), and C = 28 Day Compressive Strength (psi) determined by ASTM D4832. Round up to the nearest 0.1.

[5] For excavatable applications only. The permeability of excavatable Controlled Low Strength Materials shall be greater than or equal to the surrounding soil. For design purposes, the criteria shall meet or exceed the permeability of uniform fine sand (0.004) as specified in the table.

SECTION M5: PIPE, CULVERT SECTIONS AND CONDUIT

M5.00.0: Pipe, Culvert Sections and Conduit

These shall consist of individual sections of the kinds and sizes shown on the plans and as directed. They shall conform to the requirements of the applicable following subsections.

All pipes shall be subject to inspection at the point of manufacture as well as the site of the work. The purpose of the inspection shall be to cull and reject pipes which, independent of the physical tests, fail to con-form to the specification in the particulars of dimension, workmanship, finish, blisters, cracks or fractures.

M5.01.0: Joint Materials for Pipe

A. Jute or oakum furnished for use in pipe joints shall be of an accepted grade approved for common usage.
B. Mortar shall conform to the requirements of M4.02.15: Cement Mortar.
C. Rubber ring or plastic gaskets shall be of tough, flexible, chemical-resistant material, and of such size and shape as to ensure satisfactory pipe joints when incorporated in the work and shall conform to ASTM C443.
D. Mechanical joints shall conform to the requirements of the ASA Specifications A21.11.
E. The yarning material for cast iron bell-and-spigot pipe joints shall be sterilized braided hemp or untarred twisted jute, clean and dry and free from oil, grease, or any other deleterious matter.

M5.02.1: Reinforced Concrete Pipe

Reinforced concrete pipe shall conform to the requirements of AASHTO M 170 for the class of pipe specified in the contract documents.

- All pipe 24 in. in diameter or smaller shall be of the bell-and-spigot type.
- Pipes larger than 24 in. in diameter shall be tongue and groove or bell and spigot.

M5.02.2: Reinforced Concrete Pipe Flared Ends

Flared end sections shall be fabricated to comply with the Construction Standard Details. The method of fabrication and materials used shall conform to the requirements of AASHTO M 170, Class III, except that the three edge bearing tests shall not be required. The flare shall be of the same thickness and materials as the barrel and have steel reinforcement equaling or exceeding the amount shown on the table for AASHTO M 170, Class III, except that a double row of steel will not be required.

M5.03.0: Corrugated Metal Pipe

This pipe shall consist of metallic coated (galvanized or aluminized) corrugated metal pipe and couplings. The coating shall completely cover the inside and outside of all pipe and couplings.

Galvanizing shall conform to M7.10.0: Galvanized Coatings.

Aluminizing shall conform to M7.15.0: Metallized Coatings.

Aluminized and galvanized pipe components shall not be used together in a pipe run.

The pipe shall conform to AASHTO M 36. Pipe 8 in. or less in diameter shall be constructed of sheets not less than 0.052 in. thick. End sections shall be 16 gage for all pipes 24 in. in diameter and under, 14 gage for all 30- and 36-in. diameter pipes and 12 gage for all diameters greater than 36 in. The coating on end sections shall match the coating on the pipe connected to it.

M5.03.1: Perforated Corrugated Metal Pipe

This pipe shall meet the requirements of M5.03.0: Corrugated Metal Pipe and contain perforations conforming to AASHTO M 36, Type III. The pipe shall conform to AASHTO M 36 except that reinforcing the ends of the pipe will not be required.

M5.03.6: Metal End Sections

Metal End Sections shall be fabricated to conform with the Construction Standard Details. The method of fabrication and materials used shall conform to the applicable requirements of AASHTO M 36.

M5.03.7: Plastic (PVC) Pipe

Plastic (PVC) Pipe shall meet ASTM D1785 Standard Specification for Poly Vinyl Chloride (PVC) and Chlorinated Poly Vinyl Chloride (CPVC) Plastic Pipe, Schedule 40, 80, and 120. The pipe shall be PVC, Type I Schedule 80. Fittings, such as adapters, couplings, etc. shall be the same material as the pipe. Joints shall be made in accordance with ASTM D2855 Recommended Practice for Making Solvent-cemented Joints with Poly (Vinyl Chloride) (PVC) Pipe and Fittings. Cements shall meet ASTM D2564.

M5.03.8: Polymeric Precoated Corrugated Metal Pipe

Polymeric precoated corrugated metal pipe shall conform to the requirements of AASHTO M 246, Type B with the thinner polymeric coating a minimum of 3 mils.

M5.03.9: Slot-Perforated Corrugated Plastic Pipe

This pipe or tubing shall consist of slot-perforated corrugated polyethylene tubing, couplings and fittings. Materials, dimensions, physical properties and fabrication shall be in conformance with AASHTO M 252.

M5.03.10: Corrugated Plastic Pipe

Pipe shall consist of corrugated polyethylene or polypropylene tubing, flare ends, couplings and fittings. Materials, dimensions, physical properties and fabrication shall be in accordance with AASHTO M 294, Type S or D or AASHTO M330 Type S or D. Perforated pipe shall meet Type SP, DP or CP.

M5.03.11: Porous Concrete Pipe

Porous Concrete Pipe shall meet the requirements of AASHTO M 176M/M 176 for Extra-Strength Porous Concrete Pipe. Aggregates for the concrete may consist of inert carbon material.

M5.04.0: Asphalt Coated Corrugated Metal Pipe Arches

Asphalt coated corrugated metal pipe arches shall consist of corrugated metal pipes which have been reformed to multi-centered pipe having arch shaped tops with a slight outwardly curved

integral bottom. The pipe shall be fabricated from standard length culvert sheet and factory riveted to form a continuous length pipe arch.

Asphalt coated corrugated metal pipe arches, including coupling bands, shall conform to the requirement of AASHTO M 36 or AASHTO M 196 for corrugated metal pipe meeting the requirements for base metal, rivets, sampling, testing, brands, corrugations, end finish, weight, bands and workmanship.

FABRICATION

A. Dimensions.

Dimensions, tolerances, and areas shall be in accordance with AASHTO M 36.

The lapped longitudinal seams shall be factory riveted and shall be placed in the top arch and be staggered so as to alternate on each side of the center of the top of the arch by approximately 15% of the periphery.

B. Asphalt Coating.

The insert of the pipe arch shall be coated with asphalt conforming to AASHTO M 190. Type C Coating, so as to form a smooth pavement to widths of 40% of the circumference of the pipe arch. These widths are determined by 40% of the circumference of equivalent diameters. It shall be applied in such a manner that the corrugations are completely filled and that, excepting where the upper edges intersect the corrugations, the pavement has a minimum thickness of ⅛ in. above the crests of the corrugations. The remainder of the inside of the pipe arch and the entire outside shall be uniformly coated with asphalt cement to a minimum thickness of 0.05 in. The thickness shall be measured on the crests of the corrugations. All coupling bands shall be coated to same requirements as the pipe arch except the pavement shall be omitted.

C. Bituminous Materials.

The asphalt cement used for coating shall conform to the requirements in M5.03.0: Corrugated Metal Pipe, Paragraph B .

M5.04.2: Structural Plate for Pipe and Pipe Arches

All materials, including base metal analysis, galvanizing, bolts, nuts, corrugations, gauge determination and acceptance of plates, forming and punching holes, bearing shapes, fabrication and incidental items shall conform to AASHTO M 167M/M 167 and the following:

A. The gauge of plates shall be as specified on the Plans.
B. Bituminous Coating for Metal Surfaces. The bituminous coating shall be a coal tar blend conforming to the requirements of M7.04.01.

M5.04.3: Asphalt Coated Smooth Steel Liner Helically Corrugated Shell Metal Pipe

This pipe shall conform to AASHTO M 36, 8.1.1, Type 1A pipe. The coating shall conform to AASHTO Designation M 190, Type A.

M5.05.3: Ductile Iron Pipe and Fittings

Ductile iron pipe shall conform to the requirements of AWWA C150, C151, C111 and shall be double cement lined and asphalt seal coated in accordance with AWWA C104. The wall thickness shall be Class 52.

Ductile iron fittings for pipes 3 in. through 24 in. in diameter shall be of the compact type and conform to the requirements of AWWA C153 American National Standard for Ductile-Iron compact Fittings, 3 in. through 24 in., for water and other liquids.

Ductile iron fittings for pipes greater than 24 in. and up to 48 in. in diameter shall conform to the requirements of AWWA C110 American National Standard for Ductile-Iron and Gray-Iron Fittings, 3 in. through 48 in., for water and other liquids.

A. Hydrants.

Hydrants shall conform to the requirements of AWWA Standard C502, and/or to the type used by the particular municipality involved as specified in the Special Provisions.

B. Gate Valves.

Gate valves shall conform to the requirements of AWWA Standard C500 and/or to the type used by the particular municipality involved as specified in the Special Provisions.

M5.05.4: Acrylonitrile - Butadiene - Styrene (ABS) Pipe

This type of pipe shall conform to the requirements of AASHTO M 265.

M5.06.0: Copper Tubing

Copper Tubing shall conform to the requirements of ASTM B88, Type k, “annealed.”

M5.07.0: Electrical Conduit-Rigid Nonmetallic (Type NM)

Rigid Nonmetallic Electrical Conduit and associated fittings shall conform to Article 352 of the NEC, NEMA TS2, UL 514B and UL 651.

Unless encased in concrete, all Type NM conduit installed underground shall be Schedule 80 (Electric Polyvinyl Chloride-80).

The walls of the conduit shall have a smooth interior surface free from all substances which may injure any wire or cable covering such as is used on rubber covered or thermoplastic insulated wire or cable.

The bore of the conduit shall be circular in cross section and straight and true so as to pass freely a mandrel 3 ft long and ¼ in. less in diameter than the nominal inner diameter of the conduit.

The bore of bends, elbows, and other fittings shall pass freely a ball of ¼ in. less in diameter than the nominal inner diameter of the conduit. Couplings, elbows, bends, adapters, reducers, increasers and bell ends, shall be of the same material as the conduit.

The minimum acceptable radii dimensions for elbows and bends shall conform to the requirements of the NEC. Joints shall be machined to an accurate taper on both ends to permit a tight joint when assembled with suitable couplings or fittings.

One tapered joint coupling shall be supplied with each length of conduit and each elbow or bend.

At least 85% of the conduit in any lot shall be furnished in standard length; sections of conduit less than 5 ft will not be accepted. A tolerance of ±1 in. is permissible in the conduit lengths specified.

Each length of conduit and all associated fittings shall be clearly and durably marked at least every 10 ft with the manufacturer's name, trademark, or other descriptive marking by which the fabricator can be identified. The material type, trade size, and UL labelling shall also be included in the marking.

M5.07.1: Electrical Conduit-Rigid Metallic (Type RM)

Rigid Metallic Electrical Conduit and associated fittings shall conform to Article 344 of the NEC and the following:

Class 1 – Type A –UL Standard 6 – Rigid Metal Electrical Conduit.

Class 2 – Type A – UL Standard 1242 – Intermediate Metal Conduit.

Class 1 and 2 – Types B, C, and D – UL Standard 514B – Fittings for Conduit and Outlet Boxes.

Each length of conduit and all associated fittings shall be clearly and durably marked at least every 10 ft with the manufacturer's name, trademark, or other descriptive marking by which the fabricator can be identified. The material type, trade size, and UL labelling shall also be included in the marking.

M5.07.2: Electrical Conduit-Flexible Metallic (Type FM)

Flexible Metallic Electrical Conduit and associated fittings shall be liquid-tight and conform to Article 350 of the NEC and UL-360.

Each length of conduit and all associated fittings shall be clearly and durably marked at least every 10 ft with the manufacturer's name, trademark, or other descriptive marking by which the fabricator can be identified. The material type, trade size, and UL labelling shall also be included in the marking. Type FM conduit suitable for direct burial shall also be so marked.

M5.08.0: Pull and Junction Boxes – Metallic

Metallic pull and junction boxes made of cast iron, welded sheet steel or cast aluminum shall conform to UL 514A Metallic Outlet Boxes.

SECTION M6: ROADSIDE DEVELOPMENT MATERIALS

M6.00.0: General

This section describes requirements for materials used for soil amendments, seed, plant material, mulches, and other materials required for the care and establishment of plants.

M6.01.0: Inorganic Amendments

Limestone shall consist of pulverized limestone obtained by grinding either calcareous or dolomitic limestone such that 95% of the material will pass a 20 mesh sieve and at least 50% will pass a 100 mesh sieve. The limestone shall meet the applicable provisions of State and Federal laws which relate to commercial fertilizers.

Sulfur for adjustment of loam pH shall be elemental or flours of sulfur, unadulterated, and shall be delivered in containers with the name of the manufacturer, material, and net weight appearing on each container.

Gypsum for soil structure amendment and de-icing salt mitigation shall be agricultural grade, 80 percent calcium sulphate ($CaSO_4 \times 2H_2O$), in granular or slurry form, with 100% passing a 2 mm screen, and 90% passing through 150 µm screen. Gypsum may be derived from natural sources or from recycled wallboard.

Soil wetting agent shall be a synthetic, non-toxic acrylic polyacrylamide or natural soluble plant extract. Application rates shall be per manufacturer's recommendations. Submit supplier specifications and certification.

M6.02.0: Fertilizer

Fertilizer shall meet the applicable provisions of State and Federal laws and be furnished in containers plainly marked with the chemical analysis of the product.

Fertilizer for general planting shall be slow release and shall be commercial grade 10-10-10, or sufficient to meet the recommendations for soil amendment. At least 40% of the nitrogen content shall be slow release, phosphorus shall be available phosphoric acid, and potassium shall be water-soluble potash.

M6.03.0: Long Term Seed Mixes for Lawns and Slopes

The seed mixture specified for slopes and shoulders consists of a tough hardy type for use on slopes graded at the rate of 1 vertical to 4 horizontal, and steeper slopes, and on shoulders adjacent to the roadway pavement or as otherwise directed. The mixture for lawn grass plots is of a finer type that will produce finer turf.

Grass seed shall be of the previous year's crop and in no case shall the weed seed content exceed 1% by mass. All Bluegrass, Fescue, and Ryegrass shall be within top 25% of either of two most recent National Turfgrass Evaluation Program reports. The grass seed shall conform to the requirements of the following tables:

Table M6.03.0-1: Grass Seed Requirements for Lawn Grass Areas

Grass Type	Proportion	Germination Minimum	Purity Minimum
Creeping Red and/or Chewings Fescue	59%	85%	95%
Kentucky Blue	30%	85%	90%
Perennial Rye	5%	90%	98%
Redtop	5%	85%	92%
Dutch White Clover	1%	85%	96%

Table M6.03.0-2: Grass Seed Requirements for Slopes and Shoulders

Grass Type	Proportion	Germination Minimum	Purity Minimum
Creeping Red, Chewings, and/or Hard Fescue	50%	85%	95%
Tall Fescue	35%	85%	90%
Perennial Rye	5%	90%	98%
Redtop	5%	85%	92%
Dutch White Clover	5%	85%	96%

The seed shall be furnished and delivered premixed in the proportions specified above. All seed shall comply with State and Federal seed laws. Clover shall be pre-inoculated.

Contractor will supply a manufacturer's Certificate of Compliance to the specifications shall be submitted by the manufacturers with each shipment of each type of seed mix. Certificates will be attached to the seed bags for inspection. These certificates shall include the guaranteed percentages of purity, weed content and germination of the seed, and also the net mass and date of shipment. No seed may be sown until the Contractor has submitted the certificates.

M6.03.1: Short Term Erosion Control Seed

This seed shall consist of a mixture of the previous year's crop and shall contain the following mixture by weight with 98% purity:

Table M6.03.1-1: Requirements for Short-Term Erosion Control Seed

Seed Type	% by Weight	Germination Minimum
Winter Rye	80 minimum	85%
Red Fescue (Creeping)	5 minimum	80%
Perennial Rye Grass	5 minimum	90%
Dutch White Clover	3 minimum	90%
Other Crop Grass	0.5 maximum	
Noxious Weed Seed	0.5 maximum	
Inert Matter	1.0 maximum	

A manufacturer's certificate of compliance will be required as specified in M6.03.0: Long Term Seed Mixes for Lawns and Slopes.

M6.04.0: Mulch

Materials to be used in mulching shall conform to the following requirements:

M6.04.1: Hay Mulch

Hay Mulch shall consist of mowed and properly cured grass, clover or other acceptable plants.

M6.04.2: Straw Mulch

Straw Mulch shall be seed free, consisting exclusively of stalks or stems of grain after threshing.

M6.04.3: Wood Chip Mulch

Wood chip mulch shall consist of wood chips produced by cutting branches, limbs of trees, brush or shrubs with chippers or from the chipping of stumps, and shall be free of topsoil, stones, and other extraneous material. The chippers shall be approved for use by the Engineer. Wood chip mulch must be free from long stringy material over 4 in. in length and from live, rot-free wood and bark, except that 35% or less by volume of the wood chip mulch may consist of "slab wood," chipped to an acceptable size by chippers equipped with a ¼ in. knife set and thoroughly mixed with the live material. Wood Chip Mulch containing an excess of fine particles, such that mulch will blow or wash away, decay too quickly, or percolate too slowly, will not be acceptable. Wood Chip Mulch may be produced on the project from acceptable cuttings. Wood chip mulch containing remnants of invasive species such as Japanese Knotweed and Bittersweet shall not be used.

M6.04.4: Wood Fiber Mulch

Wood Fiber Mulch shall consist of wood fiber produced from clean, whole uncooked wood, formed into resilient bundles having a high degree of internal friction and shall be dry when delivered on the project. Recycled material may be evaluated for acceptance based on evaluation of submitted sample, specifications and certified test results from an approved laboratory, per the requirements of M1.06.0: Organic Soil Additives.

M6.04.5: Aged Pine Bark Mulch

This mulch shall consist of the outer bark of pine trees and a minimum of hardwood bark. Bark shall be processed by removal from the limbs and trunks of trees.

Bark mulch shall be shredded pine bark aged a minimum of 6 months. The mulch shall be dark brown in color, free of chunks and pieces of wood thicker than ¼ in. and shall not contain, in the judgment of the Engineer, an excess of fine particles. Do not use wood chips, recycled, dyed, wood product, or crumb rubber mulch.

Mulch must be free from long stringy material.

M6.05.0: Sod

Sod shall be composed of the grass mixture recommended by the New England Sod Producer's Association and shall be specified as:

Table M6.05.0-1: Sod Type 1 for Full Sun Turf Areas (6 or More Hours Direct Sunlight in Growing Season)

Species	Percent by Turf Area*
Kentucky Bluegrass	50% to 80%
Fine Fescues	10% to 30%
Perennial Ryegrass	0 to 20%
* All species with >70% of the mix shall have at least 3 varieties; >40% shall have at least 2 varieties.	

Table M6.05.0-2: Sod Type 2 for Partial Shade Turf Areas (4 to 6 Hours Minimum Direct Sunlight in Growing Season)**

Species	Percent by Turf Area*
Fine Fescues	75% to 90%
Kentucky Bluegrass	10% to 25%
Perennial Ryegrass	0 to 10%
* All species with >70% of the mix shall have at least 3 varieties; >40% shall have at least 2 varieties. ** Areas receiving less than 4 hours per day of direct sun during growing season should not receive sod.	

Table M6.05.0-3: Sod Type 3 for Multi-Use Turf Areas (and 4 to 6 Hours Minimum Direct Sunlight in Growing Season)

Species	Percent by Turf Area*
Tall Fescue	50% to 90%
Fine Fescues	20% to 50%
Kentucky Bluegrass	0 to 20%
Perennial Ryegrass	0 to 20%
* All species with >70% of the mix shall have at least 3 varieties; >40% shall have at least 2 varieties. ** Areas receiving less than 4 hours per day of direct sun during growing season should not receive sod.	

Lawn sods shall have been nursery grown on cultivated agricultural land used specifically for sod purposes. Grasses shall be drought tolerant cultivars.

The sods shall be free of objectionable grassy and broadleaf weeds. Sods shall be considered free of such weeds if less than 5 such plants are found per 10 yd² of area.

The sod shall be machine cut at a uniform minimum thickness of ¾ in. at the time of cutting. Measurement for thickness shall exclude top growth and thatch.

Individual pieces of sod shall be cut to the supplier's standard width and length. Maximum allowable deviation from standard widths and lengths shall be 5%. Broken pads and torn or uneven ends will not be acceptable.

Sod that has dried out, or that has been unplanted over 3 days (including weekends) since harvest, will be rejected.

M6.06.0: General Planting

The Contractor shall furnish all plants as shown on the plans.

M6.06.1: Nursery Stock – General

All scientific and common plant names of the items specified shall conform to the current edition of Hortus Third, compiled by the staff of the L.H. Bailey Hortorium, Cornell University. These standards shall determine all requirements of acceptable shrub and seedling nursery stock names. All plants will have durable, non-fading labels applied at the nursery that clearly bears the correct botanical name, including cultivar, as well as common name and size. Caliper or spread shall govern over height specifications. The Contractor must obtain written permission from the Engineer for any substitutions of types or sizes specified.

All plants shall be grown in a certified nursery. All plants shall be typical of their species or variety in growth habit. Plant sizes, habit, rootball dimensions, stem and cane count shall conform to the requirements of the American Standards for Nursery Stock (ASNS) standards as a minimum requirement for acceptance. Container sizes shall also be consistent with the guidance per plant size per the ASNS. Each plant shall have plenty of fibrous roots, healthy buds, and shall be free of disease and insect pests. No plant material from cold storage will be accepted. All plant parts shall show active green cambium when cut and shall be densely foliated when in leaf.

Deciduous shrubs shall have 4 to 6 canes coming from the roots and shall have a well-branched root system.

Vines and ground cover shall be minimum 2-year No. 1 stock. Herbaceous plants shall be minimum 1-year No. 1 stock, and clumps shall have not less than 6 buds, eyes, or crowns.

The trunk of each tree shall be free from sunscald, frost cracks, or wounds resulting from abrasions, animal pest, fire or other causes. Pruning wounds shall be no larger than 2 in. and shall show vigorous scar tissue. No trees with double-leaders or twin-heads will be acceptable without the written approval. The plants must be in a vigorous condition and free from dead wood, bruises and other root or branch injuries. Deficient plants may be rejected at any time.

Any species (including all cultivars) listed on the Massachusetts Department of Agricultural Resources Prohibited Plant List shall not be used including but not limited to the following:

Norway Maple (*Acer platanoides*)
Sycamore Maple (*Acer pseudoplatanus*)
Japanese Barberry (*Berberis thunbergii*)
Autumn Olive (*Eleagnus umbellata*)
Burning Bush or Winged Euonymus (*Euonymus alatus*)
Glossy or European Buckthorn (*Frangula alnus*)
Dames Rocket (*Hesperis matronalis*)
Yellow Iris (*Iris pseudoacoris*)
Border Privet (*Ligustrum obtusifolium*)
Honeysuckle -- Japanese, Amur, Morrow's, Tatarian, Bell's (*Lonicera japonica, L. maackia, L. morrowii, L. morrowii x tartarica*)
Plume grass (*Miscanthus sacchariflorus*)
Forget-me-not (*Myosotis scorpoides*)
Reed Canarygrass (*Phalaris arundinacea*)
Amur Cork Tree (*Phellodendron amurense*)
Common Buckthorn (*Rhamnus cathartica*)
Black Locust (*Robinia pseudoacacia*)
Wild Rose (*Rosa multiflora*)

M6.06.2: Nursery Stock – Balled and Burlapped

All plants that are to be balled and burlapped previous to shipment are designated "B&B." B&B plants shall be dug so as to retain as many fibrous roots as possible. All B&B plants shall come from soil that will hold a firm root ball and the solidity of the ball shall be carefully preserved. B&B plants shall be wrapped with untreated 8-oz burlap, firmly held in place by a stout cord or wire. Wire containers shall be of adequate size to allow root development for the plant size as per ASNS requirements. Plants prepared with plastic or other non-biodegradable wrappings will not be accepted. Rootballs shall remain intact during all operations. No plant will be accepted if the rootball has been cracked or broken prior to, or during, the process of planting. All plant materials shall be dug with reasonable care and skill immediately prior to shipment.

M6.06.3: Nursery Stock – Container Grown

All container grown plants shall be healthy, vigorous and well rooted in the container in which they are sold. They shall have tops that are of good quality and are in healthy growing condition. No single-stemmed shrubs or sparsely leafed plants will be accepted. The side branches must be generous and well twigged, and the plant as a whole must be well-branched to the ground or typical of the species or cultivar. Container-grown stock shall have been grown in the container long enough for the root system to develop sufficiently to hold the soil together firmly. No plants shall be loose in the container. Container-grown plants shall not be pot bound with spiraling roots or roots growing densely against the sides of the container. The container shall be sufficiently rigid to protect the root mass during shipment and sizes shall be provided in accordance with the ASNS standards. The size of plant, as well as minimum number of stems or canes, will conform to the type of plant per ASNS standards.

The soil medium for container-grown plant material shall be a uniformly blended, stable medium free from weeds, weed seeds, disease organisms, insects, herbicide residue, and all other harmful organisms or materials. The soil shall fill the container to at least 85% of its height, serving as a stable base for the anchorage and support of the plant growing in it. It shall be well-aerated sandy loam or fine sandy loam, per USDA Soil Classification, and of sufficient structure to provide adequate moisture to plants.

The certificate of compliance for container grown plants shall contain, in addition to the requirements listed in 771.40: General, the guaranteed composition of the potting mixture and the date of planting in the container. Plants shall have been grown in the container for a minimum of 12 weeks. A random sample is required from each delivery for soil and root inspection upon request of the Engineer.

M6.06.4: Nursery Stock – Bare-Root

Bare-root material shall be dug during dormancy within 72 hours of shipping and shall be kept moist and stored in a cool, shaded location until planting. All bare-root material shall be accompanied by certification of digging date. The roots of bare-rooted material shall be dipped in soil wetting agent and carefully protected with wet straw, moss or other suitable material that will ensure the arrival of the plants at the site of the work in good condition. All bare-root material shall be installed within 48 hours of arrival on the construction site, and shall be kept moist and out of wind or direct sunlight until planting. Maximum time between digging for shipping and installation shall be one week.

M6.06.5: Nursery Stock – Seedlings

Seedlings shall have well developed root systems and shall be acclimated and suitable in all respects for field planting. All conifers must have dormant buds and secondary needles.

Evergreen seedlings shall be two year transplants, bare rooted.

Lining out stock seedlings shall be two year seedlings.

Root cuttings shall be established in peat pots 2.5 in. deep by 2 in. wide at the open end and tapered to 1 in. wide at the closed end (inside measure).

M6.06.6: Nursery Stock – Trees

Per the requirements of the ASNS, the sizes of trees shall be as called for on the plans and measurements shall be determined by caliper at a point 6 in. above the ground for plants specified up to 4 in. in caliper. Larger minimum caliper shall be measured 12 in. from ground.

Trees for streetscape plantings (i.e., in or adjacent to walkways) shall have a single straight leader not cut back.

They shall have a symmetrical development of strong, healthy branches beginning at least 7 ft from the ground; and below this point, the trunk shall be clean for street trees. Coniferous Evergreens shall be dug before spring “candling” of new growth.

Grafted and budded trees may branch lower and be pruned off 2 ft from the ground where directed. Flowering trees shall be balled and burlapped and kept moist for delivery.

M6.06.7: Nursery Stock – Shrubs, Vines, Groundcover and Perennials

Shrubs shall have the form required per ASNS. Specified spread shall govern over height requirements.

Vines and ground cover in this group shall be 2 year, No. 1 stock.

Herbaceous plants in this group shall be minimum 1 year, No. 1 year stock, and clumps shall have not less than 6 buds, eyes or crowns.

M6.07.0: Delivery and Protection

All plants shall be packed so as to arrive at the delivery point in good growing condition and shall be kept moist for delivery and during transit. Special precautions shall be taken to avoid any unnecessary injury to, or removal of, fibrous roots. Each species or variety shall be handled and packed in the approved manner for that particular plant having regard to the soil and climatic conditions at the time and place of digging, transit and delivery, and to the time that will be consumed in transit. All precautions that are customary in good trade practice shall be taken to ensure the arrival of the plants at the site of the project in good condition for successful growth.

Shipment of plant material shall be scheduled to minimize the time between arrival and installation at the construction site. Plants may be stored at the construction site for up to 3 days on in an approved location that is out of direct sunlight and wind. Contractor shall store plants in wood chips and shall provide watering to maintain containers and root balls in moist condition at all times prior to installation.

M6.07.1: Wrapping for Transport

Wrapping material shall be used for transport only. Wrapping material for root balls shall be 8-ounce jute burlap; plastic is not acceptable. Material for tree trunks shall be 4 to 6 in. wide strips of burlap, paper, cardboard, or plastic manufactured for this purpose. Fastening for the wrapping material shall be either adhesive weather resistant tape or a minimum of 3-ply jute twine. Wrapping must be removed once tree has been installed.

M6.08.0: Materials for Guying and Staking

The stakes shall be unpainted spruce or other suitable wood free from large knots, dimensioned 2x2 by 8 ft in length and sharpened at one end. Binding and guying shall be biodegradable webbing. Stake fastenings shall be 10 penny galvanized nails. Trees shall not be wrapped.

M6.08.1: Temporary Fencing for Tree Protection

Temporary Tree Protection Fence shall be brightly colored polypropylene barricade or wooden snow fencing for tree protection or safety fencing. Fencing shall be a minimum of 4 ft high and supported by steel or hardwood stakes spaced at a maximum of 8 ft on center or by other means acceptable to the Engineer.

M6.08.2: Trunk Cladding for Tree Protection.

Cladding for trunk protection shall be 2x4 or 2x3 nominal lumber, at least 6 ft in length, sufficiently tall to protect tree trunk from construction activities, and bound together with wire. Alternatively, trunks may be shielded with sections of corrugated plastic pipe of sufficient diameter and height to

shield trunk from construction activities. Trunk protection shall include burlap, which shall be untreated 8-oz burlap.

M6.08.3: Sheeting for Tree Root Protection

Sheeting for tree root protection shall be minimum ¾-in. thickness plywood, cut and trimmed to required sizes and configurations.

M6.09.0: Water for Irrigation

Water used for irrigation of plant materials shall be free from any substance injurious to vegetation, such as oil, acids, alkalis and salts. Water shall be free from impurities injurious to vegetation.

Submittal shall be required, including anticipated demand, irrigation method, watering schedule, sources of water, and any incidental work required to provide water for the plants.

SECTION M7: PAINTS, PROTECTIVE COATINGS AND PAVEMENT MARKINGS

M7.00.0: General Requirements for Paints and Protective Coatings

All paint shall conform to the following general requirements.

1. Materials.

The raw materials used in the following specifications for paints and protective coatings shall conform to the specification designed by ASTM or AASHTO specifications.

2. Proportions.

Paint proportions and percentages given in the following specification are expressed by weight.

3. Condition in the container.

Paint and protective coatings shall be homogeneous, free of contaminant and of a consistency suitable for use in the capacity for which it is specified. The finished product shall be well ground and the pigment shall be properly dispersed and suspended in the vehicle according to the requirements of the paint or protective coating. The dispersion shall be of such nature that the pigment does not settle badly, does not cake or thicken in the container, and does not become granular, jelled or curdled. Any settlement of pigment in the paint or protective coating shall be a thoroughly wetted soft mushy mass permitting the complete and easy vertical penetration of a paddle. Settled pigment shall be easily dispersed, with a minimum resistance to the sidewise manual motion of the paddle across the bottom of the container, to form a smooth uniform product of the proper consistency.

4. Packaging.

The finished paint or protective coating shall be furnished in new 5-gal, round, non-tapered containers. The containers shall meet U.S. Department of Transportation Hazardous Materials Shipping Regulations.

The following information shall be labeled on each can in a clear legible manner:

a) Name of Manufacturer
b) Place of Manufacture
c) Manufacturer's Batch Number
d) MassDOT Specification Number
e) Date of Manufacture

Precautions concerning the handling and the application of the paint or protective coating shall be shown on the label.

5. **Testing.**

Testing of paints will be done by the Department in accordance with the methods of Federal Test Method Standard Number 141, AASHTO and ASTM methods described below.

In addition, the Department reserves the right to make use of any information or methods of testing to determine the quality of paint and paint materials.

M7.01.0: Pavement Markings

- M7.01.05 White Traffic Paint
- M7.01.06 Yellow Traffic Paint
- M7.01.08 White High Heat Rapid Drying Traffic Marking Material
- M7.01.09 Yellow High Heat Rapid Drying Traffic Marking Material
- M7.01.10 Fast Drying White Traffic Paint
- M7.01.11 Fast Drying Yellow Traffic Paint
- M7.01.12 Striping Powder
- M7.01.14 Black Non-Reflective Lane Tape
- M7.01.15 Black Traffic Paint
- M7.01.16 White and Yellow Temporary Reflective Lane Tape
- M7.01.18 Preformed Permanent Plastic Pavement Markings or Legends
- M7.01.21 Green Pavement Coatings
- M7.01.23 Fast Drying White Water-borne Traffic Paint
- M7.01.24 Fast Drying Yellow Water-borne Traffic Paint

M7.01.3 Liquid Thermoplastic Striping Material

A. General.

This specification covers a reflectorized thermoplastic pavement striping material that is extruded onto the pavement in a molten state by mechanical means with the application of glass beads. When applied properly and at the designated thickness and width the stripe shall, upon cooling, be reflectorized and be able to resist deformation by traffic. The material shall be placed on bare pavement or existing thermoplastic markings.

Materials

Prequalified batches of acceptable thermoplastic materials are listed on the QCML.

All thermoplastic material shall meet the requirements of AASHTO M 249 and tested in accordance with AASHTO T 250 and the following:

1) Glass Beads (Pre-Mix) used in the manufacture of thermoplastic shall be uncoated and meet the requirements of AASHTO M 247, Type I and M7.01.07 and have a minimum of 80% true spheres.
2) The resin shall be alkyd or hydrocarbon and meet the requirements of table M7.01.3-1.

Table M7.01.3-1 Thermoplastic Resin Requirements

Properties	Hydrocarbon	Alkyd
% Binder, Minimum	22	20
Indentation Resistance @ 115°F, ASTM D7735	--	40-75 units (Type A)
Bond Strength, Minimum, psi	180	200

The material manufacturer shall have the option of formulating a hydrocarbon resin-based or an alkyd resin-based system. However, the physical and chemical properties contained in this specification shall apply regardless of the type of formulation used. The binder must consist of a mixture of resins, at least one of which is a solid at room temperature, and high boiling point plasticizers. At least one third of the binder composition of an alkyd-based system must be maleic-modified glycerol ester of rosin and must be no less than 8% of the entire material formulation. Material of either binder type upon heating to the application temperature shall not evolve fumes which are toxic, or injurious to persons or property. The pigment, beads and filler shall be well dispersed in the resin. The material shall be free from all skins, dirt, and foreign objects.

The thermoplastic pavement marking material may be supplied in block or granular form. Block material shall be packaged in suitable containers to which it will not adhere to during shipment or storage. The blocks shall be approximately 12 in. x 36 in. x 2 in. Granular material shall be packaged in bags that when introduced to the mix hopper of the application equipment, it will become part of the mix with no adverse effect to the performance of the thermoplastic material. The packages of either type shall weigh approximately 50 lb. Each container label shall designate the color, manufacturer's name, batch number and date of manufacture. Each batch manufactured shall have its own separate number. The label shall warn the user that the material shall be heated in the range of 400°F-425°F during application.

B. Sampling and Testing

1. Sampling

Provide one bag of thermoplastic material for verification testing per batch. A batch is a unit of production that is consistent in appearance, formulation, proportions and can be identified by a unique number know as a Batch Number. Each batch shall consist of a minimum of 3,000 lb and a maximum of 44,000 lb.

2. Testing

Tests on White and Yellow Thermoplastic Striping Material shall be reported by an Independent Testing Laboratory and performed in accordance with these Specifications and AASHTO T 250.

The Independent Test Results shall be for each batch and shall identify the material by manufacturer including name and address, batch number(s), date and place of manufacture and any other information that will assist in identifying the product. It shall also note the test method used for each test. The report shall include the date tested and shall be signed by a person responsible for authenticating the veracity of the test. Below the signature shall be the person's printed name and title.

Request for prequalification for each thermoplastic material batch shall be submitted to RMS, accompanied by:

a) Certificate of Compliance stating that the material complies with AASHTO M 249, AASHTO T 250, this specification and all applicable MassDOT requirements.
b) Independent Lab test results; and

c) One bag of thermoplastic striping material per batch in sample bags meeting the specifications above for verification testing. The bag shall be sent to the attention of the Director of Research & Materials, MassDOT/Highway, 5 Macadam Road, Hopkinton, MA 01748.

M7.01.07: Glass Beads

This specification covers the requirements for glass beads which are to be dropped or sprayed on pavement markings. Glass bead suppliers and approved batch numbers are listed on the QCML.

All glass beads shall meet the requirements of AASHTO M 247, and be tested in accordance with AASHTO T 346 and the following:

1. A minimum of 80% of the glass beads shall be true spheres when tested in accordance with ASTM D1155, Procedure A.
2. The glass beads shall be manufactured from commercial grade soda lime glass cullet and shall meet the AASHTO concentration for heavy metals, 200 ppm maximum, as tested in accordance with EPA test methods 3052, 6010B and 6010c, or AASHTO T 392. The silica content shall be 60% minimum (ASTM C169).
3. Moisture Resistance - The Type 1 and Type 4 glass beads shall be treated with a moisture proof coating and be moisture resistant as tested by AASHTO T 346, Referee Method.
4. Adherence - The Type 4 glass beads shall be coated with a silane-type adherence coating to enhance embedding in, and adherence to, the applied binder film. The coated beads shall emit a yellow-green fluorescence when tested by the Dansyl Chloride test procedure.
5. Intermix glass beads used in the manufacture of thermoplastic pavement markings shall meet the requirements of AASHTO M 247, Type 1 glass beads. A moisture proof coating is optional.

A. Gradation.

The glass beads shall be tested in accordance with ASTM D1214 (By use of U.S. Standard Sieves).

Standard gradation beads shall meet the requirements of AASHTO M 247, Type 1.

Large gradation beads shall meet the requirements of AASHTO M 247, Type 4.

B. Packaging.

The beads shall be packaged in 50-lb or greater polyethylene-lined burlap bags or equal container; such containers guaranteed to furnish dry and undamaged beads. The following information shall be indelibly labeled in a clear and legible manner on each container:

(a) The name of the manufacturer.
(b) The place of manufacture.
(c) The words: "Glass Beads-Traffic".
(d) Size/Type/Coating.
(e) Materials Specification Number.
(f) The date of shipment (month and year).
(g) The batch number.
(h) Net weight.

C. Approval Procedure.

Requests for approval shall be submitted to the Department accompanied by:

a. Certificate of Compliance stating that the material complies with AASHTO M 247, and tested in accordance with AASHTO T 346 and all applicable MassDOT requirements;
b. Independent lab test results; and
c. One bag of glass beads per batch in sample bags meeting the specifications above for verification testing.

M7.02: Structural Paint

1. General

New coatings systems shall be a low VOC that meets current VOC regulations. Coating systems shall be selected from the MassDOT QCML-NEPCOAT Qualified Products List "B." Structural paint will be tested according to the following:

- ASTM D 562 Consistency
- ASTM D 1475 Density
- ASTM D3723 Pigment
- ASTM D 2369 Volatile Content
- AMS STD 595 Federal Color Index

2. Sampling

a. QCML

Each year manufacturers shall send samples of each product for each color to be used to The Department for testing. Approved paint products and colors will be posted on the QCML. If Paint products are not listed on QCML but are Nepcoat qualified products, samples shall be obtained from the project site. Samples must be taken in clean, dry, airtight, widemouthed metal quart cans. The sample container must be filled within 2 in. from the top of the can and sealed properly. Each sample must be labeled with the name of the manufacturer, brand, coat, and color prior to shipping to the Department.

b. Project Site samples

Samples from project sites are not required if the paint to be used on the project is on the QCML. If samples are obtained from the project, paint must be agitated by the contractor before sampling. Contractors shall not combine individual paint components prior to sampling. One quart sample shall be taken in containers described below. All samples shall be from the same batch.

Samples must be taken in clean, dry, airtight, widemouthed metal quart cans. The sample container must be filled within 2 in. from the top of the can and sealed properly. Each sample must be labeled with the name of the manufacturer, brand, coat, and color prior to shipping to the Department.

Project paint quantities of 40 total gallons or less shall not require sampling and testing. In lieu of sampling and testing, the contractor shall submit a letter stating the total amount of paint to be used on the project will be 40 gallons or less. A manufacturer's certificate of compliance shall be submitted with the letter.

M7.03: Enamels

- M7.03.02 Sign and Equipment Enamel

M7.04: Miscellaneous Coatings

- M7.04.01 Coal Tar Protective Coatings
- M7.04.02 Primer, Paint, Exterior, (Undercoat for Wood, Ready Mixed White and Tints)
- M7.04.03 Paint, Zinc Yellow, Iron Oxide Base Ready Mixed (Type II)
- M7.04.04 Paint, Ready Mixed, International Orange
- M7.04.05 Paint, Exterior, Black Ready Mixed
- M7.04.06 Primer Coating, Basic Lead Silico Chromate, Ready Mixed
- M7.04.07 Primer Coating, Zinc Dust-Zinc Oxide (for galvanized surfaces)
- M7.04.08 Enamel Undercoat Interior, Tints and White
- M7.04.09 Paint, Outside, Dull-Black (Formula 104)
- M7.04.10 Primer, Pretreatment (Formula 117 for Metals)
- M7.04.11 Paint, High Zinc Dust Content, Galvanizing Repair

M7.05: Epoxy Protective Coating

- M7.05.01 Epoxy- Polyamide Red Lead Paint
- M7.05.02 Epoxy- Polyamide Green Paint
- M7.05.03 Epoxy - Polyamine Concrete Coating
- M7.05.05 One Coat High Build Epoxy Mastic Coating
- M7.05.11 Epoxy - Polyamide Primer Paint (non-lead)
- M7.05.12 Brown Epoxy - Polyamide Top Coat (non-lead)
- M7.05.13 Green Epoxy - Polyamide Top Coat (non-lead)
- M7.05.15 One Coat Hi Build Mastic Coating
- M7.05.21 Coal Tar Epoxy Polyamide Paint
- M7.05.31 Self-Priming Epoxy Coating

Or those coatings listed in the QCML.

M7.10.0: Galvanized Coatings

Galvanized coatings shall conform to the following requirements:

- ASTM A143 – Standard Practice for Safeguarding Against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement.
- ASTM A384 – Standard Practice for Safeguarding Against Warpage and Distortion During Hot-Dip Galvanizing of Steel Assemblies.
- ASTM A385 – Standard Practice for Providing High-Quality Zinc Coatings (Hot-Dip).
- ASTM B6 – Standard Specification for Zinc. A range of 0.05% to 0.09% nickel (by weight) shall be added to the galvanizing bath.
- ASTM B695 Standard Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel.
- AASHTO M 111M/M 111 –Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products.
- AASHTO M 232M/M 232 – Zinc Coating (Hot-Dip) on Iron and Steel Hardware.

M7.15.0: Metallized Coatings

The wire used for metallizing shall be zinc or 85/15 zinc/aluminum per ASTM B833, Standard Specification for Zinc Wire for Thermal Spraying (Metallizing). All thermal spray wire must be manufactured domestically.

M7.20.0: Anodized Coatings

Aluminum extrusions to be anodized shall be finished in a dark bronze Architectural Integral-Color Anodized finish conforming to Aluminum Association designation AA-M10-C22-A44. The anodic coating shall be Aluminum Association Architectural Class 1 with a minimum thickness of 0.7 mils and a minimum weight of 35 mg/in^2.

Prior to production, the finisher shall submit surface smoothness samples and color range samples to RMS for the Engineer's approval, to establish inspection limits of allowable surface smoothness and allowable color shade range.

Samples of anodized extrusions from production lots, as selected by the Engineer, shall be tested in accordance with ASTM B137, ASTM B244 and ASTM B136.

M7.25.0: Powder Coatings

Aluminum to be powder coated shall be finished in a dark bronze powder coat finish to match the color of the anodized extrusions. The coating shall be a polyester-TGLC (triglycidyl isocyanurate) resin system conforming to the following:

Table M7.25.0-1: Physical and Mechanical Properties of Powder Coatings

Quality	Test	Limits
Abrasion	ASTM D4060 Taber Abraser CS-10, 1,000 gram load, 1,000 cycles	100 mg maximum weight loss
Adhesion	ASTM D3359 Initial - 1,000 hours -	 5A 5A
Gloss	ASTM D523 60°F - 600 hours 60°F - 1,000 hours	 82% Retention 90% Retention (washed)
Hardness	ASTM D3363	2H – No Gouge
Impact	ASTM D2794, Direct	Pass 80 in.-lb.
Salt Spray Resistance	ASTM B117, ASTM D1654 1,000 hours unscribed - 400 hours Scribed -	 Table 2 - 10 Table 1 - 10
Weather	ASTM G23 1,000 hours, 18 minutes Waterspray, 102 minute Light	No film failure
Color	Dark Bronze, to match color of anodized aluminum framework	n/a
Identify	Infrared Fingerprint	Match
Flexibility	180° bend with ½-in. diameter mandrel within 10 seconds	No breaks, flaking or cracks Tested with a Q- panel with 2 mils or less of coating
Humidity	ASTM D2247, 1,000 hours	No blister or film failure
Thickness	n/a	4 ±1 mils
Mar Resistance	n/a	Good

Aluminum to be powder coated shall be bare and free of oil or any mill coating. The aluminum shall be caustic cleaned to standard near white. A chromic conversion coating shall be applied after caustic cleaning. The finish coating shall be applied immediately after chromic coating as an electrostatically charged dry powder, sprayed onto the grounded aluminum using an electrostatic spray gun. The coated aluminum shall be heated in accordance with the powder manufacturer's recommend procedure to provide a fully cured finish. The coating thickness after cure shall be a minimum of 3 mils.

Prior to production, the coater shall submit a 3 ft by 1 ft coated sample and color range samples to RMS for the Engineer's approval to establish inspection limits of allowable coating coverage and color shade range.

All stainless steel fasteners shall be colored by a thermal conversion process to match the dark bronze color of the aluminum extrusions. The finish shall be such that it does not peel, chip or crack. Samples of all fasteners shall be submitted along with material certificates to the Engineer for approval.

SECTION M8: METALS AND RELATED MATERIALS

M8.00.0: General

All structural steel and miscellaneous steel products shall be welded in accordance with the requirements of the AASHTO/AWS Bridge Welding Code (ANSI/AASHTO/AWS D1.5). All aluminum material shall be welded in accordance with the AWS Structural Welding Code - Aluminum (ANSI/AWS D1.2). All stainless steel material shall be welded in accordance with the AWS Structural Welding Code – Stainless Steel (ANSI/AWS D1.6). All steel tubular material shall be welded in accordance with the AWS Structural Welding Code - Steel (ANSI/AWS D1.1). All steel reinforcing shall be welded in accordance with the AWS Structural Welding Code – Reinforcing (ANSI/AWS D1.4).

Aluminum castings shall be of uniform quality and condition, free from cracks, blow holes, porous places, hard spots or shrinkage defects which affect the suitability of the castings for their intended use.

Sampling and Testing. Samples for testing shall be taken in accordance with the applicable ASTM and/or AASHTO specification for the material. Testing will be done in accordance with latest standard procedures of ASTM and/or AASHTO.

M8.01.0: Reinforcing Bars

Reinforcing bars shall consist of deformed bars rolled from new billet steel conforming to the requirements of AASHTO M 31M/M 31, Grade 60. Spiral reinforcement for columns shall be plain steel meeting the requirements of AASHTO M 31M/M 31, Grade 60.

Steel for reinforcing shall be free from imperfections, dirt, loose scale, paint, oil, or other foreign substance that might tend to prevent bonding with concrete. Rust that occurs in scales or that pits the steel will be considered an imperfection. Surface rust will not be considered an imperfection, but the surface shall be brushed to remove loose material.

M8.01.1: Cold Drawn Steel Wire

This material shall conform to AASHTO M 336M/M 336.

M8.01.2: Welded Steel Wire Fabric

This material shall conform to AASHTO M 336M/M 336.

M8.01.3: Steel Bar Mats

This material shall conform to AASHTO M 54M/M 54.

M8.01.4: Tie Bars and Bolts

Tie bars for longitudinal joints shall be either deformed bars of new billet steel (AASHTO M 31M/M 31, Grade 60) or approved tie bolts as shown on the plans which shall conform in all respects to the standard require-ments specified for strength and design.

M8.01.5: Anchor Bolts, Nuts and Washers

All bolts, nuts and washers, with the exception of those with weathering characteristics, shall be galvanized in accordance with AASHTO M 232M/M 232.

Used For Anchoring Bridge Railing Base Plates to Concrete

Bolts, nuts, and washers shall conform to the requirements of ASTM F1554 Grade 105.

Used For Anchoring Bridge Bearings to Concrete

Bolts, nuts, and washers shall conform to the requirements of ASTM F1554 Grade 105.

Used For Anchoring Signal Lighting and Sign Structures

Bolts, nuts, and washers shall conform to the applicable requirements of one of the following:

- AASHTO M 31 Type W Grade 60
- AASHTO M 314 Grade 36
- AASHTO M 314 Grade 55
- AASHTO M 314 Grade 105
- ASTM F1554 Grade 55
- ASTM F1554 Grade 105

Notes:

1. Nuts and washers for the above shall be suited to the approved bolts.
2. Hooked smooth bars and anchor bolts shall not exceed 55 ksi.

High Strength Bolts

High strength bolts, where specified, shall conform to M8.04.3: High Strength Bolts. A galvanized hexagon nut, leveling nut and flat washer shall be furnished with each bolt.

M8.01.7: Epoxy Coated Reinforcing Bars

Epoxy coated reinforcing bars shall be bars conforming to M8.01.0: Reinforcing Bars shall be epoxy coated in accordance with ASTM A775/A775M and tested in accordance to AASHTO T 285.

M8.01.8: Galvanized Reinforcing Bars

Galvanized Reinforcing Bars shall be bars conforming to M8.01.0: Reinforcing Bars and shall be galvanized in accordance with ASTM A767.

M8.01.9: Mechanical Reinforcing Bar Splicer

Mechanical reinforcing bar splicers are devices to join two steel reinforcing bars subject to tension and compression. All mechanical reinforcing bar splicers shall meet the following requirements:

Table M8.01.9-1: Requirements for Mechanical Reinforcing Bar Splicers

Description	Test Method	Requirement
Ultimate Tensile Strength of Mechanical Splicer System	ASTM A1034 (Monotonic Tension Test)	100% of ultimate tensile strength of reinforcement bars per AASHTO M31
Allowable Slip	California Test No. 670 – Slip Test	0.01 in., maximum for #14 and smaller bars, 0.03 in. maximum for #18 bars

The mechanical splicer coating shall be consistent with the reinforcement to be spliced; therefore, uncoated splicers shall be used for uncoated rebar, epoxy coated splicers for epoxy coated rebar, and galvanized splicers for galvanized rebar. The mechanical splicer coating shall be in conformance with the applicable requirements of M8.01.7: Epoxy Coated Reinforcing Bars or M8.01.8: Galvanized Reinforcing Bars. The mechanical reinforcing bar splicer system shall be evaluated with the applicable coating.

Mechanical reinforcing bar splicers shall be tested for conformance with the above requirements. Reinforcing bar splicers that meet these requirements (coated or uncoated) shall be placed on the QCML. Only products listed on the QCML are acceptable for use.

Damage to the mechanical reinforcing bar splicer coating shall be repaired in accordance with 901.62: Reinforcement. For mechanical splicer systems that cannot be effectively sealed with an epoxy or galvanizing repair coating they shall be protected with an approved corrosion protection wrap system listed on the QCML.

M8.02.0: Drilled Steel Rods

This material shall conform to the requirements of AISI – W1.

M8.03.0: Iron Castings

Gray Iron Castings shall conform to the requirements of AASHTO M 105, Class 35B. Test bars shall conform to the requirements of tension test specimen B with a minimum of 1 in thread on each end. The thread size shall be 1 ⅛ in. – 7 UNC. Ductile Iron Casting for double grates shall conform to the requirements of ASTM A536 Grade 80-55-06. Test bars shall conform to the requirements of standard round tension specimen (2 in gage length) with a minimum of 1 in. thread on each end. The thread size shall be ⅞ in. – 9 UNC.

All iron castings shall conform to the requirements of AASHTO M 306 and shall be manufactured true to pattern in form and dimensions, free from pouring faults, cracks, blow holes and other defects affecting their strength and value for the service intended. The casting shall be boldly filleted at angles and the arises shall be sharp and perfect. The surfaces shall have a workmanlike finish.

M8.03.2: Steel Castings

Type A-3 grates shall be cast to the dimensions shown on the plans and composed of cast steel conforming to the requirements of AASHTO M 103M/M 103, Grade 65-35, full anneal.

Steel castings shall be true to pattern in form and dimensions, without sharp unfilleted angles or corners and shall be free from pouring faults, sponginess, cracks, blow holes and other defects in positions affecting their strength and value for the service intended.

Castings shall be shot blasted prior to painting. Painting shall consist of a coating system approved by RMS.

M8.04.1: Stud Shear Connectors

1. General Requirements.

B. Shear connector studs shall be of a design suitable for end welding to steel beams and girders with automatically timed stud welding equipment. Ferrules shall be kept clean and dry and stored at a temperature of 60°F.
C. An arc shield (ferrule) of heat-resistant ceramic or other suitable material shall be furnished with each stud. The material shall not be detrimental to the welds or cause excessive slag and shall have sufficient strength so as not to crumble or break due to thermal or structural shock before the weld is completed.
D. Flux for welding shall be furnished with each stud, either attached to the end of the stud or combined with the arc shield for automatic application in the welding operation.
E. Studs shall not be painted or galvanized.
F. All studs shall be qualified by AASHTO/AWS D1.5 of the Bridge Welding Code.
G. Before placing orders for studs, the Contractor shall submit to the Engineer for approval, the following information on the studs to be purchased:
    1. The name of the manufacturer.
    2. A detailed description of the stud and arc shield to be furnished.
    3. A certification from the manufacturer that the stud is qualified as specified in Paragraph 1.E hereinbefore.
    4. A copy of the qualification test report as certified by the testing laboratory.
H. The studs, after welding, shall be free from any defect or substance which would interfere with their function as shear connectors.

2. Material Requirements.

Shear connector studs shall conform to the requirements of the Specification for Cold Finished Carbon Steel Bars and Shafting, AASHTO M 169, cold-drawn bar, Grades 1015, or 1020, either semi-skilled or skilled. If flux-retaining caps are used, the steel for the caps shall be of a low carbon grade suitable for welding and shall comply with ASTM A109.

Tensile properties as determined by tests of the bar stock after drawing or of finished studs shall conform to the following requirements:

Tensile Strength	60,000 psi (400 MPa) (min.)
Yield Strength (as determined by a 0.2% offset method)	50,000 psi (345 MPa) (min.)
Elongation	20% in 2 in. (50 mm) (min.)
Reduction of area	50% (min.)

Tensile properties shall be determined in accordance with the applicable sections of ASTM A370, Mechanical Testing of Steel Products. Tensile tests of finished studs shall be made on studs welded

to test plates. If fractures occur outside of the middle half of the gage length, the test shall be repeated.

Finished studs shall be of uniform quality and condition, free from injurious laps, fins, seams, cracks, twists, bends or other injurious defects. Finish shall be as produced by cold drawing, cold rolling, or machining.

The manufacturer shall certify that the studs as delivered are in accordance with the material requirements of this Section. Certified copies of in-plant QC test reports shall be furnished to the Engineer.

M8.04.2: Steel Pins

Pins more than 9 in. in diameter shall be manufactured from carbon steel conforming to AASHTO M 102M/M 102, Classes B, C and D. Pins 9 in. or less in diameter shall conform to AASHTO M 102M/M 102, Classes B, C and D, or AASHTO M 169, Grades 1016 thru 1030 inclusive.

M8.04.3: High Strength Bolts

Bolts, nuts and washers shall conform to the appropriate material specification ASTM F3125/F3125M, ASTM A563, AASHTO M 292M/M 292 and ASTM F436/F436M as amended herein.

Material.

Hardness for bolts with diameter ½ in. to 1 in. inclusive shall be Brinell HB-minimum of 248; HB-maximum of 311 or Rockwell HRC-minimum of 24; HRC-maximum of 33.

Plain (ungalvanized) nuts shall be grades 2, C, D or C3 with a minimum Rockwell hardness of 89 HRB (or Brinell hardness 180 HB) or heat treated grades 2H, DH or DH3. Galvanized nuts shall be heat treated grades 2H or DH.

For galvanized fasteners, the nuts shall be tapped oversize, the minimum amount required for the fastener assembly. The amount of overtap in the nut shall be such that the nut will assemble freely on the bolt in the coated condition and shall meet the mechanical requirements of ASTM A563, and the rotational-capacity tests herein. Galvanized nuts shall be lubricated with a lubricant containing a dye of any color that contrasts with the color of the galvanizing. Black fasteners must be “oily” to the touch when installed. Weathered or rusted fasteners shall be cleaned and re-lubricated prior to installation.

Testing.

The tests need not be witnessed by a representative of the Department; however, the manufacturer or distributor that performs the tests shall certify that the results recorded are accurate. Documentation shall be in accordance with 960.61: Design, Fabrication and Erection.

Bolts.

Proof load tests in accordance with ASTM F606 Method 1 are required. The minimum frequency of the tests shall be as specified in ASTM F436/F436M.

Wedge tests on full size bolts (ASTM F606) are required. If the bolts are to be galvanized, the tests shall be performed after galvanizing. Minimum frequency of the tests shall be as specified in ASTM F436/F436M.

If galvanized bolts are supplied, the thickness of the zinc coating shall be measured. Measurements shall be taken on the wrench flats or the top of the bolt head.

Nuts.

Proof load tests (ASTM F606) are required. Minimum frequency of tests shall be as specified in ASTM A563 or AASHTO M 292M/M 292. If nuts are to be galvanized, the tests shall be performed after galvanizing, overtapping and lubricating.

If galvanized nuts are supplied, the thickness of the zinc coating shall be measured. Measurements shall be taken on the wrench flats.

Washers.

If galvanized washers are supplied, hardness testing shall be performed after galvanizing. (Coating shall be removed prior to taking hardness measurements.) The thickness of the zinc coating shall be measured.

Assemblies.

Rotational-capacity tests are required and shall be performed on all black or galvanized (after galvanizing) bolt, nut and washer assemblies by the manufacturer or distributor prior to shipping. Washers are required as part of the test even though they may not be required as part of the installation. The rotational capacity test is intended to evaluate the presence of a lubricant, the efficiency of the lubricant and the compatibility of assemblies as represented by the components selected for testing.

This test shall be performed in accordance with the requirements of ASTM F3125/F3125M except as modified herein:

1. Each combination of bolt production lot, nut lot and washer lot shall be tested as an assembly.
2. A rotational-capacity lot number shall be assigned to each combination of lots tested.
3. The minimum frequency of testing shall be two assemblies per rotational-capacity lot.
4. The bolt, nut and washer assembly shall be assembled in a Skidmore-Wilhelm Calibrator or an acceptable equivalent device. For bolts that are too short to be assembled in a Skidmore, a steel joint shall be used.
5. There is a different method for testing short bolts. Bolts are considered short when, after placing in the Skidmore, there is not a sufficient number of threads protruding to fully engage the nut.

Test Methods: Normal Length and Long Bolts

1. Install the bolt assembly in the Skidmore Calibrator making sure that 3 to 5 threads of the bolt are located between the bearing face of the nut and the underside of the bolt head. Spacers and/or washers with holes not exceeding $^{1}/_{16}$ in. greater than the bolt diameter may be used to achieve the 3 to 5 thread requirement. Tighten the bolt to the snug tight condition. The snug tight tensions are listed in Tables M8.04.3-1 (-0 kN, +9 kN) and M8.04.3-2 (-0 kips, +2 kips).

Table M8.04.3-1: Snug Tight Tensions (SI Units)

Bolt Diameter (mm)	13	16	19	22	25	29	32	35	38
Snug Tension (kN)	5	9	14	18	23	27	31	40	45

Table M8.04.3-2: Snug Tight Tensions (US Customary Units)

Bolt Diameter (in.)	½	⅝	¾	⅞	1	1 ⅛	1 ¼	⅜	1 ½
Snug Tension (kips)	1	2	3	4	5	6	7	9	10

2. After the snug tight condition is reached, further tighten the bolts to the following minimum rotation:
   - 240° (⅔ turn) for bolt lengths ≤4 diameters
   - 360° (1 turn) for bolt lengths >4 diameters and ≤8 diameters
   - 480° (1 ⅓ turn) for bolt lengths >8 diameters
3. The tension reached at the above rotation shall be equal to or greater than the turn test tension shown below.

Table M8.04.3-3: Turn Test Tensions (SI Units)

Bolt Diameter (mm)	13	16	19	22	25	29	32	35	38
Turn Test Tension (kN)	62	98	142	200	262	285	365	436	525

Table M8.04.3-4: Turn Test Tensions (US Customary Units)

Bolt Diameter (in.)	½	⅝	¾	⅞	1	1 ⅛	1 ¼	⅜	1 ½
Turn Test Tension (kips)	14	22	32	45	59	64	82	98	118

4. After the turn test tension requirement has been met, one reading of tension and torque shall be taken and recorded. Using a calibrated manual torque wrench, record the torque. For proper torque readings, the nut must be in motion. The measured bolt tension can be read off the Skidmore. The torque value shall conform to the following:

$$Torque \leq 0.25\,PD$$

Where: $Torque = measured\ torque\ (ft\text{–}lb)$
$P = measured\ bolt\ tension\ (lb)$
$D = bolt\ diameter\ (ft)$

5. Loosen and remove nut and examine the threads on the nut and the bolt. No signs of thread shear failure, stripping, or torsional failure of the bolt shall be evident.

Test Methods: Short Bolts

Procedure for performing rotational capacity test on bolts too short to fit in a tension calibrator is as follows:

Equipment Required

1. Calibrated torque wrench and a spud wrench.

2. Spacers and/or washers with hole size no larger than $^{1}/_{16}$ in. greater than bolt to be tested.
3. Steel section with normal size hole to install bolt. Any available splice hole can be used with a plate thickness that will provide the number of threads under the nut required in step 1 below. Mark off a vertical line and lines ⅓ of turn, 120°; ½ of a turn, 180°; and ⅔ of a turn 240°, from vertical in a clockwise direction on the plate.

Procedure

1. Install nut on bolt and measure stick out of bolt when 3 to 5 full threads of the bolt are located between the bearing face of the nut and bolt head. Measure the bolt length, the distance from the end of the threaded shank to the underside of the bolt head.
2. Install the bolt into the hole and install the required number of shim plates and/or washer (one washer under the nut must always be used) to produce the thread stickout measured in step 1.
3. Snug the bolt using a hand wrench. The snug tight tensions are listed under No. 1 of Test Methods – Normal Length and Long Bolts.
4. Match mark the nut to the vertical stripe on the plate.
5. Tighten the bolt by turning the nut using the torque wrench to the rotation listed below. A second wrench must be used to prevent rotation of the bolt head during tightening. Record the torque required to reach this rotation. Torque must be measured with the nut in motion.

Bolt Length, as measured in step 1	4 bolt diameters or less	Greater than 4, but not more than 8 bolt diameters	Greater than 8 bolt diameters
Required Rotation	⅓ of a Revolution	½ of a Revolution	⅔ of a Revolution

The measured torque should not exceed the values listed below. Assemblies which exceed the listed torque have failed the test.

Bolt Diameter (in.)	½	⅝	¾	⅞	1	1 ⅛	1 ¼	⅜	1 ½
Torque (ft-lb)	150	290	500	820	1,230	1,500	2,140	2,810	3,690

6. Tighten the bolt further to the rotation listed below. The rotation is measured from the initial marking in step 4. Assemblies that fail prior to this rotation either by stripping or fracture fail the test.

Bolt Length, as measured in step 1	4 bolt diameters or less	Greater than 4, but not more than 8 bolt diameters	Greater than 8 bolt diameters
Required Rotation	⅔ of a Revolution	1 Revolution	1 ⅓ Revolutions

7. Loosen and remove nut and examine the threads on the nut and the bolt. No signs of thread shear failure, stripping, or torsional failure of the bolt should be evident. Assemblies which have evidence of stripping have failed the test.

M8.05.0: Structural Steel

All structural steel shall conform to the requirements of AASHTO M 270 Grades 36, 50, or 50W or 70HPS.

Orientation of the test bars for the Charpy V-Notch (CVN) test specimens shall be longitudinal to the direction of final rolling. The "H" frequency of testing shall be used. CVN impact testing temperatures shall be in accordance with those specified for Zone 2. CVN tests are required for main members only. Secondary members typically including stiffeners and diaphragms do not require CVN tests.

All welding shall comply with the provisions of the AASHTO/AWS Bridge Welding Code (ANSI/AASHTO/AWS D1.5).

M8.05.1: Steel Piles

Steel piles shall consist of structural steel shapes of the section shown on the plans. The steel shall conform to the requirements of AASHTO M 270 Grade 36 (Grade 250 MPa). Copper bearing steel will not be required.

M8.05.3: Steel Baffles and Drainage Troughs

Steel used for the manufacture of baffles and drainage troughs shall conform to the requirements of AASHTO M 270M/M 270 Grade 50W (Grade 345W) with the additional requirement that the steel shall exhibit a corrosion resistance at least 4 times that of AASHTO M 270M/M 270 Grade 36 (Grade 250) Steel.

M8.05.4: Steel Sheeting

Steel sheeting shall be an approved standard section either new or used, weighing not less than 22 psf of wall. Steel sheeting which is to be left in place shall conform to the requirements of AASHTO M 202M/M 202 (ASTM A328).

M8.05.5: Steel Pipe Piles

This specification covers cylindrical steel pipe of uniform cross section and diameter throughout its length and in which the cylindrical pipe acts as a permanent load-carrying member.

The steel pipe shall be new and shall conform to the requirements of ASTM A252, Grade 2 except where it is in conflict with other parts of the specifications. In such cases those Specifications shall govern.

Pipe having seams of spiral-lap welded construction will not be permitted under this specification. Pipes having spiral welded butt joint construction will not be permitted except where the pipe is concrete filled.

The outside diameter and wall thickness of the pipe shall be as shown on the plans. All piles shall be driven as a closed end pipe and filled with concrete conforming to M4.02.00: Cement Concrete for 4,000 psi, ¾-inch, 610 cement concrete. A steel plate having the same outside diameter as the pipe and a thickness as shown on the plans shall be welded to the bottom of the pipe with a full penetration weld using an approved backing ring, which shall develop the full strength of the pipe in compression and tension.

The bottom end of the pipe shall be beveled in accordance with ASTM A252 and the top end of the pipe shall not be beveled.

Steel reinforcement shall conform to the requirements of M8.01.0: Reinforcing Bars and shall be as detailed on the plans.

M8.05.6: Steel Casing

This specification covers cylindrical steel casings of uniform cross section and diameter throughout its length in which the cylindrical casing acts as either a temporary or permanent load-carrying member.

Permanent steel casings shall conform to the requirements of ASTM A252. Temporary casings shall be of a grade selected by the Contractor. Temporary casings that are used and are in good condition without strength impairing defects are acceptable for use as temporary casings. Permanent casings shall not have been previously used. Temporary casings that are left in place and connected to permanent casings shall meet the requirements of permanent casings.

Casings having seams of spiral-lap welded construction will not be permitted for use as permanent steel casings.

The outside diameter and wall thickness of the permanent steel casings shall be as shown on the plans. When permanent casings are used to carry part of the design load, all joints shall have full-penetration welds. All welds shall be inspected using ultrasonic testing. Any attachment between permanent and temporary casings shall be welded with full penetration welds using an approved backing ring, which shall develop the full strength of the casings in compression and tension.

Temporary casings shall be the responsibility of the Contractor and shall be of sufficient strength to resist the handling, transportation, installation, and external stresses of the subsurface materials.

M8.05.7: Steel Extrusions

Material utilized to produce steel extrusions suitable to mechanically lock elastomeric strip seals shall conform to properties of AASHTO M 270M/M 270 Grade 36 or Grade 50 (ASTM A709 Grade 36 or Grade 50) and shall be hot dipped galvanized after attachment of anchorage devices. Steel extrusions shall have a minimum thickness of ¼ in. as measured from the internal locking mechanism cavity to the top surface of the steel extrusion shape and shall be capable of resisting HS-25 wheel loading. Steel shapes shall be monolithic with the extrusion cavity.

M8.07.0: Guardrail

The materials for this work shall conform to AASHTO M 180 and the suppliers/manufacturers of guardrail and guardrail components shall be listed on the QCML.

All steel components and hardware shall be galvanized. All metal fabrication work shall be done in the shop. No punching, cutting or welding shall be done in the field. Fabrication shall include all operations such as shearing, cutting, punching, forming, drilling, milling, bending, welding and riveting. Components of bolted assemblies shall be galvanized separately before assembly. When it is necessary to straighten any sections after galvanizing, such work shall be performed without damage to the zinc coating.

Galvanized surfaces that are abraded or damaged at any time after application of the zinc coating shall be repaired by thoroughly wire brushing the damaged areas and removing all loose and

cracked coating after which the cleaned areas shall be painted with two coats of paint, high zinc dust content, conforming to the requirements of M7.04.11.

A. Posts.

Steel Posts.

Steel posts and channel members for anchor posts shall be fabricated from new structural steel sections conforming to the dimensions and design shown on the plans.

Posts shall conform to the requirements of ASTM A36. Galvanizing shall meet the requirements of M7.10.0: Galvanized Coatings.

Wood Posts.

The posts shall be rough sawn (unplaned) with nominal dimensions as indicated on the plans and with tolerances of 1 in. in length and ¼ in. in width and thickness. All holes in the posts shall be drilled prior to pressure application of the preservative at a wood preserving facility.

The stress grade shall be 1,000 psi or more in extreme fiber bending. Grading for stress-graded timber shall be in accordance with AASHTO M 168.

Prior to treatment, all posts shall be seasoned, conditioned, and completely machined in accordance with AWPA M1.

Posts shall be treated with chromated copper arsenate, type C (CCA-C) conforming to AWPA P23, to a minimum retention of 0.60 pcf. Treatment shall be full length under pressure by the empty-cell or full-cell process in accordance with AWPA U1.

Manufacturers shall adhere to the processing and treatment limitations in AWPA T1. No unnecessary cutting of treated posts will be allowed after treatment. All posts with surfaces damaged by cutting, drilling or any other cause shall be field treated with a preservative solution in accordance with AWPA M4.

Certificates of compliance and certificates of inspection bearing the independent inspection agency's verification for each lot of wood must be presented before installation and contain the species of wood, the type of preservative, the retention rate and penetration of the preservative.

The certificates of inspection and compliance do not signify mandatory acceptance of the entire lot. The Department still has the option of rejecting posts (included in any particular lot) that the Engineer considers sub-standard because of unsound knots and shakes, excessive checking or other defects that may be detrimental to the structural integrity of the posts.

The fabricator shall retain an independent inspection agency to inspect and certify the treated posts in accordance with these specifications and AWPA M2, Part A.

All treated posts shall be marked in accordance with AWPA U1 (and M6 as required). (The mark is to include the identifying lot and/or charge number). The post shall also be stamped with the Inspector's identification. The mark is to be placed on the upper side head of the post and located so that it is not obstructed by the offset blocks, rails, or any other appurtenances. The Inspector's stamp shall be legibly hammer-stamped on the head of the post, in accordance with AWPA M2 and the above.

B. Offset Blocks.

The blocks shall be of the same type throughout the project. Requirements for specific material types are as follows:

- Wood Offset Blocks: Wood offset blocks shall meet the requirements of A. Posts, Wood Posts, above. When wood offset blocks are used on wood posts, they shall be the same species as the posts.
- Plastic Offset Blocks: Plastic offset blocks shall meet all applicable performance requirements of MASH and be listed on the QTCE. Each block shall be stamped at the factory with the manufacturer's identification and lot number and conform to the dimensions shown on the plans.

Prior to approval and use of the plastic guardrail offset blocks, the manufacturer shall submit to the Engineer, the manufacturers name, the product brand name and/or model number, a copy of the MASH test results, a Material Safety Data Sheet, and a sample block. Acceptance of the material will be based on the manufacturer's certification.

C. Rail Element and Terminal Sections.

The steel rail element, transition panels, terminal sections and connecting hardware shall conform to AASHTO M 180, Type II, Class A with the following additions:

The length of the rail shall be according to the plans.

Each end of the steel rail for every stretch of guard shall be fitted with a terminal section as shown on the plans.

The projecting heads of all connection and splice bolts shall be button head type so no appreciable projection will obstruct a vehicle sliding along the rail. Steel rail elements with a radius of 150 ft or less shall be shop bent.

The manufacturers are required to submit a Brand Registration and Guarantee document annually to RMS showing compliance of the Guardrail Components with AASHTO M 180 Specification.

M8.07.1: Guardrail End Treatment

The same type of tangent end or flared end treatment shall be used throughout the project.

All steel components and hardware shall conform to M8.07.0: Guardrail. All metal work shall be done in the shop.

The approach end shall have Type 3 Object Marker sheeting that conforms to the requirements of the MUTCD. The sheeting material shall meet the requirements of M9.30.0: Retroreflective Sheeting.

M8.09.0: Chain Link Fences and Gates

Materials for this work shall conform to the following requirements:

A. General.

All material used shall conform to AASHTO M 181 except as noted herein. The fence fabric shall be Type II - Aluminum Coated Steel or Type IV -- Polyvinyl Chloride (PVC) - Coated Steel. All tubular posts and rails, and roll-formed "C" section posts and rails shall be zinc coated steel. All wire shall have a diameter tolerance of ±0.005 in. diameter. For chain link fabric used on bridge protective screens Type I and II see M8.13.3: Aluminum Handrail and Protective Screen Type I and Type II. Spring tension wire shall be aluminum coated steel. Aluminum coated fence fabric and spring tension wire shall be tested in accordance with AASHTO T 213M/T 213. All zinc coated posts, hardware, and fittings shall be in conformance with AASHTO M 232M/M 232. Polyvinyl Chloride (PVC) coated steel fence fabric, posts, rails, gates and accessories shall conform to M8.09.1: Bonded Vinyl Coated Chain Link Fences, Posts, Rails, Fabric, Gates and Accessories. Post caps, rail end and other fittings and appurtenances shall be pressed steel or malleable iron. All materials shall be new and undamaged when installed. Imperfectly coated materials will be rejected.

B. Posts.

Steel round pipe posts and "C" sections shall have a tolerance of ±10% from specified weight and ±5% from specified dimensions.

Type B round pipe shall conform to ASTM A 1011. Roll-formed "C" section shall conform to ASTM F1043.

Galvanized steel Line, End, Corner and Intermediate Posts shall conform to the sizes in Table M8.09.0-1:

Table M8.09.0-1: Post Sizes for Chain Link Fence

Post Type	Under 5 Ft in Height	5 Ft and Over in Height
Line Post	1) Round Pipe - 1.90-in. O.D. Type B @ 2.29 lb per ft; or 2) "C" section - 1 ⅞ x 1 ⅝ in. @ 2.28 lb per ft	1) Round Pipe - 2 ⅜-in. O.D. Type B @ 3.117 lb per ft; or 2) "C" section-2 ¼ x 1.70 in. @ 2.64 lb per ft
End Post and Corner Post	1) Round Pipe - 2 ⅜-in. O.D. Type B @ 3.117 lb per ft	1) Round Pipe - 2 ⅞ -in. O.D. Type B @ 4.64 lb per ft
Intermediate Brace Posts	1) Round Pipe - 2 ⅜-in. O.D. Type B @ 3.117 lb per ft; or 2) "C" section - 2 ¼ x 1.70 in. @ 2.64 lb per ft	1) Round Pipe - 2 ⅞-in. O.D. Type B @ 4.64 lb per ft

Gate posts shall be 4 in. O.D. pipe, Type B with a weight of 6.56 lb per ft.

The galvanizing for "C" sections shall not be less than 2.0 oz per ft² of metal surface as per AASHTO M 232M/M 232. For Type B round pipe the external coating shall be 0.9 oz of galvanizing per ft² minimum, 15 µg of chromate per in.² minimum, plus 0.3 mils minimum of clear cross-linked polyurethane acrylic coating. The internal surface shall be coated with zinc-rich based organic coating containing not less than 87% zinc powder and capable of providing galvanic protection. All round posts shall be fitted with an approved top, so designed as to fit securely over the post and carry the top rail or cable. The base of the top fitting shall carry an apron around the outside of the post.

C. Top Rail and Spring Tension Wire.

1) Rail shall have a tolerance of ±10% from specified weight and ±5% from specified dimensions. Steel top rails shall be Type B 1.66 in. O.D. tubular pipe with a weight of 1.83 lb per ft, or 1.625 x 1.25 in. roll-formed "C" section with a weight of 1.40 lb per ft.

   The protective coating for top rails shall meet the requirements of paragraph B above.

   Couplings or expansion sleeves shall be outside sleeve type and at least 6 in. long.

2) Spring tension wire shall be coil spring steel 7 gage (0.177 in.). The base metal shall have a minimum breaking strength of 1,950 lb coated with aluminum applied at a rate of not less than 0.40 oz per ft² of surface area.

D. Braces and Truss Rods.

Compression braces shall be the same type and size as top rail. Tension truss rods shall be $^{5}/_{16}$-in. minimum round rods with drop forged turnbuckles, or other approved type of adjustments.

E. Fence Fabric.

The fabric shall consist of 9 gage (0.148 in.) wire having a minimum breaking strength of 1,290 lb coated with aluminum applied at the rate of not less than 0.40 oz per ft² of uncoated wire surface. It shall be woven into approximately 2 in. diamond mesh. The width of the fabric shall be specified or shown on current standard drawings. Fabric for chain link fence less than 6 ft in height shall be finished at top and bottom with a "knuckled" selvage. All other fence sizes shall have a knuckled selvage at the bottom and twisted selvage at the top. Barbing shall be done by cutting the wire on the bias.

F. Bands and Stretcher Bars.

All bands shall be a minimum of 12 gage (0.106 in.) and at least ¾ in. in width. Tension or stretcher bars shall be no less than $^{3}/_{16}$ in. x ¾ in. stock. Galvanizing shall conform to the requirements of AASHTO M 232M/M 232.

G. Tie Wire and Hog Rings.

Aluminum tie wire shall be a minimum of 6 gage (0.192 in.) round wire Alloy 1350-H19 or equal. Aluminum hog rings shall be a minimum of 11 gage (0.120 in.) round wire Alloy 1350-H19 or equal.

H. Barbed Wire.

Barbed wire shall consist of two strands of 0.0985 in. diameter wire with 0.08 in. diameter 4 point barbs approximately 5 in. apart, shall be aluminum coated and conform to the requirements of AASHTO M 280.

Barbed wire Extension Arms shall be at an angle of approximately 45° and shall be fitted with clips or other means for attaching three lines of barbed wire, and with top outside wire approximately 12 in. horizontally from the fence line and the other wires spaced uniformly between the top of the fence fabric and the outside barbed wire.

I. Gates.

Gate frames shall be constructed of galvanized steel of sizes and weights shown below. The corners of the gate frame shall be fastened together and reinforced with suitable fittings designed for the purpose or they may be welded.

Single gate frames 6 ft or less in width shall be 1.66 in. O.D. pipe galvanized steel conforming to Section C of this specification.

Single gate frames over 6 ft wide shall be 1.90 in. O.D. galvanized steel pipe conforming to Section B of this specification.

Cross trussing shall be $^{5}/_{16}$-in. galvanized iron adjustable rods.

Chain link fence fabric for filling the gage frame shall conform to Section E of this specification.

Each gate shall be furnished complete with necessary hinges, latch and drop bar locking device designed for the type of gate post and gate used.

Gate sizes shall be as specified with the height conforming to the height of the fence.

J. Drive Anchors and Shoes.

Drive anchors shall be galvanized steel angle iron or extruded aluminum alloy 6061-T6. Minimum dimensions shall be 1 ¼ in. x 1 ¼ in. x ⅛ in. The weight of zinc for galvanized components shall be 1.5 oz per ft² of metal surface.

Shoes for drive anchors shall be galvanized cast or malleable steel, or extruded aluminum alloy 6061-T6. The weight of zinc for galvanized components shall be 2.0 oz per ft² of metal surface.

M8.09.1: Bonded Vinyl Coated Chain Link Fences, Posts, Rails, Fabric, Gates and Accessories

The fence shall have a bonded polyvinyl chloride (PVC) coating over aluminum coated or galvanized steel. All material used shall conform to AASHTO M 181. Polyvinyl chloride coated by dipping, thermal fusion or any other method that meets the requirements of this specification.

The fence fabric shall be PVC coated wire that is woven into a 2 in. diamond mesh. The coating shall not crack, craze, or peel. The color of the PVC coated fabric and accessories shall be medium green as defined in AASHTO M 181.

All materials shall have dimensions and weights as specified in M8.09.0: Chain Link Fences and Gates except as follow:

Spring Tension Wire..... 9 gage.
Ties ..... Aluminum 10 gage
Hog Rings ..... Aluminum 11 gage

The bonded PVC coating shall be a minimum of 0.007 in. as determined by measuring the diameter of the coated wire, stripping off the coating, measuring the diameter of the stripped wire and dividing the difference by two.

M8.10.0: Steel Pipe Rail or Fence

Materials for this work shall conform to the following requirements:

A. Rails and Posts.

Steel pipe for rails and posts shall conform to requirements of ASTM A53, Grade B. Galvanized pipe ordered under this specification shall be coated with zinc inside and outside by the hot-dip process. The weight of zinc coating shall be not less than 2.0 oz per ft² of surface area. For rails and posts, a tolerance of ±10% from the specified weight and ±5% from the specified dimension is allowed.

B. Fittings.

All fittings shall be steel conforming to ASTM A307. They shall be galvanized in accordance with AASHTO M 232M/M 232.

C. Lead Wool.

Lead wool for caulking shall be of standard manufacture and shall be approved for such use by the Engineer.

D. Bitumen.

Bitumen for use with pipe sleeves shall be approved for that use by the Engineer.

M8.10.1: Aluminum Pipe Rail or Fence

Materials for this work shall conform to ASTM F1183 with 2 in. diamond mesh and the following requirements:

A. General: All materials shall be new and free from any surface coatings of paint or other materials. All castings shall be sound, free from blow-holes or other imperfections and have smooth surfaces.
B. Steel anchor bolts, nuts and washers shall conform to M8.01.5: Anchor Bolts, Nuts and Washers.
C. Stainless Steel screws shall conform to ASTM A193, Grade B8.
D. Rails, posts and bases shall conform to ASTM B221, Alloy 6061-T6, or Alloy 6351-TS.
E. Splices and clamp bars shall conform to ASTM B221, Alloy 6061-T6.
F. Rivets shall conform to ASTM B316, Alloy 6061-T6.
G. Aluminum washers shall conform to ASTM B209, Alloy Alclad 2024-T4.
H. End plugs shall conform to ASTM B26, Alloy S5A-F or SG 70 A-F.
I. Aluminum Screen Frame shall conform to ASTM B221, Alloy 6061-T6.
J. Aluminum Screen Fabric shall conform to ASTM B211, Alloy 6061-T94.

M8.11.0: Bronze Self-Lubricating Bearing Plates

The self-lubricating bronze plates shall conform to one of the following materials as called for on the design drawings:

A. Leaded Tin Bronze, conforming to the requirements of ASTM B22, Alloy D, modified to the extent that 1.5 to 2.5 % lead will be required.
B. Tin Bronze, conforming to the requirements of ASTM B22, UNS-C91100.

Finishes and Tolerances

The surfaces of the bronze and steel plates which bear upon each other shall have a surface roughness not exceeding 125 micro inches when measured in accordance with American Standards Association B46.1 for surface roughness, waviness and lay. The lay of the tool marks shall be in the direction of expansion or contraction of the bridge.

The flat surfaces of the bronze and steel plates which bear upon each other shall be flat within 0.5 mil per inch (0.0005 mm per mm) of length and width.

Bronze Bearing plates having radial convex surfaces shall have a negative tolerance of 10 mils (250 μm) maximum and a positive tolerance of 0.000 in. (10 μm) on the specified radius. Concave radial surfaces of steel bearing plates shall have a positive tolerance of 10 mils (250 μm) maximum and a negative tolerance of 0.000 in. (10 μm) on the specified radius.

Lubricated Recesses.

The recesses for the containment of the solid lubricant in the bronze bearing plates shall consist of annular rings or drilled holes with a minimum vertical wall depth of $^{3}/_{16}$ in. The recesses shall be arranged in a geometric pattern in such a manner that each successive row shall overlap in the direction of motion. The entire area of all bearing surfaces which have provision for motion shall be lubricated by means of these lubricant filled recesses. The total area of these recesses shall comprise not less than 25% nor more than 35% of the total bearing area of the plate.

Lubricant.

The lubricant for filling the recesses shall be of the solid type and shall consist of graphite and metallic lubricants with a lubricating binder. The lubricant shall be compressed into the lubrication recesses by hydraulic pressure of at least five times the design unit loading as shown on the contract drawings to form a dense nonplastic insert which shall project not less than 0.010 in. above the surface of the bronze bearing plate.

Testing.

A self-lubricating bronze test plate measuring not less than 5 in. long by 5 in. wide shall be prepared and shall conform to one of the above materials and all other requirements of the specifications.

An assembly consisting of the fixed self-lubricating test plate and a movable steel plate shall be subjected to the design vertical unit loading specified in the contract drawing. The steel plate shall then be subjected to not less than 100 cycles of horizontal movement at a speed not to exceed 30 cycles per minute. Each cycle shall consist of a forward and return movement of not more than ½ in. in each direction. The recorded horizontal force divided by the recorded vertical force shall be established as the co-efficient of friction between the sliding surfaces.

The coefficient of friction determined by the foregoing method shall not exceed 0.010. If the tests indicate a coefficient of friction greater than 0.10, the entire lot of solid lubricant shall be rejected.

Where no inspection of materials is arranged for by the Party of the First Part and before such materials are incorporated into the work, the manufacturer of the bronze bearings will be required to certify that the bronze bearing material with lubricant, when tested as hereinbefore described, shall not have a coefficient of friction greater than 0.10. Batches of solid lubricant that successfully

meet the friction coefficient requirements shall be properly identified by the manufacturer with a lot number and date marked "Approved for use on Commonwealth of Massachusetts projects."

Preparation of Mating Steel Plates.

The sliding surfaces of the mating steel plates shall be coated, just prior to installation, with a liquid lubricant recommended and furnished in sealed containers by the manufacturer of the bronze bearing plates.

Material Certifications.

Certified copies of the chemical analysis and physical properties of the bronze used in manufacturing of the bearing plates shall be supplied for each project.

Certifications shall be identified with the heat numbers of the bronze, solid lubricant lot numbers, and a statement that the solid lubricant used in the manufacture of the bronze bearing plates has successfully passed the test requirements of this specification.

M8.13.0: Bridge Railings, Aluminum, Types AL-1 & AL-3

Materials used in the fabrication of aluminum bridge railings shall conform to the following requirements:

A. General: All materials shall be new and free of paint or other materials. All castings shall be sound, free from blowholes or other imperfections and have smooth surfaces.
B. Steel anchor bolts, nuts and washers shall conform to M8.01.5: Anchor Bolts, Nuts and Washers.
C. Stainless Steel screws shall conform to ASTM A193, Grade B8.
D. Rails, posts and bases shall conform to ASTM B221, Alloy 6061-T6.
E. Splices and clamp bars shall conform to ASTM B221, Alloy 6061-T6.
F. Rivets shall conform to ASTM-B316, Alloy 6061-T6.
G. Aluminum washers shall conform to ASTM B209, Alloy Alclad 2024-T4.
H. End plugs shall conform to ASTM B26, Alloy S5A-F or SG70 A-F.
I. Tubular Pickets shall conform to ASTM B211, Alloy 6063-T5.

M8.13.1: Bridge Railing, Steel, Type S3-TL4

All steel shall be new and fabrication shall conform to 960.61: Design, Fabrication and Erection. The fabricator shall be approved by the Department in compliance with the requirements of 960.61: Design, Fabrication and Erection, Paragraph A.

Posts and base plates shall conform to the requirements of AASHTO M 270M/M 270 Grade 50. CVN tests are required.

Rails shall be made from hollow structural tubing and shall conform to the requirements of ASTM A500 Grade B or C with a minimum yield (F_y) of 50 ksi. CVN tests are required.

Anchor plates and splice tube plates shall conform to AASHTO M 270M/M 270 Grade 36. CVN tests are not required.

Picket tubes shall conform to the requirements of ASTM A513 with a certified yield (F_y) of 36 ksi or ASTM A500 Grade B. CVN tests are not required.

Carrier angles shall conform to the requirements of AASHTO M 270M/M 270 Grade 36. CVN tests are not required.

Round headed bolts shall conform to the chemical and physical requirements of ASTM F3125/F3125M. Rotational capacity tests are not required.

High strength bolts shall conform to M8.04.3: High Strength Bolts.

Anchor bolts shall conform to M8.01.5: Anchor Bolts, Nuts and Washers.

Molded fabric bearing pad shall conform to M9.16.2: Molded Fabric Bearing Pad.

Screws shall be hardened countersunk machine screws.

M8.13.2: Metal Bin-Type Retaining Wall

Metal sheets used in fabricating the retaining wall shall be of U.S. Standard Gauge thickness as specified on the plans, but no unit shall be formed from sheets thinner than 0.062 in. The base metal and coating shall conform to the requirements of AASHTO M 218.

All bolts and nuts used in the erection of the wall shall be galvanized. Bolts shall have a diameter of ⅝ in. and a minimum length of 1 ¼ in., measured from the underside of the bolt head.

M8.13.3: Aluminum Handrail, Protective Screen Type I and Type II, and Snow Fence

Material used in the fabrication of Handrail, Protective Screen Type I and Type II, and Snow Fence shall conform to the following requirements (see Subsection 975: Metal Bridge Railings, Protective Screens and Snow Fences for anodizing and powder coating requirements):

A. All materials shall be new and free of oil, mill coating, and other materials. All castings shall be sound, free from blowholes or other imperfections, and shall have smooth surfaces.
B. Aluminum extrusions and plates shall conform to ASTM B221, Alloy 6061-T6.
C. Chain link fabric shall conform to AASHTO M 181 Type III (aluminum alloy 6061-T89 or T94). Prior to bending and coating, the wire shall meet the minimum tensile strength of 54 ksi as specified in AASHTO M 181. After fabrication and coating, the minimum tensile strength of the wire shall be 43 ksi.
D. Protective Screen Type II and Snow Fence self-tapping screws shall be tempered 410 stainless steel with a hardness of 32 to 35 HRC.
E. Anchor bolts and washers shall conform to ASTM F3125/F3125M. No rotation-capacity testing shall be required. The bolts and washers shall be galvanized in accordance with AASHTO M 232M/M 232. The anchor cage shall be galvanized in accordance with AASHTO M 111M/M 111 or shall be electroplated with zinc in accordance with ASTM B633, Service Condition 1, Type III.
F. Tee Bolts shall conform to ASTM A307 and shall be galvanized in accordance with AASHTO M 232M/M 232. Type 304 stainless steel Tee Bolts may be substituted for the galvanized A307 Tee Bolts.
G. All other fasteners, nuts and washers shall be as called for on the drawings.
H. Protective Screen Type I posts, rails, bars, splices and clamps shall conform to ASTM B211, Alloy 6061-T6.

M8.14.0: Load Transfer Assembly

A. Load transfer assemblies for transverse joints shall consist of slip-bars and a metal device so designed as to hold the slip-bars exactly and firmly in their correct positions during concreting operations. The complete assembly shall conform to the requirements and dimensions as shown on the plans or as approved by the Engineer.
B. The slip-bars shall be fabricated from either plain new billet steel of the grade designated or plain rail steel. They shall be free from burring or other deformations restricting slippage in the concrete.
C. One half the length of each slip-dowel bar of load transfer units shall be rendered bondless with a coat of either a graphite lubricant or a wax base grease.
1. The graphite lubricant shall consist of flake graphite mixed with a vehicle having quick drying characteristics. The graphite paste shall be thoroughly mixed and have the following composition (Percentage by weight).

Table M8.14.0-1: Graphite Paste Composition

	Minimum	**Maximum**
Pigment: (Flake Graphite)	55%	65%
Graphite Carbon	85%	
Passing No. 100 Sieve	84%	92%
Passing No. 325 Sieve	46%	50%
Vehicle	35%	45%

Vehicle shall consist of 52% fixed oils; remainder to be volatile thinners and driers.

To prepare lubricant for application, approximately 3 to 4 lb of the graphite paste shall be placed in a suitable container and 40% by weight of 60/40 mixture of carbon tetrachloride and naphtha shall be added thereto. The resulting lubricant shall be thoroughly mixed.

2. The wax base grease shall be applied hot at temperatures of 170°F to 190°F. It shall conform to the following requirements:

a) Consistency, cone penetration at 77°F 120-160
b) Melting point ..... 140°F (minimum)
c) Stability ..... No separation at 200°F to 210°F for 1 hr
d) Abrasives ..... Free from abrasives
e) Volatile matter (% by weight) ..... 2% maximum when heated at 210°F ±3°F for 0.5 hr
f) Drying ..... Shall not dry in 14 days
g) Corrosion ..... There shall be no evidence of corrosion on steel.
h) Acidity (pH) ..... 5 (minimum)
i) Adhesion ..... Shall not slip, sag or drip at 130°F
j) Removability ..... Shall be readily removable with a cleaning solvent

M8.15.0: Strand Chuck

The chuck shall be of a design suitable for securely gripping high tensile strand steel without deformation or slippage. It shall be manufactured from a corrosion resistant steel alloy capable of

withstanding repeated use and overload conditions in excess of the ultimate tensile strength of the strand without fatigue or failure. The surface body of the chuck shall be treated to increase corrosion resistance.

M8.16.0: Electrical Wire & Cable

This specification covers all electrical wire and cable for traffic control devices, traffic signals, ITS systems, highway lighting, signs and supports. All wire and cable herein are for copper conductors rated for 600V. All traffic signal cable conductors shall not be less than #14 AWG, with an exception for individual conductor drops between a span wire hub and the signal head, which shall be not less than #16 AWG. All traffic signal conductors shall be stranded.

M8.16.1: Type 1 Traffic Signal Cable (Installed above ground or in Duct)

Traffic signal cable shall be thermoplastic and conform to requirements of IMSA Specification 19-1.

M8.16.2: Type 2 Traffic Signal Cable (Installed above ground or in Duct)

Traffic signal cable shall be thermoplastic and conform to requirements of IMSA Specification 20-1.

M8.16.3: Type 3 Traffic Signal Cable (Installed above ground)

Traffic signal cable shall be thermoplastic and conform to requirements of IMSA Specification 19-3 or 20-3.

M8.16.4: Type 4 Traffic Signal Cable (Installed above ground)

Traffic signal cable shall be thermoplastic and conform to requirements of IMSA Specification 19-4 or 20-4.

M8.16.5: Type 5 Traffic Signal Cable (Direct Burial)

Traffic signal cable shall be thermoplastic and conform to requirements of IMSA Specification 19-5 or 20-5.

M8.16.7: Type 7 General Purpose Wire (XHHW-2 with XLP Jacket)

General Purpose Wire shall conform to requirements of UL Standard UL-44 “Rubber-Insulated Wires and Cable.” Type 7 Wire installed in a tunnel shall have a VW-1 Rating.

M8.16.8: Type 8 Direct Burial Wire (USE)

Direct burial wire shall be insulated as specified for Type 8 and conform to requirements of UL Standard UL-854 “Service-Entrance Cables” for USE listed cable.

M8.16.9: Type 9 Special Purpose Wire (TW-THW-UF)

Special purpose wire shall be TW or THW conforming to requirements of UL Standard UL-83 “Thermoplastic-Insulated Wires” or UF conforming to the requirements of UL Standard UL-719 “Nonmetallic-Sheathed and Underground Feeder Cables” as specified.

M8.16.10: Type 10 Grounding and Bonding Conductors (Solid or Standard, Insulated or Bare)

Grounding and bonding conductors shall not be less than #14 AWG. Ground and bonding conductors shall be copper conforming to requirements of ASTM-B3 for soft or annealed copper wire, ASTM-B8 for stranded copper wire.

Where wire is provided with an individual covering, the covering shall be finished a continuous green color or a continuous green color with one or more yellow stripes.

M8.16.11: Shielded Loop Detector Lead-In cable

Two-conductor #14 AWG, tinned copper stranded (19 x 27) conductors, polyethylene insulated (0.032 in. thick), conductors cabled, aluminum-polyester shield (100% shielding), #16 AWG stranded tinned copper drain wire. Chrome vinyl outer jacket (0.035 in. thick), nominal cable outside diameter 0.340 in. and conform to the requirements of IMSA specification 50-2.

M8.16.12: Type 12 Multi-conductor heavy duty portable power cord

This material shall conform to the requirements of Underwriters Laboratories Standard UL-62, Flexible Cord and Fixture wire for Type 50, 600V flexible cord.

M8.16.13: Type 13 Loop Detector Wire THHN with Tube

Loop detector wire shall be PVC insulated, nylon jacketed, loose encased in a PVC or PE tube and conform to requirements of IMSA specification 51-5.

M8.16.14: Type 14 Coaxial Cable

Coaxial Cable shall be a 75-ohm, precision video cable with 20-gauge solid bare copper conductor (9.9 ohms/M), solid polyethylene insulating dielectric, 98% (minimum) tinned copper double-braided shield and black polyethylene outer covering. The signal attenuation shall not exceed 0.78 dB per 100 ft. at 10 MHz. The nominal outside diameter shall be 0.304 in. Coaxial Cable shall be suitable for installation in conduit or overhead with appropriate span wire.

M8.16.15: Type 15 Cat5e Ethernet Cable

Cat5e Ethernet Cable shall consist of a 4-pair, #24 AWG solid, color-coded conductors contained within an insulated jacket. The insulation material of the inner conductors shall be Polyolefin (PO), the insulation material of the outer jacket shall be Polyethylene (PE). The outer shield shall be aluminum foil/polyester tape and cover 100% of the inner conductors. The outer shield drain wire shall be tinned copper. Cat5e Ethernet Cable shall have an operating temperature range of -30°C to +75°C, a maximum pulling tension of 110 N, and a minimum bending radius of 50.4 mm.

Cat5e Ethernet Cable shall meet TIA/EIA 568-c.2 Category 5e, NEMA WC-63.1 Category 5e, and IEC 11801 Category 5e.

M8.16.16: Type 16 Twisted Pair Copper Cable

Twisted Pair Copper Cable shall be a flexible power cable consisting of three #16 AWG, stranded, insulated conductors contained within an insulated jacket. The operating voltage of the cable shall be rated at 300V RMS, maximum. The insulation material shall be thermoplastic elastomer (TPE) with an insulation thickness of 0.031 in. (nominal) and an insulated conductor diameter of 0.120 in.

(nominal). The cable filler type shall be polypropylene and the separator wrap shall be paper tissue. The cable shall have a temperature rating of -50°C to +105°C.

Twisted Pair Copper Cable shall meet UL Standard 62, CSA 22.2 No. 49, and NEC article 400.

M8.16.17: Type 17 Twisted Pair Copper/Fiberoptic Hybrid Cable

Twisted Pair Copper/Fiberoptic Hybrid Cable shall be a fiberoptic/power hybrid cable capable of supporting single point camera system which utilizes fiber optic-based communications for video transmission. The cable shall be of rugged, outdoor rated hybrid design consisting of four tight buffered breakout fibers and two copper conductors encased in a flame-retardant outer jacket. The cable shall also consist of aramid yarns encapsulating the tight buffered fibers under a sub-unit jacket. The cable shall contain a ripcord to facilitate outer jacket removal.

The fiber strands shall be OM3 multimode 50/125 BIF, 10 GIG. The copper conductors shall be stranded copper #16 AWG. The outer jacket shall be UV-resistant black flame-retardant PVC with a diameter of 0.40-0.42 in. The cable sub-jacket shall consist of thermoplastic elastomeric (TPE) with a diameter of 0.095 in. The central strength member shall be epoxy glass rod. The cable shall be temperature rated for a range of -40°C to +70°C.

The cable shall be RoHS compliant and meet IEC 60793-2-10 and TIA-492AAAD Optical Fiber specifications.

M8.17.0: Ground Rod

Ground Rods shall be nominal ⅝ in. diameter (measured diameter shall not be less than 0.558 in.) by a minimum of 8 ft long copper bonded to steel rod, with bolt type clamps, conforming to the requirements of UL-467.

M8.18.0: Traffic Signal, Highway Lighting and Sign Supports

This section covers the poles, posts, masts, arms and bases for traffic signals, highway lighting and sign supports.

M8.18.1: Traffic Signal Supports

Posts

Steel signal posts shall be 4 in. diameter Schedule 40 seamless pipe conforming to ASTM A53, Grade A or B. Interiors shall be coated as specified in Underwriters Laboratories UL-6 for enameled conduit, or aluminum conduit conforming to M5.07.1: Electrical Conduit-Rigid Metallic (Type RM), Paragraph C.

Aluminum signal posts shall be 4 in. diameter Schedule 40 pipe conforming to aluminum alloy 6063-T6 (ASTM B221, B429 or B241).

Poles and Mast Arms

Structures shall be made of steel. Structural steel material over ½ in. thick that is part of main load carrying tension members shall meet the Charpy V Notch impact requirements of 15 ft-lb at 40°F.

Tapered shafts shall conform to ASTM A595, Grade A, or AASHTO M 270M/M 270 Grade 50.

The arms shall conform to ASTM A595, Grade A; or ASTM A1011/A1011M, or ASTM A500 Grade B. Steel shall have a minimum yield of 50 ksi.

The shaft cap shall conform to ASTM A126, Class A.

All hardware shall be stainless steel or ASTM F3125/F3125M, fully galvanized.

Baseplates and all other standard structural shapes shall conform to AASHTO M 270M/M 270 Grades 36 or 50.

Anchor bolt covers shall meet the requirements of ASTM A181/A181M or ASTM A126, Class A or AASHTO M 103M/M 103, Grade 450-240 (Grade 65-35) or ASTM A36/A36M.

Galvanizing shall be in accordance with Section M7: Paints, Protective Coatings and Pavement Markings.

Bases

Bases shall be the same materials as the poles.

Octagonal bases are for use with posts and shall be cast iron conforming to AASHTO M 105 or cast aluminum alloy conforming to Aluminum Association No. 356.0 T-6 (ASTM B26, B108).

Pedestal bases are for use with posts and poles and shall be made of not less than No. 10 gage steel and galvanized in accordance with Section M7: Paints, Protective Coatings and Pavement Markings or cast aluminum alloy conforming to Aluminum Association No. 356.0 T-6 (ASTM B26, B108).

M8.18.2: Highway Lighting Poles and Arms

Aluminum

Tapered aluminum poles shall conform to ASTM B221, alloy 6063-T6 or 6061-T6. Structural aluminum shapes shall conform to ASTM B308, alloy 6061-T6. Bases shall conform to ASTM B108, alloy 356.0-T6.

Steel

Structural steel material over ½ in. thick that is part of main load carrying tension members shall meet the Charpy V Notch impact requirements of 15 ft-lb at 40°F.

Tapered components shall be fabricated from steel conforming to ASTM A595, Grade A; or ASTM A1011M, Grade 55; or AASHTO M 270M/M 270, Grade 50.

Gussets, flanges, baseplates, wing plates, connecting end plates, and all other standard structural shapes shall conform to AASHTO M 270M/M 270 Grades 36 or 50.

Anchor Bolts

Anchor bolts shall conform to M8.01.5: Anchor Bolts, Nuts and Washers and be fully galvanized in accordance Section M7: Paints, Protective Coatings and Pavement Markings.

M8.18.3: Sign Supports

Structural steel material over ½ in. thick that is part of main load carrying tension members shall meet the Charpy V Notch impact requirements of 15 ft-lb at 40°F.

Supports shall be fabricated from steel conforming to ASTM A595, Grade A; ASTM A1011M, Grade 55; AASHTO M 270M/M 270, Grade 50; ASTM A500, Grade B; or API-5LX-52.

Gussets, flanges, baseplates, wing plates, connecting end plates, and all other standard structural shapes shall conform to AASHTO M 270M/M 270 Grades 36 or 50.

Truss and cantilever beam connections shall be furnished with the necessary beam support clamps. The ends of beams shall have a mounting clevis and closure plate fabricated from steel plate as an assembly.

All structural steel and steel hardware shall be galvanized in accordance with Section M7: Paints, Protective Coatings and Pavement Markings. Anchor bolts, nuts, and washers shall conform to M8.01.5: Anchor Bolts, Nuts and Washers and be fully galvanized in accordance with Section M7: Paints, Protective Coatings and Pavement Markings.

Sign Posts – P5.

A. Square Tube Posts.

Square tube posts shall be square tube fabricated from 12 gage hot-rolled carbon steel conforming to the requirements of ASTM A1011, Grade 50.

Galvanizing shall be in accordance with ASTM A653, Coating Designation G140 with a minimum coating of 1.4 oz per ft² total of zinc on both sides under triple spot tests; or a minimum coating of 1.15 oz per ft² total of zinc on both sides under triple spot tests and after all fabrication and re-galvanizing the posts shall be coated with a chromate conversion coating and sealed with an air-dried clear organic polymer topcoat.

Posts shall be welded directly in the corner by high frequency resistance welding or equal and externally scarfed to agree with standard corner radius of 0.15625 in. ±0.015625 in. The corner weld and holes shall be zinc coated after scarfing operations. Holes shall be 0.4375 in. in diameter and shall be placed 1 in. on center.

B. U Channel Posts.

U-channel posts shall be fabricated from re-rolled rail steel or an equivalent steel and shall conform to the mechanical requirements of ASTM A499, Grade 60 and the mechanical requirements of ASTM A1. All steel U-channel posts shall weigh at least 4 lb per ft and be entirely galvanized in accordance with Section M7: Paints, Protective Coatings and Pavement Markings. Holes shall be 0.4375 in. in diameter spaced at 1 in. on center and be punched prior to the galvanizing of the posts.

All bolts, nuts and washers shall conform to the requirements of ASTM A307, Grade A. Bolts, nuts and washers shall be galvanized in accordance with the requirements of Section M7: Paints, Protective Coatings and Pavement Markings.

Steel posts, sign post anchors, anchor sleeves, slipbases, lap splices, and any related hardware shall all be from the same manufacturer. No mixing of brands shall be allowed.

M8.19.1: Aluminum Sign Panels

Aluminum sign panels shall be fabricated from ASTM-B209, Alloy 6061-T6, (0.080 in. thick) with 3 in. minimum diameter amber reflectors affixed thereto.

M8.20.4: Anti-Glare Systems

Anti-Glare Systems shall consist of modular sections consistent in length with standard length of concrete median barrier. Glare blocking shall be accomplished by vertical blades or panels attached to a horizontal base to create the modular units.

The anti-glare system shall be of a type listed on the QTCE.

M8.21.0: Stay-in-Place Bridge Deck Forms

Stay-in-Place Bridge Deck Forms and supports shall be fabricated from steel conforming to ASTM A653 (Grades 33, 37, 40, 50 Class 1 and 2, and 80 English and Grades 230, 255, 275, 340 Class 1 and 2, and 550 Metric) having a coating class of G165 according to ASTM A924.

M8.22.0: Cross Hole Sonic Testing Access Pipes

Steel pipe for cross hole sonic testing access pipes shall be Schedule 40 and shall conform to ASTM A53, Grade B.

SECTION M9: MISCELLANEOUS MATERIALS

M9.00.0: General

All materials in this category shall be sampled and tested in accordance with the standard methods applicable to that particular material.

M9.01.0: Calcium Chloride

Calcium Chloride shall conform to the requirements of AASHTO M 144, Type I or Type II.

M9.01.1: Sodium Chloride

Sodium Chloride to be used for road purposes shall conform to the requirements of AASHTO M 143, except that the grading shall conform to the following:

Table M9.01.1-1: Gradation Requirements for Sodium Chloride

Sieve	Percent Passing
⅜ in.	100
No. 4	82 (maximum)
No. 8	50 (maximum)
No. 30	7 (maximum)

M9.02.0: Herbicides

These specifications cover chemicals used to destroy and/ or control the growth of plants both indiscriminately (non-selective herbicides) and selectively (selective herbicides). Only those herbicides currently approved by the State Pesticide Board and the Department may be used.

M9.03.0: Insecticides

These specifications cover chemicals to be used in the control of insects which are harmful to trees and desirable growth. Only those insecticides currently approved by the State Pesticide Board and the Department may be used.

M9.04.0: Curb and Edging

All granite curb and edging shall be basically light gray in color, free from seams and other structural imperfections or flaws which would impair its structural integrity, and of a smooth splitting appearance. Natural color variation characteristic of the deposit from which the curbing is obtained will be permitted.

Whenever curbing is sawed, all surfaces that are to be exposed shall be thoroughly cleaned and any iron rust or iron particles removed by sand blasting or other approved methods satisfactory to the Engineer and any saw mark in excess of ⅛ in. shall be removed.

M9.04.1: Granite Curb

The stones for the several types of granite curb shall be cut to the dimensions and curvature hereinafter stated:

Table M9.04.1-1: Standard Granite Curbstone Dimensions

Type	Minimum Length	Width at Top	Depth	Minimum Width at Bottom
VA1	6 ft	7 in	17 in. to 19 in.	4 in. (for ⅔ length)
VA2	6 ft	7 in.	19 in. to 21 in.	4 in. (for ⅔ length)
VA3	6 ft	6 in.	19 in. to 21 in.	4 in. (for ⅔ length)
VA4	6 ft	6 in.	17 in. to 19 in.	4 in. (for ⅔ length)
VA5	5 ft	6 in.	See Plans	5 in. (for ⅔ length)
VB	3 ft	5 in.	15 in. to 17 in.	3 ½ in. (for ⅔ length)

Except for the 3 following conditions, 10% of the length of each type of VA curb installed on the project may consist of stones no more than 6 in. shorter than the length specified in either table.

1. Stones used in making closures may be as much as one third shorter than specified in either table, except that for VA5 the closure piece shall have a minimum length of 4 ft.
2. Stones used in making closures on bridge decks at paraffin joints may have one piece, no less than 4 ft between any two paraffin joints or between one paraffin joint and the end of the run of curbing.
3. On curves with radii greater than 100 ft but less than 500 ft, type VA stones may be 4 ft to not more than 6 ft in length.

Type VA stones to be set on a radius of 100 ft or less shall be cut to the required curvature and except for making closures shall be of minimum lengths as follows:

Table M9.04.1-2: Minimum Lengths of Curved Granite Curbstone

Radius	Minimum Length
50 ft to 100 ft	6 ft
25 ft to less than 50 ft	4.5 ft
Less than 25 ft	3 ft

Type VB stones to be set on a radius of 100 ft or less shall be cut to the required curvature.

All VB stones shall have a minimum length of 3 ft regardless of curvature.

The ends of all curved stones shall be cut on radial lines.

Finish

The finish and surface dimensions for the several types of curb shall conform to the following requirements:

A. Type VA Curb.

This type of curbstone shall have a top surface free from wind, shall be peen hammered or sawed to an approximately true plane, and shall have no projections or depressions greater than ⅛ in. The front and back arris lines shall be pitched straight and true and there shall be no projection on the

back surface for 3 in. down from the top which would exceed a batter of 4 in. in 1 ft, except on V A5 the back surface shall have no projection or depression greater than 1.5 in.

The front face shall be at right angles to the planes of the top and ends and shall be smooth quarry split. free from drill holes and with no projection of more than 1 in. and no depression of more than ½ in. measured from the vertical plane of the face through the arris or pitch line for a distance down from the top of 8 in. for types VA1 and VA4, 10 in. for VA2 and VA3, and the full depth of VA5. For the remaining distance there shall be no projection or depression greater than 1 in. measured in the same manner.

The ends of all stones shall be square with the planes of the top and face so that when the stones are placed end to end as closely as possible no space shall show in the joint at the top and face of more than ½ in. for the full width of the top and for 8 in. down on the face for Type VA1 and VA4, 10 in. for VA2 and VA3, and the full depth of VA5, after which the end may break back not over 8 in. from the plane of the joint. The arris formed by the intersection of the plane of the joint with the planes of the top and exposed faces shall have no variation from the plane of the top and exposed faces greater than ⅛ in.

B. Type VB Curb.

This type of curbstone shall have a top surface free from wind, shall be pointed, peen hammered or sawed to an approximately true plane and shall have no projections or depressions greater than 0.25 in. The front and back arris lines shall be pitched straight and true.

The front face shall be at right angles to the plane of the top, and shall be smooth quarry split, free from drill holes and with no projection of more than 1.5 in. and no depression greater than 1 in. measured from the vertical plane of the face through the arris or pitch lines for the full depth of the face.

The ends of all stones shall be square with the planes of the top and face so that when stones are placed end to end as closely as possible no space shall show in the joint in the top and face of more than ½ in. for the full width of the top and 8 in. down on the face after which the ends may break back not more than 1 ft from the plane of the joint. On pieces less than 4 ft in length, the ends shall not break back more than 9 in. The arris formed by the intersection of the plane of the joint with the planes of the top and exposed faces shall have no variation from the plane of the top and exposed faces greater than ⅛ in.

M9.04.2: Granite Edgestone

The stones for the several types of edging shall be cut to the dimensions given in Table M9.04.2-1.

Table M9.04.2-1: Granite Edgestone Dimensions

	Type SA	Type SB	Type SC
Minimum Length	3 ft	2 ft	1 ft
Maximum Length	6 ft	6 ft	6 ft
Thickness	5 in. to 8 in.	3 in. to 6 in.	3 in. to 6 in.
Width of Face	12 in.	11 in. to 13 in.	11 in. to 13 in.

When the edging is used on a curve of 160 ft radius or less the length shall be as directed by the Engineer except that where the edging is to be set on a radius of 10 ft the maximum length shall be 1 ft.

Finish.

Type SA Edging.

The exposed face shall be smooth quarry split to an approximately true plane having no projections or depressions which will cause over 1 in. to show between a 2-ft straight-edge and the face when the straightedge is placed as closely as possible on any part of the face.

If projections on the face are more than that specified they shall be dressed off. The top and bottom lines of the face shall be pitched off to a straight line and shall not show over 0.5 in. between stone and straightedge when straight-edge is placed along the entire length of the top and bottom lines and when viewed from a direction at right angles to the plane of the face, and for the top line only not over ½ in. when viewed from a direction in the plane of the face. The ends shall be square to the length at the face and so cut that when placed end to end as closely as possible no space shall show in the joint at the face of over ¾ in., except that where the edging is to be used on a curve having a radius of 10 ft or less the ends of the stones shall be so cut as to provide a finished joint at the face of not more than ½ in. The arris formed by the intersection of the plane of the face with the plane of the end joint shall not vary from the plane of the face or the plane of the joint more than ¼ in. Drill holes may show on the exposed face but only along the bottom edge. The sides shall not be broken under the square more than 4 in. and the side adjacent to the grass shall not project over 1 in.

Type SB Edging.

The exposed face shall be smooth quarry split to an approximately true plane having no projections or depressions which will cause over 1 in. to show between a 2 ft straight-edge and the face when the straight-edge is placed as closely as possible on any part of the face.

If projections on the face are more than that specified they shall be dressed off. The top and bottom lines of the face shall be pitched off to a straight line and shall not show over 1 in. between stone and straight-edge when straight-edge is placed along the entire length of the top and bottom lines and when viewed from a direction at right angles to the plane of the face, and for the top line only not over 1 in. when viewed from a direction in the plane of the face. The ends shall be square to the length at the face and so cut that when placed end to end as closely as possible, no space shall show in the joint at the face of over 1.5 in., except that where the edging is to be used on a curve having a radius of 10 ft or less the ends of the stones shall be so cut as to provide a finished joint at the face section of not more than ½ in. The arris formed by the intersection of the plane of the face with the plane of the end joint shall not vary from the plane of the face more than ¼ in. Drill holes not more than 3.5 in. in length and ½ in. in depth will be permitted. The sides shall not be broken under the square more than 4 in. and the side adjacent to the grass shall not project over 1 in.

Type SC Edging.

The exposed face shall be smooth quarry split to an approximately true plane having no projections or depressions which will cause over ½ in. to show between a 2 ft straight-edge and the face when the straightedge is placed as closely as possible on any part of the face. If projections on the face are more than that specified they shall be dressed off. The top and bottom lines of the face shall be

pitched off to a straight line and shall not show over 1 in. between stone and straight-edge when straight-edge is placed along the entire length of top and bottom lines and when viewed from a direction at right angles to the plane of the face, and for the top line only, not over 1 in. when viewed from a direction in the plane of the face. The ends shall be square to the length at the face and so cut that when placed end to end as closely as possible no space shall show in the joint at the face of over 1.5 in., except that where the edging is to be used on a curve having a radius of 10 ft or less the ends of the stones shall be so cut as to provide a finished joint at the face of not more than ½ in. The arris formed by the intersection of the plane of the face with the plane of the end joint shall not vary from the plane of the face more than ¼ in. Drill holes not more than 3.5 in. in length and ½ in. in depth will be permitted. The sides shall not be broken under the square more than 4 in. and the side adjacent to the grass shall not project over 1 in.

M9.04.4: Stone for Stone Masonry Walls

Stone for stone masonry walls shall consist of sound durable blasted or field stone free from seams, cracks and other structural defects and of an approved and satisfactory quality and shape.

The stone shall consist of angular blasted or field stones having straight edges without re-entrant angles. The faces shall be flat but not necessarily rectangular in shape.

Individual stone shall have, when set in the wall, no face dimension less than 8 in. Stretchers shall have a depth in the wall at least 1.5 times the rise, and a length on the face at least twice the rise. Headers shall have a length on the face at least equal to the rise. Headers shall hold in the heart of the wall the same size as shown on the face and shall extend at least 12 in. more than the stretchers into the backing.

M9.04.5: Granite Curb Inlets

The granite for curb inlet shall conform to M9.04.0: Curb and Edging. It shall have a horizontal bed and the top shall be free from wind. The stone shall be sawn or peen hammered on top and the front and back edges shall be pitched true to line. The back face for a distance of 3 in. down from the top shall have no projection greater than 1 in. The front face shall be straight split, free from drill holes, and it shall have no projection greater than 1 in or depression greater than 0.5 in. for a distance of 10 in. down from the top, and for the remaining distance there shall be no depression or projection greater than 1 in. The ends shall be squared with the top for the depth of the face finish and so cut that the curb inlet can be set with joints of not more than ½ in.

The granite curb inlet shall be 6 ft in length ±½ in., from 17 to 19 in. in depth, 6 in. wide at the top and at least 6 in. wide at the bottom.

Curb inlets to be set on a radius of 160 ft or less shall be cut to the curve required. The joints of all curved curb inlets shall be cut on radial lines.

A gutter mouth at least 3 in. in depth and at least 2 ft in length shall be cut in the front face of the stone as shown on the plans.

Granite curb inlets shall match the adjacent curbing in color.

M9.04.6: Granite Curb Corners

The granite for curb corners shall conform to M9.04.0: Curb and Edging and shall have horizontal beds. They shall match the adjacent curbing in size, color and quality. The front arris lines shall extend through one-quarter of a circle having a radius of 2 ft or 3 ft respectively for Type A or Type B Curb Comer. The back arris line shall be straight. The plane of back shall be normal to top.

M9.04.8: Granite Bounds

Granite bounds shall be of sound granite, the top and bottom faces parallel and the front and back shall be straight split. The bounds shall be cut to the dimensions shown on the plans and shall be plain or lettered as indicated on the plans or as directed.

The stone shall be pointed on the top and on three sides and hammer dressed on the face for a distance of not less than 12 in. below the top. The top shall be 6 in. square and shall have a drill hole in the center 1.5 in. in depth and ½ in. in diameter, with the bottom somewhat flared.

M9.04.9: Dry Stone Masonry

Stone for dry stone masonry shall be hard and durable and free from seams or other imperfections and of an approved quality and shape. No stone shall be less than 6 in. in its least dimension. The stone shall be roughly square on joint beds and faces.

M9.05.0: Lumber and Wood Sheeting

Lumber and Wood Sheeting shall be sound Spruce, Douglas fir, white or yellow Lodgepole or Ponderosa pine, or western hemlock plank, planed on one side and either tongue and grooved or splined. Lumber sheeting shall not be less than nominal 4 in. thick. Wood sheeting shall not be less than nominal 2 in. thick.

M9.05.1: Wood Products

Timber shall conform to the requirements of AASHTO M 168, Wood Products, Structural Timber, Lumber, and Piling.

Preservative treatment shall meet the requirements of M9.05.5: Wood Preservatives.

M9.05.5: Wood Preservatives

Preservative treatment shall meet the requirements of AASHTO M 133 and AWPA U1, except that only preservative materials meeting current EPA or DEP regulations will be allowed.

Certificates of compliance and certificates of inspection bearing the independent inspection agencies verification for each lot of wood must be presented before installation and contain the species of wood, the type of preservative, the retention rate and penetration of the preservative.

M9.05.6: Timber Piles

A. General Requirements.

Timber piles shall conform to the requirements of ASTM D25 and shall be cut from sound and live trees, preferable during the winter season. Piles shall be free from any defects which will impair their strength or usefulness for the purpose intended or that will prevent proper driving.

Untreated timber piles shall have the bark unpeeled. Treated timber piles shall be clean-peeled so that all of the outer bark and at least 95% of the inner bark well distributed over the outer surface of the pile shall be removed.

All piles shall be cut above the ground swell, shall have a uniform taper from bun to tip end, and shall be free from short kinks. Knots or blemishes shall be trimmed off close and even with the body of the pile. A line from the center of the bun to the center of the tip must lie wholly within the body of the pile.

B. Inspection.

All piles will be subject to inspection before or after shipment to the site, or both, at the option of the Engineer. Any pile that does not conform to all the requirements will be rejected.

C. Specific Requirements.

All treated piles shall have not less than 1 in. of sapwood at any point on the butt end for Douglas-fir and not less than 2 in. of sapwood at any point on the butt end for Southern Pine.

Treated timber piles shall be Douglas-fir treated with ACZA or Southern Yellow Pine treated with CCA-C in accordance AWPA U1 Treated timber piles used in a marine environment shall be Southern Yellow Pine or Douglas-fir treated with creosote in accordance with AWPA U1 Certificates of compliance and certificates of inspection bearing the independent inspection agencies verification for each lot of wood must be presented before installation and contain the species of wood, the type of preservative, the retention rate and penetration of the preservative.

Butt and tip dimension for various lengths of piles shall be as set forth in the following table:

Table M9.05.6-1: Timber Pile Butt and Tip Dimensions

Length	Minimum Dimension 3 ft from Butt	Minimum Tip Dimension
Up to 40 ft	12 in.	8 in.
40 ft and up to 50 ft	12 in.	7 in.
50 ft and over	13 in.	6 in.

For all piles the maximum dimension 3 ft from the butt shall be 20 in. Measurements are under the bark in all cases. Where the piles are to support a concrete cap, the maximum butt dimensions shall be 6 in. less than the designated width of the concrete cap.

Where piles are to be in line in a bent, all piles in the bent shall be of uniform size to permit the proper fastening of the bracing. Cutting of piles to accommodate the bracing will not be permitted.

M9.06.0: Waterproof Paper Covers

Waterproof paper covers shall conform to the requirements of ASTM C171. The name of the manufacturer shall be marked or imprinted clearly on the paper for proper identification.

M9.06.1: Polyethylene Covers

A. Black Polyethylene Sheeting.

Black polyethylene sheeting suitable for use in covering storage piles of bulk or bag salt, or sand piles which have been blended with salt shall meet the requirements of NBS Product Standard PS-17.

The covers shall be 8 mils in thickness, black in color and contain suitable inhibitors to prevent deterioration due to sunlight and heat.

The sheeting shall be 40 ft in width and 100 ft in length. It shall be folded when packaged into rolls, so that the shipping width is not greater than 10 ft.

B. White Polyethylene Sheeting.

This material shall conform to the requirements of ASTM C171.

C. Reinforced Polyethylene Sheeting.

Reinforced Polyethylene Covers for stockpiles of salt and treated sand shall be reinforced with non-woven nylon or rayon cord, shall have a minimum tear strength of 110 lb in all directions, and shall weigh no less than 20 lb per 1,000 ft². They shall be black in color. The material shall be free from any additive which would reduce its resistance to water penetration or adversely affect the durability of the film. The covers shall contain suitable inhibitors to prevent deterioration due to sunlight and heat. They shall be 40 ft in width and 100 ft in length. They shall be folded when packaged into rolls, so that the shipping width is not greater than 10 ft.

M9.06.2: Tar Paper

Tar impregnated felted paper shall conform to the requirements of ASTM D227.

M9.06.3: Burlap

Burlap shall conform to the requirements of AASHTO M 182, Class 3. It shall not have been used as a container for sugar or other substances deleterious to concrete and shall be in good condition, free from holes, tears, or other defects that would render it unsuitable for curing concrete. It shall be furnished in strips not less than 3 ft nor more than 6 ft in width and not more than 2.5 ft longer than the width of the pavement slab.

M9.06.4: Polyethylene Coated Burlap

The material shall conform to the requirements of ASTM C171.

M9.06.5: Impervious Liquid Membrane

This material shall consist of an impervious liquid conforming to the requirements of ASTM C1315, Type 1 or 2. When tested in accordance with AASHTO T 155, the liquid membrane forming compound shall restrict the loss of water present in the test specimen at the time of application of the curing compound to not more than 0.055 g per cm² of surface after 3 days. When Type I is specified, it shall contain a fugitive dye.

M9.07.0: Plastic Waterstops

Waterstops shall be fabricated from a plastic compound, the basic resin of which shall be polyvinyl chloride. The compound shall contain any additional resins, plasticizers, inhibitors or other materials such that when compounded it shall meet the performance requirements hereinafter specified. No reclaimed polyvinyl chloride shall be used.

Waterstops shall be extruded in such a manner that any cross section shall be dense, homogenous and free from porosity or other imperfections. The cross section of waterstops shall be as shown on Department Standard Sketches.

Physical Requirements.

The waterstops shall meet the following requirements:

1. Tensile Strength, Die C, ASTM D412 ..... Minimum 2,000 psi
2. Ultimate Elongation, Die C, ASTM D412 ..... Minimum 250%
3. Cold Bend Test (See Appendix I) ..... No Cracking
4. Impact Resistance (See Appendix II) ..... No Cracking
5. Resistance to Alkalis (See Appendix III) ..... No Cracking
   - Increase in weight after 7 days ..... Maximum 0.25%
   - Increase in weight after 30 days ..... Maximum 0.40%
   - Decrease in weight after 7 days ..... Maximum 0.10%
   - Decrease in weight after 30 days ..... Maximum 0.30%
   - Change in dimensions after 30 days ..... Maximum 1.00%
6. Hardness Durometer (Shore A) ASTM D2240 ..... 75 ± 5
7. Water Absorption (48 hr) ASTM D570 ..... Maximum 0.5% (by weight)

General Requirements.

The waterstops shall be spliced only at jointing made necessary by construction design.

Where joints are required, they shall be made in accordance with the manufacturer's instructions, without appreciable loss in strength, elasticity or permeability of the material.

The waterstop material shall be practically impervious to water and unaffected by most common acids, alkalis, sea water and mineral oils. The material shall be such that it will not engage in electrolytic action with steel, and will not discolor concrete.

The approved waterstop when properly installed, as in a concrete construction or expansion joint, shall be capable of maintaining a head of 75 ft of water without leakage.

Qualification Samples.

A manufacturer requesting approval of a waterstop shall furnish to RMS a 3-ft length of each type of waterstop they intend to supply and a COA shall be furnished with the samples. The certificate shall state that the material furnished conforms without exception to all the requirements specified herein; and shall also include all qualitative and quantitative test results.

M9.08.0: Waterproofing Membranes

M9.08.1: Spray-Applied Waterproofing Membrane

A. General Requirements.

Only products listed on the QCML will be accepted for use. The membrane waterproofing system shall consist of:

- Primer
- One or two coat rapid curing cold liquid spray applied seamless methyl methacrylate, polyurea, or polyurethane methyl methacrylate membrane
- Aggregate keycoat
- Polymer modified tack coat

B. Material Requirements.

The total minimum base thickness for the membrane shall be 80 mils measured over peaks. The membrane shall easily accommodate the need for day joints and patch repairs. The membrane shall be able to bridge live cracks up to ⅛ in. in width and meet the criteria specified in Table M9.08.1-2.

The membrane waterproofing system shall be asbestos-free. The chemical composition of the primer, membrane, aggregate keycoat and tack coat that make up the membrane waterproofing system shall conform to the manufacturer's specifications for the material. All components shall be approved by the manufacturer as being compatible for use with the specified membrane. Cleaning solvents shall also be approved by the manufacturer for use with the membrane.

Primer for Spray-Applied Membrane.

The primer shall promote adhesion of the membrane to the concrete surface.

Table M9.08.1-1: Primer Material Properties

Property	Test	Requirements
Gel Time		> 5 minutes
Tack Free Time		< 2.5 hours, max at 77°F
Adhesion to Concrete	ASTM D7234	≥ 100 psi minimum and failure in concrete

Membrane

The membrane shall be meet the requirements in Table M9.08.1-2.

Table M9.08.1-2: Spray Applied Waterproofing Membrane Material Properties

Property	Test	Requirements
Solids Content		100%
Stability	ASTM C836	≥ 6 months
Crack Bridging		
(Neat Material + Aggregated Keycoat)	ASTM C1305 (see Note 1)	Pass, no cracking
Extensibility after Heat Aging	ASTM C1522	For information only
Percent Elongation at Break	ASTM D638	≥ 130%
Tensile Strength	ASTM D638	≥ 1,100 psi
Shore Hardness	ASTM D2240 (see Note 2)	≥ 50 Type 00
Minimum Thickness (Membrane only)	ASTM D6132 or other approved method	≥ 80 mils minimum measured over peaks; or ≥ thickness used to pass ASTM C1305 (Whichever thickness is greater)
Membrane Waterproofing System Adhesion to Concrete	ASTM D7234	≥ 100 psi minimum and failure in concrete
Permeance	ASTM E96	≤ 1.0 perms

Note 1: ASTM C1305 shall be modified to 25 cycles at -15°F no failure at ⅛ in. per hour.
Note 2: ASTM D2240 shall be modified per ASTM C836 section 6.5.

Aggregate for Keycoat

The broadcast aggregate shall be durable and provide shear resistant to prevent the HMA from shoving. Aggregate shall have a minimum Mohs hardness rating of 7 and be approved by the manufacturer.

Polymer Modified Tack Coat

The tack coat shall consist of either a polymer modified asphalt emulsion, or a polymer modified asphalt binder approved for use by the membrane waterproofing manufacturer and the Engineer. The tack coat shall be either supplied by the membrane waterproofing manufacturer or by a MassDOT approved asphalt emulsion Supplier.

C. Material Qualification.

A manufacturer requesting approval of a spray applied membrane system shall furnish to the Research and Materials Section the following:

1. The membrane system material specifications including product performance data.
2. Certified independent test reports demonstrating conformance to Table M9.08.1-2.
    a. The independent lab shall be recognized by the National Cooperation for Laboratory Accreditation (NACLA) in Construction Materials Engineering and Testing (CMET) or an equal program approved by Research and Materials.
    b. All testing shall be performed by one independent lab. Independent test reports must be dated within 2 years from the initial submission.

   c. Samples for all required testing shall be fabricated at the same time. Test reports shall denote the lot of material as well as the sample fabrication and testing dates.
3. MassDOT shall perform prequalification testing on the membrane.
   a. Two 10 in. by 10-in. square samples of the proposed membrane with smooth surfaces (no primer or aggregate in the keycoat). The samples shall be a minimum of 80 mils thick or the thickness used to pass the crack bridging requirement found in Table M9.08-4.

All submittals shall be certified to be in conformance with the manufacturer's instructions. Systems qualified by MassDOT per the performance criteria shall be considered for placement on the QCML. Membrane waterproofing systems shall remain on the QCML for a period of 5 years at which time the manufacturer will be required to submit certified test reports demonstrating conformance to this specification.

M9.08.2: Sheet Membrane

A. General Requirements.

Only products listed on the QCML will be accepted for use. Chemical composition, physical properties and dimensional requirements of the sheet membrane shall conform to the manufacturer's specifications for the material.

Also, all accessory materials such as, flashing, primer, etc., used in the application of the sheet membrane will be considered a part of this specification and shall conform to the manufacturer's requirements. The membrane waterproofing system shall consist of:

- Primer
- Sheet Membrane
- Mastic

B. Material Requirements.

The primer shall meet the requirements of M9.09.1: Primer.

The membrane sheet shall meet the requirements in ASTM D6153 and Table M9.08.2-1.

The mastic for use with rubberized sheets shall be a rubberized asphalt cold-applied joint sealant. The mastic for use with modified bitumen sheet shall be a blend of bituminous and synthetic resins. The mastic shall be approved for use by the manufacturer.

Table M9.08.2-1: Sheet Membrane Material Properties

Property	Test	Requirements
Thickness	ASTM D3767	≥60 mils
Permeance	ASTM E96 Water Method, Procedure B	≤0.1 perms
Pliability	ASTM D146 (see Note 1)	No breaks
Note 1: The test temperature of the specimen shall be 0°F after 24 hours and 180° bend over a ¼ in. mandrel.		

C. Material Qualification.

A manufacturer requesting approval of a preformed sheet membrane shall furnish to the Research and Materials Section the following:

1. The membrane system material specifications including product performance data.
2. The peel-off backing material shall be tear resistant to prevent portions of it from remaining after the membrane is applied.
3. Certified independent test reports demonstrating conformance to ASTM D6153, Table M9.08.2-1, and the submitted product performance data.
    a. The independent lab shall be recognized by the National Cooperation for Laboratory Accreditation (NACLA) in Construction Materials Engineering and Testing (CMET) or an equal program approved by Research & Materials. All testing shall be performed by the same independent lab.
    b. Independent test reports must be dated within 2 years from the initial submission. Samples for all required testing shall be fabricated at the same time. Test reports shall denote the lot of material as well as the sample fabrication and testing dates.
4. A detailed summary of successful installations that have occurred in the United States, including owner contact information, design and construction details (substrate type & condition, membrane system components, hot mix asphalt overlay thickness and mix details, etc.), year constructed, tests performed, performance monitoring and/or testing, and any other additional information requested by the Department.

All submittals shall be certified to be in conformance with the manufacturer's instructions. The Research & Materials Section shall review the manufacturer's submitted documentation. A demonstration of the product's installation and performance may be required to be qualified by MassDOT. Systems qualified by MassDOT shall be considered for placement on the QCML. Preformed sheet membrane systems shall remain on the QCML for a period of 5 years at which time the manufacturer will be required to submit certified test reports demonstrating conformance to this specification.

M9.08.3: Hot Applied Rubberized Asphalt Membrane

A. General Requirements.

Only products listed on the QCML will be accepted for use. Chemical composition, physical properties and dimensional requirements of the sheet membrane shall conform to the manufacturer's specifications for the material. The membrane waterproofing system shall consist of:

- Primer
- Hot poured rubberized asphalt membrane consisting of a single component hot applied asphalt
- Protective covering

B. Material Requirements.

The primer shall meet the requirements of M9.09.1: Primer.

The membrane shall be able to bridge live cracks up to ⅛ in. in width and meet the criteria specified in Table M9.08.3-1.

The protective covering shall be rolled asphalt sheets conforming to ASTM D6380, Type II.

Table M9.08.3-1: Hot Applied Rubberized Asphalt Membrane Material Properties

Property	Test	Requirements
Solids Content		100%
Flash Point	AASHTO T 48	≥ 500°F
Flexibility	ASTM D5329	No delamination or cracking
Penetration	ASTM D5329	at 77°F ≤ 110; at 122°F ≤ 200
Permeance	ASTM E96 Water Method, Procedure B	≤ 0.1 perms
Softening Point	ASTM D36	≥ 176°F

C. Material Qualification.

A manufacturer requesting approval of a hot applied rubberized asphalt membrane shall furnish to the Research and Materials Section the following:

1. The membrane system material specifications including product performance data.
2. Certified independent test reports demonstrating conformance to Table M9.08.3-1.
    a. The independent lab shall be recognized by the National Cooperation for Laboratory Accreditation (NACLA) in Construction Materials Engineering and Testing (CMET) or an equal program approved by Research & Materials. All testing shall be performed by one independent lab.
    b. Independent test reports must be dated within 2 years from the initial submission. Samples for all required testing shall be fabricated at the same time. Test reports shall denote the lot of material as well as the sample fabrication and testing dates.
3. A detailed summary of successful installations that have occurred in the United States, including owner contact information, design and construction details (substrate type & condition, membrane system components, hot mix asphalt overlay thickness and mix details, etc.), year constructed, tests performed, performance monitoring and/or testing, and any other additional information requested by the Department.

All submittals shall be certified to be in conformance with the manufacturer's instructions. The Research & Materials Section shall review the manufacturer's submitted documentation. A demonstration of the product's installation and performance may be required to be qualified by MassDOT. Systems qualified by MassDOT shall be considered for placement on the QCML. Hot applied asphalt membrane systems shall remain on the QCML for a period of 5 years at which time the manufacturer will be required to submit certified test reports demonstrating conformance to this specification.

M9.09.0: Primer and Damp-Proofing

M9.09.1: Primer

This material shall be suitable for priming concrete and masonry surfaces prior to the application of waterproofing or damp-proofing and shall meet the requirements of ASTM D41.

M9.09.2: Damp-Proofing

This material shall meet one of the following requirements:

- ASTM D449, Type II.
- ASTM D1227, Type II – Class 1 or Type III – Class 1

M9.11.0: Insulation and Waterproof Jackets

Where water pipe is installed or hung on structures, it shall be covered with insulation conforming to the following requirements:

The insulating material shall be fiberglass, cellular glass, expanded polystyrene, or urethane, and shall be covered with a waterproof jacket as specified. Section lengths and thickness shall depend on the pipe size and the recommendations of the insulation manufacturers. Under no conditions shall the minimum total thickness be less than 3 in., except when urethane is the insulating material and then the total thickness shall be no less than 2 in. Only one type of insulating material shall be used throughout an installation.

M9.11.1: Cellular Glass

Cellular glass insulation shall conform to the requirements of Federal Specification, HH-1-551, Insulation Block and Pipe Covering, Thermal Cellular Glass or revisions thereof.

The following installation accessories shall be part of this specification:

a) Stainless steel strapping, ¾ in. x 0.015 in. and stainless steel clips.
b) Asphalt coated glass fabric, 20 x 20 mesh conforming to M3.06.1: Coated Glass Fabric.

M9.11.2: Fiberglass

Fiberglass insulation shall conform to the requirements of Federal Specification, HH-1-562, Insulation, Thermal, Mineral Wool, Block or Board and Pipe Insulation (Molded Type) Type II, Class 2 and 3, or revisions thereof.

The following installation accessories shall be part of this specification:

a) 1-in. galvanized wire netting.
b) Corrugated aluminum jacket, 0.02 in. thick.

M9.11.3: Polystyrene

Expanded polystyrene insulation shall conform to the requirements of Federal Specification, HH-1-524, Insulation Board, Thermal, Type I, Class 2 or revision thereof.

The following installation accessories shall be part of this specification:

a) Stainless steel strapping, ¾ in. x 0.015 in. and stainless steel clips.

b) Corrugated aluminum jacket, 0.02 in. thick with integral vapor barrier.
c) A suitable polystyrene adhesive.
d) Asphalt coated-glass fabric, 20 x 20 mesh conforming to M3.06.1: Coated Glass Fabric.

M9.11.4: Urethane

Urethane insulation shall conform to the requirements of Federal Specification, HH-1-00530, Insulation Board, Thermal (Urethane), Type II, Class 2 or revisions thereof.

The following installation accessories shall be part of this specification:

a) Stainless Steel Strapping ¾ in. x 0.015 in. and stainless steel clips.
b) Corrugated aluminum jacket 0.02 in. thick with integral vapor barrier.
c) A suitable urethane adhesive.
d) Asphalt coated glass fabric, 20 x 20 mesh conforming to M3.06.1: Coated Glass Fabric.

M9.11.5: Waterproof Jackets

Waterproof jackets for covering insulation on water pipes shall be assembled as specified from any of the following materials or combinations thereof.

a) Asphalt coated glass fabric, 20 x 20 mesh conforming to M3.06.1: Coated Glass Fabric.
b) Stainless steel strapping, ¾ in. x 0.015 in. and stainless steel clips.
c) 1-in. galvanized wire netting.
d) Corrugated aluminum jacket, 0.02 in. thick.
e) Corrugated aluminum jacket, 0.02 in. thick with integral vapor barrier.
f) A polystyrene adhesive.
g) A urethane adhesive.

M9.12.0: Reflectors for Barriers

An oversized yellow reflectorized cluster, diamond shape 24 in. x 24 in., and a 28-in. x 22-in. x ¾-in. thick plywood panel shall be bolted onto barrier as directed.

The yellow reflectorized cluster (Type H1-2) shall conform to the requirements of Section 2D of the MUTCD and the approved standard detail sheets.

The 28-in. x 22-in. panel shall be ¾-in. exterior type (Grade A-A, Commercial Standard PS-1).

M9.13.0: Hydrated Lime

Hydrated Lime shall consist of a minimum of 95% calcium and magnesium oxides, pulverized so that at least 99.5% will pass a No. 30 sieve and at least 85% pass a No. 200 sieve.

M9.14.0: Preformed Expansion Joint Filler

This specification covers non-extruding and resilient non-bituminous types of preformed expansion joint fillers and shall conform to AASHTO M 153.

M9.14.1: Preformed Compression Joint Seals (Bridges)

This specification covers the materials requirements for preformed polychloroprene elastomeric joint seals for bridges. The seal consists of a multiple-web design composed of polychloroprene and

functions only by compression of the seal between the faces of the joint with the seal folding inward at the top to facilitate compression. The seal is installed with a lubricant adhesive and is designed to seal the joint and reject incompressibles. The compression seal and the lubricant-adhesive shall conform to AASHTO M 297.

M9.14.2: Closed Cell Foam Joint Filler

This specification covers the requirements for closed cell foam used as a joint filler between different components of bridges and walls. Closed Cell Foam Joint Filler shall have a compact closed cell structure composed of synthetic isomeric polymers and shall be gray in color. It shall offer sufficient heat resistance so that it is compatible with hot applied sealing compounds. Closed Cell Foam Joint Filler shall meet the requirements of Section 5.1 through 5.4 of ASTM D1752, with the compression requirement modified to 10 psi minimum to 25 psi maximum. Typical physical properties, as determined using test method ASTM D545, shall be as follows:

Compression, 50% ..... 13 psi
Extrusion ..... 0.1 in.
Recovery 99.21%
Water Absorption, Volume 0.246%

The Contractor shall provide certified test data which documents compliance with the required physical properties. The certified test data shall be submitted to the Engineer for approval.

M9.14.3: Polyurethane Joint Sealer

This specification covers the requirements for a cold applied, two component, elastomeric joint sealing compound suitable for use as a joint sealer and/or caulking compound on joints in Portland cement concrete or steel surfaces. This material shall meet ASTM C920.

M9.14.4: Polyurethane Joint Sealer, Non-Sag

This specification covers the requirements for a cold applied, single component elastomeric joint sealing compound for sealing, caulking vertical joints on bridges and other structures. This material shall meet ASTM C920.

M9.14.5: Elastomeric Bridge Bearing Pads

Elastomeric bearing pads shall consist of plain pads (consisting of elastomer only) and laminated bearings (consisting of layers of elastomers restrained at their interfaces by bonded metal laminates). The elastomeric compound shall be composed of 100% low temperature Grade 3 virgin crystallization resistant polychloroprene (neoprene) meeting the requirements of AASHTO M 251 and Division II, Section 18 of the AASHTO Standard Specifications for Highway Bridges. The type of bearing (plain or laminated), hardness, dimensions, design compressive load, design compressive stress, and whether the bearings are subject to shear deformation shall be as specified on the Plans. All bearings shall be tested by a nationally recognized testing laboratory approved by the Engineer to ensure compliance with all applicable requirements of AASHTO M 251.

The Contractor shall provide the Department with written notification 30 days prior to the start of bearing production. The notification shall include the contract number, quantity, type, and size of bearing being produced, manufacturer's name, and the representative who will coordinate production, inspection, sampling, and testing with the Department. At least 30 days prior to the

scheduled date of beam erection, the Contractor shall deliver to the job site all bearings called for on the plans plus one additional elastomeric bearing pad of each size and type identified on the Plans. Certified test result data that demonstrates compliance with all applicable requirements of AASHTO M 251 shall also be provided to the Engineer at least 30 days prior to the scheduled date of beam erection. One elastomeric bearing pad of each size and type identified on the Plans shall be randomly sampled from the job site by the Engineer for additional destructive testing at least 30 days prior to the scheduled date of beam erection. No beams shall be erected until the bearings have been accepted by the Engineer.

All components of the elastomeric bearing pad shall be molded together as an integral unit and all surfaces of the steel laminations shall be covered with a minimum of $^{3}/_{16}$ in. of elastomer. The finished pads shall be free of cuts, blemishes, and molding defects. All bearings that are delivered to the job site with exposed steel laminations are rejected. All imperfections or exposed laminations that result in either less than $^{3}/_{16}$ in. of elastomer cover over any surface of the steel laminations shall be repaired by the manufacturer at the point of manufacture. The repair shall consist of sealing the imperfections flush on the finished pad with a bonded vulcanized patch material compatible with the elastomeric bearing pad. Repairs employing caulking type materials or repairing the bearings in the field shall not be permitted.

M9.14.6: Bonded Closed Cell Joint System

The joint seal shall be composed of either closed cell cross linked ethylene vinyl acetate polyethylene copolymer or of closed cell polychloroprene (neoprene). The joint seal shall feature grooves or ribs which run the full length of the joint. The joint seal shall be bonded to the concrete surfaces on each side of the joint using a two-component epoxy based adhesive.

The joint seal shall have the following typical physical properties:

Tensile Strength, (ASTM D412).....115 psi, Minimum
Elongation @ Break (ASTM D3575).....200%, Minimum
Water Absorption, Volume %.....5%, Maximum

The two-component epoxy based adhesive shall conform to ASTM C881, Type I & II, Grade 2, Class B & C, and shall have the following physical properties:

Tensile Strength, (ASTM D638).....3,500 psi, Minimum
Compressive Strength.....7,000 psi, Minimum
Bond Strength .....430 psi, Minimum

The Contractor shall provide certified test data which documents compliance with the required physical properties. The certified test data shall be submitted to the Engineer for approval.

M9.15.0: Liquid Penetrant/Sealant

Liquid penetrant/sealant for Portland cement concrete surfaces used to protect concrete surfaces from chloride intrusion shall be a material previously approved by the Department for the purpose intended and listed on the QCML.

M9.16.1: Rubber-Cotton Duck Bearing Pad

The bearing pads shall be manufactured of all new (unused) materials and composed of multiple layers of prestressed duck, 8.1 oz per net square yard, duck warp count 50 ±2 threads per inch and filling count 40 ± threads per inch, 64 plies per inch of finished pad thickness, impregnated and bound with a high quality rubber compound, containing rot and mildew inhibitors and anti-oxidants, compounded into resilient pads of uniform thickness.

The pads shall withstand compressive loads perpendicular to the plane of laminations of not less than 10,000 psi before breakdown. Load deflection properties in accordance with procedures of MIL-C-882 shall be the following maximum percentages of total pad thickness: 10% at 1,000 psi, 15% at 2,000 psi. When loaded to 1,500 psi, permanent set as load is removed in accordance with procedures of MIL-C-882 shall be a maximum of 2.5% of the original "zero point" thickness. Shore Durometer shall not be less than 85 nor more than 95. The ratio of lateral expansion to vertical deflection shall not exceed 0.25 when loaded to 1,500 psi. The material shall not lose effectiveness throughout a temperature range of -65°F to +200°F. No visual evidence of damage or deterioration by environmental effects of sunshine, humidity, salt spray, fungus, and dust in accordance with MIL-E-5272. Thickness shall be as shown on drawings within tolerances of ±5%.

M9.16.2: Molded Fabric Bearing Pad

The preformed pads shall consist of a fabric and rubber body.

The pad shall be made with new unvulcanized rubber and unused fabric fibers in proper proportion to maintain strength and stability.

The surface hardness expressed in standard rubber hardness figures shall be 80 Shore A Durometer ±10 durometer average, the ultimate breakdown limit of the pad under compression loading shall be no less than 7,000 psi for the specified thickness without extrusion or detrimental reduction in thickness.

The pads shall be furnished to specified dimensions with all bolt holes accurately located.

M9.17.0: Asphaltic Binder for Asphaltic Bridge Joint System

The thermoplastic polymeric modified asphalt binder shall conform to physical properties based on the designated ASTM testing methods found in Table M9.17.0-1.

Table M9.17.0-1: Physical Properties of Asphaltic Binder for Asphaltic Bridge Joint Systems

Test	ASTM Test Method	Required Properties
Softening Point	D36	180°F minimum
Tensile Adhesion	D5329	700% minimum
Ductility at 77°F	D113	400 mm minimum
Penetration at 77°F, 150 g, 5 sec.	D3407	7.0 mm maximum
Flow, 5 hours at 140°F	D3407	3.0 mm maximum
Resiliency at 77°F	D3407	70% maximum
Asphalt Compatibility	D3407	Pass
Low Temperature Penetration at 0°F, 200g, 60 sec.	D5 with cone*	1.0 mm minimum
Flexibility at -10°F	D5329	Pass
Bond 3 Cycles at -20°F, 50% Elongation	D3405	Pass
Bond 3 Cycles at 0°F, 100% Elongation	D3405	Pass
Recommend Installation Range		360°F to 390°F
Safe Heating Temperature Range		390°F to 420°F

* Use Method D5; however replace the standard penetration needle with a penetration cone conforming to the requirements given in Test Method D217, except the interior construction may be modified as desired. The total moving weight of the cone and attachments shall be 150.0 g ± 0.10.

M9.17.1: Aggregate for Asphaltic Bridge Joint System

The aggregate shall be granite, basalt or gabbro. The aggregate shall be selected, crushed, processed, double-washed and dried at the source. It shall be delivered to job site in prepackaged waterproof containers. The supplier shall certify the above requirements are met.

The aggregate shall be made available in ¾-in., ½-in. and ⅜-in. sizes and shall meet gradation requirements specified by the manufacturer for the joint system.

M9.17.2: Backer Rod

The backer rod shall be closed cell foam expansion joint filler, compatible with polymeric binder and the elevated temperatures of the polymeric binder application. The size of the backer rod shall be in accordance with the manufacturer's recommendations for the gap width.

The backer rod shall meet ASTM D1752 and have the following typical physical properties using a ½ in. specimen and the test method ASTM D545:

Compression, 50% ..... 13.3 psi
Extrusion ..... 0.1 in.
Recovery 99.21%
Water Absorption, Volume 0.246%

M9.17.3 Bridge Plate for Asphaltic Bridge Joint System

The bridge plate shall be AASHTO M 270M/M 270 Grade 36 steel, minimum width and thickness of 8 in. x 0.25 in. and shall be galvanized in accordance with AASHTO M 111M/M 111. Holes for the locating pins shall be 12 in. on center. Locating pins shall be 16d common nails or larger, hot dipped galvanized.

M9.17.4: Neoprene Seals

Neoprene seals shall be composed of flexible, non-reinforced, extruded neoprene compound exhibiting the physical properties listed in Table M9.17.4-1. All neoprene seals shall incorporate a matching locking lug that mechanically snaps into the corresponding extrusion shape cavity to ensure watertightness and proper joint performance. All mitering and/or splicing of the neoprene seal shall be performed under controlled conditions at the place of manufacturer. The neoprene seal shall be supplied and installed in one continuous length without field splices.

Table M9.17.4-1: Physical Properties of Neoprene Seals

Property	Test Method	Requirement
Tensile Strength	ASTM D412	2,000 psi
Tensile Strength, Elongation at Break	ASTM D412	250%, minimum
Hardness, Durometer Type A	ASTM D2240 Modified	50 to 60
Oven Aging, 70 hours at 212°F:		
Loss of Tensile Strength	ASTM D573	20% loss maximum
Loss of Elongation	ASTM D573	20% loss maximum
Maximum Change in Hardness	ASTM D573	-0 to +10 points
Oil Swell, ASTM Oil #3, 70 hours at 212°F	ASTM D471	45% maximum weight increase
Low Temperature	ASTM D746	Not Brittle
Ozone Resistance, 70 hours at 104°F, 20% elongation, 300 pphm, in air, Wipe Surfaces to Remove Contamination	ASTM D1149	No Cracks
Low Temperature Stiffening, 7 days at 14°F, Hardness, Durometer Type A	ASTM D2240	0 to +15 points change
Compression Set, 70 hours at 212°F	ASTM D395 Method B	40% maximum

M9.18.0: Impact Attenuators

All Impact Attenuators shall be tested to MASH crash testing standards.

M9.18.1: Redirective Impact Attenuators

To be classified as a Redirective Impact Attenuator, the results of the following crash test designations must fall within the acceptable impact tolerances and evaluation criteria show in Table 2-3 of MASH (n = Test Level): n-30, n-31, n-32, n-33, n-34, n-35, n-36, n-37 (2270P Pickup Truck, only), and n-38.

Redirective Impact Attenuators will be designated as such on the QTCE.

M9.18.2: Non-Redirective Impact Attenuators

To be classified as a Non-Redirective Impact Attenuator, the results of the following crash test designations must fall within the acceptable impact tolerances and evaluation criteria show in Table 2-3 of MASH (n = Test Level): n-40, n-41, n-42, n-43, n-44, and n-45.

Non-Redirective Impact Attenuators will be designated as such on the QTCE.

M9.18.3: Low-Maintenance Impact Attenuators

To be classified as a Low-Maintenance Impact Attenuator, the device must:

- Meet the criteria of M9.18.1: Redirective Impact Attenuators.
- Meet the Department's minimum requirements for the evaluation of Low-Maintenance Impact Attenuators.

Low-Maintenance Impact Attenuators will be designated as such on the QTCE. A single product may be listed as both a Redirective Impact Attenuator and a Low-Maintenance Impact Attenuator.

M9.30.0: Retroreflective Sheeting

This specification covers retroreflective sheeting designed to reflectorize traffic control signs, delineators, barricades, and other devices. All retroreflective sheeting shall meet the requirements of ASTM D4956 and AASHTO M 268, and as listed below:

Table M9.30.0-1: Retroreflective Sheeting Requirements

Retroreflective Sheeting Application	Allowable Retroreflective Sheeting Classification(s) per ASTM D4956
Type A Permanent Sign Panels (per Subsection 828.42: Panels)	Type IV
Temporary Rigid Sign Panels (flat panel aluminum or plywood substrate)	Type IV, Type VIII, Type IX
Temporary Roll-Up Signs	Type VI
Type B Sign Panels (per Subsection 828.42: Panels)	Type VII, Type IX, Type XI
Traffic Cones	Type VI
Reflectorized Drums	Type IV, Type VIII, Type IX
Portable Breakaway Barricades Type III	Type IV, Type VIII, Type IX
Flexible Delineator Posts	Type IV, Type V, Type VIII, Type IX
Guardrail End Treatments	Type VIII, Type IX
Guardrail Terminal Delineators	Type IV, Type VIII, Type IX
Demountable Reflectorized Delineator, Guard Rail	Type VIII, Type IX
Impact Attenuator Delineators	Type IV, Type VIII, Type IX

Sheeting shall only be applied to a substrate that is recommended by the sheeting manufacturer.

M9.30.4: Acrylic Plastic 3.25 Inch Diameter Center-Mount Reflectors

Acrylic plastic 3.25 in. diameter center-mount reflectors shall be a material previously approved by the Department for the purpose intended and listed on the QTCE.

M9.30.6: Temporary Raised Pavement Markers

Temporary raised pavement markers shall consist of a durable plastic or another type of durable material and have the following characteristics.

- Color: (ASTM D1535) White or Yellow.
- Dimensions are to be at least 4 in. wide and a minimum reflective area of 1.5 in.² of retroreflective sheeting meeting M9.30.0, Type C.
- Markers shall contain one way or two way retro reflective faces as required by the Engineer.

Markers shall provide daytime delineation and shall adhere to HMA or PCC surfaces using adhesives and/or methods recommended by the manufacturer. Markers shall be removable from HMA and PCC pavements without the use of heat, solvents, grinding or blasting. After removal, permanent marks, scars or damage to the pavement surface shall be minimal, free from dirt or any other contaminants.

M9.30.7: Guardrail Delineator

Guardrail delineators shall be fabricated from galvanized steel having a minimum coating thickness of 0.9 oz per square foot, polycarbonate plastic or thermoplastic and shall allow a minimum of 8 in.² of retroreflective sheeting per face, conforming to M9.30.0: Retroreflective Sheeting.

Guardrail delineators shall be shaped to fit in the valley of the W shape. Circular holes shall be used for the bolt connecting the delineator to the W beam. Adhesive connections shall not be allowed.

M9.30.8: Reflectorized Flexible Delineator Post

Reflectorized Flexible Delineator Posts shall be used as directed for delineation of roadways and ramps. Only those products previously approved for the purpose intended and listed on the QTCE may be used.

M9.30.9: Reflectorized Drum

Reflectorized drums shall be plastic and shall meet the requirements of the MUTCD.

Retroreflective sheeting for drums shall meet the requirements of M9.30.0: Retroreflective Sheeting and be 6 in. wide.

Reflectorized drums are listed on the QTCE.

M9.30.10: Guardrail Termini Delineator

Guardrail termini delineators shall be fabricated in accordance with the Plans. The panel shall consist of Type A aluminum sign panel. Retroreflectorized sheeting shall conform to M9.30.0: Retroreflective Sheeting.

M9.30.11: Traffic Cones

Traffic cones shall be orange in color, 36 in. tall and with retroreflective sheeting collars that conform to M9.30.0: Retroreflective Sheeting.

Traffic cones are listed on the QTCE.

M9.31.0: Non-motorized Traffic Counting Stations (NTCS)

NTCS shall have a count accuracy of 85% or greater, by direction of travel. When located on a facility that has both pedestrian and bicycle traffic, such as a multi-use path, the minimum count accuracy shall apply to both user types. When located on a facility that is limited to pedestrians, such as a sidewalk, the minimum count accuracy shall only apply to pedestrian counts. When located on a facility that is limited to bicyclists, such as a bike lane, the minimum count accuracy shall only apply to bicyclist counts.

NTCS shall have the capability to collect counts by direction and log the data for pedestrians and bicyclists separately.

The data collected shall be in predefined time interval bins. These bins shall, at a minimum, include options for 1-minute, 5-minute, 15-minute, 1-hour, and 24-hour intervals. 24-hour counts shall be formatted with intervals that start at midnight (0:00 a.m.). Data shall be exportable in a Department-defined .csv, .xlsx, and/or .xml format.

NTCS shall have an independent, battery-operated power source and shall not require a hard-wired service connection, with exceptions to Permanent NTCS for Intersections as described below. Batteries shall be sized to allow uninterrupted operation of the NTCS for a minimum of 1 year. Solar panels, if required, may be used to keep the batteries at a sufficient charge. All batteries shall carry a minimum 1-year warranty. Replacement batteries shall be industry standard, commercially available, and not proprietary to device.

As an exception to the independent power source requirement, a traffic signal cabinet may be used to leverage the installation of a Permanent NTCS for Intersections by providing Power over Ethernet (PoE) from the cabinet to the proposed device.

All NTCS shall offer free, manufacturer support available during typical business hours, Monday through Friday. Permanent devices shall be furnished with a manufacturer's warranty for all materials for at least one year following acceptance.

Firmware, software, and security updates shall be included at no cost for the life of the product.

M9.31.1: NTCS for Intersections

Items classified for use at Intersections shall have the capability of uniquely identifying, classifying, and discretely counting pedestrians and/or bicyclists passing through one or more user-defined zones, traveling in both directions along multiple axes.

The accuracy of Intersection Devices shall not be influenced by the presence of motor vehicles adjacent to the user-defined detection zones, if separate, or within the detection zone if the space is shared between motorized and non-motorized traffic, such as a shared lane or crosswalk.

M9.31.2: NTCS for Trails

Items classified for use on Trails shall have the capability of uniquely identifying, classifying, and discretely counting pedestrians and/or bicyclists passing a user-defined point or zone in both directions on a single axis.

The accuracy of Trail Devices shall not be influenced by the presence of motor vehicles that are offset a minimum of 6 ft from the edge of the detection point or zone.

M9.40.0: Drilling Slurry

Drilling slurry shall conform to one of the following specifications. Reports of all required tests shall be furnished to the Engineer upon completion of each drilled shaft.

Mineral Slurry.

Mineral slurry shall be premixed thoroughly with water and adequate time, as prescribed by the manufacturer, shall be allotted for hydration prior to introduction into the shaft hole. Slurry tanks of adequate capacity are required for slurry circulation, storage, and treatment. Control tests shall be performed on the mineral slurry by the Contractor to determine density, viscosity, sand content and pH. Properties of mineral slurry (Bentonite or Attapulgite) in water shall meet the range of values found in Table M9.40.0-1.

Table M9.40.0-1: Physical Properties of Mineral Slurry

Property	Value Required	Test Method
Density*	64 to 75 pcf	Mud Density API 13B-1 Section 1
Viscosity	26 to 50 s per qt	Marsh Funnel and Cup API 13B-1 Section 2.2
pH	8 to 11	Glass Electrode, pH Meter, or pH Paper
Sand Content	4.0% by volume maximum	Sand Content API 13B-1 Section 5
* To be increased by 2 pcf in salt water or brackish water.		

Tests to determine density, viscosity and pH shall be performed during shaft excavation to establish a consistent working pattern. Four sets of tests shall be made during the first 8 hr of slurry use. When the results show consistent behavior, one set of testing shall be made every 4 hr of slurry use thereafter.

Water Slurry.

The use of water slurry without full length steel casings will only be allowed if approved in writing by the Engineer. In that case, all of the properties of mineral slurry shall be met, except that the maximum density shall not exceed 70 pcf. Mixtures of water and on-site soils shall not be allowed for use as a drilling slurry, since particulate matter falls out of suspension easily and can contaminate the concrete.

Polymer slurry.

Natural or synthetic slurry shall have specific properties at the time of mixing and of concreting that are in conformance with the written recommendations of the manufacturer and the Contractor's Drilled Shaft Installation Plan. The Contractor shall perform the required tests at the

specified frequency and shall provide slurry that complies with the maximum and/or minimum property requirements for the subsurface conditions at the site and with the construction methods that are used. Whatever product is used, the sand content at the base of the shaft excavation shall not exceed 1% when measured by the API sand content test, immediately prior to concreting.

M9.40.1: Well casing Pipe

Well casing pipe shall conform to the requirements for welded and seamless steel pipe, ASTM A53.

M9.40.2: Water Pumps

Water pumps (jet, submersible or shallow well) shall be of a standard commercial quality. The capacity of the pump shall be such that it will be capable of discharging water at the rate and pressure for the pumping depth specified for the installation.

The motor voltage of the pump shall be compatible with the voltage available at the electrical source.

The Contractor shall submit for approval to the Engineer five days before placing any purchase orders for the water pump, accessories and electrical equipment, the name of the manufacturer, the specifications for the pump, accessories and electrical equipment that they propose to furnish.

M9.40.3: Chlorine Solution

Chlorine solution used for disinfecting springs, wells and other water systems, shall consist of a solution of water and liquid chlorine, sodium hypochlorite, calcium hypochlorite or chloride of lime.

Liquid forms of chlorine or sodium hypochlorite and powder forms of calcium hypochlorite or chloride of lime shall be used according to the instructions supplied by the manufacturer and as recommended by the DEP.

If sodium hypochlorite is already in solution as a laundry bleach containing 5.25% sodium hypochlorite, it shall be used at the rate of 1 qt per 3,000 gallons of water to be disinfected. The dosage should be sufficient to produce a chlorine taste in the water.

M9.40.4: Plastic Water Pipe, Flexible

Flexible plastic pipe shall be polyethylene plastic pipe schedule 40 or 80 suitable for the transportation of potable water and conform with the requirements of AASHTO M 258. The material grade selected shall be capable of withstanding a minimum sustained water pressure of 160 psi at 73.4°F. The pipe shall be inside diameter controlled. Fittings may be either nylon, copper or bronze. Clamps shall be stainless steel.

M9.40.5: Plastic Water Pipe, Rigid (PVC)

Rigid polyvinyl chloride (PVC) plastic pipe shall be suitable for transportation of potable water and conform. with the requirements of AASHTO M 258. The material grade and standard pipe dimension ratio (SDR) shall be capable of withstanding a minimum sustained water pressure of 160 psi at 73.4°F. Fittings shall be PVC plastic conforming with AASHTO M 258. The burst strength of the fittings shall be not less than that of the pipe being furnished.

M9.40.6: Plastic Water Pipe, Rigid (ABS)

Rigid Acrylontrile-Butadiene-Styrene (ABS) plastic pipe shall be suitable for the transportation of potable water and conform with the requirements of AASHTO M 258. The material grade and SDR shall be capable of withstanding a minimum sustained water pressure of 160 psi at 73.4°F. Fittings shall be ABS plastic conforming with AASHTO M 258. The burst strength of the fittings shall be not less than that of the pipe being furnished.

M9.40.7: Copper Water Tube, Seamless

Seamless copper water tube suitable for general plumbing shall conform to the requirements of AASHTO M 258. Tube material shall conform to ANSI/ASTM 888, Type k.

M9.40.8: Steel Water Pipe, Galvanized

Galvanized steel water pipe shall be the standard weight class conforming to the requirements of AASHTO M 258. Pipe material shall conform with the ASTM A120 option.

M9.50.0: Geotextile Fabrics

Geotextile fabric used for subsurface drainage, separation, stabilization, permanent erosion control, temporary silt fences, or paving fabric shall conform to requirements of AASHTO M 288 for the intended application and be listed on the QCML.

SECTION M10: TRAFFIC CONTROL DEVICES

M10.00.0: General

All Traffic Control Devices shall be designed, manufactured and tested in accordance with the applicable standards of the ANSI, IMSA, ITE, NEMA, UL and these Specifications.

Inclusion on the Qualified Traffic Control Equipment (QTCE) List is contingent upon meeting these Specifications.

M10.01.0: Advanced Transportation Controller Cabinets (General)

Definitions

All Advanced Transportation Controller (ATC) Cabinets shall conform to the requirements defined in the Advanced Transportation Controller Cabinet (ATCC) 5301 v02 Standard.

ATC Cabinet types are classified in Table M10.01.0-1:

Table M10.01.0-1: ATC Cabinet Types

Type	Description	Doors	Nominal Dimensions (Height x Width x Depth)	Material Specification
P4	Ground-mount NEMA "P"	4 (2 front, 2 rear)	67 in. x 44 in. x 26 in.	M10.01.1
P1	Ground-mount NEMA "P"	1	67 in. x 44 in. x 26 in.	M10.01.2
352	Ground-mount Caltrans 352	2 (1 front, 1 rear)	67 in. x 30 in. x 24 in.	M10.01.3
336S	Side-of-pole-mount Caltrans 336S	1	46 to 48 in. x 24 to 26 in. x 22 to 24 in.	M10.01.4

Cabinet Fabrication

All ATC Cabinets shall be fabricated from a minimum of ⅛-in. thick 5052-H32 sheet aluminum alloy and be of all-weather construction. All internal and external hardware shall be fabricated from non-corrosive material. Finish and surface preparation of the cabinet shall conform to Section 7.7 of the NEMA TS2-2016 Standard. The door hinge shall be a continuous type with a stainless-steel hinge pin. The door handle and all external fasteners used in the cabinet construction shall be stainless steel. All unwelded cabinet seams shall be sealed with clear RTV silicone sealant to prevent dust intrusion.

Cabinet Rack Cage

Standard rack cages shall be installed inside the cabinet. The EIA rack portion of the cage shall consist of four continuous, adjustable equipment mounting angles. The mounting angle nominal thickness shall be 11-gauge plated steel. The mounting angles shall be tapped with 10-32 threads with Electronic Industries Association (EIA) universal spacing. The mounting angle shall comply with EIA-310-B and shall be supported at the top and bottom be either welded or bolted support angle to form the cage. The mounting angles shall provide holes to mount the side panels. Clearance between the rails for mounting assemblies shall be 17.75 in. The cage shall be bolted to the cabinet at four points via the housing cage supports and four points via associated spacer brackets and the top and bottom. The cage shall be centered within the cabinet door opening.

Cabinet Power

The main cabinet circuit breaker shall be rated at 30 amps. Circuit breakers shall be approved and listed by the UL. All circuit breakers shall be quick-make, quick-break on either automatic or manual operation and shall conform to UL 489. Contacts shall be silver alloy enclosed in an arc quenching chamber.

Back of Door Documentation

All ground-mount ATC Cabinets shall be supplied with a 6-in. high riser aluminum base that elevates the cabinet above the cabinet foundation. The color and finish of the base shall match the color and finish of the cabinet it supports.

ATC Cabinets shall be supplied with a laminated door sticker. This sticker shall be permanently affixed to the inside front control side of the cabinet door. At a minimum, the sticker shall contain the following information:

a. Vehicle detection information including all detector channel assignments, phases assigned, approaches, and cabinet termination points.
b. Per approach preemption information including channel, approach/direction, and termination points.
c. Field termination chart showing per approach/per phase numbering of all signal circuits.
d. Signal phasing and signal plan with intersection geometry and signal head designations.

The back of the main front door shall contain a resealable, heavy-duty opaque plastic envelope with two grommets that provide mounting to two integrated hooks installed on the back side of the front cabinet door. The heavy-duty plastic envelope shall be used to store cabinet wiring diagrams and operations manuals that cannot be accommodated in the pull-out drawer storage tray.

Electric Meter Trim

The cabinet shall be supplied and installed with an electric service meter socket trim and electrical service disconnect switch mounted on the exterior of the cabinet. The meter and disconnect switch shall be installed centered on the side of the cabinet without doors such that it is not less than 48 in. nor more than 60 in. above final grade.

The Contractor shall coordinate with the local electric utility company to determine the appropriate type of electric service meter socket trim and electrical conductors to be used.

The line side cable shall be routed external to the cabinet from the ground to a 50A disconnect switch, then continuing to the bottom of the electric service meter socket trim, all through rigid steel conduit furnished and installed by the Contractor. The load side cable shall be routed through the cabinet and terminated on the line side of the main cabinet circuit breaker.

The cable shall be routed through the interior of the cabinet such that it does not block or enter into available rack space preventing that space from being used either by equipment supplied as part of the project, or future equipment that would be installed in the rack system. The cable shall be routed between the edge of the rack system and the cabinet side wall, along the bottom of the cabinet and below the bottom opening of the doors.

Care shall be taken by the Contractor when installing the electric service meter socket trim and electrical service disconnect switch so that there is no damage inflicted on installed devices or the rack system during the installation. All metal shavings produced during the drilling of the access hole for the electric service shall be removed from the cabinet interior by the Contractor. The Contractor shall install appropriate bushings to all cabinet penetrations.

All wiring shall comply with all applicable local electrical codes and the MEC.

Detector Test Switch Panel

The cabinet shall be supplied with a detector test switch panel. There shall be a total of 48 switches to allow for the manual placement of detector calls into the controller. Each switch shall be clearly labelled as to input channel. Each switch position shall correspond to the same controller input; switch 1 is for controller input channel 1, switch 2 is for controller input channel 2, etc. The detector switch panel shall be comprised of switches that are wired directly to the corresponding input channels on the rack assemblies. Each switch shall be supplied with a red LED indicator to be illuminated whenever a channel input is active via the three-position detector switch. The use of an SIU internal to the detector test switch panel to provide this capability is not allowed. The switches shall be three position type and function as follows:

a. Up Position: provides a constant call
b. Center Position: normal operation (phase receives call from detectors)
c. Down Position: provides a momentary call

Standard Cabinet Devices

A Cabinet Monitor Unit (CMU) and Auxiliary Display Unit (ADU) shall be supplied and installed in each cabinet. The CMU and ADU shall conform to requirements defined in the Advanced Transportation Controller Cabinet (ATCC) 5301 v02 standard. The CMU/ADU units supplied and installed as part of this project shall support 32 channels. All configuration programming shall be resident in a non-volatile Datakey device. Each CMU shall be supplied with a Datakey programmer and associated software. The Datakey programming software shall include a set-up wizard which shall assist the user with the initial set up of the device. The Contractor shall program the Datakey with data entries appropriate for each intersection. All programing resident on the Datakey shall be included in the hardcopy.

A cabinet power supply shall be supplied with each cabinet. The cabinet power supply shall comply with ATCC 5301 v02. A full complement of switch packs shall be supplied with each cabinet, switch packs shall comply with ATCC 5301 v02.

A full complement of flashers shall be supplied with each cabinet, flashers shall comply with ATCC 5301 v02.

A full complement of SIUs shall be supplied with each cabinet, the Serial Interface Units (SIU) shall comply with ATCC 5301 v02.

A full complement of flash transfer relays shall be supplied with each cabinet, flash transfer relays shall comply with ATCC 5301 v02.

The Contractor shall reconfigure the default username and passwords on all communications/control equipment within the ATC Controller and Cabinet. This includes but is not

limited to the ATC traffic controller, ATC ancillary equipment, video detection equipment, Ethernet switches, and routers. The new username and passwords shall be created in accordance with the Department Information Technology (IT) standards; no manufacture default level passwords shall be allowed.

All SDLC cables used to interconnect devices within the cabinet shall be supplied with factory installed protective wire covers to protect the connector side of the cables. The use of Contractor supplied/installed cable protector covers shall not be allowed.

The Contractor shall utilize network communications encryption settings on all forms of wired Ethernet data paths. No "in the clear" communications shall be allowed. At a minimum all wired Ethernet connections shall meet 802.1AE standards. The Contractor shall supply and configure a Cyber Intrusion and Prevention Device (CIPD) in each ATC cabinet. The CIPD shall prevent any unauthorized access/connections to the traffic control system. Upon detection of unauthorized attempts, the CIPD shall notify the Department via SMS message and/or email and log the event. The CIPD shall be installed prior to any remote access device.

The Contractor shall coordinate with the Engineer for final configuration of the CIPD. No direct access to the traffic system shall be allowed without the installation of a CIPD and/or Router/Firewall.

Surge Suppression

Electrical filtering/surge protection shall be supplied and installed in each cabinet in accordance with ATCC 5301 v02 requirements and the manufacturer's recommendations. At a minimum, surge suppression shall be provided for incoming electric utility power conductors, all signal control circuits, vehicle detection, pedestrian detection, communications, and preemption system terminations. The use of a single fuse for surge suppression shall not be allowed.

The cabinet shall be electrically bonded and grounded to comply with Section 643, the National Electrical Code (NEC) and the National Electrical Safety Code (NESC), latest versions of each document.

Each in-cabinet current interrupting device (controller unit, flasher, and all other devices) shall be equipped with a suitable radio interference suppressor installed at the input power point. Interference suppressors shall be designed to minimize interference in both broadcast and aircraft frequencies. Suppressors shall be designed for 125 percent of the total connected load and shall meet standards of the UL and the EIA.

External GFCI Outlet

The cabinet shall be supplied with a GFCI outlet to be installed on the upper left, exterior of the control side wall of the ground-mount cabinet and the upper left side of the pole-mount cabinet. The electrical outlet will be GFCI protected, house in a locked access enclosure. The GFCI outlet shall be supplied via its own 15-amp circuit breaker. The GFI outlet assembly shall be housed in a heavy-duty vandal resistant, weatherproof, dustproof enclosure designed for exterior applications. The GFCI enclosure door shall contain a weatherproof seal and supplied with a lock accessed with a skeleton style (#1) key.

Generator Transfer Switch

The cabinet shall be supplied with a generator panel. The generator panel shall consist of a manual transfer switch and a twist-lock connector for generator hookup. The manual generator transfer switch shall be Reliance Controls model CSR302 or approved equivalent. The transfer switch and twist-lock connector shall be located inside a surface mounted generator access enclosure with a separate lockable door mounted on the lower left, exterior wall of the cabinet.

The door shall be equipped with a tamper resistant hinge. The generator panel assembly shall be housed in a heavy-duty, vandal resistant, weatherproof, dustproof enclosure designed for exterior applications. The connection to an external generator shall be via a waterproof, secure connection. The connection shall allow authorized personnel to access, connect, and secure an external electrical source to the cabinet for power restoration. The generator panel door shall be constructed with a weatherproof seal and supplied with a lock accessed with a J201 key.

Output Channel Assignments

The cabinet shall be configured to provide output channel assignments per Table M10.01.0-2:

Table M10.01.0-2: Output Channel Assignments

Channels	Outputs (16 Channel Cabinet)	Outputs (32 Channel Cabinet)
1-8	Phases 1-8	Phases 1-8
9-12	Flashing Yellow Arrow, Overlaps, As Needed	Flashing Yellow Arrow
13-16	Pedestrians	Pedestrians
17-20	n/a	Overlaps
21+	n/a	As Needed

M10.01.1: P4 ATC Cabinet

Cabinet Enclosure

The cabinet size and functional requirements shall conform to the NEMA TS2-2016 Standard, Section 7.

The cabinet enclosure shall be a dust and moisture-proof aluminum housing with an auxiliary door in door feature. The cabinet shall be configured to eliminate arc flash. All electrical equipment shall be dead front, no open terminals, busbars, breakers, or exposed terminal strips. All cabinet switches and circuit breakers shall be permanently labeled as to function. The cabinet shall be designed, constructed, and installed with all necessary provisions to comply with the latest NFPA 70E requirements. All electrically live contact points over 50V shall be covered with Lexan or a suitable physical barrier to eliminate the possibility of arc flash.

The lock for the police door switch compartment shall unlock with a skeleton style (#1) key. The lock for the main door(s) of the cabinet shall unlock with a Corbin #2 key. Two sets of two keys (main door/police door) shall be furnished with each cabinet.

The cabinet shall be supplied with a permanent label mounted on the upper portion of the inside front main door that shall contain the name of the cabinet manufacturer, controller manufacturer, model/part number and year/month of assembly.

The cabinet shall be supplied with a GFCI duplex outlet and a rack mounted multi-outlet strip.

The quantity, size and location of the equipment shall correspond to the contract drawings for the ATC Cabinet. All equipment shall be installed with the correct number of mounting screws/mounting support devices. All internal cabinet wiring shall be routed such that there is no conflict for access to cabinet devices or interference with door mechanisms.

The cabinet shall be provided with two removable lifting eyes for placing the cabinet on its foundation. Each eye opening shall have a minimum diameter of ¾ in. Each lifting eye shall be able to support a weight limit of 1,000 lbs.

The cabinet shall be equipped by the with an internal cable management system. The cable management system shall be comprised of nonconductive channels designed to facilitate wire and cable routing within an electrical enclosure.

All shelving used on the Power and Auxiliary side of the cabinet shall be constructed of .125-gauge aircraft grade aluminum or mold steel and designed to support a minimum of 250 lbs. The shelves shall be securely attached to the 19-in. cage.

Cabinet Configuration

The cabinet shall be supplied with two side-by-side, 19-in. rack cages which shall extend from the bottom to the top of the cabinet. The cabinet front shall provide for user interface to the in-cabinet equipment including the front panel of the controller, the cabinet status displays and detection system control interfaces. The cabinet rear shall provide access for termination of field cables and shall only be accessed for installation and for cabinet troubleshooting. The left-side rack of the cabinet relative to facing the cabinet from the front, to be referred to as the “Control” side, shall house the control devices such as the Controller, Cabinet Monitor Unit (CMU) and Auxiliary Display Unit (ADU), switch packs, and the power distribution panel. As such, this rack shall be referred to as the “Control” side of the cabinet. The right-side rack of the cabinet relative to facing the cabinet from the front, to be referred to as the “Power and Auxiliary” side, shall house the spare card cage assembly, battery back-up devices (if required), communications elements and future ancillary devices.

Cabinet Doors

The cabinet shall be supplied with four main doors: two on the front face and two on the back face. Each door shall open independently with an independent center post latching for each of the four doors. The front control door shall be defined as the “primary” door; the remaining three main doors shall be defined as “secondary” doors.

The cabinet main doors shall be provided with a stop to limit door opening to both 90° and 180° ±10°. The door stop bars shall be a captive-type mechanism that serves to keep the bars in contact with the cabinet at both stop bar ends and provided with a catch that can be operated when the doors reach these two positions and shall hold the doors open securely until released. The cabinet shall be supplied with a three-point draw roller latching system consisting of the following latching points:

a. Center of the cabinet (lock)
b. Top of the cabinet – controlled by door handle
c. Bottom of the cabinet – controlled by door handle

The latching points on the top and bottom of the cabinet doors shall remain in the locked position until the door locks are disengaged. The locking mechanism shall be equipped with nylon rollers to secure the top and bottom of the doors.

The cabinet shall be supplied with a ¾-in. diameter shank, stainless steel latching handle for each door. The latching handle shall have a provision for padlocking the door in a closed position. The cabinet shall have a pliable seal composed of caulking compound or mastic installed between the cabinet base and the concrete foundation and in between the riser base and the cabinet to prevent dust and dirt from entering the cabinet.

Internal Cabinet Lighting

The cabinet shall be supplied with white LED light panels which shall automatically illuminate via a door open switch whenever any one of the four main cabinet doors are opened. The LED panels shall produce a minimum of 1,000 lumens on the Control side of the cabinet and 1,000 lumens on the Power/Auxiliary side of the cabinet and be protected by a clear shatterproof shield. The cabinet shall contain four light panels: two at the top of each rack assembly and two at the bottom portion of each rack assembly. There shall be two switches on each of the four main doors. LED light panel mounting brackets shall be installed such that they do not interfere with the unused rack mounting holes which could potentially conflict with the installation of future rack mounted devices. The second door switch shall be used to monitor when the door has been opened. The front control side door monitoring switch shall be connected to one of the door status inputs of the controller. The door monitoring switches for the remaining doors shall be connected to the second door status input to the controller. The door status inputs shall log a report event that one of the doors was opened.

Cabinet Fans

The cabinet shall be provided with thermostatically controlled ventilating fans and throwaway glass fiber air filters. The electric fans shall have ball or roller bearings and shall have a capacity of 100 ft^3 per minute. The fans shall be rated for continuous duty with a minimum service life of 3 years. The fan blades shall be supplied with a safety screen to prevent accident contact with the blades. The ventilating system shall be designed to prevent the entrance of rain, snow, dust, and insects. The fans and vents shall be arranged in such a manner that the air intake is at the cabinet bottom and the exhaust is at the cabinet top. The air intake shall be rain tight and covered with a removable glass fiber air filter. The removable air filter shall be firmly held in place with aluminum louvered backing plate such that cracks, and openings are eliminated to ensure that all air is filtered. The cabinet shall contain two fans. The thermostat panel shall be mounted to the top, rear of the cabinet's 19-in. equipment rack and oriented to be clearly visible allowing user adjustable temperature settings from a minimum of 70°F to 140°F and capable of activating the fans within plus or minus five degrees of the set temperature; the thermostat shall be initially set to 100°F. Any exposed terminals shall be covered to protect a technician's hand. There shall be two intake vents provided with the cabinet, one in each front door.

Cabinet Switches/Manual Control

The cabinet shall be supplied with a police door panel located in the middle area of the front door on the Power and Auxiliary side. The switches shall be mounted in the police panel and labelled as to function. The three switches shall be supplied as follows:

a. Signal On/Off
b. Signal/Flash
c. Manual/Auto with cord

The manual control cord shall be a coiled type, sealed weatherproof covered hand switch extending to 6 ft when fully stretched. The cord shall be fastened to the cabinet via a compression type connector to provide strain relief for the cord's electrical connections. The police door panel shall be of sufficient size so as to store the manual control cord when panel door is closed.

The cabinet shall be supplied with a technician's panel mounted integral to the front of the input/output rack assemblies. This panel shall be supplied with the following switches:

a. Flash/Auto (Allows the controller to cycle while flashing)
b. Signals On/Off (Allows the controller to cycle with signal displays being dark)
c. Stop Time Normal/On (Provides the ability to manually activate a controller stop time input)

Slide Out Tray

The cabinet shall contain a pull-out drawer, 19-in. wide with sufficient strength to hold a laptop computer. The top of the drawer shall be covered with a non-conductive, non-skid material and hinged such that a storage space is available to store cabinet documentation or small parts. The pull-out drawer shall be located in the Power and Auxiliary side below the first top unused empty shelf.

Spare Devices

The cabinet shall be supplied with a Spare Lateral Rack (SLR) assembly. This rack assembly shall not be wired to any cabinet device, but rather used to store spare rack mounted cabinet devices such as switch packs, isolators, serial interface units (SIUs), CMUs and phase selectors. This spare rack assembly shall be located at the top of the Power and Auxiliary rack.

In addition to the full complement of switch packs, flashers, SIU's and flash transfers relays, 2 additional SIU's, 32 additional Phoenix connectors, and 1 additional CMU USB datakey programmer tool with software shall be supplied. All spare equipment required to be supplied with the cabinet shall be stored in the SLR and any additional spare equipment shall be placed on the Power and Auxiliary side shelves. No spare equipment shall be placed on the interior cabinet foundation.

Input and Output Channels

The cabinet shall be supplied with one of the following Input and Output Channel configurations, as called for in the Plans or Special Provisions:

a. 32 Output Channels and 48 Input Channels
b. 32 Output Channels and 24 Input Channels
c. 16 Output Channels and 24 Input Channels

M10.01.2: P1 ATC Cabinet

Cabinet Enclosure

The cabinet size and functional requirements shall conform to the NEMA TS2-2016 Standard, Section 7.

The cabinet enclosure shall be a dust and moisture-proof aluminum housing with an auxiliary door in door feature. The cabinet shall be configured to eliminate arc flash. All electrical equipment shall be dead front, no open terminals, busbars, breakers, or exposed terminal strips. All cabinet switches and circuit breakers shall be permanently labeled as to function. The cabinet shall be designed, constructed, and installed with all necessary provisions to comply with the latest NFPA 70E requirements. All electrically live contact points over 50V shall be covered with Lexan or a suitable physical barrier to eliminate the possibility of arc flash.

The lock for the police door switch compartment shall unlock with a skeleton style (#1) key. The lock for the main door(s) of the cabinet shall unlock with a Corbin #2 key. Two sets of two keys (main door/police door) shall be furnished with each cabinet.

The cabinet shall be supplied with a permanent label mounted on the upper portion of the inside front main door that shall contain the name of the cabinet manufacturer, controller manufacturer, model/part number and year/month of assembly.

The cabinet shall be supplied with a GFCI duplex outlet and a rack mounted multi-outlet strip.

The quantity, size and location of the equipment shall correspond to the contract drawings for the ATC Cabinet. All equipment shall be installed with the correct number of mounting screws/mounting support devices. All internal cabinet wiring shall be routed such that there is no conflict for access to cabinet devices or interference with door mechanisms.

The cabinet shall be provided with two removable lifting eyes for placing the cabinet on its foundation. Each eye opening shall have a minimum diameter of ¾ in. Each lifting eye shall be able to support a weight limit of 1,000 lbs.

Cabinet Configuration

The cabinet shall be supplied with three shelves. The top two shelves shall be supplied with two side by side 19” rack support systems. The cabinet front shall provide for user interface to the in-cabinet equipment including the front panel of the controller, the cabinet status displays and detection system control interfaces as well as provide access to the field cable terminations.

Cabinet Doors

The cabinet shall be supplied with one main door. The main door shall be defined as the “primary” door The cabinet main door shall be provided with a stop to limit door opening to both 90° and 180° ±10°. The door stop bars shall be a captive type mechanism that serves to keep the bars in contact with the cabinet at both stop bar ends and provided with a catch that can be operated when the doors reaches these 2 positions and shall hold the doors open securely until released. The cabinet shall be supplied with a three-point draw roller latching system consisting of the following latching points:

a. Center of the cabinet (lock)
b. Top of the cabinet – controlled by door handle
c. Bottom of the cabinet – controlled by door handle

The latching points on the top and bottom of the cabinet doors shall remain in the locked position until the door locks are disengaged. The locking mechanism shall be equipped with nylon rollers to secure the top and bottom of the doors.

The cabinet shall be supplied with a ¾-in. diameter shank, stainless steel latching handle for each door. The latching handle shall have a provision for padlocking the door in a closed position. The cabinet shall have a pliable seal composed of caulking compound or mastic installed between the cabinet base and the concrete foundation and in between the riser base and the cabinet to prevent dust and dirt from entering the cabinet.

Internal Cabinet Lighting

The cabinet shall be supplied with white LED light panels which shall automatically illuminate via a door open switch whenever the main cabinet door is opened. The LED panels shall produce a minimum of 1,000 lumens and be protected by a clear shatterproof shield. The cabinet shall contain two light panels: one at the top of the cabinet and one at the bottom portion of the cabinet. There shall be two switches on the main door. LED light panel mounting brackets shall be installed such that they do not interfere with the installation of any in cabinet devices. A second door open status switch shall activate a controller input to log a report event that one of the doors was opened.

Cabinet Fans

The cabinet shall be provided with thermostatically controlled ventilating fans and throwaway glass fiber air filters. The electric fans shall have ball or roller bearings and shall have a capacity of 100 ft^3 per minute. The fans shall be rated for continuous duty with a minimum service life of 3 years. The fan blades shall be supplied with a safety screen to prevent accident contact with the blades. The ventilating system shall be designed to prevent the entrance of rain, snow, dust, and insects. The fans and vents shall be arranged in such a manner that the air intake is at the cabinet bottom and the exhaust is at the cabinet top. The air intake shall be rain tight and covered with a removable glass fiber air filter. The removable air filter shall be firmly held in place with aluminum louvered backing plate such that cracks, and openings are eliminated to ensure that all air is filtered. The cabinet shall contain two fans. The thermostat shall be mounted on the top interior of the cabinet and user adjustable to allow for temperature settings from a minimum of 70°F to 140°F and capable of activating the fans within plus or minus five degrees of the set temperature; the thermostat shall be initially set to 100°F. Any exposed terminals shall be covered to protect a technician's hand. There shall be one intake vent provided with the cabinet in the front door.

Cabinet Switches/Manual Control

The cabinet shall be supplied with a police door panel located in the middle area of the front door. The switches shall be mounted in the police panel and labelled as to function. The three switches shall be supplied as follows:

a. Signal On/Off
b. Signal/Flash
c. Manual/Auto with cord

The manual control cord shall be a coiled type, sealed weatherproof covered hand switch extending to six ft when fully stretched. The cord shall be fastened to the cabinet via a compression type connector to provide strain relief for the cord's electrical connections. The police door panel shall be of sufficient size so as to store the manual control cord when panel door is closed.

The cabinet shall be supplied with a technician's panel mounted integral to the front of the input/output rack assemblies. This panel shall be supplied with the following switches:

a. Flash/Auto (Allows the controller to cycle while flashing)
b. Signals On/Off (Allows the controller to cycle with signal displays being dark)
c. Stop Time Normal/On (Provides the ability to manually activate a controller stop time input)

Slide Out Tray

The cabinet shall contain a pull-out drawer, 19-in. wide with sufficient strength to hold a laptop computer. The top of the drawer shall be covered with a non-conductive, non-skid material and hinged such that a storage space is available to store cabinet documentation or small parts. The pull-out drawer shall be located under the top shelf on the left-hand side.

Spare Devices

In addition to the full complement of switch packs, flashers, SIU's and flash transfers relays; 2 additional SIU's, 32 additional Phoenix connectors, and 1 additional CMU USB datakey programmer tool with software shall be supplied. All spare equipment required to be supplied with the cabinet shall be stored on the lower shelf. No spare equipment shall be placed on the interior cabinet foundation.

Input and Output Channels

The cabinet shall be supplied with one of the following Input and Output Channel configurations, as called for in the Plans or Special Provisions:

a. 32 Output Channels and 48 Input Channels
b. 32 Output Channels and 24 Input Channels
c. 16 Output Channels and 24 Input Channels

M10.01.3: 352 ATC Cabinet

Cabinet Enclosure

The cabinet size and functional requirements shall conform to the Caltrans Transportation Electrical Equipment Specifications (TEES), 2020 for cabinet size 352.

The traffic signal control equipment shall be enclosed within a dust and moisture-proof aluminum housing with an auxiliary door in door feature. The cabinet shall be configured to eliminate arc flash. All electrical equipment shall be dead front, no open terminals, busbars, breakers, or exposed terminal strips. All cabinet switches and circuit breakers shall be permanently labeled as to function. The cabinet shall be designed, constructed, and installed with all necessary provisions to comply with the latest NFPA 70E requirements. All electrically live contact points over 50V shall be covered with Lexan or a suitable physical barrier to eliminate the possibility of arc flash.

The lock for the police door switch compartment shall unlock with a skeleton style (#1) key. The lock for the main door(s) of the cabinet shall unlock with a Corbin #2 key. Two sets of two keys (main door/police door) shall be furnished with each cabinet.

The cabinet shall be supplied with a permanent label mounted on the upper portion of the inside front main door that shall contain the name of the cabinet manufacturer, controller manufacturer, model/part number and year/month of assembly.

The cabinet shall be supplied with a GFCI duplex outlet, as well as a cabinet mounted multi-outlet strip.

The quantity, size and location of the equipment shall correspond to the contract drawings for the ATC cabinet. All equipment shall be installed with the correct number of mounting screws/mounting support devices. All internal cabinet wiring shall be routed such that there is no conflict for access to cabinet devices or interference with door mechanisms.

The cabinet shall be provided with two lifting eyes for placing the cabinet on its foundation. Each eye opening shall have a minimum diameter of ¾ in. Each lifting eye shall be able to support a weight limit of 1,000 lb.

Cabinet Configuration

The cabinet shall be supplied with a single 19-in. rack cage which shall extend from the bottom to the top of the cabinet. The cabinet front shall provide for user interface to the in-cabinet equipment including the front panel of the controller, the cabinet status displays and detection system control interfaces as well as provide access to the field cable terminations.

Cabinet Doors

The cabinet shall be supplied with two main doors: one on the front face and one on the back face. The front control door shall be defined as the “primary” door; the rear door shall be defined as “secondary” door.

The cabinet main doors shall be provided with a stop to limit door opening to both 90° and 180° ±10°. The door stop bars shall be a captive-type mechanism that serves to keep the bars in contact with the cabinet at both stop bar ends and provided with a catch that can be operated when the doors reach these 2 positions and shall hold the doors open securely until released. The cabinet shall be supplied with a three-point draw roller latching system consisting of the following latching points:

a. Center of the cabinet (lock)
b. Top of the cabinet – controlled by door handle
c. Bottom of the cabinet – controlled by door handle

The latching points on the top and bottom of the cabinet doors shall remain in the locked position until the door locks are disengaged. The locking mechanism shall be equipped with nylon rollers to secure the top and bottom of the doors.

The cabinet shall be supplied with a ¾-in. diameter shank, stainless steel latching handle for each door. The latching handle shall have a provision for padlocking the door in a closed position. The cabinet shall have a pliable seal composed of caulking compound or mastic installed between the

cabinet base and the concrete foundation and in between the riser base and the cabinet to prevent dust and dirt from entering the cabinet.

Internal Cabinet Lighting

The cabinet shall be supplied with white LED light panels which shall automatically illuminate via a door open switch whenever any one of the two main cabinet doors are opened. The LED panels shall produce a minimum of 1,000 lumens and be protected by a clear shatterproof shield. The cabinet shall contain two light panels: one at the top of the rack assembly and one at the bottom portion of the rack assembly. There shall be two switches on each of the two main doors. LED light panel mounting brackets shall be installed such that they do not interfere with the unused rack mounting holes which could potentially conflict with the installation of future rack mounted devices. A second door open status switch per door shall activate a controller input to log a report event that one of the doors was opened. The door open status switches shall be connected to separate controller inputs.

Cabinet Fans

The cabinet shall be provided with a thermostatically controlled ventilating fan and throwaway glass fiber air filter. The electric fan shall have ball or roller bearings and shall have a capacity of 100 ft^3 per minute. The fan shall be rated for continuous duty with a minimum service life of 3 years. The fan blades shall be supplied with a safety screen to prevent accident contact with the blades. The ventilating system shall be designed to prevent the entrance of rain, snow, dust, and insects. The fan and vent shall be arranged in such a manner that the air intake is at the cabinet bottom and the exhaust is at the cabinet top. The air intake shall be rain tight and covered with a removable glass fiber air filter. The removable air filter shall be firmly held in place with aluminum louvered backing plate such that cracks, and openings are eliminated to ensure that all air is filtered. The cabinet shall contain one fan. The thermostat panel shall be mounted to the top, rear of the cabinet's 19-in. equipment rack and oriented to be clearly visible allowing user adjustable temperature settings from a minimum of 70°F to 140°F and capable of activating the fans within plus or minus five degrees of the set temperature; the thermostat shall be initially set to 100°F. Any exposed terminals shall be covered to protect a technician's hand. There shall be one intake vent provided with the cabinet in the front door.

Cabinet Switches/Manual Control

The cabinet shall be supplied with a police door panel located in the middle area of the front door. The switches shall be mounted in the police panel and labelled as to function. The three switches shall be supplied as follows:

a. Signal On/Off
b. Signal/Flash
c. Manual/Auto with cord

The manual control cord shall be a coiled type, sealed weatherproof covered hand switch extending to six ft when fully stretched. The cord shall be fastened to the cabinet via a compression type connector to provide strain relief for the cord's electrical connections. The police door panel shall be of sufficient size so as to store the manual control cord when panel door is closed.

The cabinet shall be supplied with a technician's panel mounted integral to the front of the input/output rack assemblies. This panel shall be supplied with the following switches:

a. Flash/Auto (Allows the controller to cycle while flashing)
b. Signals On/Off (Allows the controller to cycle with signal displays being dark)
c. Stop Time Normal/On (Provides the ability to manually activate a controller stop time input)

Slide Out Tray

The cabinet shall contain a pull-out drawer, 19-in. wide with sufficient strength to hold a laptop computer. The top of the drawer shall be covered with a non-conductive, non-skid material and hinged such that a storage space is available to store cabinet documentation or small parts. The pull-out drawer shall be located in the rack directly under the 24 channel input assembly.

Spare Devices

In addition to the full complement of switch packs, flashers, SIU's and flash transfers relays; 2 additional SIU's, 32 additional Phoenix connectors, and 1 additional CMU USB datakey programmer tool with software shall be supplied. All spare equipment required to be supplied with the cabinet shall be delivered to the Department.

Input and Output Channels

The cabinet shall be supplied with 16 output channels and 24 input channels.

M10.01.4: 336S ATC Cabinet

Cabinet Enclosure

The cabinet size and functional requirements shall conform to the Caltrans Transportation Electrical Equipment Specifications (TEES), 2020 for cabinet size 332.

The traffic signal control equipment shall be enclosed within a dust and moisture-proof aluminum housing with an auxiliary door in door feature. All cabinets shall be configured to eliminate arc flash. All electrical equipment will be dead front, no open terminals, busbars, breakers, or exposed terminal strips. All cabinet switches and circuit breakers shall be permanently labeled as to function. The cabinet shall be designed, constructed, and installed with all necessary provisions to comply with the latest NFPA 70E requirements. All electrically live contact points over 50 volts shall be covered with Lexan or a suitable physical barrier to eliminate the possibility of an arc flash.

The lock for the police door switch compartment shall unlock with a skeleton style (#1) key. The lock for the main door(s) of the cabinet shall unlock with a Corbin #2 key. Two sets of two keys (main door/police door) shall be furnished with each cabinet.

The cabinet shall be supplied with a permanent label mounted on the upper portion of the inside front main door that shall contain the name of the cabinet manufacturer, controller manufacturer, model/part number and year/month of assembly.

The cabinet shall be supplied with a GFCI duplex outlet, as well as a rack mounted multi-outlet strip.

The quantity, size and location of the equipment shall correspond to the contract drawings for the ATC cabinet. All equipment shall be installed with the correct number of mounting

screws/mounting support devices. All internal cabinet wiring shall be routed such that there is no conflict for access to cabinet devices or interference with door mechanisms.

The cabinet shall be provided with two lifting eyes for placing the cabinet on its mount. Each eye opening shall have a minimum diameter of ¾ in. Each lifting eye shall be able to support a weight limit of 1,000 lb.

The cabinet shall be equipped by the with an internal cable management system. Comprised of nonconductive channels designed to facilitate wire and cable routing within an electrical enclosure.

Cabinet Configuration

The cabinet shall be supplied with a single 19-in. rack cage which shall extend from the bottom to the top of the cabinet. The cabinet front shall provide for user interface to the in-cabinet equipment including the front panel of the controller, the cabinet status displays and detection system control interfaces. The cabinet rear shall provide access for field cable termination and shall only be accessed for installation and for cabinet troubleshooting.

Cabinet Doors

The cabinet shall be supplied with two doors: one on the front face and one on the back face. The front main door shall be defined as the "primary" door; the rear main door shall be defined as the "secondary" door.

The cabinet main doors shall be provided with a stop to limit door opening to both 90° and 180° ±10°. The door stop bars shall be a captive type mechanism that serves to keep the bar in contact with the cabinet at both stop bar ends and provided with a catch that can be operated when the doors reaches these 2 positions and will hold the doors open securely until released. The cabinet shall be supplied with a three-point draw roller latching system consisting of the following latching points:

a. Center of the cabinet (lock)
b. Top of the cabinet – controlled by door handle
c. Bottom of the cabinet – controlled by door handle

The latching points on the top and bottom of the cabinet doors shall remain in the locked position until the door locks are disengaged. The locking mechanism shall be equipped with nylon rollers to secure the top and bottom of the doors.

The cabinet shall be supplied with a ¾-in. diameter shank, stainless steel latching handle for each door. The latching handle shall have a provision for padlocking the door in a closed position. The cabinet shall have a pliable seal composed of caulking compound or mastic installed between the cabinet base and the concrete foundation and in between the riser base and the cabinet to prevent dust and dirt from entering the cabinet.

Internal Cabinet Lighting

The cabinet shall be supplied with white LED light panels which shall automatically illuminate via a door open switch whenever any one of the two main cabinet doors are opened. The LED panels shall produce a minimum of 1,000 lumens and be protected by a clear shatterproof shield. The cabinet shall contain two light panels: one at the top of the rack assembly and one at the bottom

portion of the rack assembly. There shall be two switches on each of the two main doors. LED light panel mounting brackets shall be installed such that they do not interfere with the unused rack mounting holes which could potentially conflict with the installation of future rack mounted devices. A second door open status switch per door shall activate a controller input to log a report event that one of the doors was opened. The door open status switches shall be connected to separate controller inputs.

Cabinet Fans

The cabinet shall be provided with a thermostatically controlled ventilating fan and throwaway glass fiber air filter. The electric fan shall have ball or roller bearings and shall have a capacity of 100 ft^3 per minute. The fan shall be rated for continuous duty with a minimum service life of 3 years. The fan blades shall be supplied with a safety screen to prevent accident contact with the blades. The ventilating system shall be designed to prevent the entrance of rain, snow, dust, and insects. The fan and vent shall be arranged in such a manner that the air intake is at the cabinet bottom and the exhaust is at the cabinet top. The air intake shall be rain tight and covered with a removable glass fiber air filter. The removable air filter shall be firmly held in place with aluminum louvered backing plate such that cracks, and openings are eliminated to ensure that all air is filtered. The cabinet shall contain one fan. The thermostat panel shall be mounted to the top, rear of the cabinet's 19-in. equipment rack and oriented to be clearly visible allowing user adjustable temperature settings from a minimum of 70°F to 140°F and capable of activating the fans within plus or minus five degrees of the set temperature; the thermostat shall be initially set to 100°F. Any exposed terminals shall be covered to protect a technician's hand. There shall be one intake vent provided with the cabinet in the front door.

Cabinet Switches/Manual Control

The cabinet shall be supplied with a police door panel located in the middle area of the front door. The switches shall be mounted in the police panel and labelled as to function. The three switches shall be supplied as follows:

a. Signal On/Off
b. Signal/Flash
c. Manual/Auto with cord

The manual control cord shall be a coiled type, sealed weatherproof covered hand switch extending to six ft when fully stretched. The cord shall be fastened to the cabinet via a compression type connector to provide strain relief for the cord's electrical connections. The police door panel shall be of sufficient size so as to store the manual control cord when panel door is closed.

The cabinet shall be supplied with a technician's panel mounted integral to the front of the input/output rack assemblies. This panel shall be supplied with the following switches:

a. Flash/Auto (Allows the controller to cycle while flashing)
b. Signals On/Off (Allows the controller to cycle with signal displays being dark)
c. Stop Time Normal/On (Provides the ability to manually activate a controller stop time input)

Slide Out Tray

The cabinet shall contain a pull-out drawer, 19-in. wide with sufficient strength to hold a laptop computer. The top of the drawer shall be covered with a non-conductive, non-skid material and hinged such that a storage space is available to store cabinet documentation or small parts. The pull-out drawer shall be located in the rack directly under the controller.

Spare Devices

In addition to the full complement of switch packs, flashers, SIU's and flash transfers relays; 2 additional SIU's, 32 additional Phoenix connectors, and 1 additional CMU USB datakey programmer tool with software shall be supplied. All spare equipment required to be supplied with the cabinet shall be delivered to the Department.

Input and Output Channels

The cabinet shall be supplied with 16 output channels and 24 input channels.

M10.02.0: Advanced Transportation Controller

All Advanced Transportation Controllers (ATC) shall be solid state, menu driven, keyboard units.

The Contractor shall supply a rack-mounted ATC unless otherwise indicated in the Plans or Special Provisions.

The ATC shall be supplied with the latest firmware. The ATC firmware shall be upgradeable via a USB connection at the front of the controller. No additional software shall be required to perform this function. The ATC shall be supplied with a manufacture's Software Development Kit (SDK) for the supplied firmware version to allow for future system modifications/expansions.

The ATC shall be able to backup and restore programing data via a USB connection at the front of the controller. No additional software shall be required to perform this function.

No additional hardware, software items, licenses, and/or subscription fees/costs shall be needed or allowed to satisfy the ATC requirements as defined in these specifications.

The ATC shall be supplied with all necessary interfaces needed to support Advanced Transportation Controller Cabinet (ATCC) / Serial Interface Unit (SIU) communications.

Compliance with Standards

The ATC conform to or be compliant with the following standards:

- ATC 5201 Standard v06.25
- NTCIP 1201 and 1202
- NEMA TS2-2016, including all amendments

The ATC shall contain Application Programming Interface (API) software conforming to ATC 5401 Standard v02.

Operating Environment

The ATC shall be configured to operate in an ATCC 5301 v02 cabinet platform conforming to M10.01.0: Advanced Transportation Controller Cabinets (General) unless otherwise indicated in the Plans or Special Provisions.

Operating System

The ATC shall be supplied with the appropriate version of the Linux operating system, Board Support Package (BSP) and internal processing levels necessary to support connected vehicle (CV) as well as local and system operations.

The ATC shall be supplied with programming documentation fully defining the coding (compiler and C libraries) used to create the ATC controller applications residing in the unit.

The ATC shall be supplied with the source code used to produce and support the Linux kernel environment.

Serial Interface Ports

The ATC shall have a minimum of two SDLC ports.

The ATC shall have a minimum of three Universal Serial Bus (USB) ports. The ports shall conform to USB v2.0 or later.

The ATC shall have a minimum of three 10/100BaseT, RJ45 ethernet connector ports.

All data communication connectors shall be supplied and installed with an outer boot molded cover designed specifically for the connector to ensure physical protection for the connector wire terminations. There shall be no exposed wires visible between the connector and the cable insulated jacket.

User Interface

The ATC shall contain the ability to alter the controller unit's internal database using a built-in front panel keyboard, using a computer connected to the controller unit with a USB cable or an Ethernet cable, and remotely using a central management system application. In addition, a remote access system shall be provided using HTTPS.

The ATC shall contain real-time context sensitive Help screens.

The Real-Time Clock (RTC) shall be capable of daily, weekly, and yearly event time programming via a scheduler.

A user shall have the ability to alter the controller unit's internal database using a built-in front panel keyboard, using a computer connected to the controller unit with a USB cable or an Ethernet cable, and remotely using the central management system application.

Functional Requirements

The ATC shall support the following:

- A minimum of 8 vehicle/pedestrian phases and 8 overlaps.
- The ability to provide 12 unique preemption/priority inputs.
- Dedicated phase detection inputs, pedestrian detection inputs, and system detection inputs.
- Flashing Yellow Arrow (FYA) and Flashing Red Arrow (FRA) operation with the ability to provide a minimum of 6 flashing pairs.
- An internal database which stores all configurable parameters, including but not limited to phase timings, phase sequencing, overlaps, coordination parameters, preemption and priority parameters, time base parameters, communications parameters, detection parameters, flashing operation parameters, and security parameters.
- The ability to generate user defined alarms and alerts.
- Detector failure algorithms that initiate user defined actions when user defined criteria are met.

The ATC shall not utilize internal logic processing or script programming to directly control conditional timing or operation of vehicle or pedestrian field signal circuits.

Transit Signal Priority

The ATC shall support Transit Signal Priority (TSP) without the need for additional software, hardware, data key device or any recurring licensing fees. TSP shall be available during both coordinated and free operation and shall include the following:

- TSP shall support a minimum of six priority routines.
- The TSP program shall be capable of extending the priority phase green time and truncating the non-priority phase(s) green when a priority call is received by the ATC unit.
- TSP operation shall not cause the ATC unit to skip any phases that have active vehicle/pedestrian demand.
- Emergency vehicle preemption (EVP) shall override TSP operation.
- The TSP program shall have the ability to delay and/or extend priority calls.
- The TSP program shall have the ability to support user defined time periods between servicing valid priority calls.
- All TSP events shall be logged (time/date stamped) in the ATC unit.
- The TSP algorithm shall allow for non-TSP phases to be conditionally truncated based on the absence of a concurrent pedestrian service of the non-TSP phase.
- It shall be possible to user define in the traffic controller a minimum time between responses to priority calls.

Under coordinated operation, the controller shall modify existing signal operation to accommodate a priority call. This may include modification to per phase termination points established under normal coordinated control. During a priority event, per phase coordination modes shall remain in effect. Priority and non-priority phase duration shall be user programmable per coordination pattern.

Under free operation, upon receipt of a valid priority call, the controller shall either extend the priority phase or reduce the non-priority(s). These settings for the adjusted green times shall be user defined, on a per phase basis, and adjustable on a time-of-day basis.

Reporting

The ATC shall be supplied with all necessary hardware, software elements and instruction procedures needed to facilitate the extraction and processing of Automated Traffic Signal Performance Measures (ATSPM) data.

The ATC shall collect and process all 255 high resolution enumerations as defined in the report "Indiana Traffic Signal Hi Resolution Data Logger Enumerations." This data will be processed in the controller and available via download from the controller USB Ethernet port or, if available, via system communications.

At a minimum, the ATC shall be configured to provide the following performance reports:

- Approach delay
- Preemption events
- Transit Priority Events
- Split Monitor
- Approach Volumes
- Purdue Coordination Diagrams
- Arrivals on Red
- Arrivals on Green
- Phase Termination
- Pedestrian Delay