SECTION M8

METALS AND RELATED MATERIALS

M8.00.0 General.

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.

All welding and welding material shall conform to the requirements of the AASHTO/AWS Bridge Welding Code (ANSI/AASHTO/AWS D1.5), unless otherwise specified.

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.

Iron castings shall be true to pattern in form dimensions, free from pouring faults, sponginess, cracks, blow holes and other defects in positions 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.

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 unless otherwise specified. 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 unless otherwise specified. The bars shall be rolled from new billet steel conforming to the requirements of AASHTO M 31, Grade 400. Deformed steel will not be required for spiral reinforcing columns.

M8.01.1 Cold Drawn Steel Wire.

This material shall conform to AASHTO M 32.

M8.01.2 Welded Steel Wire Fabric.

This material shall conform to AASHTO M 55.

M8.01.3 Steel Bar Mats.

This material shall conform to AASHTO 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, Grade 400) or approved tie bolts as shown on the plans which shall conform in all respects to the standard requirements specified for strength and design.

M8.01.5 Anchor Bolts, Nuts and Washers.

Bolts, nuts and washers used for anchoring bridge railing base plates to concrete shall be fabricated from steel conforming to the requirements of ASTM A 449. No rotation capacity testing shall be required.

Bolts, nuts and washers used for anchoring bridge bearings to concrete shall conform to the requirements of ASTM A 307 or ASTM A 449.

Bolts, nuts and washers used for anchoring signal lighting and sign structures shall conform to the requirements of one of the following:

AASHTO M 31 Grade 400 with a minimum yield strength of 400 MPa.

ASTM A 687 Type II with a minimum yield strength of 724 MPa.

AASHTO M 31 Grade 500 with a minimum yield strength of 500 MPa.

AASHTO M 183 with a minimum yield strength of 380 MPa, tensile strength of 515 MPa to 655 MPa, and maximum elongation of 18% in 200 millimeters.

Nuts and washers for the above shall be suited to the approved bolts.

High tension bolts, where specified, shall conform to AASHTO M 164. A galvanized hexagon nut, leveling nut and flat washer shall be furnished with each bolt.

All bolts, nuts and washers shall be galvanized in accordance with AASHTO M 232.

M8.01.6 Anchor Rods (Prestressed Beams).

Anchor rods shall be steel conforming to AASHTO M 270 Grade 250 and shall be hot dipped galvanized in accordance with AASHTO M 111. The galvanizing bath shall contain nickel (0.05% to 0.09% by mass).

M8.01.7 Epoxy Coated Reinforcing Bars.

Epoxy coated reinforcing bars shall be bars conforming to M8.01.0 and shall be epoxy coated in accordance with AASHTO M 284.

M8.01.8 Galvanized Reinforcing Bars

Galvanized reinforcing bars shall be bars conforming to M8.01.0 and shall be galvanized in accordance with ASTM A 767M.

M8.02.0 Drill Steel Rods.

This material shall conform to the requirements of ANSI-W1.

M8.03.0 Iron Castings.

These materials shall conform to the requirements of AASHTO M 105, Class No. 30 unless otherwise specified. Test bars required shall be Test Bar B, 30.5 millimeters in diameter.

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 103, Grade 450-240, full anneal.

Castings shall be shot blasted prior to painting. Painting shall consist of a coating system approved by the Department's Research and Materials Section.

M8.04.1 Stud Shear Connectors.

1. General Requirements.

A. Shear connector studs shall be of a design suitable for end welding to steel beams and girders with automatically timed stud welding equipment. The type, size or diameter, and length of stud shall be as specified by the plans, specifications, or special provisions as approved by the Engineer, with the following allowable tolerances and dimensions.

Standard Dimensions (Millimeters)

Diameter of Shank	Length of Welded Stud*	Diameter of Head	Thickness of Head
19.05 - 0.38	101.6 + 1.57 - 3.18	38.10 ± 0.40	9.52 min.
22.22 - 0.38	100.00 + 1.57 - 3.18	34.92 ± 0.40	9.52 min.

*100 millimeter length is standard. Other lengths may be obtained by special order. Length is from outside of head to face of base metal after welding is completed.

B. 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.

C. 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.

D. Studs shall not be painted or galvanized.

E. Only qualified studs shall be used. A stud, to be qualified, shall have passed the tests prescribed under Part 3, “Shear Connector Stud Weldability Qualification Procedure”. The arc shield used in production shall be the same as used in the qualification tests.

F. 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 1.E hereinbefore.
4. A copy of the qualification test report as certified by the testing laboratory.

G. The studs, after welding, shall be free from any defect or substance which would interfere with their function as shear connectors.

Material Requirements.

A. 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, wither semi-killed or killed. 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 A 109.

B. Tensile properties as determined by tests of the bar stock after drawing or of finished studs shall conform to the following requirements:

Tensile Strength	400 MPa, minimum
Yield Strength*	345 MPa, minimum
Elongation	20% in 50 millimeters, minimum
Reduction of Area	50%, minimum

*As determined by a 0.2% offset method.

C. Tensile properties shall be determined in accordance with the applicable sections of ASTM A 370, 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.

D. 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.

E. The manufacturer shall certify that the studs as delivered are in accordance with the material requirements of this Section. Certified copies of in-plant quality control test reports shall be furnished to the Engineer.

3. Shear Connector Stud Weldability Qualification Procedure.

A. Purpose.

The purpose of this procedure is to prescribe weldability tests which will qualify a shear connector stud for welding under shop or field conditions. The tests may be performed by a university, independent laboratory or other testing agency. The agency performing the tests shall submit to the manufacturer of the stud a certified report giving procedures and results for all tests including the information listed under 3.H hereinafter.

B. Duration of Qualification.

A type and size of stud with arc shield, once qualified, is considered qualified until the manufacturer makes any change in the base of the stud, the flux, or the arc shield which effect the welding characteristics.

C. Preparation of Specimens.

Test specimens shall be prepared by welding representative studs to the center of square specimen plates, 12 to 20 millimeters thick, of structural steel, AASHTO M 183. At the option of the manufacturer, studs may be welded to a large plate and the specimen plates cut to a size suitable for test equipment used.

Studs shall be welded with power source, welding gun and control equipment as recommended by the manufacturer. Welding voltage, current and time (see D below) shall be measured by suitable instrumentation and recorded for each specimen.

Lift and plunge shall be at the optimum setting as recommended by the manufacturer.

D. Number of Test Specimens.

1. Thirty test specimens shall be welded consecutively with optimum current and time. Optimum current and time shall be the mid-point of the range normally recommended by the manufacturer for production welding.

2. Thirty test specimens shall be welded consecutively with time held constant at optimum but with current 10% below optimum.

3. Thirty test specimens shall be welded consecutively with time held constant at optimum but with current 10% above optimum.

E. Qualification Tests.

1. Tensile Tests – Ten of the specimens welded in accordance with D.1, ten in accordance with D.2, and ten in accordance with D.3 shall be subjected to a tensile test in a fixture approved by the Department's Research and Materials Section. A stud shall be considered as qualified if all test specimens have a tensile strength above the minimum specified in 2.B hereinbefore.

2. Bend Tests – Twenty of the specimens welded in accordance with D.1, twenty in accordance with D.2, and twenty in accordance with D.3 shall be placed in the bend testing device approved by Department's Research and Materials Section and bent alternately 30° in opposite directions until failure occurs. A stud shall be considered as qualified if, on all test specimens, fracture occurs in the shank of the stud and not in the weld.

F. Retests.

If a weld failure occurs in any of the tensile or bend tests groups, that group may be retested. If weld failure repeats, the stud shall fail to quality.

G. Qualification.

For a manufacturer's studs and arc shields to be qualified, each group of thirty studs shall, by test or retest, meet the requirements prescribed in E.1 and E.2 above.

H. Report of Tests.

The laboratory report shall include the following:

a) Drawings which show shapes and dimensions with tolerances of studs, arc shields and flux.

b) A complete description of materials used in the studs and arc shields, including the quantity and analysis of the flux.

c) A certification that the studs and arc shields described in the report are qualified in accordance with 3.G herein.

M8.04.2 Steel Pins.

Pins more than 225 millimeters in diameter shall be manufactured from carbon steel conforming to AASHTO M 102, Classes B, C and D. Pins 225 millimeters or less in diameter shall conform to AASHTO M 102, Classes B, C, and D, or AASHTO M 169, Grades 1016 thru 1030 inclusive.

M8.04.3 High Tensile Strength Bolts.

Bolts, nuts and washers shall conform to the appropriate AASHTO Materials Specification M 164, M 291, M 292 and M 293 as amended herein.

Material.

Hardness for bolts with diameter 16 to 24 millimeters 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, DH or DH3.

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 AASHTO M 291 and the rotational-capacity tests herein. The overtapping requirements shown in AASHTO M 291, Section 7.4 shall be considered the maximum values instead of the minimum as currently shown. 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 Massachusetts Highway Department; however, the manufacturer or distributor that performs the tests shall certify that the results recorded are accurate. Documentation shall be in accordance with Subsection 960.61 E.

Bolts.

Proof load tests in accordance with ASTM F 606 Method 1 are required. The minimum frequency of the tests shall be as specified in AASHTO M 164, Section 9.2.4.

Wedge tests on full size bolts (ASTM F 606, Section 3.5) 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 AASHTO M 164, Section 9.2.4.

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 F 606, Section 4.2) are required. Minimum frequency of tests shall be as specified in AASHTO M 291, Section 9.3 or AASHTO M 292, Section 7.1.2.1. 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.

Test Methods for Normal Length, Long, and Short Bolts.

Rotational capacity tests shall not be performed on metric bolts pending completion of the Federal Highway Administration's research.

M8.05.0 Structural Steel.

Unless otherwise specified, all structural steel shall conform to the requirements of AASHTO M 270, Grades 250, 345, or 345W.

Orientation of the test bars for the Charpy V-Notch (CVN) test specimens shall be longitudinal to the direction of final rolling. CVN impact testing temperatures shall be in accordance with those specified for Zone 2.

All fabrication 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 183. Copper bearing steel will not be required.

M8.05.2 Steel Shells, Cast-in-Place Piles.

This specification covers steel shell type piles where the steel shell is not considered to act as a permanent load carrying member.

Steel shells shall be of sufficient strength and rigidity to permit driving and to prevent distortion caused by soil pressures or the driving of adjacent piles, until filled with concrete. The shells shall be also sufficiently watertight to exclude water during the placing of concrete.

Any pile with a wall thickness greater than 5 millimeters will not be considered a shell for a Cast-in-Place Pile.

Steel shells for cast-in-place concrete piles shall have a uniform taper, or a combination of uniform sections of increasing diameter, or a combination of uniform sections of equal length that increase progressively not more than twice the thickness of the shell at each change in diameter, or a uniform section throughout; but only one type shall be used for the contract. The tip shall be of steel fully welded to tightly close the bottom of the pile to make a watertight closure. Care must be exercised to avoid the use of more than one short section at the butt end when necessary to extend the pile length.

If steel shells consisting of a succession of cylindrical sections of increasing diameter are used, all sections shall be of equal length and increasing in diameter by not more than 25 millimeters between adjoining sections from the section at the tip to the section at the butt of the pile.

The minimum tip diameter shall be 200 millimeters. The minimum butt diameter at the point of cut-off shall be 300 millimeters when the specified loading is 350 kiloNewtons or less, or shall be 350 millimeters when the specified loading is over 350 kiloNewtons and less than 500 kiloNewtons.

Steel reinforcement shall conform to the requirements of M8.01.0 and shall be as detailed on the plans.

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 222 with the additional requirement that the steel shall exhibit a corrosion resistance at least 4 times that of AASHTO M 183 Steel.

M8.05.4 Steel Sheeting.

Steel sheeting shall be an approved standard section either new or used, weighing not less than 110 kilograms per square meter of wall. Steel sheeting which is to be left in place shall conform to the requirements of AASHTO M 202.

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 A 252, Grade 2 except where it is in conflict with other parts of the specifications. In such cases these Specifications shall govern.

Pipe having seams of spiral-lap welded construction will not be permitted under this specification.

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 for 30 MPa - 20 mm - 390 kg 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 bending.

The bottom end of the pipe shall be beveled in accordance with the ASTM A 252 specification and the top end of the pipe shall not be beveled.

Steel reinforcement shall conform to the requirements of M8.01.0 and shall be as detailed on the plans.

M8.05.6 Precast-Prestressed Piles.

Piles shall be standard 350 millimeter square precast-prestressed concrete piles, designed and manufactured in accordance with the joint AASHTO and PCI Committee recommendations, latest revision. Piles shall support design loads and moments shown on the Plans.

No piles shall be delivered to the site until at least three (3) days after casting and until concrete strength is at least 35 MPa as determined by compression tests on 100 millimeter or 150 millimeter diameter standard concrete cylinders.

M8.05.7 Pressure Injected Footing Piles.

Concrete

Materials, mixing and testing of concrete shall conform to requirements of Section M4, Cement and Cement Concrete Materials, of these Specifications for 30 MPa concrete, using 20 millimeters as the nominal maximum size of coarse aggregate. Zero-slump concrete shall be developed by reducing water in the regular-mix concrete to quantities that cause slump to approach zero as measured at the point of discharge into the casing.

Steel Reinforcement

Steel reinforcement shall be made of new billet steel complying with AASHTO M 31, Grade 400, or as shown on the drawings.

Permanent Casings

Permanent casing, where required, shall be of steel with strength and rigidity sufficient to prevent distortion caused by driving adjacent piles, or collapse due to soil or hydrostatic pressure, and to maintain shape. Casings shall be free from dents and deformations and shall be water tight to assure placing concrete in the dry.

M8.07.0 Steel Beam Highway Guard Type SS.

The materials for this work shall conform to the following requirements:

A. Fabrication.

All metal work shall be fabricated in the shop. No punching, cutting or welding shall be done in the field. Holes for special details in exceptional cases may be made in the field when approved by the Engineer but such holes shall be drilled. Field punching may be permitted, if approved by the Engineer, after it has been demonstrated that such punching will not result in damage to the surrounding metal. 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 (2) coats of paint, high zinc dust content, conforming to the requirements of M7.04.11.

B. Posts.

1. 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. All posts, including end anchor posts, and anchor posts for use at drives, shall be steel "H" sections.

All holes drilled in the galvanized post sections shall be cleaned and painted, before bolts are installed, with two coats of paint, high zinc dust content, conforming to M7.04.11.

Structural steel shall conform to the requirements of AASHTO M 183, except that copper bearing steel will not be required. Galvanizing shall meet the requirements of AASHTO M 111. Each member shall be stamped with AASHTO designation and the grams of galvanizing per square meter of surface area.

Posts may be of the conventional Hot Rolled Structural Shape or of the Welded Type as approved by the Department.

2. Wood Posts.

The Posts and Offset Blocks shall be rough sawn (unplained) with nominal dimensions as indicated on the plans and with tolerances of 25 millimeters in length and 6 millimeters in width and thickness. All holes in the Posts and Offset Blocks shall be drilled prior to the application of the preservative.

The timber used for Wood Posts and Offset Blocks shall be of the same species. The Stress Grade shall be 6.9 megaPascals or more, extreme fiber in bending.

Testing for Stress Grade shall be in accordance with the Northeastern Lumber Manufacturers Association Inc., Northern Hardwood and Pine Manufacturers Association, Inc., Southern Pipe Inspection Bureau, West Coast Lumber Inspection Bureau, or the Western Wood Products Association, Standard Grading Rules. If another Timber Association is proposed, it must receive the approval of the Department before it will be considered or accepted.

Prior to treatment, all Posts and Offset Blocks shall be seasoned, conditioned and completely machined in accordance with AWPA Standard M1.

Posts and Offset Blocks shall be treated with either chromated copper arsenate (CCA) or ammoniacal copper arsenate (ACA). Treatment shall be full length under pressure by the empty-cell or full-cell process in accordance with AWPA Standards C1 and C4. The preservatives, minimum retention thereof and applicable AWPA standards are listed in the following table:

Preservative	Retention kg/m^3 of Post	AWPA Standards
ACA	9.6	P5
CCA, Type A	9.6	P5
CCA, Type B	9.6	P5
CCA, Type C	9.6	P5

When water borne preservatives are used, temperature requirements, as stipulated in Section 2.221 of AWPA Standard C1, shall be closely regulated. Species of wood that are difficult to penetrate shall be incised in

accordance with Section 2.2 of AWPA Standard C6. No unnecessary cutting of treated posts will be allowed after treatment. All posts and blocks with surfaces damaged by cutting, drilling or any other cause shall be field treated with a hot preservative solution in accordance with AWPA Standard M4. Preservatives used for this purpose shall be the same as those used for the basic treatment and shall conform to the same specifications.

Certificates of compliance and certificates of inspection for each lot of Wood Posts and Offset Blocks must be presented before any Posts are installed. The certificates bearing the approved inspection agencies verification must specify the species.

The certificates of inspection and compliance do not signify mandatory acceptance of the entire lot. The Engineer still has the option of rejecting Posts or Offset Blocks (included in any particular lot) that he/she may consider sub-standard because of unsound knots and shakes, excessive checking or other defects that may be detrimental to the structural integrity of the posts or offset blocks.

The fabricator shall retain a Department approved Agency to inspect and certify the treated Posts and Blocks in accordance with these specifications and AWPA Standard M2.

All treated Posts shall be marked in accordance with AWPA Standards M1 and M6. (The mark is to include the identifying lot number). The Post shall also be stamped with the Inspector's identification. The mark is to be placed on an upper side 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 AWP Standard M2 and the above.

C. Rail Element and Terminal Sections.

The steel rail element and terminal sections shall conform to AASHTO M 180, Class A, (base metal thickness 2.7 millimeters), Type 2 with the following additions:

The length of the railing shall be according to the plans and not over 4.127 meters.

Each end of the steel rail for every stretch of guard shall be fitted with a terminal section as shown on the plans. The terminal section shall have the same splice detail as the rail.

The projecting heads of all connection and splice bolts shall be rounded and shallow so that no appreciable projection will obstruct a vehicle sliding along the rail.

Where railing is to be constructed on curves which have a radius of 45 meters or less, the rail elements shall be fabricated to the proper radius with the road side of the rail either concave or convex as required.

D. Bolts, Nuts and Washers.

All bolts, nuts and washers used in assembling and erecting the rail shall conform to the requirements of ASTM A 307 and shall be of the size shown on the plans. They shall be designed to develop the required joint strength. Galvanizing shall be by the hot-dip process to conform to the requirements of AASHTO M 232.

M8.09.0 Chain Link Fences and Gates

Chain link fences and gates shall conform to the requirements of AASHTO M 181 Chain Link Fence.

Fence height, gage and details shall be specified in the contract documents.

Fabric Type I, II, III, or IV. The fabric shall be woven in a mesh size of 50 millimeters.

Metallic coated steel posts, rails, or gate frames shall be Grade 1 or 2. Type 1 fabric shall be Class D and Type 1 tension wire shall be Class 3.

M8.09.1 Woven Wire Fence

A. Woven Wire Fencing. Woven wire fencing may be either galvanized steel wire fencing or aluminum coated steel wire fencing. Galvanized steel wire fencing shall conform to the requirements of AASHTO M 279, Class 3, Design Number 939-6-11. Aluminum coated steel wire fencing shall conform to the requirements of ASTM A 584. Design numbers 939-6-11.

B. Barbed Wire. Barbed wire may be either galvanized steel barbed wire or aluminum coated steel barbed wire consisting of 2 strands of $12^{1}/_{2}$ gage wire with 4-point barbs of 14 gage wire spaced
125 millimeters apart.

Galvanized barbed wire shall conform to the Specifications for zinc-coated (galvanized) steel barbed wire,

AASHTO M 280, Class 3 with a minimum coating of 245 grams/square meter of wire surface.

Aluminum coated steel barbed wire shall conform to the Specifications for galvanized steel barbed wire, except the wire shall be aluminum coated. The wire shall have not less than 76 grams coating of aluminum alloy per square meter of uncoated surface. The weight of the aluminum alloy coating shall be determined in accordance with AASHTO T 213.

C. Brace Wires. Brace wires shall be galvanized or aluminum alloy coated 9 gage steel wire conforming to the Specifications for galvanized steel or aluminum alloy coated fencing.

D. Metal Posts. Metal posts shall be the shapes and dimensions shown on the plans. Line posts shall include a firmly attached, taper anchor plate having an area of not less than 12 000 square millimeters. The anchor plate shall be fabricated form not less than 12 gage thickness steel. Steel pipe for metal posts shall be steel pipe, Type A, Type B or Type C in accordance with Article 706.27. Structural shapes for posts shall be fabricated from steel conforming to the requirements of AASHTO M 281.

Grades A or B. All structural shapes shall be galvanized in accordance with AASHTO M 111 using zinc of any grade conforming to the requirements of AASHTO M 120. The zinc coating shall be not less than 610 grams/square meter of surface.

Square hollow structural tubing shall conform to the requirements of ASTM A 500, Grade B or ASTM A 501. The tubing shall be galvanized inside and outside in accordance with AASHTO M 111, using zinc of any grade conforming to the requirements of AASHTO M 120. The coating shall be not less than 610 grams/square meter of surface.

E. Metal Braces. Metal braces shall have the shapes and dimensions shown on the plans. They shall conform to the Specifications for metal posts. either steel pipe or structural shapes, and shall be galvanized as specified for the metal posts.

F. Gate Frames. Gate frames shall consist of galvanized steel pipe having the dimensions shown on the plans and conforming to the specifications for steel pipe line posts.

G. Miscellaneous Materials. Miscellaneous materials such as, but not limited to, wire, clips, or other metal devices for fastening the barbed wire and fencing to the posts, shall be of good commercial quality and galvanized wire.

H. Post Tops. Steel pipe and steel tubing posts shall be furnished with steel or malleable iron or wrought iron post tops of approved type, and shall be galvanized in accordance with AASHTO M 232.

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 A 53, Grade B. Galvanized pipe ordered under this specification shall be coated with zinc inside and outside by the hot-dip process. The mass of zinc coating shall be not less than 610 grams per square meter of surface area.

B. Fittings.

All fittings shall be steel conforming to ASTM A 307. They shall be galvanized in accordance with AASHTO 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 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.
C. Stainless Steel screws shall conform to ASTM A 193, Grade B8.
D. Rails, posts and bases shall conform to ASTM B 221, Alloy 6061-T6, or Alloy 6351-T5.
E. Splices and clamp bars shall conform to ASTM B 221, Alloy 6061-T6.
F. Rivets shall conform to ASTM B 316, Alloy 6061-T6.
G. Aluminum washers shall conform to ASTM B 209, Alloy Alclad 2024-T4.
H. End plugs shall conform to ASTM B 26, Alloy S5A-F or SG 70 A-F.
I. Aluminum Screen Frame shall conform to ASTM B 221, Alloy 6061-T6.
J. Aluminum Screen Fabric shall conform to ASTM B 211, 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 AASHTO M 107, Alloy D modified to the extent that 1.5 to 2.5% lead will be required.

B. Tin Bronze, conforming to the requirements of AASHTO M 107, 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 3.18 micrometers 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 0.0005 millimeters per millimeter of length and width.

Bronze Bearing plates having radial convex surfaces shall have a negative tolerance of 250 micrometers maximum and a positive tolerance of 10 micrometers on the specified radius. Concave radial surfaces of steel bearing plates shall have a positive tolerance of 250 micrometers maximum and a negative tolerance of 10 micrometers 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 4.7 millimeters. 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 non-plastic insert which shall project not less than 0.25 millimeter above the surface of the bronze bearing plate.

Testing.

A self-lubricating bronze test plate measuring not less than 125 millimeters long by 125 millimeters 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 13 millimeters in each direction. The recorded horizontal force divided by the recorded vertical force shall be established as the coefficient 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.

C. Stainless Steel screws shall conform to ASTM A 193, Grade B8.

D. Rails, posts and bases shall conform to ASTM B 221, Alloy 6061-T6.

E. Splices and clamp bars shall conform to ASTM B 221, Alloy 6061-T6.

F. Rivets shall conform to ASTM B 316, Alloy 6061-T6.

G. Aluminum washers shall conform to ASTM B 209, Alloy Alclad 2024-T4.

H. End plugs shall conform to ASTM B 26, Alloy 356.0-F.

I. Tubular Pickets shall conform to ASTM B 221 Alloy 6063-T5.

M8.13.1 Bridge Railing, Steel, Type S3-PL2.

Materials used in the fabrication of the steel bridge rail shall conform to the following requirements:

A. General.

All structural steel shall be new and shall be blast cleaned prior to fabrication in accordance with Section 960.61C. The fabricator shall be approved by the Engineer in compliance with the requirements of Section 960.61A.

B. Steel anchor bolts, nuts and washers shall conform to M8.01.5. Anchor plate shall conform to AASHTO M 183.

C. Steel posts and base plates shall conform to AASHTO M 270, Grade 50.

D. Steel rail and tubular pickets shall conform to ASTM A 500, Grade C.

E. Rail splice tube plates and picket carrier angles shall conform to AASHTO M 270, Grade 36.

F. Threaded Welded Studs.

Stainless steel threaded welded studs conforming to ASTM A 304 which have been annealed after cold working shall be used to attach the rail tubes to the posts. Threaded welded studs conforming to ASTM A 108 shall be used to attach: the tubular pickets to the carrier angles; the picket panel assembly to the rails. All threaded studs shall be supplied with nuts, washers, and lock washers. Stud welding shall conform to the current edition of the ANSI/AASHTO/AWS D1.5, Bridge Welding Code. The ferrules used in stud welding shall be kept clean and dry and shall be stored at a temperature of 15 °C.

G. Rubber-cotton duck bearing pad shall conform to M9.16.1.

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 1.6 millimeters. The base metal and spelter 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 16 millimeters and a minimum length of 32 millimeters measured from the underside of the bolt head.

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 mass).

	Minimum	Maximum
Pigment: (Flake Graphite)	55%	65%
Graphite Carbon	85%	
Passing 150 µm	84%	92%
Passing 45 µm	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 1.4 to 1.8 kilograms of the graphite paste shall be placed in a suitable container and 40% by mass of a suitable solvent mixture shall be added thereto. The resulting lubricant shall be thoroughly mixed.

2. The wax base grease shall be applied hot at temperatures of 75 °C to 85 °C. It shall conform to the following requirements:

a)	Consistency, cone penetration at 25 °C	120 - 160
b)	Melting point	60 °C (minimum)
c)	Stability	No separation at 95 °C to 100 °C for 1 hour
d)	Abrasives	Free from abrasives
e)	Volatile matter (% by mass)	2% max. when heated at 99 °C ± 1.5 °C for 1/2 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 55 °C
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, signals, highway lighting, signs and supports. Unless otherwise specified, all wire and cable herein are for copper conductors rated for 600 volts, all traffic signal cable conductors shall not be less than No. 14 AWG, solid or stranded and all conductors for mast arm wiring shall be not less than No. 16 AWG 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 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.

M8.16.6 Type 6 Traffic Signal Wire (TFF or TEW).

Traffic signal head wire shall be color coded No. 18 AWG or larger conforming to requirements of UL Standard UL-62, “Flexible Cord and Fixture Wire” for TFF or TEW listed wire.

M8.16.7 Type 7 General Purpose Wire (RHH, RHW or XHHW).

General Purpose Wire shall conform to requirements of UL Standard UL-44 “Rubber-Insulated Wires and Cable.”

M8.16.8 Type 8 Direct Burial Wire (USE).

Direct burial wire shall be insulated as specified for Type 7 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 Wire (Solid or Standard, Insulated or Bare).

Ground and bonding wire shall be copper conforming to requirements of ASTM B 3 for soft or annealed copper wire, ASTM B 8 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 No. 14 AWG, tinned copper stranded (19 x 27) conductors, polyethylene insulated (0.8 millimeters thick), conductors cabled, aluminum-polyester shield (100% shielding), No. 16 AWG stranded tinned copper drain wire. Chrome vinyl outer jacket (0.9 millimeters thick), nominal cable outside diameter 8.6 millimeters 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, 600 Volt 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.

M8.17.0 Ground Rod.

Ground Rods shall be nominal 16 millimeter diameter (measured diameter shall not be less than 14 millimeters) by a minimum of 2.5 meter long copper bonded to steel rod, with bolt type clamps, conforming to the requirements of UL-467.

M8.18.0 Signal Posts.

Signal posts shall be 100 millimeter standard seamless steel pipe conforming to ASTM A 53, Grade A or B. Interiors shall be coated as specified in Underwriters Laboratories UL-6 for enameled conduit, or aluminum conduit conforming to M5.07.1C.

M8.18.1 Octagonal Bases.

Octagonal Bases shall be cast iron conforming to AASHTO M 105 or cast aluminum alloy SG70A (ASTM B 26, B 108).

M8.18.2 Pedestal Bases.

Pedestal Bases shall be made of not less than 3.5 millimeter steel and galvanized after fabrication to meet the requirements of AASHTO M 111 or cast aluminum alloy SG70A (ASTM B 26, B 108).

M8.18.3 Aluminum Signal Posts & Bases.

Aluminum signal posts shall be tapered seamless tube aluminum alloy 6063 (ASTM B 221, B 241, B 429), having a minimum wall thickness of 4.0 millimeters. The posts shall taper from approximately 150 millimeters at the base to 115 millimeters at the top. The post shall have a satin brush finish. The transformer base shall be of cast aluminum alloy SG70A (ASTM B 26, B 108) and shall be provided with means for grounding

and a waterproof door for wiring purposes.

The post shall be wrapped for protection during handling and shipping. The base shall be capable of being mounted on a concrete foundation with a 325 millimeter bolt circle.

M8.18.4 Mast Arms.

Mast arms shall be made of aluminum or steel as specified.

A. Aluminum

1. Shaft - Aluminum alloy 6005-6061-6351-6063 (ASTM B 221, B 241, B 429).
2. Base flange - Aluminum alloy SG70A (ASTM B 26, B 108).
3. Transformer base - Aluminum alloy SG70A (ASTM B 26, B 108).
4. Arm - Aluminum alloy 6063 (ASTM B 221, B 241, B 429).
5. Shaft cap - Aluminum alloy SG70A or S5A (ASTM B 26, B 108), or aluminum alloy 3003 (ASTM B 209).
6. Hardware - Stainless steel.
7. Anchor bolt covers - Aluminum alloy SG70A, SG100B or S5A (ASTM B 26, B 85, B 108), or aluminum alloy 3003 (ASTM B 209).

B. Steel

1. Shaft - ASTM A 595, Grade A; or ASTM A 607, Grade 310; or AASHTO M 223, Grade 450.
2. Base flange - ASTM A 181 or ASTM A 126, Class A or AASHTO M 103, Grade 450-240 or AASHTO M 183.
3. Transformer base - SAE-1020 or AASHTO M 183.
4. Arm - ASTM A 595, Grade A; or ASTM A 607, Grade 310; or ASTM A 53, Grade B; or AASHTO M 183.
5. Shaft cap - ASTM A 126, Class A.
6. Hardware - Stainless steel or ASTM A 307 or AASHTO M 164. A 307 and M 164 hardware shall be galvanized in accordance with AASHTO M 232.
7. Anchor bolt covers - ASTM A 181 or ASTM A 126, Class A or AASHTO M 103, Grade 450-240 or AASHTO M 183).
8. Galvanizing - AASHTO M 111 or M 232 as applicable.

When a steel other than those listed above is proposed for use, the weldability of the steel and the welding procedure shall be established by the requirements prescribed by the Engineer prior to review of the material for approval.

M8.18.5 Steel Supports.

Tapered components shall be fabricated from steel conforming to ASTM A 595, Grade A; or ASTM A 607, Grade 450; or AASHTO M 223, Grade 450.

Seamless steel pipe shall conform to ASTM A 53.

Hot formed welded and seamless carbon steel, square, rectangular and special shape structural tubing shall conform to ASTM A 501.

Cold-formed welded and seamless carbon steel, round, square, rectangular and special shape structural tubing shall conform to ASTM A 500, Grade C.

All other standard structural shapes shall conform to AASHTO M 183.

Gussets, flanges, baseplates, wing plates and connecting end plates shall be of steel plate conforming to AASHTO M 183.

For baseplates that are more than 25 millimeters in thickness AASHTO M 223, Grade 290 may be used.

Anchor bolts shall conform to Subsection M8.01.5.

All flange bolts, complete with hexagon nuts and washers, shall be of high strength steel conforming to ASTM A 193, Grade B-7 or AASHTO M 164. The bolts and attached nuts shall be hot-dip galvanized conforming to AASHTO M 232.

Truss and cantilever beam connections shall be furnished with the necessary beam support clamps. The ends of beams shall have a special mounting clevis and closure plate fabricated from steel plate as an assembly. A matching clamp-on shall be furnished for each post.

All structural steel used for fabricating sign support structures shall be galvanized in accordance with AASHTO M 111. Steel hardware shall be galvanized in accordance with AASHTO M 232.

All damaged or scraped galvanized steel shall be spot primed with primer meeting the requirements of Subsection M7.04.11.

When a steel other than those listed above is proposed for use, the weldability of the steel and the welding procedure shall be established by requirements prescribed by the Engineer prior to review of the material for approval.

The diameter of the vertical main members of all sign supports shall not exceed 450 millimeters.

The wall thickness of all members of the sign supports shall be a minimum of 3 millimeters for steel.

M8.19.1 Aluminum Sign Panels.

Aluminum sign panels shall be fabricated from ASTM B 209, Alloy 6061-T6 or alloy 5052-H12, 2 millimeters thick).

M8.20.3 Modular Guidance Systems.

Modular Guidance Systems shall consist of those systems which are on the current approved products list maintained by the Department's Research and Materials Section.

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 approved products list maintained by the Research & Materials Section, 400 D Street, South Boston, Massachusetts 02210-1953.

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 A 446 (Grades A through E) having a coating class of G165 according to ASTM A 525.