DIVISION 500

STRUCTURES

SECTION 501- HPC STRUCTURAL CONCRETE

501.01 DESCRIPTION. This work shall consist of furnishing and placing high performance portland cement concrete for structures and incidental construction.

The portland cement concrete shall consist of a homogeneous mixture of cement, fine aggregate, coarse aggregate, water, admixtures, and pozzolans, proportioned and mixed according to these Specifications.

501.02 MATERIALS. Materials shall meet the requirements of the following Subsections:

The coarse aggregate shall be conditioned so that 24 hours prior to the anticipated concrete placement time, the total moisture percentage is a minimum of 0.75% greater than the absorption percentage for the aggregate. The minimum moisture percentage shall be maintained throughout the 24 hour period.

Precast concrete stay-in-place forms (prestressed deck panels) shall conform to the requirements of Section 510.

501.03 CLASSIFICATION AND PROPORTIONING. The following classes of concrete are included in these specifications and shall be used as shown on the plans:

TABLE 501.03A (Metric)

HP Class	Req. [2] Cem. Mat. (kg/m^3)	Max. Water-Cem. Mat. Ratio	Max. Slump (mm)	Air Content (%)	Coarse Aggregate Gradation Table	28Day[1] Comp. Strength (MPa)	28Day[1] Modulus of Rupture (MPa)
AA	419	0.40	180	7.0 ± 1.5	704.02A	30	4.48
A	362	0.44	180	7.0 ± 1.5	704.02B	30	4.48
B	335	0.49	180	7.0 ± 1.5	704.02C	25	4.48
SCC[3]	362[6]	0.44	N/A	7.0 ± 1.5	N/A	30	N/A
LW	391	0.44	150	7.0 ± 1.5	704.14	30	N/A

[1]The listed 28-day compressive strength or modulus of rupture will serve as the basis of designing or approving the concrete mix.
[2]See additional (Metric unit) tables below for required cementitious materials.
[3]Additional requirements for Class SCC are as follows:

Inverted slump cone flow[4] (mm)		56 Day Permeability[5] (Coulombs)	VSI Rating	T_{50} (Seconds)	
Min	Max			Min	Max
500	700	2500	=/< 1	2	5

[4]A higher maximum flow greater than 700 mm may be allowed if the Visual Stability Index (VSI) is 1 or less.
[5] The permeability may be tested prior to 56 days but results must still be 2500 Coulombs or less.
[6]A 20% fly ash or 25% GGBFS replacement of total cement content is required.

SCC = Self Consolidating Concrete
LW = Lightweight

TABLE 501.03A (English)

HP Class	Req.[2] Cem. Mat. (lbs/yd^3)	Maximum Water-Cem. Mat. Ratio	Max. Slump (in)	Air Content (%)	Coarse Aggregate Gradation Table	28Day[1] Comp. Strength (psi)	28Day[1] Modulus of Rupture (psi)
AA	705	0.40	7	7.0 ± 1.5	704.02A	4000	650
A	611	0.44	7	7.0 ± 1.5	704.02B	4000	650
B	564	0.49	7	7.0 ± 1.5	704.02C	3500	650
SCC[3]	611[6]	0.44	N/A	7.0 ± 1.5	N/A	4000	N/A
LW	660	0.44	6	7.0 ± 1.5	704.14	4000	N/A

[1]The listed 28-day compressive strength or modulus of rupture will serve as the basis of designing or approving the concrete mix.
[2]See additional (English unit) tables below for required cementitious materials.
[3]Additional requirements for Class SCC are as follows:

Inverted slump cone flow[4] (Inches)		56 Day Permeability[5] (Coulombs)	VSI Rating	T_{50} (Seconds)	
Min	Max			Min	Max
20	28	2500	=/< 1	2	5

[4]A higher maximum flow greater than 700 mm may be allowed if the Visual Stability Index (VSI) is 1 or less.
[5]The permeability may be tested prior to 56 days but results must still be 2500 Coulombs or less.
[6]A 20% fly ash or 25% GGBFS replacement of total cement content is required.

SCC = Self Consolidating Concrete
LW = Lightweight

Required Cementitious Materials
(Metric Units)

HP Class	Cement (kg/m³)		Fly Ash (kg/m³)		Silica Fume Admixture (kg/m³)		Cementitious Materials (kg/m³)
AA	311	+	84	+	24	=	419
A	266	+	72	+	24	=	362
B	244	+	67	+	24	=	335
LW	313	+	78	+	0	=	391

OR

HP Class	Cement (kg/m³)		GGBFS (kg/m³)		Silica Fume Admixture (kg/m³)		Cementitious Materials (kg/m³)
AA	290	+	105	+	24	=	419
A	248	+	90	+	24	=	362
B	227	+	84	+	24	=	335
LW	293	+	98	+	0	=	391

OR

HP Class	Blended Silica Fume Cement (8.0%) (kg/m³)		Fly Ash (kg/m³)		Cementitious Materials (kg/m³)
AA	335	+	84	=	419
A	290	+	72	=	362
B	268	+	67	=	335

OR

HP Class	Blended Silica Fume Cement (8.0%) (kg/m³)		GGBFS (kg/m³)		Cementitious Materials (kg/m³)
AA	314	+	105	=	419
A	272	+	90	=	362
B	251	+	84	=	335

OR

Required Cementitious Materials
(English Units)

HP Class	Cement (lbs/cy)		Fly Ash (lbs/cy)		Silica Fume Admixture (lbs/cy)		Cementitious Materials (lbs/cy)
AA	524	+	141	+	40	=	705
A	449	+	122	+	40	=	611
B	412	+	113	+	40	=	565
LW	528	+	132	+	0	=	660

OR

HP Class	Cement (lbs/cy)		GGBFS (lbs/cy)		Silica Fume Admixture (lbs/cy)		Cementitious Materials (lbs/cy)
AA	489	+	176	+	40	=	705
A	418	+	153	+	40	=	611
B	384	+	141	+	40	=	565
LW	495	+	165	+	0	=	660

OR

HP Class	Blended Silica Fume Cement (8.0%) (lbs/cy)		Fly Ash (lbs/cy)		Cementitious Materials (lbs/cy)
AA	564	+	141	=	705
A	489	+	122	=	611
B	452	+	113	=	565

OR

HP Class	Blended Silica Fume Cement (8.0%) (lbs/cy)		GGBFS (lbs/cy)		Cementitious Materials (lbs/cy)
AA	529	+	176	=	705
A	458	+	153	=	611
B	424	+	141	=	565

If bagged silica fume is being used, the total number of bags for the batch shall be the least number of whole bags required - round fractional numbers of bags required down to the next whole number. The maximum amount of silica fume used shall be 24 kg/m³ (40 lbs/cy). The total batch weight of silica fume ignored shall be substituted with portland cement. Exceptions: For a one cubic yard batch, use 50 lbs of silica fume. For a one cubic meter batch, use 34 kilograms of silica fume.

If the blended silica fume cement contains silica fume at a rate other than that required for the approved design mix, the Contractor shall provide additional silica fume or cement, as required, to provide concrete meeting the mix design requirements. The additional cement or silica fume provided shall be of the same brand and type as contained in the silica fume cement blend.

Type A Water-Reducing or Type D Water-Reducing and Retarding, or Type F Water-Reducing, High Range, or Type G Water-Reducing, High Range, and Retarding Admixture shall be required to produce a workable mixture. The use of an accelerating or water-reducing-accelerating admixture to alter the setting characteristics of concrete mixtures shall be employed only with the approval of the Engineer. The use of chlorides or admixtures containing chlorides is prohibited. All admixtures will be considered incidental to the work and included in the Contract unit price of the concrete.

The Contractor, following mix design criteria and procedures outlined by the Agency, shall submit the mix design, required data, and test results to the Structural Concrete Engineer for review and approval. For initial submittals, a minimum of two weeks shall be allowed for evaluation of the submitted mix design, test results and required data. No production of concrete for the project shall commence until the Structural Concrete Engineer has reviewed and approved the concrete mix design.

The concrete materials shall be proportioned using the absolute volumes method in accordance with the requirements for each class as specified in Table 501.03A or a reviewed and approved alternate mix design. The volumetric proportioning method such as that outlined in ACI Standard 211.1, *Recommended Practice for Selecting Proportions for Normal Weight Concrete*, or other approved volumetric proportioning methods shall be employed in the mix design.

Production activities shall operate so that no intentional deviations are made from the reviewed and approved mix design. If test results indicate a failure to obtain the 28-day compressive strength as specified in Table 501.03A as tested in accordance with AASHTO T 22 or AASHTO T 97, changes to the mix design shall be made with no extra payment. Changes may include, but are not limited to, using additional cementitious materials, changing the sources of cementitious materials or aggregates, using a high range water-reducer or other additives, or, if necessary obtaining concrete from another supplier.

Also, in lieu of the high performance concrete mix specifications provided herein, the Contractor may submit (for the Structural Concrete Engineer's and Engineer's review and acceptance) a high performance portland cement concrete mix, provided the following requirements are met:

A minimum of thirty (30) calendar days – thirty seven (37) calendar days, if the first time the mix is being submitted – prior to placement (or prior to the pre-placement meeting, if one is required), the Contractor shall submit (for approval) the mix design for the class of concrete specified. The mix design(s) shall be submitted to the Agency's Materials and Research Laboratory, 1716 Barre-Montpelier Rd., Berlin, Vermont 05602, attention Structural Concrete Engineer. No class of concrete shall be placed on a project until the mix design is approved. The mix design must contain the following (including name and source of materials):

Saturated Surface Dry or Dry Weights
Compressive Strength
Cement Content in kg/cubic meter (lbs/cubic yard)
Mineral Admixture Content (each) in kg/cubic meter (lbs/cubic yard)
Air Content
Water/Cementitious Material Ratio
Chemical Admixtures (types, brand names, dosages)
Laboratory Test Results (strength, air content, water/cement ratio, slump)
Alkali-Silica Reactivity (ASR) AASHTO T 303 modified. The modification shall be run using the proposed job cementitious material proportioning with the aggregate found to have the highest ASR potential. The expansion shall be below 0.10%.

The first time a mix design is submitted, the Contractor shall include permeability test results for (a minimum of) three (3) 4 inch diameter x 8 inch high (100 mm diameter x 200 mm high) test cylinders, made and cured in accordance with AASHTO T 22. The information shall include the individual results from testing 3 specimens, but no specimen shall exceed the maximum specified. Testing shall be performed by a Cement

and Concrete Reference Laboratory (CCRL) qualified laboratory. The maximum allowed rapid chloride ion coulomb permeability result as tested per AASHTO T 277 is 2000, tested at 56 days from the date specimens were cast.

The first time a mix design is submitted, the Contractor shall include ASR – AASHTO T 303 test data from both fine and coarse aggregates**.** Testing shall be performed by a CCRL qualified laboratory. If potentially reactive aggregates are to be used in a mix design, then proposed mitigation method(s) and test results shall be provided. The AASHTO T 303 test shall be run again with the proposed mitigation method(s) and using the proposed job cementitious material proportioning. The maximum allowable mortar bar expansion when tested per AASHTO T 303 (with proposed mitigation method(s), as described previously, if required) shall be 0.10%.

The cylinder test results shall be submitted with the following data regarding fabrication of the specimens:

Size of Batch
Type of Mixer
Mixing Time
Type of Cure
Age Upon Delivery

After the materials to be furnished by the Contractor have been reviewed and accepted, no proposed change in the source, proportions, or characteristics of the materials shall be made without the review and acceptance of the Engineer. No new materials shall be used until such materials and their proportions have been reviewed and accepted by the Engineer. In no case shall concrete from more than one batch plant be permitted on the same structure without prior written approval of the Engineer.

The Engineer may order concrete production and delivery suspended and a new mix or altered mix design submitted if components or final product material characteristics are determined to be out of tolerances, unsatisfactory, or if proposed changes in the source, proportions, or characteristics of the materials are proposed. No production of concrete for the project shall resume until the Structural Concrete Engineer has reviewed and accepted the new or altered mix design. For evaluation, new mix design submittals shall be considered as initial mix design submittals.

The various classes of concrete shall have air content by volume as specified. The entrained air shall be obtained by the use of an approved admixture.

Strict adherence to the requirements of Subsection 501.07 is required when using concrete with mineral admixtures. The setting time may be retarded in cool weather. The Resident Engineer, after consultation with the Agency's Structural Concrete Engineer, may require that the curing period, as designated in Table 501.17, be extended.

501.04 BATCHING. Measuring and batching of materials shall be done at an approved batch plant. Batch plants shall have an inspection completed prior to the first concrete placement on an Agency project if it has been longer than 12 calendar months from the last inspection. Request for inspection and required documentation must be received by the Structural Concrete Engineer a minimum of 15 working days prior to the date of the requested inspection. All deficiencies shall be corrected and verified a minimum of 3 working days prior to the first concrete placement for any Agency project. The batch plant shall meet the requirements of AASHTO M 157, except as modified and shall be maintained in good repair at all times and shall be subject to a periodic inspection by an authorized representative of the Agency. The batch plant shall have an approved method of storing, measuring, and dispensing approved mineral admixtures.

All new or relocated concrete batch plants offered for Agency approval shall be equipped for semi-automatic batching and proportioning of all cementitious material, aggregates, water and for automatic insertion of admixtures. The plants shall be equipped to automatically and accurately record (in English and metric units) the quantity of all aggregates, cementitious material and the water incorporated into each batch and shall identify and record the addition of the required admixtures.

Proper facilities shall be provided for the Engineer to inspect ingredients and processes used in the batching and delivery of the concrete. The Contractor shall, without charge, afford the Engineer all reasonable facilities for securing samples to determine whether the concrete is being furnished in accordance with these Specifications.

The Contractor shall give the Engineer 24-hour notice of intent to place concrete so that arrangements can be made for laboratory inspection and control. Failure to give notice which causes postponement of placing operations shall not be reason for determining extension of Contract time per specifications of Subsection 108.11 of the Standard Specifications for Construction.

(a) Semiautomatic Batch Plants. When actuated by a starting mechanism, the semiautomatic batch controller shall start the mass measuring (weighing) operation of the materials and stop the flow automatically when the designated mass (weight) has been reached. It shall be interlocked to ensure that the discharge mechanism cannot be opened until the mass (weight) is within the tolerance specified in Subsection 501.04 (d).

Water and admixtures may be batched in a weigh batcher or by volume in a volumetric device. When actuated, volumetric controls shall start the measuring operation and stop the flow automatically when the designated volume has been reached.

(b) Testing Laboratory. The Contractor shall provide at the plant site a weatherproof building or room for the use of Agency personnel as a testing laboratory. The Contractor shall attain and maintain a qualified laboratory status in accordance with the current edition of the Agency's Qualified Laboratory Program. Failure to comply with this program may result in suspension or revocation of acceptance testing at the facility.

The laboratory shall have a minimum gross internal area of 14 m^2 (150 square feet) with a layout providing a minimum internal width of 2.1 m (7 feet), in which to house and use the equipment specified. Should the Contractor elect to provide additional equipment relevant to testing of portland cement concrete and materials, the gross inside floor area of the laboratory shall be increased in proportion to the area required to house and operate the additional equipment. If the additional equipment is to be operated on a bench, the length of bench sections shall also be proportionally increased. An adequate method of ventilation, lighting, heating, and necessary electrical or gas connections shall be provided. Sanitary toilet facilities with lavatory shall be available for use by Agency personnel at the plant site. A dedicated private telephone service shall be provided in the laboratory. A dedicated internet connection, which provides Agency personnel a minimum speed of 700 Kbps (Kilobits Per Second) download, without utilizing compression algorithms, shall be provided in the laboratory. The connection bandwidth speed shall be verifiable using an online speed test.

The laboratory shall be equipped with the following:

1 Standard office desk, with lockable drawers or a separate lockable two-drawer file cabinet and chair.

1 VTrans' Qualified Laboratory Binder with Producer equipment calibration data

1 Bench section(s) at least 600 mm (2 feet) wide providing a minimum of 2.6 m^2 (28 square feet) of working area with undercounter shelving.

1 Standard laboratory stool.

1 Fully automatic electronic calculator with eight digit capacity.

1 Standard laboratory sink and faucet provided with an adequate supply of water meeting the requirements of Subsection 745.01. The sink shall drain to the outside of the laboratory.

1 Bench brush.

1 Floor brush.

1 Motorized 203 mm (8 inch) sieve shaker (with adjustable timer) with sieving operation conducted by means of lateral and vertical motion of the sieve accompanied by jarring action with the following 203 mm (8 inch) diameter sieves: 9.5 mm (3/8 inch), 4.75 mm (No. 4), 2.36 mm (No. 8), 1.18 mm (No. 16), 600 μm (No. 30), 300 μm (No. 50), 150 μm (No. 100), plus pan and cover.

1 Mechanical aggregate shaker (with adjustable timer) with a 0.0283 m^3 (1 cubic foot) capacity with the following screens: 45 mm (1 3/4 inch), 37.5 mm (1 1/2 inch), 25 mm (1 inch), 19 mm (3/4 inch), 12.5 mm (1/2 inch), 9.5 mm (3/8 inch), 6.3 mm (1/4 inch), 4.75 mm (No. 4), 2.36 mm (No. 8), 1.18 mm (No. 16), and pan. The aggregate shaker may be placed in a separate enclosed area or be shielded for dust and sound. When the aggregate shaker is placed in a separate enclosed area, there shall be a minimum of 1.5 m (5 feet) of clear space measured from the front frame of the shaker outward. The enclosed area shall be well lighted and ventilated. Also, the shaker shall have an adjacent bench section approximately 900 mm (36 inches) high, 600 mm (24 inches) deep and 1250 mm (50 inches) long.

1	Electronic balance with a minimum capacity of 22 kg (50 pounds) accurate to 0.1 g (0.0002 pound). If separate fine and coarse aggregate scales are to be used, the fine aggregate scale shall meet AASHTO M 231 4.2 Table 2 Class G2 with a minimum capacity of 800 grams (1.75 lbs) and readable to 0.1g (0.0002 lbs). The coarse aggregate scale shall meet AASHTO M 231 4.2 Table 2 Class G5 with a minimum capacity of 22 kg (50 lbs) and readable to 1 gram (0.002 lbs).
1	Double burner hot plate, in which both burners are hot, with variable temperature.
5	Metal pans, nominal size, 230 by 230 by 50 mm (9 × 9 × 2 inches).
3	Metal pans, nominal size, 230 by 330 by 50 mm (9 × 13 × 2 inches).
1	Sample splitter, 63.5 mm (2 1/2 inch) chute.
1	250 mm (10 inch) blunted trowel.
1	1.25 by 1.25 m (4 × 4 feet) minimum heavy canvas for quartering samples.
1	Brass wire bristle brush.
1	Pair, heat resistant gloves.
2	38 mm (1 1/2 inch) soft bristle paint brushes.
3	355 mL (12 ounce) clear graduated glass bottles.
1	Reference color comparison chart with five organic plate number colors. Reagent sodium hydroxide solution (3 percent) in sufficient quantity for the duration of the project.

Acceptable substitutes for the aforementioned equipment may be provided when approved by the Materials and Research Engineer.

Batching operations shall not begin until the testing laboratory has been approved as being in compliance with these Specifications and all equipment and equipment calibration requirements of the current VTrans Quality Assurance Program and Qualified Laboratory Program documents. Removal of any equipment, except at the direction of the Engineer, will revoke any prior approvals and/or qualifications and require the termination of batching operations.

The building or room designated as a testing laboratory shall be maintained in a clean condition by the producer and kept free of all articles not necessary for the testing of materials. Cleaning supplies shall be furnished by the Contractor.

(c) Bins and Scales. The batch plant shall include bins, weighing hoppers, and scales with adequate separate compartments for fine aggregate and for each required separate size of coarse aggregate. If cement is used in bulk, a bin, hopper, and scale for cement shall be included. Each compartment shall be designed to discharge efficiently and freely into the weighing hopper or hoppers. Means of control shall be provided so that when required, the material may be added slowly in minute quantities and shut off with precision. Means of removing the overload of any one of the several materials shall be provided. Hoppers shall be constructed so as to eliminate accumulations of tare materials and to discharge fully without jarring the scales. Partitions between compartments shall be ample to prevent spilling under any working condition. All batch plant structures shall be properly leveled and maintained in that condition within the tolerance required by the design of the mass measuring (weighing) mechanism.

The scales for determining the mass (weight) of aggregate and cementitious material shall be comprised of a suitable system of levers or load cells. The levers or load cells will determine the mass (weight) consistently within 0.5 percent under operating conditions, with loads indicated either by means of a beam with balance indicator, a full-reading dial, or a digital read-out or display.

Adequate means for checking the accuracy of the scales shall be provided by the Contractor either by the use of 22.68 kg masses (50 pound weights) or by other methods approved by the Engineer. All exposed fulcrums, clevises, and similar working parts of scales shall be kept clean. When beam-type scales are used, provision shall be made for indicating to the operator that the required load in the weighing hopper is being approached. Poises shall be designed to be locked in any position to prevent unauthorized change of position. All mass measuring (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.

The scales shall be serviced and their accuracy verified annually by a hopper scale service person licensed by the Division of Weights and Measures of the Vermont Department of Agriculture. For Vermont plants, an inspector representing the Division of Weights and Measures shall witness all testing conducted by the service person and will attach a seal to each hopper scale, provided it meets the current specifications, tolerances, and regulations adopted by the Division of Weights and Measures. Standard test masses (weights) used to determine the accuracy of hopper scales shall be certified yearly by the Division of Weights and Measures in accordance with their established standards.

The ready-mixed concrete producer shall hire a licensed hopper scale service person for annual checking and service of scales. In addition, Vermont producers shall schedule an inspection with the Division of Weights and Measures between February 15th and April 30th of each year. After April 30th, Vermont plants without current seals affixed to the hopper scales will not be permitted to supply concrete to Agency projects, unless otherwise directed by the Engineer or until the seals are affixed.

Out of state concrete producers shall observe all annual hopper scale mass measurement (weighing) and seal requirements of their respective states of location.

(d) Accuracy of Plant Batching. For weighed ingredients, accuracy of batching is determined by comparison between the desired mass (weight) and the actual scale reading; for volumetric measurement of water and admixtures, accuracy is determined by checking the quantity either by mass (weight) on a scale or by volume in a calibrated container.

Chemical admixture containers or scales shall be calibrated annually by a qualified admixture distributor representative.

Batching shall be conducted to accurately measure the desired quantities within the following tolerances:

Cement:	± 1 percent	Aggregates:	± 2 percent
Water:	± 1 percent	Chemical Admixtures:	± 3 percent
Mineral Admix.:	+ 10 percent, - 1 percent		

(e) Storage and Proportioning of Materials.

(1) Portland Cement. Either sacked or bulk cement may be used. No fraction of a sack of cement shall be used in a batch of concrete unless the cement is weighed.

All bulk cement shall be weighed on an approved mass measuring (weighing) device. The bulk cement-weighing hopper shall be properly sealed and vented to preclude dusting during operation. Facilities shall be provided for the sampling of cement at the batch plant, either from the storage silo or from the weighing hopper. This device shall be a permanent installation located so as to allow safe and easy access. It shall provide a sample that represents the true nature of the material being used.

(2) Water. Water may be measured either by volume or by mass (weight). When measurement is by meter, the water meter shall be so located that the measurements will not be affected by variable pressure and temperature in the water supply line.

Measuring tanks shall be equipped with an outside tap and valve to provide for checking the setting, unless other means are provided for readily and accurately determining the amount of water in the tanks.

All water metering methods shall be verified/calibrated on an annual basis or at any time there is a question of accuracy. All water added to the concrete at any point shall be through an approved metering method.

(3) Aggregates. In stockpiling aggregates, the location and preparation of the sites shall be subject to the approval of the Engineer. Stockpiles shall be formed on hard well-drained areas that prevent contamination from underlying material and accumulation of excessive moisture.

Aggregates from different sources or of different gradations shall not be stockpiled together. Only rubber-tired equipment shall be permitted to operate on aggregate stockpiles.

Stockpiles shall be constructed as follows:

a. If the stockpile is to be made using mechanical equipment (front end loader, clam bucket, rock ladder, radial stacker, or other approved equipment), the stockpile shall be made in such a manner that segregation is kept to a minimum.

b. If the stockpile is to be made by dumping from trucks in multiple layers, each layer shall be approximately 1.2 m (4 feet) in depth. Each layer shall be completely in place before commencing the next layer. Care shall be taken that successive layers do not "cone" down over the previous layer.

c. No equipment shall be used to haul aggregate over the stockpiled material except to deposit the material for the layer being placed. It shall be the responsibility of the Contractor that the aggregate be kept free from deleterious material or degradation.

Stockpiles shall be maintained in such a manner that twice the anticipated aggregate requirement for any Agency project placements will be on hand and available for sampling and testing at least 48 hours before mixing operations for the placements are scheduled to begin. The Engineer may modify this requirement when special aggregates are required.

Aggregates shall be handled from stockpiles or other sources to the batch plant in such a manner as to secure a uniform grading of the material. Aggregates that have become segregated, or mixed with earth or foreign material, shall not be used. All aggregates, except lightweight coarse aggregate, produced or handled by hydraulic methods and washed aggregates shall be stockpiled or binned for draining at least 12 hours before being batched. In case the aggregates contain high

or non-uniform moisture content, storage or stockpile period in excess of 12 hours may be required by the Engineer.

d. Lightweight coarse aggregate stockpiles shall be presoaked for a minimum period of 48 hours immediately prior to use. Soaking shall be accomplished by continuous sprinkling or other suitable means that will provide a uniform moisture content throughout the stockpile.

(4) Admixtures. The Contractor shall follow an approved procedure for adding the necessary amount(s) of admixture(s) to each batch. Admixture(s) shall be dispensed in such a manner that will ensure uniform distribution of the material throughout the batch within the required mixing period. Except as specified herein, all admixtures shall be added to the batch at the plant, unless otherwise authorized by the Engineer.

All dispensers shall include visual inspection aids such as graduated transparent cylinders. A separate dispenser shall be provided for each liquid admixture. Storage and dispensing systems for liquid admixtures shall be equipped so as to allow thorough circulation and/or agitation of all liquid in the system. This shall be required prior to the first batching of concrete for Agency projects in any calendar year and periodically thereafter at intervals not to exceed 60 calendar days for the duration of the period the plant is supplying concrete for Agency projects. If the circulation method is used, the admixture shall be circulated until a complete exchange of admixture is achieved. If an agitation method is used, the method shall be subject to approval by the Engineer.

Storage and dispensing systems for liquid admixtures shall be sufficiently protected to prevent freezing of admixtures at all times.

It shall be the responsibility of the Contractor to use the quantity of Agency approved admixtures needed to obtain concrete meeting the requirements of the Contract. All admixtures will be approved by the Engineer prior to incorporation into the mix.

a. Air-Entraining Admixture. Air-entraining admixture shall be used as required to obtain the specified air content.

b. Water-Reducing, Retarding, and Water-Reducing and Retarding Admixtures. Dosages shall be those recommended by the Manufacturer, unless otherwise approved by the Engineer.

(5) Fly Ash or GGBFS. Fly Ash or GGBFS shall be stored at the batch plant in separate storage or holding bins or other approved holding container and shall be protected from rain and moisture.

501.05 MIXING AND DELIVERY.

(a) General. Concrete may be mixed at the site of construction, at a central point, or wholly or in part in transit mixers. The production of concrete shall meet the requirements of AASHTO M 157 with the following additional requirements:

(1) All concrete shall reach its final position in the forms within 1.5 hours after the cement has been added to the aggregates. When the ambient air temperature is 16 °C (60 °F) or above, the elapsed time may be reduced as necessary as directed by the Engineer or in accordance with Subsection 501.07(a).

(2) The Engineer may authorize the addition of water at or near the site, or the use of admixtures, prior to concrete discharge, at the Contractor's expense.

(3) The addition of water in excess of the design water-cementitious material ratio for purposes of meeting the slump limits will not be permitted. Concrete that is not within the specified slump or water/cementitious limits at time of placement shall not be used.

(4) Each load of concrete delivered at the job site shall be accompanied by a State of Vermont Batch Slip signed by the authorized Agency representative, if present, at the plant.

(5) The Contractor shall provide direct communication service from the site of the work to the batch plant that shall be available to the Engineer at all times during concrete operations. The cost of this service will be considered incidental to the work.

(6) When use of a Water-Reducing, High Range Admixture or Water-Reducing, High Range, and Retarding Admixture is specified for deck concrete, the contractor shall submit, for the Engineer's approval, the following information: Admixture manufacturer, admixture addition rate, and when the admixture is to be added to the mixture (i.e., at the plant, on project, or a combination thereof). In order to obtain the required slump, a representative from the concrete producer is required on the project to determine the final admixture dosage for each load of concrete. This representative shall be responsible for adding the Water-Reducing, High Range Admixture or Water-Reducing, High Range, Retarding Admixture and Air Entraining Admixture to the mixer. The dosage shall be applied by means of a dispenser, or by other means as approved by the Engineer. The Contractor shall provide QC concrete testing personnel to confirm the concrete is within specifications for the required work.

(7) Not including initial mixing revolutions, all concrete shall be discharged into the forms before 300 revolutions of the drum or blades. The total revolutions may be increased as directed by the Engineer.

Mortar shall be mixed in an approved mixer at the site of placement or in transit mixers when approved by the Engineer. The Engineer will withdraw approval for use of transit mixers, if necessary, to ensure a quality product or if the rate of delivery cannot be coordinated with finishing requirements.

(b) Stationary Mixers. When a stationary mixer is used for the complete mixing of the concrete, the mixing time for mixers having a capacity of 7.5 m^3 (10 cubic yards) or less shall be not less than 90 seconds. For mixers of more than 7.5 m^3 (10 cubic yards) capacity, the mixing time shall be determined by the concrete producer. The time is valid provided mixer efficiency tests prove the concrete is satisfactory for uniformity and strength. The plant shall be equipped with a timing device that will not permit the batch to be discharged before the predetermined mixing time has elapsed. Vehicles used in hauling shall comply with the requirements of Subsection 501.05(c).

(c) Transit Mixers. Transit mixers and agitators shall be subject to a periodic inspection by an authorized representative of the Agency. Such equipment shall bear a currently dated inspection "sticker" supplied by the Agency indicating that the transit mixer or agitator conforms to the Agency's requirements.

Transit mixers shall be equipped with a water-measuring tank with a visible sight gauge for use when the water for the batch is supplied from the transit mixer tank. The gauge shall be clean and legibly graduated. Measuring tanks shall be provided with outside drain valves or other means to check their calibration. These should be easily opened for checking at any time.

No transit mixer or agitator shall be charged with the ingredients of the concrete unless an authorized Agency representative is present and authorizes it. This requirement may be waived by the Engineer if a batch slip accompanies the delivery vehicle to the site.

Electrically actuated revolution counters shall be required on all transit mixers except on mixers charged at central mix plants and utilized as agitator trucks only.

If bagged mineral admixtures are being used, transit mixer maximum load size shall be limited to 80 percent of the manufacturer's rated mixing capacity**.** Also, legal vehicle load restrictions shall not be exceeded. 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.

If bagged mineral admixtures are being used, agitators, when loaded, shall also not exceed 80 percent of the manufacturer's rated mixing capacity or legal load restrictions and 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.

The Engineer may require the Contractor to perform uniformity tests on a transit mixer or agitator. Two samples shall be taken. The first shall be after 15% of the load volume discharge and the second prior to 85% of the load volume discharge. Slump and air content shall be performed on each sample. The maximum difference in air content between the two samples shall be 1%. For slumps of concretes with specified slumps of 100 mm (4 inches) or less, the maximum difference shall be 25 mm (1 inch). For concretes with a specified slump greater than 100 mm (4 inches), the maximum difference shall be 38 mm (1.5 inches). If both conditions are not met, then the Contractor will be required to either modify the mixing procedure and/or batching sequence, or that transit mixer or agitator will not be allowed to deliver concrete to the project. The Contractor will be required to perform uniformity tests to confirm the changes have satisfactory results.

All mechanical details of the mixer or agitator such as water measuring and discharge apparatus, condition of the blades, speed of rotation of the drum, general mechanical condition of the unit and clearance of the drum shall be checked before a further attempt to use the unit will be permitted.

Mixers and agitators shall be kept free from accumulation of hardened concrete or mortar. The mixing blades shall be rebuilt or replaced when any part or section is worn 19 mm (3/4 inch) or more below the original height of the manufacturer’s design. A copy of the manufacturer’s design, showing the dimensions and arrangements of blades shall be available to the Engineer at the plant at all times.

The mixing of concrete containing silica fume is very important and shall be mixed in accordance with the appropriate situation:

1. When silica fume is added to the batch by bags or in bulk from a silo, each batch of concrete shall be mixed for not less than 150 revolutions of the drum or blades at the rate of rotation designated by the manufacturer of the equipment as the mixing speed. The mixing and agitating speeds shall be found on the metal plate on the mixer.

2. When silica fume is blended with cement or a combination of cement and mineral admixture at the cement plant prior to being delivered to the concrete plant, 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 as the mixing speed. The mixing and agitating speeds shall be found on the metal plate on the mixer. If inconsistent test results are obtained or the batch of concrete appears not to be completely mixed, the mixing revolutions shall be extended as necessary.

When a transit mixer or agitator is used for transporting concrete, mixing during transport shall be continuous and at the speed designated by the manufacturer of the equipment as agitating speed. Failure to do so is cause for rejection of the concrete.

Transit mixers and agitators assigned to a project shall not be used for other purposes until the desired work is completed at the site, and shall arrive at the project within the cycle that anticipated placement conditions dictate. The interval between loads shall be controlled in order that concrete in place shall not become partially hardened prior to placing succeeding batches. The plant capacity and transportation facilities shall be sufficient to ensure continuous delivery at the rate required.

Before discharging transit mix from a transit mixer that has been operating at agitating speed, the drum or blades shall be rotated approximately one minute at mixing speed. The same procedure shall apply to agitators if admixtures, water, or other ingredients are added to the mix in the field.

If additional mixing water is required to maintain the specified slump and is added with the permission of the Engineer, a minimum of 20 revolutions of the transit mixer drum at mixing speed shall be required before discharge of any concrete. At no time shall the total water introduced into any mix exceed the maximum water- cementitious material ratio shown in Table 501.03A.

Upon discharge of the concrete from the drum, a sufficient amount of water shall be charged into the drum to properly cleanse the drum. This water shall not be used as a part of the next succeeding batch but shall be discharged from the drum prior to the charging of the drum with the concrete ingredients. The drum shall be completely emptied before receiving materials for the succeeding batch. Retempering of concrete or mortar that has partially hardened, by remixing with or without additional materials, shall not be permitted.

501.06 FIELD TESTS. The Contractor shall provide assistance, equipment, materials, and curing for field sampling and testing as required by the Engineer. All costs shall be included in the Contract unit prices under Section 631. The Engineer shall perform all acceptance sampling and testing in accordance with the Agency's Quality Assurance Program. For bridge deck pours, the Contractor shall perform all on-site Quality Control (QC) sampling and testing. The person performing the QC sampling and testing shall have, as a minimum, current ACI Concrete Field Testing Technician Grade I Certification.

(a) Sampling. Sampling for tests shall be taken in accordance with AASHTO T 141 or other procedures approved by the Agency.

(1) Changes. Any time that there is a change, whether modified at the batch plant, en route, or at the site, in the source or proportions of materials (cement, water, aggregate, admixture, etc.) from a previously QC tested load, additional QC sampling and testing shall be performed on the modified load prior to incorporating the concrete into the work.

(2) Beginning of Load Sampling. Beginning of Load Sampling is sampling for QC testing purposes that is taken before 15% of the load has been discharged. For certain loads, Beginning of Load Sampling may be permitted or required by the Engineer. If Beginning of Load Sampling is performed, the following modifications to the slump and air content limits shall be in effect for possible QC acceptance. :

a. The maximum slump shall be within 10 mm (0.5 inch) of the values listed in Table 501.03A for the Class of concrete being tested.

b. The air content shall be within the range shown in Table 501.03A for the class of concrete being tested plus 0.5% above the upper limit. While these limits shall be in effect for Beginning of Load Sampling, loads that meet these criteria are not guaranteed to be within the acceptance testing criteria when acceptance testing is performed, and thus the load may still fail the acceptance testing.

(b) Slump Tests. Slump tests shall be made in accordance with AASHTO T 119. Slump tests shall not be required for Class SCC.

(c) Air Content Tests. Air content tests shall be made in accordance with the pressure method in AASHTO T 152, for acceptance or rejection, with the exception that for Class SCC the air meter shall be filled in one lift by using a scoop and dropping the concrete into the center of the pot from a distance of 150 mm (6 inches) from the top edge of the pot with no rodding. Only tap the sides of the pot prior to running the test.

(d) Compressive Strength Tests.

(1) General. The number of compressive strength tests performed should be in accordance with the guidance given in the current edition of the VTrans Materials Sampling Manual, which is dependent upon the QAP level for each project. The Engineer may order additional tests as deemed necessary.

Compressive test cylinders shall be made in accordance with AASHTO T 23, and tested for compressive strength in accordance with AASHTO T 22.
For Class SCC, the cylinders shall be filled in one lift using a scoop and dropping the concrete into the center of the mold from a distance of 150 mm (6 inches) from the top edge. The mold shall not be rodded, vibrated, or tapped on the sides.

(2) Categories of Testing.

a. Acceptance testing utilizes specimens to determine the compliance with strength requirements for the project. All test cylinders used for quality acceptance testing shall be stored in an approved curing box until they are shipped to the central laboratory.

Acceptance testing shall be performed at 28 days.

b. Job control testing utilizes specimens to determine whether adequate curing procedures are being followed and for early form removal or early loading of structure. All job control specimens shall be stored on the structure and shall receive the same curing and protection from the elements as the concrete that they represent up until 24 hours before anticipated testing of specimens.

c. Specimen curing requirements shall be as follows or as directed by the Engineer:

Number of Specimens	Category	Location of Curing
2*	Acceptance - 28 days	Curing Box
2*	Job Control - Applicable Curing Period	On Structure

*3 for Class LW only.

(e) Additional Tests for Class SCC. Flow tests shall be performed in accordance with ASTM C 1611, Procedure B. Do not tamp the self-consolidating concrete inside the cone. The concrete

flow will be tested on the first 2 loads and at a minimum of every 30 m^3 (40 cy), including the yardage of the first two loads.

T_{50} Spread Flow tests shall be performed in accordance with ASTM C 1611, Appendix X.1. The T_{50} shall be performed every time the flow test is run.

Visual Stability Index (VSI) tests shall be performed in accordance with ASTM C 1611, Appendix X.1 and shall be performed on each completed flow test.

501.07 WEATHER AND TEMPERATURE LIMITATIONS-PROTECTION OF CONCRETE. The temperature of the concrete just prior to placement in the forms shall not be less than 10 ºC (50 ºF) nor more than 29 ºC (85 ºF), except that Concrete, High Performance Class AA mix shall not exceed 27 ºC (80 ºF) just prior to placement. Aggregates and water shall be heated or cooled as necessary to produce concrete within these temperature limits.

Placement and curing procedures shall be approved by the Engineer prior to actual placement.

(a) Hot Weather Concrete. Placement of concrete during hot weather may be limited by the Engineer based on an assessment of temperature, humidity, wind velocity, and sun radiation conditions.

No concrete shall be placed when the ambient air temperature is, or is expected to be, above 32 ºC (90 ºF). However, no Concrete, High Performance Class AA mix shall be placed when the ambient air temperature is, or is expected to be, above 29 ºC (85 ºF) during the placement, except by written permission of the Engineer.

(b) Cold Weather Concrete.

(1) General. When it is necessary to place concrete or mortar at or below an ambient air temperature of 5 °C (40 °F), concrete temperatures shall be maintained by an approved method and the work protected by adequate housing, covering and heating, or insulated forms.

The Contractor shall have on the job, ready to install prior to starting any placing operation adequate equipment meeting the approval of the Engineer for

heating and protecting the materials and freshly placed concrete.

No concrete shall be placed when the temperature of the surrounding atmosphere is lower than -12 °C (10 °F) except by written permission of the Engineer.

No concrete shall be placed in any superstructure or thin section under cold weather conditions (ambient air temperature of 5 ºC (40 ºF) or less) without written permission of the Engineer.

(2) Heating of Materials. The heating equipment shall be capable of heating the materials uniformly. Aggregates shall not be heated over 66 °C (150 °F). If water is heated in excess of 60 °C (140 °F), the water shall be mixed with the aggregate before the cementitious material is added. The materials shall be heated in such a manner, for such a period of time, and in such quantity as to produce concrete having a uniform temperature within the specified temperature range at the time of placing. Materials containing frost or frozen lumps shall not be used. Stockpiled aggregates may be heated by the use of dry heat or steam. Aggregates shall not be heated directly by gas or oil flame or on sheet metal over fire. When aggregates are heated in bins, steam-coil or water-coil heating, or other methods that will not be detrimental to the aggregates, may be used.

(3) Antifreeze Compounds. Salts, chemicals, or other foreign materials shall not be used in the mix to lower the freezing point of the concrete.

(4) Preparation of Forms. Before placing concrete; ice, snow, and frost shall be completely removed from the forms.

Concrete shall not be placed on a surface or in forms that are frozen, have surface temperatures below 0 ºC (32 ºF), or that contain frozen materials. The frozen surface or forms shall be completely thawed the day previous to the placing of the concrete and shall be kept continuously thawed until the concrete is poured.

(5) Housing. The Contractor shall furnish sufficient canvas and framework or other suitable type of housing to enclose and protect the structure. The sidewalls of the housing for protecting abutments and piers shall be completely built before the placing of any concrete. They shall be constructed independent of the forms and bracing and with space large enough to provide for form removal and initial finishing of concrete as required during the heating period. Joists adequately spaced to prevent sagging shall support the top of the housing. The housing shall be completely built and the heat applied before placing any concrete.

Bridge decks, floor slabs, and roof slabs placed when the ambient air temperature is below 5 °C (40° F) shall be protected by a housing which also encloses the space beneath and which extends approximately 300 mm (12 inches) outside the edge of the floor. Alternatively, the deck may be insulated in accordance with part (b)(8)b. below.

When the temperature readings taken on or in the concrete indicate the temperature of the concrete may fall below 10 °C (50 °F), the Contractor shall, without exposing the concrete, immediately build the necessary enclosures around the area involved and supply heat to ensure curing conditions as specified in Subsection 501.17. The enclosure shall be removed when directed by the Engineer.

(6) Heating the Enclosure. The enclosure shall be heated in such a manner that the temperature of the concrete and the enclosed air shall be kept above 10 °C (50 °F), but recommended to be no more than 11 °C (20 °F) above the concrete temperature, for the designated curing period. During this time, the concrete shall be kept continuously wet to provide proper curing. After the curing period, the temperature shall be gradually lowered to that of the surrounding atmosphere, taking at least 48 hours for the transition but at no time exceeding a 0.5 °C (1 °F) change per hour.

When dry heat is used, a means of maintaining atmospheric moisture shall be supplied. The Contractor shall maintain adequate fire protection and shall provide personnel to keep the heating units in continuous operation. When operations are in locations where water levels may fluctuate, the supports for heating equipment shall be built so that the heating equipment can be raised and steam lines shall be placed above the probable high water level.

When using direct fired or indirect fired heaters, the enclosure shall be well ventilated to avoid accumulation of carbon dioxide and carbon monoxide.

When using hydronic heaters, a heat transfer fluid that circulates through a series of hoses, the heat transfer hoses shall be laid on top of the vapor barrier, for example plastic, then covered with approved insulating materials or by other approved method for retaining heat.

(7) Temperature Records. The Contractor shall provide an automatic temperature recorder to continuously record concrete curing temperatures and ambient air temperatures for the entire curing period. Recording thermometers shall be capable of measuring and recording temperatures within the range of -20 to 100 °C (-4 to 212 °F) with maximum graduations of 5 °C (10 °F).

Temperature sensors shall be carefully placed within the curing enclosure or the concrete to ensure that temperatures are measured at typical locations. Recorder accuracy shall be certified once every 12 months, and the certificate displayed with each recorder. The Engineer may make random checks of each recorder. On each recorder chart, the Engineer shall indicate the location of the representative concrete, date of placement, and time of start and finish of the record. At the completion of the curing period, the recorder charts shall be given to the Engineer.

When the Contractor places concrete at more than one location within the specified curing period, additional recorders shall be furnished to provide temperature records at each location.

(8) Insulated Forms.

a. General. When authorized by the Engineer, the concrete forms shall be completely covered with an approved insulating material.

To prevent loss of heat, immediately upon completion of concrete placement, all exposed surfaces shall be covered with a double thickness of burlap or cotton mats. This covering will be designed to prevent loss of moisture from the concrete and then covered with sufficient hay, straw, or insulated mats to prevent loss of heat from the concrete during the curing period. Tarpaulins shall be used as additional cover when directed.

To prevent excessive heat build up, provisions shall be made for loosening of insulation to provide ventilation and the subsequent cooling of the concrete if the surface temperature of the concrete approaches 38 °C (100 °F). In no case shall this temperature drop below 10 °C (50 °F) during the curing period.

The following table shall be used as a guide in determining the outside temperature at which concrete walls, piers, abutments, or floor slabs above ground shall be protected with blanket insulation.

TABLE 501.07A
MINIMUM AIR TEMPERATURE ALLOWABLE
FOR ALL CLASSES OF CONCRETE

Concrete Thickness		Insulation Rating of R-4		Insulation Rating of R-8	
mm	in.	°C	°F	°C	°F
150	6	5	40	-2	29
300	12	-2	28	-18	0
450	18	-11	13	-34	-29
600	24	-18	0	-48	-55
900	36	-33	-27	---	---
1200	48	-40	-40	---	---
1500	60	-40	-40	---	---

b. Bridge Decks, Floor Slabs, and Roof Slabs. Immediately upon completion of the finishing, the surface shall be protected as specified under part (b)(5) above. When approved in writing by the Engineer, the Contractor may insulate the top and bottom of the slab as specified in Table 501.07A instead of constructing a heated housing. This insulating material shall be installed immediately upon the completion of finishing in such a way that the fresh concrete surface is not marred.

c. Concrete With Water-Reducing, High Range Admixture or Water-Reducing, High Range, and Retarding Admixture. These admixtures are not to be used if the ambient temperature is below 10 ºC (50 ºF) at the time of placement, or if it is forecasted to drop below 10 ºC (50 ºF) and within 24 hours after completion of the placement, unless hot water is used or the concrete temperature is maintained in accordance with Subsection 501.07(b), subparts (5) and (7).

501.08 THIS SUBSECTION RESERVED

501.09 FORMS. Construction Drawings including falsework and form work plans shall be submitted by the Contractor in accordance with Section 105 before being used. In all cases, the Contractor shall be responsible for, and shall make good, any injury arising from inadequate forms. The Engineer shall inspect and accept all forms prior to concrete placement. Unless the Plans specifically allow for the use of stay-in-place forms, such forms shall not be used in the construction of any superstructure or bridge deck. Stay-in-place forms will only be allowed in the construction of substructure elements in locations where the Engineer agrees that removable formwork is impossible to use.

(a) Falsework. In general, falsework that cannot be founded upon a solid footing shall be supported by falsework piling.

The Engineer may require the Contractor to employ screw jacks or hardwood wedges to take up any slight settlement in the falsework.

(b) Construction. Forms shall be mortar tight and sufficiently rigid to prevent distortion due to the pressure of the concrete and other loads incident to the construction operations including vibration. Forms shall be constructed and maintained so as to prevent the opening of joints due to shrinkage of the lumber. Sealer/caulking as approved by the Engineer shall be used where forms abut structural steel members, such as top flanges of beams and girders, etc.

Forms shall be filleted and chamfered at all sharp corners, unless otherwise shown on the Plans or directed by the Engineer, and shall be given a bevel or draft in the case of all projections, such as girders and copings to ensure easy removal.

Falsework and forms for slabs, beams, and girders shall be constructed to provide camber shown on the Plans or ordered by the Engineer.

Falsework and forms for Class SCC shall be designed with consideration given to concrete placement rates, mix temperature, additives, and placement procedures that effect hydrostatic pressure of the concrete. Forms shall be water tight and sufficiently rigid to prevent distortion due to the pressure of the concrete and other loads incident to the construction operations, including vibration, which should not be needed.

(c) Form Lumber. All face form lumber for exposed surfaces shall be concrete form exterior grade plywood, not less than five ply and not less than 19 mm (3/4 inch) in thickness. In computing stud spacing, plywood shall be considered 25 mm (1 inch) lumber provided that the grain of three of the plys runs perpendicular to the studs.

Form lumber for unexposed surfaces may be dressed tongue and groove, dressed shiplap, or square edge sized four sides of uniform width and thickness. It shall have a minimum thickness, after finishing, of 19 mm (3/4 inch).

All form lumber shall be sound and free from loose or rotten knots, knotholes, checks, splits, or wanes showing on the surface in contact with the concrete. Used face form lumber, having defects or patches which may produce work inferior to that resulting from new material, shall not be used.

Other form material may be used with permission of the Engineer.

(d) Studs. Studs shall have a minimum nominal size of 51 by 152 mm (2 × 6 inches), except that 51 by 102 mm (2 × 4 inch) nominal size studs may be used for pours not exceeding 1.1 m (3 1/2 feet) in height. Studs shall be spaced center to center not more than 16 times the actual thickness of the form lumber.

Studs shall be capped at the top with a plate of not less than 51 by 152 mm (2 × 6 inches) nominal size, carefully selected as to straightness. All joints in plates shall be scabbed 1.2 m (4 feet) each way to provide continuity.

(e) Wales. All wales shall be at least 102 by 152 mm nominal size (4 × 6 inches, minimum section) or equivalent and shall be scabbed at least 1.2 m (4 feet) each side of joints to provide continuity. A row of wales shall be placed within 150 mm (6 inches) of the bottom of each pour unless studding can be extended below the bottom of the pour and secured by wales fastened to ties in the previous pour. Wales shall have a maximum spacing of 900 mm (36 inches).

(f) Form Ties. Metal ties or anchorages within the forms shall be constructed to permit their removal to a depth of at least 25 mm (1 inch) from the face without injury to the concrete.

Wire ties shall be used only in locations where they will not extend through surfaces exposed in the finished work and then only when authorized.

The cavities shall be filled with cement mortar in accordance with Subsection 501.16.

(g) Walls. Where the bottom of the form is inaccessible, the lower form boards shall be left loose or other provisions made so that extraneous material may be removed from the form immediately before placing the concrete.

(h) Surface Treatment. All forms shall be treated with commercial form oil prior to placing reinforcement and wood forms shall be saturated with water immediately before placing the concrete. Any material that will adhere to or discolor the concrete shall not be used.

(i) Metal Forms. The specifications for forms regarding design, mortar tightness, filleted corners, beveled projections, bracing, alignment, removal, reuse, and oiling also apply to metal forms. The metal used for forms shall be of such thickness that the forms will remain true to shape. All bolt and rivet heads shall be countersunk. Clamps, pins, or other connecting devices shall be designed to hold the forms rigidly together and to allow removal without injury to the concrete. Metal forms that do not present a smooth surface or do not line up properly shall not be used. Care shall be exercised to keep metal forms free from rust, grease, or other foreign matter.

(j) Removal of Forms. The forms, or their supports, for any portion of a structure shall not be removed without the approval of the Engineer. Forms under arches, beams, floor slabs, pier caps, or special designs may be removed upon approval of the Engineer after the concrete attains 85 percent of the minimum compressive strength as specified in Table 501.03A.

If field operations are not controlled by cylinder tests, the following periods for removal of forms and supports, exclusive of days when the ambient air temperature is below 5 °C (40 °F), may be used as a guide:

Arch Center	14 Days
Centering under Beams	14 Days
Supports under Flat Slabs	14 Days
Floor Slabs	14 Days
Vertical Wall Surfaces	24 Hours
Columns	24 Hours
Sides of Beams	12 Hours
Top Slabs R.C. Box Culverts	14 Days

When field operations are controlled by compressive strength tests, the removal of forms and supports may begin when the concrete is found to have the required strength. In no case shall the number of curing days be less than specified in Table 501.17A**.**

Methods of form removal likely to cause overstressing of the concrete shall not be used. Forms and their supports shall not be removed without approval. Supports shall be removed in such a manner as to permit the concrete to uniformly and gradually take the stresses due to its own dead load.

(k) Stay-in-Place Corrugated Metal Forms (SIPCMF) for Superstructure Deck Slabs.

(1) Use. Use of SIPCMF for superstructure deck slab construction shall be subject to the following requirements:

a. Fascia overhangs shall be formed with removable forms. The forms used shall leave the resulting concrete flat-surfaced.

b. Any bay, constructed in stages such that a longitudinal joint is required, shall be formed with removable forms.

(2) Design Requirements. The following requirements shall govern the design of SIPCMF:

a. Design span shall be the clear span of form plus 50 mm (2 inches) measured parallel to the form flute (also referred to as the form valley).

b. Design load shall be the sum of the weight of forms, bar reinforcement, plastic concrete, and 2.7 kPa (55 psf) for construction loads.

c. Unit working stress shall not exceed 0.725 of the specified minimum yield strength of the material.

d. Dead load deflection shall not exceed 1/180 times the form span length or 13 mm (1/2 inch), whichever is less.

e. Physical design properties shall be computed with the requirements of the American Iron and Steel Institute Specifications for the Design of Cold Formed Steel Structural Members, latest edition.

(3) Construction Requirements. The following construction requirements shall apply to the use of SIPCMF:

a. The Contractor shall submit Construction Drawings for SIPCMF in accordance with Subsection 105.03. These Drawings shall contain the following information as a minimum:

1. A layout showing the compression and tension region of each beam/girder.

2. The method of SIPCMF attachment for the compression and tension regions.

3. Geometric properties of each type of panel being used.

4. Identification of the supplier of the SIPCMF.

5. The number, location, and type of panels being used within each girder bay.

6. Panel laps, taking into account the direction of concrete pours.

7. The specifications for the material used to fill the flutes.

8. Any other material data, erection information, or miscellaneous notes that may be required.

b. Handling and Installation. Care and protection shall be given the metal form sheets, supports, and accessory items during handling, shipping, and storage. During loading, hoisting, and unloading operations, extra precaution and care shall be taken to prevent damage to ends, corners, and edges of form sheets, supports, and accessory items. If the form units and accessories are to be stored prior to installation, they shall not be placed in contact with the ground and shall be adequately covered or protected to keep them dry.

Form supports shall be placed in direct contact with the flange of beam/girder/stringer or floorbeam. All attachments shall be made by permissible welds, bolts, clips, or other approved means. The welding of form supports to steel not considered weldable or to portions of flanges subject to tensile stresses shall not be permitted. Welds and welding shall be in accordance with Subsection 506.10, with the exception that a 3 mm (1/8 inch) fillet weld will be permitted.

Form sheets shall not be permitted to rest directly on the flanges. They shall be securely fastened to form supports by self-tapping screws and shall have a minimum bearing length of 25 mm (1 inch) at each end. Transverse construction joints shall be located at the bottom of a valley. A 6 mm (1/4 inch) diameter weep hole shall be drilled at the lower end of each flute or valley.

Screed and pouring runway supports shall not be located directly on the form sheets, form supports, or reinforcing steel. No loose sheets or miscellaneous hardware shall be left on the structural slab at the end of the working day.

The corrugated metal sheets shall be fabricated for the placement sequence used, with the joints between sections of sheets overlapped or securely fastened to eliminate differential deflections. Any exposed form metal where galvanizing has been damaged shall be cleaned and repaired to the satisfaction of the Engineer.

(4) Inspection Procedures. The following three step inspection procedure will be used to check the soundness of the concrete deck against the SIPCMF:

a. Not less than two days after completion of a concrete structural slab pour, but prior to the next slab pour, one panel of the SIPCMF shall be removed from the most recently completed pour of each span, at a location selected by the Engineer, in order to provide visual evidence that the concrete mix or the construction procedures are obtaining the desired results. If the concrete mix or the construction procedures are varied significantly within a pour, such as a change in the extent of vibration or change in the workability of the mix, another section of forming shall be removed to verify that the new procedures are yielding desirable results.

b. After the concrete has attained 85% of the specified design strength, the Engineer will spot-check the underside areas of the steel forms by sounding with a suitable weight hammer. If honeycomb or voided areas are detected, the SIPCMF at that location shall be removed for a visual inspection.

c. A minimum of two percent of the total SIPCMF area shall be removed for visual inspection of the concrete surface. The amount of sounding and form removal may be moderated, at the Engineer's discretion, after a substantial amount of the slab has been constructed and inspected, if the Contractor's methods of construction and results of the inspections as outlined above indicate that sound concrete is being obtained throughout the slab.

If, after removing a section of form, the concrete is found to be defective, additional panels shall be removed as directed by the Engineer. All defective concrete shall be repaired to match the adjacent concrete in section and color to the satisfaction of the Engineer.

The Contractor shall provide all facilities required for the safe, suitable, and convenient means of access to the forms for the Engineer's inspection procedures.

The form sections shall be removed by a metal saw or air-carbon-arc gouging with minimum damage to the concrete. Cuts shall only be sufficiently deep to sever the form. Any other method of removal shall be submitted to the Structures Engineer for approval. Cuts parallel to the corrugations in the forms shall be located on the sloping surface midway between a crest and valley. Cuts parallel to the supporting beams/girders shall be made through the supporting angles taking care not to damage the structural steel beams/girders.

The Contractor will not be required to replace the forms which have been removed.

501.10 PLACING CONCRETE.

(a) Workforce. The Contractor shall have sufficient skilled personnel at all times during the concreting operations to properly place, consolidate, and finish the concrete. If, in the opinion of the Engineer, the Contractor does not have sufficient skilled personnel to handle the concrete properly, the Engineer may postpone the start of the concreting operations until such time as the Contractor has remedied this condition.

(b) Pre-Placement Meeting. For deck pours and all pours with Class SCC, or as required by the Engineer, a pre-placement meeting shall take place at least 7 calendar days before concrete placement. Attendees at the pre-placement meeting shall include, but not be limited to, the Contractor's Project Superintendant, the Engineer, the Agency's Structural Concrete Engineer, and the concrete producer. The Contractor shall provide a placement plan detailing the horizontal length of the pour(s), and, if applicable, all location(s) at which the self-consolidating concrete will be deposited, and the timing of the placement.

(c) Placement Limitations. All concrete shall be placed in daylight, unless otherwise authorized in writing by the Engineer. Authorization to place concrete at any other time shall not be given unless an adequate lighting system is provided prior to beginning the concreting operation.

Concrete shall not be placed under adverse environmental conditions that the Engineer determines will interfere with acceptable placement and/or finishing operations.

Concrete shall not be placed until the depth and character of the foundation, the apparent adequacy of the forms and falsework and the placing of the reinforcing steel have been approved by the Engineer. The interior of the forms shall be clean of all debris before concrete is placed.

The Contractor shall submit to the Engineer a schedule of batching, delivery, and placement prior to the beginning of the concreting operations. The Contractor shall comply with the requirements of Subsection 501.05.

Equipment and tools necessary for handling materials and performing all parts of the work shall meet the approval of the Engineer as to design, capacity, and mechanical condition and must be on the site before the work is started. Any equipment, in the judgment of the Engineer, that proves inadequate to obtain results prescribed shall be improved or new equipment substituted or added.

For simple spans, concrete should be deposited by beginning at the lower end of the span and working toward the upper end. Concrete in girders shall be deposited uniformly for the full length of the girder and brought up evenly in horizontal layers. For continuous spans, where required by design considerations, the concrete placing sequence shall be as shown on the Plans or in the Special Provisions.

Concrete shall not be deposited in the forms more than 2 m (6 feet) from its final position, except that for Class SCC the concrete shall not be deposited in the forms more than 6 m (20 feet) horizontally from its final position.

Dropping of unconfined self-consolidating concrete more than 1.5 m (5 feet) will not be permitted.

Concrete shall not be deposited in running water.

The rate of placing the concrete shall be so regulated that no excessive stresses are placed on the forms. Concrete in all slabs, decks, girders, or ribs of arches shall be placed in one continuous operation, unless otherwise specified.

Concrete shall be placed in continuous horizontal layers, the thickness of which shall not exceed 450 mm (18 inches), unless otherwise directed by the Engineer. Each succeeding layer shall be placed before the underlying layer has taken initial set and shall be consolidated in a manner that will eliminate any line of separation between the layers. When it is necessary, by reason of any emergency, to place less than a complete horizontal layer at one operation, such layer shall terminate in a vertical bulkhead.

After the concrete has taken its initial set, care shall be exercised to avoid jarring the forms or straining the ends of projecting reinforcing bars.

(d) Placement of Overlays. Unless otherwise shown on the Plans, existing expansion joints and dams shall be maintained through the overlay. A bulkhead equal in width to that of the joint shall be installed to the required grade and profile prior to placing the overlay material. Expansion dam treatment shall be as shown on the Plans.

Screed rails shall be placed and fastened in position to ensure finishing the new surface to the required profile. Supporting rails shall be anchored in such a manner as to provide horizontal and vertical stability. Screed rails shall not be placed so as to create a recess in the overlay surface and shall not be treated with form oil.

A construction dam or bulkhead shall be installed in case of major delay in placement. During minor delays of one hour or less, the end of the placement shall be protected from drying with several layers of wet burlap.

For a period of at least one hour before the placement of overlay material, the prepared surface shall be flooded with water. After removal of all free water, the overlay material shall be deposited on the damp surface and manipulated so as to coat the horizontal and vertical surfaces to be covered. The rate of progress shall be controlled so as to prevent the drying of previously deposited material.

(e) Use of Chutes. Chutes, troughs, and pipes used in placing concrete shall be arranged so as to avoid segregation of the materials and the displacement of the reinforcement and shall be approved by the Engineer. Aluminum chutes, troughs, or pipes will not be permitted.

All chutes, troughs, and pipes shall be kept clean and free of hardened concrete by thoroughly flushing with water after each run. Open troughs or chutes shall be either of metal or metal lined and shall extend as nearly as possible to the point of deposit. When the discharge must be intermittent, a hopper or other device for regulating the discharge shall be provided.

Dropping of unconfined concrete more than 1.5 m (5 feet) or depositing a large quantity at any point and running or working it along the forms will not be permitted.

(f) Use of Vibrators. Unless otherwise specified, the concrete shall be consolidated with mechanical vibrators, of an approved type and design, operating within the concrete. When required, vibrating may be supplemented by hand spading with suitable tools to ensure proper and adequate consolidation. Vibrators shall be manipulated to work the concrete thoroughly around the reinforcement and imbedded fixtures and into corners and angles of the forms to produce surfaces free of imperfections. Vibrators shall not be used as a means to cause concrete to flow or run into position instead of placing. The vibration at any point shall be of sufficient duration to accomplish consolidation but shall not be prolonged to the point where segregation occurs.

Vibrators shall have non-metallic or rubber coated heads. Vibrating machines shall at no time be left running unattended in the concrete.

When it is necessary by reason of an emergency to discontinue the placing of a monolithic section, the use of vibrators shall cease. Vibrators shall not again be used until a sufficient depth of fresh concrete is placed to prevent any possibility of the effect of vibration on the concrete already in place and in no case shall this depth be less than 600 mm (2 feet).

The number of vibrators used shall be ample to consolidate the incoming concrete immediately after it is deposited in the form. The Contractor shall have at least one spare vibrator in serviceable condition at the site of the structure in which more than 20 m^3 (25 cubic yards) of concrete are to be placed. The vibrators shall be capable of transmitting vibration to the concrete at frequencies of not less than 4500 impulses per minute under load. The vibration shall be of sufficient intensity and duration to cause plasticity, settlement, and complete consolidation of the concrete without causing segregation. The vibrator shall visibly affect a mass of concrete of 50 mm (2 inch) slump over a radius of at least 450 mm (18 inches).

Unless otherwise specified, Class SCC shall not be consolidated with mechanical vibrators. If the Engineer requests the use of a vibrator, it shall be of an approved type and design, operating within the concrete. To avoid segregation of the concrete, it shall be used as little as possible .

(g) Blasting Operation. All blasting operations within 60 m (200 feet) of any concrete work shall be completed prior to the placement of the concrete. Regardless of the above limitation on blasting operations, the Contractor shall be responsible for any damage resulting from blasting operations.

501.11 DEPOSITING CONCRETE UNDERWATER.

(a) General. Concrete shall not be deposited under water except as specified by the Contract Documents or upon approval of the Engineer and shall be subject to the following specifications:

(1) The Contractor shall submit for the Structural Concrete Engineer's approval a Portland cement concrete mix design per the following requirements:

A minimum of thirty-seven (37) calendar days prior to placement (or prior to pre-placement meeting, if one is required), the Contractor shall submit (for review and acceptance) the mix design for the class of concrete specified. The mix design(s) shall be submitted to the Agency's Materials and Research Laboratory, 1716 Barre-Montpelier Rd., Berlin, Vermont 05602, attention Structural Concrete Engineer. No class of concrete shall be placed on a project until the mix design is reviewed and accepted. The mix design must contain the following and state the names and sources of all materials:

Saturated Surface Dry or Dry Weights
Compressive Strength
Cement Content in kg/cubic meter (lbs/cubic yard)
Mineral Admixture Content (each) in kg/cubic meter (lbs/cubic yard)
Air Content
Water/Cementitious Material Ratio
Chemical Admixtures (types and dosages)
Laboratory Test Results (strength, air content, water/cementitious material ratio, slump)

(2) Mix Design Requirements. High Performance Concrete, Class SCC shall be the preferred mix design for depositing concrete underwater. If Class SCC is not used then the following requirements shall apply:

a. The mix shall contain a minimum of 356 kg/cubic meter (600 lbs/cubic yard) of cementitious material with: a minimum of 25% GGBFS substitution, or a minimum of 20% Fly Ash substitution, or other approved mineral admixture substitution at an approved rate.

b. Air content shall be 7.0% +/- 1.5%.

c. The maximum water/cementitious material ratio shall be 0.45. When a water-reducing, high range admixture has been included in the reviewed and accepted mix design, the concrete shall not demonstrate segregation at the proposed spread, as determined by the Engineer, but at no time shall the spread be less than 500 mm (20 inches).

d. If needed for a cofferdam and/or seal design, the concrete shall provide a minimum 28 day design strength of 20 MPa (3000 psi). Otherwise, minimum strength requirements for underwater concrete shall be as specified in the Contract Documents or approved by the Engineer.

(b) Placement. When placing concrete underwater, the Contractor shall use a tremie or an alternate method of conveyance, approved by the Engineer, which minimizes the mixing of fresh concrete and water. A tremie shall have a hopper at the top that empties into a watertight tube at least 250 mm (10 inches) in diameter. The discharge end of the tube on the tremie shall include a device to seal out water while the tube is first filled with concrete. An inflatable ball will not be permitted. The device shall keep its shape and float without danger of deflation,.

The placement shall be continuous to the elevations shown on the Plans and the resulting concrete shall be monolithic and homogeneous.

Concrete shall not be deposited in water having a temperature of 2 °C (35 °F) or below. When the water temperature is between 2 and 5 °C (35 and 40 °F), the mixing water, the aggregates, or both shall be heated as specified in Subsection 501.07(b).

A tremie shall be constructed of heavy-gauge steel pipe and consist of ~~a~~ watertight joints between the tremie sections with a diameter of not less than 250 mm (10 inches). The tremie hopper shall have a capacity of at least 0.4 m^3 (1/2 cubic yard). When a batch is dumped into the hopper, the flow of the concrete shall be induced by slightly raising the discharge tube, always keeping it in the concrete.

Tubes shall be kept continuously submerged in concrete during discharge. The depth that the tube is submerged in concrete and the height of the concrete in the tube shall be sufficient to prevent water from entering the tube. The Contractor shall continuously monitor the difference in elevation between the top of the concrete and the end of the discharge tube.

Horizontal movement of discharge tubes through the concrete will not be allowed.

For minor quantities, at the sole discretion of the Engineer, a direct pumping method may be approved. If a direct pumping method is to be implemented, the pipe discharging the concrete shall consist of heavy-gauge steel sections. The Contractor shall demonstrate the ability to pump the concrete without the pump line surging or otherwise moving in the water as concrete is being pumped.

501.12 PUMPING. Where concrete is conveyed and placed by mechanically applied pressure, the equipment shall be suitable in kind and adequate in capacity for the work. The pump shall be capable of pumping concrete within the specified slump limits. The use of aluminum pipe as a conveyance for the concrete will not be permitted.

The operation of the pump shall be such that a continuous stream of concrete without air pockets is produced. When pumping is completed, the concrete remaining in the pipeline, if it is to be used, shall be ejected in such a manner that there will be no contamination of the concrete or separation of the ingredients. The equipment shall be arranged so that no resulting vibrations may damage freshly placed concrete.

501.13 CONSTRUCTION JOINTS.

(a) Location of Construction Joints. Joints shall be formed at the location shown on the Plans. Any variation or new location of joints shall require written permission of the Engineer. Feather edges at construction joints will not be permitted. Joints shall be formed with inset form work so that each layer of concrete will have a thickness of not less than 150 mm (6 inches).

(b) Joining Fresh Concrete to Previously Set Concrete. In joining fresh concrete to concrete that has hardened, the surface shall be roughened in such a manner that will not leave loosened particles or damaged concrete at the surface and be thoroughly cleaned of all laitance, loose, and foreign material. Immediately prior to the placing of the new concrete, the surface shall be saturated with water. When shown on the Plans or ordered by the Engineer, the surface shall be thoroughly coated with a very thin coating of mortar, neat cement grout, or approved bonding agent and all forms drawn tight against the face of the concrete. The neat cement mortar or bonding agent shall not be allowed to dry out before being covered with fresh concrete.

(c) Filled Construction Joints. Filled construction joints shall contain a preformed cork joint filler or other preformed joint filler that may be shown in the Contract Documents. Joint filler shall be cut to fit exactly and shall completely fill the space that is shown on the Plans. Where a pour grade or caulking grade filler is indicated to be used in the joints, that portion of the joint to be filled shall be formed with a separate material (other than the preformed joint filler) that can easily be removed prior to placement of the above indicated filler.

(d) Water Stops. Approved water stops shall be placed at locations shown on the Plans. They shall form continuous watertight joints.

(e) Bond Breakers. Bond breakers shall be one of the following materials as shown on the Plans: asphalt-treated felt, pipe insulation, or tar emulsion.

501.14 EXPANSION JOINTS. All joints shall be constructed according to details shown on the Plans.

(a) Filled Compression and Expansion Joints. Filled compression and expansion joints shall be made with a preformed self-expanding cork joint filler or other preformed joint filler that may be shown in the Contract Documents. Joint filler shall be cut to fit exactly and shall completely fill the space that is shown on the Plans. Where a pour grade or caulking grade filler is indicated to be used in the joint, that portion of the joint to be filled shall be formed with a separate material (other than the expansion joint filler) that can easily be removed prior to placement of the above indicated filler.

(b) Special Types of Expansion Joints. Special types of expansion joints may be used when shown on the Plans or ordered by the Engineer.

501.15 THIS SUBSECTION RESERVED

501.16 CONCRETE FINISHING.

(a) Formed Concrete. Unless otherwise specified, the surface of formed concrete shall be finished immediately after form removal.

All concrete surfaces shall be given a dressed finish. If further finishing is required, exposed surfaces shall be given a rubbed finish. Other finish classes may be shown on the Plans for designated surfaces.

(1) Dressed Finish. The dressed finish work shall begin within 12 hours after removal of forms and shall continue until completed. All fins and irregular projections shall be removed from all surfaces except from those that are not to be exposed. On all surfaces, the cavities produced by form ties and all other holes, honeycomb spots, broken corners or edges, and other defects shall be thoroughly cleaned, saturated with water, and carefully pointed and trued with a mortar composed of the same type of cement and fine aggregate and mixed in the same proportions used in the class of the concrete being finished. Mortar used in pointing shall be not more than one hour old. The mortar patches shall be cured a minimum of 72 hours in accordance with Subsection 501.17. All construction and expansion joints in the completed work shall be left carefully tooled and free of all mortar and concrete.

The joint shall be left exposed to its full length with clean and true edges.

(2) Aesthetic Finish. In addition to a dressed finish the following work shall be performed:

a. Repairs/Patching. Areas that contain minor defects shall be repaired. Minor defects are defined as holes, honeycombing, or spalls, which are 150 mm (6 inches) or less in diameter, that do not penetrate deeper than 25 mm (1 inch) into the concrete. Surface voids or "bugholes" that are less than 6 mm (1/4 inch) in diameter and less than 3 mm (1/8 inch) deep need not be repaired. Repairs shall be made using an overhead and vertical concrete repair material satisfactory to the Engineer. The repair material shall be cured as specified by the manufacturer. Repairs shall be approved by the Engineer.

(b) Float Finish. This finish for horizontal surfaces shall be achieved by placing an excess of material in the form and removing or striking off the excess with a template, forcing the coarse aggregate below the mortar surface. Creation of concave surfaces shall be avoided. After the concrete has been struck off, the surface shall be made uniform by longitudinal or transverse floating.

Immediately after float finishing, the surface shall be given a broom finish, burlap drag finish, or left smooth as determined by the Engineer.

(c) Bridge Seats. Surfaces of bridge seats under bearing devices shall be level. The entire bridge seat surface shall be smoothed with a magnesium float.

(d) Finishing Bridge Decks.

(1) General. The Contractor shall follow the procedures and details for placing the deck in accordance with the pre-pour meeting. The procedure shall provide for adequate labor, equipment, and material supply to complete placement of concrete on the entire deck, or specified portion thereof. If, during the placement, unforeseen circumstances delay the progression of the pour to a point where the concrete begins to lose plasticity the Contractor shall be prepared to place a bulkhead, as directed by the Engineer.

Approval of the method and equipment will not relieve the Contractor of full responsibility for obtaining the required surface finish.

Prior to texturing, the finished concrete surface shall be examined by the Contractor and the Engineer using a straightedge. The straightedge shall be not less than 3 m (10 feet) long. While the concrete is still plastic, surface depressions shall be filled with concrete as the placement progresses. The added concrete shall be worked sufficiently into the underlying concrete to ensure that it creates a single monolithic layer. Surface irregularities greater than 3 mm (1/8 inch) in 3 m (10 feet) in either the longitudinal or the transverse direction shall be corrected in a manner acceptable to the Engineer. When a bituminous concrete surface is to be placed on a bridge deck, the deviation shall not be greater than 6 mm (1/4 inch). When a sheet membrane is being applied, sharp ridges shall not be allowed. Thin mortar or laitance, which may have accumulated ahead of the finishing machine screed, shall be removed from the work site. These materials shall not be used to fill depressions.

If the bridge deck concrete does not meet the above smoothness requirements, the Contractor shall remove high spots up to 13 mm (1/2 inch) high by means of grinding. Any other corrections shall be made only with the written approval of the Engineer. The use of bush hammers will not be allowed. No concrete shall be removed that will result in a concrete slab thickness less than that shown on the Plans.

Any deck that cannot be corrected by a method satisfactory to the Engineer shall be removed and replaced at the Contractor's expense.

Sidewalks shall receive their final finish with a fine bristled broom.

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(2) Bridge Decks With No Asphalt Wearing Surface. After finishing, the surface shall be given a suitable texture with an artificial turf drag made of molded polyethylene. The selection of turf drag should be capable of producing a surface texture with a horizontal peak to peak distance ranging from 0.5 mm to $\leq$ 6.35 mm (0.02 inch to $\leq$ 0.25 inch) and having a peak to peak amplitude of 0.1 mm to 20 mm (0.005 inch to 0.8 inch). Select a turf drag material that will minimize tearing and rolling of coarse aggregate from the surface.

The Contractor shall apply texture in a transverse direction by hand methods. Other directions may be allowed with the approval of the Engineer. All texturing shall be performed from a work bridge immediately following the finishing operations and prior to curing operations. A second work bridge will be required for curing purposes unless a method using a single work bridge has been approved by the Engineer.

One pass of the turf drag over the finished area is desired. The drag shall leave a seamless strip between passes. Texture resulting from the drag shall stop within 375 mm (15 inches) of the curb face, rail anchor bolts, or edge of deck. Any build up of concrete at the beginning or end of the pass shall be hand troweled to provide an even transition. An acceptable broom finish may be applied to small areas of deck surface where a turf drag cannot be operated.

The drag should produce a transverse, skid resistant micro-texture acceptable to the Engineer, but should not tear the surface. If the drag is not producing an acceptable micro-texture, the Contractor shall adjust the means and methods until an acceptable micro-texture is achieved.

The Contractor shall check the drag material before the deck pour and from time to time during finishing for tears, worn surface, or hardened concrete. The Contractor should clean or replace the drag as often as necessary to maintain a well-defined micro-texture.

The turf drag should not be applied when the surface is so wet or plastic that the ridges formed flow back into the valleys when the drag has passed, nor should dragging be delayed until the concrete is so hard that sharp ridges cannot be formed by the drag.

If the 10 minute maximum, as specified in Subsection 501.17(c), for applying the wet cure cannot be met, then fogging of the area shall be performed in a manner that keeps the relative humidity above the evaporation rate of the concrete surface, but not so excessive that water begins to collect on the surface prior to texturing or other surface manipulating procedures.

(3) Bridge floors shall be struck off and finished by an approved self-propelled finishing machine. This machine will be supported on suitable rails and equipped with adjustable strike-off or finishing screeds capable of producing the required finish surface for the full width of the bridge from face to face of curbs. Machines shall be kept in true adjustment. Machines shall not be used until proper adjustments have been made and the adjustments have been checked and approved by the Engineer.

Finishing machine rail supports shall be accurately set and of substantial construction so that the finished deck surface will conform to the profile and transverse sections shown in the Plans. Finishing machine rail supports shall be placed and adjusted to properly provide for the deflection of forms, falsework, and structural supporting members which will occur during the placement of the concrete. The finishing machine rail supports shall be spaced at a maximum of 600 mm (2 feet) on center and of sufficient design as to secure the rail to prevent it from falling off the support. Sufficient time shall be provided prior to beginning concreting operations for the finishing machine to be operated over the full length of the bridge deck segment to be placed. This test run shall be made with the screed adjusted to its finishing position. While operating the finishing machine in this test, the screed rails shall be checked for deflection and proper adjustment, the cover on slab reinforcement measured, and the controlling dimensions of slab reinforcement and forms checked.

After the concrete has been placed, it shall be struck off by a self-propelled finishing machine and the operation repeated as necessary to produce a uniformly consolidated, dense, smooth surface. The final passage of the finishing machine shall result in a uniform surface at the required grade and slope over its entire area.

In areas which are inaccessible to finishing machines, use of approved manual vibratory-equipped power screeds with approved grade control method may be used, with approval of the Engineer. Straightness shall be checked as specified in Subsection 501.16(d)(1) to ensure a smooth ride and seamless transition to the finishing machine's finished area. If manual vibratory-equipped power screeds are used, then initial vibration of the concrete for consolidation in those areas shall be of the minimal duration possible to avoid over vibration and loss of air entraining of the surface concrete in these areas.

Hand finishing shall be allowed only in areas inaccessible to finishing machines or manually driven vibratory-equipped power screeds. Hand screeds or bullfloats shall be magnesium and 250 mm (10 inches), or more, in width. Care shall be taken not to overwork the concrete surface during any finishing operation. Straightness shall be checked as specified in Subsection 501.16(d)(1) to ensure a smooth ride and seamless transition to the finishing machine's finished area.

The Contractor shall furnish a work bridge or bridges of an approved type, capable of spanning the entire width of the deck, supported on the finishing machine rails, and supporting at least a 2.2 kN (500 pound) load without deflection to the concrete slab surface.

(4) Screed rails shall be rigidly set to grade and supported sufficiently on adjustable chairs so as to allow no deflection in the rails under operating conditions. Screed guides or chairs shall be supported on structural members where possible. Sufficient screed rails shall be provided so that all rails necessary for any one continuous pour may be preset and graded before the start of concreting operations. The removal of screed rails and exposed chairs shall be accomplished without walking in the fresh concrete.

The Contractor shall furnish a minimum of one work bridge of an approved type, capable of spanning the entire width of the deck and supporting at least a 2.2 kN (500 pound) load without deflection to the concrete slab surface.

After the concrete is placed, it shall be struck off by one of the following methods:

a. A self-propelled concrete finishing machine used as specified in part (d)(2) above; or

b. An approved mechanical vibrating screed exerting a force of not less than 175 N/m (12 pounds per foot), the vibrations of which shall be of not less than 6500 vibrations per minute when checked by a vibration reed-type tester, uniform throughout its entire length and adjusted so as not to drive the aggregate more than 6 mm (1/4 inch) below the surface;

After the preliminary screeding, floats shall be operated with a combined longitudinal and transverse motion, planing off the high areas and floating the material removed into the low areas. Each pass shall lap the previous pass by 50 percent of the length of the float.

Hand finishing shall be allowed only in areas inaccessible to finishing machines or manually driven vibratory-equipped power screeds. Hand screeds or bullfloats shall be magnesium and 250 mm (10 inches), or more, in width. Care shall be taken not to overwork the concrete surface during any finishing operation. Straightness shall be checked as specified in Subsection 501.16(d)(1) to ensure a smooth ride and seamless transition to the finishing machine's finished area.

501.17 CURING CONCRETE.

(a) General. Water for use in curing concrete shall conform to the provisions of Subsection 745.01.

Effective cure time shall be only the time that the concrete has been maintained in a wet condition with the concrete surface temperature above 10 °C (50 °F). If the concrete is not maintained in a wet condition and/or the concrete surface temperature drops below 10 °C (50 °F), it shall not be counted as effective cure time. The cure period will be extended 4 hours for every 1 hour the concrete is below 10 °C (50 °F), beginning when the concrete temperature is raised to or exceeds the minimum curing temperature.

Regardless of the curing medium specified, the entire surface of the newly placed concrete shall be kept damp. This shall be achieved by applying water with a nozzle that atomizes the flow so that a mist and not a spray is formed. The moisture shall not be applied under pressure directly upon the concrete and shall not be allowed to accumulate in a quantity sufficient to cause a flow or washing of the surface.

The atomized flow shall be applied continuously until the surfaces can be covered by the specified curing mediums. For bridge barriers, curbs, and sidewalks the curing method shall be applied within 15 minutes of the completion of the finishing process.

TABLE 501.17A
CURING OF CONCRETE COMPONENTS

Type of Construction	Curing Methods	Effective Cure Time (Days)
Substructure	501.17(b)(1),(2),(3),(5),(7),(8)	7
Superstructure	501.17(b)(2),(8)	10
Retaining Walls	501.17(b)(1),(2),(5),(6),(8)	7
Headwalls	501.17(b)(1),(2),(5),(6),(8)	7
Sidewalks, Curbs, and Gutters	501.17(b)(2),(8)	7

(b) Methods of Curing. All exposed surfaces of newly placed concrete shall be cured by one of the following specified methods:

(1) Water Curing. Curing with water shall be by continuously sprinkling or flooding of all exposed surfaces for the entire required curing period.

(2) Burlap Curing. The entire exposed surface of the concrete shall be covered with two layers of approved burlap that has been pre-soaked with water. The burlap shall then be covered with a lapped layer of white polyethylene sheeting. Once the concrete superstructure has hardened sufficiently, a stream of water (per soaker hose or other device) shall be continuously applied under the polyethylene sheeting until the cure period is complete.

(3) Sand Cover. The entire exposed surface of the concrete shall be covered with at least 75 mm (3 inches) of approved sand that shall be kept wet for the entire curing period.

(4) White Polyethylene Sheeting. The entire exposed surface of the concrete shall be covered with a blanket of white polyethylene sheeting, maintained and fastened to provide a nearly airtight condition in contact with the surface where possible. If, in the opinion of the Engineer, this cover is not adequately provided or maintained to ensure the proper conditions for concrete cure, then white polyethlyene sheeting cure shall be terminated and another method substituted.

(5) White Burlap-Polyethylene Sheeting. The entire exposed surface of the concrete shall be covered with a blanket of white burlap-polyethylene sheeting. The burlap shall be thoroughly dampened prior to placing and shall be placed next to the concrete. All joints shall be lapped a minimum of 450 mm (18 inches). The burlap shall be kept damp throughout the curing period.

(6) Membrane Forming Curing Compound. White pigmented or fugitive dye membrane curing solution may be used for curing concrete in minor drainage structures. All other use of curing compound shall be approved in writing by the Engineer. When membrane curing is used, the exposed concrete shall be thoroughly sealed immediately after the free water has left the surface. The concrete inside the forms shall be sealed immediately after the forms are removed and necessary finishing has been done. The solution shall be applied in one or two separate applications. If the solution is applied in two increments, the second application shall follow the first application within 30 minutes. Satisfactory equipment shall be provided, together with means to properly control and ensure the direct application of the curing solution on the concrete surface so as to result in a uniform coverage of the surface area at the rate of 275 mL/m^2 (1 gallon for each 150 square feet).

If rain falls on the newly coated concrete before the film has dried sufficiently to resist damage, or if the film is damaged in any other manner, a new coat of the solution shall be applied to the affected portions equal in curing value to that specified above.

Should the surface be subject to continuous injury or the use of curing compound result in a streaked or blotchy appearance, the method shall be stopped and water curing applied.

Only curing compounds approved by the Agency's Materials and Research Section may be used.

(7) White Polyethylene Sheeting with Sand Cover. This method may be used only when approved by the Engineer and shall conform to the requirements of part (b)(4) above. The airtight condition shall be obtained by the addition of a uniform sand cover at a minimum depth of 50 mm (2 inches).

(8) Pre-dampened cotton mats. The entire exposed surface of the concrete shall be covered with a blanket of cotton mats that has been pre-dampened with water. The mats shall be maintained in a damp condition until the curing period is complete.

(c) Bridge Decks. For bridge decks the curing method shall promptly follow the screed machine, within a maximum lag time of 10 minutes and without interruption. If this lag time cannot be met, then fogging of the area shall be performed in a manner that keeps the relative humidity above the evaporation rate of the concrete surface, but not so excessive that water begins to collect on the surface prior to texturing or other surface manipulating procedures.

If, in the opinion of the Engineer, the Contractor's curing procedure is not producing an adequate cure, the Engineer may direct a change in the cure method at no additional cost to the Agency.

501.18 LOADING OF CONCRETE. After the concrete has been placed and the finishing operations concluded, it shall not be walked on or disturbed in any manner, including removal of forms, for a minimum period of 18 hours. If retarder is used as an admixture, this minimum period may be extended as directed by the Engineer.

(a) Substructure. No backfill material shall be placed against a newly completed structure unless the concrete cure is maintained in accordance with Table 501.17A, and until the field cured test cylinders have attained 85 percent of the compressive strength specified in Table 501.03A. However, the Contractor may erect forms for subsequent concrete placement on footings after 18 hours have elapsed from the time that the footing placement was completed, provided the concrete has sufficient strength to allow it to be worked on without damage, and proper cure is maintained.

Static loads, such as forms, reinforcing steel, or other materials necessary for construction, may be placed on any concrete after it has been in place 72 hours, or a compressive strength of 12.4 MPa (1800 pounds per square inch) has been obtained, provided proper curing is maintained. Superimposed loads from subsequent concrete pours will not be allowed on any substructure unit or section in place until the field cured test cylinders have attained 85 percent of the compressive strength specified by Table 501.03A, and provided curing of the supporting section is maintained in accordance with Table 501.17A.

(b) Superstructure. Static loads, such as forms, granite curbing, cast-in-place concrete curb, and other materials necessary for deck construction, may be placed on deck concrete as long as the field cured test cylinders for this concrete have attained 85 percent of the compressive strength specified in Table 501.03A or 7 days, whichever is longer, as long as the proper curing is maintained, and the materials are spread out uniformly to avoid point loading.

The Contractor shall keep bridge floors free of all motor vehicles, transit mixers, and heavy construction equipment until the curing period is satisfactorily completed, the field cured test cylinders for the bridge floor concrete have attained the compressive strength specified in Table 501.03A, and the field cured test cylinders for the curb concrete have attained 85 percent of the compressive strength specified in Table 501.03A.

(c) Vertical Joint. Concrete shall not be placed against a vertical construction joint until the previously placed concrete has been in place a minimum of 72 hours.

The Contractor must not allow loads that are in excess of the legal loads permitted by the laws of the State to travel over the completed structure, except with written permission of the Engineer.

501.19 METHOD OF MEASUREMENT. The quantity of Concrete of the High Performance Class specified, to be measured for payment will be the number of cubic meters (cubic yards) of the class of concrete specified in the complete and accepted work, as determined by the prismoidal method using dimensions shown on the Plans or as directed by the Engineer, including the volume of superstructure precast concrete stay-in-place forms, but excluding the volume of steel or other stay-in-place forms and form filling materials. No deductions will be made for the volume of concrete displaced by steel reinforcement, structural steel, expansion joint material, scuppers, weep holes, conduits, tops of piles, scoring, chamfers or corners, inset panels of 38 mm (1 1/2 inches) or less in depth, or any pipe less than 200 mm (8 inches) in diameter.

501.20 BASIS OF PAYMENT. The accepted quantities of the Contract items specified will be paid for at the Contract unit prices. Payment will be full compensation for performing the work specified, including designing the mix, satisfactory finishing and curing, and for furnishing all forms, materials, including joint filler and bond breaker, labor, tools, admixtures, equipment, including automatic temperature recording units, trial batches, and incidentals necessary to complete the work.

The cost of heating materials and protecting the concrete against cold weather, and any additional cost for cement, will not be paid for separately but will be considered incidental to the Contract unit prices for Section 501.

The cost of furnishing testing facilities and supplies at the batch plant and the setting of inserts, bench marks, and bridge plaques furnished by the Agency will not be paid for separately but will be considered incidental to the Contract unit price(s) for High Performance concrete.

Costs for all materials, labor and incidentals for steel or other stay-in-place forms and form filling materials will not be paid for separately, but will be considered incidental to the Contract unit price(s) for High Performance concrete.

Payment will be made under:

Pay Item	Pay Unit
501.32 Concrete, High Performance Class AA	Cubic Meter (Cubic Yard)
501.33 Concrete, High Performance Class A	Cubic Meter (Cubic Yard)
501.34 Concrete, High Performance Class B	Cubic Meter (Cubic Yard)
501.35 Concrete, High Performance Class SCC	Cubic Meter (Cubic Yard)
501.36 Concrete, High Performance Class LW	Cubic Meter (Cubic Yard)

SECTION 502 - SHORING SUPERSTRUCTURES

502.01 DESCRIPTION. This work shall consist of furnishing the necessary shoring, or vertically jacking of any structure or bearing to a position immediately above its present location, holding it in position during any construction process, lowering it to its supports, removing all shoring or falsework, and cleaning up of the site.

502.02 CONSTRUCTION DRAWINGS. Construction Drawings shall be submitted in accordance with Section 105. The Contractor shall submit the drawings and associated calculations, procedures**,** and details to the Structures Engineer at least four weeks prior to the anticipated start of work.

502.03 CONSTRUCTION REQUIREMENTS. Associated details**,** procedures**,** and calculations for shoring and jacking shall be prepared by a Professional Engineer (Structural or Civil) using Section 506 and the latest version of the AASHTO *LRFD Bridge Design Specifications*.

The Contractor shall be responsible for the strength, capacity, and performance of the construction method(s) employed.

When components and/or materials that are not otherwise specified for removal are removed from the structure during shoring operations and the components and/or materials are to be re-installed in the construction, the components and/or materials shall be carefully removed and salvaged by the Contractor.

Components and/or materials to be retained and re-installed shall be stored at the location specified in the Contract or as directed by the Engineer.

The Contractor shall take every precaution necessary to prevent damage to remaining components and/or materials and those to be retained for re-installation. Damage to remaining structure components and/or materials and to those to be re-installed shall be repaired or replaced by the Contractor both to the satisfaction of the Engineer and at no additional cost to the Agency.

502.04 METHOD OF MEASUREMENT. The quantity of Shoring Superstructure to be measured for payment will be on a lump sum basis for each location in the complete and accepted work specified in the Contract or ordered by the Engineer.

Unless otherwise specified in the Contract, all work for removing, salvaging, stockpiling, and re-installing existing structure components and/or materials during the Contractor's shoring operations will not be measured for payment, but will be considered incidental to Shoring Superstructure.

The quantity of Shoring Superstructure Bearings to be measured for payment will be on a unit basis for each bearing shored in the complete and accepted work in accordance with the Contract or ordered by the Engineer.

502.05 BASIS OF PAYMENT. The accepted quantity of Shoring Superstructure will be paid for each location specified at the Contract lump sum price. Payment will be full compensation for preparing and submitting construction drawings, details, procedures, and calculations as specified, performing the work specified including assuming all liability for the structure being shored and for furnishing all labor, tools, equipment, materials, and incidentals necessary to complete the work.

The accepted quantity of Shoring Superstructure Bearings will be paid for at the Contract unit price for each. Payment will be full compensation for preparing and submitting construction drawings, details, procedures, and calculations as specified, performing the work specified including assuming all liability for the structure being shored and for furnishing all labor, tools, equipment, materials, and incidentals necessary to complete the work.

When the structure or bearing has been jacked and blocked onto its temporary position, a payment of 75 percent of the Contract unit price will be allowed. The remaining 25 percent will be paid when all shoring or falsework has been removed and the site cleaned up.

Payment will be made under:

Pay Item	Pay Unit
502.10 Shoring Superstructure	Lump Sum
502.11 Shoring Superstructure Bearings	Each

SECTION 503

THIS SECTION RESERVED

SECTION 504 - FURNISHING EQUIPMENT FOR DRIVING PILING

504.01 DESCRIPTION. This work shall consist of furnishing the equipment required to drive piles.

504.02 EQUIPMENT.

(a) General. Prior to beginning test pile or production pile driving, the Contractor shall obtain approval for the pile driving equipment. During the pile driving operations, no changes to the approved equipment will be permitted without the Engineer's permission. The Contractor shall obtain from the Engineer a copy of the PILE AND DRIVING EQUIPMENT DATA FORM. The Contractor shall complete this form in every detail and shall submit copies to the Geotechnical Consultant employed by the Contractor, (when load tests are required) and the Engineer so that a wave equation analysis may be performed. At least 14 calendar days prior to the beginning of any pile driving, the Contractor shall furnish for the Engineer's approval specifications and applicable information to verify the capacity and capability of the proposed hammer.

(b) Hammers. The type of hammer or driver shall be adequate in size to develop sufficient energy to drive the type and length of pile specified to the maximum ultimate pile capacity or nominal axial pile resistance shown on the Plans.

Each hammer shall be equipped with an anvil or clamp suitable for transmitting the driving force to the pile. The valve mechanism and the other parts of the air or diesel hammer shall be maintained in first class condition to ensure that the length of stroke for a single-acting hammer and the design number of blows per minute for a double-acting hammer will be obtained.

The drive head shall be axially aligned with the hammer and pile and shall be guided by leads and not be free-swinging. It shall fit around the pile head in such a manner as to prevent transfer of torsional forces during driving while maintaining proper alignment of the hammer and pile.

The pile driving equipment shall not induce a compressive stress greater than 90 percent of the yield stress of the pile material. In addition, the pile driving equipment shall be capable of driving the pile to the required ultimate capacity at a blow count of between 3 and 15 blows per 25 mm (1 inch) as indicated by the wave equation analysis program (WEAP).

(c) Leads and Bracing. The Contractor shall locate and brace each pile so that upon driving, its final position and alignment will be as specified and as shown on the Plans. The selection of leads or form of bracing must be adequate to align and restrain the piling during placement. If the leads or bracing are not adequate to place the piling to within the specified tolerance, the Contractor shall modify the leads or system of bracing until it obtains results acceptable to the Engineer.

(d) Hammer Cushion. All impact pile driving equipment except gravity hammers shall be equipped with a suitable thickness of hammer cushion material to prevent damage to the hammer or pile and to ensure uniform driving behavior. Hammer cushions shall be made of durable manufactured materials, such as Micarta, provided in accordance with the hammer manufacturer's guidelines. Wood, wire rope, or asbestos hammer cushions will not be permitted. A striker plate, as recommended by the hammer manufacturer, shall be placed on the hammer cushion to ensure uniform compression of the cushion material.

The hammer cushion shall be inspected in the presence of the Engineer prior to beginning pile driving at each substructure unit or after each 100 hours of pile driving, whichever is less.

Hammer cushions shall be replaced when either damaged or worn to 75 percent of their original thickness.

(e) Saximeter. The Contractor shall provide a Saximeter or equivalent device to assist the Inspector in collecting data to monitor blow count (for all hammer types), stroke (for open end diesel hammers only), or kinetic energy (if hammer is equipped with proximity switches for measuring impact velocity). The Saximeter shall be completely charged and in sound working order prior to Agency use and shall be available for the duration of the pile driving operation. Pile driving operations shall not be conducted without the use of a Saximeter.

The Saximeter shall perform the following functions:

(1) Detect hammer blow automatically, using sound recognition circuit, or manually, via keypad.

(2) Automatically count blows and determine blows per minute (BPM) for all impact hammers.

(3) Calculate the stroke for open end diesel hammers, either in metric or English units.

(4) Store the following in memory: blow count, penetration and average stroke or BPM.

(5) Permit viewing of results on built in screen.

(6) Permit data transfer to PC or printer.

For hammers equipped with proximity switches the Saximeter shall acquire Hammer Impact Velocity data by communicating with a transmitter mounted on the hammer, and use this information to calculate the Hammer Kinetic Energy.

The Saximeter shall operate on rechargeable batteries. Batteries and recharger shall be supplied by the Contractor.

(f) Other Equipment. Other equipment required and not specified in this Section shall be suitable for the use intended and shall be approved by the Engineer.

504.03 GENERAL. The type and size of the equipment for driving piling shall be approved by the Engineer prior to being moved onto the project. Unsatisfactory equipment shall be removed from the site and replaced with satisfactory equipment when directed by the Engineer.

504.04 METHOD OF MEASUREMENT. The quantity of Furnishing Equipment for Driving Piling to be measured for payment will be on a lump sum basis for furnishing the equipment to drive all piles required on the project.

504.05 BASIS OF PAYMENT. The accepted quantity of Furnishing Equipment for Driving Piling will be paid for at the Contract lump sum price. Payment will be full compensation for furnishing and mobilizing the required equipment to the project and demobilizing equipment from the project, including the erecting, dismantling, and all incidentals necessary to complete the work.

When the equipment for driving piles has been set up and driving operations have started, a payment of 50 percent of the Contract unit price will be allowed. The remaining 50 percent will be paid when pile-driving operations are complete and the equipment has been removed from the site.

The cost of all labor and materials, including operation and maintenance of the equipment for driving piles when used in connection with the driving of piles, with the exception of the costs specified in this Subsection, will be considered as being included in the Contract unit price(s) for the type(s) of piles being driven.

Payment will be made under:

Pay Item	Pay Unit
504.10 Furnishing Equipment for Driving Piling	Lump Sum

SECTION 505 – PILING

505.01 DESCRIPTION. This work shall consist of furnishing and driving piles of the size and type specified, making field splices and performing pile load tests.

505.02 MATERIALS. Materials shall meet the requirements of the following Subsections:

Bar Reinforcement	713.01
Steel Piling	730.01
Steel Sheet Piling	730.02

Receipt of approved mill test reports and verification that they correspond to the heat or lot numbers marked on the piles is required before the piles are driven.

505.03 FURNISHING OF PILING.

(a) General. Piling shall be of the type and size shown on the Plans. The lengths shown for a structure are for estimating purposes only, unless otherwise specified.

(b) Steel Piling. Steel piling up to and including 6 m (20 feet) in length shall be furnished in one unwelded piece.

Steel piling over 6 m (20 feet) in length shall be furnished with not more than the number of splices allowed by Table 505.05A.

(c) Permanent Steel Sheet Piling. The length, type, and classification of permanent steel sheet piling shall be as shown on the Plans.

(d) Temporary Sheet Piling. When temporary sheet piling is shown on the Plans, the project quantities shall include an estimated quantity of temporary sheet piling. The temporary piling is estimated for specific locations. With the approval of the Engineer it may be used, and paid for, at other appropriate locations.

The Contractor shall submit Construction Drawings in accordance with Section 105. The drawings shall be submitted to the Construction Engineer for documentation purposes only at least four weeks prior to the anticipated start of work. The length, type, classification, and necessary quantity of Temporary Sheet Piling at each location shall be calculated and detailed by a Professional Engineer (Structural or Civil). The design and details shall be signed, stamped, and dated by the Contractor's Professional Engineer.

505.04 DRIVING OF PILING.

(a) General. Piling other than sheet piling shall not be driven until the excavation has been made to the elevation shown for the bottom of the entire footing. In embankment areas, the fill shall be completed to the bottom of the footing elevation prior to driving any piles. Any material forced up between the piles shall be removed at the Contractor's expense to the correct elevation before concrete for the foundation is placed.

Driving shall be done in a manner that will not damage or overstress the piles.

All piling shall be driven to the required maximum ultimate axial pile capacity or nominal axial pile resistance and to the penetration depth as shown on the Plans. Under no condition shall the required maximum ultimate axial pile capacity or nominal axial pile resistance be less than that shown on the Plans except upon written approval of the Engineer. When the Contractor proposes to use a vibratory or sonic method for driving of piling, the Engineer reserves the right to require the Contractor to demonstrate that such methods are capable of driving the piles to the penetration and resistance shown on the Plans. Acceptance of this method shall be based on load tests on one or more piles driven by sonic or vibratory methods or verification of required maximum ultimate axial pile capacity or nominal axial pile resistance of one or more piles with an air, or diesel hammer. Verification of required maximum ultimate axial pile capacity or nominal axial pile resistance of sonic or vibratory driven piles shall be at the Contractor's expense.

Piling shall not be driven within 35 m (115 feet) of any concrete footings or structures that have not cured for at least seven days or attained 85 percent of their designed compressive strength.

Piling that penetrates a very soft stratum overlying a hard stratum shall penetrate the hard material sufficiently to rigidly fix the ends. Piles pushed up by driving adjacent piles or by any other cause shall be redriven to the required maximum ultimate axial pile capacity or nominal axial pile resistance and to the required penetration depth as shown on the Plans.

Any pile damaged during installation, driven out of its proper location, or driven below the elevation shown on the Plans or by the Engineer, shall be corrected at the Contractor's expense by one of the following methods approved by the Engineer:

(1) Withdrawing and replacing with a new and, if necessary, longer pile.

(2) Driving a second pile adjacent to the defective pile.

(3) Splicing the pile or extending the footing to properly enclose the pile.

The driving operation shall be continuous in the sequence determined by the Engineer and shall, in general, either start at the center of the foundation and proceed each way or start at the outside row and work progressively across the footing. Piling shall be driven in conformity with the requirements shown on the Plans or as ordered by the Engineer and shall be either vertical or battered as shown.

(b) Tolerances. Piling after driving shall not vary more than 20 mm/m (1/4 inch per foot) from vertical or the specified batter. The Engineer may require that driving be stopped in order to check the pile for plumb. Pulling or pushing laterally on piles to correct out-of-plumb errors, or splicing a section that meets the tolerances for plumb in this section on an out-of-plumb section will not be permitted. Piles for trestle bents shall be so driven that the cap may be placed in its proper location without inducing excessive stresses in the piling.

The tops of foundation piling after driving shall not vary from the position shown on the Plans by more than 150 mm (6 inches) and shall have a minimum of 150 mm (6 inches) of concrete encasement.

The rotation about the vertical axis of the pile shall not vary by more than 5 degrees from that shown on the Plans.

The Contractor shall demonstrate how the tolerances will be met to the satisfaction of the Engineer prior to driving. If the verticality, location, and/or rotation tolerances specified herein are exceeded, the extent of corrective measures will be evaluated by the Engineer. If in the judgment of the Engineer corrective measures are necessary, suitable measures shall be designed and constructed by the Contractor. The Contractor shall bear all costs, including delays, associated with the corrective action.

(c) Pile Load Tests. Pile load tests, when required, shall be performed prior to driving any production piles. When not driven as a permanent production pile, the test pile shall be driven in the vicinity of the substructure footing, at a location acceptable to the Engineer.

When pile load tests are required, the Contractor shall provide the services of a Geotechnical Consulting firm for the purpose of dynamic and/or static testing of the test pile(s). A list of approved Geotechnical Consultants may be obtained from the Agency's Materials and Research Section, telephone: (802) 828-2561.

A static load test pile shall not be used as a permanent production pile. A dynamic load test pile may be used and paid for as a permanent production pile if it meets all of the following requirements:

(1) After testing is completed, the test pile meets all of the requirements for a permanent production pile (that is, it is driven to the required maximum ultimate axial pile capacity or nominal axial pile resistance and to the required penetration depth as shown on the Plans);

(2) The test pile is driven at the correct location and with the correct batter and has not failed under test loading, i.e., is not damaged, does not exceed maximum number of splices, etc.); and

(3) Use of the test pile as a permanent production pile is approved by the Engineer.

(d) Determination of the Maximum Ultimate Axial Pile Capacity or Nominal Axial Pile Resistance. These values shall be determined by dynamic loading tests, static loading tests, wave equation analysis, or a combination thereof as follows:

(1) Static Load Test. Static pile load tests shall be performed by the procedures set forth in ASTM D 1143, using the quick load test method, except that the test shall be taken to plunging failure or the capacity of the loading system. Testing equipment and measuring systems shall conform to ASTM D 1143 with the following exceptions:

a. The loading system shall be capable of applying 200 percent of the ultimate pile capacity.

b. The jack, load cell, and reaction system shall be capable of withstanding 200 percent of the ultimate pile capacity shown on the Plans. The load cell shall have been calibrated within the previous six months.

The load shall be applied to the pile through a hydraulic jack acting against a weighed platform or reaction pile system. The Contractor shall submit to the Engineer, for approval, detailed plans of the proposed loading apparatus prepared by a Professional Engineer. The apparatus shall be constructed to allow the various increments of the load to be placed gradually without causing vibration to the test pile.

The failure load for the pile shall be defined as follows:

For piles 610 mm (24 inches) or less in diameter or width, the failure load of a pile test under axial compressive load is that load which produces a settlement at failure of the pile head equal to:

$$SF = S + (3.81 + 0.008D) \quad \text{[Metric]}$$
$$SF = S + (0.15 + 0.008D) \quad \text{[English]}$$

where:

SF = Settlement at failure in millimeters (inches)
D = Pile diameter or width in millimeters (inches)
S = Elastic deformation of total pile length in millimeters (inches)

The top elevation of the test pile shall be determined immediately after driving and again just before load testing to check for heave. Any pile that heaves more than 0.25 inch (6 mm) shall be redriven or jacked to the original elevation prior to testing. Unless otherwise specified in the Contract, a minimum three-day waiting period shall be observed between the driving of any anchor piles or the load test pile and commencement of the load test.

(2) Dynamic Load Test. Dynamic monitoring of the test piles shall be conducted by the Contractor's Geotechnical Consultant and results will be used by the Engineer to verify that the required maximum ultimate axial pile capacity or nominal axial pile resistance has been met.

In addition to equipment and services to dynamically monitor the pile driving, the Contractor's Geotechnical Consultant shall perform wave equation analyses (WEAP) as necessary to determine the suitability of the pile driving equipment proposed by the Contractor and to determine the preliminary driving criteria for testing. The Geotechnical Consultant shall submit copies of the wave equation analysis a minimum of 14 calendar days prior to the beginning of any pile driving. Also, the Geotechnical Consultant shall perform a laboratory case pile wave analysis (CAPWAP) for each test pile to verify the field results.

The Geotechnical Consultant shall provide a preliminary and final written report including all data collected and the results of both the WEAP and CAPWAP for each test pile in accordance with ASTM D 4945. The preliminary report shall be presented to the Engineer prior to the completion of static load tests, when required, and the final report shall be submitted following completion of all load tests.

The effective capacity of battered piles shall be reduced by the following factors:

Batter	Factor
1 to 12	0.99
2 to 12	0.97
3 to 12	0.95
4 to 12	0.92

As a guide, a pile may be considered driven to refusal when the driving resistance is 15 blows per 25 mm (1 inch) or 10 blows per 13 mm (½ inch), but only when the hammer stroke is equal to or above the required stroke as specified in the wave equation analysis. This refusal value may be adjusted by the Engineer according to the results of the dynamic pile monitoring.

The Contractor's driving operations shall be monitored with a pile driving analyzer supplied and operated by the Contractor's Geotechnical Consultant during the installation and restriking of the test piles. Both dynamic and static pile load tests shall be performed on the test pile prior to driving production piles at any substructure. Production pile driving procedures may be adjusted based on the results from the pile driving analyzer. Dynamic monitoring shall be performed in accordance with ASTM D 4945 with equipment capable of determining the maximum force, velocity, and transmitted energy as well as the ultimate static bearing capacity computed by the case method for each pile tested. Gauges shall be attached to the pile approximately 1 m (3 feet) below the pile head and connected with a cable to recording instruments on the ground, away from the pile. The gauge system shall include two accelerometers, two strain transducers, and a junction box. Dynamic monitoring shall be

performed with the assistance of the Contractor, as specified in this Subsection.

The Contractor may be required by the Engineer to modify the test pile driving operation based on the results from the pile driving analyzer.

The Geotechnical Consultant shall furnish the pile driving analyzer and supplemental equipment specified in these Specifications. All test piles shall be monitored using the pile driving analyzer. The Contractor shall make the test piles available for drilling and tapping holes prior to driving. The Geotechnical Consultant shall furnish equipment, materials, and labor necessary for drilling and tapping holes in the test piles for attaching the monitoring instruments. The Contractor shall provide the following support equipment:

a. Access. The Contractor shall provide the Geotechnical Consultant's personnel safe and reasonable means of access to the pile head for attaching transducers. A platform having a minimum size of 1.2 x 1.2 m (4 × 4 feet) shall be equipped so that it may be raised to the top of the pile while the pile is located in the leads.

b. Power Source. The Contractor shall furnish an electric power source for the pile driving analyzer. If a field generator is used as the power source, it shall be equipped with functioning meters for monitoring voltage and frequency levels. Single-phase, 10 A, 115 V AC with line frequency of 60 Hz shall be provided.

   Dynamic measurements shall be taken by the Geotechnical Consultant during full length driving of all test piles and during all restriking of the test piles. The stresses in the piles shall be monitored to ensure that the driving stresses do not exceed 90 percent of the yield stress of the pile. The Contractor shall reduce the energy transmitted to the pile by using cushions or reducing the energy of the hammer in order to maintain the above criteria.

The Contractor shall assist in preparing the piles to be monitored with the necessary gauge attachments on opposite sides of the pile. The gauges shall be attached by drilling and threading the appropriate size holes. The estimated time for performing the above tasks is approximately 30 minutes per section of pile driven. The Geotechnical Consultant shall do the drilling and tapping of holes in each section to be driven. The Contractor shall assist in moving and giving access to the piles. All drilling and tapping of holes shall be done on the ground.

After the gauge attachments are prepared and all gauges and cables are removed from the pile segment, the Contractor shall lift and spot the pile according to normal procedures. The pile shall be made available for the installation of gauges after placing the pile in the leads. The Contractor shall then send one person up to the pile head to assist the Geotechnical Consultant in attachment of the gauges. Time required to ascend, complete the attachments, and descend is estimated to be approximately one hour.

Pile driving during monitoring is typical of conventional driving. The cable from the gauges hangs freely down along the pile and to the monitoring equipment. The Geotechnical Consultant may temporarily stop the pile driving during the monitoring to review the data or change gauges or other equipment. The Contractor shall assist and cooperate with the Geotechnical Consultant as required during dynamic monitoring. Delays to pile driving due to dynamic monitoring after pile driving has begun should not exceed more than one hour per pile.

When the level of the gauges approaches the ground, the driving shall be halted to remove the gauges from the pile. The time required for removal of gauges is estimated to be about 30 minutes. If additional driving is required, the Contractor shall complete the pile splice and shall repeat the process of attaching gauges at the top of the next segment. The gauges shall be attached prior to continuation of driving.

Restriking of all test piles is required. The minimum time between the end of initial driving and restriking shall be 48 hours. Prior to restriking the test piles, the dynamic testing gauges shall be reattached to the pile and the pile hammer shall be warmed up by striking at least 20 blows on another pile. Restrike shall consist of either 50 mm (2 inches) of penetration or 30 hammer blows, whichever occurs first.

(3) Wave Equation Analysis. When load tests are not specified, the Engineer will verify the required maximum ultimate axial pile capacity or nominal axial pile resistance based on the Agency's wave equation analysis.

(e) Steel Sheet Piling. Permanent sheet piling shall be left in place as part of the finished structure. Temporary sheet piling shall not become a part of the finished structure but shall be removed after it has served its purpose in the construction.

(f) Steel Piling. Unless otherwise specified, the driving point of all piling, including test piling, shall be reinforced. Point reinforcement may be either a commercially fabricated weldment or a casting designed to protect the end of the pile during driving or for seating the pile on ledge. Point reinforcement details shall conform to the Contract requirements and shall be approved by the Engineer. Requirements for commercially fabricated weldments are:

(1) Fabrication Drawings and welding procedures shall be submitted to the Structures Engineer for approval in accordance with the requirements in Subsection 105.03.

(2) Weldments shall be fabricated so that the direction of rolling of weldment plates is in the same direction as the axis of the pile.

Pile flanges shall be welded to the outside faces of a pile point with a continuous bevel groove weld. The depth of the groove weld shall be at least 50 percent of the pile flange thickness but in no case less than 8 mm (5/16 inch).

The minimum thickness of the cutting edge of the point shall be 25 mm (1 inch) or 150 percent of the flange thickness of the pile, whichever is greater.

When the Contract requires the piles to be driven to point bearing on ledge, the ledge bearing surface of the point shall have at least five cutting wedges, a minimum of one centered along the strong axis of the web and one on each corner of the flanges.

505.05 SPLICES.

(a) Splices for Steel Piling. Splices shall be made in accordance with details shown on the Plans at the locations approved by the Engineer.

Splices will be allowed as shown in the following table:

TABLE 505.05A
ALLOWABLE SPLICES

Length of Steel Piling		Maximum Number of Splices Allowed
meters	Feet	
Over 6 to and including 18	Over 20 to and including 60	1
Over 18 to and including 37	Over 60 to and including 120	3
Over 37 to and including 55	Over 120 to and including 180	5

All piles to be spliced shall be cut square and even, and the flanges shall be beveled in accordance with an approved welding procedure. Webs shall be cut so that full bearing is obtained between the two surfaces. The splice shall be made in such a manner that the spliced pile shall be straight and true.

Welds shall be continuous and develop the full strength of the parts being welded

When a substructure unit contains only a single row of piles, only one pile splice shall be allowed in the top 6 m (20 ft) of that substructure unit.

(b) Splices for Steel Sheet Piling. Splicing will not be permitted unless authorized in writing by the Engineer.

505.06 WELDING. Welding shall conform to the requirements of Subsection 506.10.

505.07 CUTTING OF PILING. Piling shall be cut to the elevation shown on the Plans or as ordered by the Engineer. Cut-offs shall remain the property of the Contractor.

505.08 METHOD OF MEASUREMENT. The quantities to be measured for payment will be measured as follows:

(a) Piling.

(1) Steel Piling will be the total number of meters (linear feet) for each pile driven, accepted, and left in place, measured to the nearest meter (linear foot).

If a test pile is driven within foundation limits and subsequently accepted as permanent foundation piling, measurement for payment as Steel Piling will be made for the test pile.

If a test pile is driven outside of foundation limits, no measurement for payment as Steel Piling will be made for the test pile.

(2) Steel sheet piling will be the total number of square meters (square feet) of Permanent Steel Sheet Piling driven, accepted, and left in place after cut-off; or the total number of square meters (square feet) of Temporary Steel Sheet Piling driven, as shown on the Plans or directed by the Engineer, and retracted after use.

(b) Pile Loading Tests. Pile Loading Tests will be measured in units of one for each load tested pile. Any necessary retests shall be at the Contractor's expense.

505.09 BASIS OF PAYMENT. The accepted quantities of piling will be paid for at the Contract unit prices as follows:

(a) Steel Piling of the size specified will be paid for at the Contract unit price per meter (linear foot).

(b) Steel Sheet Piling of the type specified will be paid for at the Contract unit price per square meter (square foot).

Payment for the above specified items will be full compensation for furnishing, transporting, storing, handling, and placing the material specified, including metal collars, metal shoes, reinforcing material for ends of steel piling, reinforcing steel, splices, wales, and braces for steel sheet piling, and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

The accepted quantity of Dynamic Pile Loading Test will be paid for at the Contract unit price for each. Payment will be full compensation for providing, cooperating with, and assisting the Geotechnical Consultant in the performance of dynamic testing; for providing dynamic testing equipment; for restriking the test pile; for cutting off the test pile at the elevation directed by the Engineer; for preparing and submitting geotechnical reports; and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

Payment for furnishing and driving test piling driven outside of foundation limits will be included in the unit price bid for Dynamic Pile Loading Test.

The accepted quantity of Static Pile Load Test will be paid for at the Contract unit price for each. Payment will be full compensation for furnishing, transporting, handling, and driving the test pile and test equipment, including hydraulic jacks and loading apparatus; for providing, cooperating with, and assisting the Geotechnical Consultant during testing; for providing the settlement measuring devices, load cells, etc., required to perform the static pile load test as detailed in Subsection 505.04(b); for cutting off the test pile at the elevation directed by the Engineer; for preparing and submitting geotechnical reports; and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

Payment will be made under:

Pay Item	Pay Unit
505.10 Steel Piling, HP 250 x 62 (HP 10 × 42)	Meter (Linear Foot)
505.15 Steel Piling, HP 310 x 79 (HP 12 × 53)	Meter (Linear Foot)
505.155 Steel Piling, HP 310 x 93 (HP 12 × 63)	Meter (Linear Foot)
505.16 Steel Piling, HP 310 x 110 (HP 12 x 74)	Meter (Linear Foot)
505.165 Steel Piling, HP 310 x 125 (HP 12 x 84)	Meter (Linear Foot)
505.17 Steel Piling, HP 360 x 108 (HP 14 x 73)	Meter (Linear Foot)
505.18 Steel Piling, HP 360 x 132 (HP 14 x 89)	Meter (Linear Foot)
505.19 Steel Piling, HP 360 x 152 (HP 14 x 102)	Meter (Linear Foot)
505.20 Steel Piling, HP 360 x 174 (HP 14 x 117)	Meter (Linear Foot)
505.35 Permanent Steel Sheet Piling	Square Meter (Square Foot)
505.36 Temporary Steel Sheet Piling	Square Meter (Square Foot)
505.40 Static Pile Loading Test	Each
505.45 Dynamic Pile Loading Test	Each

SECTION 506 - STRUCTURAL STEEL

506.01 DESCRIPTION. This work shall consist of furnishing, erecting, and when specified, coating fabricated metal structures and structural components.

506.02 MATERIALS. Materials shall meet the requirements of the following Subsections:

Mortar, Type IV	707.03
Paint	708.01
General Requirements for Structural Steel	714.01
Structural Steel	714.02
High-Strength Low-Alloy Structural Steel	714.03
Carbon Steel Bolts and Nuts	714.04
High-Strength Bolts, Nuts, and Washers	714.05
Heat-Treated Structural Bolts	714.06
Anchor Bolts, Bearing Devices	714.08
Welded Stud Shear Connectors	714.10
Steel Tubing	714.11
Direct Tension Indicators	714.12
Tension Control Assemblies	714.13
Iron Castings	715.01
Bronze Castings	715.02
Galvanizing	726.08
Metalizing	726.09

Unless otherwise specified in the Contract, all steel shall be high-strength low-alloy structural steel conforming to AASHTO M 270M/M 270, Grade 345W (Grade 50W).

All materials shall conform to the prescribed AASHTO or ASTM specifications, and no substitutions will be allowed.

506.03 GENERAL FABRICATION REQUIREMENTS. Material furnished under this Section that is permanently incorporated into a Federal-Aid project shall be entirely manufactured and coated in the United States.

Except as modified below, fabrication shall be performed in accordance with the latest editions of the applicable AASHTO design code, ANSI/AASHTO/AWS D1.5 hereinafter designated as AWS D1.5, and interim specifications in effect on the date of the Contract. Unless otherwise indicated in the Contract, the applicable AASHTO design code shall be the latest edition of the AASHTO LRFD Bridge Design Specifications .

Prior to performing any work under this Section, the Fabricator must have received approval for all Fabrication Drawings, welding procedures and any special Contract requirements and have notified the Structures Engineer at least seven days in advance of fabrication. The Contractor shall bear full responsibility and costs for all materials ordered, raw materials stockpiled, or for work performed prior to approval of the Fabrication Drawings or written authorization from the Structures Engineer.

All work shall be performed by the Fabricator indicated on the approved Fabrication Drawings unless otherwise authorized in writing by the Structures Engineer.

Structural steel furnished under this Section shall be fabricated in a plant having an AISC Major Steel Bridges (cbr) Certification and in a plant approved by the Agency prior to award of the Contract. Minor steel components including but not limited to downspouts, scuppers, and pedestrian hand railings may be fabricated in a fabrication plant that does not have an AISC Major Steel Bridges (cbr) Certification provided the fabrication plant is approved in writing by the Structures Engineer prior to the award of the Contract. All plants without certification shall have an organization, operation and equipment capable of producing a product equal to a certified plant.

The Fabricator shall demonstrate full capability for fabricating material(s) meeting the requirements of the Contract. Failure to meet Contract requirements will result in rejection of the material being fabricated and the termination of the ability to fabricate material for the State.

All plants must satisfy the following minimum requirements:

(a) Reference Materials. The plant shall have a library containing the latest editions of the following publications:

(1) AWS A5.0, A5.5, A5.17, A5.20, A5.23, C2.18, D1.1, D1.2, D1.3, D1.4, and D1.5.

(2) AASHTO *Standard Specifications for Transportation Materials and Methods of Sampling and Testing*, Parts I and II.

(3) AISC Quality Criteria and Inspection Standards, A Guide to the Shop Painting of Structural Steel, Manual of Steel Construction, and Structural Steel Detailing.

(4) Vermont *Standard Specifications for Construction*.

(5) AASHTO LRFD *Bridge Design Specifications*.

(6) AASHTO LRFD *Bridge Construction Specifications*.

(7) AASHTO *Standard Specifications for Welding of Structural Steel Highway Bridges*.

(8) AREMA specifications, when applicable.

(9) American Society for Nondestructive Testing (ASNT) SNT-TC-1A.

(10) SSPC *Steel Structures Painting Manual*, Volumes 1 and 2.

(11) AASHTO/NSBA G1.1-1999.

In addition to the above, access to the latest editions of any applicable ASTM standards is required.

(b) Files. The Fabricator shall maintain an organized file containing:

(1) Records of material purchased.

(2) Inventory of material in stock.

(3) Certification records of all material and welding supplies.

(c) Personnel. Fabrication personnel shall meet the following minimum requirements:

The Fabricator's representative responsible for inspection, testing and quality matters shall be qualified and certified in accordance with the provisions of AWS QC 1, entitled *Standard for Qualification and Certification of Welding Inspectors*.

Welders shall be certified for each process and position of prequalified joints in the approved welding procedures, including tacking, in accordance with AWS D1.5 for all structural bridge items and ANSI/AWS D1.1, hereinafter designated as AWS D1.1, for items not covered in AWS D1.5.

(d) Material Fabrication Facilities.

(1) All fabrication shall be performed in an enclosed permanent structure, unless otherwise approved by the Structures Engineer.

To meet minimum requirements, a plant shall have the following:

a. Dry storage for manual electrodes and fluxes.

b. Ovens with proper temperature ranges for drying electrodes and fluxes.

c. Calibrated tools, gauges, tapes, and instruments.

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d. Suitable preheating equipment and means for measuring preheat.

e. DC and AC manual shielded metal arc welding equipment capable of at least 500 A output.

f. Mechanically guided burning equipment.

g. Machine shop facilities sufficient to perform the work specified.

h. Facilities and equipment for applying shop paint to perform the work specified.

i. Blast cleaning equipment suitable for preparing a surface meeting the requirements of Subsection 506.14.

j. Suitable storage for materials and finished products.

(2) A plant engaged in fabrication of plate girders, rolled beams, and other main member components requiring continuous welds over 600 mm (2 feet) in length shall also have the following equipment:

a. Automatic arc equipment.

b. Semiautomatic arc equipment.

c. Stud welding equipment capable of installing a 22 mm (7/8 inch) diameter stud, when applicable.

d. Equipment suitable for heat curving or heat cambering.

e. Hydraulic jacking equipment suitable for aligning and positioning structural components.

(3) Adequate office facilities and equipment for the Agency's Quality Assurance Inspector shall be separate from the Quality Control facilities and shall include the following:

a. A standard office desk with drawers, locks, and keys.

b. Adjustable office chair.

c. Telephone.

d. Plan rack and file cabinet with lock and keys.

e. The following tools shall be available for the Inspector's use:

Weld gauges, micrometer, dry and wet film paint gauge, 3 m (10 foot) steel tape, 30 m (100 foot) steel tape, 2 m (6 foot) straightedge, temperature and marking crayons, ambient air thermometer, a level at least 600 mm (2 feet) long and a 600 mm (2 foot) carpenter's square.

The Engineer reserves the right to reject inadequate office facilities and require suitable alternatives.

(e) Testing Equipment. When code requirements necessitate nondestructive testing for quality control or quality assurance, the Fabricator shall have available the necessary nondestructive testing equipment for material or weld inspection (such as magnetic particle, radiograph, ultrasonic, or dye penetrant) or employ an outside inspection firm to fulfill the necessary nondestructive test requirements of the code. Nondestructive tests shall be performed in accordance with the applicable code in effect on the date of the Contract.

506.04 DRAWINGS AND PROCEDURES.

(a) General. As soon as practical after award of the Contract, the Fabricator shall prepare Fabrication Drawings in accordance with Section 105. Drawings, details, and welding procedures must be submitted as a complete package for each structure sufficiently in advance of fabrication to allow for review, resubmittals, and approval.

The Agency will review Fabrication Drawings, details, and procedures for their compliance with the Contract. The Agency uses AASHTO/NSBA G1.1-1999, Section 4 as the basis for review of structural steel Fabrication Drawings. The Agency assumes no responsibility for dimensions and other information calculated by the Fabricator. The Fabricator is responsible for the fit of all components. If errors occur that cause problems during erection, the Contractor is responsible to make acceptable corrections.

The Agency is responsible for all principal dimensions and material properties contained in the Contract. The Fabricator and Contractor are responsible for bringing to the Agency's attention any errors or discrepancies they discover.

The Fabricator is responsible for dimensioning members and ordering material to compensate for weld shrinkage, distortion, elastic deformation, sweep, slope, machining, waste from cutting, and other incidentals that are affected by the fabrication process.

(b) Details. Details not shown on the Plans that are necessary for completing the Fabrication Drawings shall be developed by the Fabricator.

The Fabrication Drawings shall provide a material list on each sheet for tabulating the number of pieces, piece marks, description, dimensions, type of material, and mass (weight) of each piece. When the Contract item pay unit is on a per kilogram (pound) basis, the mass (weight) of each piece shall be extended and summarized for each sheet as specified in Subsection 506.24. Mass (weight) extensions (extended weights) shall be submitted to the Agency upon completion of fabrication.

All welds shown on the Fabrication Drawings shall identify, by symbol, the applicable procedure(s) and appropriate nondestructive testing requirements. A separate symbol must be used to identify each approved welding procedure. When more than one procedure is available, the Fabricator may identify several procedures for any given weld.

(c) Welding Procedures. Detailed welding procedures shall be prepared in accordance with the provisions of the applicable AWS/ANSI/AASHTO code revisions and submitted in accordance with the following:

(1) Welding procedures for each structure shall be a separate package of consecutively numbered sheets. Each sheet of the set shall identify the project name, number, structure, and procedure qualification record.

(2) All procedures shall be prequalified. Procedure qualification test records shall be submitted along with each procedure. Heat input values during welding shall be shown for each procedure. The minimum heat input shall be 1.4 kJ/mm for material 10 to 19 mm (35 kilojoules per inch for material 3/8 to 3/4 inch) in thickness and 2.0 kJ/mm for material over 19 mm (50 kilojoules per inch for material over 3/4 inch) in thickness.

$$\text{Kilojoules per Millimeter} = \left(\frac{\text{Volts} \times \text{Amps} \times 0.06}{\text{Travel Speed in Millimeters per Minute}} \right)$$

[Metric]

$$\text{Kilojoules per Inch} = \left(\frac{\text{Volts} \times \text{Amps} \times 0.06}{\text{Travel Speed in Inches per Minute}} \right)$$

[English]

(3) Procedure specifications shall be presented in a format similar to Form E-1 of AWS D1.1, Appendix E, or Form E-2 of AWS D1.5, Appendix IV. Procedure qualification test records shall be presented in a format similar to Form E-2 of AWS D1.1, Appendix E, or Form E-1 of AWS D1.5, Appendix IV.

(4) Details of welded joints not prequalified under AWS D1.5, Section 2.6 shall be qualified.

(d) Revisions. Adjacent to or incorporated with the title box of each sheet shall be a revision record box including provision for: date of revision, symbol of revision number, revision made by, and description of each revision. As changes or revisions are made to previously approved sheets, the appropriate information shall be recorded, a revision number symbol placed adjacent to the appropriate detail, and the sheet resubmitted for approval. It is the Fabricator's responsibility to transfer all "as noted" corrections to the originals.

Revisions of welding procedures shall also be resubmitted, as they occur**.**

506.05 QUALITY ACCEPTANCE. Quality Acceptance is inspection of fabrication by the Agency or the Agency's representative to verify compliance with these Specifications.

(a) Scope of Work. Inspection will include the examination of materials, processes, quality of work, reports, and test results; the performance of tests specified; the evaluation of reports and tests; the approval, disapproval, or rejection of materials, processes, quality of work, reports, and test results; or other work specified or directed by the Engineer.

(b) Control of Work. The Inspector is a representative of the Engineer and will perform all the duties assigned and delegated to the Engineer in Section 105 as they pertain to the Contract with the exception of quantities of materials and payment thereof. The Inspector will witness, interpret, and accept or reject all testing.

The Inspector will have the authority to reject any material or work that does not conform to the Contract requirements. Inspection of the work will conform to the requirements of the applicable AWS/ANSI/AASHTO codes and specifications referenced in the Contract.

(c) Tools and Equipment. Inspectors are expected to furnish their own personal safety equipment. They may make use of any tools the Fabricator is required to make available; however, the Fabricator is responsible for verifying that the equipment is properly calibrated and in working order.

506.06 QUALITY CONTROL.

(a) General. Quality Control is the inspection, testing, and management of quality matters necessary for producing a product that conforms to the requirements of the Contract. The Fabricator is responsible for Quality Control.

The Fabricator is responsible for performing all nondestructive tests required by the Contract and any nondestructive tests necessary to determine the extent of metallurgical defects discovered in the base metal.

(b) Qualifications of Inspectors. The Fabricator's representative responsible for Quality Control shall be an AWS Certified Welding Inspector (CWI), qualified and certified in accordance with the provisions of AWS QC 1.

(c) Nondestructive Testing. The Fabricator shall notify the Agency sufficiently in advance of any scheduled nondestructive testing so that all tests can be witnessed by an Agency Inspector. Nondestructive tests shall be performed in accordance with AWS D1.5.

Personnel performing and interpreting nondestructive tests (radiographic, magnetic particle, ultrasonic and dye penetrant) shall be NDT certified for Level II qualification in accordance with the American Society for Nondestructive Testing, Recommended Practice Number SNT-TC-1A.

(d) Ultrasonic Testing. Ultrasonic testing will not be permitted as a substitute for radiographic testing; however, ultrasonic testing may be used by the Fabricator to determine the extent of discontinuities, laminations, and inclusions discovered in any weld or base metal.

506.07 MATERIAL IDENTIFICATION.

(a) Material Certifications. Certifications shall be prepared in accordance with Subsection 700.02. Prior to any fabrication or stockpile payment for material the Contractor shall furnish the Agency's Inspector one copy of all Type C Certification material test reports. Any material not properly identified or lacking acceptable test information shall not be incorporated in the work. If no Quality Acceptance Inspector is assigned or available when fabrication begins or at the time of the raw material stockpile payment, it is the Contractor's responsibility to ensure that Contract requirements are complied with.

Prior to shipment of any material, a copy of all Type C Certification material test reports and all applicable Type A Certifications, both pertaining to the items to be shipped, shall be sent to the Agency's Materials and Research Section. Acceptable certifications received by the Agency are a pre-requisite to payment for any fabricated material.

(b) Material Traceability. The origin of each piece of material to be incorporated in a product shall be clearly identified at all times during the fabrication of the product. If fabrication operations could obliterate the identity, the Fabricator may use a low-stress die stamp placed in an area not exposed on the finished structure. The die stamp character size shall be a minimum of 3 mm (1/8 inch) and a maximum of 6 mm (1/4 inch). Nonmetallic materials shall be identified to the satisfaction of the Engineer.

When requested, the Contractor shall furnish an affidavit certifying that throughout the fabrication operation identification of the steel has been maintained in accordance with this Specification.

When a steel stamp identification is used at a tension joint transition, the impression shall be placed on the thicker of the members.

506.08 BASE METAL REQUIREMENTS. When backing bars, extension bars, and runoff plates are part of a welding process, the material used shall be of the same chemistry as the base metal.

Discontinuities, laminations, inclusions, or other anomalies discovered in the base metal during the manufacturing process shall be individually evaluated. The Agency may require nondestructive testing to determine the extent of the defect. Repair procedures or replacement will be approved on an individual case basis.

Rolled beams shall be ordered from the mill without camber.

Primary stress carrying material (e.g., flanges, webs, splice plates, and lateral connection plates) shall be ordered and prepared so that the direction of rolling is parallel to the stress in the member.

Members identified as “fracture critical” shall be subject to additional base metal requirements as specified in Subsection 506.11.

Members or components of members designated in the Contract as requiring Charpy V-Notch (CVN) testing, or members subject to tensile or compressive stress as specified in Subsection 714.01 shall be identified as a main member and shall therefore be subject to the requirements of main members.

506.09 PREPARATION OF BASE METAL. Material flame cuts by any thermal cutting process shall be made with an approved mechanically guided torch. The Fabricator shall use preheating, post heating, or control of the cutting process to ensure that flame cut edges of main members of structural steel [e.g., AASHTO M 270M/M 270, Grade 345W (Grade 50W) or Grade 345 (Grade 50)] are not flame hardened. Flame cut edges that will not be included in a permanent weld shall have a Rockwell Hardness Value not greater than C30.

Pieces that are to be bent during fabrication shall be done so in accordance with AWS D1.5 and the applicable design code as defined in Subsection 506.03.

Cold bending of main members will not be permitted without written approval of the Agency. This approval may limit the radius of curvature and require nondestructive testing to verify that no internal distress or separation has occurred. Expenses incurred in performing any such nondestructive test examination shall be the responsibility of the Fabricator.

506.10 WELDING.

(a) General. All design details, quality of work, procedures, and inspection of welding shall conform to the requirements of the AWS D1.5 Bridge Welding Code. For welding items other than those covered in AWS D1.5, one of the following publications shall be adhered to:

ANSI/AWS D1.1 Structural Welding Code - Steel
ANSI/AWS D1.2 Structural Welding Code - Aluminum
ANSI/AWS D1.3 Structural Welding Code - Sheet Steel
ANSI/AWS D1.4 Structural Welding Code - Reinforcing Steel

Welding will not be permitted without approved welding procedures and Fabrication Drawings meeting the requirements of Subsection 506.04.

Welding and inspection of shear connectors shall conform to the requirements of Section 508.

Stitch welds are not permitted; however, the skip and fill technique may be used when applicable to prevent distortion.

Prior to performing any corrective weld repairs, the Fabricator shall:

(1) Submit the proposed repair procedure to the Inspector in writing. Corrective procedures for radiographed butt welds may be included in the welding procedure.

(2) Receive written authorization from the Agency to proceed. Repair procedures detailed in an approved welding procedure may be authorized by the Agency's Inspector.

The Fabricator will be permitted a maximum of two repairs on any given welded joint. Should nondestructive test inspection indicate weld rejection after two repairs, the Agency may reject the entire weld and require its removal.

(b) Welding Processes. Shielded metal arc welding (SMAW) conforming to AWS D1.5, Section 1 shall be deemed prequalified. Submerged arc welding (SAW), flux core arc welding (FCAW), and gas metal arc welding (GMAW) shall be subject to qualification testing as described in AWS D1.5, Section 5 prior to approval. Other processes may be approved, on a project by project basis, provided procedure qualification results meet the specified acceptance criteria.

Submerged arc welding shall be used for all principal welds:

(1) The fully automatic process shall be used for attaching cover plates, flange to web welds, and attaching connection or stiffener plates to girder webs.

(2) The semiautomatic process may be used when joint length, position, or physical location restricts the use of the automatic process.

The manual shielded metal arc process shall be limited to attaching connection plates to rolled beams, welding bearing assemblies, repairs, tack welding, joints under 600 mm (24 inches) in length, minor attachments, and other applications where the use of an automatic process is impractical.

When prior authorization has been granted, the gas metal arc welding (GMAW) and flux cored arc welding (FCAW) processes will be limited to indoor shop welding of bearing devices, scuppers, sign fixtures, light fixtures, and low stressed members or components.

Gas metal arc welding short circuit arc (GMAW-S) will not be permitted.

Any gas shielded process subject to wind velocities in excess of 8.0 km/h (5 miles per hour) shall be protected by the use of a draft barrier(s).

(c) Shop Welding. The Fabricator shall maintain a file of the qualifications of all welders, welding operators, and tackers qualified in accordance with AWS D1.5, Section 5. Requalification may be required in accordance with AWS D1.5, Section 6. AWS D1.1 shall be adhered to for welding of items not covered in AWS D1.5.

Groove welds shall be started and terminated with extension bars or runoff plates.

Fillet welds shall be performed in the flat or horizontal position unless restricted by member size or physical position.

(d) Field Welding. Welding performed in the field shall be done by welders or welding operators who have an AWS Certification designating them as qualified in the appropriate category for Structural Welding for the Agency.

The Agency's qualification requirements for field welding are contained in the *Manual for Field Welding*. This document may be obtained from the Agency's Construction Section. The Contractor shall have a copy for use any time field welding is anticipated.

The axis of any weld used to attach miscellaneous construction fixtures to main members as defined in Subsection 714.01 shall be in the same direction as the primary stress in the member and shall be approved in writing by the Engineer.

Welding performed in the field is subject to all of the requirements of Subsection 506.10. The shielded metal arc welding (SMAW) process is the only process approved for field welding.

Welding of miscellaneous construction fixtures such as form supports, screed supports, and reinforcing steel chairs to any portion of the bridge structure will not be permitted without approved drawings and welding procedures. Any increase in material thickness made necessary by reduced allowable stresses resulting from such welding shall be at the Contractor's expense. Approval for any welding requiring an increase in material thickness must be obtained before the affected structural steel is fabricated.

Shear connectors shall be installed in accordance with Section 508.

(e) Process and Procedure Qualification.

(1) General. Welding processes and procedures requiring qualification shall be qualified in accordance with AWS D 1.5.

Welding and testing of samples shall be witnessed by an Agency Inspector or an authorized representative of a testing agency that is AWS certified in accordance with the provisions of AWS QC 1.

Process and procedure qualification record tests shall be reported in a format similar to those provided in AWS D15.

Procedure specifications shall be reported in a format similar to those provided in AWS D1.5.

(2) Acceptance Requirements. The basis for acceptance shall conform to the requirements of AWS D1.5. AWS D1.1 shall be used only for those items not covered in AWS D1.5.

506.11 FRACTURE CRITICAL MEMBERS. The Agency will identify in the Contract the members or member components that are categorized as "fracture critical."

Material for members or member components identified as "fracture critical" shall be furnished and fabricated in conformance with the requirements of AWS D1.5 for fracture critical components.

Welding performed on fracture critical members or components, and testing, shall be witnessed by an Agency representative. Qualification acceptance for any welding procedure shall be based on the results of mechanical tests and chemical analysis of deposited weld metal. Procedure requirements and basis of acceptance shall meet the requirements in AWS D1.5 for fracture critical components.

506.12 ASSEMBLY

(a) Camber. Beams and girders shall be fabricated to the camber indicated on the approved Fabrication Drawings.

(b) Curved Girders. Welded girders with radii less than 230 m (750 feet) shall be fabricated by cutting the flange plates to the required curvature. Each plate shall be flame cut simultaneously on both edges to reduce unbalanced shrinkage stresses. The flange plate lengths between shop splices shall not be less than 6 m (20 feet). Web plates shall be aligned to the center of the flange plates.

If the final curvature is not as specified after the flanges have been welded to the web, the girder shall be corrected by application of heat in accordance with an approved procedure.

(c) Heat Curving and Cambering. The final horizontal curvature and vertical camber shall be measured only after the member has cooled. The member shall be supported in a manner that will ensure accurate measurements for sweep and camber. The web shall be in a vertical position for measuring curvature and in a horizontal position for measuring camber.

Heating shall be performed in such a manner that the temperature of the steel does not exceed 610 °C (1125 °F). Artificial cooling will not be permitted until a member has cooled to 315 °C (600 °F). Under no conditions will water be permitted for cooling. Air may be used subject to the approval of the Inspector. Any member heated in excess of 650 °C (1200 °F) shall be rejected.

(d) Finish. All sharp corners and edges that are marred, cut, or roughened in handling shall be rounded to a 1.6 mm (1/16 inch) radius by grinding.

(e) Connections and Bolting. The materials and fabrication procedure shall comply with the provisions of Subsection 506.19.

(f) Bearing Connections. Field bearing connections shall not be permitted. Connections in bearing may require different tolerances of fit. Terms used to define the fit of connections are:

(1) Tight Fit (Welded Ends Only). Fifty percent of the projected bearing area shall be in contact within 0.5 mm (0.02 inch) with a permissible variation of 1.6 mm (1/16 inch) for the remaining 50 percent of projected area.

(2) Grind to Bear. Seventy-five percent of the projected area shall be in contact within 0.25 mm (0.01 inch) with a permissible variation of 0.8 mm (1/32 inch) for the remaining projected area.

(3) Mill to Bear. One hundred percent of the projected bearing area shall be in full contact.

(g) Intermediate Stiffeners. Where tight fit of intermediate stiffeners is specified, 50 percent of the projected bearing area shall be in contact within 0.5 mm (0.02 inch) with a permissible variation of 1.6 mm (1/16 inch) for the remaining 50 percent of the projected bearing area.

(h) Straightening Material. Straightening or repair of any member or component will be subject to written approval by the Agency. Procedures will be required describing in detail the distortion to be corrected and all procedures for heating, cooling, verifying final dimensions, and nondestructive tests.

506.13 TOLERANCES. Rolled steel plates, shapes, and bars shall be supplied to the permissible tolerances specified in ASTM A 6/A 6M. The camber and sweep of fabricated rolled members shall be subject to the same dimensional tolerances specified for welded members in AWS D1.5.

The metal bearing surface of any masonry bearing plate shall be flat, with a maximum permissible variation of 1 mm (0.04 inch) from a plane determined by any three of its corners.

There will be no permissible tolerance for over grinding. Welded butt joints shall be finished so that the final thickness of the joint is not less than the thickness of the thinner adjacent plate. Welded butt joints subjected to only compressive stresses shall be finished so the final thickness of the joint is not less than the ordered thickness of the thinner plate.

The Fabricator is responsible for straightening to specification tolerances any weldments that may have been distorted through stress relieving during the galvanizing process.

506.14 SURFACE PREPARATION. All materials shall be blast cleaned to the grade specified as defined by the pictorial surface preparation standard SSPC-VIS 1.

Further preparation shall conform to the following:

(a) Surfaces to Remain Uncoated. Surfaces may be blast cleaned either before or after fabrication.

The final surface appearance after fabrication shall be at least equivalent to preparation grade SSPC-SP10.

(b) Surfaces to be Galvanized or Metalized. Prior to galvanizing or metalizing, all corners and edges of steel plates, shapes, etc., shall be ground to a 1.6 mm (1/16 inch) radius.

(c) Surfaces to be Painted. All material to be painted shall be cleaned in accordance with the appropriate painting item(s) in the Contract.

506.16 MARKING, STORING, AND SHIPPING.

(a) Marking. Each member shall be identified with an erection mark corresponding with the member identification mark on the approved Fabrication Drawings.

Identification marks may be painted on members that will receive field coats of paint.

Identification marks on unpainted steel shall be impressed into the member (with a low-stress stamp) in a non-stressed or low stressed area of the member. The Fabricator shall identify to the Contractor the procedure used for marking material.

(b) Storing. Material at the Fabricator's plant shall be stored above ground on platforms, skids, or other suitable supports. It shall be kept clean, properly drained, and protected from unwanted corrosion. Free circulation of air shall be provided around all surfaces.

Girders and beams shall be stored in the upright position, supported at their ends or points of bearing. Long members (e.g., columns and chords) shall be supported at sufficient points to prevent damage from deflection.

Special care shall be taken for unpainted steel to ensure that it has the opportunity to weather uniformly.

In addition to the requirements specified above, material or raw material stockpile storage shall be subject to any other storage criteria deemed necessary by the Engineer in accordance with Subsection 106.09.

(c) Shipping. Beams and girders shall be transported in the upright position. If the member's size or shape prohibits shipment in the upright position, the Fabricator shall submit a proposed method and details of shipment to the Agency for approval.

The Fabricator shall not ship any material, either to the project or to another manufacturer, without the Agency's approval. The Agency's Inspector will place a seal of approval on all material that has been accepted and will approve the loading, positioning, and anchorage of all material being shipped.

506.17 FIELD HANDLING AND STORING. The Contractor is responsible for providing equipment that is adequate for safely lifting and placing, without damage, all material furnished. Permanent distortion caused by handling or storage will be cause for rejection.

The edges of nicks or bumps caused by handling shall be carefully ground to a 2 mm (1/16 inch) radius.

The storage requirements in Subsection 506.16 shall be applicable for all material stored in the field.

506.18 ERECTION.

(a) Methods and Equipment. Cranes, lifting devices, and other equipment for all structural steel erection shall be of adequate design and capacity to safely erect, align, and secure all members and components in their final positions without damage. The Contractor is solely responsible for the methods and equipment employed for the erection of the structural steel. However, the Contractor shall lift and erect curved girders so that the web of the girder is maintained vertical within a 10 degree vertical tolerance.

The Contractor shall submit Construction Drawings in accordance with Section 105 for the methods and sequence of structural steel erection, the temporary bracing, and the equipment to be used for the erection. The erection plan shall include the necessary computations to indicate the magnitude of stress in the segments during erection and to demonstrate that all of the erection equipment has adequate capacity for the work to be performed. The erection plan shall contain provisions for all stages of construction, including temporary stoppages.

(1) Curved Girders. The Contractor shall include additional information in the erection plan for curved girders as indicated in AASHTO LRFD *Bridge Construction Specifications* Section 11.8.2.

The structural steel may be used for support of equipment prior to placement of the deck only with the written permission of the Engineer. The proposed use of structural steel for support of equipment shall be detailed in the erection plan.

Submittal of the erection plan is for documentation purposes only, and shall in no way be construed as approval of the proposed method of erection. Unless otherwise directed by the Engineer, the Contractor shall follow the erection plan as submitted.

(b) Assembly.

(1) Parts shall be accurately assembled as shown on the Contract Plans, Fabrication Drawings, or erection drawings, following match marks when provided. Material shall be carefully handled so that no members or pieces will be bent, broken, or damaged.

Hammering that will injure or deform members will not be permitted. Bearing surfaces and contact surfaces shall be clean. Members shall be erected to the position specified and externally supported until all connections have been completed.

(2) Drift pins shall be used to align and center the connections of main and secondary members. Only light drifting will be permitted. Any member subjected to drifting that results in distortion of the member or elongation of the holes will be rejected. Cylindrical erection pins, the same size as the hole, shall be used at least in the extreme corners of all main member connections.

Main members have been match marked and shop reamed to fit a specified profile and should fit together easily.

Main members shall not be reamed larger than the hole size indicated on the approved Fabrication Drawings without written authorization from the Engineer.

Secondary members may be subjected to limited field reaming. Reaming or drilling to connect misaligned holes will not be permitted without the approval of the Engineer. Reaming of secondary members shall be approved by the Engineer on a case by case basis prior to the reaming. Reaming or drilling shall not cause elongation of any hole more than 1.6 mm (1/16 inch) for 75 percent of the holes in any subassembly and 3.2 mm (1/8 inch) for the remaining 25 percent of the subassembly (diaphragm, lateral bracing, etc.). Reaming that produces results in excess of these limits will be cause for rejection. Assembled parts requiring drilling or reaming shall be disassembled to remove any burrs or shavings.

Pins used for hinged connections and bearings shall be inserted with care and aligned so the members take full and even bearing. Nuts shall be adequately tightened and locked in position either by upsetting the threads or tack welding the nut to the bolt.

(3) The correction of minor misfits involving reaming (within specified limits) and cutting will be considered a legitimate part of the erection. However, errors in shop fabrication that prevent proper assembly shall be reported immediately to the Engineer. The Engineer shall approve any corrective action prior to it occurring.

506.19 BOLTING AND CONNECTIONS.

(a) General. Connections shall be made with high-strength bolts conforming to AASHTO M 164M (AASHTO M 164). Bolts and nuts shall be furnished by the same supplier. Bolts, nuts, and washers shall be packaged and shipped so they are kept dry. When not in transit, bolts, nuts, and washers shall be stored indoors under dry, ventilated conditions. All bolts and nuts shall be adequately and uniformly lubricated. Bolts and nuts not properly lubricated shall be cleaned and relubricated prior to installation in accordance with applicable specifications.

Bolt holes are specified as 2 mm (1/16 inch) larger in diameter than the bolt.

Bolt holes shall be fabricated to the requirements of the AASHTO *LRFD Bridge Construction Specifications*, Section 11.4.8, except that holes shall not be punched full-size unless otherwise permitted in the Contract Documents or approved by the Engineer.

(b) Bolted Parts. Bolted parts shall fit solidly together when assembled and shall not be separated by gaskets or other interposed compressible material. All joint contact surfaces and areas adjacent to bolt holes shall be free of scale, burrs, dirt, and other foreign material that may prevent solid seating of the parts.

Prior to assembly, contact surfaces of galvanized stress-carrying members shall be lightly brushed or blasted to a dull gray appearance.

Faying surfaces of bolted connections shall meet the Class B slip coefficient value of not less than 0.50 as specified by AASHTO.

Splices and field connections of main members shall have all holes filled with high-strength bolts or cylindrical drift pins, with bolts fully tightened before external support systems are removed.

(c) Installation. Bolted connections shall be assembled with a hardened washer under the turned element. Hardened steel washers shall be used under both the head and the nut when bolts are used for the following connections:

(1) Oversized holes (fabricated as per Contract).

(2) Replacing existing bolts or rivets.

(3) Oversized and irregular hole conditions caused from field drilling or reaming.

(4) Connections between new steel and existing steel.

Where an outer face of the bolted parts has a slope of more than 1:20 (vertical:horizontal) with respect to a plane normal to the bolt axis, a smooth beveled washer shall be used to compensate for the lack of parallelism.

Bolts installed with the stem vertical shall have the heads up. Bolts installed with the stem horizontal shall have the head towards the weather unless clearance restrictions dictate otherwise.

Normally the nut will be the tightened element; however, if the position of bolt entering or wrench operation clearances prohibit this procedure the bolt may be the turned element.

Tightening of a bolt group shall progress systematically from the most rigid part of the joint to its free edges.

Previously tightened bolts shall be re-tightened until all bolts in the connection are tightened to the minimum required tension.

Recalibration of a wrench may be required any time there appears to be a significant change in the condition of bolt tightening.

All bolts in a connection shall first be brought to a “snug tight” condition. “Snug tight” is defined as initial tension sufficient to bring all the plies of the connection into firm contact while the drift pins remain in the connection. Snugging shall progress systematically, beginning at the most rigid part of the connection and progressing to the free edges until the connection is fully compacted.

All high-strength bolts shall be tightened to the specified tension as soon after installation as feasibly possible. Under no circumstances shall bolts be left untightened for more than five days after installation unless specific requirements to do so are indicated in the Contract or directed by the Engineer. Bolts left in place beyond five days without specific requirements in the Contract or as directed by the Engineer shall be removed and replaced with new bolts at the Contractor's expense.

Bolts shall be tightened to develop a tension not less than 5 percent in excess of the minimum bolt tension specified in Table 506.19A by either the calibrated wrench, turn of the nut, torque, tension control assembly ("twist-off"), or direct tension indicator method. Bolts shall not be tightened to more than the maximum tension specified in Table 506.19A.

Bolts shall be tensioned by the Contractor in the presence of the Engineer using one of the following methods:

(1) Calibrated Wrench Method. A random sample of not less than three bolt and nut assemblies of each diameter, length, grade, and type to be used in the work shall be checked a minimum of each working day in a device capable of indicating bolt tension.. The test shall be performed on each wrench to be used to determine the working torque for the wrench. Variations in the number or location of washers will require separate checks. Additional calibration of the wrenches being used shall be performed as directed by the Engineer.

All powered wrenches shall be adjusted to stall or cut-out at the specified tension. Power wrenches without cut-outs will not be permitted.

(2) Turn of the Nut Method. All bolts shall be tightened by the applicable amount of nut or head rotation specified in Table 506.19B. During the tightening operation, there shall be no rotation of the part not turned by the wrench.

A random sample of not less than three bolt and nut assemblies of each diameter, length, grade, and type to be used in the work shall be checked each working day in a device capable of indicating bolt tension. The test shall demonstrate that the method of estimating the "snug tight" condition and controlling turns from "snug tight" to be used by the bolting crew(s) develops a tension of at least 5 percent in excess of the minimum bolt tension specified in Table 506.19A, and not more than the maximum tension specified in Table 506.19A. Separate checks will be required for each diameter fastener with hardened washers placed under the nut and/or bolt head as they will be used in the structure. Variations in the number or location of washers will require separate checks.

(3) Torque Method. Manual torque wrenches for installation shall be supplied by the Contractor, calibrated yearly, and each accompanied by a certificate indicating its date of calibration. A random sample of not less than three bolt and nut assemblies of each diameter, length, grade, and type to be used in the work shall be checked a minimum of each working day in a device capable of indicating bolt tension. The test shall be performed on each wrench to be used to determine the working torque for the wrench. Additional calibration of the wrenches shall be performed as directed by the Engineer. Separate checks will be required for each diameter fastener with hardened washers placed under the nut and/or bolt head as they will be used in the structure. Variations in the number or location of washers will require separate checks.

This method may be used to "touch up" bolts previously tightened and that may have been loosened by the tightening process or as a means of bringing all bolts in any given connection to the specified tension.

(4) Tension Control Assembly Method. A tension control assembly consists of a tension control bolt with a spline end and a suitable nut and washer. This method shall be employed when installing "button" or "dome" headed high strength bolts.

All bolts shall be tightened by the application of torque to the nut and counter-torque to the spline end of the bolt using an approved spline drive installation tool. A random sample of not less than three tension control assemblies of each diameter, length, grade, and type to be used in the work shall be checked a minimum of each working day in a device capable of indicating bolt tension. The test shall be performed to verify that the spline twist-off develops a tension of at least 5 percent in excess of the minimum bolt tension specified in Table 506.19A, and not more than the maximum tension specified in Table 506.19A. Additional verification of the tension control assemblies shall be performed as directed by the Engineer. Separate checks will be required for each diameter fastener with hardened washers placed under the nut and/or bolt head as they will be used in the structure. Variations in the number or location of washers will require separate checks.

(5) Direct Tension Indicator Method. Direct tension indicators (DTIs) are compressible washers capable of indicating that a specified minimum bolt tension has been attained. DTIs installed with high strength bolts to indicate bolt tension shall be subjected to field verification testing prior to installation and the installation requirements specified below.

DTIs installed with high-strength bolts to indicate bolt tension shall be placed under the head of the bolt with the protrusions facing the head of the bolt, and the nut shall be turned, with a hardened washer underneath it, to tension the fastener. If for reasons of installation or inspection accessibility it is necessary to place the DTI under the turned element, the DTI shall be oriented so that the protrusions face outward from the work, and a hardened washer shall be placed between the DTI and the turned element.

The bolt, DTI, hardened washer and nut assembly used in the verification testing device and installed in the work shall be such that at least 3 and preferably not more than 5 threads are located in the grip. The grip is defined as the distance between the bearing face of the nut and the bolt head.

Bolts used in the verification test and installed in the work shall not be tightened to a "no-visible" gap condition such that all of the DTI protrusions are completely compressed. A visible gap must remain in at least one space after installation. It is permissible to have no entries and still have a visible gap. The tension in the bolt becomes indeterminate when no visible gap exists and may exceed the maximum tension of the fastener.

The Contractor shall supply 5 mil tapered feeler gages, a calibrated bolt tension-measuring device and equipment necessary to perform field verification testing and inspection of tensioned bolts. The feeler gages, fasteners, and impact and manual wrenches shall be the same as that to be used in the work.

The Contractor shall obtain the services of a qualified technical advisor employed by the DTI manufacturer to make at least one site visit to assist the Contractor and to assure the proper installation and use of DTIs. This requirement may be waived by the Engineer if the Contractor can demonstrate to the Agency's satisfaction successful use of DTIs on previous projects for the Agency.

Verification testing shall be performed in a calibrated bolt tension measuring device, such as a Skidmore-Welhelm Calibrator, with a special flat insert (supplied by the Contractor) replacing the normal bolt head-holding insert. The special insert allows the DTI to be located on the flat front face of the tension measuring device for ease of observation and improved access for measuring the DTI gap during testing.

The verification testing shall demonstrate that the DTIs were properly manufactured. The fastener shall develop a tension of at least 5 percent in excess of the minimum bolt tension specified in Table 506.19A when the DTI has been compressed to allow entries for fewer than half the number of spaces, and the fastener shall not plastically deform when the DTI is compressed to the maximum allowable limit for the project.

Three verification tests are required to be performed on random samples of each combination of fastener rotational-capacity lot, DTI lot and DTI position (under the nut or bolt head) used on the project. All three tests must pass for the DTI and assembly combination to be approved. Testing shall be performed at the project site by the Contractor and witnessed by the Engineer.

When testing for the normal DTI position, the nut shall be turned with the bolt head against the DTI restrained from turning with another wrench. When testing with the DTI under the turned element, the turned element shall be placed on the flat front face of the tension measuring device and the unturned element will be in the rear held by another wrench.

a. Verification Test. The verification test shall be conducted in two stages as follows:

1. Stage 1. Tension the fastener to the Verification Tension load specified in Table 506.19C for the grade and size of fastener. If an impact wrench is used, tension to a load two-thirds below the required load and use a manual wrench to attain the required tension. Determine and record the number of entries of a 5 mil feeler gage in the spaces between the protrusions. When using coated (galvanized or epoxy coated) DTIs under the turned element, there shall be at least one entry of the feeler gage. The DTI lot will be rejected if the number of entries is less than the value in column 3 of Table 506.19C, or for coated DTIs used under the turned element, there are no entries.

2. Stage 2. Further tension the fastener beyond the verification load with a manual wrench until there are no entries for the 5 mil feeler gage but a visible gap exists in at least one space. Note and record the load in the bolt at this condition (the maximum allowable limit of DTI compression) and remove the fastener from the tension measuring device. The capability of the bolt to tolerate the maximum allowable limit of DTI compression is determined in two ways. The simplest is to hand turn the nut down the complete thread length of the bolt, excluding thread runout. If this is successful, then the bolt has not undergone significant plastic deformation and the assembly passes the verification test. Alternatively, if the nut cannot be turned down the complete thread length, the DTI lot will be rejected unless the load recorded is less than 95% of the average load measured in the rotational capacity test of the fastener lot as specified in the applicable AASHTO design code, in which case the assembly is deemed to have passed the test.

Bolts and DTIs used in verification tests shall be marked and shall not be reused in the work.

If the bolts are too short to be tested in the tension measuring device, Stage 1 of the Verification Test for the DTI shall be conducted on a longer bolt. Stage 2 of the Verification Test shall be conducted for the short bolt with the short bolt in a convenient hole in the work. The fastener assembly shall be tensioned with a manual wrench until there are no entries for the 5 mil feeler gage but a visible gap exists in at least one space. The fastener shall then be disassembled.

Subsequently, the nut must be run down, by hand, for the complete thread length of the bolt excluding thread runout. The DTI lot will be rejected if the nut cannot be assembled to this thread length. Three verification tests are required as specified above.

b. Installation. Installation of fasteners utilizing DTIs shall be conducted in two steps as follows:

1. Step 1. All of the bolts in a connection shall be installed to a snug tight condition. Snugging shall progress systematically beginning at the most rigid part of the connection and progressing to the free edges until the connection is fully compacted. At the snug tight condition all of the DTIs shall be inspected with the feeler gage to verify that they meet the number listed in column 3 of Table 506.19C. If the number of entries is less than the values specified in the Table, the fastener must be removed and another DTI installed, followed by re-snugging of the fastener. This is required because a fastener's tension may have relaxed during the snugging of adjacent fasteners. A compressed DTI does not rebound if the fastener tension is reduced. If a DTI which has fewer entries were left in place, it would give a false indication of bolt tension.

2. Step 2. The bolts in the connection shall then be further tensioned to the point that the number of entries for a 5 mil feeler gage meets the number listed in Column 5 of Table 506.19C. Tightening shall progress systematically beginning at the most rigid part of the connection and progressing to the free edges. Drift pins shall be removed during this process. Several cycles may be required. If the fastener is tightened so that no visible gap in any space remains, the bolt and DTI shall be removed and replaced by a new properly tightened fastener and DTI.

TABLE 506.19A (METRIC)
BOLT TENSION
AASHTO M 164M (ASTM A 325M) BOLTS

Nominal Bolt Diameter (mm)	Minimum Bolt Tension (kN)*	Maximum Bolt Tension (kN)**
M16	91.0	117.0
M20	142.0	182.7
M22	176.0	225.9
M24	205.0	263.7
M27	267.0	342.9
M30	326.0	419.4
M36	475.0	610.2

* Equal to 70 percent of specified maximum tensile strength of bolts.

** Equal to 90 percent of specified maximum tensile strength of bolts.

TABLE 506.19A (ENGLISH)
BOLT TENSION
AASHTO M 164 (ASTM A 325) BOLTS

Nominal Bolt Diameter (inches)	Minimum Bolt Tension (pounds)*	Maximum Bolt Tension (pounds)**
1/2	12,050	15,500
5/8	19,200	24,700
3/4	28,400	36,500
7/8	39,250	50,500
1	51,500	66,200
1 1/8	56,450	72,600
1 1/4	71,700	92,200
1 3/8	85,450	109,800
1 1/2	104,000	133,700

* Equal to 70 percent of specified maximum tensile strength of bolts.

** Equal to 90 percent of specified maximum tensile strength of bolts.

TABLE 506.19B
NUT ROTATION FROM SNUG TIGHT CONDITION
AASHTO M 164M (ASTM A 325M)
[AASHTO M 164 (ASTM A 325)] BOLTS

	Disposition of Outer Faces of Bolted Parts		
Bolt Length (as measured from underside of head to extreme end of point)	Both faces normal to bolt axis	One face normal to bolt axis and other face sloped not more than 1:20 (v:h) (bevel washer not used)	Both faces sloped not more than 1:20 (v:h) from normal to bolt axis (bevel washers not used)
Up to and including 4 diameters	(120 °) 1/3 turn	(180 °) 1/2 turn	(240 °) 2/3 turn
Over 4 diameters but not exceeding 8 diameters	(180 °) 1/2 turn	(240 °) 2/3 turn	(300 °) 5/6 turn
Over 8 diameters but not exceeding 12 diameters	(240 °) 2/3 turn	(300 °) 5/6 turn	(360 °) 1 turn

Nut rotation is relative to bolt, regardless of the element (nut or bolt) being turned. For bolts installed by 1/2 turn (180 degrees) and less, the tolerance shall be ± 30 degrees; for bolts installed by 2/3 turn (240 degrees) and more, the tolerance shall be ± 45 degrees.

For bolt lengths exceeding 12 diameters, the required rotation must be determined by actual test in a suitable tension device simulating the actual conditions.

Table 506.19C (Metric) – AASHTO M 164 M(ASTM A 325M) Direct Tension Indicators

Bolt Size	Verification Tension[1] (kN)	Verification Required number of Entries[2,3]	Number of DTI Spaces between Protrusions	Installation Required Number of Entries[2,4]
M16	96	3-4	4	0-2
M20	149	3-5	5	0-2
M22	185	3-5	5	0-2
M24	215	3-5	5	0-2
M27	280	4-6	6	0-3
M30	342	4-7	7	0-3
M36	499	5-8	8	0-4

Table 506.19C (English) – AASHTO M 164 (ASTM A 325)
Direct Tension Indicators

Bolt Size (in.)	Verification Tension (kips)[1]	Verification Required number of Entries[2,3]	Number of DTI Spaces between Protrusions	Installation Required Number of Entries[2,4]
½	13	3-4	4	0-2
5/8	20	3-4	4	0-2
3/4	29	3-5	5	0-2
7/8	41	3-5	5	0-2
1	54	4-6	6	0-3
1-1/8	59	4-6	6	0-3
1-1/4	75	4-7	7	0-4
1-3/8	89	4-7	7	0-4
1-1/2	108	5-8	8	0-4

[1] Verification tension is 1.05 x the minimum tension in Table 506.19A.

[2] An entry occurs when a 5 mil tapered feeler gage fits into the space between DTI protrusions and touches the bolt shank.

[3] For coated DTIs under the turned element at least one entry is required.

[4] For coated DTIs under the turned element no entries are allowed.

(d) Acceptance of Bolt Tensioning. The installation and tightening of bolted connections shall be observed to determine if the tightening procedure is working properly and the correct tension has been achieved. The Engineer will observe and verify the checking of impact wrenches used for the calibrated wrench method. The Engineer will also observe and verify the checking of manual torque wrenches used for the torque method.

The Contractor shall provide a tension measuring device, such as a Skidmore-Wilhelm Calibrator, that has been calibrated within the last year and is accompanied by a certificate verifying its date of calibration. The wrench shall be calibrated yearly and accompanied by a certificate indicating the date of calibration.

Before the installation of fasteners in the work, the Engineer shall check the marking, surface condition, and storage of bolts, nuts, and washers and the faying (contact) surfaces of joints for compliance with the Contract requirements.

With the exception of inspecting direct tension indicators and the tension control assemblies, the Engineer will inspect fasteners after installation by applying the inspecting wrench to a minimum of 10 percent of the bolts, but not less than two bolts, selected at random in each connection. The actual torque value of each inspected bolt will be determined as the head or nut is rotated 5 degrees in the tightening direction. This value shall be within the minimum and maximum job inspecting torque values as determined during the calibration of the inspection torque wrench using the bolt tension values specified in Table 506.19A.

The Engineer will determine the inspection torque at least once each day by tightening five bolts of the diameter, length, and grade being used in the work in a device capable of indicating actual bolt tension. The job inspecting torque shall be taken as the average of three values thus determined after rejecting the high and low values. The inspecting wrench shall then be applied to the tightened bolts in the work and the torque necessary to turn the nut or head 5 degrees [approximately 25 mm at a 300 mm radius (1 inch at a 12 inch radius)] in the tightening direction shall be determined. Either the Engineer, or at the Engineer's option the Contractor in the presence of the Engineer, shall use the inspection wrench.

Bolt tension for fasteners with DTIs shall be verified by the use of a manual inspection torque wrench (which indicates torque by means of a dial) or by using 5 mil tapered feeler gages provided and operated by the Contractor.

All bolts installed using DTIs shall be inspected after snug tightening and again after full tensioning, with 100% of the bolts inspected visually and 10% of the bolts in any connection (but not less than two) inspected by feeler gage. If the installation of inspected bolts is accepted, then the connection shall be accepted as properly tensioned. If any bolt in a connection does not pass inspection, then all (100%) of the bolts in that connection shall be inspected with the feeler gage. Any bolt which does not pass inspection as described herein shall be further tensioned if required, or if over tensioned, removed and replaced by a new properly tensioned bolt and DTI.

Bolts installed using tension control assemblies shall be visually inspected for consistent "twist-off" and thread stick out.

If any bolt in a connection is found to have a torque value below the minimum or above the maximum job inspecting torque, all bolts in that connection shall be inspected. All under-tightened bolts shall be tightened and reinspected. All over-tightened bolts shall be loosened and the bolt and nut removed for visual inspection of the bolt and nut threads. If there is visible thread damage or the nut does not spin freely on the bolt when turned by hand without the aid of a wrench, a new bolt and nut shall be installed.

Undamaged fasteners may be reinstalled with the following exception: Galvanized bolts, AASHTO M 253M (AASHTO M253) bolts, tension control assemblies, and direct tension indicators shall not be reused.

This specification does not recognize standard torques determined from tables or from formulas which are assumed to relate torque to tension. Testing using such standard torques shall not be considered valid. Inspection torques must be determined directly from calibrations performed at the project site reflecting actual work conditions.

The procedure specified is intended for inspection of bolted connections and verification of pretension within 24 hours of tensioning the joint. If verification of bolt tension is required after a passage of a period of time and exposure of the completed joints, the procedures will provide an indication of bolt tension that is of questionable accuracy. Procedures appropriate to the specific situation should be used for verification of bolt tension. This might involve use of the inspection procedure, or might require the development and use of alternate procedures.

An additional required inspection step is to check the bolt thread stickout on the nut side after installation to the final specified gap to look for inconsistency of pattern. Any stickouts greater than the other bolts shall be investigated and discarded (e.g. if necking down of the bolt has occurred or the wrong length bolt was used). The end of the properly installed bolt shall be at least flush with the nut or stick out not more than three threads.

The Engineer shall be provided with safe access in accordance with Section 105 to conduct all inspection deemed necessary during and after the installation of the bolts. If the Engineer determines that the access provided is unsafe, work will be ordered to halt until such time the access is made safe. Any delays incurred by the unsafe access will not be cause for a monetary, material or delay claim.

506.20 THIS SUBSECTION RESERVED

506.21 STRAIGHTENING BENT MATERIAL. Damaged, bent, or misaligned structural steel may only be straightened or corrected by procedures approved by the Agency. The method of repair proposed by the Contractor shall be submitted as Construction Drawings for approval in accordance with Section 105. No corrective work shall be performed without Agency approval. Heating limitations and procedures shall conform to the requirements of Subsection 506.12.

Members or parts to be heat straightened must be free of stress from external forces other than those necessary and used in conjunction with the application of heat. Following straightening, the surface of the metal shall be free of any evidence of distortion or fracture. Required nondestructive tests shall be performed by NDT Level II or III personnel at the Contractor's expense.

506.22 FIELD CLEANING. When assembly of the fabricated structural components is complete, any rust, scale, dirt, grease, or other foreign material shall be removed from the metal components.

If the components are new steel which are metalized or galvanized or which are to remain unpainted, the cost of such necessary cleaning will not be paid for directly, but will be considered incidental to the Section 506 items in the Contract.

506.23 UNCOATED STEEL. Care must be taken to keep chemicals and oils from contacting the exposed surfaces of unpainted steel during storage, erection, and construction of the deck.

(a) Staining of Masonry. The Contractor shall protect all concrete and masonry from staining due to oxide formation on the steel.

(b) Cleaning of Steel. After all concrete has been placed, the outside surface of the fascia beams and bottom surface of their lower flanges shall be cleaned of all foreign material to a uniform appearance. The Engineer may require the exposed surfaces to be blast cleaned to preparation grade SSPC-SP10 defined by SSPC-VIS 1. The use of acids for cleaning is prohibited.

506.24 METHOD OF MEASUREMENT.

(a) Bids on a Kilogram (Pound) Basis. The quantity of Structural Steel, or other material being paid under this item, to be measured for payment will be the number of kilograms (pounds) used in the complete and accepted work. The mass (weight) of the material to be measured for payment under this item will be computed based on the approved Fabrication Drawings, as follows:

(1) Mass (weight) determined by the volume of material will be computed on the basis of the following densities:

Material	kg/m^3	$lbs./ft^3$
Aluminum, alloy	2800	173
Bronze, cast	8600	536
Copper, alloy	8600	536
Copper, sheet	8900	558
Iron, cast	7100	445
Iron, wrought	7800	487
Lead, sheet	11 300	707
Steel; rolled, cast, copper bearing, silicon, nickel and stainless	7850	490

For any material not listed above, the material will be paid for by actual mass (weight) as measured on a certified scale.

(2) The mass (weight) of rolled structural shapes will be computed on the basis of their nominal mass per meter (weight per foot) as shown on the Plans or, if not shown on the Plans, by the masses (weights) shown in the current edition of the AISC Manual.

The mass (weight) of rolled shapes will be based on the overall net length shown on the approved Fabrication Drawings, with no allowance for milling, finishing, or overrun, and with no deduction for cuts, clips, copes, or open holes.

(3) The mass (weight) of plates will be based on the net finished dimensions shown on the approved Fabrication Drawings, with no allowance for milling, finishing, tolerance, or overrun, and with no deductions for copes, clips, and open holes. The masses (weights) of beveled plates or curved surface plates will be based on the finished maximum thickness shown on the approved Fabrication Drawings.

For gusset plates, scupper components, slotted plates, and similar minor fixtures the net finished dimensions will be the minimum rectangular dimensions from which the parts are cut, except when it is practical to cut the parts in multiples from pieces of larger dimensions, in which case the mass (weight) will be based on the dimensions of the larger pieces, making necessary allowance for the material lost in cutting.

The net finished dimensions of flange plates will be the nominal width and the finished length measured along the centerline of the flange without deduction for width transitions, bevels, or chamfers.

The net finished dimensions of the webs of all girders and of the webs of rigid frame legs will be the actual area of the web as detailed on the approved Fabrication Drawings.

(4) The mass (weight) of fabricated metal items such as U-bolts, welding studs, and lugs will be based on the overall net dimensions of the finished product as shown on the approved Fabrication Drawings.

(5) All welding shall be considered as incidental work to the fabrication, and no measurement will be made for the mass (weight) of weld metal used.

(6) Measurement for castings will be by mass (weight) measured on scales.

(7) When it is specified that any part of the material is to be measured by actual mass (weight), finished work shall be weighed in the presence of the Inspector. In such case, the scales shall have been certified for accuracy within a one-year period.

(8) When the Contract includes bearings or bearing connections as part of this work, the mass (weight) of anchor bolts to be embedded in concrete will be based on the nominal dimensions shown on the approved Fabrication Drawings with no deduction for deformations but including the mass (weight) of nuts and washers. The mass (weight) of pins, pintels, and rollers will be based on the overall finished dimensions shown on the approved Fabrication Drawings with no deductions for threads, open holes, or pockets or allowance for excess diameter required for finishing.

(9) The mass (weight) of permanent shop and field bolts, nuts, direct tension indicators, and washers incorporated into the structure and temporary erection bolts, nuts, and washers shall be incidental to the Structural Steel item and no measurement will be made for mass (weight) of the bolts, nuts, direct tension indicators, and washers.

(b) Bids on Lump Sum Basis. The quantity of Structural Steel, or other material being paid under this item, to be measured for payment will be the number of units for each structure complete and accepted as specified in the Contract.

506.25 BASIS OF PAYMENT. The accepted quantity of Structural Steel will be paid for at the Contract unit price per kilogram (pound) for the items specified in the Contract. Payment will be full compensation for furnishing, detailing, handling, transporting, and placing the materials specified, including nondestructive testing of welds; for preparing the surface of new steel to be galvanized, metalized, or to remain unpainted; for necessary field cleaning; for sealer coating of metalized surfaces; for metalizing or galvanizing of surfaces unless otherwise paid for; for furnishing and implementing the erection plan, and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

Payment for Structural Steel on a lump sum basis will be full compensation for performing all work specified and for furnishing all labor, materials, tools, equipment, erection plan(s), and incidentals necessary to complete the work.

The costs of surface preparation of new steel to remain unpainted or to be galvanized or metalized will not be paid for directly, but will be considered incidental to the Section 506 items in the Contract.

Surface preparation of rehabilitated or reconditioned steel, whether it is to receive protective coating(s) or it is to remain uncoated; surface preparation of galvanized steel that is to receive additional protective coating(s); and surface preparation of new steel that is to receive protective coating(s), except for the sealer coating of metalized surfaces are not included in any Contract item in Section 506. The costs of this work will be paid under the appropriate painting item(s) in the Contract.

The Engineer may authorize progress payments in the following manner:

(a) A maximum of 75 percent of the estimated quantity may be paid when the steel has been delivered to the site.

(b) A maximum of 95 percent of the estimated quantity may be paid when the steel has been erected, falsework removed, extended weights have been received and checked, and painting of connections and “touch up” completed where required.

(c) After completion and acceptance of all work under this Section, 100 percent of the quantity will be paid.

All nondestructive testing and required quality control activities will be considered incidental to fabrication, and no separate payment will be made.

Payment will be made under:

Pay Item		Pay Unit
506.50	Structural Steel, Rolled Beam	Kilogram (Pound)
506.55	Structural Steel, Plate Girder	Kilogram (Pound)
506.56	Structural Steel, Curved Plate Girder	Kilogram (Pound)
506.57	Structural Steel, Truss	Kilogram (Pound)
506.60	Structural Steel	Kilogram (Pound)
506.75	Structural Steel	Lump Sum

SECTION 507 - REINFORCING STEEL

507.01 DESCRIPTION. This work shall consist of furnishing and placing bar reinforcement, dowels, wire, welded wire reinforcement (WWR)**,** and mechanical bar connectors.

507.02 MATERIALS. Materials shall meet the requirements of the following Subsections:

Mortar, Type IV	707.03
Bar Reinforcement	713.01
Mechanical Splices for Bar Reinforcement	713.02
Cold Drawn Steel Wire	713.04
Welded Wire Reinforcement (WWR)	713.05
Coated Bar Reinforcement	713.07

Spiral reinforcement for columns may be bar reinforcement or cold-drawn steel wire.

507.03 FABRICATION AND SHIPMENT.

(a) General. Bar reinforcement shall be cold bent to the shapes required..

Bar reinforcement shall be fabricated, bundled, tagged, marked, and shipped in accordance with the CRSI *Manual of Standard Practice*. The Fabricator shall maintain records that will provide traceability of identifying heat numbers for all material being fabricated for Agency projects or Contract orders referencing materials covered under this Section.

(b) Submittals. Prior to fabricating materials, the Contractor shall submit in accordance with Subsection 105.03 Fabrication Drawings of the reinforcement with splice details. The submittal shall include material lists, material designations, bending details, and manufacturer's literature for any securing materials.

507.04 PROTECTION OF MATERIAL. Reinforcing steel shall be protected from damage at all times by storing on blocking, racks, or platforms. When placed in the work, the reinforcing steel shall be free from dirt, detrimental scale, paint, oil, or other foreign substances.
All systems for handling and storing coated reinforcement shall have padded contact areas. Epoxy coated reinforcement stored on a project shall be covered with canvas or other suitable material that will effectively protect it against damage from ultraviolet light.

All damaged areas of reinforcement coating shall be repaired with materials and procedures recommended by the coating manufacturer. The materials and procedures must be approved by the Resident Engineer prior to the repairs. The epoxy coating shall be repaired prior to installation of the reinforcement. Repair prior to installation does not relieve the Contractor from repairing areas damaged during placement.

All repairs shall be inspected and accepted by the Resident Engineer prior to placing concrete. All bars with total damage, including previously repaired areas, greater than 2 percent of the bar surface area shall be rejected.

When cutting coated reinforcement, a cutting torch shall not be used. The use of a power hacksaw is acceptable. All cut ends shall be repaired as required for damaged areas.

507.05 PLACING AND FASTENING REINFORCING STEEL. Steel reinforcement shall be placed in the position shown on the Plans and held securely in place during the placing of concrete. Placement tolerances for reinforcing steel shall be 5 mm (1/4 inch) for cover and clearance and 25 mm (1 inch) for spacing of bars. Stirrups and spirals shall pass around main tension members and be securely attached to those members.

Reinforcing steel shall be spaced as specified from the face of the forms. Horizontal layers shall be spaced vertically by means of approved supports. Support material within 40 mm (1 1/2 inches) of a finished concrete surface shall be stainless steel, epoxy, plastic coated galvanized steel, or plastic.

Bar reinforcement shall not be further bent or straightened from the curvature produced at initial fabrication except when approved by the Engineer. If heating is approved for field bends, the temperature should not exceed that which produces a dull red color in the bar.

Bars spaced 300 mm (12 inches) apart or greater shall be tied at every intersection. Bars spaced less than 300 mm (12 inches) apart shall be tied at every other intersection. If reinforcement shows signs of distress during construction, the Engineer may direct additional tying.

Welding procedures shall be submitted for approval for any type of reinforcement welding. Welding of reinforcement steel will not be permitted without written permission of the Engineer. Welding shall conform to the requirements of Subsection 506.10. Special care shall be taken so that no undercut will occur and reduce the effective area of the reinforcing bars.

Tie wires and supports used for installation of coated reinforcement shall be coated with or be constructed of plastic, epoxy, or other approved materials that will prevent damage to the bar surface.

Horizontal mats of reinforcing steel shall have lines of support not exceeding 1 m (4 foot) spacing in either direction. Additional individual chairs may be required in the area of the fascia.

Reinforcement placed in any member shall be inspected and approved before any concrete is placed. Mechanical bar connectors shall be installed per the manufacturer's instructions.

507.06 PLACING DOWELS. Dowels shall be placed in existing concrete or ledge at locations shown on the Plans. Where Type IV mortar is to be used, holes shall be drilled to the depth shown on the Plans and shall be at least 25 mm (1 inch) greater in diameter than the dowel. Where approved adhesives are used, the manufacturer's recommendations shall be followed for hole sizing. Dowels shall be grouted with Type IV mortar or other approved material.

507.07 SPLICES. All reinforcement shall be furnished in the lengths shown on the Plans. No splicing of any type, except where shown on the Plans, will be permitted without the written approval of the Engineer.

Welded butt splices or mechanical splices shall be used only when specified in the Contract or with written approval of the Engineer.

507.08 LAPPING. Sheets of WWR shall overlap not less than the wire spacing and be securely fastened at the ends and edges. The edge lap shall be not less than the wire or bar spacing.

507.09 BAR LISTS. Bar lists and bending schedules shall be prepared by the vendor. It is the Contractor's responsibility to verify the vendor's bar lists and schedules for quantity, size, and shape of bar reinforcement for constructing the structural components shown in the Contract Documents or made a part thereof. If a Reinforcing Steel Schedule is provided in the Plans, it is solely for the purpose of arriving at an estimated quantity and any errors shall not be considered cause for an adjustment of the Contract unit price. Upon delivery of the fabricated material, one copy of the shipping schedule and tabulation of masses (weights) shall be furnished to the Engineer.

507.10 METHOD OF MEASUREMENT. The quantity of Reinforcing Steel, Epoxy Coated Reinforcing Steel, and Galvanized Reinforcing Steel to be measured for payment will be the total number of kilograms (pounds) of reinforcing bars, dowels, wire, and WWR used in the complete and accepted work except as otherwise provided, computed on the following basis:

(a) The mass (weight) of bars, wire, and dowels will be measured as either:

(1) The product of the length as shown on the approved shop bar lists and the standard mass per meter (weight per foot) of length as adopted by the CRSI, or

(2) If approved by the Engineer, the mass (weight) on a certified Bill of Lading from the reinforcement supplier. The Bill of Lading must be broken down and sub-totaled based on individual bar marks and types of reinforcement.

(b) The mass (weight) of WWR will be measured as either:

(1) The computed mass (weight) in accordance with the details shown on the Plans based on the standard mass (weight) accepted by the trade for the unit of material specified, or

(2) If approved by the Engineer, the mass (weight) on a certified Bill of Lading from the reinforcement supplier. The Bill of Lading must be broken down and sub-totaled based on individual bar marks and types of reinforcement.

(c) Measurement for payment will not be made for any clips, wire, or other material that may be used by the Contractor for keeping the reinforcing bars in their correct position.

(d) Measurement for payment will be adjusted for any material accepted with an overall dimensional length less than or greater than the 25 mm (1 inch) CRSI tolerance.

(e) When the substitution of bars of greater diameter than specified is permitted by written authorization of the Engineer, payment will be made for only the mass (weight) of steel that would have been required if the specified diameter had been used. In case short bars are used when full length bars are shown on the Plans, the mass (weight) to be measured will be only the equivalent of the mass (weight) of full length bars as if they had been used, with no allowance for laps.

The quantity of Drilling and Grouting Dowels to be measured for payment will be for the length of hole in meters (linear feet) to be drilled as shown on the Plans. If not shown on the Plans, the depth of drilled holes shall be 600 mm (2 feet). The dowel will be measured as Reinforcing Steel.

The quantity of Mechanical Bar Connectors will be the number of mechanical connectors installed in the complete and accepted work.

507.11 BASIS OF PAYMENT. The accepted quantities of Reinforcing Steel of the type specified will be paid for at the Contract unit price per kilogram (pound). Payment will be full compensation for furnishing, handling, welding, and placing the material specified and for furnishing all labor, fastening devices, tools, equipment, and incidentals necessary to complete the work.

The accepted quantity of Drilling and Grouting Dowels will be paid for at the Contract unit price per meter (linear foot). Payment will be full compensation for drilling the dowel hole, grouting the dowel in the hole, and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

When the Contract does not contain a quantity for Drilling and Grouting Dowels, this work will not be paid for directly but will be considered as incidental to other Contract items.

The accepted quantity of Mechanical Bar Connectors will be paid for at the Contract unit price for each.

Payment will be full compensation for furnishing, handling, placing, and joining the materials; and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

Payment will be made under:

Pay Item	Pay Unit
507.15 Reinforcing Steel	Kilogram (Pound)
507.16 Drilling and Grouting Dowels	Meter (Linear Foot)
507.17 Epoxy Coated Reinforcing Steel	Kilogram (Pound)
507.18 Galvanized Reinforcing Steel	Kilogram (Pound)
507.19 Mechanical Bar Connector	Each

SECTION 508 - SHEAR CONNECTORS

508.01 DESCRIPTIONS. This work shall consist of furnishing and welding shear connectors.

508.02 MATERIALS. Materials shall meet the requirements of the following Subsections:

Welded Stud Shear Connectors 714.10

508.03 WEATHER LIMITATIONS. Application of stud shear connectors or other welding on shear connectors shall not be done when the base metal temperature is below -18 °C (0 °F) or when the surface is wet or exposed to falling rain or snow.

508.04 PLACING, INSPECTING, AND TESTING.

(a) General. The Contractor shall install the shear connectors as detailed in the Contract and the approved structural steel fabrication drawings. Shear connectors shall be placed, inspected, and tested in accordance with the latest edition of AWS D 1.5.

When the base metal temperature of a member to which automatically welded shear connectors are to be attached is less than 2.0 °C (35 °F), the following requirements shall apply:

(1) Base Metal in Compression Only. The Contractor has the option of obtaining an approved welding procedure for application of the studs or preheating the base metal to a minimum of 10 °C (50 °F).

(2) Base Metal in Tension or Stress Reversal Zones. The base metal shall be preheated to a minimum of 20 °C (70 °F).

The base metal of all portions of a member in tension to which shear connectors are to be welded shall be preheated to 20 °C for thicknesses up to 40 mm (70 °F for thicknesses up to 1 1/2 inches); preheated to 65 °C for thicknesses over 40 to 65 mm (150 °F for thicknesses over 1 1/2 to 2 1/2 inches); and preheated to 110 °C for thicknesses over 65 mm (225 °F for thicknesses over 2 1/2 inches). Preheating applies to either shop or field applied shear connectors.

If, during the progress of the work, inspection and testing indicate that the shear connectors being furnished are not satisfactory, the Contractor shall make changes in the welding procedure, welding equipment, and type of shear connector as necessary to provide satisfactory results. Such changes shall be made at the Contractor's expense.

(b) Studs. Installation and acceptance of stud shear connectors shall be in accordance with the latest edition of AWS D1.5.

After being allowed to cool, the first two studs welded on each beam or girder shall be bent 45 degrees by striking the stud with a hammer. If failure occurs in the weld zone of either stud, the procedure shall be corrected, and two additional studs shall be successfully welded and tested before any more studs are welded to the beam or girder. The Contractor shall promptly inform the Engineer of any changes in the welding procedure. After the studs have been welded to the beams, the Engineer will make a visual inspection, and each stud will be given a light blow with a hammer. Any stud that does not emit a ringing sound when given a light blow with a hammer, that has been repaired by welding, or that has less than normal reduction in height due to welding shall be struck with a hammer and bent 15 degrees from the correct axis of installation. In the case of a repaired weld, the stud shall be bent 15 degrees in the direction that will place the repaired portion of the weld in the greatest tension. Studs that crack either in the weld or in the shank shall be replaced.

All tested shear connectors that show no sign of failure shall be left in the bent position.

The Engineer may select additional studs to be subjected to the bend test specified above.

508.05 METHOD OF MEASUREMENT. The quantity of Shear Connectors to be measured for payment will be on a lump sum basis for all the shear connectors installed in the complete and accepted work at each structure specified.

508.06 BASIS OF PAYMENT. The accepted quantity of Shear Connectors will be paid for at the Contract lump sum price for each structure specified. Payment will be full compensation for detailing, furnishing, transporting, handling, preheating, and welding of the material specified and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

Payment will be made under:

Pay Item	Pay Unit
508.15 Shear Connectors	Lump Sum

SECTION 509 - LONGITUDINAL DECK GROOVING

509.01 DESCRIPTION. This work shall consist of saw cutting longitudinal grooves into the surface of a concrete deck at the locations indicated in the Plans.

509.02 MATERIALS AND EQUIPMENT. Use multibladed wet saw cutting equipment using circular saw blades. The Engineer may allow the use of single blade, circular saw equipment, where it is determined such equipment is necessary to complete the work as required.

The equipment the Contractor proposes to use will be subject to the approval of the Engineer prior to use.

Water shall meet the requirements of Section 745.

509.03 CONSTRUCTION DETAILS. The Contractor is hereby notified that concrete curing requirements may have a significant effect upon the specific time at which saw cut grooving may be performed. The Contractor shall be familiar with the limits imposed by these factors and conduct operations accordingly.

Start saw cutting only after the specified curing period has elapsed, unless otherwise allowed by the Structural Concrete Engineer. Cut longitudinal grooves parallel to the centerline of roadway using a single pass. Space the center-to-center of grooves at 19 mm ± 2 mm (3/4" ± 1/16"). Cut all grooves rectangular in shape conforming to the following dimensions:

Width: 2.5 mm (+ 0.5 mm, - 0.0 mm) ((3/32") (+ 1/32", - 0.0"))
Depth: 4 mm (± 2 mm) ((5/32")(± 1/16"))

During the grooving operations, the Engineer will verify, at random, that the minimum groove depth is being achieved. Should the Engineer determine that minimum groove depth is not being achieved, the Contractor shall stop grooving operations and make all adjustments necessary to achieve the minimum depth. The Contractor shall go back and correct any previous grooves to bring them into conformance with the specification.

Prior to beginning grooving operations, the Contractor shall supply the Engineer with two (2) accurate, easily readable gauges with which to verify groove depth. The gauges shall come with applicable manufacturer's instructions.

Terminate grooves within the following limits unless otherwise indicated in the Contract Documents:

Location	Closest Allowable Distance	Farthest Allowable Distance
Drainage Structure:	100 mm (4 inches)	380 mm (15 inches)
Face of Curb or Barrier:	100 mm (4 inches)	380 mm (15 inches)
Joint System (Dimension measured perpendicular to the centerline of the joint system):	100 mm (4 inches)	380 mm (15 inches)

The Contractor shall use a self-contained system to continuously collect any slurry or debris created by the grooving operation such that it does not accumulate on the surface.

509.04 METHOD OF MEASUREMENT**.** The quantity of Longitudinal Deck Grooving to be measured for payment will be the number of square meters (square yards) of deck satisfactorily grooved in the complete and accepted work, measured transversely between curb or barrier and longitudinally between the ends of the deck, computed to the nearest whole square meter (square yard). No deduction will be made for areas left ungrooved near concrete railing, joints, or other objects embedded in the deck.

509.05 BASIS OF PAYMENT. The accepted quantity of Longitudinal Deck Grooving will be paid for at the Contract unit price per square meter (square yard). Payment will be full compensation for performing the work specified and for furnishing all materials, labor, tools, equipment, and incidentals necessary to complete the work.

Payment will be made under:

Pay Item	Pay Unit
509.10 Longitudinal Deck Grooving	Square Meter (Square Yard)

SECTION 510 – PRESTRESSED CONCRETE

510.01 DESCRIPTION. This work shall consist of manufacturing, transporting, and erecting precast prestressed concrete members.

510.02 MATERIALS. Materials shall meet the requirements of the following Subsections:

Portland Cement 701.02
High Early Strength Portland Cement 701.04
Blended Silica Fume Cement 701.06
Tar Emulsion 702.05
Fine Aggregate for Concrete 704.01
Coarse Aggregate for Concrete 704.02
Mortar, Type I 707.01
Mortar, Type IV 707.03
Asphalt-Treated Felt 707.08
PVC Waterstop 707.10
Bar Reinforcement 713.01
Prestressing Strand 713.06
Structural Steel 714.01-714.05
Concrete Curing Materials 725.01
Air-Entraining Admixtures ..... 725.02(b)
Retarding Admixtures ..... 725.02(c)
Water-Reducing Admixtures ..... 725.02(f)
Water-Reducing and Retarding Admixturse ..... 725.02(g)
Water-Reducing, High Range Admixtures ..... 725.02(h)
Water-Reducing, High Range, and Retarding Admixtures ..... 725.02(i)
Accelerating Admixtures ..... 725.02(j)
Water-Reducing and Accelerating Admixtures ..... 725.02(k)
Low Shrinkage Admixtures ..... 725.02(l)
Mineral Admixtures 725.03
Silica Fume ..... 725.03(b)
Ground Granulated Blast-Furnace Slag (GGBFS) ..... 725.03(c)
Polystyrene Insulation Board 735.01
Blanket Insulation Material 735.02
Pipe Insulation 740.08
Water 745.01

510.03 GENERAL FABRICATION REQUIREMENTS.

(a) General. The manufacture of the prestressed units shall be in accordance with the latest editions of PCI MNL-116 *Manual for Quality Control for Plants and Production of Precast and Prestressed Concrete Products* and PCI MNL 135-00 *Tolerance Manual for Precast and Prestressed Concrete Construction***,** except as modified in this Section.

(b) Qualification. The prestressed members shall be manufactured in a plant that has been certified by the Prestressed Concrete Institute under its Plant Certification Program for prestressed concrete.

(c) Quality Control. The Fabricator shall demonstrate a level of quality control testing that satisfies the Agency as to its ability and commitment to produce concrete to the requirements of this Section. A satisfactory program of quality control shall include gradation and moisture determinations of the aggregates, as well as slump, air content, and strength determinations of the concrete. These tests shall be performed at regular and suitable intervals and actively used to maintain the quality of the concrete within the specified requirements.

510.04 DESIGN AND DRAWINGS. As soon as practical after award of the Contract, Fabrication Drawings, calculations, and pertinent data shall be submitted in accordance with Section 105. In addition to the requirements in Section 105, the following shall be included:

(a) The dimensions of the sections to be fabricated.

(b) The concrete mix design**,** including but not limited to the following:

(1) Batch weights specifying dry or saturated surface dry.

(2) Material names and sources.

(3) Aggregate properties and date tested.

(4) Chemical and physical properties of cementitious material.

(5) Admixture names and sources.

(6) Lab data that shall include, but not be limited to:

a. Slump.

b. Air Content.

c. Temperature.

d. Ratio of Water/Cementitious Material.

e. Cylinder breaks for 3, 7, and 28 days cured in the same manner as the piece to be fabricated.

f. 56 day Rapid Chloride Ion Permeability – AASHTO T 277 test data. The information shall include the individual results from testing 3 specimens, but no specimen shall exceed the maximum specified in Subsection 510.05 (b)(6). Testing shall be performed by a CCRL qualified laboratory.

g. Alkali-Silica Reactivity (ASR) – AASHTO T 303 test data from both fine and coarse aggregates**.** Testing shall be performed by a CCRL qualified laboratory.

(7) Alkali-Silica Reactivity (ASR) – If potentially reactive aggregates are to be used in a mix design, then proposed mitigation method(s) and test results must be provided. The AASHTO T 303 test must be run again with the proposed mitigation method(s) and using the proposed job cementitious material proportioning. The proposed mitigation method(s) shall reduce expansion to below 0.10%.

If a mix design, including the testing results, has been submitted and approved within a 12 month period for the manufacture of prestressed concrete units, it may be used in lieu of submitting an additional mix design. However, if any change in the material sources or properties has occurred, then a new mix design with lab test data will be required regardless of previous approval.

(c) The sources and properties of the materials proposed for use.

(d) The methods of prestressing, including certified calibration charts for all jack and gauge combinations.

(e) Tensioning calculations for prestress strands that include gauge pressure, elongations**,** and movement of anchorage abutments.

(f) The method and sequence of strand detensioning.

(g) The placement of reinforcing steel and prestress strands.

(h) The type of surface finish and how the finish will be obtained.

(i) The curing method, detailing sequence and duration.

(j) The grouting procedure.

(k) The design of the lifting attachments.

(l) Transportation, handling, and storage details.

(m) The installation procedure.

(n) Description of Quality Control procedures.

All design details shall be in accordance with the most recent edition of the Vtrans *Structures Design Manual* available on the Agency's website and the AASHTO *LRFD Bridge Design Specifications.*

510.05 CONCRETE.

(a) Batch plant equipment, materials, and batching procedures shall conform to the following provisions of Section 501:

501.04	BATCHING, paragraphs 1 and 3 only.
501.04(b)	Testing Laboratory.
501.04(c)	Bins and Scales.
501.04(d)	Accuracy of Plant Batching.
501.04(e)	Storage and Proportioning of Materials.
501.05	MIXING AND DELIVERY, for plants not located in the State, the Agency has the option of waiving the requirements of Part (a)(4) and Part (c), paragraphs 1 and 3 only.

(b) Concrete for prestressed members shall conform to the following:

(1) Compressive strength at 28 days, as determined in accordance with AASHTO T 22, of not less than the design compressive strength shown on the Plans. When a 28-day test result is below the specified strength, all concrete represented by that test shall be unacceptable for the requirements of this Section. The Engineer reserves the right to reject all members that were manufactured from this concrete.

(2) The cementitious material content in the mix design shall be between 363 and 475 kg/m³ (611 and 800 pounds per cubic yard) of concrete.

(3) The percent of air entrainment shall be 7 percent with a tolerance of +/- 2 percent, as tested in accordance with AASHTO T 152.

(4) The temperature of the concrete at the time of placement shall be between 10 and 29 ºC (50 and 85 ºF), as tested in accordance with AASHTO T 309.

(5) The maximum water-cementitious material ratio shall be 0.44. When a water-reducing, high range admixture (AASHTO M 194, Type F or Type G) has been included in the approved mix design, the concrete shall not demonstrate segregation at the proposed slump.

(6) The maximum allowed rapid chloride ion coulomb permeability result as tested per AASHTO T 277 is 2000, tested at 56 days from the date specimens were cast.

(7) The maximum allowable mortar bar expansion when tested per AASHTO T 303 (with proposed mitigation method(s), as described previously, if required) shall be 0.10%.

(c) The proposed concrete mix design, including performance history and all requests for variance from the material requirements of these Specifications, shall be submitted for review and acceptance as part of Subsection 510.04. The Structural Concrete Engineer may require 8 weeks for testing, review and acceptance of the mix design.

(d) Any admixture containing calcium chloride shall not be used. Type II, Type III, or Blended Silica Fume portland cement may be used. Only one type of cement and only one source of that type shall be used for the prestressed units required for any one structure.

510.06 INSPECTION. Materials furnished and the work performed under Section 510 shall be inspected by the Agency. The inspector will have the authority to reject any material or work that does not meet the requirements of these Specifications. Advance notification of at least one week shall be provided by the Fabricator to the Agency's Engineer and Structural Concrete Engineer indicating the fabrication start date.

Prior to shipment of any members, the Materials and Research Engineer will have approved all applicable material certifications required in accordance with Subsection 700.02.

510.07 PRESTRESSING. Prestressing shall be accomplished by the pre-tensioning method.

The Fabricator shall provide all equipment necessary for the prestressing operations. Prestressing shall be done with approved jacking equipment. Hydraulic jacks shall be equipped with pressure gauges or other indicating devices. The combination of jack and pressure gauge, or other tensioning system, shall be accompanied by a certified calibration chart showing the relationship between the gauge reading and force in the ram for both ascending and descending movements of the ram. The calibration date of each combination jack and gauge or indicating device shall be within the 12-month period immediately prior to the start of work.

If other types of jacks are used, calibrated proving rings or other devices shall be furnished so that the jacking force may be accurately determined.

Suitable precautions shall be taken by the Fabricator to prevent accidents due to breaking of the prestressing steel or slippage of the grips during prestressing operations.

The tensioning operation shall proceed until the calculated gauge reading has been reached. The elongation of each strand shall then be measured. If the measured elongation differs from the theoretical by more than 5 percent, the tensioning operation shall be stopped, and the cause of the discrepancy determined prior to continuing.

Immediately after tensioning, the final position of each strand shall be marked for the purpose of checking possible strand relaxation.

510.08 FABRICATION.

(a) Pre-Production Meeting. Unless the Engineer deems, in writing, that a pre-production meeting is unnecessary, then a pre-production meeting shall be held a minimum of seven (7) calendar days prior to beginning concrete placement. The pre-production meeting shall be attended by, and including but not limited to, the Crew Supervisor, Plant Manager, Inspector or Inspector's Supervisor, and Project Manager and/or Designer.

(b) Forming Members. Side forms shall be supported without the use of ties or spreaders within the body of the member. Any defects or damage due to form work, stripping, or handling may be cause for rejection. Forms for interior voids or holes in the members shall be constructed of a material that will adequately resist breakage or deformation during concrete placement and that will not materially increase the mass (weight) of the members. Interior void forms shall be accurately positioned as shown on the Plans and secured to prevent displacement during concrete placement. All voids shall be adequately vented to prevent damage to the members during curing. Each void shall contain a suitably located drain hole. Holes or cutouts for anchoring devices, diaphragm connections, openings for connection rods, recesses for grout holes for railing bolts, and any other related details shown on the Plans shall be provided for in the members. Where diaphragm dowels do not pass through the member, the dowels may be attached by use of an approved anchorage embedded in the concrete member.

(c) Placing Transverse Conduits and Tendons. Each tendon to be post-tensioned shall be encased in an approved conduit. Unless otherwise shown on the Plans, the ratio of cross-sectional area of the tendon to be encased to the interior cross-sectional area of the conduit shall not exceed 0.4, except when a steel bar is used as a tendon, the inside diameter of the conduit shall be at least 10 mm (3/8 inch) greater than the diameter of the bar. Conduit that has been crushed or has opened seams shall not be used.

The conduit shall be rigidly constructed, completely sealed, accurately placed, and securely fastened to maintain the desired profile during concreting. No conduit shall be located more than 6 mm (1/4 inch) from the position shown on the Plans. Bundling of conduits will not be permitted.

(d) Placing Prestress Strands. Prestress strands shall be accurately placed in position to achieve the center of gravity of the steel as shown on the approved shop drawings. Prestress strands shall be protected against corrosion and be free of nicks, kinks, dirt, rust, oil, grease, and other deleterious substances.

(e) Bar Reinforcement. Bar reinforcement shall be furnished and installed in conformance with Subsections 507.03, 507.04, 507.05, and 507.07.

(f) Pre-Tensioning. The prestress strands shall be stressed by jacking in accordance with Subsection 510.07, and in the presence of an Agency representative. The jacking force exerted and the elongation produced shall be recorded. Several units may be cast and stressed at one time in a continuous line. Sufficient space shall be maintained between the ends of the units to permit access for cutting strands after the concrete has attained the required strength.

(g) Thermal Effects. For abutment anchorage set-ups where the strands are anchored to abutments that are independent from the form, thermal adjustments shall be made if the ambient temperature at the time of tensioning differs by more than 15 ºC (25 ºF) from the concrete temperature prior to placement and if the net force differential is greater than 2.5%. Consideration shall be given to partial bed length usage and adjustments made when the net effect on the length of the bed used exceeds the allowable. The thermal coefficient of steel shall be taken as 12 x 10^{-6}/ºC (6.5 x 10^{-6}/ºF).

(h) Placing Concrete. Concrete shall not be deposited in the forms until the Agency representative has approved placement of the reinforcement, conduits, anchorages, and prestressing strand. The concrete shall be vibrated internally, externally, or a combination thereof to the required consolidation. The vibrating shall be done with care and in such a manner that:

(1) Concrete is uniformly consolidated.

(2) Displacement of reinforcement, conduit, voids, and prestressing strand is avoided.

(3) Acceptable finish surfaces are produced.

(i) De-tensioning. No stress shall be transferred to the concrete until 80 percent of the design compressive strength (f'c) has been attained. The compressive strength shall be determined by cylinders tested in accordance with Subsection 510.09. The prestressing strands shall be released in the de-tensioning pattern detailed on the shop drawing. If de-tensioning is accomplished by single strand release, each strand shall be cut by gradually heating the strand at both ends of the member simultaneously. A minimum length of 125 mm (5 inches) of strand shall be heated to prevent any shock or snap when the strand is finally severed. Each strand shall be cut at all spaces between members cast continuously, before starting de-tensioning on the following strand in sequence.

(j) Dimensional Tolerances. All dimensional tolerances shall be in accordance with the latest editions of PCI MNL – 116 *Manual for Quality Control for Plants and Production of Precast and Prestressed Concrete Products* and PCI MNL 135-00 *Tolerance Manual for Precast and Prestressed Concrete Construction*, unless otherwise noted in the Contract Documents or as approved by the Engineer. Camber shall be measured as soon as possible after detensioning and at approximately the same time for each product piece. Camber shall be noted for process monitoring/consistency of production.

(1) Dimensional Tolerances for Prestress Deck Panel.

Vertical position of strand group (measured from bottom of panel)	+0, -3 mm (+0,-1/8 inch)
Dunnage	± 150 mm (± 6 inches)
Warping (distance from nearest adjacent corner)	5 mm per m (1/16 inch per foot)
Finish of strands (minimum extension beyond ends of panel)	100 mm (4 inches)

(k) Repairs/Patching. Projecting strands shall be torch cut unless otherwise specified on the Plans. If strands are required to be recessed**,** the recess shall be thoroughly cleaned and patched with Mortar, Type IV. The mortar shall be wet cured for three days or as specified by the manufacturer. Units that contain minor defects caused by manufacture or handling may be repaired at the manufacturing site. Minor defects are defined as holes, honeycombing, or spalls, which are 150 mm (6 inches) or less in diameter, that do not penetrate deeper than 25 mm (1 inch) into the concrete. Surface voids or "bugholes" that are less than 16 mm (5/8 inch) in diameter and less than 6 mm (1/4 inch) deep need not be repaired. Repairs shall be made using an overhead and vertical concrete repair material satisfactory to the Engineer. The repair material shall be cured as specified by the manufacturer. Repairs shall be approved by the Engineer.

(l) Cracking. Cracks less than 0.25 mm (0.01 inch) in width shall be sealed by a method approved by the Engineer. Cracks in excess of 0.25 mm (0.01 inch) may be cause for rejection. At the Engineer's discretion, cracked members shall be repaired or replaced at the Contractor's expense. De-tensioning procedures causing web splitting or other member cracking shall be revised before de-tensioning the next bed.

(m) Deck Panel Rejection Criteria.

(1) Any crack transverse or diagonal to strand pattern and crossing more than one strand.

(2) Any crack parallel to a strand and longer than 33% of the panel length.

(3) Cracks shorter than 33% of the panel length and present at more than 12% of the total number of strands in the panel.

(4) Voids or honeycombed areas with exposed strands.

(5) Any other reason the Engineer determines could have an adverse impact on the structural integrity of the deck panel.

(n) Finishing Riding Surfaces with No Asphalt Wearing Surface. All exposed riding surfaces not covered with an asphalt wearing surface shall be given a turf drag finish in accordance with Subsection 501.16.

(o) Welding. All welding shall conform to the requirements of Subsection 506.10.

510.09 CONCRETE TESTING.

(a) General. Prestressed members shall be manufactured in a plant that maintains a quality control laboratory that meets the requirements of the Agency's Qualified Laboratory Program, available on the Agency's website. The laboratory shall be complete with equipment for measuring the properties of fresh and hardened concrete. As a minimum, the laboratory shall be equipped with a compression testing machine, curing room, or chamber, apparati for measuring slump and air entrainment, and a complete set of aggregate sieves. The compression testing machine shall be power operated and capable of applying the load continuously rather than intermittently, and without shock.

(b) Testing of Compressive Strength. Specimens shall be standard cylinders made by the Fabricator in accordance with AASHTO T 23. Fabrication of test specimens shall be witnessed by an Agency representative. Molds for forming test specimens shall conform to AASHTO M 205 and shall be supplied by the Fabricator. For each bed of pre-tensioned members, the Fabricator shall make for the Agency the following minimum number of specimens:

(1) Six specimens to determine strength prior to de-tensioning. These specimens shall be cured from the time of casting, under the same conditions as the concrete in the work.

(2) Four specimens to determine compliance with the 28-day strength requirement. The specimens shall be cured under the same conditions as the member from the time of casting until the member is removed from the form. At that time, the specimens shall be moved to storage where curing shall continue under standard conditions in accordance with AASHTO T 23. These specimens shall be retained by the Fabricator for testing by the Agency.

The average of the compressive strengths of two specimens shall constitute a test result. Specimens shall be tested either at the Agency's Materials and Research Section laboratory, or at the manufacturer's plant laboratory. An Agency representative will witness all tests. Unless otherwise specified, de-tensioning shall only be permitted after two successive specimens have been tested and the average strength of these specimens is equal to or greater than the strength required in the Contract for de-tensioning.

If the average strength of specimens from a member does not reach the 28-day design strength within 28 days, the member shall be rejected.

510.10 CURING.

(a) General. All curing methods shall be subject to the Engineer's approval. Where the Fabricator elects to cure by method(s) other than low pressure steam or radiant heat as described below, the Fabricator shall submit with the Fabrication Drawings complete details of the proposed method(s) for approval.

The Fabricator shall provide one automatic temperature recorder for every 30 m (100 feet) of casting bed. The recorder shall continuously record curing temperature for the entire curing period. Temperature sensors shall be carefully placed within the curing enclosure to ensure that ambient temperatures are measured at typical locations. Recorder accuracy shall be certified at least once every 12 months, and the certificate displayed with the recorder. Calibration and certification shall be performed by either the manufacturer, the supplier, or an independent laboratory. Random temperature checks of each recorder may be made by an Agency representative. Each recorder chart shall indicate the casting bed, date of casting, time of start and finish of record, and the mark number of prestressed units being cured. At the completion of the curing period, the recorder charts shall be given to the Agency representative. Temperatures recorded on the charts shall be used to determine whether the prestressed units have been cured in accordance with the specifications and the approved Fabrication Drawings.

Curing by the approved method shall continue uninterrupted until the start of de-tensioning operations. De-tensioning shall be accomplished immediately after the steam curing or heat curing has been discontinued. After the de-tensioning is complete, the unit shall be wet cured for seven (7) days.

(b) Curing with Low-Pressure Steam or Radiant Heat.

(1) Immediately upon completing placement of the concrete for each unit, an enclosure shall be placed over the casting bed. This enclosure shall be suitable for containing the live steam or heat. The Fabricator shall make these covers available for inspection prior to casting.

(2) When low pressure steam methods are used for curing, precautions shall be taken to prevent live steam from being directed on the concrete or forms in such a way as to cause localized high temperatures.

(3) When radiant heat is used for accelerated curing, all exposed concrete surfaces shall be covered with plastic sheeting. Radiant heat may be applied by means of a circulation pipe containing steam, hot oil, or hot water, or by electric heating elements.

(4) The concrete shall be allowed to attain its initial set before commencing accelerated curing. This waiting period shall not exceed four hours from time of placement for concrete with no retarder added, or eight hours from the time of placement for concrete with retarder. During this initial curing period, while waiting for the initial set to take place, the temperature within the enclosure shall be maintained between 10 and 27 ºC (50 and 80 ºF).

(5) During the initial application of heat or steam, the ambient air temperature within the enclosure shall increase at a rate not exceeding 20 ºC (40 ºF) per hour until the maximum curing temperature is reached. The maximum curing temperature shall not exceed 71 ºC (160 ºF). The selected curing range shall be as approved on the Working Drawings. The maximum temperature shall be held until the concrete has reached a minimum of 80 percent of f'c, unless otherwise specified in the Contract.

510.11 HANDLING. Handling and installation of prestressed members shall be performed with members in an up-right position and with points of support and direction of reactions in approximately the same locations as designated for the final position of the members in the structures. The Contractor must receive authorization from the Agency prior to shipment or erection of any members.

Care shall be taken during storage, hoisting, and handling of the precast units to prevent cracking or damage. Units damaged by improper storing or handling shall be replaced at the Contractor's expense.

510.12 INSTALLATION.

(a) Prestressed Concrete Members.

(1) Methods, Equipment and Erection. Cranes, lifting devices, and other equipment for all prestressed concrete member erection shall be of adequate design and capacity to safely erect, align and secure all members and components in their final positions without damage. The Contractor is solely responsible for the methods and equipment employed for the erection of the prestressed concrete member.

Construction Drawings for prestressed concrete member erection shall be submitted in accordance with Section 105. The erection plan shall include the methods and sequence of prestressed concrete member erection, temporary bracing requirements, the equipment to be used for the erection, the necessary computations to demonstrate that all of the erection equipment has adequate capacity for the work to be performed, and provisions for all stages of construction, including temporary stoppages. When the Fabricator designed lifting hooks will be used by the Contractor, computations indicating the magnitude of stress in the segments during erection are not required, unless otherwise ordered by the Engineer.

The prestressed concrete members may be used for support of equipment prior to placement of the deck only with written permission of the Engineer. The proposed use of the prestressed members for support of equipment shall be detailed in the erection plan.

Submittal of the erection plan is for documentation purposes only and shall in no way be construed as approval of the proposed method of erection. The Contractor shall follow the erection plan as submitted.

(2) Initial Post-tensioning. Initial post-tensioning shall not commence until 24 hours after the last prestressed unit has been placed. The Contractor shall insert post-tensioning strand in the conduits and pull to 13.3 kN (3.0 kips) tension.

(3) Grout. Grout shall be placed according to the requirements of Subsection 510.13.

(4) Fairing Surface. This work shall consist of placing grout between precast members as required for fairing out any unevenness between adjacent units. Mortar, Type IV shall be used. Placement shall be at the same time mortar is placed to fill shear keys between members and in accordance with Subsection 510.13.

The mortar shall be placed to eliminate unevenness, forming a smooth surface from the higher beam edges to the lower surface. The finished surface shall be feathered smoothly and be free of depressions or sharp edges.

(5) Final Post-tensioning. Strands shall be tensioned in accordance with the requirements of Subsection 510.14.

(b) Prestressed Deck Panels.

(1) Panels shall be installed as shown on the Plans. The temporary supports shall be attached to the top of the flange of the girder with an adhesive, approved by the Engineer, in accordance with the manufacturer's recommendations. The temporary supports shall be cut in the field to the required height after the blocking depth has been determined.

(2) Panels shall not be used to support heavy loads, such as additional deck panels, until the top slab is cast and cured. Construction loads on individual panels shall be uniformly applied and shall not exceed an average loading of approximately 2000 Pa (40 pounds per square foot).

(3) After the panels have been placed on temporary supports, the area under the ends of the panels and over the girder flanges up to the bottom of the panels shall be completely filled with Concrete, High Performance Class AA (or other material, as specified on the Plans). Temporary support/grout dams for precast deck panels shall consist of continuous, high density, expanded polystyrene strips (grout dam) with a minimal compressive strength of 380 Pa (55 psi). If leveling screws are used, a 27.2 kg per cubic meter (1.7 pounds per cubic foot) polyethylene foam shall be used as a grout dam. The concrete shall be wet cured until a minimum of 85 percent of f'c is attained by the average strength of two field cured cylinders prior to placement of the cast-in-place deck. If leveling screws are used, they shall be completely removed and the holes filled with grout prior to the placement of deck concrete.

(4) Prior to placing the deck concrete, laitance or other contaminates that would interfere with full bond to the panels shall be removed by an approved method.

510.13 GROUT.

(a) The Fabricator shall sandblast surfaces to be grouted to ensure a clean, oil-free, roughened surface.

(b) Grout used to fill shear keys, leveling screw voids, transverse tie anchor recesses, dowel holes, and for fairing joints shall be Mortar, Type IV. Acceptable grout materials shall be those included on the Approved Products list on file with the Agency's Materials and Research Section. Additional aggregates shall not be added to the material during field mixing.

The Contractor shall submit a grouting procedure proposal to the Engineer, including a premix name brand for approval.

For testing, 6 neat 50 mm (2 inch) cubes shall be molded and cured in accordance with AASHTO T 106 (ASTM C 109). The average compressive strength of 3 cubes at 3 days shall be a minimum of 7 MPa (1000 psi) and a minimum of 35 MPa (5000 psi) in 28 days.

(c) The surface to be grouted shall be thoroughly cleaned, wetted, and free of all standing water.

The grout shall be mixed using a mechanical mixer according to the manufacturer's recommendations and shall be readily pourable so that it completely fills the shape of the shear keys or holes, depending on the product being installed. The placement of the grout for each shear key shall be continuous. The grouting of each shear key shall be completed in its entirety within a single working day.

The Contractor, with the written permission of the Engineer, has the option to use ready mixed mortar for the grouting process. However, the maximum quantity that can be delivered in a single load is one cubic meter (1.25 cubic yard), which must be delivered and placed within the time limits set by the manufacturer.

(d) All exposed grout shall be cured for a period of not less than three days by the wetted burlap method in accordance with Section 501. Curing shall commence immediately following completion of grouting of individual shear keys. During this curing period, the Contractor shall not apply any additional post-tensioning force.

510.14 TRANSVERSE POST-TENSIONING. Transverse post-tensioning strands shall not be bonded to the concrete. Post-tensioning strands shall be protected against corrosion as specified in the Contract.

Post-tensioning of strands shall not commence until a minimum compressive strength of 10 MPa (1500 psi) has been attained in the grout and the grout has cured for three days.

Strands shall be stressed in the following sequence: Before grouting, the strands shall be pulled with a maximum force of 13.3 kN (3.0 kips). After the grout has attained required strength and proper cure time is complete, the strands shall be pulled to a final 133.4 kN (30.0 kips) tension. The sequence shall begin by pulling the inner-most strands first, then proceeding symmetrically towards the members ends. The inner strands shall be rechecked to ensure the strands have 133.4 kN (30.0 kips) tension. In the case where the Plans call for top and bottom strands, the sequence shall be followed using an initial pull of 66.7 kN (15.0 kips), top and bottom, followed by a sequence using a final (total) pull of 133.4 kN (30.0 kips) tension.

510.15 METHOD OF MEASUREMENT. The quantities of Prestressed Concrete Box Beams and Voided Slabs to be measured for payment will be the number of meters (linear feet) of the types and sizes of prestressed concrete members used in the complete and accepted work.

The quantity of Grouting Shear Keys to be measured for payment will be the number of meters (linear feet) of grouted shear keys in the complete and accepted work.

Prestressed deck panels and concrete support beds for the panels will not be separately measured for payment, but will be considered within the volume measurement limits for payment of superstructure concrete.

510.16 BASIS OF PAYMENT. The accepted quantities of Prestressed Concrete Box Beams and Voided Slabs will be paid for at the Contract unit price per meter (linear foot) for the types and sizes of prestressed concrete members specified. Payment will be full compensation for detailing, fabricating, repairing, sandblasting, quality control testing, transporting, handling, and installing the materials specified, including the concrete, reinforcement, prestressing steel, transverse ties, enclosures for prestressing steel, anchorages, mortar, anchor rods, any other material contained within or attached to the members, for furnishing and implementing the erection plan, and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

The accepted quantity of Grouting Shear Keys will be paid for at the Contract unit price per meter (linear foot). Payment will be full compensation for providing all materials and performing the work specified herein, and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

Any other grouting work, such as fairing out unevenness between adjacent units and filling leveling screw holes, transverse anchor recesses, and dowel holes, is considered incidental to the work for prestressed concrete members.

Payment will be made under:

Pay Item	Pay Unit
510.21 Prestressed Concrete Box Beams	Meter (Linear Foot)
510.22 Prestressed Concrete Voided Slabs	Meter (Linear Foot)
510.23 Prestressed Concrete Girders	Meter (Linear Foot)
510.24 Grouting Shear Keys	Meter (Linear Foot)

SECTION 511

THIS SECTION RESERVED

SECTION 513

THIS SECTION RESERVED

SECTION 514 - WATER REPELLENT, SILANE

514.01 DESCRIPTION. This work shall consist of furnishing and applying a penetrating-type protective sealer on concrete surfaces.

514.02 MATERIALS. The material shall be a one-component material consisting of a penetrating-type sealer which does not alter the color or texture of the Portland cement concrete.

Acceptable penetrating-type sealers shall be those appearing on the Approved Products List on file with the Agency's Materials and Research Section.

514.03 PACKAGING, DELIVERY, AND STORAGE. The material shall be delivered to the project in original, manufacturer's unopened containers and stored in accordance with the manufacturer's recommendations.

514.04 PREPARATION OF SURFACES. All surfaces on which the protective sealer is to be applied shall be clean and thoroughly dry to the satisfaction of the Engineer and in accordance with the manufacturer's recommendations. Dirt, grease, curing compounds, asphalt, or other foreign materials shall be removed from the concrete surface before application of the sealer.

514.05 APPLICATION. The material shall be applied to the satisfaction of the Engineer and in accordance with the manufacturer's recommendations.

In the absence of specific recommendations from the manufacturer, the protective sealer shall not be applied to new concrete surfaces that are less than 14 days old. The concrete surfaces shall be free from precipitation for 48 hours prior to application of the sealer. Application of the sealer shall be completed within 40 days of original concrete placement.

514.06 PROTECTION. After application of the sealer, the concrete surfaces shall be protected to the satisfaction of the Engineer and in accordance with the manufacturer's recommendations.

514.07 METHOD OF MEASUREMENT. The quantity of Water Repellent, Silane to be measured for payment will be the number of liters (gallons) of solution applied in the complete and accepted work, measured to the nearest liter (gallon).

514.08 BASIS OF PAYMENT. The accepted quantity of Water Repellent, Silane will be paid for at the Contract unit price per liter (gallon). Payment will be full compensation for furnishing, transporting, handling, and placing the material specified and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

Payment will be made under:

Pay Item	Pay Unit
514.10 Water Repellent, Silane	Liter (Gallon)

SECTION 516 - EXPANSION DEVICES

516.01 DESCRIPTION. This work shall consist of furnishing and installing expansion devices.

516.02 MATERIALS. Materials shall meet the requirements of the following Subsections:

Joint Sealer, Preformed Neoprene 707.06
Preformed Fabric Material 707.07
Joint Sealer, Butyl Rubber Tape 707.12
Asphalt Plug Bridge Joint 707.15
Structural Steel 714.02
High-Strength Low-Alloy Structural Steel 714.03
Carbon Steel Bolts and Nuts 714.04
High-Strength Bolts, Nuts, and Washers 714.05
Welded Stud Shear Connectors 714.10
Epoxy Bonding Compound 719.02
Galvanizing……..726.08
Metalizing……726.09

516.03 FABRICATION DRAWINGS. The Fabricator of the expansion devices furnished under this Section shall submit detailed Fabrication Drawings in accordance with Sections 105 and 506.

516.04 FABRICATION. Material furnished under this Section shall conform to all applicable provisions of Section 506.

Assemblies shall be fabricated to the designed roadway cross-section within 3 mm (1/8 inch) tolerance of the theoretical dimensions at any point.

Unless otherwise specified, all expansion devices shall be galvanized or metalized.

Extruded cellular and strip type sealers shall be furnished in one continuous piece without splices.

When it is specified that a neoprene seal be bonded to a steel surface that is not galvanized, the contact surface area shall be blast cleaned and properly primed with adhesive. Contact surfaces of neoprene seals that will be bonded with an adhesive shall be cleaned and primed in accordance with the seal manufacturer's instructions.

Expansion devices shall be fabricated, assembled, and certified by one supplier. Each device shall be completely shop assembled and shipped as a whole unit except that curb or other assemblies designed to be attached and adjusted by field bolting may be removed for transport. Angles or other suitable sections shall be furnished to secure opposite halves of a unit during shipment. Temporary shipping attachments shall be attached by bolting; welding will not be permitted.

516.05 INSTALLATION. Expansion devices shall be installed in conformance with the plans and all applicable provisions of Section 506.

Final gap adjustments of an expansion joint assembly shall be made during installation in accordance with the movement chart shown on the Plans, Fabrication Drawings, or as directed by the Engineer.

Joint assemblies shall be properly positioned within 3 mm (1/8 inch) of theoretical crown and straightness and attached to the structure by anchorages furnished with the assembly or as specified in the Contract. Prior to the placement of the concrete, all steel surfaces that will be embedded in concrete shall be coated with epoxy bonding compound. Application of the epoxy bonding compound shall be done in accordance with the manufacturer's recommendations.

516.06 METHOD OF MEASUREMENT. The quantity of Bridge Expansion Joint of the type specified to be measured for payment will be the number of meters (linear feet) used in the complete and accepted work, measured along its centerline.

516.07 BASIS OF PAYMENT. The accepted quantity of Bridge Expansion Joint of the type specified will be paid for at the Contract unit price per meter (linear foot). Payment will be full compensation for detailing, furnishing, handling, transporting, and placing the material specified, including nondestructive testing of welds, surface preparation,

protective coating, and epoxy bonding compound, and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

Payment will be made under:

Pay Item	Pay Unit
516.10 Bridge Expansion Joint, Asphaltic Plug	Meter (Linear Foot)
516.11 Bridge Expansion Joint, Vermont	Meter (Linear Foot)
516.12 Bridge Expansion Joint, Finger Plate	Meter (Linear Foot)

SECTION 519 – SHEET MEMBRANE WATERPROOFING, TORCH APPLIED

519.01 DESCRIPTION. This work shall consist of the application of reinforced asphalt, synthetic resin, or coal-tar based preformed sheet membrane to bridge decks to serve as a waterproof barrier between the concrete deck and the bituminous concrete surface pavement. The system shall include the use of a prime coat over the horizontal deck surface and an acceptable polyurethane liquid membrane on the lower portion of the curb face and adjacent deck area.

519.02 MATERIALS. This material shall consist of an approved prefabricated reinforcement of synthetic nonwoven material, thoroughly impregnated and coated with styrene-butadiene-styrene (SBS) modified bitumen. The system shall include a primer which provides an adhesive bond between the concrete deck and the membrane.

Acceptable torch applied membrane systems shall be those included on the Approved Products List on file with the Agency's Materials and Research Section.

519.03 WEATHER LIMITATIONS. Waterproofing shall not be done in rainy weather or when the temperature is below 5˚C (40˚F) without the authorization of the Engineer.

519.04 SURFACE PREPARATION. The surface of the deck shall have a smooth, fine-textured finish. All honeycombed areas and surface cavities shall be cleaned and filled with approved patching materials. The entire deck shall be abrasive blast cleaned to achieve an anchor profile that is clean and free of laitance, oil, and foreign materials. Prior to blasting, the surface shall be dry and free of sharp protrusions.

519.05 CONSTRUCTION DETAILS.

(a) General. All work performed shall be in accordance with the manufacturer's recommendations. The entire system shall be applied by an individual (Applicator) certified by the manufacturer. The Engineer shall receive written certification from the manufacturer regarding the Applicator's qualifications at least seven days prior to the application of any system component. The certification shall apply only to the named individual(s) performing the application. A manufacturer's representative shall be present at all times during the installation of the membrane system.

(b) Surface Condition. Prior to application of primer, the concrete deck shall be cured such that the moisture content reaches 6% or less. Except on minor areas of the deck as approved by the Engineer, torching or other forms of rapidly evaporating free moisture from the surface will not be allowed to achieve initial surface conditions. Cracks should be blown out to ensure excess water is not present. The Contractor shall supply a portable electronic surface moisture meter capable of measuring the moisture content of concrete surfaces in percent.

Immediately prior to application of the primer, the deck shall be cleaned by brooms and compressed air free of oil. The concrete surfaces shall be inspected and approved by the Engineer and the Applicator prior to priming.

(c) Application of Primer. The air temperature for primer application shall be at least 5˚C (40˚F) and rising.

The primer shall consist of one coat covering the entire deck with an overall coverage rate of 5 m^2/liter (200 ft^2/gal) or as specified by the manufacturer.

The primer shall be applied by brush, roller, or sprayer.

The primer shall cure tack-free in accordance with the manufacturer's recommendations before application of the waterproofing membrane.

(d) Application of Membrane. The waterproofing membrane shall be applied by equipment approved by the Engineer. The equipment shall be capable of applying the membrane in a uniform manner onto the prepared substrate in accordance with the manufacturer's recommendations to assure bond with the primed surface and elimination of air bubbles. In small areas, the membrane shall be hand welded by torch around drains, joints, and along the curb as directed by the Engineer. The Applicator shall be responsible for the protection of adjacent areas.

The membrane shall be installed in a shingled pattern so that water is permitted to drain to the low areas of the deck without accumulating against seams. Laps shall be staggered at the beginning and ends of rolls, shall overlap the previous roll and shall be sealed in accordance with the manufacturer's recommendations. Prior to suspension of work for any reason, all exposed edges shall be heated, troweled, and sealed in accordance with the manufacturer's recommendations.

Damaged membrane or membrane that is not properly bonded to the deck surface shall be patched or repaired in accordance with the manufacturer's recommendations.

519.06 PROTECTION OF MEMBRANE. No traffic shall be permitted on an exposed membrane surface. Care shall be exercised to prevent damage to the completed membrane, especially during paving operations. All damaged areas shall be cleaned and patched to the satisfaction of the Engineer.

The specified bituminous overlay shall be placed on the membrane within three days after application.

A rubber tired or rubber-tracked paver shall be used to place the bottom course of bituminous mix.

The temperature of the bituminous concrete pavement to be placed on the membrane shall be as recommended by the membrane manufacturer and approved by the Engineer.

The Contractor shall maintain a small supply of portland cement on the project during the time of paving. The cement dust shall be sparingly cast over the membrane surface to reduce tackiness and thereby prevent the paver or truck tires from sticking to the membrane and damaging it.

The paver operator shall be directed not to ride the curb lines while paving such areas since the screed shoe may damage the polyurethane sealant on the vertical curb face.

519.07 PROTECTION OF EXPOSED SURFACES. The Contractor shall exercise care in the application of the waterproofing materials to prevent surfaces not receiving treatment from being spattered or marred. Particular reference is made to the face of curbs, copings, finished surfaces, substructure exposed surface, and outside faces of the bridge. Any material that spatters on these surfaces shall be removed and the surfaces cleaned to the satisfaction of the Engineer.

519.08 METHOD OF MEASUREMENT. The quantity of Sheet Membrane Waterproofing, Torch Applied to be measured for payment will be the number of square meters (square yards) of the specified type used in the complete and accepted work. Measurement will be based on the horizontal distance between the face of the curbs and the horizontal length of membrane installed. Any material specified to be lapped up the face of the curb will not be included in the measured quantity.

519.09 BASIS OF PAYMENT. The accepted quantity of Sheet Membrane Waterproofing, Torch Applied will be paid for at the Contract unit price per square meter (square yard). Payment will be full compensation for furnishing, transporting, handling, and placing the waterproofing system specified, including primer, mastic, polyurethane membrane sealant, and surface preparation, and for furnishing all materials, labor, tools, equipment, and incidentals necessary to complete the work.

Payment will be made under

	Pay Item	Pay Unit
519.20	Sheet Membrane Waterproofing, Torch Applied	Square Meter (Square Yard)

SECTION 522 – LUMBER AND TIMBER

522.01 DESCRIPTION. This work shall consist of detailing, furnishing, fabricating, transporting, framing, and placing or erecting lumber, structural timber, or structural glued laminated timber; installing hardware; and applying preservative treatment.

522.02 MATERIALS. Materials shall meet the requirements of the following Subsections:

Joint Sealer, Hot Poured .....707.04(a)
Coatings for Wood..... 708.05
Structural Lumber and Timber 709.01
Miscellaneous Hardware, Shapes, and Fabricated Materials..... 709.01(h)
Nonstructural Lumber..... 709.02
Structural Glued Laminated Timber 709.03
Timber Preservative..... 726.01
Copper Naphthenate Solution..... 726.04
Waterproofing Pitch 726.05
Galvanizing…….. ..... ….. 726.08

Unless otherwise specified, all metal parts and hardware shall be galvanized.

522.03 GENERAL FABRICATION REQUIREMENTS. Glued laminated timber furnished under this Section shall be fabricated by an AITC licensed laminator and shall comply with ANSI/AITC A190.1. In addition to being a licensed laminator, the Fabricator must demonstrate the capability to fabricate the end products specified.

Unless otherwise specified, all material shall be fabricated prior to preservative treatment.

Dimensions and bolt hole locations of prefabricated material shall be within a tolerance of 2 mm (1/16 inch) of the details specified.

522.04 DRAWINGS. Unless otherwise specified, as soon as practical after award of the Contract, the Contractor shall prepare and submit Fabrication Drawings for glued laminated timber in accordance with Section 105.

The Contractor shall prepare and submit Construction Drawings for structural timber erection in accordance with Section 105.

The erection plan shall include methods and sequence of structural timber erection, temporary bracing requirements, the equipment to be used for the erection, the necessary computations to indicate the magnitude of stress in the segments during erection and to demonstrate that all of the erection equipment has adequate capacity for the work to be performed, and provisions for all stages of construction, including temporary stoppages. The Contractor shall follow the erection plan as submitted.

522.05 STORAGE. Timber, lumber, and glued laminated materials stored on the site shall be kept in orderly piles, open stacked, and on supports that provide at least 300 mm (12 inches) of ground clearance. For outside storage, the ground area in the vicinity of the material shall be cleared of grass, weeds, and rubbish. Free circulation of air shall be provided between the tiers, courses, and the ground.

Timber, lumber, and glued laminated timber (treated or untreated) shall be stored under cover. The covering shall adequately protect these materials from direct and blowing rain or snow while providing full circulation of air.

Fabricated material shall be stored in a manner that will prevent dimensional changes in the members prior to assembly.

522.06 HANDLING. Material shall be carefully handled to avoid damaging the edges or surface and to keep it clean.

Materials shall be picked up or moved with slings or other devices that will not damage or mar the surface. Peavies, cant hooks, timber dogs, or other pointed tools will not be permitted.

Cranes, lifting devices, and other equipment for all structural timber erection shall be of adequate design and capacity to safely erect, align, and secure all members and components in their final positions without damage. The Contractor is solely responsible for the methods and equipment employed for the erection of the structural timber members.

522.07 FRAMING. Timber, lumber, and glued laminated timber shall be accurately cut and framed to a close fit in such a manner that the joints will have full and even bearing over the entire contact surface. Mortises shall be true to size for their full depth, and tenons shall fit snugly. Except as indicated in the Contract, shimming will not be permitted in making joints, and open joints will not be accepted. Nails and spikes shall be driven with the heads set flush with the surface of the wood. Except as directed by the Engineer, structure framing and boarding shall be constructed square, plumb, and straight.

When permitted by the Engineer, forms or temporary braces may be attached to treated material. Upon removal, any holes, cuts, or abrasions shall be treated in accordance with Subsection 522.13.

522.08 CONNECTIONS.

(a) Holes for Bolts, Dowels, Rods, and Lag Screws. Holes for metal round drift-bolts or dowels shall be bored with a bit 2 mm (1/16 inch) less in diameter than the drift-bolt or dowel to be used. The diameter of holes for metal square drift-bolts or dowels shall be equal to the least dimension of the drift-bolt or dowel.

Except as required for timber connectors in part (d) of this Subsection, holes for machine bolts shall be bored with a bit the same diameter as the bolt.

Holes for round wood dowels shall be bored with a bit the same diameter as the dowel.

Holes for rods shall be bored with a bit 2 mm (1/16 inch) greater in diameter than the rod.

Lead holes for lag screws, wood screws and spikes shall conform to requirements specified within the latest edition of the AITC Timber Construction Manual.

(b) Countersinking. Countersinking shall be done wherever smooth faces are required. All recesses in treated lumber and timber formed for countersinking shall be painted with copper naphthenate solution. Recesses likely to collect injurious materials shall be filled with a hot-poured joint sealer or other material, as directed by the Engineer.

(c) Bolts and Washers. A washer of the size and type specified shall be used under all bolt heads and nuts that would otherwise come in contact with wood.

All nuts shall be effectively locked after they have been finally tightened.

(d) Timber Connectors. In addition to wood dowels, bolts, and rods, timber (wood member) connectors may be the split ring, shear plate, or spike grid type. The split ring and shear plate types shall be installed in precut grooves of dimensions as recommended by the manufacturer. The spike grid type shall be forced into the contact surfaces of the wood members joined by means of pressure equipment. All connectors of this type at any given joint shall be embedded simultaneously and uniformly.

Bolt holes shall be perpendicular to the face of the material and 2 mm (1/16 inch) larger in diameter than the bolt.

(e) Framed Bents. Framed bents shall be constructed in accordance with AASHTO *LRFD Bridge Construction Specifications* and interim specifications in effect on the date of the Contract.

522.09 TRUSSES. Trusses, when completed, shall show no irregularities of line. Chords shall be straight and true from end to end in horizontal projection and, in vertical projection, shall show a smooth curve through panel points conforming to the correct camber. All bearing surfaces shall fit accurately. Uneven or rough cuts at the points of bearing shall be cause for rejection of the piece containing the defect.

522.10 TRUSS HOUSING. The finished appearance of the housing is considered of primary importance. Special care shall be taken to secure a high quality of work and finish on this portion of the structure.

Unless otherwise directed by the Engineer, housing and railings shall be constructed after the removal of the falsework and the adjustment of the trusses to correct alignment and camber.

522.11 DECKING.

(a) Plank Flooring. Plank material shall be of dimension lumber of the grade specified.

Unless otherwise specified, all material shall be surfaced four sides (S4S).

Single layer plank floors shall consist of a single thickness of dimension lumber planks supported by stringers or floor beams. The planks shall be laid heart side down, with 6 mm (1/4 inch) openings between them. Each plank shall be securely spiked to each supporting member. The planks shall be carefully graded as to thickness and so laid that no two adjacent planks vary in thickness by more than 2 mm (1/16 inch). Unless otherwise specified, the lengths of transverse planks on stringers shall be full width of the designed cross-section.

Two-ply plank floors shall consist of two layers of dimension lumber planks supported on stringers or floor beams. Each plank of the top course shall be securely fastened to the lower course. At the ends of the bridge, if required, the decking shall be beveled to match the approach surfaces. For stringer supports, the top course of planks may be laid either diagonal or parallel to the centerline of roadway. Joints in the top layer shall be staggered at least 1 m (3 feet) and care shall be taken to securely fasten the ends of each plank. For floor beam supports, unless otherwise specified, the lengths of transverse top course planks shall be full width of the designed cross-section.

(b) Nail Laminated Decking. Nail laminate deck material shall be furnished and installed in accordance with the Contract or as ordered by the Engineer. Deck material shall be of the grade specified. Unless otherwise specified, in transverse applications the lengths of planks shall be full width of the designed cross-section. Each plank shall be spiked to the preceding plank at each end and at intervals of approximately 450 mm (18 inches) with the spikes driven alternately near the top and bottom edges. The spikes shall be of sufficient length to pass through two planks and at least halfway through a third plank.

When timber nailing strips are used, every other plank shall be toe-nailed to every other nailing strip. The size of the spikes shall be as shown on the Plans or as directed by the Engineer.

When shown on the Plans or authorized by the Engineer, the laminated decking may be attached to steel supports by the use of approved galvanized metal clips. Care shall be taken to have each strip vertical and tight against the preceding one and bearing evenly on all supports.

(c) Glued Laminated Decking. Glued laminated decking material shall be furnished and installed in accordance with the Contract, approved Fabrication Drawings, or as directed by the Engineer.

522.12 SAWN LUMBER STRINGERS. Stringers shall be sized at bearings and shall be placed in position so that knots near edges will be in the compression portions of the stringers.

Outside stringers may have butt joints with the ends cut on a taper, but interior stringers shall be lapped to take bearing over the full width of the floor beam or cap at each end. The lapped ends of untreated stringers shall be separated at least 15 mm (1/2 inch) for the circulation of air and shall be securely fastened by drift-bolting where specified. When stringers are two panels in length, the joints shall be staggered.

Cross-bridging between stringers shall be neatly and accurately framed and securely toe-nailed with at least two nails in each end. All cross-bridging members shall have full bearing at each end against the sides of stringers. Unless otherwise specified, cross-bridging shall be placed at the center of each span.

522.13 PRESERVATIVE TREATMENT.

(a) Pressure Treatment. Timber, lumber, and glued laminated timber shall be pressure treated with the type of preservative specified in the Contract. When a specific type or options are not specified, Type II preservative shall be used. Prior to handling or erecting pressure treated timber, lumber, or glued laminated timber the Contractor shall read and provide a copy of any Material Safety Data Sheets (or Consumer Information Sheets required for the material) to the Resident Engineer. The Contractor shall also provide the Resident Engineer with a plan detailing clean-up, storage, and disposal procedures for pressure treated sawdust and cutoffs.

(1) Treatment of Cuts, Abrasions and Holes. Cuts, abrasions, and holes bored after treatment shall be treated with two coats of copper naphthenate solution. Cuts and abrasions shall be carefully trimmed prior to treatment. Holes left unfilled shall be filled with wooden plugs treated with copper naphthenate solution.

(2) Temporary Attachments. Holes remaining after the removal of nails and spikes used to attach temporary forms or bracing to treated material shall be filled by driving galvanized nails or spikes flush with the surface or plugging the holes with wooden plugs treated with copper naphthenate solution.

(b) Untreated Timber, Lumber and Glued Laminated Timber. For untreated timber, lumber, and glued laminated timber, all cuts, notches, bore holes, contact surfaces and other areas specified by the Contract shall be treated with two coats of copper naphthenate solution.

(c) Field Treatment. When field applications of preservative are specified, the materials shall be furnished, prepared, and applied in accordance with AWPA Standard M4.

522.14 PAINTING. The surface of any material to be painted or stained shall be dry and free of dirt, dust, oil, or other foreign materials. Unless otherwise specified, all surfaces shall be coated with a prime coat and one finish coat.

522.15 METHOD OF MEASUREMENT. The quantity of Structural Lumber and Timber and of Nonstructural Lumber to be measured for payment will be the number of cubic meters (thousand feet board measure – MFBM) incorporated into the complete and accepted work, as computed from the nominal cross-section sizes and the actual in-place lengths of members. Final accepted in-place length of any member will be determined as the maximum length of a member as projected along one edge-line, measured to the next 0.25 m (1 foot) increment. Further measurement shall not be made for cutoffs or actual stock lengths. For longitudinal nail-laminated decking, longitudinal plank decking, and runners, member length will be measured as the overall superstructure length of in place decking and runners, measured to the next 0.25 m (1 foot) increment.

If round timbers and English units are specified, the number of board feet will be computed by the Vermont Log Rule: Board Feet = (DxRxL)/12; where D = diameter in inches, measured under the bark at the small end; R = D/2; and L = length in feet.

The quantity of Structural Glued Laminated Timber to be measured for payment will be on a lump sum basis for each structure or each structural unit in the complete and accepted work.

522.16 BASIS OF PAYMENT. The accepted quantities of Structural Lumber and Timber and of Nonstructural Lumber will be paid for at the Contract unit prices per cubic meter (thousand feet board measure – MFBM). Payment for each quantity will be full compensation for detailing, fabricating, furnishing, transporting, handling, placing or erecting, and painting or treating the material specified, including all hardware and timber connectors; for providing all falsework, forms, bracing, sheeting, or other timber used for erection purposes; for furnishing and implementing the erection plan, when required; and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

The accepted quantity of Structural Glued Laminated Timber will be paid for at the Contract lump sum price. Partial payments will be made as follows:

1. The first payment of 50% of the lump sum price will be made upon the original delivery of the timbers to the project, provided the materials are acceptable and certified.

2. The remaining 50% will be paid when the installation is complete and the work accepted.

   Payments for the quantity of Structural Glued Laminated Timber will be full compensation for detailing, fabricating, furnishing, transporting, handling, placing or erecting, and painting or treating the material specified, including all hardware and timber connectors; for providing all falsework, forms, bracing, sheeting, or other timber used for erection purposes; for furnishing and implementing the erection plan, when required; and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

Payment will be made under:

Pay Item	Pay Unit
522.20 Structural Lumber and Timber, Untreated	Cubic Meter (MFBM)
522.25 Structural Lumber and Timber, Treated	Cubic Meter (MFBM)
522.30 Nonstructural Lumber, Untreated	Cubic Meter (MFBM)
522.35 Nonstructural Lumber, Treated	Cubic Meter (MFBM)
522.40 Structural Glued Laminated Timber	Lump Sum

SECTION 523

THIS SECTION RESERVED

SECTION 524 - JOINT SEALER

524.01 DESCRIPTON. This work shall consist of furnishing and placing a joint sealer of the type specified at the locations shown on the Plans.

524.02 MATERIALS. Materials shall meet the requirements of the following Subsections:

Joint Sealer, Hot Poured.....707.04(a)
Joint Sealer, Cold Poured.....707.04(b)
Backer Rod .....707.04(c)
Joint Sealer, Polyurethane 707.05
Bond Breaker.....707.05(c)
Asphaltic Plug Joint Binder……707.15

Joints sawn in bituminous concrete pavement shall be filled and sealed with hot poured or cold poured joint sealer or asphaltic plug joint binder, appropriate backer rod, and an approved bond breaker.

524.03 TEMPERATURE LIMITATIONS. The joint sealer shall be applied per manufacturer's recommendations, however, the ambient air and pavement temperatures must be greater than 5 °C (40 °F) at the time of application.

524.04 SAWED JOINTS. Roadway or bridge deck joints shall be formed by means of concrete floor sawing equipment capable of dry cutting the designed joint in a single pass.

The joint shall be cut and sealed in one continuous operation. The sawed joint shall not be exposed to traffic until after the sealer has been placed, cured, and is not subject to "picking."

When placing new bituminous concrete pavement, each lift of pavement shall be scored with a single blade cut to a depth of 75 percent of the lift thickness, at the location of the center of the proposed joint. This work shall be completed prior to exposing the location to traffic or, where traffic is not maintained, the same working day that the lift of pavement is placed.

The sawed joint in the newly placed wearing course shall be cut and sealed within 24 hours of paving. If the joint location will not be exposed to traffic, the Engineer may allow the Contractor an additional 48 hours to cut and seal the joint.

The width of the sawed joint shall be as shown on the Plans or may be adjusted by the Engineer for seasonal temperature variations. The depth of the sealant shall be approximately 50 percent of the width of the sawn joint when hot or cold poured materials are specified in the Contract.

The equipment for sawing the single blade cut shall be on the project and approved by the Engineer prior to beginning paving operations.

524.05 PREPARATION OF JOINTS. Surfaces to which the joint sealer is to adhere shall be free of all foreign material, including curing compound, oil, dirt, sawing film, laitance, and rust. All surfaces shall be thoroughly dry before placing of sealers.

(a) For Poured or Preformed Joint Sealers. Prior to placing poured or preformed joint sealers, the vertical faces of the sawed joint and the horizontal pavement surfaces within 25 mm (1 inch) of the joint edge shall be thoroughly blast cleaned to improve joint sealant adhesion. The resulting dust, blasting debris, etc. shall be removed with a blast of high-pressure air or industrial vacuum equipment.

Regardless of the cleaning method used, the Contractor shall take all necessary precautions to avoid contaminating the other project construction work with the removed dust and debris.

(b) For Polyurethane Joint Sealer. Prior to placing polyurethane joint sealer, the concrete surface shall be blast cleaned to remove surface mortar and expose underlying aggregate. Blast cleaning equipment shall be such that no oil is introduced into the air line. Surfaces formerly sealed with other sealers shall be bush hammered or sawed to clean the material and then blast cleaned.

Steel surfaces shall be blast cleaned to the bare metal. Primer shall be applied immediately after the blast cleaning is completed.

Epoxy mortar surfaces shall be cleaned by use of suitable solvents or by blast cleaning as required.

524.06 PLACEMENT.

(a) Joint Sealer, Hot Poured. The material shall be heated in a double walled, oil-jacketed kettle equipped with positive temperature controls that allow the sealer to be heated to, and maintained within, a range of 200 to 210 °C (390 to 410 °F) or such other temperature range as recommended by the sealant manufacturer. The kettle shall arrive on the project empty.

Heating of the sealant to the placement temperature and maintaining the sealer at placement temperature shall not exceed six hours. The Contractor shall empty the kettle before heating more material. New material shall not be added to a partially filled kettle and cooled material shall not be reheated.

Prior to pouring the sealant into the joint, a heat resistant backer rod shall be placed in the bottom of the joint. The rod shall be 3 mm (1/8 inch) greater in diameter than the joint width to ensure a leak-proof seal and to maintain the proper depth of sealant. The rod shall be specifically manufactured for use with hot poured sealants.

The hot sealant shall be poured into the joint in a single layer, except that multiple layers will be permitted if lateral flow is a problem. The joint shall be slightly overfilled, and the excess sealant shall be leveled with a U- or V-shaped squeegee to provide a thin layer of sealant spread over the blast cleaned, horizontal, pavement surfaces adjacent to the joint.

(b) Joint Sealer, Cold Poured. The two-component material shall be mixed in the container in which it is furnished using 100 percent of both components. Mixing shall be accomplished with a variable speed drill and mixing paddle operated at speeds not greater than 400 rpm for a period of not less than five minutes. Mixing by hand will not be permitted.

The mixed sealant may be transferred to a smaller clean container for ease of pouring. All mixed sealants must be placed within the 30 to 45 minute pot life of the material.

Prior to pouring the sealant into the joint, a backer rod shall be placed in the bottom of the joint. The rod shall be 3 mm (1/8 inch) greater in diameter than the joint width to ensure a leak-proof seal and to maintain the proper depth of sealant. The rod shall be specifically manufactured for use with poured sealants.

The sealant shall be poured into the joint in a single layer, except that multiple layers will be permitted if lateral flow is a problem. The joint shall be slightly overfilled, and the excess sealant shall be leveled with a U- or V-shaped squeegee to provide a thin layer of sealant spread over the blast cleaned, horizontal, pavement surfaces adjacent to the joint.

(c) Joint Sealer, Polyurethane. Polyurethane joint sealer shall be placed as shown on the Plans in accordance with the manufacturer's recommendations. Joint sealer shall not be installed until concrete has been in place for 28 days.

A foam spacer, approved by the Engineer, shall be installed in such a manner to control the depth of the sealer and give support during its cure time. The foam spacer shall fit tightly against the sides of the opening beneath the sealer.

Polyurethane coated tape, or other strip material approved by the Engineer, shall be applied to those surfaces where bond is not desired.

Primer material(s) shall be applied strictly as specified by the joint sealer manufacturer on the surfaces to which the joint sealer is intended to adhere. Primed surfaces that may have been contaminated by dirt or other foreign material shall be cleaned and primed again prior to the application of the joint sealer.

The finished surface of the joint sealer shall present a smooth, even appearance. Only minimum tooling of horizontal joints will be allowed. Overlaying or shimming material shall not be applied over material that has cured.
When it is necessary to place a portion of a joint, the edge of the cured material shall be primed as specified by the manufacturer prior to placing additional sealer.

Any joint sealer that is not completely bonded to the intended surface after being in place for 72 hours shall be removed, the joint prepared again, and the application repeated as specified.

(d) Asphaltic Plug Joint Binder. Asphaltic plug joint binder shall only be used in the saw cut joint as indicated in the Plans.

The material shall be heated in a double-walled, oil-jacketed kettle equipped with positive temperature controls that allow the sealant to be heated to such temperature range as recommended by the sealant manufacturer. The kettle shall arrive on the project empty. Heating of the sealant to the placement temperature and maintaining the sealer at placement temperature shall not exceed the time interval recommended by the manufacturer. The Contractor shall empty the kettle before heating more material. New material shall not be added to a partially filled kettle and cooled material shall not be reheated.

Prior to pouring the sealant into the joint, a heat resistant backer rod shall be placed in the bottom of the joint. The rod shall be 3 mm (1/8 inch) greater in diameter than the joint width to ensure a leak-proof seal and to maintain the proper depth of sealant. The rod shall be specifically manufactured for use with hot poured sealants.

The hot sealant shall be poured into the joint in a single layer, except that multiple layers will be permitted if lateral flow is a problem. The joint shall be slightly overfilled, and the excess sealant shall be leveled with a U or V-shaped squeegee to provide a thin layer of sealant spread over the blast cleaned, horizontal pavement surfaces adjacent to the joint.

524.07 JOINT PROTECTION. The completed joint shall be protected against damage from traffic during the curing time.

Polyurethane joint sealer shall be covered with impervious material to prevent contact with linseed oil-mineral spirits mixtures, paints, or other materials containing mineral spirits and similar solvents.

524.08 METHOD OF MEASUREMENT. The quantity of Joint Sealer, of the kind specified, to be measured for payment will be the number of meters (linear feet) or the number of liters (gallons) used in the complete and accepted work.

524.09 BASIS OF PAYMENT. The accepted quantity of Joint Sealer, of the kind specified, will be paid for at the Contract unit price. Payment will be full compensation for furnishing, handling, placing, and installing the specified materials, including any required backer rod or bond breaker; for preparing, including saw cutting where required, and cleaning the joint prior to installing the sealer; and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work. Payment will be made under:

Pay Item	Pay Unit
524.10 Joint Sealer, Hot Poured	Liter (Gallon)
524.11 Joint Sealer, Hot Poured	Meter (Linear Foot)
524.12 Joint Sealer, Cold Poured	Liter (Gallon)
524.13 Joint Sealer, Cold Poured	Meter (Linear Foot)
524.20 Joint Sealer, Polyurethane	Liter (Gallon)
524.21 Joint Sealer, Polyurethane	Meter (Linear Foot)

SECTION 525 - BRIDGE RAILINGS

525.01 DESCRIPTION. This work shall consist of furnishing and erecting bridge railing and performing repairs to existing bridge railing.

525.02 MATERIALS. Materials shall meet the requirements of the following Subsections:

Mortar, Type IV 707.03
Grease Rustproof`ing Compound..... 708.04
Anchor Bolts, Bridge Railing 714.07
Galvanizing……..726.08
Metalizing……726.09
Delineation Devices..... 728.04
Preformed Fabric Bearing Pads..... 731.01
Bearing Pads……731.02
Metal Hand Railing 732.01
Galvanized Box Beam Bridge Railing 732.03
Steel Beam Bridge Railing 732.04

Concrete shall meet the requirements of Section 501 for High Performance Concrete, Class A or High Performance Concrete, Class SCC. If High Performance Concrete, Class A is used then a shrinkage compensating admixture shall be added during the initial concrete mixing phase or as recommended by the chemical manufacturer product representative.

Reinforcing steel shall meet the requirements of Section 507.

525.03 FABRICATION DRAWINGS. The Fabricator of steel components furnished under this Section shall submit detailed Fabrication Drawings in accordance with Sections 105 and 506.

The Contractor shall submit a bending schedule for concrete bridge railing reinforcement in accordance with Sections 105 and 507.

These requirements do not apply to work performed under part (d) of Subsection 525.06.

525.04 FABRICATION.

(a) Steel Components. Material furnished under this Section shall conform to the applicable provisions of Section 506. Railing shall be fabricated in a plant approved by the Structures Engineer.

Unless otherwise specified, all ferrous metal railing components shall be galvanized.

(b) Concrete Forms. Forms shall conform to the railing design shown in the Plans and forming requirements of Section 501. Forms shall be constructed to allow for checking and correcting the railing alignment and grade after the concrete has been placed and prior to initial set. The forms shall be reinforced in such a manner that finishing of the railing tops will not disturb the final adjusted alignment.

525.05 CONSTRUCTION TOLERANCES. Tolerances for railing components shall meet the requirements of the latest edition of the AASHTO *LRFD Bridge Construction Specifications.*

525.06 INSTALLATION.

(a) General. Railings shall be installed in conformance with the applicable provisions of Sections 501, 506, 507, and these specifications. Alignment, grade, and clearances at joints shall be adjusted to the satisfaction of the Engineer.

Posts shall be adjusted and aligned to the satisfaction of the Engineer prior to placing any mortar.

Unless otherwise specified, removed railing shall become the property of the Contractor and shall be removed from the project.

Sleeves for hand railing shall be secured and accurately aligned prior to placement of any concrete.

Galvanized surfaces that have been scratched or have received minor abrasions shall be repaired in accordance with Subsection 726.08 or as directed by the Engineer.

(b) Painting. Railing required to be painted shall be coated in accordance with the appropriate painting item(s) in the Contract.

Wherever bridge railing panels are nested or overlapped full length, the surfaces on both panels that will be in contact with each other shall be coated with a grease rustproof compound.

(c) Delineation. Delineation devices shall be of the design shown on the Plans and shall be securely fastened to the bridge railing posts as shown on the Plans or as directed by the Engineer.

(d) Bridge Railing Repair. Bridge railing repair of the Type specified shall be performed at the locations indicated in the Plans and as directed by the Engineer.

(1) Bridge Railing Repair, Type I. Type I bridge railing repair shall consist of installing new heavy duty steel beam panels and offset blocks on existing fascia-mounted or curb-mounted posts spaced at 1.9 meters (6.25 feet) or less.

(2) Bridge Railing Repair, Type II. Type II bridge railing repair shall consist of installing new nested heavy duty steel beam panels and offset blocks on existing fascia-mounted or curb-mounted posts spaced greater than 1.9 meters (6.25 feet).

(3) Bridge Railing Repair, Type III. Type III bridge railing repair shall consist of installing new heavy duty steel beam panels and offset blocks on new fascia-mounted or curb-mounted posts utilizing existing anchor bolts.

525.07 METHOD OF MEASUREMENT. The quantity of Removal of Existing Bridge Railing or Reset Existing Bridge Railing to be measured for payment will be the number of meters (linear feet) of existing railing dismantled and disposed of, or repaired and reset, between the limits specified or as ordered by the Engineer.

The quantity of Bridge Railing of the type specified to be measured for payment will be the number of meters (linear feet) of the type of rail used in the complete and accepted work. Measurement will be made along the face of the rail from end to end or between the pay limits specified. No deductions or additions will be made for joints.

The quantity of Bridge Railing Repair of the Type specified to be measured for payment will be the number of meters (feet) of railing repaired in the complete and accepted work, measured within the limits shown on the Plans or as directed by the Engineer. No additional measurement will be made for nested beam panels.

525.08 BASIS OF PAYMENT. The quantity of Removal of Existing Bridge Railing or Reset Existing Bridge Railing will be paid for at the Contract unit price bid per meter (linear foot). Payment will be full compensation for dismantling and disposing of, or for repairing and resetting, existing railing and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

The accepted quantity of Bridge Railing of the type specified will be paid for at the Contract unit price per meter (linear foot). Payment will be full compensation for detailing, furnishing, handling, placing, delineating, galvanizing, applying grease rustproof compound, and painting the railing components; and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

The accepted quantity of Bridge Railing Repair of the Type specified will be paid for at the Contract unit price per meter (linear foot). Payment will be full compensation for detailing, treating, furnishing, handling, and placing railing components; for bolts and hardware necessary for installing railing components; for all work necessary for verifying and adjusting post height and/or bolt spacing of existing posts; and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

Removal and disposal of existing railing components required for performing Bridge Railing Repair of the Type specified will be paid for under Contract item 525.10.

Payment will be made under:

	Pay Item	Pay Unit
525.10	Removal of Existing Bridge Railing	Meter (Linear Foot)
525.11	Reset Existing Bridge Railing	Meter (Linear Foot)
525.33	Bridge Railing, Galvanized 2 Rail Box Beam	Meter (Linear Foot)
525.335	Bridge Railing, Galvanized 3 Rail Box Beam	Meter (Linear Foot)
525.34	Bridge Railing, Galvanized 4 Rail Box Beam	Meter (Linear Foot)
525.41	Bridge Railing, Galvanized HD Steel Beam/Fascia Mounted	Meter (Linear Foot)
525.44	Bridge Railing, Galvanized HDSB/ Fascia Mounted/Steel Tubing	Meter (Linear Foot)
525.50	Bridge Railing Repair, Type I	Meter (Linear Foot)
525.55	Bridge Railing Repair, Type II	Meter (Linear Foot)
525.60	Bridge Railing Repair, Type III	Meter (Linear Foot)
525.70	Bridge Railing, Concrete F-Shape	Meter (Linear Foot)

SECTION 526

THIS SECTION RESERVED

SECTION 527 - MAINTENANCE OF STRUCTURES AND APPROACHES

527.01 DESCRIPTION. This work shall consist of the maintenance of existing structure(s) and approaches within the project limits.

527.02 ROAD MAINTENANCE. The Contractor shall maintain all highway sections within the confines of the work under the Contract to the satisfaction of the Engineer. When traffic is to be maintained over the present highway, the full width of the roadway shall be maintained.

The maintenance shall be done by means of an approved road grader or other approved equipment of a type that will be efficient in keeping the roadway in a reasonably smooth and passable condition for traffic and shall be subject to the approval of the Engineer. The material for and the necessary filling of holes and similar depressions that develop in the roadway shall be included in the Contract price for this item. If, in the opinion of the Engineer, the Contractor fails to maintain a reasonably smooth roadway surface, and fails to fix the same after written notification, the Engineer will make the necessary provisions to maintain the roadway surface, and the cost shall be deducted from any money due or to become due under the Contract.

527.03 BRIDGE MAINTENANCE. When traffic is maintained over an existing structure, the Contractor shall keep all parts of the structure safe for the legal or posted load of the structure including satisfactory maintenance of the substructure, superstructure, and the bridge surface. The Contractor shall strengthen, patch, shore, or renew any part or parts of this substructure or superstructure when necessary for the safety of the traveling public.

If the existing structure over which traffic is being maintained becomes unsafe for public travel, and if, on written order by the Engineer, the Contractor fails to make satisfactory repairs, the Engineer will make the necessary provisions to repair the structure, and the cost will be deducted from any monies due under the Contract.

527.04 METHOD OF MEASUREMENT. The quantity of Maintenance of Structures and Approaches to be measured for payment will be on a lump sum basis.

527.05 BASIS OF PAYMENT. The accepted quantity of Maintenance of Structures and Approaches will be paid for at the Contract lump sum price. Payment will be full compensation for performing the work specified and for furnishing all labor, materials, tools, equipment, and incidentals necessary to properly maintain substructures, superstructure(s), and roadway approaches.

Payment for this work will be made periodically as follows:

(a) 50 percent of the Contract lump sum price will be paid after all required repairs to the bridge(s) or approaches have been made to the satisfaction of the Engineer and traffic is being maintained over the existing bridge(s) and approaches.

(b) The remaining 50 percent of the Contract lump sum price will be paid when traffic is permanently moved to the new/rehabilitated bridge(s) and approaches.

When the Contract specifically provides for Item 607, Roadway Patrol Maintenance, the Contract item Maintenance of Structures and Approaches shall only cover maintenance of the existing structure(s).

Payment will be made under:

Pay Item	Pay Unit
527.10 Maintenance of Structures and Approaches	Lump Sum

SECTION 528 - TEMPORARY BRIDGE

528.01 DESCRIPTION. This work shall consist of the design, construction, maintenance, and removal of a temporary bridge, its substructures and approaches.

528.02 MATERIALS. The Contractor may use any material or combination of materials that will conform to the requirements of this Subsection and meet the approval of the Engineer. The Engineer reserves the right to reject materials and details that are structurally unsafe for the use proposed.

Unless specifically permitted in the Contract or upon written authorization of the Construction Engineer, the use of pipes will not be allowed for temporary bridges.

Unless otherwise authorized on the approved drawings, all main load carrying members shall be continuous between supports. Splices will only be approved for:

(a) A fully bolted connection, with high-strength bolts, designed for its location in accordance with the AASHTO *LRFD Bridge Design Specifications*.

(b) A fully welded connection designed, welded, inspected, and tested in accordance with the AASHTO *LRFD Bridge Design Specifications* and AWS requirements. Any welded connection performed in the absence of and without the approval of the Agency's Welding Inspector will not be approved.

Any welding done for work under this Section must be detailed on the Working Drawings and performed in conformance with Section 506.

528.03 DRAWINGS. Working Drawings shall be prepared by the Contractor for the proposed work under this item in accordance with Section 105. Drawings for the bridge approaches shall include plan, profile, typical section, and specific cross-sections for the temporary roadway and channel (when applicable) with complete details and identification of materials to be used. Geometrics of the temporary bridge and its approaches shall be adequate for the volume of traffic served and individual conditions encountered.

Plan, elevation, and section views of the structure shall include size and spacing of all members or components for:

Abutments
Piers
Main supporting members or stringers
Floor system
Diaphragms and lateral bracing
Railing (bridge and approach)
Curbs
Bearings
Other applicable information

528.04 DESIGN AND CONSTRUCTION DETAILS. The design and structural details of the temporary bridge, its substructures and approaches shall be signed, stamped, and dated by a Professional Engineer (Structural or Civil).

In designing and constructing a temporary bridge, the Contractor shall provide for the waterway and clearances shown on the Plans. When temporary bridge requirements are not shown on the Plans, the opening area shall be at least equal to 40 percent of the waterway provided for the 100-year event (Q 100) for the new structure, with a clear height equal to a ten-year event (Q 10) headwater; this waterway to be adequate for safely conveying a mean annual flood (Q 2.33) at a headwater no greater than what would be created by the existing structure during a ten-year event.

Fill placed in or adjacent to the stream shall be clean granular or rock material meeting the requirements of Subsection 703.04 or 703.05 and protected with sufficient stone to prevent erosion to a Q 10 headwater elevation (based on the new structure). Any fill placed in the stream to protect the temporary bridge and approaches shall be removed to the satisfaction of the Engineer upon completion of the project. The sizing of any temporary bridges to be left in place between January 1st and May 1st, or for any period greater than seven months shall be approved by the Engineer. Questions regarding hydraulic information not furnished shall be addressed to the Engineer.

(a) Roadway. Approach embankments shall be constructed of acceptable fill material, compacted to adequately support design loading requirements. A minimum of 380 mm (15 inches) of approved gravel or other acceptable surfacing material shall be provided for the full width of the typical section.

When the Contract Plans designate paved approaches, the approaches shall be paved with a minimum 50 mm (2 inches) wearing course of Type III or Type IV bituminous concrete pavement and the approaches and bridge shall have temporary pavement markings applied as per Section 646. Bituminous concrete pavement shall conform to the requirements of Section 406 or 490, except the mix design submittal and plant inspection requirements set forth in Section 406 or 490 will not be required. The Engineer may also waive weather limitations. The temporary pavement shall extend for the full length of the approaches and the full clearance width described below.

Turnouts with adequate space for two-way traffic shall be provided at each end of a one-way structure or coordinated with traffic signalization, if used.

(b) Bridge.

(1) Loading. Unless otherwise specified, all temporary bridge structures shall be designed for an MS-18 (HS-20) or HL-93 live load, and for all other applicable forces, in accordance with the AASHTO *Standard Specifications for Highway Bridges* or *LRFD Bridge Design Specifications*. Sidewalks and pedestrian structures shall be designed for a minimum live load of 2.9 kPa (60 pounds per square foot).

(2) Clearances. A one-way temporary bridge shall have a minimum clear width between faces of railing of 4.4 m (14 feet, 6 inches). A two-way temporary bridge shall have a minimum clear width between faces of railing of 7.3 m (24 feet). Sidewalks and pedestrian bridges shall have a minimum clear width of 1.2 m (4 feet) between faces of railing or edge of curb and face of railing. A minimum vertical clearance of 4.3 m (14 feet) shall be provided for vehicular traffic and 2.4 m (8 feet) for pedestrian traffic.

(3) Erection. As part of the Working Drawings submittal, the Contractor shall, dependent upon the type of structure being erected, include the information required under Section 506 or 510 pertaining to erection or installation. Submittal of the computations indicating magnitude of stresses in the segments is not required.

(c) Railing. Approach railing and temporary barrier rail shall conform to Subsection 621.07.

Details for either rail system or combination thereof shall conform to applicable AASHTO requirements. Rail sections shall be continuous from the approaches across the structure. Approach railing shall be provided for a minimum of 7.65 m (25 feet) off the ends of any structure and shall be provided for all approach fill slopes steeper than 1:3 (vertical:horizontal).

The free end of any steel beam rail shall be protected with a W-beam end section RE-6 (rounded) as defined in the Guide to Standardized Highway Barrier Rail Hardware, flared to a 1.25 m (4 foot) offset. The free end of any concrete barrier rail shall be flared horizontally to a 1.25 m (4 foot) offset for a minimum panel length 3 m (10 feet) and project a maximum of 150 mm (6 inches) above the adjacent roadway surface.

The top of the steel beam railing shall be 760 ± 25 mm (30 ± 1 inch) above the adjacent surface and the concrete barrier railing shall be 790 ± 25 mm (31 ± 1 inch) above the adjacent surface.

Vehicular bridge rail posts and anchorage shall be designed to withstand a horizontal loading of 8.76 kN/m (600 pounds per foot) applied 530 mm (1 foot, 9 inches) above the deck surface. Pedestrian railing and posts shall provide protection for a height of 1070 mm (42 inches) above the walkway surface and be designed to withstand a horizontal loading of 730 N/m (50 pounds per foot) applied 1070 mm (42 inches) above the walkway surface.

When a pedestrian walkway is specified or used in conjunction with vehicular traffic, a 300 by 300 mm (12 × 12 inch) curb separation shall be provided. Curbs shall be anchored to withstand a horizontal loading of 3.65 kN/m (250 pounds per foot). The outside pedestrian railing shall be a combination of vehicular and pedestrian railing. The pedestrian railing shall be constructed to limit clearance between horizontal rail components to 150 mm (6 inches).

When temporary barrier rail is specified or used as a movable rail system (e.g., adjusting traffic flow patterns), the "concrete median barrier" specified herein shall be used. An adequate connection shall be provided when concrete median barrier is used in combination with standard steel beam rail.

(d) Walkways and Approaches. Temporary bridges with walkways, temporary pedestrian bridges, walkways, and approaches to walkways shall be designed and constructed to provide width, grade, surface, etc. in conformance with the requirements set forth in the current ADA standards for sidewalks.

528.05 MAINTENANCE AND LIABILITY. The Contractor shall maintain each temporary bridge and its approaches in conformance with Contract requirements and to the satisfaction of the Engineer. The Contractor shall assume all liability for the installation, maintenance, and removal of the temporary bridge and its approaches. Unless otherwise specified, all rights-of-way on private property required for the performance of this work shall be provided by the Contractor.

Costs for replacing the loss of any part of the temporary bridge or its approaches shall be included in the unit price for the temporary bridge item except as provided in Subsection 107.18.

528.06 METHOD OF MEASUREMENT. The quantity of One-Way Temporary Bridge, Two-Way Temporary Bridge, or Temporary Pedestrian Bridge measured for payment will be on a lump sum basis for each type specified, in the complete and accepted work.

528.07 BASIS OF PAYMENT. The accepted quantity of One-Way Temporary Bridge, Two-Way Temporary Bridge, or Temporary Pedestrian Bridge will be paid for at the Contract lump sum price for each type specified. Payment will be full compensation for designing, detailing, constructing, maintaining, and removing the bridge and its approaches, including placing and removing pavement and pavement markings when paved approaches are required.

When Working Drawings have been submitted and approved in accordance with Section 105, a payment of 10 percent of the lump sum price will be allowed. When a temporary bridge, its substructures, and approaches have been fully constructed and accepted by the Engineer, a further payment of 65 percent of the lump sum price will be allowed. When the temporary bridge and its approaches have been removed, a further payment of 15 percent of the lump sum price will be allowed. The remaining 10 percent of the lump sum price will be paid when the site is cleaned up and vegetation has been established to the satisfaction of the Engineer.

Unless otherwise specified as a separate Contract item, the costs of all approach and bridge railing associated with the temporary bridge will be considered to be included in the Contract lump sum price for Temporary Bridge.

Payment will be made under:

Pay Item	Pay Unit
528.10 One-Way Temporary Bridge	Lump Sum
528.11 Two-Way Temporary Bridge	Lump Sum
528.12 Temporary Pedestrian Bridge	Lump Sum

SECTION 529 - REMOVAL OF STRUCTURES AND BRIDGE PAVEMENT

529.01 DESCRIPTION. This work shall consist of the removal, wholly or in part, and the satisfactory disposal of all structures, including accessories and appurtenances, bridge pavements, and the backfilling of holes when required.

529.02 GENERAL. Unless otherwise specified, all materials resulting from the Removal of Structures and Removal of Bridge Pavements shall become the property of the Contractor, who shall properly dispose of them.

529.03 REMOVAL OF BRIDGE PAVEMENTS. The removal of pavement on bridges shall include the removal of bituminous concrete material. If removal is by cold planing, work shall be done in accordance with Section 210. Removal methods shall be subject to the approval of the Engineer and shall be such as to prevent any damage to the remaining surface. Sealants or membranes shall remain in place as shown on the Plans or directed by the Engineer. Any necessary deck repair will be paid for as shown on the Plans, except damage caused by Contractor's negligence shall be repaired at the Contractor's expense.

529.04 REMOVAL OF STRUCTURES. The Contractor shall dismantle the structure and shall remove the dismantled members or materials. Removal of structures spanning bodies of water will be conducted so as to avoid dropping materials into the water. The entire site of the old structure shall be restored to a condition satisfactory to the Engineer.

The existing concrete or masonry shall be removed by drilling, chipping, or other methods approved by the Engineer. All cut surfaces, unless otherwise specified, shall be on a reasonably vertical or horizontal plane with sharp straight corners. Existing reinforcing steel to be retained shall be carefully preserved and cleaned for use in the new construction. Existing reinforcing steel damaged beyond reuse as determined by the Engineer shall be replaced by splicing a bar of equal diameter to the damaged bar in a manner approved by the Engineer at no additional compensation to the Contractor. Holes for expansion bolts or dowels shall be drilled in the retained concrete at the locations shown on the Plans.

When the material from the structure is to be retained by the Agency or others, or is to be reused in the construction, it shall be carefully dismantled by the Contractor and all adhering concrete removed. Materials to be retained or reused shall be stored at the location specified in the Contract or as directed by the Engineer. When the existing superstructure steel is to be retained for future use, the Contractor shall take every precaution necessary to prevent damage to the existing steel. Damage to the existing steel caused by the Contractor's operations shall be repaired by the Contractor to the satisfaction of the Engineer at no additional cost to the Agency.

Where portions of existing structures are to be removed, the portions indicated shall be removed to the lines shown on the Plans, or as directed by the Engineer, in such a manner as to leave the remainder of the structure undamaged and in proper condition for the intended use. Any damages to the portions remaining in service shall be satisfactorily repaired by the Contractor at no additional cost to the Agency. Explosives will not be permitted for partial removal of any structure.

Removed parts of the existing structure that are to be reused in the new construction shall be safeguarded, cleaned, or otherwise prepared as shown on the Plans or in the Contract and incorporated into the work as shown on the Plans or as directed by the Engineer.

529.05 METHOD OF MEASUREMENT. The quantity of Removal of Bridge Pavement to be measured for payment will be the number of square meters (square yards) of bridge deck from which bituminous pavements have been removed as shown on the Plans or ordered by the Engineer.

The quantity of Removal of Structure to be measured for payment will be as follows:

(a) Removal of Structure will be on a unit basis for each removal at the locations shown on the Plans.

(b) Partial Removal of Structure will be on a unit basis for removal of the materials between the limits shown on the Plans.

(c) Removal of Concrete or Masonry will be the number of cubic meters (cubic yards) or square meters (square yards) of concrete or masonry measured in place and removed between the limits shown on the Plans or as ordered by the Engineer.

529.06 BASIS OF PAYMENT. The accepted quantity of Removal of Bridge Pavement will be paid for at the Contract unit price per square meter (square yard). The accepted quantity of Removal of Structure and of Partial Removal of Structure will be paid for at the Contract unit price per each. The accepted quantity of Removal of Concrete or Masonry will be paid for at the Contract unit price per cubic meter (cubic yard) or square meter (square yard). Payment will be full compensation for the removal and disposal of the specified items; for removal, salvage, and stockpiling of components and materials specified in the Contract; for excavating, backfilling, regrading, and performing site restoration incidental to the removal of specified items; and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

Removal of Bridge Pavement, when not included as a separate pay item, will not be paid for directly, but will be considered incidental to either Removal of Structure or Partial Removal of Structure as specified in the Plans.

Payment will be made under:

Pay Item		Pay Unit
529.10	Removal of Bridge Pavement	Square Meter (Square Yard)
529.15	Removal of Structure	Each
529.20	Partial Removal of Structure	Each
529.25	Removal of Concrete or Masonry	Cubic Meter (Cubic Yard)
529.26	Removal of Concrete or Masonry	Square Meter (Square Yard)

SECTION 530

THIS SECTION RESERVED

SECTION 531 - BRIDGE BEARING DEVICES

531.01 DESCRIPTION. This work shall consist of furnishing and installing bridge bearing devices.

531.02 MATERIALS. Materials shall meet the requirements of the following Subsections:

Mortar, Type IV	707.03
Structural Steel	714.02
High-Strength Low-Alloy Structural Steel	714.03
High-Strength Bolts, Nuts, and Washers	714.05
Anchor Bolts, Bearing Devices	714.08
Galvanizing	726.08
Metalizing	726.09
Bearing Pads	731.02
Elastomeric Material	731.03
Stainless Steel	731.05
Brass Rings	731.07
PTFE Material	731.08

Unless otherwise specified, all materials shall conform to Section 14 of the AASHTO *LRFD Bridge Design Specifications*, Section 14 of the Vtrans *Structures Design Manual* available on the Agency's website, Section 18 of AASHTO *LRFD Bridge Construction Specifications*, and all AASHTO or ASTM specifications specified in this Section. Substitutions will not be allowed unless approved on the Fabrication Drawings.

531.03 FABRICATION DRAWINGS. The Fabricator of bearings furnished under this Section shall submit detailed Fabrication Drawings, bonding procedures, welding procedure specifications, and welder qualification test records in accordance with Sections 105. Fabrication Drawings shall identify the number of layers of vulcanized sheets and corresponding sheet thicknesses to be used for fabricating the bearing pad and shall include detailed procedures for bonding these sheets together.

531.04 FABRICATION.

(a) General. Material furnished under this Section shall conform to all applicable provisions of Subsections 506.03 through 506.16. Bearings shall be fabricated in a plant having as a minimum an AISC Major Steel Bridges (cbr) Certification or in a plant approved by the Agency prior to the award of the Contract. Plants that are not certified must satisfy the requirements of Subsection 506.03.

During any welding, surfaces in contact with the elastomer shall be restricted to 93°C (200° F), and surfaces in contact with PTFE shall be restricted to 148°C (300°F). Temperatures shall be determined by temperature indicating wax pencils or other suitable means.

All corners and edges of steel plates shall be ground to a 1.6 mm (1/16 inch) radius.

Bearing devices shall be fabricated, assembled, and certified by one supplier. Anchor bolt assemblies may be fabricated and supplied by an alternate supplier.

Alternate configurations for bearings from that shown in the Plans may be submitted for approval. Any alternate submitted shall be designed and stamped in accordance with Subsection 105.03. All designs shall meet the design loads and criteria specified in the Plans.

The Fabricator may propose minor alterations to the design of each device from that shown on the Plans to conform to the particular method of fabrication used at that Fabricator's plant. The general design intent of the Plans shall be followed with modifications approved on the Fabrication Drawings, including minor changes to the overall height of the bearing.

If proposed bearing height varies from that shown in the Contract Documents, the Contractor shall propose a method for accommodating the difference in height, which shall be shown in the submittal.

(b) Surface Protection. All bearings, except interior surfaces of pot bearings, shall be galvanized in accordance with Subsection 726.08 or metalized in accordance with Subsection 726.09,.

(c) Tolerances. After fabrication and application of surface protection, bearing devices or components shall be within the following tolerances:

(1) Plain elastomeric pads and steel reinforced elastomeric pads shall be within the tolerances specified in Table 2 of AASHTO M251.

(2) High load mulit-rotational bearings, external load plates, and guides shall be within the tolerances specified in Section 18 of the AASHTO *LRFD Bridge Construction Specifications*.

(d) Sliding Surfaces.

(1) Stainless steel used as a mating surface with PTFE shall conform to the following:

a. The thickness of the stainless steel sheet shall be at least 1.9 mm (14 gauge) when the maximum dimension of the surface is less than or equal to 305 mm (12 inches), and at least 3.0 mm (11 gauge) when the maximum dimension is larger than 305 mm (12 inches).

b. For bonded applications, stainless steel sheets may be affixed to backup plates with a combination of high-temperature resistant epoxy and mechanical attachment by spot welding or other approved procedures. The Fabricator must demonstrate that any proposed alternate procedure for attachment will maintain adhesion between the backup material and stainless steel under loading, movement, and weather conditions anticipated to be encountered during life of the bearing.

c. For welded applications, stainless steel sheets shall be circumferentially seal welded to backup plates. Procedure qualification will be required for any welding process and welding procedures shall be submitted for approval in accordance with Subsections 506.04 and 506.10.

d. Prior to adhesion or attachment of the stainless steel to a backup plate, the contact surface of the backup plate shall meet the sliding surface tolerance specified herein and shall be blast cleaned to an appearance equivalent to SSPC-SP10. The contact surface of stainless steel sheets to be bonded with epoxy shall be mechanically abraded or etched prior to application of adhesive.

(e) High Load Multi-Rotational (Pot or Disc). In addition to the requirements of Section 14 of the AASHTO *LRFD Bridge Design Specifications* and Section 18 of the AASHTO *LRFD Bridge Construction Specifications*, the following shall apply to the design and fabrication of pot bearings:

(1) General. Bearings shall be designed for the vertical and horizontal forces shown on the Plans.

Exposed PTFE material on a guide bar or other component shall be pigmented to prevent penetration of ultraviolet light

The shape characteristics, clearances, and sealing mechanism of the piston and cylinder must be designed to prevent extrusion of the elastomer under load and rotational movement.

Either PTFE sheets or other approved material shall be provided to lubricate compressive surfaces of the elastomer.

The internal floating portion of the bearing must be sealed to prevent the intrusion of foreign material.

The steel housing shall be manufactured by welding or machining from a single piece of plate. The shear restriction mechanism shall be connected to the bearing plate by mechanically fastening, welding, or other means approved by the Engineer.

High load multi-rotational bearings shall be tested in accordance with the AASHTO *LRFD Bridge Design Specifications* and Section 18 of the AASHTO *LRFD Bridge Construction Specifications*, modified as follows:

a. For each structure or pair of structures on a project, one of every ten fixed bearings and one of every ten expansion bearings shall be selected at random from the production lot. Sample or specially made test bearings will not be permitted.

b. Load measuring instruments used in conjunction with the testing equipment should be calibrated yearly and be accompanied by a certificate indicating their date of calibration.

c. Measured static coefficient of friction shall be less than 4 percent.

d. Measured dynamic coefficient of friction shall be less than 4 percent

e. Basis of acceptance:

1. Coefficients of friction are less than 4 percent.

2. Acceptable material certifications.

3. Assembled bearings meet requirements and tolerances of Contract.

4. Inspection of tested bearings show no visual defects, such as extruded or deformed elastomer, polyether urethane, or PTFE, damaged seals or limiting rings, evidence of metal-to-metal contact between the pot wall and the top plate, or cracked steel.

f. Test results and material certifications shall be sent to the Agency's Materials and Research Section with a copy of the test results sent to the Structures Engineer.

g. Acceptable test results are a prerequisite for certification acceptance. Expenses for performing any testing shall be incidental to the work.

531.05 INSTALLATION.

(a) General. Bearings shall be set level and parallel. with full and uniform bearing. Pedestals detailed to be on a slope shall be set at the elevation and position specified.

The concrete under the bearing device shall be level.

Anchor bolts shall be positioned to the alignment and dimensions specified or approved in the Fabrication Drawings. When preset or cast-in anchorages are not specified, the Contractor shall drill holes and set the anchor bolts in a Type IV mortar. Additional aggregates shall not be added to the material during field mixing.

Prior to ordering materials and starting the work, the Contractor shall submit a drilling and mortaring proposal to the Engineer for approval, including a premixed mortar material brand name.

The drilled holes to be mortared shall be thoroughly cleaned, wetted, and free of standing water.

The mortar shall be mixed in a mechanical mixer in accordance the manufacturer's recommendations and shall be readily pourable so that when poured it completely fills the remaining hole cavities. The placement of mortar for each bearing shall be continuous and complete at all hole locations.

All exposed mortar shall be cured for a period of not less than three (3) days by the wetted burlap method in accordance with Section 501. Curing shall commence as soon as practical after mortar placement. The Contractor shall not apply any forces to the anchor bolts during the curing period.

If allowed in the Contract or ordered by the Engineer, a pre-approved adhesive may be used to set the anchor bolts into the concrete. If an adhesive is used, the manufacturer's installation requirements for the adhesive shall be followed during installation. The Engineer shall be provided a copy of the Material Data Safety Sheet (MSDS) and a copy of the manufacturer's installation requirements.

Unless otherwise specified on the Plans, anchor bolts shall have a minimum embedment of 450 mm (18 inches) into the concrete and shall conform to Subsection 714.08.

Anchor bolts to be double nutted shall use the following procedure: install lower nut in contact with top of sole plate, and then back off ½ turn; install upper nut snug tight to prevent lower nuts from loosening.

Whenever a bridge seat is off by 6 mm (1/4 inch) or more from its designed or adjusted elevation, corrective measures shall be required.

If shims are required, they shall be a single thickness plate of AASHTO M 270M/M 270, Grade 250 or 345 (Grade 36 or 50) steel, galvanized in accordance with Subsection 726.08 or metalized in accordance with Subsection 726.09. Details of shims shall be furnished and approved in accordance with Subsection 105.03. The cost of any necessary corrective measures, including any costs due to a delay, shall be borne by the Contractor.

(b) Elastomeric Pad with External Load Plate and High Load Multi-Rotational Bearings. During any welding, surfaces in contact with the elastomer shall be restricted to 93°C (200°F), and surfaces in contact with PTFE shall be restricted to 148°C (300°F). Temperatures shall be determined by temperature indicating wax pencils or other suitable means. No welding current shall be permitted to pass between the pot and piston components.

The welds for the sole plate connection should only be along the longitudinal girder axis. Transverse joints should be sealed with an acceptable caulking material.

Metal bearing plates shall be placed on a 3 mm (1/8 inch) thick bearing pad conforming to Subsection 731.02. The bearing pad shall be the same size as the bearing plate with holes to accommodate the anchor bolts.

PTFE and stainless steel sliding surfaces shall be protected from splatter during welding, grouting, or painting operations if applicable.

High load multi-rotational bearings shall not be disassembled once they have left the manufacturer, since the process could result in damage to the components or malfunction of the device. Pot bearings that have been disassembled shall not be accepted unless recertified by the manufacturer.

531.06 METHOD OF MEASUREMENT. The quantity of Bearing Device Assembly of the type specified to be measured for payment will be the number of units used in the complete and accepted work. All bearing device components and anchor bolt assemblies will be included as part of the measured unit. Anchor bolt assemblies include bolts, threaded rods, nuts, washers, and beveled plates required for attachment of bearing devices to the superstructure and substructure.

The quantity of Remove and Replace Existing Anchor Bolt to be measured for payment will be the number of each anchor bolt removed and replaced in the complete and accepted work.

531.07 BASIS OF PAYMENT. The accepted quantity of Bearing Device Assembly of the type specified will be paid for at the Contract unit price for each. Payment will be full compensation for detailing, furnishing, handling, transporting, and placing the material specified, including surface preparation, protective coating, testing, anchor bolt assemblies, drilling for anchor bolts, mortar, proprietary anchoring systems, bearing device components, and welding, and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

Payment for alternate bearing designs and submittals will be considered incidental to the appropriate Section 531 pay item in the Contract.

Payment for Remove and Replace Existing Anchor Bolt will be paid for at the Contract unit price for each. Payment will be full compensation for removing the existing anchor bolt, removing and replacing the existing bearing assembly, welding, drilling for new anchor bolt, mortar, proprietary anchoring systems, and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

Payment will be made under:

	Pay Item	Pay Unit
531.15	Bearing Device Assembly, High Load Multi-Rotational	Each
531.16	Bearing Device Assembly, Plain Elastomeric Pad	Each
531.17	Bearing Device Assembly, Steel Reinforced Elastomeric Pad	Each
531.18	Bearing Device Assembly, Elastomeric Pad with External Load Plates	Each
531.19	Remove and Replace Existing Anchor Bolt	Each

SECTION 540 – PRECAST CONCRETE

540.01 DESCRIPTION. This work shall consist of manufacturing, transporting, and erecting precast concrete structure components. This specification also addresses the manufacture of precast concrete mechanically stabilized earth (MSE) wall panels. Hereafter, the phrase "precast concrete" will be used to include both precast concrete structure components and MSE wall panels.

540.02 MATERIALS. Materials shall meet the requirements of the following Subsections:

Portland Cement 701.02
High Early Strength Portland Cement 701.04
Blended Silica Fume Cement 701.06
Tar Emulsion 702.05
Fine Aggregate for Concrete 704.01
Coarse Aggregate for Concrete 704.02
Mortar, Type I 707.01
Mortar, Type IV 707.03
Asphalt-Treated Felt 707.08
PVC Waterstop 707.10
Bar Reinforcement 713.01
Mechanical Splices for Bar Reinforcement 713.02
Welded Steel Wire Fabric 713.05
Coated Bar Reinforcement 713.07
Structural Steel 714.01-714.05
Concrete Curing Materials 725.01
Air-Entraining Admixtures ..... 725.02(b)
Retarding Admixtures ..... 725.02(c)
Water-Reducing Admixtures ..... 725.02(f)
Water-Reducing and Retarding Admixtures ..... 725.02(g)
Water-Reducing, High Range Admixtures ..... 725.02(h)
Water-Reducing, High Range, and Retarding Admixtures ..... 725.02(i)
Accelerating Admixtures ..... 725.02(j)
Water-Reducing and Accelerating Admixtures ..... 725.02(k)
Low Shrinkage Admixtures ..... 725.02(l)
Mineral Admixtures 725.03
Silica Fume ..... 725.03(b)
Ground Granulated Blast-Furnace Slag (GGBFS) ..... 725.03(c)
Bearing Pads for Structures 731
Polystyrene Insulation Board 735.01
Blanket Insulation Material 735.02
Pipe Insulation 740.08
Water 745.01
Overhead and Vertical Concrete Repair Material 780.02

540.03 GENERAL FABRICATION REQUIREMENTS.

(a) Qualification. For all Contracts advertised for bids after December 31, 2006, precast concrete shall be manufactured in a plant that has been certified by either the Prestressed Concrete Institute (PCI) under its Plant Certification Program for precast concrete or by the National Precast Concrete Association (NPCA) Plant Certification Program.

Precast concrete shall be manufactured in a plant that maintains a quality control laboratory complete with equipment for measuring the properties of fresh and hardened concrete. As a minimum, the laboratory shall be equipped with a compression testing machine, curing room or chamber, apparati for measuring slump and air entrainment, and a complete set of aggregate sieves. The compression testing machine shall be calibrated yearly by an independent laboratory using equipment that is certified by the National Institute of Standards and Technology. The testing machine shall be power operated and capable of applying the load continuously rather than intermittently, and without shock.

(b) Quality Control. The manufacture of precast concrete shall be in accordance with the latest editions of PCI MNL-116 *Manual for Quality Control for Plants and Production of Precast and Prestressed Concrete Products* and PCI MNL 135 *Tolerance Manual for Precast and Prestressed Concrete Construction***,** except as modified in this Section, or with the *National Precast Concrete Association (NPCA) Quality Control Manual for Precast Plants.*

The Fabricator shall demonstrate a level of quality control testing that satisfies the Agency as to its ability and commitment to produce precast concrete to the requirements of this Section. A satisfactory program of quality control shall include gradation and moisture determinations of the aggregates, as well as slump, air content, and strength determinations of the concrete. These tests shall be performed at regular and suitable intervals and actively used to maintain the quality of the concrete within the specified requirements.

540.04 SUBMITTALS. As soon as practical after award of the Contract, all required information shall be prepared and submitted.

A complete copy of the structural design calculations for the precast concrete shall be submitted as Construction Drawings in accordance with Section 105. The design calculations shall substantiate that the proposed precast concrete satisfies the design parameters of the Contract. The design calculations shall include a load rating for superstructures for the seven standard axle configurations shown in the load rating block in the Contract Plans and any general or construction notes required for the fabrication and construction of the precast concrete. The applicable design code will be the latest edition of the AASHTO *LRFD Bridge Design Specifications* unless indicated otherwise in the Contract Documents.

Fabrication Drawings for the precast concrete shall be submitted in accordance with Section 105, with an additional copy to the Structural Concrete Engineer. In addition to the requirements for Fabrication Drawings in Section 105, the following shall be included:

(a) Dimensions of the precast concrete to be fabricated.

(b) The concrete mix design**,** including but not limited to the following:

(1) Batch weights specifying dry or saturated surface dry.

(2) Material names and sources.

(3) Aggregate properties and date tested.

(4) Chemical and physical properties of cementitious material.

(5) Admixture names and sources.

(6) Lab data that shall include, but not be limited to:

a. Slump.

b. Air Content.

c. Temperature.

d. Ratio of Water/Cementitious Material.

e. Cylinder breaks for 3, 7, and 28 days cured in the same manner as the piece to be fabricated.

f. 56 day Rapid Chloride Ion Permeability – AASHTO T 277 test data. The results shall be the average from testing 3 specimens, but the individual specimen results shall also be included. Testing shall be performed by a CCRL qualified laboratory.

g. Alkali-Silica Reactivity (ASR) – AASHTO T 303 data from testing of both the fine and coarse aggregates**.** Testing shall be performed by a CCRL qualified laboratory.

(7) Alkali-Silica Reactivity (ASR) – If potentially reactive aggregates are to be used in a mix design, then proposed mitigation method(s) and test results must be provided. The AASHTO T 303 test must be run again with the proposed mitigation method(s) and using the proposed job cementitious material proportioning. The proposed mitigation method(s) shall reduce expansion to below 0.10%.

If a mix design, including the testing results, has been submitted and approved within a 12 month period for the manufacture of precast concrete, it may be used in lieu of submitting an additional mix design. However, if any change in the material sources or properties has occurred, then a new mix design with lab test data will be required regardless of previous approval.

The requirements for testing in Subsections 540.04(b)(6)f, 540.04(b)(6)g, and 540.04(b)(7) above shall be waived if the submitted mix design has a minimum proportion of the cementitious material content of 25% ground granulated blast-furnace slag (GGBFS) and 6% silica fume or 20% fly ash and 6% silica fume.

The mix design shall be approved by the Structural Concrete Engineer prior to fabrication.

(c) The sources and properties of the materials proposed for use.

(d) The placement of reinforcing steel, welded wire fabric, mechanical bar connectors, and inserts.

(e) The type of surface finish and how the finish will be obtained. Include details of potential repair procedures.

(f) The curing method, detailing sequence and duration.

(g) The minimum required concrete strength for form removal.

(h) The design of the lifting attachments.

(i) Transportation, handling, and storage details.

(j) The installation procedure including a detailed grouting procedure.

(k) Description of Quality Control procedures.

540.05 CONCRETE.

(a) Batch plant equipment, materials, and batching procedures shall conform to the following provisions of Section 501:

501.04	BATCHING, paragraphs 1 and 3 only.
501.04 (b)	Testing Laboratory.
501.04 (c)	Bins and Scales.
501.04 (d)	Accuracy of Plant Batching.
501.04 (e)	Storage and Proportioning of Materials.
501.05	MIXING AND DELIVERY, for plants not located in the State, the Agency has the option of waiving the requirements of Subsections 501.05(a)(4) and 501.05(c), paragraphs 1 and 3 only.

(b) Concrete for precast concrete shall conform to the following:

(1) The cementitious material content in the mix design shall be between 363 and 475 kg/m³ (611 and 800 pounds per cubic yard) of concrete.

(2) The percent of air entrainment shall be 7 percent with a tolerance of +/- 2 percent, as tested in accordance with AASHTO T 152.

(3) The temperature of the concrete at the time of placement shall be between 10 and 29 ºC (50 and 85 ºF), as tested in accordance with AASHTO T 309.

(4) The maximum water-cementitious material ratio shall be 0.44. When a water-reducing, high range admixture (AASHTO M 194, Type F or Type G) has been included in the approved mix design, the concrete shall not demonstrate segregation at the proposed slump.

(5) The maximum allowed rapid chloride ion coulomb permeability result as tested per AASHTO T 277 is 2000, tested at 56 days from the date specimens were cast.

(6) The maximum allowable mortar bar expansion when tested per AASHTO T 303 (with proposed mitigation method(s), as described previously, if required) shall be 0.10%.

(c) The proposed concrete mix design, including performance history and all requests for variance from the material requirements of these Specifications, shall be submitted for approval as part of Subsection 540.04. The Structural Concrete Engineer may require a minimum of 8 weeks for testing and approval of the mix design.

(d) Any admixture containing calcium chloride shall not be used. Type II, Type III, or Blended Silica Fume portland cement may be used. Only one type of cement and only one source of that type shall be used for the precast concrete units required for any one structure.

(e) Compressive Strength.

(1) Compressive strength for precast concrete structure components at 28 days, as determined in accordance with AASHTO T 22, shall not be less than 35 MPa (5000 psi). When an acceptance test result, as defined in this Section, is below the specified strength, all concrete represented by that test shall be unacceptable for the requirements of this Section. The Engineer shall reject all precast concrete structure components that were manufactured from this concrete. Acceptance of precast concrete structure components, with respect to compressive strength, shall be determined on the basis of representative compression strength tests. The representative samples shall be taken per each piece cast, a single day's production or 75 CM (100 CY) placed, whichever is less or other sampling sequence accepted by the Structural Concrete Engineer.

Specimens shall be standard cylinders made by the Fabricator in accordance with AASHTO T 23. Fabrication of test specimens shall be witnessed by an Agency representative.

Four specimens are required to determine compliance with the 28-day strength requirement. The specimens shall be cured under the same conditions as the piece from the time of casting until the piece is removed from the form. At that time, the specimens shall be moved to storage where curing shall continue under standard conditions in accordance with AASHTO T 23. These specimens shall be retained by the Fabricator for testing.

The average of the compressive strengths of two specimens shall constitute a test result. Specimens shall be tested either at the Agency's Materials and Research Section laboratory, or at the Fabricator's plant laboratory. An Agency representative shall witness all tests.

If the average strength of specimens representing precast concrete structure components does not reach the 28-day design strength within 28 days, the precast concrete structure components shall be rejected.

(2) Acceptance of the MSE wall panels, with respect to compressive strength, shall be determined on the basis of production lots. A production lot is defined as a group of panels that shall be represented by a single set of compressive strength samples and shall consist of not more than 80 panels or a single day's production, whichever is less.

Compressive strength test specimens shall be prepared in accordance with AASHTO T23. During the production of the concrete panels, the manufacturer shall randomly sample the concrete in accordance with AASHTO T141.

A single set of compressive strength samples, consisting of a minimum of four (4) cylinders, shall be made for every production lot.

For every compressive strength sample, a minimum of two cylinders shall be cured in the same manner as the panels and tested at seven (7) days or less. The average compressive strength of these cylinders, when tested in accordance with AASHTO T22, will determine the initial strength of the concrete.

In addition, a minimum of two cylinders shall be cured in accordance with AASHTO T23 and tested at 28 days. The average compressive strength of the cylinders, when tested in accordance with AASHTO T22, will determine the compressive strength of the production lot.

If the initial strength test results indicate a compressive strength greater than or equal to 27.6 MPa (4000 psi), then this test result will be utilized as the compressive strength test result for that production lot, and the requirement for testing at 28 days will be waived for that particular production lot.

A production lot will be accepted if the compressive strength test result is greater than or equal to 27.6 MPa (4000 psi) at 28 days.

If the compressive strength test result is less than 27.6 MPa (4000 psi) at 28 days, the acceptance of the production lot will be based on its meeting each of the following acceptance criteria:

a. Ninety (90) percent of the compressive strength test results for the overall production shall exceed 28.6 MPa (4150 psi).

b. The average of any six (6) consecutive compressive strength test results, including the one in question, shall exceed 29.3 MPa (4250 psi).

c. No individual compressive strength test result shall be below 24.8 MPa (3600 psi).

In the event that a production lot fails to meet the specified compressive strength requirements, the production lot shall be rejected. Such rejection shall prevail unless the manufacturer, at the manufacturer's expense, obtains and submits evidence to the Engineer that the strength and quality of the concrete placed within the panels of the production lot is acceptable. If such evidence consists of tests made on cores taken from the panels within the production lot, then the cores shall be obtained and tested in accordance with AASHTO T24.

540.06 INSPECTION. Materials furnished and the work performed under Section 540 shall be inspected by the Agency. The inspector shall have the authority to reject any material or work that does not meet the requirements of these Specifications. Advance notification of at least two weeks must be provided by the Fabricator to the Agency's Engineer and the Structural Concrete Engineer concerning the proposed intention to commence work. A minimum of five working days notification must be provided to the Structural Concrete Engineer by the Fabricator to confirm the fabrication start date.

Prior to shipment of any precast concrete, the Materials and Research Engineer shall have approved all applicable material certifications required in accordance with Subsection 700.02.

540.07 FABRICATION.

(b) Pre-Production Meeting. Unless the Engineer deems, in writing, that a pre-production meeting is unnecessary, then a pre-production meeting shall be held a minimum of seven (7) calendar days prior to beginning concrete placement. The pre-production meeting shall be attended by, and including but not limited to, the Crew Supervisor, Plant Manager, Inspector or Inspector's Supervisor, and Project Manager and/or Designer.

(b) Forming Members. Any defects or damage due to form work, stripping, or handling may be cause for rejection. Holes or cutouts for anchoring devices, diaphragm connections, openings for connection rods, recesses for grout holes for railing bolts, and any other related details shown on the Plans shall be provided for in the members.

(c) Post Tensioning Strands and Conduits. Each post tensioning strand to be post-tensioned shall be encased in an approved conduit. Unless otherwise shown on the Plans, the ratio of cross-sectional area of the post tensioning strand to be encased to the interior cross-sectional area of the conduit shall not exceed 0.4, except when a steel bar is used as a tendon, the inside diameter of the conduit shall be at least 10 mm (3/8 inch) greater than the diameter of the bar. Conduit that has been crushed or has opened seams shall not be used.

The conduit shall be rigidly constructed, completely sealed, accurately placed, and securely fastened to maintain the desired profile during concreting. No conduit shall be located more than 6 mm (1/4 inch) from the position shown on the Plans. Bundling of conduits will not be permitted.

(d) Bar Reinforcement and Welded Wire Reinforcement. Bar reinforcement and welded wire reinforcement shall be furnished and installed in conformance with Subsections 507.03, 507.04, 507.05, 507.07, and 507.08. The chairs or spacers used to support or locate the reinforcement that bears on the faces of the forms shall be made of, or be coated with a non-corrosive material so that no discoloration will show on the faces of the precast concrete units.

(e) Placing Concrete. Concrete shall not be deposited in the forms until the Agency representative has approved placement of the reinforcement, conduits, and anchorages. The concrete shall be vibrated internally, externally, or a combination thereof to the required consolidation. The vibrating shall be done with care and in such a manner to ensure that:

(1) The concrete is uniformly consolidated.

(2) Displacement of reinforcement, inserts, conduits, and anchorages is avoided.

(3) Acceptable finish surfaces are produced.

(f) Repairs/Patching. Precast concrete structure components that contain minor defects caused by manufacture or handling may be repaired at the manufacturing site. Minor defects are defined as holes, honeycombing, or spalls, which are 150 mm (6 inches) or less in diameter, that do not penetrate deeper than 25 mm (1 inch) into the concrete. Surface voids or "bugholes" that are less than 16 mm (5/8 inch) in diameter and less than 6 mm (1/4 inch) deep need not be repaired. Repairs shall be made using a material from the Approved Products List for overhead and vertical concrete repair. The repair material shall be cured as specified by the manufacturer. Repairs shall be approved by the Engineer.

(g) Cracking. Cracks less than 0.25 mm (0.01 inch) in width shall be sealed by a method approved by the Engineer. Cracks in excess of 0.25 mm (0.01 inch) may be cause for rejection. At the Engineer's discretion, cracked precast concrete structure components shall be repaired or replaced at the Contractor's expense.

(h) Dimensional Tolerances for Precast Concrete Structure Components. All tolerances shall be in accordance with the latest editions of both PCI MNL 116 *Manual for Quality Control for Plants and Production of Precast and Prestressed Concrete Products* and PCI MNL 135 *Tolerance Manual for Precast and Prestressed Concrete Construction*, or with the *National Precast Concrete Association (NPCA) Quality Control Manual for Precast Concrete*, unless otherwise noted in the Contract Documents or as approved by the Engineer.

(i) Welding. All welding shall conform to the requirements of Subsection 506.10.

(j) Cold Weather. When the concrete is cast in ambient air temperatures of 10˚C (50˚F) or less, the requirements of Subsection 501.07(b) shall apply.

(k) Marking. The date of manufacture, the production lot number and the piece mark shall be clearly marked on each individual piece of precast concrete. The mark shall be in a location that will not be visible in the finished product.

(l) Form Removal. Unless otherwise specified, form removal shall be permitted only after the strength required and approved in Subsection 540.04 (g) is attained on two successive test specimens.

(m) MSE Wall Panel Tolerances and Acceptance/Rejection. MSE wall panels shall have a minimum structural thickness of 140 mm (5 inches) and a minimum cover for steel reinforcement of 40 mm (1 1/2 inches). The concrete surface for the front face shall have a form liner finish as required on the approved Fabrication Drawings. The concrete surface on the rear face shall be an unformed flat finish. The concrete panels shall be constructed using colored concrete. The color shall be as specified in the Plans. A full size test panel shall be produced and approved by the Agency prior to production of the MSE wall panels. The panel shall be available for review a minimum of five working days prior to the start of production. The approved test panel shall be used as a benchmark for the correct color and form liner finish.

All MSE wall panels shall be manufactured within the following tolerances with respect to the dimensions shown on the approved Fabrication Drawings:

(1) Attachment Device Locations and Alignment. Lateral position of reinforcing element attachment devices shall be within 25 mm (1 inch). Embedment measured from the back face of the panel shall be 100 mm (4 inches) within +6 mm (1/4 inch) or -13 mm (1/2 inch).

(2) Panel Dimensions. All panel dimensions shall be within 6 mm. All hardware embedded in the panel with the exception of attachment devices shall be within 6 mm (1/4 inch).

(3) Panel Squareness. Squareness, as determined by the difference between the two diagonals, shall not exceed 13 mm (1/2 inch).

(4) Panel Surface Finish. Surface defects on smooth-formed surfaces, measured on a length of 1.5 m (5 feet), shall not exceed 6 mm (1/4 inch). Surface defects on textured-finished surfaces, measured on a length of 1.5 m (5 feet), shall not exceed 8 mm (5/16 inch).

MSE wall panels shall be accepted for use in wall construction provided the concrete strength meets or exceeds the minimum compressive strength requirement, the soil reinforcement connection devices and the panel dimensions are within tolerances, and any chipping, cracks, honeycombing, or other defects are repaired to the satisfaction of the Structural Concrete Engineer using methods submitted and approved under Subsection 540.04.

The MSE wall panels shall be subject to inspection by the Engineer at the time of unloading and once placed in their final position. MSE wall panels that do not meet the required specifications are subject to rejection. Individual panels may be rejected for any of the following:

(1) Variations in the exposed face that deviate from the approved model as to color and texture in accordance with precast concrete industry standards.

(2) Dimensions not conforming to 540.07 (l), Tolerances.

(3) Honeycombed or open texture not properly repaired.

(4) Defects which would affect the structural integrity of the unit.

540.08 CURING.

(a) General. All curing methods for precast concrete shall be subject to the Structural Concrete Engineer's approval.

Where the Fabricator elects to cure precast concrete structure components by method(s) other than low pressure steam or radiant heat as described below, the Fabricator shall submit with the Fabrication Drawings complete details of the proposed method(s) for approval.

The Fabricator shall provide one automatic temperature recorder for each precast concrete structure component. The recorder shall continuously record curing temperature for the entire curing period. Temperature sensors shall be carefully placed within the curing enclosure to ensure that ambient temperatures are measured at typical locations. Recorder accuracy shall be certified at least once every 12 months, and the certificate displayed with the recorder. Calibration and certification shall be performed by either the manufacturer, the supplier, or an independent laboratory. Random temperature checks of each recorder may be made by an Agency representative. Each recorder chart shall indicate the casting bed, date of casting, time of start and finish of record, and the mark number of the precast concrete structure component being cured. At the completion of the curing period, the recorder charts shall be given to the Agency representative. Temperatures recorded on the charts shall be used to determine whether the precast concrete structure components have been cured in accordance with the specifications and the approved Fabrication Drawings.

Regardless of the curing method chosen the following requirements shall apply:

(1) Except as allowed in Subsection 540.08(b), precast concrete structure components shall be cured by one of the methods specified in Subsection 501.17 until design strength has been achieved.

(2) MSE wall panels shall have an approved curing compound applied to the back face of the panel immediately following finishing.

(3) The precast concrete shall not be subjected to temperatures less than 20 ºC (36 ºF) until the design strength has been achieved.

(4) After the curing period, the temperature of the precast concrete shall be gradually lowered to that of the surrounding atmosphere. The cooling rate shall not exceed 10°C/hr (50°F/hr) and the precast concrete shall not be more than 5°C (40°F) warmer than the ambient air temperature when removed from a curing enclosure.

(b) Curing with Low-Pressure Steam or Radiant Heat.

(1) Immediately upon completing placement of the concrete for each precast concrete structure component, an enclosure shall be placed over the forms. This enclosure shall be suitable for containing the live steam or heat. The Fabricator shall make these covers available for inspection prior to casting.

(2) When low pressure steam methods are used for curing, precautions shall be taken to prevent live steam from being directed on the concrete or forms in such a way as to cause localized high temperatures.

(3) When radiant heat is used for accelerated curing, all exposed precast concrete surfaces shall be covered with plastic sheeting. Radiant heat may be applied by means of a circulation pipe containing steam, hot oil, or hot water, or by electric heating elements.

(4) The precast concrete shall be allowed to attain its initial set before commencing accelerated curing. This waiting period shall not exceed four hours from time of placement for concrete with no retarder added, or eight hours from the time of placement for concrete with retarder. During this initial curing period, while waiting for the initial set to take place, the temperature within the enclosure shall be maintained between 10 and 27ºC (50 and 80ºF).

(5) During the initial application of heat or steam, the ambient air temperature within the enclosure shall increase at a rate not exceeding 20ºC (36ºF) per hour until the maximum curing temperature is reached. The maximum curing temperature shall not exceed 82ºC (180ºF). The selected curing range shall be as approved on the Working Drawings. The maximum temperature shall be held until the concrete has reached a minimum of 80 percent of f'c, unless otherwise specified in the Contract.

540.09 HANDLING, STORAGE, AND SHIPPING. All precast concrete shall be handled, stored, and shipped in such a manner as to minimize chipping, cracks, fractures, discoloration, and excessive bending stresses. Units damaged by handling, storage, or shipping shall be replaced at the Contractor's expense.

MSE wall panels shall be stored and shipped in stacks, front face down. Firm blocking of sufficient thickness to prevent the reinforcement attachments from contacting the adjacent panels shall be used. Lifting inserts shall be installed on the top edge of the MSE wall panels to permit lifting at the project site. Reinforcement connection inserts (tie strips) shall not be used for lifting or handling the panel at the project site.

Precast concrete will not be considered for shipment until it has been accepted. This acceptance shall include verification that the pieces are free from defects and all specification requirements including the compressive strength and tolerance requirements have been achieved. In addition, precast concrete will not be considered for shipment for a minimum of 72 hours following the completion of casting.

540.10 INSTALLATION.

(a) Methods, Equipment and Erection. Cranes, lifting devices, and other equipment for precast concrete structure erection shall be of adequate design and capacity to safely erect, align, and secure all members and components in their final positions without damage. The Contractor is solely responsible for the methods and equipment employed for the erection of the precast concrete structure components.

Construction Drawings for precast concrete structure component erection shall be submitted in accordance with Section 105. The erection plan shall include the necessary computations to indicate the magnitude of stress in the units during erection and to demonstrate that all of the erection equipment has adequate capacity for the work to be performed, and provisions for all stages of construction, including temporary stoppages.

Submittal of the erection plan is for the Agency's documentation only and shall in no way be construed as approval of the proposed method of erection. The Contractor shall follow the erection plan as submitted.

(b) When included in the Contract Documents, the installation of MSE wall panels shall be as specified in the MSE wall specification.

540.11 GROUT.

(a) Grout shall be used to fill shear keys, leveling screw voids, transverse tie anchor recesses, dowel holes, and for fairing joints as detailed in the Contract or as ordered by the Engineer.

Grout shall be Mortar, Type IV. Acceptable grout materials shall be those included on the Approved Products List on file with the Agency's Materials and Research Section. Additional aggregates shall not be added to the material during field mixing.

The Contractor, with written permission from the Engineer, has the option to use ready mixed mortar for the grouting process. The Contractor shall prepare and submit for approval the mix design for the grout. The maximum quantity that can be delivered in a single load is one cubic meter (1.25 cubic yards), which must be delivered and placed within the time limits specified by the manufacturer.

For testing, 6 neat 50 mm (2 inch) cubes shall be molded and cured in accordance with AASHTO T 106 (ASTM C 109). The average compressive strength of 3 cubes shall be a minimum of 7 MPa (1000 psi) at 3 days and a minimum of 35 MPa (5000 psi) at 28 days.

(b) The surface to be grouted shall be thoroughly cleaned, wetted, and free of all standing water.

The grout shall be mixed using a mechanical mixer according to the manufacturer's recommendations and shall be readily pourable so that it completely fills the shape of the shear keys or holes, depending on the product being installed. The placement of the grout shall be continuous. The grouting of each shear key shall be completed in its entirety within a single working day.

(c) Grout shall be placed between precast concrete structure components as required for fairing out any unevenness between adjacent components. Mortar, Type IV shall be used.

The mortar shall be placed to the thickness necessary to eliminate unevenness, forming a smooth surface from the higher beam edges to the lower surface. The finished surface shall be feathered smoothly and be free of depressions or sharp edges.

(d) All exposed grout shall be cured for a period of not less than three days by the wetted burlap method in accordance with Section 501. Curing shall commence as soon as practical after grout placement.

540.12 POST-TENSIONING. Post-tensioning strands shall not be bonded to the concrete. Post-tensioning strands shall be double protected against corrosion as specified in the Contract.

Post-tensioning of strands shall not commence until a minimum compressive strength of 10 MPa (1500 psi) has been attained in the grout and the grout has cured for three days.

540.13 METHOD OF MEASUREMENT. The quantity of Precast Concrete Structure of the type and size specified to be measured for payment shall be on a lump sum basis. The lump sum shall include all of the precast concrete structure components in the complete and accepted work for each location specified in the Contract.

MSE wall panels will not be measured separately for payment, but will be considered in the measurement for the Mechanically Stabilized Earth (MSE) Wall item in the Contract.

540.14 BASIS OF PAYMENT. The accepted quantity of Precast Concrete Structure of the type and size specified will be paid for at the Contract lump sum price. Payment shall be full compensation for designing, detailing, fabricating, repairing, transporting, handling, and erecting the materials specified, for furnishing and implementing the erection plan, and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

Any grouting work, such as fairing out unevenness between adjacent precast concrete structure components and filling leveling screw holes, shear keys, transverse anchor recesses, and dowel holes, is considered incidental to the work for Precast Concrete Structure.

Payment will be made under:

Pay Item	Pay Unit
540.10 Precast Concrete Structure	Lump Sum

SECTION 541 - STRUCTURAL CONCRETE

541.01 DESCRIPTION. This work shall consist of furnishing and placing portland cement concrete for structures and incidental construction.

The portland cement concrete shall consist of a homogeneous mixture of cement, fine aggregate, coarse aggregate, water, admixtures, and pozzolan (when used), proportioned and mixed according to these Specifications.

541.02 MATERIALS. Materials shall meet the requirements of the following Subsections:

Portland Cement 701.02
High Early Strength Portland Cement 701.04
Portland-Pozzolan Cement 701.05
Portland Blast-Furnace Slag Cement 701.07
Tar Emulsion 702.05
Fine Aggregate for Concrete 704.01
Coarse Aggregate for Concrete 704.02
Lightweight Coarse Aggregate for Structural Concrete 704.14
Mortar, Type I 707.01
Mortar, Type IV 707.03
Asphalt-Treated Felt 707.08
PVC Waterstop 707.10
Concrete Curing Materials 725.01
Air-Entraining Admixtures ..... 725.02(b)
Retarding Admixtures ..... 725.02(c)
Water-Reducing Admixtures ..... 725.02(f)
Water-Reducing and Retarding Admixtures ..... 725.02(g)
Water-Reducing, High Range Admixtures ..... 725.02(h)
Water-Reducing, High Range, and Retarding Admixtures ..... 725.02(i)
Accelerating Admixtures ..... 725.02(j)
Water-Reducing and Accelerating Admixtures ..... 725.02(k)
Low Shrinkage Admixtures…….. .725.02(l)
Mineral Admixtures 725.03
Ground Granulated Blast-Furnace Slag ..... 725.03(c)
Polystyrene Insulation Board 735.01
Blanket Insulation Material 735.02
Pipe Insulation 740.08
Water 745.01

Precast concrete stay-in-place forms (prestressed deck panels) shall conform to the requirements of Section 510.

541.03 CLASSIFICATION AND PROPORTIONING. The following classes of concrete are included in these Specifications and shall be used as shown on the Plans:

TABLE 541.03A (Metric)

Class	Minimum Cement (kg/m^3)	Max Water-Cement Ratio	Range in Slump (mm)	Air Cont. (%)	Coarse Aggregate Gradation Table	28-Day** Comp. Strength (MPa)	28-Day** Modulus of Rupture (MPa)
AA	418	0.40	25 to 65	7.0 ± 1	704.02A	30	4.48
A*	392	0.44	50 to 100*	6.0 ± 1	704.02B	30	4.48
B	363	0.49	50 to 100	5.0 ± 1	704.02B, C	25	4.14
C	335	0.49	50 to 100	4.5 ± 1	704.02B, C	20	3.79
D	279	0.58	50 to 100	4.5 ± 1	704.02B, C	20	3.10
LW	392	0.44	25 to 75	6.0 ± 1	704.02B	30	---

* When this class of concrete is used for bridge decks, the range in slump shall be 25 to 75 mm.

** The listed 28-day compressive strength or modulus of rupture will serve as the basis of designing or approving the concrete mix.

TABLE 541.03A (English)

Class	Minimum Cement (lbs./cy)	Max Water-Cement Ratio	Range in Slump (in.)	Air Content (%)	Coarse Aggregate Gradation Table	28-Day** Comp. Strength (psi)	28-Day** Modulus of Rupture (psi)
AA	705	0.40	1 to 2 1/2	7.0 ± 1	704.02A	4000	650
A*	660	0.44	2 to 4*	6.0 ± 1	704.02B	4000	650
B	611	0.49	2 to 4	5.0 ± 1	704.02B, C	3500	600
C	564	0.49	2 to 4	4.5 ± 1	704.02B, C	3000	550
D	470	0.58	2 to 4	4.5 ± 1	704.02B, C	2500	450
LW	660	0.44	1 to 3	6.0 ± 1	704.02B	4000	---

* When this class of concrete is used for bridge decks, the range in slump shall be 1 to 3 inches.

** The listed 28-day compressive strength or modulus of rupture will serve as the basis of designing or approving the concrete mix.

The maximum unit density of Class LW concrete shall be:

(a) Plastic: 1922 kg/m^3 (120 pounds per cubic foot).

(b) Dry: 1842 kg/m^3 (115 pounds per cubic foot).

Unless otherwise specified in the Contract, Class B concrete shall be used.

A water-reducing, retarding, or water-reducing-retarding admixture shall be used for all Class AA, Class A, Class B, and Class LW concrete, unless otherwise authorized in writing by the Engineer. These admixtures may be used in Class C and Class D concretes when required or approved by the Engineer. The use of an accelerating or water-reducing-accelerating admixture to alter the setting characteristics of concrete mixtures shall be employed only with the approval of the Engineer. The use of chlorides or admixtures containing chlorides is prohibited. All admixtures will be considered incidental to the work and included in the Contract unit price of the concrete.

The Contractor, following mix design criteria and procedures outlined by the Agency, shall submit the mix design, required data, and test results to the Structural Concrete Engineer for review and acceptance. For initial submittals a minimum of two weeks shall be allowed for evaluation of the submitted mix design, test results and required data. No production of concrete for the project shall commence until the Structural Concrete Engineer has reviewed and accepted the concrete mix design.

The concrete materials shall be proportioned using the absolute volumes method in accordance with the requirements for each class as specified in Table 541.03A. The volumetric proportioning method such as that outlined in ACI Standard 211.1, *Recommended Practice for Selecting Proportions for Normal Weight Concrete*, or other approved volumetric proportioning methods shall be employed in the mix design.

Production activities shall operate so that no intentional deviations are made from the reviewed and accepted mix design. If test results indicate a failure to obtain the 28-day compressive strength as specified in Table 541.03A as tested in accordance with AASHTO T 22 or AASHTO T 97, changes to the mix design shall be made with no extra payment. Changes may include, but are not limited to, using additional cement, changing the source of cement or aggregates, using a water reducer or other additives, or, if necessary obtaining concrete from another supplier.

After the materials to be furnished by the Contractor have been approved, no proposed change in the source, proportions, or characteristics of the materials shall be made without the review and acceptance of the Engineer. No new materials shall be used until such materials and their proportions have been reviewed and accepted by the Engineer. In no case shall concrete from more than one batch plant be permitted on the same structure without prior written approval of the Engineer.

The Engineer may order concrete production and delivery suspended and a new mix or altered mix design submitted if components or final product material characteristics are determined to be out of tolerances, unsatisfactory, or if proposed changes in the source, proportions, or characteristics of the materials are proposed. No production of concrete for the project shall resume until the Engineer has reviewed and accepted the new or altered mix design. For evaluation, new mix design submittals shall be considered as initial mix design submittals.

The various classes of concrete shall have an air content by volume as specified. The entrained air may be obtained by the use of an approved admixture.

The Contractor may substitute fly ash for portland cement. The substitution rate shall be 20 percent of the required portland cement for concrete. The fly ash shall be substituted at a ratio of 1 kg (1 pound) of fly ash for 1 kg (1 pound) of portland cement.

The use of fly ash in high early strength concrete will not be permitted. When any mineral admixture is incorporated into a standard class of concrete, necessary adjustments to the mix design shall be made by the Contractor and reviewed and accepted by the Engineer. Proportioning of the concrete mixtures containing mineral admixture shall be by the absolute volumes method in accordance with the requirements for each class as specified in Table 541.03A except that the listed water-cement ratio shall be based on total cementitious material (portland cement and fly ash).

The Contractor, at its option, may substitute ground granulated blast-furnace slag (GGBFS), Grade 100 or 120 for portland cement. The substitution rate shall be 25.0 percent of the required portland cement for concrete. The GGBFS shall be substituted at a ratio of one unit of GGBFS for one unit of portland cement. Fly ash and GGBFS will not be permitted in the same concrete mixture.

The proportioning of the concrete mixture shall be by the absolute volumes method and in accordance with the requirements for each class of concrete as specified in Table 541.03A, except that the listed water-cement ratio shall be based on the total cementitious material (portland cement plus GGBFS).

Strict adherence to the requirements of Subsection 541.07 is required when using concrete with mineral admixtures. The setting time may be retarded in cool weather. The Resident Engineer, after consultation with the Agency's Structural Concrete Engineer, may require that the curing period, as designated in Table 541.17A, be extended.

541.04 BATCHING. Measuring and batching of materials shall be done at an approved batch plant. The batch plant shall meet the requirements of AASHTO M 157, except as modified and shall be maintained in good repair at all times and shall be subject to a periodic inspection by an authorized representative of the Agency.

All new or relocated concrete batch plants offered for Agency approval shall be equipped for semi-automatic batching and proportioning of all cementitious material, aggregates, water, and fly ash (when used) and for automatic insertion of admixtures. The plants shall be equipped to automatically and accurately record the quantity of all aggregates, cementitious material, and the water incorporated into each batch and shall identify and record the addition of the required admixtures.

Proper facilities shall be provided for the Engineer to inspect ingredients and processes used in the batching and delivery of the concrete. The Contractor shall, without charge, afford the Engineer all reasonable facilities for securing samples to determine whether the concrete is being furnished in accordance with these Specifications.

The Contractor shall give the Engineer 24-hour notice of intent to place concrete so that arrangements can be made for laboratory inspection and control.

(a) Semiautomatic Batch Plants. When actuated by a starting mechanism, the semiautomatic batch controller shall start the mass measuring (weighing) operation of the materials and stop the flow automatically when the designated mass (weight) has been reached. It shall be interlocked to ensure that the discharge mechanism cannot be opened until the mass (weight) is within the tolerance specified in Subsection 541.04(d).

Water and admixtures may be batched in a weigh batcher or by volume in a volumetric device. When actuated, volumetric controls shall start the measuring operation and stop the flow automatically when the designated volume has been reached.

(b) Testing Laboratory. The Contractor shall provide at the plant site a weatherproof building or room for the use of Agency personnel as a testing laboratory. The laboratory shall have a minimum gross internal area of 14 m^2 (150 square feet) with a layout providing a minimum internal width of 2.1 m (7 feet), in which to house and use the equipment specified. Should the Contractor elect to provide additional equipment relevant to testing of portland cement concrete and materials, the gross inside floor area of the laboratory shall be increased in proportion to the area required to house and operate the additional equipment. If the additional equipment is to be operated on a bench, the length of bench sections shall also be proportionally increased. An adequate method of ventilation, lighting, heating, and necessary electrical or gas connections shall be provided. Sanitary toilet facilities with lavatory shall be available for use by Agency personnel at the plant site. A private telephone service shall be provided in the laboratory.

The laboratory shall be equipped with the following:

1 Standard office desk, with lockable drawers or a separate lockable two-drawer file cabinet.
1 Side chair.
1 Bench section(s) at least 600 mm (2 feet) wide providing a minimum of 2.6 m^2 (28 square feet) of working area with undercounter shelving.
1 Standard laboratory stool.
1 Fully automatic electronic calculator with eight digit capacity.
1 Standard laboratory sink and faucet provided with an adequate supply of water meeting the requirements of Subsection 745.01. The sink shall drain to the outside of the laboratory.
1 Bench brush.
1 Floor brush.
1 Motorized 203 mm (8 inch) sieve shaker (with adjustable timer) with sieving operation conducted by means of lateral and vertical motion of the sieve accompanied by jarring action with the following 203 mm (8 inch) diameter sieves: 9.5 mm (3/8 inch), 4.75

	mm (No. 4), 2.36 mm (No. 8), 1.18 mm (No. 16), 600 μm (No. 32), 300 μm (No. 50), 150 μm (No. 100), plus pan and cover.
1	Mechanical aggregate shaker **(**with adjustable timer) with a 0.0283 m^3 (1 cubic foot) capacity with the following screens: 45 mm (1 3/4 inch), 37.5 mm (1 1/2 inch), 25 mm (1 inch), 19 mm (3/4 inch), 12.5 mm (1/2 inch), 9.5 mm (3/8 inch), 6.3 mm (1/4 inch), 4.75 mm (No. 4), 2.36 mm (No. 8), 1.18 mm (No. 16), and pan. The aggregate shaker may be placed in a separate enclosed area or be shielded for dust and sound. When the aggregate shaker is placed in a separate enclosed area, there shall be a minimum of 1.5 meters (5 feet) of clear space measured from the front frame of the shaker outward. The enclosed area shall be well lighted and ventilated. Also, the shaker shall have an adjacent bench section approximately 900 mm (36 inches) high, 600 mm (24 inches) deep and 1250 mm (50 inches) long.
1	Electronic balance with a minimum capacity of 22 kg (50 pounds) accurate to 0.1 g (0.0002 pound).
1	Double burner hot plate, variable temperature.
5	Metal pans, nominal size, 230 by 230 by 50 mm (9 × 9 × 2 inches).
1	Sample splitter, 63.5 mm (2 1/2 inch) chute.
1	250 mm (10 inch) blunted trowel.
1	1.25 by 1.25 m (4 × 4 feet) minimum heavy canvas for quartering samples.
1	Brass wire bristle brush.
1	Pair, heat resistant gloves.
2	38 mm (1 1/2 inch) soft bristle paint brushes.
3	355 mL (12 ounce) clear graduated glass bottles.
1	Reference color comparison chart with five organic plate number colors. Reagent sodium hydroxide solution (3 percent) in sufficient quantity for the duration of the project.

Acceptable substitutes for the aforementioned equipment may be provided when approved by the Materials and Research Engineer.

Batching operations shall not begin until the testing laboratory has been approved as being in compliance with these Specifications and all requirements of the current VAOT Quality Assurance Program document. Removal of any equipment, except at the direction of the Engineer, will revoke any prior approval and require the termination of batching operations.

The building or room designated as a testing laboratory shall be maintained in a clean condition by the user and kept free of all articles not necessary for the testing of materials. Cleaning supplies shall be furnished by the Contractor.

(c) Bins and Scales. The batch plant shall include bins, weighing hoppers, and scales with adequate separate compartments for fine aggregate and for each required separate size of coarse aggregate. If cement is used in bulk, a bin, hopper, and scale for cement shall be included. Each compartment shall be designed to discharge efficiently and freely into the weighing hopper or hoppers. Means of control shall be provided so that when required, the material may be added slowly in minute quantities and shut off with precision. Means of removing the overload of any one of the several materials shall be provided. Hoppers shall be constructed so as to eliminate accumulations of tare materials and to discharge fully without jarring the scales. Partitions between compartments shall be ample to prevent spilling under any working condition. All batch plant structures shall be properly leveled and maintained in that condition within the tolerance required by the design of the mass measuring (weighing) mechanism.

The scales for determining the mass (weight) of aggregate and cementitious material shall be comprised of a suitable system of levers or load cells. The levers or load cells will determine the mass (weight) consistently within 0.5 percent under operating conditions, with loads indicated either by means of a beam with balance indicator, a full-reading dial, or a digital read-out or display.

Adequate means for checking the accuracy of the scales shall be provided by the Contractor either by the use of 22.68 kg masses (50 pound weights) or by other methods approved by the Engineer. All exposed fulcrums, clevises, and similar working parts of scales shall be kept clean. When beam-type scales are used, provision shall be made for indicating to the operator that the required load in the weighing hopper is being approached. Poises shall be designed to be locked in any position to prevent unauthorized change of position. All mass measuring (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.

The scales shall be serviced and their accuracy verified annually by a hopper scale service person licensed by the Division of Weights and Measures of the Vermont Department of Agriculture. For Vermont plants, an inspector representing the Division of Weights and Measures shall witness all testing conducted by the service person and will attach a seal to each hopper scale, provided it meets the current specifications, tolerances, and regulations adopted by the Division of Weights and Measures. Standard test masses (weights) used to determine the accuracy of hopper scales shall be certified yearly by the Division of Weights and Measures in accordance with their established standards.

The ready-mixed concrete producer shall hire a licensed hopper scale service person for annual checking and service of scales. In addition, Vermont producers shall schedule an inspection with the Division of Weights and Measures between February 15th and April 30th of each year. After April 30th, Vermont plants without current seals affixed to the hopper scales will not be permitted to supply concrete to Agency projects, unless otherwise directed by the Engineer or until the seals are affixed.

Out of state concrete producers shall observe all annual hopper scale mass measurement (weighing) and seal requirements of their respective states of location.

(d) Accuracy of Plant Batching. For weighed ingredients, accuracy of batching is determined by comparison between the desired mass (weight) and the actual scale reading; for volumetric measurement of water and admixtures, accuracy is determined by checking the quantity either by mass (weight) on a scale or by volume in a calibrated container.

Chemical admixture containers or scales shall be calibrated annually by a qualified admixture distributor representative.

Batching shall be conducted to accurately measure the desired quantities within the following tolerances:

Cement:	± 1 percent	Aggregates:	± 2 percent
Water:	± 1 percent	Chemical Admixtures:	± 3 percent
Mineral Admix.:	± 1 percent		

(e) Storage and Proportioning of Materials.

(1) Portland Cement. Either sacked or bulk cement may be used. No fraction of a sack of cement shall be used in a batch of concrete unless the cement is weighed.

All bulk cement shall be weighed on an approved mass measuring (weighing) device. The bulk cement-weighing hopper shall be properly sealed and vented to preclude dusting during operation. Facilities shall be provided for the sampling of cement at the batch plant, either from the storage silo or from the weighing hopper. This device shall be a permanent installation located so as to allow safe and easy access. It shall provide a sample that represents the true nature of the material being used.

(2) Water. Water may be measured either by volume or by mass (weight). When measurement is by meter, the water meter shall be so located that the measurements will not be affected by variable pressure and temperature in the water supply line.

Measuring tanks shall be equipped with an outside tap and valve to provide for checking the setting, unless other means are provided for readily and accurately determining the amount of water in the tanks.

(3) Aggregates. In stockpiling aggregates, the location and preparation of the sites shall be subject to the approval of the Engineer. Stockpiles shall be formed on hard well-drained areas that prevent contamination from underlying material and accumulation of excessive moisture.

Aggregates from different sources or of different gradations shall not be stockpiled together. Only rubber-tired equipment shall be permitted to operate on aggregate stockpiles.

Stockpiles shall be constructed as follows:

a. If the stockpile is to be made using mechanical equipment (front end loader, clam bucket, rock ladder, radial stacker, or other approved equipment), the stockpile shall be made in such a manner that segregation is kept to a minimum.

b. If the stockpile is to be made by dumping from trucks in multiple layers, each layer shall be approximately 1.2 m (4 feet) in depth. Each layer shall be completely in place before commencing the next layer. Care shall be taken that successive layers do not "cone" down over the previous layer.

c. No equipment shall be used to haul aggregate over the stockpiled material except to deposit the material for the layer being placed. It shall be the responsibility of the Contractor that the aggregate be kept free from deleterious material or degradation.

Stockpiles shall be maintained in such a manner that twice the anticipated aggregate requirement for any Agency project placements will be on hand and available for sampling and testing at least 48 hours before mixing operations for the placements are scheduled to begin. The Engineer may modify this requirement when special aggregates are required, such as when lightweight concrete is being produced.

Aggregates shall be handled from stockpiles or other sources to the batch plant in such a manner as to secure a uniform grading of the material. Aggregates that have become segregated, or mixed with earth or foreign material, shall not be used. All aggregates produced or handled by hydraulic methods and washed aggregates shall be stockpiled or binned for draining at least 12 hours before being batched. In case the aggregates contain high or non-uniform moisture content, storage or stockpile period in excess of 12 hours may be required by the Engineer.

d. Lightweight aggregate stockpiles shall be presoaked for a minimum period of 48 hours immediately prior to use. Soaking shall be accomplished by continuous sprinkling or other suitable means that will provide a uniform moisture content throughout the stockpile.

(4) Admixtures. The Contractor shall follow an approved procedure for adding the necessary amount(s) of admixture(s) to each batch. Admixture(s) shall be dispensed in such a manner that will ensure uniform distribution of the material throughout the batch within the required mixing period. All admixtures shall be added to the batch at the plant, unless otherwise authorized by the Engineer.

All dispensers shall include visual inspection aids such as graduated transparent cylinders. A separate dispenser shall be provided for each liquid admixture. Storage and dispensing systems for liquid admixtures shall be equipped so as to allow thorough circulation and/or agitation of all liquid in the system. This shall be required prior to the first batching of concrete for Agency projects in any calendar year and periodically thereafter at intervals not to exceed 60 calendar days for the duration of the period the plant is supplying concrete for Agency projects. If the circulation method is used, the admixture shall be circulated until a complete exchange of admixture is achieved. If an agitation method is used, the method shall be subject to approval by the Engineer.

Storage and dispensing systems for liquid admixtures shall be sufficiently protected to prevent freezing of admixtures at all times.

It shall be the responsibility of the Contractor to use the quantity of Agency approved admixtures needed to obtain concrete meeting the requirements of the Contract. All additions of admixtures will be approved by the Engineer prior to incorporation into the mix.

The use of calcium chloride as an admixture or an admixture ingredient will not be permitted.

a. Air-Entraining Admixture. Air-entraining admixture shall be used as required to obtain the specified air content.

b. Water-Reducing, Retarding, and Water-Reducing and Retarding Admixtures. Dosages shall be those recommended by the Manufacturer, unless otherwise approved by the Engineer.

(5) Fly Ash or GBBFS. Fly ash or GBBFS shall be stored at the batch plant in a separate storage or holding bin and shall be protected from rain and moisture.

541.05 MIXING AND DELIVERY.

(a) General. Concrete may be mixed at the site of construction, at a central point, or wholly or in part in transit mixers. The production of concrete shall meet the requirements of AASHTO M 157 with the following additional requirements:

(1) All concrete shall reach its final position in the forms within 1.5 hours after the cement has been added to the aggregates. When retarded concrete or concrete with a water reducer is being used, time in excess of the 1.5-hour limit may be allowed. The Engineer will determine this additional time. When the ambient air temperature is 16 °C (60 °F) or above, the elapsed time may be reduced as necessary as directed by the Engineer or in accordance with Subsection 541.07(a).

(2) The Engineer may authorize the addition of cement and water at or near the site, or the use of admixtures at the Contractor's expense.

(3) The addition of water in excess of the design water-cementitious material ratio for purposes of meeting the slump limits will not be permitted. Concrete that is not within the specified slump limits at time of placement shall not be used.

(4) Each load of concrete delivered at the job site shall be accompanied by a State of Vermont Batch Slip signed by the authorized Agency representative, if present, at the plant. Batch Slips shall contain such information as is deemed necessary by the Engineer.

(5) The Contractor shall provide direct communication service from the site of the work to the batch plant that shall be available to the Engineer at all times during concrete operations. The cost of this service will be considered incidental to the work.

(6) When use of a Water-Reducing, High Range or Water-Reducing, High Range, and Retarding Admixture is specified for deck concrete, the contractor shall submit, for the Engineer's approval, the following information: Admixture manufacturer, admixture addition rate, and when the admixture is to be added to the mixture (i.e., at the plant, on project, or a combination thereof). In order to obtain the required slump, a representative from the concrete producer is required on the project to determine the final admixture dosage for each load of concrete. This representative shall be responsible for adding the Water-Reducing, High Range or Water-Reducing, High Range, and Retarding Admixture to the mixer. The dosage shall be applied by means of a dispenser, or by other means as approved by the Engineer.

(7) Not including initial mixing revolutions, all concrete shall be discharged into the forms before 300 revolutions of the drum or blades. The total revolutions may be increased as directed by the Engineer.

Mortar shall be mixed in an approved mixer at the site of placement or in transit mixers when approved by the Engineer. The Engineer will withdraw approval for use of transit mixers, if necessary, to ensure a quality product or if the rate of delivery cannot be coordinated with finishing requirements.

(b) Stationary Mixers. When a stationary mixer is used for the complete mixing of the concrete, the mixing time for mixers having a capacity of 7.5 m^3 (10 cubic yards) or less shall be not less than 60 seconds. For mixers of more than 7.5 m^3 (10 cubic yards) 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. The plant shall be equipped with a timing device that will not permit the batch to be discharged before the predetermined mixing time has elapsed. Vehicles used in hauling shall comply with the requirements of Subsection 541.05(c).

(c) Transit Mixers. Transit mixers and agitators shall be subject to a periodic inspection by an authorized representative of the Agency. Such equipment shall bear a currently dated inspection "sticker" supplied by the Agency indicating that the transit mixer or agitator conforms to the Agency's requirements.

Transit mixers shall be equipped with a water-measuring tank with a visible sight gauge for use when the water for the batch is supplied from the transit mixer tank. The gauge shall be clean and legibly graduated. Measuring tanks shall be provided with outside drain valves or other means to check their calibration.

No transit mixer or agitator shall be charged with the ingredients of the concrete unless an authorized Agency representative is present and authorizes it. This requirement may be waived by the Engineer if a batch slip accompanies the delivery vehicle to the site.

Electrically actuated revolution counters shall be required on all transit mixers except on mixers charged at central mix plants and utilized as agitator trucks only.

Transit mixer maximum load size shall be limited to the manufacturer's rated mixing capacity; however legal vehicle load restrictions shall not be exceeded. 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.

Agitators, when loaded, shall also not exceed the manufacturer's rated mixing capacity or legal load restrictions and 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.

The Engineer may make tests for consistency (slump) of individual samples at approximately the beginning, the midpoint and end of the load. If the range of results exceeds 50 mm (2 inches), the mixer or agitator shall not be continued in use unless the condition is corrected.

All mechanical details of the mixer or agitator such as water measuring and discharge apparatus, condition of the blades, speed of rotation of the drum, general mechanical condition of the unit and clearance of the drum shall be checked before a further attempt to use the unit will be permitted.

Mixers and agitators shall be kept free from accumulation of hardened concrete or mortar. The mixing blades shall be rebuilt or replaced when any part or section is worn 19 mm (3/4 inch) or more below the original height of the manufacturer's design. A copy of the manufacturer's design, showing the dimensions and arrangements of blades shall be available to the Engineer at the plant at all times.

When a transit mixer is used for complete mixing, each batch of concrete shall be mixed for at least 70 or more than 100 revolutions of the drum at the rate of rotation designated as mixing speed by the mixer manufacturer. Additional mixing, if any, shall be at the speed designated by the manufacturer as agitating speed. The mixing and agitating speeds shall be found on the metal plate on the mixer.

When a transit mixer or agitator is used for transporting concrete, mixing during transport shall be continuous and at the speed designated by the manufacturer of the equipment as agitating speed. Failure to do so is cause for rejection of the concrete.

Transit mixers and agitators assigned to a project shall not be used for other purposes until the desired work is completed at the site, and shall arrive at the project within the cycle that anticipated placement conditions dictate. The interval between loads shall be controlled in order that concrete in place shall not become partially hardened prior to placing succeeding batches. The plant capacity and transportation facilities shall be sufficient to ensure continuous delivery at the rate required.

Before discharging a transit mixer that has been operating at agitating speed, the drum or blades shall be rotated approximately one minute at mixing speed. The same procedure shall apply to agitators if admixtures, water, or other ingredients are added to the mix in the field.

If additional mixing water is required to maintain the specified slump and is added with the permission of the Engineer, a minimum of 20 revolutions of the transit mixer drum at mixing speed shall be required before discharge of any concrete. At no time shall the total water introduced into any mix exceed the maximum water cement ratio shown in Table 541.03A.

Upon discharge of the concrete from the drum, a sufficient amount of water shall be charged into the drum to properly cleanse the drum. This water shall not be used as a part of the next succeeding batch but shall be discharged from the drum prior to the charging of the drum with the concrete ingredients. The drum shall be completely emptied before receiving materials for the succeeding batch. Retempering of concrete or mortar that has partially hardened, by remixing with or without additional materials, shall not be permitted.

541.06 FIELD TESTS. The Contractor shall provide assistance, equipment, materials, and curing for field sampling and testing as required by the Engineer. All costs shall be included in the Contract unit prices under Section 631. The Engineer shall perform all sampling and testing.

(a) Sampling. Sampling for tests shall be taken in accordance with AASHTO T 141 or other procedures approved by the Agency.

(b) Slump Tests. Slump tests shall be made in accordance with AASHTO T 119.

(c) Air Content Tests. Air content tests shall be made in accordance with the pressure method in AASHTO T 152, for acceptance or rejection. The Chace meter may be used in conjunction with the pressure method of AASHTO T 152 for monitoring other air content tests. A volumetric air meter shall be used for determining the air content of Class LW concrete in accordance with AASHTO T 196.

(d) Strength Tests.

(1) General. Strength tests shall be by test cylinder, except that when specified in the Contract or when authorized in writing by the Engineer, test beams may be used.

A test shall be the average of the strengths of at least two specimens from the same sample of concrete.

The number of strength tests shall be as follows:

a. A minimum of one test shall be required for each project.

b. One test shall be required for each placement of 75 m^3 (100 cubic yards) or fraction thereof except that a test will not be required on placements of less than 7.5 m^3 (10 cubic yards).

c. The Engineer may order additional tests as deemed necessary.

Test Cylinders. Test cylinders shall be made in accordance with AASHTO T 23, and tested for compressive strength in accordance with AASHTO T 22.

Test Beams. Test beams of dimensions 152 by 152 by 508 mm (6 × 6 × 20 inches) shall be made in accordance with AASHTO T 23, and tested for flexural strength in accordance with AASHTO T 97. Beam molds for constructing test beams shall be reusable steel molds conforming to the requirements of AASHTO T 23.

(2) Categories of Testing.

a. Quality acceptance testing utilizes specimens to determine the compliance with strength requirements for the project. All test cylinders used for quality acceptance testing shall be stored in an approved curing box until they are shipped to the central laboratory.

When the Engineer gives written permission to use test beams for quality acceptance testing, the beams will be cured in accordance with a method approved by the Engineer.

Quality acceptance testing shall be performed at 28 days except as follows:

1. When 90 percent of the 28-day design compressive strength requirement is obtained at 14 days, the 28-day testing may be omitted when approved by the Engineer.

2. When high early strength concrete is used, specimens will be tested at seven days at which time 100 percent of 28-day design strength must be obtained.

b. Job control testing utilizes specimens to determine whether adequate curing procedures are being followed and for early form removal or early loading of structure. All job control specimens shall be stored on the structure and shall receive the same curing and protection from the elements as the concrete that they represent up until 24 hours before anticipated testing of specimens.

c. Specimen curing requirements shall be as follows or as directed by the Engineer:

Number of Specimens	Category	Location of Curing
2	Quality Acceptance - 28 days	Curing Box
2	Quality Acceptance - 14 days	Curing Box
4	Quality Acceptance - 7 days (Type III only)	Curing Box
2	Job Control - Applicable Curing Period	On Structure

541.07 WEATHER AND TEMPERATURE LIMITATIONS - PROTECTION OF CONCRETE. The temperature of the concrete just prior to placement in the forms shall not be less than 10 ºC (50 ºF) nor more than 29 ºC (85 ºF), except that Concrete, Class AA mix shall not exceed 27 ºC (80 ºF) just prior to placement. Aggregates and water shall be heated or cooled as necessary to produce concrete within these temperature limits.

Placement and curing procedures shall be approved by the Engineer prior to actual placement.

(a) Hot Weather Concrete. Placement of concrete during hot weather may be limited by the Engineer based on an assessment of temperature, humidity, wind velocity, and sun radiation conditions.

No concrete shall be placed when the ambient air temperature is, or is expected to be, above 32 ºC (90 ºF). However, no Concrete, Class AA mix shall be placed when the ambient air temperature is, or is expected to be, above 29 ºC (85 ºF) during the placement, except by written permission of the Engineer.

(b) Cold Weather Concrete.

(1) General. When it is necessary to place concrete or mortar at or below an ambient air temperature of 5 °C (40 °F), or whenever in the opinion of the Engineer, ambient air temperatures may fall below this limit within the curing period, the mixing water, aggregates, or both, shall be heated and the work protected by adequate housing, covering and heating, or insulated forms.

When using concrete with mineral admixtures, strength gain may be retarded in cool weather. When the ambient air temperature is 10 ºC (50 ºF) or less, the Resident Engineer, after consultation with the Agency's Structural Concrete Engineer, may require special preparation and protection of the concrete and its components and that the curing period, as indicated in Subsection 541.17, be extended.

The Contractor shall have on the job, ready to install prior to starting any placing operation adequate equipment meeting the approval of the Engineer for heating and protecting the materials and freshly placed concrete.

No concrete shall be placed when the temperature of the surrounding atmosphere is lower than -12 °C (10 °F) except by written permission of the Engineer.

No concrete shall be placed in any superstructure or thin section under cold weather conditions (ambient air temperature 5ºC (40ºF) or less) without written permission of the Engineer.

(2) Heating of Materials. The heating equipment shall be capable of heating the materials uniformly. Aggregates shall not be heated over 66 °C (150 °F). If water is heated in excess of 66 °C (150 °F), the water shall be mixed with the aggregate before the cementitious material is added. The materials shall be heated in such a manner, for such a period of time, and in such quantity as to produce concrete having a uniform temperature within the specified temperature range at the time of placing. Materials containing frost or frozen lumps shall not be used. Stockpiled aggregates may be heated by the use of dry heat or steam. Aggregates shall not be heated directly by gas or oil flame or on sheet metal over fire. When aggregates are heated in bins, steam-coil or water-coil heating, or other methods that will not be detrimental to the aggregates, may be used.

(3) Antifreeze Compounds. Salts, chemicals, or other foreign materials shall not be used in the mix to lower the freezing point of the concrete.

(4) Preparation of Forms. Before placing concrete; ice, snow, and frost shall be completely removed from the forms.

Concrete shall not be placed on a surface or in forms that are frozen, have surface temperatures below 0 ºC (32 ºF), or that contains frozen materials. The frozen surface or forms shall be completely thawed the day previous to the placing of the concrete and shall be kept continuously thawed until the concrete is poured.

(5) Housing. The Contractor shall furnish sufficient canvas and framework or other suitable type of housing to enclose and protect the structure. The sidewalls of the housing for protecting abutments and piers shall be completely built before the placing of any concrete. They shall be constructed independent of the forms and bracing and with space large enough to provide for form removal and initial finishing of concrete as required during the heating period. Joists adequately spaced to prevent sagging shall support the top of the housing. The housing shall be completely built and the heat applied before placing any concrete.

Bridge decks, floor slabs, and roof slabs placed when the ambient air temperature is below 5 °C (40° F) shall be protected by a housing which also encloses the space beneath and which extends approximately 300 mm (12 inches) outside the edge of the floor. Alternatively, the deck may be insulated in accordance with part (b)(8)b. below.

When the temperature readings taken on or in the concrete indicate the temperature of the concrete may fall below 10 °C (50 °F), the Contractor shall, without exposing the concrete, immediately build the necessary enclosures around the area involved and supply heat to ensure curing conditions as specified in Subsection 541.17. The enclosure shall be removed when directed by the Engineer.

(6) Heating the Enclosure. The enclosure shall be heated in such a manner that the temperature of the concrete and the enclosed air shall be kept above 10 °C (50 °F) for the designated curing period. During this time, the concrete shall be kept continuously wet to provide proper curing. After the curing period, the temperature shall be gradually lowered to that of the surrounding atmosphere, taking at least 48 hours for the transition but at no time exceeding a 0.5 °C (1 °F) change per hour.

When dry heat is used, a means of maintaining atmospheric moisture shall be supplied. The Contractor shall maintain adequate fire protection and shall provide personnel to keep the heating units in continuous operation. When operations are in locations where water levels may fluctuate, the supports for heating equipment shall be built so that the heating equipment can be raised and steam lines shall be placed above the probable high water level.

(7) Temperature Records. The Contractor shall provide an automatic temperature recorder to continuously record concrete curing temperatures for the entire curing period. Recording thermometers shall be capable of measuring and recording temperatures within the range of -20 to 100 °C (-4 to 212 °F) with maximum graduations of 5 °C (10 °F).

Temperature sensors shall be carefully placed within the curing enclosure or the concrete to ensure that temperatures are measured at typical locations. Recorder accuracy shall be certified once every 12 months, and the certificate displayed with each recorder. The Engineer may make random checks of each recorder. On each recorder chart, the Engineer shall indicate the location of the representative concrete, date of placement, and time of start and finish of the record. At the completion of the curing period, the recorder charts shall be given to the Engineer.

When the Contractor places concrete at more than one location within the specified curing period, additional recorders shall be furnished to provide temperature records at each location.

In addition to concrete curing temperatures, a permanent daily record of ambient air temperatures shall be maintained. Thermometer readings shall be taken twice daily and data recorded showing the date, hour, location of each reading, and any conditions that might have an effect on the temperature.

(8) Insulated Forms.

a. General. When authorized by the Engineer, the concrete forms shall be completely covered with an approved insulating material.

To prevent loss of heat, immediately upon completion of concrete placement, all exposed surfaces shall be covered with a double thickness of burlap or cotton mats. This covering will be designed to prevent loss of moisture from the concrete and then covered with sufficient hay, straw, or insulated mats to prevent loss of heat from the concrete during the curing period. Tarpaulins shall be used as additional cover when directed.

To prevent excessive heat buildup, provisions shall be made for loosening of insulation to provide ventilation and the subsequent cooling of the concrete if the surface temperature of the concrete approaches 38 °C (100 °F). In no case shall this temperature drop below 10 °C (50 °F) during the curing period.

The following table shall be used as a guide in determining the outside temperature at which concrete walls, piers, abutments, or floor slabs above ground shall be protected with blanket insulation.

TABLE 541.07A
MINIMUM AIR TEMPERATURE ALLOWABLE
FOR ALL CLASSES OF CONCRETE

Concrete Thickness		Insulation Rating of R-4		Insulation Rating of R-8	
mm	in.	°C	°F	°C	°F
150	6	5	40	-2	29
300	12	-2	28	-18	0
450	18	-11	13	-34	-29
600	24	-18	0	-48	-55
900	36	-33	-27	---	---
1200	48	-40	-40	---	---
1500	60	-40	-40	---	---

b. Bridge Decks, Floor Slabs, and Roof Slabs. Immediately upon completion of the finishing, the surface shall be protected as specified under part (b)(5) above. When approved in writing by the Engineer, the Contractor may insulate the top and bottom of the slab as specified in Table 541.07A instead of constructing a heated housing. This insulating material shall be installed immediately upon the completion of finishing in such a way that the fresh concrete surface is not marred.

c. Concrete With Water-Reducing , High Range or Water-Reducing, High Range, and Retarding Admixture.

These admixtures are not to be used if the ambient temperature is below 10 ºC (50 ºF) at the time of placement, or if it is forecasted to drop below 10 ºC (50 ºF) and within 24 hours after completion of the placement, unless hot water is used or the concrete temperature is maintained in accordance with Subsection 541.07(b), subparts (5) and (7).

541.08 THIS SUBSECTION RESERVED

541.09 FORMS. Construction Drawings including falsework and form work plans shall be submitted by the Contractor in accordance with Section 105 before being used. In all cases, the Contractor shall be responsible for, and shall make good, any injury arising from inadequate forms. The Engineer shall inspect and accept all forms prior to concrete placement. Unless the Plans specifically call for the use of stay-in-place forms, such forms shall not be used in the construction of any superstructure or bridge deck. Stay-in-place forms will only be allowed in the construction of substructure elements in locations where the Engineer agrees that removable formwork is impossible to use.

(a) Falsework. In general, falsework that cannot be founded upon a solid footing shall be supported by falsework piling.

The Engineer may require the Contractor to employ screw jacks or hardwood wedges to take up any slight settlement in the falsework.

(b) Construction. Forms shall be mortar tight and sufficiently rigid to prevent distortion due to the pressure of the concrete and other loads incident to the construction operations including vibration. Forms shall be constructed and maintained so as to prevent the opening of joints due to shrinkage of the lumber. Sealer/caulking as approved by the Engineer shall be used where forms abut structural steel members, such as top flanges of beams and girders, etc.

Forms shall be filleted and chamfered at all sharp corners, unless otherwise shown on the Plans or directed by the Engineer, and shall be given a bevel or draft in the case of all projections, such as girders and copings to ensure easy removal.

Falsework and forms for slabs, beams, and girders shall be constructed to provide camber shown on the Plans or ordered by the Engineer.

(c) Form Lumber. All face form lumber for exposed surfaces shall be concrete form exterior grade plywood, not less than five ply and not less than 19 mm (3/4 inch) in thickness. In computing stud spacing, plywood shall be considered 25 mm (1 inch) lumber provided that the grain of three of the plys runs perpendicular to the studs.

Form lumber for unexposed surfaces may be dressed tongue and groove, dressed shiplap, or square edge sized four sides of uniform width and thickness. It shall have a minimum thickness, after finishing, of 19 mm (3/4 inch).

All form lumber shall be sound and free from loose or rotten knots, knotholes, checks, splits, or wanes showing on the surface in contact with the concrete. Used face form lumber, having defects or patches which may produce work inferior to that resulting from new material, shall not be used.

Other form material may be used with permission of the Engineer.

(d) Studs. Studs shall have a minimum nominal size of 50 by 150 mm (2 × 6 inches), except that 50 by 100 mm (2 × 4 inch) nominal size studs may be used for pours not exceeding 1.1 m (3 1/2 feet) in height. Studs shall be spaced center to center not more than 16 times the actual thickness of the form lumber.

Studs shall be capped at the top with a plate of not less than 50 by 150 mm (2 × 6 inches) nominal size, carefully selected as to straightness. All joints in plates shall be scabbed 1.2 m (4 feet) each way to provide continuity.

(e) Wales. All wales shall be at least 100 by 150 mm nominal size (4 × 6 inches, minimum section) or equivalent and shall be scabbed at least 1.2 m (4 feet) each side of joints to provide continuity. A row of wales shall be placed within 150 mm (6 inches) of the bottom of each pour unless studding can be extended below the bottom of the pour and secured by wales fastened to ties in the previous pour. Wales shall have a maximum spacing of 900 mm (36 inches).

(f) Form Ties. Metal ties or anchorages within the forms shall be constructed to permit their removal to a depth of at least 25 mm (1 inch) from the face without injury to the concrete.

Wire ties shall be used only in locations where they will not extend through surfaces exposed in the finished work and then only when authorized.

The cavities shall be filled with cement mortar in accordance with Subsection 541.16.

(g) Walls. Where the bottom of the form is inaccessible, the lower form boards shall be left loose or other provisions made so that extraneous material may be removed from the form immediately before placing the concrete.

(h) Surface Treatment. All forms shall be treated with commercial form oil prior to placing reinforcement and wood forms shall be saturated with water immediately before placing the concrete. Any material that will adhere to or discolor the concrete shall not be used.

(i) Metal Forms. The specifications for forms regarding design, mortar tightness, filleted corners, beveled projections, bracing, alignment, removal, reuse, and oiling also apply to metal forms. The metal used for forms shall be of such thickness that the forms will remain true to shape. All bolt and rivet heads shall be countersunk. Clamps, pins, or other connecting devices shall be designed to hold the forms rigidly together and to allow removal without injury to the concrete. Metal forms that do not present a smooth surface or do not line up properly shall not be used. Care shall be exercised to keep metal forms free from rust, grease, or other foreign matter.

(j) Removal of Forms. The forms, or their supports, for any portion of a structure shall not be removed without the approval of the Engineer. Forms under arches, beams, floor slabs, pier caps, or special designs may be removed upon approval of the Engineer after the concrete attains 85 percent of the minimum compressive strength as specified in Table 541.03A.

If field operations are not controlled by beam or cylinder tests, the following periods for removal of forms and supports, exclusive of days when the ambient air temperature is below 5 °C (40 °F), may be used as a guide:

Arch Center	14 Days
Centering under Beams	14 Days
Supports under Flat Slabs	14 Days
Floor Slabs	14 Days
Vertical Wall Surfaces	24 Hours
Columns	24 Hours
Sides of Beams	12 Hours
Top Slabs R.C. Box Culverts	14 Days

If high early strength is obtained with Type III cement or an altered concrete mix design is reviewed and accepted**,** these periods may be reduced as directed by the Engineer.

When field operations are controlled by strength tests, the removal of forms and supports may begin when the concrete is found to have the required strength. In no case shall the number of curing days be less than specified in Table 541.17A.

Methods of form removal likely to cause overstressing of the concrete shall not be used. Forms and their supports shall not be removed without approval. Supports shall be removed in such a manner as to permit the concrete to uniformly and gradually take the stresses due to its own dead load.

541.10 PLACING CONCRETE.

(a) Workforce. The Contractor shall have sufficient skilled personnel at all times during the concreting operations to properly place, consolidate, and finish the concrete. If, in the opinion of the Engineer, the Contractor does not have sufficient skilled personnel to handle the concrete properly, the Engineer may postpone the start of the concreting operations until such time as the Contractor has remedied this condition.

(b) Pre-placement Meeting. For deck pours, or as required by the Engineer, a pre-placement meeting shall take place at least 7 calendar days before concrete placement. The pre-placement meeting shall be attended by all participating parties, including but not limited to, the Contractor’s Project Superintendent, the Engineer, and the concrete producer.

(c) Placement Limitations. All concrete shall be placed in daylight, unless otherwise authorized in writing by the Engineer. Authorization to place concrete at any other time shall not be given unless an adequate lighting system is provided prior to beginning the concreting operation.

Concrete shall not be placed under adverse environmental conditions that the Engineer determines will interfere with acceptable placement and/or finishing operations.

Concrete shall not be placed until the depth and character of the foundation, the apparent adequacy of the forms and falsework and the placing of the reinforcing steel have been approved by the Engineer. The interior of the forms shall be clean of all debris before concrete is placed.

The Contractor shall submit to the Engineer a schedule of batching, delivery, and placement prior to the beginning of the concreting operations. The Contractor shall comply with the requirements of Subsection 541.05.

Equipment and tools necessary for handling materials and performing all parts of the work shall meet the approval of the Engineer as to design, capacity, and mechanical condition and must be on the site before the work is started. Any equipment, in the judgment of the Engineer, that proves inadequate to obtain results prescribed shall be improved or new equipment substituted or added.

For simple spans, concrete should be deposited by beginning at the lower end of the span and working toward the upper end. Concrete in girders shall be deposited uniformly for the full length of the girder and brought up evenly in horizontal layers. For continuous spans, where required by design considerations, the concrete placing sequence shall be shown on the Plans or in the Special Provisions.

Concrete shall not be deposited in the forms more than 2 m (6 feet) from its final position.

Concrete shall not be deposited in running water.

The rate of placing the concrete shall be so regulated that no excessive stresses are placed on the forms. Concrete in all slabs, decks, girders, or ribs of arches shall be placed in one continuous operation, unless otherwise specified.

Concrete shall be placed in continuous horizontal layers, the thickness of which shall not exceed 450 mm (18 inches), unless otherwise directed by the Engineer. Each succeeding layer shall be placed before the underlying layer has taken initial set and shall be compacted in a manner that will eliminate any line of separation between the layers. When it is necessary, by reason of any emergency, to place less than a complete horizontal layer at one operation, such layer shall terminate in a vertical bulkhead.

After the concrete has taken its initial set, care shall be exercised to avoid jarring the forms or placing any strain on the ends of projecting reinforcing bars.

(d) Placement of Overlays. Unless otherwise shown on the Plans, existing expansion joints and dams shall be maintained through the overlay. A bulkhead equal in width to that of the joint shall be installed to the required grade and profile prior to placing the overlay material. Expansion dam treatment shall be as shown on the Plans.

Screed rails shall be placed and fastened in position to ensure finishing the new surface to the required profile. Supporting rails shall be anchored in such a manner as to provide horizontal and vertical stability. Screed rails shall not be placed so as to create a recess in the overlay surface and shall not be treated with form oil.

A construction dam or bulkhead shall be installed in case of major delay in placement. During minor delays of one hour or less, the end of the placement shall be protected from drying with several layers of wet burlap.

For a period of at least one hour before the placement of overlay material, the prepared surface shall be flooded with water. After removal of all free water, the overlay material shall be deposited on the damp surface and manipulated so as to coat the horizontal and vertical surfaces to be covered. The rate of progress shall be controlled so as to prevent the drying of previously deposited material.

(e) Use of Chutes. Chutes, troughs, and pipes used in placing concrete shall be arranged so as to avoid segregation of the materials and the displacement of the reinforcement and shall be approved by the Engineer. Aluminum chutes, troughs, or pipes will not be permitted.

All chutes, troughs, and pipes shall be kept clean and free of hardened concrete by thoroughly flushing with water after each run. Open troughs or chutes shall be either of metal or metal lined and shall extend as nearly as possible to the point of deposit. When the discharge must be intermittent, a hopper or other device for regulating the discharge shall be provided.

Dropping of unconfined concrete more than 1.5 m (5 feet) or depositing a large quantity at any point and running or working it along the forms will not be permitted.

(f) Use of Vibrators. Unless otherwise specified, the concrete shall be consolidated with mechanical vibrators, of an approved type and design, operating within the concrete. When required, vibrating may be supplemented by hand spading with suitable tools to ensure proper and adequate consolidation. Vibrators shall be manipulated to work the concrete thoroughly around the reinforcement and imbedded fixtures and into corners and angles of the forms to produce surfaces free of imperfections. Vibrators shall not be used as a means to cause concrete to flow or run into position instead of placing. The vibration at any point shall be of sufficient duration to accomplish consolidation but shall not be prolonged to the point where segregation occurs.

Vibrators shall be used in concrete with reasonable care and shall not come in contact with structural steel, reinforcing steel, ties, forms, or partially set or hardened concrete at any time. Vibrators used in concrete with epoxy coated reinforcing steel shall have non-metallic or rubber coated heads. Vibrating machines shall at no time be left running unattended in the concrete.

When it is necessary by reason of an emergency to discontinue the placing of a monolithic section, the use of vibrators shall cease. Vibrators shall not again be used until a sufficient depth of fresh concrete is placed to prevent any possibility of the effect of vibration on the concrete already in place and in no case shall this depth be less than 600 mm (2 feet).

The number of vibrators used shall be ample to consolidate the incoming concrete immediately after it is deposited in the form. The Contractor shall have at least one spare vibrator in serviceable condition at the site of the structure in which more than 20 m^3 (25 cubic yards) of concrete are to be placed. The vibrators shall be capable of transmitting vibration to the concrete at frequencies of not less than 4500 impulses per minute under load. The vibration shall be of sufficient intensity and duration to cause plasticity, settlement, and complete consolidation of the concrete without causing segregation. The vibrator shall visibly affect a mass of concrete of 50 mm (2 inch) slump over a radius of at least 450 mm (18 inches).

(g) Blasting Operation. All blasting operations within 60 m (200 feet) of any concrete work shall be completed prior to the placement of the concrete. Regardless of the above limitation on blasting operations, the Contractor shall be responsible for any damage resulting from blasting operations.

541.11 DEPOSITING CONCRETE UNDER WATER.

(a) General. Concrete shall not be deposited under water except as specified by the Contract Documents or upon approval of the Engineer and shall be subject to the following specifications:

(1) The Contractor shall submit for the Engineer's review and acceptance a Portland cement concrete mix per the following requirements:

A minimum of thirty-seven (37) calendar days prior to placement (or prior to pre-placement meeting, if one is required), the Contractor shall submit (for approval) the mix design for the class of concrete specified. The mix design(s) shall be submitted to the Agency's Materials and Research Laboratory, 1716 Barre-Montpelier Rd., Berlin, Vermont 05602, attention Structural Concrete Engineer. No class of concrete shall be placed on a project until the mix design is reviewed and accepted. The mix design must contain the following and state the names and sources of all materials:

Saturated Surface Dry or Dry Weights

Compressive Strength

Cement Content in kg/cubic meter (lbs/cubic yard)

Mineral Admixture Content (each) in kg/cubic meter (lbs/cubic yard)

Air Content

Water/Cementitious Material Ratio

Chemical Admixtures (types and dosages)

Laboratory Test Results (strength, air content, water/cementitious material ratio, slump)

(2) Mix Design Requirements:

a. The mix shall contain a minimum of 356 kg/cubic meter (600 lbs/cubic yard) of cementitious material with: a minimum of 25% GGBFS substitution, or a minimum of 20% Fly Ash substitution, or other approved mineral admixture substitution at an approved rate.

b. Air content shall be 4.5% +/- 1.5% unless any portion of this concrete shall experience freeze-thaw conditions - then the air content shall be 6% +/- 1.5%.

c. The maximum water/cementitious material ratio shall be 0.45. When a water-reducing, high range admixture (AASHTO M 194, Type F or Type G) has been included in the reviewed and accepted mix design, the concrete shall not demonstrate segregation at the proposed slump, as determined by the Engineer, but at no time shall the slump be less than 180 mm (7 inches).

d. If needed for a cofferdam and/or seal design, the concrete shall provide a minimum 28 day design strength of 20 MPa (3000 psi). Otherwise, minimum strength requirements for underwater concrete shall be as specified in the Contract Documents.

(b) Placement. Concrete deposited under water shall be carefully placed in still water by use of a tremie hopper and tube, and shall not be disturbed after being deposited.

In no case shall vibrators be used for underwater concrete**.**

The placement shall be continuous to the elevations shown on the Plans and the resulting concrete shall be monolithic and homogeneous.

Concrete shall not be deposited in water having a temperature of 2 °C (35 °F) or below. When the water temperature is between 2 and 5 °C (35 and 40 °F), the mixing water, the aggregates, or both shall be heated as specified in Subsection 541.07(b).

A tremie shall be constructed of heavy-gauge steel pipe and consist of ~~a~~ watertight joints between the tremie sections with a diameter of not less than 250 mm (10 inches). The tremie hopper shall have a capacity of at least 0.4 m^3 (1/2 cubic yard). When a batch is dumped into the hopper, the flow of the concrete shall be induced by slightly raising the discharge tube, always keeping it in the concrete.

The discharge tubes for tremies shall be equipped with a device that will prevent water from entering the tube while charging the tube with concrete. Such tubes shall be supported to permit free movement of the tubes over the entire work surface and to permit rapid lowering, when necessary to retard or stop the flow of concrete from the tube.

Tubes shall be kept continuously submerged in concrete during discharge. The depth that the tube is submerged in concrete and the height of the concrete in the tube shall be sufficient to prevent water from entering the tube. The Contractor shall continuously monitor the difference in elevation between the top of the concrete and the end of the discharge tube.

Horizontal movement of discharge tubes through the concrete will not be allowed.

If a direct pumping method is to be implemented, then the pipe shall consist of heavy-gauge steel sections.

541.12 PUMPING. Where concrete is conveyed and placed by mechanically applied pressure, the equipment shall be suitable in kind and adequate in capacity for the work. The pump shall be capable of pumping concrete within the specified slump limits. The use of aluminum pipe as a conveyance for the concrete will not be permitted.

The operation of the pump shall be such that a continuous stream of concrete without air pockets is produced. When pumping is completed, the concrete remaining in the pipeline, if it is to be used, shall be ejected in such a manner that there will be no contamination of the concrete or separation of the ingredients. The equipment shall be arranged so that no resulting vibrations may damage freshly placed concrete.

The pumping of Class LW concrete will not be permitted.

541.13 CONSTRUCTION JOINTS.

(a) Location of Construction Joints. Joints shall be formed at the location shown on the Plans. Any variation or new location of joints shall require written permission of the Engineer. Feather edges at construction joints will not be permitted. Joints shall be formed with inset form work so that each layer of concrete will have a thickness of not less than 150 mm (6 inches).

(b) Joining Fresh Concrete to Previously Set Concrete. In joining fresh concrete to concrete that has hardened, the surface shall be roughened in such a manner that will not leave loosened particles or damaged concrete at the surface and be thoroughly cleaned of all laitance, loose, and foreign material. Immediately prior to the placing of the new concrete, the surface shall be saturated with water. When shown on the Plans or ordered by the Engineer, the surface shall be thoroughly coated with a very thin coating of mortar or neat cement grout and all forms drawn tight against the face of the concrete. The neat cement mortar or bonding agent shall not be allowed to dry out before being covered with fresh concrete.

(c) Keys. Suitable keys shall be formed at construction joints. Unless otherwise directed by the Engineer, these keys shall be of the type and detail shown on the Plans.

(d) Filled Construction Joints. Filled construction joints shall contain a preformed cork joint filler or other preformed joint filler that may be shown in the Contract Documents. Joint filler shall be cut to fit exactly and shall completely fill the space that is shown on the Plans. Where a pour grade or caulking grade filler is indicated to be used in the joints, that portion of the joint to be filled shall be formed with a separate material (other than the preformed joint filler) that can easily be removed prior to placement of the above indicated filler.

(e) Water Stops. Approved water stops shall be placed at locations shown on the Plans. They shall form continuous watertight joints.

(f) Bond Breakers. Bond breakers shall be one of the following materials as shown on the Plans: asphalt-treated felt, pipe insulation, or tar emulsion.

541.14 EXPANSION JOINTS. All joints shall be constructed according to details shown on the Plans.

(a) Filled Compression and Expansion Joints. Filled compression and expansion joints shall be made with a preformed self-expanding cork joint filler or other preformed joint filler that may be shown in the Contract Documents. Joint filler shall be cut to fit exactly and shall completely fill the space that is shown on the Plans. Where a pour grade or caulking grade filler is indicated to be used in the joint, that portion of the joint to be filled shall be formed with a separate material (other than the expansion joint filler) that can easily be removed prior to placement of the above indicated filler.

(b) Special Types of Expansion Joints. Special types of expansion joints may be used when shown on the Plans or ordered by the Engineer.

541.15 PATCHING. Patching of existing concrete shall be accomplished with the type of material shown on the Plans. Type IV mortar shall be used where a non-shrink or expansive mortar is shown on the Plans. Patching of new concrete shall be as specified in Subsection 541.16(a)(1).

541.16 CONCRETE FINISHING.

(a) General. Unless otherwise specified, the surface of the concrete shall be finished immediately after form removal.

All concrete surfaces shall be given a dressed finish. If further finishing is required, exposed surfaces shall be given a rubbed finish. Other finish classes may be shown on the Plans for designated surfaces.

(1) Dressed Finish. The dressed finish work shall begin within 12 hours after removal of forms and shall continue until completed. All fins and irregular projections shall be removed from all surfaces except from those that are not to be exposed. On all surfaces, the cavities produced by form ties and all other holes, honeycomb spots, broken corners or edges, and other defects shall be thoroughly cleaned, saturated with water, and carefully pointed and trued with a mortar composed of the same type of cement and fine aggregate and mixed in the same proportions used in the grade of the concrete being finished. Mortar used in pointing shall be not more than one hour old. The mortar patches shall be cured a minimum of 72 hours in accordance with Subsection 541.17. All construction and expansion joints in the completed work shall be left carefully tooled and free of all mortar and concrete. The joint shall be left exposed to its full length with clean and true edges.

All surfaces that cannot be repaired to the satisfaction of the Engineer shall be "rubbed" as specified for a Rubbed Finish.

(2) Rubbed Finish. After removal of forms, the rubbing of concrete shall be started as soon as its condition will permit. Immediately before starting this work, the concrete shall be kept thoroughly saturated with water. Sufficient time shall have elapsed before the wetting down to allow the mortar used in the pointing to thoroughly set. Surfaces to be finished shall be rubbed with a medium coarse carborundum stone, using a small amount of mortar on its face. The mortar shall be composed of the same type of cement and fine sand mixed in proportions used in the concrete being finished. Rubbing shall be continued until all form

marks, projections, and irregularities have been removed, all voids filled, and a uniform surface has been obtained. The paste produced by this rubbing shall be left in place.

After all concrete above the surface being treated has been cast, the final finish shall be obtained by rubbing with a fine carborundum stone and water. This rubbing shall be continued until the entire surface is of a smooth texture and uniform color.

After the final rubbing is completed and the surface has dried, it shall be rubbed with burlap to remove loose powder and shall be left free from all unsound patches, paste, powder, and objectionable marks.

(3) Float Finish. This finish for horizontal surfaces shall be achieved by placing an excess of material in the form and removing or striking off the excess with a template, forcing the coarse aggregate below the mortar surface. Creation of concave surfaces shall be avoided. After the concrete has been struck off, the surface shall be made uniform by longitudinal or transverse floating.

When the concrete has hardened sufficiently, the surface shall be given a broom finish, burlap drag finish, or left smooth as determined by the Engineer.

(b) Finishing Bridge Deck.

(1) General. At least one week prior to placing any bridge deck concrete, the Contractor shall review the proposed procedure and details for placing deck concrete with the Engineer. The procedure shall provide for adequate labor, equipment, and material supply to complete placement of concrete on the entire deck or specified portion thereof within an eight-hour period. If, during the placement, unforeseen circumstances make placement within the eight-hour period impossible, the Contractor shall be prepared to place a bulkhead, as directed by the Engineer, to limit the placement to eight hours.

A finishing machine shall be provided on all decks constructed with Class LW concrete regardless of length.

Approval of the method and equipment will not relieve the Contractor of full responsibility for obtaining the required surface finish.

Finishing shall continue until such time as there remains no deviation greater than 3 mm (1/8 inch) when tested for trueness with a metal straightedge at least 3 m (10 feet) in length. The Contractor shall furnish the straightedge. When a bituminous concrete surface is to be placed on a bridge deck, the deviation shall be not greater than 6 mm (1/4 inch). When a sheet membrane is being applied, sharp ridges shall not be allowed. All costs of providing a straightedge to test the trueness of the concrete finishing shall be included in the Contract unit prices under Section 631.

Immediately after finishing has been completed**,** and as soon as all excess moisture has disappeared, the bridge deck shall be textured to a uniform gritty surface using a burlap, felt, or other drag satisfactory to the Engineer. Sidewalks and safety curbs shall receive their final finish with a fine bristled broom.

If the bridge deck concrete does not meet the above smoothness requirements, the Contractor shall remove high spots up to 13 mm (1/2 inch) high by means of grinding. Any other corrections shall be made only with the written approval of the Chief Engineer. The use of bush hammers will not be allowed. No concrete shall be removed that will result in a concrete slab thickness less than that shown on the Plans.

Any deck that cannot be corrected by a method satisfactory to the Chief Engineer shall be removed and replaced at the Contractor's expense.

(2) Overall Length of Bridge Over 18 m (60 feet). Bridge floors over 18 m (60 feet) in length shall be struck off and finished by an approved self-propelled finishing machine. This machine will be supported on suitable rails and equipped with adjustable strike-off or finishing screeds capable of producing the required finish surface for the full width of the bridge from face to face of curbs. Machines shall be kept in true adjustment. Machines shall not be used until proper adjustments

have been made and the adjustments have been checked and approved by the Engineer.

Sufficient time shall be provided prior to beginning concreting operations for the finishing machine to be operated over the full length of the bridge deck segment to be placed. This test run shall be made with the screed adjusted to its finishing position. While operating the finishing machine in this test, the screed rails shall be checked for deflection and proper adjustment, the cover on slab reinforcement measured, and the controlling dimensions of slab reinforcement and forms checked.

After the concrete has been placed, it shall be struck off by a self-propelled finishing machine and the operation repeated as necessary to produce a uniformly consolidated, dense, smooth surface. The final passage of the finishing machine shall result in a uniform surface at the required grade and slope over its entire area.

The Contractor shall furnish a work bridge or bridges of an approved type, capable of spanning the entire width of the deck, supported on the finishing machine rails, and supporting at least a 2.2 kN (500 pound) load without deflection to the concrete slab surface.

(3) Overall Length of Bridge 18 m (60 feet) and Less. Screed rails shall be rigidly set to grade and supported sufficiently on adjustable chairs so as to allow no deflection in the rails under operating conditions. Screed guides or chairs shall be supported on structural members where possible. Sufficient screed rails shall be provided so that all rails necessary for any one continuous pour may be preset and graded before the start of concreting operations. The removal of screed rails and exposed chairs shall be accomplished without walking in the fresh concrete.

The Contractor shall furnish a minimum of one work bridge of an approved type, capable of spanning the entire width of the deck and supporting at least a 2.2 kN (500 pound) load without deflection to the concrete slab surface.

After the concrete is placed, it shall be struck off by one of the following methods:

a. A self-propelled concrete finishing machine used as specified in part (b)(2) above for concrete finishing on bridges longer than 18 m (60 feet);

b. A straight steel roller with a minimum diameter of 100 mm (4 inches), at least 300 mm (12 inches) longer than the distance between screed strips, and equipped with handles at each end, which shall be rolled back and forth until the surface is smooth and even with all holes filled;

c. An approved mechanical vibrating screed exerting a force of not less than 175 N/m (12 pounds per foot), the vibrations of which shall be of not less than 6500 vibrations per minute when checked by a vibration reed-type tester, uniform throughout its entire length and adjusted so as not to drive the aggregate more than 6 mm (1/4 inch) below the surface; or

d. An approved wood, metal shod template fitted with handles. If satisfactory results are not obtained with the type of screed selected, the Engineer may direct the use of another type of screed.

After the preliminary screeding, floats shall be operated with a combined longitudinal and transverse motion, planing off the high areas and floating the material removed into the low areas. Each pass shall lap the previous pass by 50 percent of the length of the float.

541.17 CURING CONCRETE.

(a) General. Water for use in curing concrete shall conform to the provisions of Subsection 745.01.

Effective cure time shall be only the time that the concrete has been maintained in a wet condition with the concrete surface temperature above 10 °C (50 °F). The effective cure time may be extended as directed by the Engineer.

Regardless of the curing medium specified and before any premature drying has set in, the entire surface of the newly placed concrete shall be kept damp. This shall be achieved by applying water with a nozzle that atomizes the flow so that a mist and not a spray is formed. The atomized flow shall be applied continuously until the exposed surface is sufficiently hard so that it can be covered by the specified curing mediums. The moisture shall not be applied under pressure directly upon the concrete and shall not be allowed to accumulate in a quantity sufficient to cause a flow or washing of the surface.

The atomized flow shall be applied continuously until the surfaces can be covered by the specified curing mediums. For bridge barriers, curbs and sidewalks the curing method shall be applied within 15 minutes of the completion of the finishing process. For bridge decks the curing method shall promptly follow the screed machine, within a maximum lag time of 10 minutes and without interruption.

TABLE 541.17A
CURING OF CONCRETE COMPONENTS

Type of Construction	Curing Methods	Curing Period Days
Substructure	541.17(b)(1), (2), (3), (5), (7), (8)	7
Superstructure	541.17(b) (2), (8)	10
Retaining Walls	541.17(b)(1), (2), (5), (6), (8)	7
Headwalls	541.17(b)(1), (2), (5), (6), (8)	7
Sidewalks, Curbs, and Gutters	541.17(b)(1), (2), (3), (5), (6), (7), (8)	7

If high early strength (Type III) portland cement is permitted and used, the curing period may be reduced as directed by the Engineer.

Concrete placed after September 30th shall have a drying period of seven (7) days immediately following the end of the cure period. The concrete shall be kept moisture free and above freezing for this period.

(b) Methods of Curing. All exposed surfaces of newly placed concrete shall be cured by one of the following specified methods:

(1) Water Curing. Curing with water shall be by continuously sprinkling or flooding of all exposed surfaces for the entire required curing period.

(2) Burlap Curing. The entire exposed surface of the concrete shall be covered with two layers of approved burlap. The burlap shall be soaked with water and kept wet for the entire curing period. For superstructures the burlap shall then be covered with a lapped layer of white polyethylene sheeting. Once the concrete superstructure has hardened sufficiently, a stream of water (per soaker hose or other device) shall be continuously applied under the polyethylene sheeting until the cure period is complete.

(3) Sand Cover. The entire exposed surface of the concrete shall be covered with at least 75 mm (3 inches) of approved sand that shall be kept wet for the entire curing period.

(4) White Polyethylene Sheeting. The entire exposed surface of the concrete shall be covered with a blanket of white polyethylene sheeting, maintained and fastened to provide a nearly airtight condition in contact with the surface where possible. If, in the opinion of the Engineer, this cover is not adequately provided or maintained to ensure the proper conditions for concrete cure, then white polyethlyene sheeting cure shall be terminated and another method substituted.

(5) White Burlap-Polyethylene Sheeting. The entire exposed surface of the concrete shall be covered with a blanket of white burlap-polyethylene sheeting. The burlap shall be thoroughly dampened prior to placing and shall be placed next to the concrete. All joints shall be lapped a minimum of 450 mm (18 inches). The burlap shall be kept damp throughout the curing period.

(6) Membrane Forming Curing Compound. White pigmented or fugitive dye membrane curing solution may be used for curing concrete in minor drainage structures. All other use of curing compound shall be approved in writing by the Engineer. When membrane curing is used, the exposed concrete shall be thoroughly sealed immediately after the free water has left the surface. The concrete inside the forms shall be sealed immediately after the forms are removed and necessary finishing has been done. The solution shall be applied in one or two separate applications. If the solution is applied in two increments, the second application shall follow the first application within 30 minutes. Satisfactory equipment shall be provided, together with means to properly control and ensure the direct application of the curing solution on the concrete surface so as to result in a uniform coverage of the surface area at the rate of 275 mL/m^2 (1 gallon for each 150 square feet).

If rain falls on the newly coated concrete before the film has dried sufficiently to resist damage, or if the film is damaged in any other manner, a new coat of the solution shall be applied to the affected portions equal in curing value to that specified above.

Should the surface be subject to continuous injury or the use of curing compound result in a streaked or blotchy appearance, the method shall be stopped and water curing applied.

Only curing compounds approved by the Agency's Materials and Research Section may be used.

(7) White Polyethylene Sheeting with Sand Cover. This method may be used only when approved by the Engineer and shall conform to the requirements of part (b)(4) above. The airtight condition shall be obtained by the addition of a uniform sand cover at a minimum depth of 50 mm (2 inches).

(8) Pre-dampened cotton mats. The entire exposed surface of the concrete shall be covered with a blanket of cotton mats that has been pre-dampened with water. The mats shall be maintained in a damp condition until the curing period is complete

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If, in the opinion of the Engineer, the Contractor's curing procedure is not producing an adequate cure, the Engineer may direct a change in the cure method at no additional cost to the Agency.

541.18 LOADING OF CONCRETE. After the concrete has been placed and the finishing operations concluded, it shall not be walked on or disturbed in any manner, including removal of forms, for a minimum period of 18 hours. If retarder is used as an admixture, this minimum period may be extended as directed by the Engineer.

(a) Substructure. No backfill material shall be placed against a newly completed structure until the concrete has been cured in accordance with Table 541.17A, and until the field cured test cylinders have attained 85 percent of the compressive strength specified in Table 541.03A. However, the Contractor may erect forms for subsequent concrete placement on footings after 18 hours have elapsed from the time that the footing placement was completed, provided the concrete has sufficient strength to allow it to be worked on without damage, and proper cure is maintained.

Static loads, such as forms, reinforcing steel, or other materials necessary for construction, may be placed on any concrete after it has been in place 72 hours, or a compressive strength of 12.4 MPa (1800 pounds per square inch) has been obtained, provided proper curing is maintained. Superimposed loads from subsequent concrete pours will not be allowed on any substructure unit or section in place until the field cured test cylinders have attained 85 percent of the compressive strength specified by Table 541.03A, and provided curing of the supporting section is maintained in accordance with Table 541.17A.

(b) Superstructure. Static loads, such as forms, granite curbing, cast-in-place concrete curb, and other materials necessary for deck construction, may be placed on deck concrete as long as the field cured test cylinders for this concrete have attained 85 percent of the compressive strength specified in Table 541.03A, the proper curing is maintained, and the materials are spread out uniformly to avoid point loading.

The Contractor shall keep bridge floors free of all motor vehicles, transit mixers, and heavy construction equipment until the curing period is satisfactorily completed, the field cured test cylinders for the bridge floor concrete have attained the compressive strength specified in Table 541.03A, and the field cured test cylinders for the curb concrete have attained 85 percent of the compressive strength specified in Table 541.03A.

(c) Vertical Joint. Concrete shall not be placed against a vertical construction joint until the previously placed concrete has been in place a minimum of 72 hours.

The Contractor must not allow loads that are in excess of the legal loads permitted by the laws of the State to travel over the completed structure, except with written permission of the Engineer.

541.19 METHOD OF MEASUREMENT. The quantity of Concrete, Class AA, A, B, C, D, or LW to be measured for payment will be the number of cubic meters (cubic yards) of the class of concrete specified in the complete and accepted work, as determined by the prismoidal method using dimensions shown on the Plans or as directed by the Engineer, including the volume of superstructure precast concrete stay-in-place forms, but excluding the volume of steel or other stay-in-place forms and form filling materials. No deductions will be made for the volume of concrete displaced by steel reinforcement, structural steel, expansion joint material, scuppers, weep holes, conduits, tops of piles, scoring, chamfers or corners, inset panels of 38 mm (1 1/2 inches) or less in depth, or any pipe less than 200 mm (8 inches) in diameter.

The quantity of Mortar, Type I or Type IV to be measured for payment will be the number of cubic meters (cubic yards) of the type of mortar specified in the complete and accepted work. The number of cubic meters (cubic yards) will be based on sack count of cement used. One cubic meter (1 cubic yard) of Type I or Type IV mortar is considered equivalent to 950 kg (1600 pounds) of portland cement.

541.20 BASIS OF PAYMENT. The accepted quantities of the Contract items specified will be paid for at the Contract unit prices. Payment will be full compensation for performing the work specified, including designing the mix, satisfactory finishing and curing, and for furnishing all forms, materials, including joint filler and bond breaker, labor, tools, admixtures, equipment, including automatic temperature recording units, trial batches, and incidentals necessary to complete the work.

The cost of heating materials and protecting the concrete against cold weather, and any additional cost for cement, will not be paid for separately but will be considered incidental to the Contract unit prices for Section 541.

The cost of furnishing testing facilities and supplies at the batch plant and the setting of inserts, bench marks, and bridge plaques furnished by the Agency will not be paid for separately but will be considered incidental to the Contract unit price of structural concrete.

Payment will be made under:

Pay Item	Pay Unit
541.21 Concrete, Class AA	Cubic Meter (Cubic Yard)
541.22 Concrete, Class A	Cubic Meter (Cubic Yard)
541.25 Concrete, Class B	Cubic Meter (Cubic Yard)
541.30 Concrete, Class C	Cubic Meter (Cubic Yard)
541.31 Concrete, Class D	Cubic Meter (Cubic Yard)
541.40 Concrete, Class LW	Cubic Meter (Cubic Yard)
541.55 Mortar, Type I	Cubic Meter (Cubic Yard)
541.58 Mortar, Type IV	Cubic Meter (Cubic Yard)

SECTION 580 - STRUCTURAL CONCRETE REPAIR

580.01 DESCRIPTION. This work shall consist of the removal and disposal of delaminated and unsound concrete from an existing superstructure or substructure and its replacement with new portland cement concrete or an approved patching material.

This Section shall be used in conjunction with Section 501 or Section 541, whichever is applicable to other concrete items in the Contract. Where both specifications are used, Section 501 shall be used for this work. Anything not specifically addressed in this Section relative to concrete shall be governed by Section 501 or Section 541.

580.02 MATERIALS. Materials shall meet the requirements of the following Subsections:

Coarse Aggregate for Concrete (TABLE 704.02A)	704.02
Concrete Repair Materials	780
Overhead and Vertical Concrete Repair Material	780.02
Rapid Setting Concrete Repair Material	780.03
Rapid Setting Concrete Repair Material with Coarse Aggregate	780.04

Concrete, High Performance (Class AA, Class A, and Class B) shall meet the applicable requirements of Subsections 501.02 through 501.19 or Concrete (Class AA, Class A, and Class B) shall meet the applicable requirements of Subsections 541.02 through 541.19. Where further references in this Specification are made to Concrete (Class AA, Class A, or Class B), they shall mean that class or corresponding class of concrete described in the governing concrete specifications.

580.03 PROPORTIONING AND MIXING. All Concrete Repair Materials shall be mixed with a mechanical mixer at the project site in accordance with the manufacturer's recommendations on the project packaging, one bag (unit) at a time. Except for Rapid Setting Concrete Repair Material with Coarse Aggregate, the product shall not be extended with sand or gravel.

At no time shall recommended water content be exceeded nor shall any mixture be retempered by adding water and/or remixing once the material has reached initial set.

Rapid Setting Concrete Repair Material with Coarse Aggregate shall be mixed with approved materials in the proportions designated by the Materials and Research Engineer. When Rapid Setting Concrete Repair Material with Coarse Aggregate is used on a project, the Contractor shall submit three (3) 100 mm (4 inch) diameter test cylinders to the Agency's Materials & Research Section Structural Concrete Unit for information for the first quantity of 25 bags (units) of materials or less used on the project. Thereafter, three (3) more test cylinders shall be submitted for each increment of 100 bags of materials used on the project.

580.04 SURFACE PREPARATION FOR REPAIRS, OVERLAYS AND MEMBRANES. Surfaces to be repaired or overlaid shall be chipped back to sound concrete as directed by the Engineer using approved hand or mechanical methods.

When removing unsound portions of an existing structure in preparation for repair, the edges of all areas to be repaired shall be saw cut in straight lines to a minimum depth of 25 mm (1 inch).

After complete removal of unsound concrete, the entire area to be patched or overlaid and all exposed steel which will have concrete placed against or around it (metal plate expansion joints, scuppers, finger plate expansion joints, reinforcing steel, etc.) shall be blast cleaned to remove contaminants and laitance a maximum of 24 hours prior to placing the new concrete. The area shall be vacuumed or flushed using high pressure air or water to remove all loose particles, dust, and debris.

Air or water used for cleaning shall be free of oil and other contaminants. After blast cleaning, once the concrete is wet, whether from flushing or rain, the concrete must be kept wet until the placing of concrete materials. If the concrete is allowed to dry out or the 24 hour time limit has lapsed, the entire area shall be blast cleaned and vacuumed or flushed again.

Following concrete removal, additional surface preparation for the application of Overhead and Vertical Concrete Repair Material shall be as recommended on the product packaging by the manufacturer.

Where Rapid Setting Concrete Repair Material or Rapid Setting Concrete Repair Material with Coarse Aggregate is to be used, concrete surfaces shall be thoroughly blast cleaned and prepared as recommended by the manufacturer.

Concrete bridge decks or other surfaces designated by the Engineer to be prepared for application of a waterproofing membrane shall be ground to a smooth uniform surface by either a hand held grinder or a wheel mounted grinder unit specifically designed for the purpose. Ridges or areas of unevenness designated by the Engineer shall be ground so that no surface deviation greater than 1.6 mm (1/16 inch) remains.

580.05 FORMS. The forms shall be constructed in such a manner that the final concrete surface has the same architectural score marks and exterior face appearance as the original surface.

For additional requirements for forms see either Subsection 501.09 or 541.09.

580.06 PLACING CONCRETE. The Contractor shall comply with the requirements of Subsection 501.07 or 541.07 as well as Subsection 501.10 or 541.10 for this work.

In addition, the following is applicable to concrete repair:

(a) Portland Cement Concrete. When Epoxy Bonding Compound is not specified on the Plans, the prepared concrete surface shall be flooded with water for at least one hour prior to fresh concrete placement, standing water shall be removed and a neat cement paste shall be brushed into the surface. The cement (AASHTO M 85, Type II) and water shall be mixed to a thick latex paint consistency. The neat cement paste shall not be allowed to dry out before it is covered with fresh concrete.

(b) Concrete Repair Material. The moisture condition of the prepared concrete surface, the use of bonding agents and the placement of Overhead and Vertical Concrete Repair Material, Rapid Setting Concrete Repair Materials or Rapid Setting Concrete Repair Material with Coarse Aggregate shall be as recommended by the manufacturer of the product being placed.

(c) Alternate Methods of Repair. The Contractor may propose an alternate means of repairing vertical and overhead surfaces. The alternate may include, but is not limited to, the use of pneumatically applied materials. Should the Contractor choose an alternate method of repair, the written approval of the Structures Engineer shall be obtained prior to beginning work utilizing the alternate method.

580.07 CURING CONCRETE. In addition to the requirements of Subsection 501.17 or 541.17, the following requirements shall apply to concrete repair:

A membrane-forming curing compound may be used to cure the repairs made with concrete, provided the patched areas are covered with white polyethylene sheeting after the curing compound is applied. White Polyethylene Sheeting shall conform to Subsection 725.01(c). The type of curing compound shall be approved by the Engineer prior to its use. The curing period for patches made with concrete shall be seven (7) days regardless of the curing method chosen.

Concrete patches may be cured in accordance with Subsection 501.17(b) or 541.17(b), Parts 1, 2, 3, 5, or 7 only. If the method used does not produce the desired results, alternate curing procedures may be required by the Engineer. Evidence of improper cure could be a dry surface, a cracked or cracking surface, or a streaked or blotchy appearance of the surface.

Overlay concrete shall be cured in accordance with Subsection 501.17(b) or 541.17(b), Parts 1, 2, 5, or 7 only.

Concrete Repair Materials shall be cured in accordance with the manufacturer's recommendations on the product packaging or specification sheet.

580.08 METHOD OF MEASUREMENT. The quantity to be measured for payment of Repair of Concrete Superstructure Surface, Class I or Class II will be the number of square meters (square yards) of repaired concrete surfaces.

Repair of Concrete Superstructure Surface, Class I, shall include the removal of concrete from the surface of existing concrete to a maximum depth as determined by the top of the top bars of the top mat of existing reinforcing steel.

Repair of Concrete Superstructure Surface, Class II, shall include removal of concrete from the surface of the existing concrete to a maximum depth as determined by the top of the top bars of the bottom mat of reinforcing steel. The minimum depth removed under this item shall be 19 mm (± 6 mm) [¾ of an inch (±¼ inch)] below the bottom bars of the top mat of reinforcing steel.

The quantity to be measured for payment of Concrete Substructure Surfaces, Class I or Class II, will be the number of square meters (square yards) of repaired substructure surfaces, whether they are flat, vertical, or overhead.

Repair of Concrete Substructure Surface, Class I shall include removal of concrete from the plane of the original concrete surface to a maximum depth as determined by the outside face of the first mat of reinforcing steel.

Repair of Concrete Substructure Surface, Class II shall include removal of concrete from the plane of the original concrete surface to a maximum depth of 150 mm (6 inches) measured from the plane of the original surface. The minimum depth removed under this item shall be 19 mm (± 6 mm) [¾ of an inch (±¼ inch)] beyond the inside face of the first mat of reinforcing steel.

The quantity to be measured for payment of Repair of Concrete Superstructure Surface, Class III, will be the number of cubic meters (cubic yards) of concrete removed. Repair of Concrete Superstructure Surface, Class III, shall include removal from the top of the existing concrete surface to the bottom of the concrete deck (i.e. full depth removal).

The quantity to be measured for payment of Repair of Concrete Substructure, Class III, will be the number of cubic meters (cubic yards) of concrete removed. Repair of Concrete Substructure Surface, Class III, shall include removal from the face of the existing concrete surface to a depth greater than 150 mm (6 inches).

The quantity to be measured for payment for Surface Preparation for Membrane will be the number of square meters (square feet) of prepared surface. Payment will be made for surface preparation of existing surfaces and not for new patches, which will be the responsibility of the Contractor.

The quantity to be measured for Rapid Setting Concrete Repair Material, Overhead and Vertical Concrete Repair Material and Rapid Setting Concrete Repair Material with Coarse Aggregate will be the number of cubic meters (cubic feet) of material mixed for use, as approved by the Engineer. The volume will be computed on the basis of the quantity identified as being contained in the product packaging.

The quantity to be measured for payment of Concrete, Class AA Overlay will be the number of square meters (square yards) of finished surface complete in place. The limits of removal shall be as specified for Repair of Concrete Superstructure Surface, Class II or Class III as determined by the Engineer.

580.09 BASIS OF PAYMENT. The accepted quantities will be paid for at the Contract unit prices for the pay items specified, which price shall be full compensation for performing the work specified, including surface preparation as specified, satisfactory completion of curing, and the furnishing of all forms, materials, including joint filler, labor, tools, admixtures, equipment, and incidentals necessary to complete the work.

The cost of heating or cooling materials and protecting the concrete against cold weather and any additional cost for cement shall be included in the Contract unit price for the applicable concrete repair item in the Contract.

The unit price bid for Repair of Concrete Superstructure Surface, Class I, Repair of Concrete Superstructure Surface, Class II and Repair of Concrete Superstructure Surface, Class III will be full compensation for the removal and replacement of concrete. Replacement material shall be Concrete, Class AA or an acceptable alternate as approved by the Engineer.

The unit price bid for Repair of Concrete Substructure Surface, Class I and Repair of Concrete Substructure Surface, Class II will be full compensation for the removal and replacement of concrete. Replacement material shall be Concrete, Class AA or an acceptable alternate as approved by the Engineer, such as pneumatically applied concrete.

The unit price bid for Repair of Concrete Substructure Surface, Class III will be full compensation for the removal and replacement of concrete. Replacement material shall be Concrete, Class AA, Class A, Class B, or an acceptable alternate as approved by the Engineer.

The accepted quantity of Surface Preparation for Membrane will be paid for at the contract unit price per square meter (square foot), which price shall be full compensation for the furnishing of all labor, tools, equipment, and incidentals necessary to complete the work.

The accepted quantity of Rapid Setting Concrete Repair Material, Overhead and Vertical Concrete Repair Material and Rapid Setting Concrete Repair Material with Coarse Aggregate will be paid for at the Contract unit price bid per cubic meter (cubic foot), which price shall be full compensation for furnishing, transporting, storing, handling, and placing the materials specified and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

The unit price bid for Concrete, Class AA Overlay will be full compensation for the removal and replacement of concrete. Replacement concrete shall be Concrete, Class AA.

Duplicate payment will not be made for preparation of concrete surfaces in any area. For example, if an area is originally prepared as Class I and the Engineer orders a change to the Class II depth, the area will be paid as Class II.

Payment will be made under:

	Pay Item	Pay Unit
580.10	Repair of Concrete Superstructure Surface, Class I	Square Meter (Square Yard)
580.11	Repair of Concrete Superstructure Surface, Class II	Square Meter (Square Yard)
580.12	Repair of Concrete Superstructure Surface, Class III	Cubic Meter (Cubic Yard)
580.13	Repair of Concrete Substructure Surface, Class I	Square Meter (Square Yard)
580.14	Repair of Concrete Substructure Surface, Class II	Square Meter (Square Yard)
580.15	Repair of Concrete Substructure Surface, Class III	Cubic Meter (Cubic Yard)
580.16	Surface Preparation for Membrane	Square Meter (Square Foot)
580.17	Rapid Setting Concrete Repair Material	Cubic Meter (Cubic Foot)
580.18	Overhead and Vertical Concrete Repair Material	Cubic Meter (Cubic Foot)
580.19	Concrete, Class AA Overlay	Square Meter (Square Yard)
580.20	Rapid Setting Concrete Repair Material with Coarse Aggregate	Cubic Meter (Cubic Foot)