SECTION M4

CEMENT AND CEMENT CONCRETE MATERIALS

M4.00.00 General.

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

M4.01.0 Portland Cement.

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

M4.01.1 Blended Hydraulic Cements.

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

M4.01.2 Fly Ash.

Fly ash shall conform to AASHTO M 295.

M4.02.00 Cement Concrete.

Cement concrete shall be composed of specified proportions by the mass of cement, aggregates, water and approved additives to form a homogeneous composition.

Cement concrete shall be designated by class according to strength, cement factor, coarse aggregate size, entrained air content, slump, and by the mass for light-weight concrete. The classes of concrete to be used shall be designated on the plans or in the specifications for the particular work. The Contractor will furnish to the Engineer, for approval, a specific job mix formula for the particular uniform combination of materials and sources of supply to be used on each project complete with test results from trial batches. A new job mix formula shall be supplied any time any source of material has been changed.

Classifications of Concrete Mixes

28-Day Compressive Strength (MPa)	Minimum Cement Content* (Kilograms per Cubic Meter for Coarse Aggregate)		
	10 mm	20 mm	40 mm
20	335	300	280
25	365	335	310
30	425	390	335
35	450	420	400
40	510	475	450
45	535	500	480
50	565	530	500
55	620	585	560
% Entrained Air (±1.0%)	7.0	6.0	5.0

All concrete shall contain a water reducing admixture.

* Fly ash may be substituted for cement up to a maximum of 15% by mass.

Concrete which will be subjected to conditions of severe exposure will be minimum 30 MPa with air-entrained content of 7.0 ± 1.0% when so specified.

The use of an approved additive other than air entraining (AASHTO M 154) or water reducer (AASHTO M 194, Type A) shall require written approval of the Engineer and additives shall not affect a change in the minimum cement content. The minimum cement content can be changed only with the prior written approval of the Engineer.

M4.02.01 Cement.

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

When high early strength concrete is required it shall be obtained by using Type III or by adding an accelerator meeting AASHTO M 194.

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

The temperature of the cement at the time of mixing shall not exceed 65 °C.

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

Each shipment, regardless of quantity, shall be accompanied by a certified Mill Test Report, three copies of which shall be furnished to the Engineer before the cement may be incorporated in the work.

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

M4.02.02 Aggregates.

A. Fine Aggregates.

Sand shall be composed essentially of clean, hard, strong, durable and impermeable particles, resistant to wear and frost, inert to cement and water, reasonably free from structurally weak grains, organic matter, loam, clay, silt, salts, mica or other fine materials that may affect bonding of the cement paste. Sand shall be taken from a natural deposit. The sand particles shall be relatively spherical in shape, and shall have gritty surfaces.

Sand for cement concrete shall be properly washed to satisfactorily remove deleterious materials and surface coatings, and shall be stockpiled after washing for a period as long as necessary to drain off all excess water.

The sand shall conform to the following requirements:

	AASHTO Test Method	Maximum Percent by Mass
Clay Lumps and Friable Particles	T 112	3.0
Coal and Lignite	T 113	0.5
Materials Passing 75 µm Sieve	T 11	3.0
Organic Impurities	T 21	*Pass
Soundness (Na_2SO_4) - 5 Cycles	T 104	10

*Sand when tested for mortar making properties as specified above shall produce a compressive strength, at any period of time, equal to or greater than that developed by mortar of the same proportions and consistency made of the same cement and sand after the sand has been treated in a 3% solution of sodium hydroxide in accordance with AASHTO T 71.

Sand not conforming to requirement specified above for organic impurities shall be rejected unless the 28 day strength tests show the color is due to impurities not detrimental to the strength of the concrete.

The sieve analysis of the sand shall show it to be well graded and conforming to the following:

Sieve Designation	Fine Aggregate Minimum	Fine Aggregate Maximum
9.5 mm	100	–
4.75 mm	95	100
1.18 mm	45	80
300 µm	10	30
150 µm	2	10
75 µm	0	3

The fineness modulus of fine aggregate shall be not less than 2.5 and not greater than 3.0. For the purpose of determining the degree of uniformity, a fineness modulus determination will be made upon representative samples from any one source. Fine aggregate from any one source having a variation in fineness modulus greater than 0.20 either way from the representative sample will be rejected.

Samples for tests of fine aggregate will be taken under the direction of the Engineer from approved storage piles at the site of the batch plant or from approved storage piles at the producing pit.

The fineness modulus of fine aggregate shall be determined by adding the cumulative percentages, by weight, of materials retained on U.S. Standard Sieves 4.75 mm, 2.36 mm, 1.18 mm, 600 µm, 300 µm, 150 µm and dividing by 100.

Fine aggregate failing to pass the minimum requirements for material passing the 300 µm and/or 150 µm sieves may be used, provided an approved inorganic fine material is added to correct the deficiency in grading.

Sand for cement mortar shall conform to the requirements specified above except that the compressive strength shall not be less than 85% of that developed by mortar of the same proportions and consistency made of the same cement and sand after the sand has been treated in a 3% solution of sodium hydroxide in accordance with AASHTO T 71. The sieve analysis shall conform to the following requirements:

Sieve Designation	Minimum	Maximum
2.36 mm	100	–
300 µm	15	40
150 µm	2	10
75 µm		3

B. Coarse Aggregates.

Coarse aggregate for cement concrete shall consist of crushed rock or screened gravel, and shall be composed essentially of clean, hard, strong, and impermeable particles, resistant to wear and frost, and free from deleterious amounts of organic matter, loam, clay, salts, mica, and soft, thin, elongated, laminated or disintegrated stone, and it shall be inert to water and cement. Where finishing of the concrete is to be done by hammering or any other method that breaks the surface of the concrete, only crushed rock shall be used for coarse aggregate.

The aggregates shall conform to the requirements shown below.

Gravel stone shall be thoroughly washed to remove impurities if surfaces are coated with dust.

A deleterious amount of thin and elongated stones will be considered any amount in excess of 15% of the total mass. Thin stones shall be considered to be such stone whose average width exceeds four (4) times their average thickness. Elongated stones shall be considered to be such stone whose average length exceeds four (4) times their average width.

	AASHTO Test Method	Maximum Percent by Mass
Clay Lumps and Friable Particles	T 112	2.0
Chert (Less than 2.40 Sp. Gr. SSD)*		3.0
Sum of Clay Lumps, Friable Particles and Chert (Less than 2.40 Sp. Gr. SSD)*		3.0
Material Finer than 75 µm Sieve	T 11	1.0
Coal and Lignite	T 113	0.5
Percent of Wear (Los Angeles Abrasion Test)	T 96	45 except 30 for all concrete 35 MPa and above
Sodium Sulphate Solution Soundness (5 Cycles)	T 104	10

*These limitations apply only to aggregates in which chert appears as an impurity.

C. Sieve Analysis.

When tested by U.S. Standard laboratory sieves, coarse aggregate for cement concrete shall be blended from stone sizes to meet the graduation requirements for each designation listed below. The limits shown in the table define master ranges of variation for general application and are minimum and maximum in each case. To insure uniformity of material used on any one job or project, the range of variations may be reduced to 1/2 of the range upon determination of the character and source of the materials that the Contractor proposes to furnish.

Percent by Mass Passing (AASHTO T 27)

Designation and Nominal Sieve Size	40 mm Min	40 mm Max	20 mm Min	20 mm Max	10 mm Min	10 mm Max
37.5 mm	90	100				
19.0 mm	35	60	90	100		
12.5 mm					100	
9.5 mm	10	25	20	50	85	100
4.75 mm	0	5	0	10	10	30
2.36 mm			0	5	0	10
1.18 mm					0	5

Stone retained on the largest sieve shall be within an oversize tolerance of 6.30 millimeters.

40 millimeter aggregate shall be proportioned in two or more sizes, separately weighed in the mix. The combined grading as proportioned in the mix shall meet the grading requirements for 40 millimeter coarse aggregate, as determined by actual test.

20 millimeter aggregate may be proportioned in two sizes or processed to the specified gradation.

For use in mass concrete the Engineer may allow the use in 40 millimeter aggregate of not more than 30% of coarse aggregate passing 56.5 millimeter and retained on a 37.5 millimeter sieve, provided such aggregate is separately proportioned as an additional size.

M4.02.03 Lightweight Aggregates.

Lightweight aggregates for Structural Concrete shall meet AASHTO M 195.

M4.02.04 Water.

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

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

1. pH 3.0-11.7
2. Total Solids:
   a) Organics 0.01% maximum
   b) Inorganics 0.10% maximum
   c) Sulphate 0.05% maximum

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

M4.02.05 Cement Concrete Additives

Air-entraining admixtures, water-reducers, retarders, etc., shall conform to the following specifications:

A. Air-entraining admixtures, AASHTO M 154
B. Retarders, AASHTO M 194
C. Water reducers, AASHTO M 194

M4.02.06 Proportioning.

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

A. Proportioning by Mass.

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

B. Scope of Control for Proportioning.

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

1. Minimum Cement Content and Minimum Strength.

The cement proportion is subject to adjustment and approval by the Engineer in order to insure compliance with minimum strength requirements. Standard field test specimens (AASHTO T 23) shall be taken on the job and the Contractor shall be required to add additional cement as directed by the Engineer if test specimens, strength fails to meet the requirements of ASTM C 94, Section 17.

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

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

2. Consistency.

The Contractor shall uniformly regulate the consistency of the mix to the slump directed by the Engineer. The Engineer may reject all batches not conforming to this requirement and the Contractor shall receive no additional compensation.

The general requirements in regard to consistency are as follows:

Mass Concrete	50 ± 13 mm slump
Exposed Bridge Deck Concrete	63 ± 13 mm slump
Reinforced Concrete	75 ± 25 mm slump
Very Constricted Placement Conditions	100 ± 25 mm slump
Pump Concrete	100 ± 25 mm slump
Tremie Concrete	150 ± 25 mm slump

When the specified slump is less than 75 millimeters the tolerance shall be plus or minus 13 millimeters. When the specified slump is 75 millimeters or greater the tolerance shall be plus or minus 25 millimeters. The Engineer will specify the lowest slump with which it is practical to properly place and consolidate the mix within the forms.

3. Workability.

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

4. Air Content.

The air content of the concrete by volume shall be as shown in the table above when tested in accordance with AASHTO T 152. A tolerance of plus or minus 1% in the above percentages will be allowed.

C. Automatic Proportioning Plants.

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

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

The controls shall be set so that:

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

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

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

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

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

D. Admixture Dispensing Systems.

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

E. Recording the Batching.

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

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

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

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

M4.02.07 Measuring Materials.

A. Cement shall be measured by mass or in bags of 42 kilograms each. When fly ash is specified in the mix design, it may be weighed cumulatively with cement. Cement should be weighed before fly ash. When cement is measured by mass, it shall be weighed on a scale separate from those used for other materials, and in a hopper entirely free and independent of the hoppers used for weighing the aggregates. All beam type scales for weighing cement shall be equipped with a tare beam. When cement is measured in bags, no fraction of a bag shall be used unless weighed. The cement as weighed shall be within 1% of required mass.

B. Aggregates shall be measured by mass. Batch masses shall be based on dry materials and shall be the required masses of dry materials plus the total mass of moisture (both absorbed and surface) contained in the aggregate. The individual aggregates as weighed shall be within ± 1% of the required mass.

C. Mixing water shall consist of water added to batch, ice added to batch, water occurring as surface water on the aggregates, and water introduced in the form of admixtures. Water shall be measured by volume or by mass. The device for the measurement of the water shall be readily adjustable and shall be capable of being set to deliver the required amount and cut off the flow automatically when this amount has been discharged. Under all operating conditions the device shall have an accuracy within 1% of the quantity of water required for the batch. The device shall be so arranged that measurements will not be affected by variable pressures in the water supply line. Measuring tanks shall be of adequate capacity to furnish the maximum mixing water required and shall be equipped with outside taps and valves to provide for checking their calibration unless other means are provided for readily and accurately determining the amount of water in the tank. All wash water must be removed from truck mixers or agitators. All water measuring systems shall be capable of discharging total quantity of measured water into the mixer drum in a time not greater than one-third of the specified mixing time.

D. Dry admixtures shall be measured by mass, and paste or liquid admixtures by mass or volume, within a limit of accuracy of 3%. When admixtures are used in small quantities in proportion to the cement, as in the case of air-entraining admixtures, mechanical dispensing equipment shall be used.

M4.02.08 Plant and Equipment.

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

A. Batching Plant.

1. Bins with adequate separate compartments for fine aggregates and for each required size of coarse aggregate shall be provided in the batching plant. Each compartment shall be designed to discharge efficiently and freely into the weighing hopper. Means of control shall be provided so that, as the quantity desired in the weighing hopper is being approached, the material may be added slowly and shut off with precision. Weighing hoppers shall be constructed so as to eliminate accumulation of tare materials and to discharge fully.

2. Fly ash shall be stored at the batch plant in a separate storage or holding bin and shall be protected from rain and moisture.

3. Scales for weighing aggregates and cement shall be of either the springless-dial type or the load cell type and shall indicate the load at all stages of the weighing operation from zero to full capacity. They shall conform to the applicable sections of the current edition of the National Bureau of Standards Handbook 44, Specification, Tolerances, and other Measuring Devices, except as may be otherwise specified. They shall be accurate within one half of 1% under operating conditions. Ten 22 kilogram masses shall be available at the plant at all times for checking accuracy. All exposed fulcrums, clevises, and similar working parts shall be kept clean. When beam-type scales are used, provisions shall be made for indicating to the operator that the required load in the weighing hopper is being approached; the device shall indicate within the last 90 kilograms of load and within 22 kilograms of overload. All weighing and indicating devices shall be in full view of the operator while charging the hopper and he/she shall have convenient access to all controls.

4. The materials, including admixtures, shall be proportioned by automatic proportioning devices, approved by the Engineer. The automatic proportioning equipment shall be installed in an area enclosed for protection against dust and inclement weather.

B. Testing Facilities.

A weatherproof building or room shall be furnished at the site of the producing plants suitable for the housing and use of equipment necessary to carry on the various tests required and for recording and processing test results. This building shall be for the exclusive use of the Engineer or his/her representative for testing and recording purposes. The building or room shall have a least dimension of 2.1 meters and a minimum of
20 square meters. Windows and doors shall be adequately screened and satisfactory lighting and heating shall be provided for a 24 hour day and be supplied with water. The room shall have adequate ventilation and be air conditioned in the warm months to provide a minimum of 23.9 °C. A table, chairs, desk, work bench, file cabinet, electronic calculator, and a minimum of two 2.27 kilogram fire extinguishers shall be provided.

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

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

1	Fine Aggregate Sieve Shaker, power driven, for 200 millimeter minimum diameter sieves.
1	Each of the following standard 200 millimeter minimum diameter square opening sieves: 4.75 mm, 2.36 mm, 1.18 mm, 0.60 mm, 300 µm, 150 µm, and 75 µm with pan and cover.
1	Sample Splitter with a minimum capacity of 0.03 cubic meter. It shall be of the clam shell type and the chute width shall be adjustable from a minimum of 12.5 millimeters to 50 millimeters.
1	Solution Balance, 20 kilogram capacity, weighing directly to 1 gram, with two weighing beams and a taring beam; tare capacity to be 2 kilograms; weight beams to read 1000 grams by 100 gram divisions and 100 gram by 1 gram divisions. Additional matching weights (one - 1 kg, two - 2 kg, one - 5 kg, and one - 10 kg) shall be provided to fulfill capacity of 20 kilograms. The platform to be 280 millimeters diameter. An electronic, direct reading, top loading, 20 kilogram minimum capacity, balance with a precision of 0.1 gram may be substituted for the solution balance.

1 Approved Scale with a minimum capacity of 2000 grams and with a sensitivity of 0.50 grams. An electronic, top-loading balance, with a capacity of 2000 grams minimum, and reading to 0.1 gram may be used in place of the scale.
1 Approved Dial Thermometer, range of 10 °C to 260 °C.
1 Approved Hot Plate.

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

M4.02.09 Mixers and Agitators.

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

B. The truck mixer when loaded with concrete shall not contain more than 63% of the gross volume of the drum. The mixer shall be capable of combining the ingredients of the concrete into a thoroughly mixed and uniform mass and of discharging the concrete with a satisfactory degree of uniformity.

C. The stationary mixer, when loaded at the manufacturer's guaranteed mixing capacity, and the concrete mixed for the time prescribed, shall be capable of combining the ingredients of the concrete into a thoroughly mixed and uniform mass and discharging the concrete with satisfactory uniformity.

D. The agitator, when loaded not to exceed 80% of gross drum volume, shall be capable of maintaining the mixed concrete in a thoroughly mixed and uniform mass and of discharging the concrete with a satisfactory degree of uniformity.

M4.02.10 Mixing and Delivery.

A. Ready-mixed concrete shall be mixed and delivered to the point designated by the Engineer by means of one of the following combinations of operations.

1. Mixed completely in a stationary mixer and the mixed concrete transported to the point of delivery in a truck agitator or in a truck mixer operating at agitator speed or in nonagitating equipment when approved by the Engineer.

2. Mixed completely in a truck-mixer at the point of delivery under the supervision of the Resident Engineer or his/her designated assistant, one of whom shall certify on a delivery slip that he/she observed the complete mixing of the concrete.

B. Truck mixers and truck agitators shall be operated within a capacity not to exceed 63%, or 80% respectively, of the gross volume of the drum and at a speed of rotation for mixing or agitating as designated by the manufacturer of the equipment. A truck mixer or truck agitator used for transporting concrete that has been completely mixed in a stationary mixer shall be operated within the limits of capacity and speed of rotation designated by the manufacturer for agitating, except that the agitator capacity in no event exceeds 80% of the gross drum volume.

C. When a stationary mixer is used for the complete mixing of the concrete, the mixing time for mixers having a capacity of 7.6 cubic meters or less shall be not less than 60 seconds. For mixers of more than 7.6 cubic meters capacity, the mixing time shall be determined by the Engineer. The time is valid provided mixer efficiency tests prove the concrete is satisfactory for uniformity and strength. Mixing time shall be measured from the time all cement and aggregates are in the drum. The batch shall be so charged into the mixer that some water will enter in advance of cement and aggregates, and all water shall be in the drum by the end of the first one-fourth of the specified

mixing time.

D. When a truck mixer is used for complete mixing, each batch of concrete shall be mixed for not less than 70 nor more than 100 revolutions of the drum or blades at the rate of rotation designated by the manufacturer of the equipment on the metal plate on the mixer as mixing speed. Additional mixing, if any, shall be at the speed designated by the manufacturer of the equipment as agitating speed. All materials including adding water shall be in the mixer drum before actuating the revolution counter for determination of number of revolutions of mixing.

E. When a truck mixer or truck agitator is used for transporting central-mixed concrete, or when all ingredients including water have been added to the truck mixer at the batching plant, the drum shall be constantly rotated at the agitating speed designated by the manufacturer of the equipment, both during transport and while on the project prior to discharge, except during the period required for mixing.

F. When a truck mixer or truck agitator is used for transporting concrete, the concrete shall be delivered to the site of the work and discharge shall be completed within 90 minutes after the addition of the cement to the aggregates. Each batch of concrete delivered at the job site shall be accompanied by a time slip issued at the batching plant, bearing the time of charging of the mixer drum with cement and aggregates. In hot weather or under conditions contributing to quick stiffening of the concrete or when the temperature of the concrete is 29 °C or above, the time between the introduction of the cement to the aggregates and discharge shall not exceed 1 hour. When a truck mixer is used for the complete mixing of the concrete, the mixing operation shall begin within 30 minutes after the cement has been added to the aggregate.

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

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

If additional mixing water is required to maintain the specified slump and is added with permission of the Engineer, a minimum of 20 revolutions of the truck mixer drum at mixing speed shall be required before discharge of any concrete.

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

G. When approved by the Engineer, central-mixed concrete which is designed for the purpose may be transported in suitable nonagitating equipment.

I. When nonagitating equipment is used for transportation of concrete:

a) Bodies of equipment shall be smooth, water-tight, metal containers equipped with gates that will permit control of the discharge of the concrete. Covers meeting the approval of the Engineer shall be provided for protection against the weather.

b) The concrete shall be delivered to the site of the work in a thoroughly mixed and uniform mass and discharged with a satisfactory degree of uniformity. Slump tests of representative samples taken during the discharge shall not differ by more than 50 millimeters. Discharge shall be completed within 30 minutes after introduction of the mixing water to the cement and aggregates.

II. Concrete delivered in outdoor temperatures lower than 4 °C shall arrive at the work having a temperature not less than 15 °C nor greater than 32 °C.

M4.02.11 Storage and Handling of Materials.

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

A. Cement.

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

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

B. Aggregates.

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

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

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

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

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

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

M4.02.12 Cold Weather Concrete.

Concrete mixed or placed when the air temperature is below 5 °C will be considered cold weather concrete and will require special treatment. In general the special treatment is indicated below.

When concrete operations are permitted when the air in the shade and away from artificial heat is 5 °C or lower temperature, the mixing water and/or aggregates may be heated (prior to cement being added) by approved methods so that the temperature of the aggregates and water mixture is not less than 20 °C nor more than 60 °C. The temperature of the concrete shall not be less than 15 °C nor more than 32 °C at the time of placing it in the forms. The heating shall be done in a manner to preclude the occurrence of overheated areas which might result in damage to the materials. Any material containing frost or lumps of hardened material shall not be used.

M4.02.13 Test Specimens.

A. Samples of concrete shall be obtained in accordance with the Standard Method of Sampling Fresh Concrete (AASHTO T 141) in the case of individual samples secured to determine uniformity of consistency for approval of the mixer or agitator. In securing individual samples to determine uniformity of consistency, AASHTO T 141 shall be followed but the requirements shall be so modified as to permit obtaining and testing of each of three samples: one at approximately the beginning, one at approximately the midpoint and one at approximately the end of discharge.

B. For the purpose of making tests to determine the flexural or compressive strength of concrete, the Engineer reserves the right to cast such test beams or cylinders as he/she deems necessary.

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

The specimens shall be protected and cured on the project by the Contractor, without additional compensation, under the direction of the Engineer. After 24 hours specimens taken to insure compliance with minimum strength requirement shall be removed from the mold and imbedded in moist sand or cured by other methods approved by Department's Research and Materials Section for five days with temperatures ranging from 15 °C to 27 °C by the Contractor, without additional compensation, under the direction of the Engineer.

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

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

consistency or air-content falls outside the limits specified, check list shall be made. In the event of a second failure, the Engineer may refuse to permit the use of the load of concrete represented.

D. Methods of testing ready-mixed concrete shall be in accordance with the following methods of the American Association of State Highway and Transportation Officials:

1. Sampling Fresh Concrete (AASHTO T 141).
2. Weight Per Cubic Foot, Yield and Air Content (Gravimetric) of Concrete (AASHTO T 121).
3. Flexural Strength of Concrete (Using Simple Beam with Third Point Loading) (AASHTO T 97).
4. Compressive Strength of Molded Concrete Cylinders (AASHTO T 22).
5. Making and Curing Concrete Compression and Flexure Test Specimens in the Field (AASHTO T 23).
6. Slump Test for Portland Cement Concrete (AASHTO T 119).
7. Air Content of Freshly Mixed Concrete by the Pressure Method (AASHTO T 152).
8. Air Content of Freshly Mixed Concrete by the Volumetric Method (AASHTO T 196).

M4.02.14 Precast Units.

Precast concrete units shall be manufactured of air-entrained 30 MPa - 20 mm - 390 kg cement concrete, true to line, plane and dimensions, in accordance with the following special requirements:

A. Plant Requirements.

The units shall be manufactured in an approved area or enclosed building under the Engineer's control and inspection with guaranteed provision to meet the requirements for curing and protecting the concrete as specified.

The concrete shall be proportioned as specified in M4.02.06 and mixed in accordance with M4.02.10. No delay or shutdown of over 30 minutes duration in continuous filling of individual forms will be allowed. The units shall be cast true to line and dimensions, free from checking, cracking, voids, surface honey combing and without requiring additional rubbing or patching.

B. Forms.

As specified below metal or wood forms of tight, rigid construction, true to shape, and with smooth finish shall be used. Concrete forms may be used if approved by the Engineer. The forms shall be oiled in any approved manner. Re-use of old, worn, or misshapen form, will not be allowed.

Bounds	Wooden or wooden-faced; Metal or metal-faced
Catch Basins & Manholes	Metal or metal-faced
Cribbing	Metal or metal-faced
Curb	Wooden or wooden-faced
Curb corners	Wooden or wooden-faced
Edging	Wooden or wooden-faced
Railings	Wooden or wooden-faced
Posts	Wooden or wooden-faced; Metal or metal-faced
Box Culverts	Metal
Light Foundations	Metal
Median Barrier	Metal
Retaining Walls	Metal
Noise Barrier Panels	Metal
Pull Boxes	Metal
Handholes	Metal

C. Vibration.

Vibrators shall be provided and used as specified in 901.65C and as directed by the Engineer. Prolonged vibration shall be avoided in order to prevent surface finish susceptible to crazing. Units showing surface checking or crazing will be rejected.

D. Protection and Curing.

The units shall be cured either by steam or water for a sufficient length of time for the concrete to obtain the minimum compressive strength.

1. Steam Curing.

Two to four hours after the concrete has been placed and attained the initial set, the first application of steam shall be made. Forms shall be removed after the units have been steam cured for 24 hours.

The steam shall be at 100% relative humidity to provide moisture for proper hydration of cement. The steam shall be directly applied onto the concrete. During application of steam the ambient temperature shall increase at the rate not to exceed 22 C° per hour until a minimum temperature of 55 °C is reached.

When discontinuing the steam application, the ambient temperature shall be decreased at the rate of 22 C° per hour until a temperature of 11 C° above the atmospheric temperature has been attained. The concrete shall not be exposed to temperatures below freezing for a minimum of 6 days after casting.

2. Water Curing.

The units may be water cured with water, saturated material or other acceptable or approved methods that will keep the units moist for a period of 5 days. Under no condition will the use of curing compounds be permitted.

Concrete delivered in outside temperatures lower than 4 °C shall arrive at work having a temperature not less than 15 °C nor greater than 32 °C. Water and aggregates shall be heated if necessary but the water shall not be heated above 60 °C The use of direct heating torch in mixer shall not be approved.

3. Protective Coating.

A protective coating approved by the Engineer shall be used on Curb, Curb Corners, Edging, Railings and Posts.

After the concrete is at least 14 days old and thoroughly dry, the surface shall be cleaned to remove all oil, grime and loose particles which would prevent the protective compound from penetrating the concrete. Immediately before the application of the compound an air blast shall be directed over the surface to be treated so that all dust will be removed and then treated as follows:

The rate and number of applications for each unit shall be in accordance with the manufacturer's recommendations.

After curing a minimum of 14 days, the outside surface of the tapered or cone section of pre-cast cement concrete catch basins shall be dried, cleaned and given a protective coating of Koppers Bitumastic Super Service Black, or equal.

E. Finish and Color.

Edging curb corners, precast fence rails and similar units shall be rub finished in the following manner:

After the concrete has properly hardened, the exposed surfaces shall be rubbed with a No. 16 carborundum stone or an abrasive of approved equal in a manner to fully remove cement enamel finish and expose a durable sand grain finish satisfactory to the Engineer. No cement shall be used in the rubbing process.

The color and finish of these units shall be uniform and shall conform to those of adjacent work in their final position.

F. Testing and Sampling.

Representative test specimens of the concrete shall be taken by the Engineer. No precast units will be shipped to a project until the test specimens cured as required in M4.02.13 show a compressive strength of 30 megaPascals.

G. Inspection.

All precast units shall be subject to inspection at the point of manufacture and on the project and any units showing defects or damage before the completion of the project shall be removed and replaced at the expense of the Contractor.

H. Quality Control.

The Contractor shall provide quality control in the form of personnel, equipment and laboratory and office space.

1. Personnel:

There shall be sufficient personnel trained and licensed to perform the tests listed under M4.02.13, Part D.

2. Equipment:

Air Content Meter Type A or B (AASHTO T 152)
Air Content Meter Volumetric Method (AASHTO T 196)
Slump Cone (AASHTO T 119)
Cylinder Molds (AASHTO T 205)
Concrete Testing Machine (AASHTO T 22)
Screening Sieve (AASHTO T 27, T 11)
Curing Box (AASHTO T 23)
And other necessary items such as ovens, scales, hot plates, pans, etc., to perform tests.
Portable Temperature Recorders

3. Laboratory:

The laboratory will be a room of sufficient size to house all equipment and to adequately perform all these tests. The room shall have either a separate moisture storage room or curing box for concrete cylinders and it shall be thermostatically controlled to maintain 23 °C. The laboratory room shall be heated and air conditioned to maintain 23 °C. It shall include a deck and file cabinet for proper record keeping, and have good lighting and ventilation. This room shall be kept for testing and quality control and not used for any other purpose. Additional space in the form of a desk and file cabinet shall be provided for the exclusive use of the Engineer.

No exception from these requirements will be allowed without the expressed written permission of the Engineer.

M4.02.15 Cement Mortar.

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

M4.03.00 Prestressed Concrete Beams.

This work consists of fabricating pretensioned bonded prestressed concrete deck beams and I beams in accordance with the plans and these specifications.

The Contractor shall order all materials and services for this work immediately after execution of the Contract.

The work under this Section shall conform to the relevant requirements of the current AASHTO Standard Specifications for Highway Bridges, and shall be supplemented by the relevant provisions of "The Manual for Quality Control for Plants and Production of Precast and Prestressed Concrete Products," Prestressed Concrete Institute Publication Number MNL-116-85, except as noted herein.

The angle at the ends of the beam shall be determined from the skew angle of the bridge which is shown on the construction plans. This angle will also determine the placing of the sleeves for the transverse cables. All exterior deck beams shall be cast to show the year in the center of the beam in the center of the coping unless otherwise specified in the Special Provisions or shown on the plans. The numerals shall be
125 millimeters high of a style and type furnished by the Engineer.

The Contractor shall properly identify each beam giving the bridge number and the type of beam
(Type A, B, or C).

M4.03.01 Drawings.

Detailed working or shop drawings will be required in accordance with the pertinent provisions of Subsection 5.02. The shop drawings shall show the number and type of beams; location and spacing of strands and tensioning load to be applied per strand; span length from centerline to centerline of anchor rods; total length of beams; skew angle; and locations, type and size of sleeves and inserts; location, type and size of handling hooks, steel

reinforcement and all other information required for proper fabrication and handling of the beams.

When prestressed concrete beams are used to support screed rails for mechanical finishing of bridge decks, the Contractor shall submit for approval his/her method of incorporating this support into the prestressed concrete beam before fabrication of the beam has begun.

After the shop drawings have been approved, the Contractor shall give the Inspection Agency a minimum two weeks notice prior to the commencement of fabrication.

M4.03.02 Quality Control.

The Contractor shall be responsible for any failure to cast the beams to the correct dimensions or for any other omissions or inaccuracies in his/her work. If the Engineer determines that proper corrections cannot be made, the beams will be rejected and replaced with new beams at the Contractor's expense.

Satisfactory proof shall be given to the Department that the fabricator of the prestressed concrete beams is capable of and has the organization and plant for performing the work involved in fabricating the beams.

The quality of all materials, the process of manufacture, and the finished sections shall be subject to inspection and approval by the Engineer. Such inspection may be made at the place of manufacture, or on the work site after delivery, or at both places. Sections rejected after delivery shall be marked for identification and shall be removed from the site at once. The Department shall be notified three days prior to the shipment from the fabrication shop so that a representative may be present during the loading operations.

All sections which have been damaged after delivery will be rejected or, if already installed, shall be repaired or removed and replaced entirely at the Contractor's expense as may be directed by the Engineer.

All sections shall be inspected for general appearance, dimensions, and soundness. The surface shall be dense, close textured, and free of blisters, cracks, roughness, and exposure of reinforcement.

Minor imperfections may be repaired, subject to the approval of the Engineer, after demonstration by the manufacturer that strong and permanent repairs result. Repairs shall be carefully inspected before final approval. Cement mortar used for repairs shall have a minimum compressive strength of 30 MPa at the end of 7 days and 45 MPa at the end of 28 days when tested in 50 millimeter cubes stored in the standard manner. Epoxy mortar may be utilized for repairs, subject to the approval of the Engineer.

The Contractor shall provide quality control in the form of personnel, equipment, and laboratory and office space in accordance with section M4.02.14H.

MATERIALS

M4.03.03 Concrete.

Concrete for the bonded prestressed concrete beams shall be made in accordance with the pertinent provisions of M4.02.00 supplemented by the following:

Prestressed concrete beams shall be made in a plant with approved facilities and equipment for prestressing and ready for immediate production. Special plant supervision and control will be required to meet the precision standards for quality and workmanship.

The beams shall be cast with Type I or II Portland cement, or Type III high-early strength cement may be used at the Contractor's option and expense. The air content of the concrete by volume shall be 5-1/2% with a tolerance of plus or minus 1%.

M4.03.04 Aggregates.

The aggregate shall be fully drained, free from excess entrapped water in voids, to a uniform moisture content of plus or minus 1% in the fine aggregate and 1/2% in the coarse aggregate. The standard organic color test of the sand shall be minus plate 2.

The aggregate shall meet the requirements of M4.02.02. Crushed stone or gravel with a maximum Los Angeles abrasion of 30% shall be used.

M4.03.05 Steel.

Reinforcing Steel shall conform to the requirements of M8.01.0 and shall be epoxy coated in accordance with M8.01.7.

Structural steel for prestressed concrete beams, including anchor plates, shall conform to AASHTO M 270 Grade 250 unless otherwise shown on the plans, and the relevant provisions of Section M8. Other steel not actually attached to the beams, such as bed plates, pipe supports, bolts, nuts and washers, is not included under "Prestressed Concrete Beams".

M4.03.06 Pretensioning Strands.

Pretensioning Strands shall be uncoated, seven-wire, low-relaxation Grade 270 strands conforming to the requirements of AASHTO M 203.

Strand diameter shall be 13 millimeters unless otherwise specified on the plans.

The approval of the Engineer is required if the Contractor desires to use strands of larger diameter.

Where required, strands shall be debonded for the length specified by a wrapped plastic sheath taped to the strand. Other methods of debonding strands such as greasing, chemical retarders and taping alone will not be allowed.

CONSTRUCTION METHODS

M4.03.07 Forms.

The side forms shall be of metal of approved design and construction to meet rigid conformance to line, dimension, design, workmanship, and finish. Any defects or damage of more than minor nature due to form work, stripping or handling shall be cause for rejections. Forms shall be so designed that they will not restrict the longitudinal movement of the casting when the prestressing force is transferred to the casting.

Tubes for forming the voids in the concrete deck beams shall be fabricated of material sufficiently strong and resistant to water to carry the wet concrete, which is to be packed around the tubes, without collapsing. The tubes shall be capped at both ends to exclude concrete from entering the tubes. The tubes shall be securely anchored so that no movement will occur during placing and consolidation of the concrete.

M4.03.08 Placing Tension Strands.

Prestressing strands shall be accurately placed in position and tensioned before the concrete is placed. Care shall be exercised to keep the strands clean of form oil and other substances harmful to the bond.

Each strand shall be tensioned to the percentage of the Manufacturer's rated ultimate strength as specified in the AASHTO Standard Specifications for Highway Bridges for the type of strand used and the tension held until the concrete has attained the minimum required strength for prestressing.

The strands shall be tensioned in the casting bed by holding the tension with end anchorages until the concrete is cast and hardened, and then releasing the tension gradually by an approved method. Each strand shall be finally burned or cut off at a depth of 15 millimeters into the end of the beam and the recessed area around the strand shall be filled with cement mortar, as designated in Subsection M4.02.15.

When two or more strands are tensioned simultaneously, means as approved by the Engineer shall be provided to obtain equal tension in each strand as may be practicable.

Jacks for tensioning shall be of approved design and shall be equipped with gauges for determining the tensioning load. The accuracy of the gauge shall be checked when and as directed by placing a recently calibrated dynamometer in the line. A further check of the tension shall be made by measuring the actual elongation against the elongation figured from the modulus of elasticity of the element. Suitable allowance shall be made in the tensioning for anchorage efficiency as determined by test.

M4.03.09 Draped Pretensioned Strands.

Draped pretensioned strands may be tensioned partially by jacking at the end of the bed and partially by uplifting or depressing strands or they may be tensioned entirely by jacking with the strands being held in their draped positions by means of rollers or pins or other approved methods during the jacking operation.

Whatever means is used, low friction devices must be used at all points of change in slope of strand trajectory at the time of tensioning.

The tension for draped strands applied by jacking is done in essentially the same manner and must conform to the same requirements as the tensioning for straight strand, unless otherwise noted.

If draped strands are tensioned in their draped position, they should be supported by lubricated rollers with bronze bushings or roller bearings at all hold-up points and low friction free turning rollers at all hold-down points.

A recommended procedure for tensioning draped strands in the deflected trajectory by single strand jacking is as follows:

1. Applying initial tensioning load to strand.
2. Mark the strand for elongation measurement.
3. Apply the full tension load as determined by the jack gauge, not by elongation.
4. Measure elongation and determine the remaining elongation required for full tension based on computed elongation.
5. Jack the strand from the other end to remaining required elongation and note the load measured by the jack gauge. The actual gauge reading will probably be in excess of the theoretical gauge reading but should not exceed it by more than 5%.

Single strand tensioning of strands in the draped position by jacking the strands from only one end is permissible provided the required strand elongation is obtained without the jack gauge pressures exceeding the theoretical by more than 5%.

When strands are deflected after partial tensioning, the strands must be raised or depressed exactly the correct distances and they should be deflected simultaneously at all points or in an approved specific sequence. Disregard of these requirements could result in incorrect strand tension and put stress distribution along the strand.

The lengths of the strands to be used in calculating elongations should be the actual length of the strand along its trajectory between the fixed anchorage and the reference point at the jacking end of the strand.

It is imperative that the actual dimensions of the bed layout and locations of hold-up and hold-down points agree with the dimensions shown on the approved working drawings.

Up-lift and hold-down devices must be attached in such a manner as to maintain the specified center-to-center spacing of strands in both the vertical and the horizontal directions.

Provisions should be made for a minimum of 25 millimeters of concrete cover on all metal parts of the hold-down devices remaining within the beams. Use of approved fiber sleeves for the hold-down bolts is satisfactory.

M4.03.10 Mix Design.

Unless otherwise specified on the Plans the concrete mix shall be designed to produce a minimum 28 day strength of 45 MPa. The job-mix design shall be submitted by the fabricator and approved by the Engineer. No job-mix design will be approved with a cement content less than 385 kilograms. The use of additives will be at the option of the fabricator with approval of the Engineer.

M4.03.11 Slump.

The Engineer shall specify the consistency of the mix to have a minimum slump so as to place the stiffest mix practical without excessive vibration, free from segregation and voids. The Contractor shall control the slump, as directed, uniformly within a tolerance specified in M4.02.06.

M4.03.12 Mixing, Placing and Curing Concrete.

The concrete shall be proportioned as specified in M4.02.06 and mixed in accordance with M4.02.10.

No delay or shutdown of over 30 minutes duration in continuous filling of individual forms will be allowed.

The forms shall be cleaned and properly oiled, and the mix shall be carefully placed without excess vibration to avoid segregation or displacement of reinforcing or forms. The surface shall be cured during the initial setting period to avoid shrinkage cracking. The beams shall be cast true to line and dimensions, free from checking, cracking, voids and surface honeycomb without requiring additional rubbing or patching.

The top surface of pretensioned butted deck beams and box beams shall be screeded to a smooth surface except where concrete is to be placed over the top surface, in which case the surface shall be rough. The top surface of all prestressed I beams, bulb tees, and spread deck and box beams shall be rough. Recesses shall be provided where the handling hooks enter the concrete surface of the beams. The recesses shall be 50 millimeters greater in diameter of the bar or strand, and 25 millimeters deep. For purpose of definition the following is provided:

Rough = Raked to a minimum 6 millimeters amplitude in any direction (intended for concrete to concrete secondary casting).

Smooth = A float finish with maximum amplitude of 3 millimeters at ridges (intended for application of membrane waterproofing).

Sleeves and galvanized steel or cast inserts shall be placed in the beams as shown on the plans. They shall be carefully located and securely fastened to the forms to prevent displacement. Sleeves or inserts not properly placed may be cause for rejection of the beams.

Curing.

The beams shall be cured at a minimum temperature of 21 °C and minimum humidity of 95% for the minimum curing period necessary to produce the minimum cylinder strength as specified on the plans transferring prestress. A longer period of curing shall be required if curing test specimens fail to meet the minimum compressive strength. Steam curing may be permitted under the Engineer's direction and approval as specified in M4.02.14D.

M4.03.13 Test Requirements.

Unless another concrete strength is specified on the Plans, standard comparison test specimens of concrete shall meet a minimum strength requirement of 45 MPa as follows:

Concrete made with:	
Type I or II Cement	28 Days
Type III Cement	7 Days

Three representative test cylinders shall be made for each day's pour and they shall be cured under standard job conditions (AASHTO T 23). Failure of any test specimen to meet 90% of minimum strength, or failure of average to meet the full minimum strength requirement, shall be cause for rejection of all beams poured that day.

M4.03.14 Transferring Tension to Concrete.

In pretensioning, after the concrete has developed the required strength the tension in the strands shall be transferred to the concrete gradually. This may be done by a system of jacking or by burning or cutting the strands. If the latter method is used, the strands shall be cut by burning, and the number of strands cut at a time shall be such that the stress in the remaining strands will not reach the ultimate-strength of the strands after due allowance has been made for the friction in the bed. They shall be cut or burned between each pair of beams in the casting bed so that all of the tension in these strands is transferred to the concrete before other strands are cut or burned.

A symmetrical pattern shall be followed in releasing the tension by this method. In order for release of the

strands to occur gradually they should not be quickly cut, but should be heated until the metal gradually loses its strength.

Draped pretensioned strands should be detensioned in accordance with the following:

A. Unless the total load of the precast concrete member is as much as twice the total of the forces required to hold the strands in the low position within the member, or unless the members are loaded or restrained in an approved manner to resist the uplifting forces on the member at the hold-down points, the following sequence should be followed for detensioning:

1. Release the tensions in the draped strands at the ends of the members by heating each strand until it fails. The draped strands should be heated to failure at each up-lifted point in accordance with an approved sequence as shown on the working drawings.
2. All hold-down devices for the draped strands should be released and the hold-down bolts within the members removed.
3. If any straight pretensioned strands are located within the members, they should be detensioned after the draped strands have been detensioned. Straight strands shall be detensioned by releasing the tension in these strands gradually and uniformly.

B. When the total load of the precast concrete member is more than twice the total of the forces required to hold the deflected strand in the low position within the member, the following sequence may be used, at the fabricator's option, for detensioning the prestressed strands:

1. Hold-down devices for the deflected strands may be released and the hold-down bolts within the members removed.
2. Deflected strands and straight strands may be detensioned by releasing the tension in the strands gradually and uniformly.

When the total load of the member is less than twice the total of the hold-down forces, loads or approved vertical restraint may be applied to the member in order to counteract the uplifting forces at the hold-down points when hold-down devices are released.

The load or approved vertical restraint added to the member should be placed directly over the hold-down points for the deflected strands. When the total of the load of the member plus the added loads or restraint is more than twice the hold-down forces, the strand-detensioning method of releasing hold-down devices before strand tension may be followed.

It is very important that the procedures for transfer of prestressing forces to members with deflected pretensioned strands are followed. Disregarding the procedures for transferring the forces to the members will probably result in unacceptable members.

M4.04.0 Mortar for Prestressed Concrete Deck Beams.

The mortar shall conform to the following specification:

General.

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

Materials.

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

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

pH	4.5 - 6.5
Minimum film forming temperature	Approx. 20 °C
Tear strength	Approx. 7 MPa - 10 MPa
Elongation of break	500-900%
Particle size range	Less than 0.1 micrometer

b) Component B shall be a blend of a selected Portland Cement, specially graded aggregates, organic accelerator, and admixtures for controlling setting time, water reducers for workability and a corrosion inhibiter.

c) The component ratio A:B shall be 1:7.2 by mass. The system shall not contain chlorides, nitrates, added gypsum, added lime, or high alumna cements. The system shall be non-combustible, either before or after cure.

Typical Properties of Mixed Components:

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

Typical Properties of Cured System:

a)	Abrasion Resistance		6 times greater than Control
b)	Bond Strength (Pulloff method)		100% concrete substrate failure.
c)	Modulus of Elasticity		31 000 MPa
d)	Surface Scaling (De-icing salt freeze/thaw)		No deterioration after 120 cycles
e)	Compressive Strength	(4 hours 50% RH)	690 kPa minimum
f)	Compressive Strength	(28 days 50% RH)	36.6 MPa minimum
g)	Flexural Strength (28 days 50% RH)		8.3 MPa minimum

h) System shall conform to EPA/USPHS Standards for surface contact with potable water.

i) The system shall not produce a vapor barrier.

j) The system shall be thoroughly compatible with concrete.

M4.05.0 Cement Concrete Brick.

Cement concrete brick shall be machine made solid segments conforming to the requirements of ASTM C 139, except that the minimum average compressive strength for five (5) representative bricks shall be 20 MPa. The minimum compressive strength for one individual brick shall be 17.5 MPa. Dimensional requirements shall be the same as for Clay Brick M4.05.2.

M4.05.1 Cement Concrete Blocks.

Cement concrete blocks shall be machine made solid segments, conforming to the requirements for Concrete Masonry Units for Construction of Catch Basins and Manholes, ASTM C 139, supplemented by the following requirements:

The blocks shall be 150 millimeters in width for basins and manholes of 2.7 meters or less in depth, 200 millimeters in width below a depth of 2.7 meters when used in structures having a depth greater than 2.7 meters.

The permissible dimensional variation for nominal size shall be in accordance with ASTM C 139. The inside and outside surfaces of the blocks shall be carved to the necessary radius and so designed that the interior surfaces of the structures shall be cylindrical, except the top batter courses which shall be designed to reduce uniformly the inside section of the structure to the required top size and shape. The blocks used in the top courses shall be designed to produce a surface 200 millimeters in width upon which to seat the frame, and the curb inlet when one is used. Blocks shall be so designed that only full length units are required to lay any one course.

Blocks shall be sampled and tested in accordance with ASTM C 140. The minimum average compressive strength for 5 representative blocks shall be 20 MPa. The minimum compressive strength for one individual block shall be 17.5 MPa.

M4.05.2 Clay Brick.

Clay brick shall conform to the requirements of AASHTO M 91 with the following exceptions:
The size of brick furnished shall be 197 millimeters long x 95 millimeters wide x 57 millimeters deep.
All dimensions shall be nominal.
The average of the absorption of 5 representative samples shall not exceed 15% and the individual absorption of any one sample shall not exceed 17-1/2%. The average compressive strength of 5 representative samples shall not be less than 20 MPa and the compressive strength of any one sample shall not be less than 17.5 MPa.

M4.05.3 Precast Concrete Block for Slope Paving.

Precast blocks shall be solid segments, conforming to requirements for Concrete Masonry Units for Construction of Catch Basins and Manholes, ASTM C 139, supplemented by the following requirements:
The thickness shall be 100 millimeters. The width shall be 300 millimeters and the length 400 millimeters. Blocks shall be sampled and tested in accordance with ASTM C 140. Dimensional tolerances shall be in accordance with ASTM C 139.

M4.05.4 Sidewalk Brick.

Sidewalk brick shall conform to the requirements of ASTM C 902 except that the absorption shall be 5% maximum when subjected to 5 hours of submersion in boiling water.

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

This specification covers two-component, epoxy-resin bonding systems for application to Portland cement concrete. The material shall meet ASTM C 881. The Type, Grade and Class shall be specified for each individual application.

Types:
Type I For use in bonding hardened concrete and to other materials to hardened concrete.
Type II For use in bonding fresh mixed concrete to hardened concrete.
Type III For use in bonding skid-resistant materials to hardened concrete, and as a binder in epoxy mortars or epoxy concretes.

Grades:
Grade 1 Low viscosity
Grade 2 Medium viscosity
Grade 3 Non-sagging consistency

Classes:
Class A For use below 4 °C
Class B For use between 4 °C and 15 °C
Class C For use above 15 °C

M4.07.0 Latex Modified Mortar and Concrete Overlayments.

DESCRIPTION

This work shall consist of furnishing and constructing a one course protective wearing surface of latex Portland cement mortar or concrete on the prepared surface of concrete bridge decks.

MATERIALS

The materials used in producing latex modified mortar or concrete shall meet the applicable requirements of Section M4 of the Standard Specifications for Highways and Bridges and as described herein.

A. Portland cement shall be non-air entraining cement of recent manufacture, free of lumps and conform to the requirements of AASHTO M 85, Type I or Type II.

B. Aggregates shall meet the requirements of M4.02.02A. Maximum nominal size of coarse aggregate shall not be larger than 19.0 millimeters and in no case greater than one half the thickness of section to be placed.

C. Water shall meet the requirements of M4.02.4.

D. Latex Emulsion Admixture-Formulated latex admixture shall be a non-hazardous, film forming polymeric emulsion in water to which all stabilizers have been added at the point of manufacture and shall be homogeneous and uniform in composition. The latex shall be a styrene butadiene latex emulsion that has been approved for use in latex modified concretes/mortars by the FHWA using procedures covering by FHWA-RD-78-35. The latex supplier shall provide certification that each lot of material meets the requirements of the certification program in FHWA-RD-78-35.

Note: Air-entraining admixtures will *not* be used.

Mix Design:

	Latex Modified Mortar	Latex Modified Concrete
Average Thickness, millimeters	25	31+
Cement, kilograms/cubic meter	448	392
Latex Emulsion Admixture, liters/kilogram	0.31	0.31
*Water, liters/kilogram	0.22	0.22
Air content, % of plastic mix (AASHTO T 152)	0-9	0 - 6.5
**Slump, millimeters	100 - 150	100 - 150
***Mass ratio of cement:		
fine coarse aggregates (dry basis agg. spg. = 2.65)	1:3.25	1:2.5:2.0
Strength (28 days) megaPascals	30 minimum	30 minimum

*The net water added shall be adjusted to control the slump within the prescribed limits and to produce a water-cement ratio of 0.35-0.40.

**The slump shall be measured 4 to 5 minutes after discharge from the mixer. During this waiting period, it shall be deposited on the deck and not be disturbed. Care shall be exercised that traffic vibrations do not affect the measurement.

***The dry mass ratios are approximate and should produce accurate yield and good workability but due to gradation changes and/or variable specific gravity may be adjusted within limits by the Engineer. A maximum adjustment of ±20% may be made in aggregate mass.

EQUIPMENT

All equipment for the deck preparation, mixing, placing and finishing of latex modified mortar or concrete shall be approved by the Engineer prior to start of any work.

A. Surface preparation equipment shall be of the following types:

1. Blast cleaning equipment capable of removing hardened curing compound, laitance dust layer or any other contaminates detrimental to achieving bond and also capable of removing rust from reinforcing bars and removing small chips of concrete partially loosened by a scarifying or chipping operation.

2. Sawing equipment capable of sawing concrete to the specified depth.

3. Power-operated mechanical scarifier capable of removing not less than 6 millimeters from old surface.

4. Power driven hand tools for removal of unsound concrete subject to the following restrictions:

a) Pneumatic hammers heavier than nominal 14 kilogram class shall not be used, unless approved by the Engineer. No hammers heavier than 27 kilograms shall be used in any case.

b) Triple-headed tampers fitted with star drills shall not be less than 50 millimeters diameter in the tamper sockets.

B. Proportioning and mixing equipment shall be self-contained, mobile, continuous mixing subject to the following:

1. The mixer shall be self-propelled and be capable of carrying sufficient unmixed dry bulk cement, aggregates, latex modifier, and water to produce on the site not less than 4.5 cubic meters of concrete.

2. The mixer shall be capable of positive measurement of cement being introduced into mix. A recording meter visible at all times and equipped with a ticket printout shall indicate this quantity.

3. Mixers shall be calibrated to accurately proportion the specified mix at 75 cubic meter intervals. Certification of the calibration by approved testing authority will be accepted as evidence of this accuracy if the yield is shown to be true within a tolerance of 1.0% according to the following test:

With the cement meter set on zero and all controls set for the desired mix, activate the mixer, discharging mixed material into a one quarter cubic meter container (1 meter x 1 meter x 250 millimeters) and when the container is level-struck full, making provision for settling the material into all corners, the cement meter must show a discharge of 96 kilograms of cement for modified concrete, (385 kilograms/cubic meter).

4. The mixer shall provide positive control of the flow of water and polymeric emulsion into the mixing chamber. Water flow shall be indicated by flow meter and be readily adjustable to provide minor variations in aggregate moisture.

5. The mixer shall be capable of being calibrated to automatically proportion and blend all components of the indicated composition on a continuous or intermittent basis as required by the finishing operation. It shall discharge mixed material through a conventional chute directly in front of the finishing machine.

6. The mixer shall be capable of spraying water over the entire placement width as it moves ahead to insure that the surface to be overlaid is damp prior to receiving the modified material.

C. Mixing and Delivery Control: Cement and aggregates shall be proportioned, measured and batched by a volumetric mass equivalent method. In operation, the entire measuring and batching mechanism must produce the specified proportions of each ingredient. Tolerance in proportioning the various ingredients shall be as follows:

Cement, mass	0 to + 4%
Aggregates, mass	± 4%
Water, mass or volume	± 1%
Latex, mass or volume	± 2%

The tolerances are based on a mass/volume relationship established during the calibration or by the measuring devices.

During mixing, the drive shaft speed as indicated by the tachometer shall be maintained at operation speed ±50 rpms. The auger mixer angle shall be set in the range determined by the manufacturer. The interval between the continuous placing of succeeding batches shall not exceed 30 minutes.

D. Placing and Finishing Equipment shall include hand tools for placement and brushing-in freshly mixed latex modified material and for distributing it to approximately the correct level for striking off with the screed.

An approved finishing machine complying with the following requirements shall be used for finishing the work:

The finishing machine shall be self-propelled and capable of forward and reverse movement under positive control. Provisions shall be made for raising all screeds to clear the screeded surface for traveling in reverse.

A rotating cylinder type self-propelled finishing machine with one or more rotating rollers, augers, and vibratory pans may be used.

Any modifications shall be subject to approval by the Engineer.

Travel rails for the machine shall be 50 millimeter x 50 millimeter perforated steel bar stock,

50 millimeter pipe rail or approved equal.

One or more suitable portable lightweight or wheeled work bridges shall be required and used behind the finishing operation for touch-up work, surface texturing and curing cover pavement.

CONSTRUCTION METHODS

A. Preparing the surface.

1. For new construction:

Newly constructed concrete bridge decks shall be cured a minimum of 14 days before placement of the latex modified concrete wearing surface.

Within 24 hours prior to applying the latex modified concrete overlayment, the concrete surface to be covered shall be thoroughly blast cleaned. This operation shall remove all hardened curing compound and/or laitance layer and shall expose the concrete aggregate. The edge of previously placed lanes shall be similarly treated to promote bond. The surface shall be thoroughly cleared of all debris created by this operation and then pressure flushed with clean water. Immediately prior to placement of the latex cement composition, the clean surface shall be thoroughly wetted for a period of not less than one hour. Any standing water shall be blown clear before the placement is made.

2. For Repair or Deck Restoration:

Prior to applying the latex modified concrete overlayment, the concrete surface to be covered shall be machine scarified to the depth shown on the plans. In areas where scarifying cannot reach, in areas of deep spalling and where steel reinforcement is exposed, deteriorated concrete will be removed to sound material by chipping and by use of hand tools.

Forty-eight hours of good curing shall have elapsed prior to scarifying or chipping on adjacent concrete within 2 meters of latex modified concrete.

Area from which unsound concrete and epoxy patches have been removed shall be kept free of slurry produced by wet sawing or wet scarifying by planning the work so that this slurry will drain away from the complete areas of preparation. All such slurry shall be removed from prepared areas before resurfacing. Before placement begins, and within 24 hours, the entire surface shall be thoroughly cleaned by blasting. The edge of previously placed lanes of overlayment shall be blasted to remove the trowel cut surfacing and promote bond. If necessary, to remove rust, oil and other foreign materials detrimental to achieving bond, detergent cleaning followed by sandblasting and air blast cleaning will be required. Immediately prior to placement of latex modified concrete, the clean surface shall be thoroughly wetted for a period of not less than one hour. Any standing water in depressions, holes or areas of concrete removal shall be blown out with compressed air.

All corroded reinforcing bars shall be thoroughly cleaned by blasting. Those bars that have lost 1/4 or more of their original diameter shall be supplemented by new bars spliced in place. In splicing new bars they shall be lapped sufficiently to develop the full strength of the bar and, if necessary additional chipping will be required to provide for this lap. Dual bars of equivalent or greater section may be used. Where the bond between existing concrete and reinforcing steel has been destroyed, or where more than half the diameter of the steel is exposed, the concrete adjacent to the bar shall be removed to a depth that will permit modified concrete to bond to the entire periphery of the bar exposed. A minimum of 19 millimeters clearance shall be required except where lower bar mats makes this impractical. Care shall be exercised to prevent cutting, stretching or damaging any exposed reinforcing steel. Any exposed old copper waterstop shall be removed to the limits designated by the Engineer.

B. Proportioning and Mixing of Latex Modified Concrete:

The operations of proportioning and mixing latex cement materials shall comply with the following requirements:

Mixers shall be clean and the ingredients accurately proportioned.

Latex Modified Concrete shall be mixed at the site in accordance with the specified requirements for the equipment used. The latex modified concrete as discharged from the mixer shall be uniform in composition and consistency. Mixing capability shall be such that finishing operations can proceed at a steady pace with final finishing completed before the formation of the plastic surface film.

C. Placing and Finishing.

Existing expansion joints and dams shall be raised prior to placing overlayment.

A bulkhead shall be installed to the required grade and profile prior to placing latex cement material. Joint filler and STYROFOAM (trademark of Dow Chemical Company) or equal brand plastic foam may be used but casting full across the joint and later sawing will not be allowed.

Travel rails shall be placed and fastened in position to insure finishing at the new surface to the required profile. Anchorage for supporting rails shall provide horizontal and vertical stability.

All surfaces shall be completely cleaned as approved by the Engineer prior to placing mixtures.

The latex cement mix shall be brushed onto the wetted, prepared surface. Care shall be exercised to insure that all vertical as well as horizontal surfaces receive a thorough, even coating and that the rate of the progress is limited so that the brushed material does not become dry before it is covered with additional material as required for the final grade. Material used for brushing which has had the mortar used up shall be disposed.

The mixture shall be placed and struck-off to approximately 6 millimeters above final grade. It shall then be consolidated and finished at final grade with the vibrating devices. Spud vibration will be required at edges and adjacent to joint bulkheads. Hand finishing with a float may be required along the edge of the pour. Edge tooling is required at joints, except next to metal expansion dams, curbs, and previously placed lanes.

When a tight uniform surface has been achieved it shall be textured to provide a relatively skid resistant surface. Texturing shall be done by use of wire rake before the plastic film forms on the surface. The wire rake shall have flexible tines approximately 13 millimeters on center and will be subject to the approval of the Engineer.

Screed rails and/or construction bulkheads shall be separated from the newly placed material by passing a pointing trowel along their inside face. Metal expansion dams shall not be separated from the overlayment. Care shall be exercised to insure that this trowel cut is made for the entire depth and length of rails after the mixture has stiffened sufficiently.

The surface shall be promptly covered with a single layer of clean, wet burlap as soon as the surface will support it without deformation.

Immediately following covering with wet burlap, a layer or polyethylene film (minimum 10 micrometers) shall be placed on the wet burlap and the surface cured for 24 hours. The curing material shall then be removed for an additional 72 hours air cure. Wet burlap-polyethylene sheets may be substituted for the polyethylene film with the approval of the Engineer, but shall not replace the initial wet burlap.

Limitation of Operations:

No vehicular traffic shall be permitted on the latex cement composition until at least 5 days after placement.

No latex cement composition shall be placed at temperatures lower than 7 °C. They may be placed at 7 °C and rising.

At temperatures below 13 °C, the Engineer will require a longer curing period and compliance with applicable sections of the Standard Specifications for curing bridge deck concrete during cold weather.

At temperatures above 30 °C, the Engineer may require placement to be made at night or early morning hours, if in his/her opinion a satisfactory placement is not being achieved.

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

Adequate precautions shall be taken to protect freshly placed material from sudden or unexpected rain. All placing operations shall stop when it starts to rain. The Engineer may order removal of any material damaged by rainfall.

Application of Live Loads:

Truck mixers and other heavy equipment shall not be permitted on the latex modified concrete overlay, nor the traveling public until authorized by the Engineer. Such authorization may only be given after the prescribed curing period has taken place, after the last concrete has been placed, and provided the concrete in the deck has attained a minimum strength of 25 MPa. Specimens shall be cured in the same manner as the deck.

M4.08.0 Controlled Density Fill.

Controlled Density Fill (CDF) material is a flowable, self consolidating, rigid setting, low density material that can substitute for compacted gravel for backfills, fills and structural fills. There are two main categories of CDF's, excavatable and non-excavatable with a subcategory of flowable and very flowable. It shall be a mixture of portland cement, flyash (if very flowable), sand, and water designed to provide strengths within the range specified.

The categories of CDF's are:

Type 1	Very Flowable (Non-Excavatable)
Type 1E	Very Flowable (Excavatable)
Type 2	Flowable (Non-Excavatable)
Type 2E	Flowable (Excavatable)

The Very Flowable mixes (Type 1 and 1E) shall contain a minimum of 115 kilograms of Class F Fly Ash or high air (25% plus) and will be self leveling.

Excavatable mixes (Type 1E and 2E) shall be hand tool excavatable.

Type 1 mixes are intended for permanent installations such as structural fills under structures. It has very flowable characteristics needed for distances and small areas. This type of mix should not be used as a bedding material. It is used to fill small hard-to-reach areas.

Type 1E mixes are excavatable material designed to have very flowable characteristics needed for filling small or far areas that later may need to be removed.

Type 2 mixes are used in areas where size and distance do not need the very flowable characteristic. It is intended for permanent installations such as thick fills under structures.

Type 2E mixes are excavatable mixes where size and distance of the installation do not require the flowable characteristics of a Type 1E mix.

CDF is to be batched at a ready mix plant and is to used at a high or very high slump of approximately 250 millimeters to 300 millimeters. It shall be flowable, require no vibration and after it has been placed can, for Types 1E and 2E, be excavatable by hand tools and/or small machines.

The ingredients shall comply with the following:

Portland Cement	AASHTO M 85
Fly Ash	AASHTO M 295 Class F
Sand	M4.02.02
Air entraining admixtures	M4.02.05

Note 1. In lieu of the slump test, a 150 millimeter long, 75 millimeter diameter tube may be filled to the top and then slowly raised. The diameter of the resulting "pancake" may be measured and the range of the diameter shall be 230 millimeters to 360 millimeters.

Note 2. The maximum strength for structural flowable fills may be expressed in increments of 5 MPa's and will depend on the Engineer's requirements.

Note 3. High air (25% plus) may be used instead of fly ash with an adjustment in sand content.

The following Type 1E mix design is for information only, the actual mix designs submitted by the ready mix operator, in accordance with standard Department practice, must be confirmed by trial batches.

Cement	23 kilograms
Fly Ash	115 kilograms
Sand	1225 kilograms
Water	225 liters

The following Type 1 mix design is for information only, the actual mix designs submitted by the ready mix

operator, in accordance with standard Department practice, must be confirmed by trial batches.

Cement	45 kilograms
Fly Ash	115 kilograms
Sand	1200 kilograms
Water	225 liters

Various types of controlled density fill must meet the requirements set forth in the table below:

Controlled Density Fill	Type 1 & 2	Type 1E & 2E
Compressive Strength @ 28 days	210 - 1030 kPa	210 - 550 kPa*
Compressive Strength @ 90 days	1380 kPa max.	700 kPa max.*
Slump	250-300 mm	250 - 300 mm

* May be changed by design engineer to fit particular job requirements.