

### 460.1 DESCRIPTION

This work consists of falsework and form construction, and the furnishing, handling, placing, curing, and finishing of concrete for bridges, box culverts, and miscellaneous structures.

### 460.2 MATERIALS

Materials shall conform to the following Sections:

- A. **Cement:** Section 750. Type II cement shall be used for all Class A40 (A28), Class A45 (A31), and Class A50 (A35) concrete.
- B. **Fine Aggregate:** Section 800.
- C. **Coarse Aggregate:** Section 820.
- D. **Water:** Section 790.
- E. **Admixtures:** Sections 751 and 752.
- F. **Reinforcing Steel:** Section 1010.
- G. **Curing Materials:** Section 821.
- H. **Joint Filler:** Section 860.
- I. **Joint Sealer:** Section 870.
- J. **Fly Ash:** Section 753.

### 460.3 CONSTRUCTION REQUIREMENTS

- A. **Concrete Quality and Proportion:** The Contractor shall design and be responsible for the performance of all concrete mixes used in structures. The mix proportions selected shall produce concrete that is sufficiently workable and finishable for all uses intended and shall conform to the following requirements:

Table 1

	③ Minimum Cement Content	④ Maximum Water/Cementitious Material Ratio	Slump Range at Time of Placement ①	② Entrained Air Content Range	Minimum Coarse Aggregate Content	Minimum 28 Day Compressive Strength
Class of Concrete	Lbs./cubic yard (Kg/cubic meter)	Lbs./Lb. (Kg/Kg)	Inches (mm)	Percent	Percent	psi (MPa)
A40 (A28)	585 (347)	0.45	1" - 4½" (25 - 115mm)	5 to 7.5	55	4000 (28)
A45 (A31)	650 (386)	0.45	1" - 4½" (25 - 115mm)	5 to 7.5	55	4500 (31)
A50 (A35)	715 (424)	0.45	1" - 4½" (25 - 115mm)	5 to 7.5	55	5000 (35)

- ① The slump of concrete used in bridge decks, including barrier curbs, shall be maintained between 1 and 3½ inches (25 and 90mm) at time of placement. The slump of concrete used in barrier curbs that are approved to be slipformed, shall be maintained between 1 and 1½ inches (25 and 38 mm) at time of placement.
- ② Concrete used in bridge decks, including barrier curbs, shall contain 5.5 to 7.5 percent entrained air.
- ③ The maximum cementitious content (total cement, fly ash, and other cementitious admixture) content shall be 800 pounds per cubic yard (475 Kilograms per cubic meter).
- ④ The mix design shall establish a maximum water cementitious material ratio for the concrete mix (never to exceed 0.45).

The absolute volume method as described in the American Concrete Institute Publication 211.1 shall be used in selecting mix proportions. The mix design shall be based upon obtaining an average concrete compressive strength sufficiently above the specified minimum 28 day compressive strength so that considering the expected variability of the concrete and test procedures no more than 1 in 10 strength tests will be expected to fall below the specified strength. Mix designs shall be modified during the course of the work when necessary to assure compliance with the strength and consistency requirements.

Satisfactory performance of the proposed mix design shall be verified by laboratory tests on trial batches. Trial batches shall be conducted in accordance with the American Concrete Institute Publication 211.1, 318 and the following:

1. The slump of each mix shall be within 3/4" ± (19mm ±) of the maximum specified.
2. The air content shall be within 0.5 ± percent of the maximum specified.

The results of such tests shall be furnished by the Contractor to the Engineer at the time the proposed mix design is submitted.

Concrete mix design previously used in other work within the last 5 years will be considered in compliance with the mix design requirements provided all of the following conditions are met:

1. The concrete mix proportions should be in accordance with Section 460.3.A.
2. The mix design, including all material and admixtures, are identical to those previously used and tested.
3. The average 28 day compressive strength of 10 or more test results from an approved testing facility is at least 1.34 standard deviations above the specified strength. These test results are submitted to the Engineer. No more than 1 in 10 below specified strength.

In lieu of submitting a proposed concrete mix design, the Department has approved standard mix designs available for use by the Contractor. If the Contractor chooses to use one of these standard mix designs, the Contractor accepts all responsibility for the mix design meeting all of the applicable specification requirements, including 28 day compressive strength.

All mix designs and any modifications thereto, including changes in admixtures, shall be approved by the Engineer prior to use. Mix design data and test results shall be recorded on a DOT Form 24 and submitted to the Engineer.

- B. Determination of 28 Day Compressive Strength and Acceptance Criteria:** The Engineer will be responsible for the sampling, preparing, properly curing, and breaking of all concrete cylinders for concrete compressive strength in accordance with the Materials Manual. The 28 day compressive strength shall be determined in accordance with SD 420.

The 28 day compressive strength acceptance criteria shall be as follows:

1. **Concrete Cylinder Testing:** If the 28 day cylinder compressive strength is greater than or equal to the specified 28 day compressive strength, the quantity of concrete represented by the cylinder shall be accepted.

If the 28 day cylinder compressive strength is less than the specified 28 day compressive strength, the backup cylinder shall be broken as soon as possible after breaking the 28 day cylinder. The compressive strength for the backup cylinder will be the strength at the time that it was broken and will not be corrected back to a 28-day strength.

2. **Backup Concrete Cylinder Testing:** If the backup cylinder compressive strength is greater than or equal to the specified 28 day compressive strength, the quantity of concrete represented by the cylinder shall be accepted.

If the backup cylinder compressive strength is less than the specified 28 day compressive strength by no more than 500 psi (3.5 Mpa), the Bridge Construction Engineer will determine if the unit is structurally adequate at the average compressive strength of the 28-day and the backup cylinder. If structurally adequate, the concrete will be allowed to remain in place and will be subject to price adjustment based on the average compressive strength of the two

cylinders. If the analysis shows the average cylinder compressive strength is not structurally adequate, the concrete will be removed and replaced at the Contractor's expense.

If the average compressive strength of the 28-day and the backup cylinder compressive strength is more than 500 psi (3.5 Mpa), below the specified 28 day compressive strength, the concrete represented by the cylinders shall be removed and replaced, unless the Area Engineer approves other corrective measures.

- 3. Suspect Test Results:** If there is some reason to suspect that the compressive strength test results are not valid due to a damaged concrete cylinder, malfunction of testing equipment, etc. or that the test results are not representative of the in place concrete, the Department may core the concrete represented by the cylinders. When cores are deemed necessary by the Department and are required at no fault of the Contractor, the Department will arrange for the additional testing and all costs will be borne by the Department. The coring and compressive testing shall be in accordance with the current edition of AASHTO T24 (ASTM C42).

If the average core compressive strength is greater than or equal to the specified 28 day compressive strength, the quantity of concrete represented by the cylinders shall be accepted.

If the average core compressive strength is less than the specified 28 day compressive strength by no more than 500 psi (3.5 Mpa), the Bridge Construction Engineer will determine if the unit is structurally adequate at the lower compressive strength. If structurally adequate, the concrete will be allowed to remain in place and will be subject to price adjustment. If the analysis shows the average core compressive strength is not structurally adequate, the concrete will be removed and replaced at the Contractor's expense.

If the average core compressive strength is more than 500 psi (3.5 Mpa) below the specified 28 day compressive strength, the concrete represented by the cylinders shall be removed and replaced, unless Area Engineer approves other corrective measures.

- 4. Contractor Coring Option:** If the Contractor disputes the accuracy of the 28 day cylinder compressive strength, the Contractor has the option to core the concrete represented by the cylinders. Upon notification of a deviation from the specified compressive strength, the Contractor shall provide written notification of the intent to core the represented concrete within 5 calendar days. Coring shall be done in accordance with Section 460.3.B.5.

If the average core compressive strength is greater than or equal to the specified 28 day compressive strength, the quantity of concrete represented by the cylinder shall be accepted.

If the average core compressive strength is less than the specified 28 day compressive strength by no more than 500 psi (3.5 Mpa), the Bridge Construction Engineer will determine if the unit is structurally adequate at the lower compressive strength. If structurally adequate, the concrete will be allowed to remain in place and will be subject to price adjustment. If the analysis shows the average core compressive strength is not structurally adequate the concrete will be removed and replaced at the Contractor's expense.

If the average core compressive strength is more than 500 psi (3.5 Mpa) below the specified 28 day compressive strength, the concrete represented by the cylinders shall be removed and replaced, unless the Area Engineer approves other corrective measures.

- 5. Coring & Compressive Testing:** If the Contractor utilizes the option to core as specified in Section 460.3.B.4, the Contractor shall arrange for an independent testing laboratory to perform the coring and compressive testing within 30 calendar days of notification of the failing compressive strength of the backup cylinder. The independent testing laboratory must be approved by the Area Engineer prior to starting the coring and compressive testing. The coring and compressive testing shall be in accordance with the current edition of AASHTO T24 (ASTM C42).

The Contractor will take 3 cores of the area representing the cylinders in which the compressive strength is in question and have them tested for compressive strength. The coring and compressive testing shall be witnessed by the Region Materials Engineer. The Department will determine whether the cores will be tested in a dry or wet state in accordance with AASHTO T24 (ASTM C42).

The Contractor will be responsible to locate the reinforcing steel prior to coring. It is critical that the coring operation avoids all reinforcing steel. The core holes shall be grouted with a grout that conforms to Section 460.3.S.

The average compressive strength of 3 cores will be used for the determination of acceptance of concrete represented by each set of 28 day cylinders. One core compressive strength may be 15% below the specified strength if the average of the 3 core compressive strengths is above the specified strength. ASTM E 178.4 (Standard Practice for Dealing With Outlying Observations) will be used with the 10% significance level to deal with excessively high or low core strengths. If a core compressive strength is an outlier, then the set of cores will be averaged using the 2 remaining cores.

The average compressive strength of the cores will prevail over all other compressive strength determination methods.

If it is determined by the additional testing that the concrete is in compliance with the specified 28 day compressive strength, the Department will reimburse the contractor for the cost of the coring and compressive testing. If it is determined by the additional testing that the 28 day compressive strength is less than that specified, all costs for the coring and compressive testing will be borne by the Contractor and the concrete shall be either accepted or rejected as per Section 460.3.B.4.

The following information shall be provided for each core taken:

- a. Include DOT project number, county, & PCEMS number.
- b. Core identification number & location of each core (be specific - representing cylinder number, structure number, location of cores sketch, date concrete was cast, date cores taken, date cores tested, etc.)
- c. Age of the concrete at the time of testing.

- d. Length & diameter of each core tested.
- e. Unit weight of each core.
- f. End preparation (capped or neoprene).
- g. Date of last calibration of the compression machine.
- h. What, if any, correction factor was used to compute the compressive strength.
- i. Actual calculations including load & cross-sectional area.
- j. Type of fracture as per ASTM C39. Note if the bond to the coarse aggregate is not adequate due to cement adhesion.
- k. Any defects in either the core or the cap.

**C. Equipment:** Equipment shall be at the job site in advance of the start of construction operations to allow for thorough examination by the Engineer.

1. **Batching Equipment:** Batching plant structures shall be leveled so the accuracy of the weighing mechanism is maintained.

Hoppers shall fully discharge without jarring the scales.

Clearances between scale parts, hoppers, and bin structure shall be maintained to avoid displacement of, or friction between, parts due to materials accumulations, vibration, or other cause. Pivot mountings shall be designed so parts will not jar loose, and be constructed to assure unchanging spacing of knife edges under all circumstances. Scales shall be designed so exposed fulcrums, clevises, and similar working parts may readily be kept clean.

Weighing hoppers and other parts that are effected by wind action shall be protected by means of shelters or wind breaks.

The scale dials shall be completely enclosed in weather proof cases and provided with glass opening to permit observation and reading.

Dial scales shall be provided with markers to indicate the position of the dial indicator for predetermined loads. Beam scales shall be equipped with an over and under indicator which will show the beam in balance at zero load at any beam setting. The indicator shall have an over and under travel equal to not more than five percent of the capacity of the beam.

The scales for weighing aggregates, cement, water, and admixtures shall be of the beam or springless dial type designed as an integral part of the batch equipment. The scales shall be accurate within 0.5 percent at any point throughout the range of the scale. Scale graduations shall be not greater than 0.1 percent of the capacity of the scale. The scales shall be sensitive to the weight indicated by one graduation.

When water is measured by volume, means shall be provided for determining the accuracy of the measuring device.

**Computerized Batching Equipment:** The following provisions shall apply to all Class A or Class M (Class I) concrete batched by computerized ready mix plants:

A printed, computer generated, ticket shall be automatically produced for each load of concrete batched. The printed computer ticket shall accompany each load of concrete to the project and shall be presented to the Engineer prior to discharging the load at the project site.

Batching equipment shall be automatic. Manual operations will be permitted when automatic controls fail provided concrete meeting specified results is produced. However, the automatic operation shall be restored before work may commence the day following the failure.

The printed ticket must contain the following minimum information:

- Truck Number
- Date and Time batched
- Total volume of the load, in cubic yards (cubic meters)
- Mix Identification [ID]
- Actual weight (mass) or volume of each component of the mix:
  - coarse aggregate
  - fine aggregate
  - cement
  - fly ash
  - water
  - admixtures

The above information must be automatically printed in such a manner that the Engineer may verify that the mix adheres to the proportions specified by the design mix.

- 2. Mixing and Hauling Equipment:** Mixers and agitators shall have attached in a prominent place, the manufacturer plate or plates showing the various uses for which the equipment is designed and the capacity of the drum or container in terms of volume of mixed concrete.

The pickup and throw over blades in the drum shall be restored or replaced when any part or section is worn down 3/4 inch (20 mm) or more below the original height of the manufactured design. A copy of the manufactured design, showing dimensions and arrangement of blades in reference to original height and depth, shall be available. Mixers that have an accumulation of hard concrete or mortar shall not be used.

Mixers, except truck mixers, shall be equipped with an approved timing device which automatically locks the discharge lever when the drum has been charged and releases it at the end of the mixing period. The timing device shall be equipped with a bell or other suitable warning device adjusted to give a signal each time the lock is released.

Truck mixers shall be equipped with counters to record the number of revolutions of the drum or blades. The revolution counter on the truck mixers shall be set to zero as each new load is batched. The counters shall be automatically actuated at the time mixing starts at mixing speed.

Mixers shall be capable of combining the ingredients of the concrete into a thoroughly mixed and uniform mass and uniformly discharging the concrete.

The hauling bodies of nonagitating equipment shall be smooth, mortar tight metal containers equipped with gates that permit uniform control of the discharge of the concrete.

**3. Forms and Falsework:** Forms and falsework shall conform to Section 423.

**D. Handling, Measuring and Batching Materials:** The separate aggregate components shall not become intermixed prior to being weighed and the weigh hopper or hoppers shall be charged so the batched weights are within the following tolerances:

1. The following applies when aggregates are weighed accumulatively into one hopper:

The hopper inlet mechanisms shall be interlocked against opening when the hopper discharge gate is open.

The hopper inlet mechanism for any ingredient shall be interlocked against opening if the previous ingredients already in the hopper are overweight or underweight by more than 0.5 percent of the net weight of the total aggregate batch.

The hopper discharge mechanism shall be interlocked against opening while the hopper is being charged or if the batch in the hopper is overweight or underweight by more than 0.5 percent of the net weight of the total aggregate batch.

2. The following controls shall apply to the aggregate batching equipment where each aggregate is weighed separately:

The hopper inlet mechanism shall be interlocked against opening when the discharge gate is open.

The hopper discharge mechanism shall be interlocked against opening while the hopper is being charged.

The hopper discharge mechanism shall be interlocked against opening if the material in the hopper is either overweight or underweight by more than one percent of the specified weight.

3. Cement shall be measured by the sack or by weight. When cement is weighed, separate scales and hoppers shall be used with a device to indicate positively the complete discharge of the batch of cement into the batch box or container. The cement batching equipment shall be operated within a delivery tolerance of one percent of the net weight of the cement per batch. The cementitious material (cement and flyash) batching equipment shall also operate within a delivery tolerance of one percent of the net weight of the total cementitious material per batch.

4. Water may be measured by volume or by weight. The measuring equipment shall be operated within a delivery tolerance of one percent of the net weight or volume of water per batch.

5. Air entraining or other admixtures shall be measured by volume or by weight. The measuring equipment shall be operated within a delivery tolerance of three percent of the net weight or volume of admixture per batch.

Admixtures shall be used in accordance with the manufacturer’s recommendations. When multiple types of admixtures are being used, the admixtures shall be individually dispensed. Compatibility of the admixtures shall be verified prior to use.

**E. Mixing Concrete:** Concrete shall be mixed at a central stationary plant site or in truck mixers.

Mixers shall not be charged in excess of the rated capacity.

When a concrete batch is transported in a truck mixer or agitator and the batch is smaller than 60 percent of the rated capacity of the truck mixer or agitator, the following percentage of additional cementitious material shall be added to the batch:

40% to 60% rated cap	5%
20% to 39% rated cap	10%
10% to 19% rated cap	15%
0% to 9% rated cap	20%

The above provisions regarding extra cementitious material shall also apply to the mixing of small batches in central plants.

Mixing and agitating speeds shall be as designated by the manufacturer of the equipment.

1. **Central Plant Mixing:** Manual operation of mixers shall be permitted only in case of failure of the automatic timing device. Automatic operation must be restored before work may commence the day following the failure.

The batch shall be charged in the drum so a portion of the mixing water enters in advance of the cement and aggregates. The flow of water shall be uniform and all water shall be in the drum by the end of the first 15 seconds of the mixing period.

Concrete shall be mixed for a period of not less than one minute after all materials, are in the mixer.

Concrete mixed less than the specified mixing time shall be discarded and disposed of.

2. **Truck Mixing:** Mixing time for truck mixed concrete shall be not less than 70 nor more than 100 revolutions of the drum or blades at mixing speed after all ingredients, including water, are in the drum. Additional mixing beyond 100 revolutions, shall be done at agitating speed.

The mixing water shall be added at the time of batching. Additional water, cement, or admixtures may be added to the full load after completion of the original mixing, provided that slump, entrained air, and water cement specifications are adhered to. Addition of water, cement, or admixtures to partial loads is not allowed (partial loads of concrete are defined as

loads that have been partially discharged). Admixtures shall be added in accordance with the manufacturer's recommendations. When additional water, cement or admixture is added, the batch shall be mixed an additional 30 revolutions at mixing speed. The Contractor shall provide means to accurately measure the amount of additional materials added.

3. **Water/Cementitious Material Ratio:** The water/cementitious material ratio of the concrete placed shall not exceed the maximum water/cementitious ratio established for the mix design.

#### F. Volumetric Batching and Continuous Mixing:

1. **Equipment:** The proportioning and mixing equipment shall be a self-contained, mobile, continuous mixer meeting the following requirements:

- a. The mixer shall be capable of carrying sufficient unmixed dry bulk cement, fine aggregate, coarse aggregate, admixtures, and water in separate compartments to produce not less than six cubic yard (4.5 cubic meters) of concrete.

For full depth bridge deck placements, the production capacity shall be a minimum of 60 cubic yards (45 cubic meters) per hour. More than one mixer may be required to provide a satisfactory placement rate.

- b. The mixer shall be capable of positive measurement of cement being introduced into the mix. A visible recording device, equipped with a ticket printout, shall indicate this quantity.
- c. The mixer shall provide positive control of water introduced into the mixer. Water flow shall be coordinated with the cement and aggregate feeding mechanisms, and shall be readily adjustable to provide for minor variations in aggregate moisture. Water flow shall be controlled by a calibrated metering device.

In addition to the metering device, mixers used for bridge deck concrete, low slump concrete, and latex modified concrete shall be equipped with recording water meters recording the number of gallons (liters) introduced into the mixer to the nearest 0.1 gallon (0.1 liter).

- d. The mixer shall be capable of being calibrated to automatically proportion and blend all components on a continuous or intermittent basis.
- e. The mixer shall provide positive control of admixtures introduced into the mix. Admixture flow shall be coordinated with the feeding mechanisms of the other ingredients and shall be readily adjustable. The admixture injection system shall meet the mixer recommendations of the manufacturer regarding type and design.
- f. When mixing latex modified concrete, the mixer shall be equipped with recording meters capable of recording, to the nearest 0.1 gallon (0.1 liter), the number of gallons (liters) of latex emulsion introduced into the mix.

## 2. Equipment Calibration:

- a. Calibration and inspection by the Department will be required for each mixer before the start of the first project on which the mixer will be used each year. The calibration will establish the meter count, e.g., the number of revolutions and discharge time in seconds required to dispense 94 pounds (43 kilograms) of cement. Gate openings and pointer adjustments for aggregates and general operating condition of the equipment will also be inspected.

The Contractor shall have a representative to witness the calibration, and a qualified mixer operator. The Contractor shall furnish all scales, containers, stop watches, mixer operating manuals, materials, and equipment necessary for the calibration and inspection.

- b. A materials discharge verification check may be ordered whenever conditions warrant. Individual components may be ordered verified. On latex modified mixtures, cement, and latex emulsion discharge shall be verified prior to the first placement on each project.
- c. Proportioning of individual components shall be within the following tolerances:

Cement (weight percent)	0% to +4%
Fine aggregate (weight percent)	±2%
Coarse aggregate (weight percent)	±2%
Water (weight or volume percent)	±1%
Latex emulsion (weight percent)	±1%
Yield (volume percent)	±2%

The discharge time interval for components, other than aggregates, shall be the time established for the discharge of 94 pounds (43 kilograms) of cement. A lesser discharge time may be used for aggregates. Individual components used during discharge checks shall be from the sources to be used on the project. When performing materials discharge checks, manufacturer recommendations relative to minimum quantities of materials in the bins shall be adhered to. If the cement discharge is not within tolerance a new meter count and discharge time shall be established using calibration form DOT-293.

## 3. Proportioning and Mixing: The operations of proportioning and mixing concrete shall comply with the following requirements:

- a. The proportioning and mixing equipment operator shall be thoroughly familiar with the equipment and its operation.
- b. Mixers shall be clean and ingredients accurately proportioned.
- c. Concrete shall be mixed at the site in accordance with the specific requirements for the equipment used.

- d. Concrete 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 and the final finishing is completed before the formation of a plastic surface film.

4. **Termination of Use:** Permission for continued use of a mixer may be rescinded for failure to maintain acceptable production or inability to meet the specifications.

**G. Limitations of Mixing:** Concrete shall be mixed in the quantities required for immediate use and shall be placed before initial set has occurred. Concrete in which initial set has begun prior to beginning placement shall be wasted at the Contractors expense. Retempering of concrete after initial set has occurred will not be allowed.

Concrete shall not be mixed and placed unless the natural light is sufficient for finishing operations, or an adequate artificial lighting system is provided.

Mixing water shall not be heated above 160° F (71° C). Aggregates shall not be heated above 100° F (38°)C and shall be free of frozen lumps, ice, and snow.

**H. Delivery Requirements:** When concrete is continuously agitated in the hauling unit, it shall be discharged within 90 minutes, and discharged and screeded within 105 minutes after the cement has been placed in contact with the aggregates. When the concrete temperature is 80° F (27° C) or above, the time limitation shall be reduced to discharged within 45 minutes, and discharged and screeded within 60 minutes.

When concrete is not continuously agitated in the hauling unit, it shall be discharged within 45 minutes, and discharged and screeded within 60 minutes after the cement has been placed in contact with the aggregates. When the concrete temperature is 80° F (27° C) or above, the time limitation shall be reduced to discharged within 30 minutes, and discharged and screeded within 45 minutes.

The rate of delivery of concrete shall be uniform. The interval between batches shall not exceed 30 minutes.

For delivery of concrete in remote locations where the preceding concrete delivery requirements will be difficult to meet, the Contractor may be allowed to use a set retarding admixture to control initial set when approved by the Engineer. When set retarding admixtures are allowed, the concrete delivery requirements may be adjusted.

**I. Construction Tolerances:** Construction tolerances and reinforcing steel placement tolerances shall be in accordance with the latest edition of ACI 117, Standard Tolerances for Concrete Construction and Materials.

**J. Pre-pour Inspection Requirements for Concrete Bridge Decks:** Pre-pour inspections will be conducted for all new concrete bridge decks. The Contractor shall advise the Engineer 24 hours in advance of the time when deck preparation will be complete and ready for inspection. The following items of work shall have been completed at the time of inspection:

1. **Formwork:** Formwork and decking shall be complete and joints made mortar tight.
2. **Reinforcing Steel:** Reinforcing steel shall be accurately placed, secured, and tied according to specifications.
3. **Screed:** Screed rails shall be set and adjusted for final grade.
4. **Finishing Machine:** Finishing machine shall be adjusted for crown slope and placed upon the screed rails.
5. **Safety:** Necessary walkways and safety railing shall have been installed.
6. **Inspections:** A responsible Contractor employee shall be designated to accompany the Engineer during the pre-pour inspection.

Following the pre-pour inspection, corrective work shall be completed during the normal work shift and shall not extend into the late evening hours. Violation of this provision will be cause to postpone the scheduled deck placement.

- K. Placing Concrete:** The Contractor shall give sufficient notice before starting to place concrete to permit inspection of forms, reinforcing steel, and preparation for placing. Concrete shall not be placed without approval of the Engineer.

Placement of concrete on a frozen foundation will not be permitted. The surface temperature of forms, steel, and adjacent concrete which will come in contact with the concrete being placed shall be raised to a temperature above freezing prior to placement.

The temperature of concrete immediately after placing shall be not less than 50° F (10° C) nor more than 90 F (32 C). The top limit for bridge deck concrete shall be 80° F (27° C) except as indicated below.

During periods of extreme and sustained hot weather it may become extremely difficult to maintain the 80° F (27° C) maximum concrete temperature for bridge deck concrete. When such conditions exist the Engineer may authorize the maximum concrete temperature to be raised to 85° F (29° C) provided the following conditions are met:

1. The aggregate piles must be flushed with water.
2. A minimum rate of pour of 40 cubic yards (30 cubic meters) per hour must be maintained.
3. Wet burlap and polyethylene sheeting must be placed as soon as possible after the pour.
4. If the ambient temperature is 80° F (27° C) or less the concrete shall be cured with a linseed oil base emulsion curing compound, as specified in 460.3.N. Whenever the ambient temperature exceeds 80° F (27° C), a continuous fogging shall be applied from the time of initial strike off until the wet burlap is in place. This continuous fogging shall be in addition to the linseed oil base emulsion compound.

Fogging equipment shall be capable of applying a fine mist, not a spray, under pressure through an atomizing nozzle. The fogging option will not be allowed when wind conditions preclude complete coverage.

Placement of concrete for bridge decks, including barrier curbs, will not be permitted during the period from November 1 to April 1, without written authorization from the Engineer. Authorization will be given only if there is a distinct advantage to the Department.

Barrier curbs shall not be placed with a slipform paver without approval of the Bridge Construction Engineer. Prior to placing the bridge deck, the Contractor shall submit his plan for placing the barriers, through the proper channels, to the Bridge Construction Engineer. This plan shall include, but not be limited to, the concrete mix design to be used, the method of bracing the reinforcement from movement, and the method to be used for protection of the bridge deck from the paver tracks.

Before placing concrete, sawdust, chips, debris, and extraneous matter shall be removed from the interior of forms. Temporary struts, stays, and braces holding the forms in the correct shape and alignment, shall be removed when the fresh concrete has reached an elevation rendering their service unnecessary. These temporary members shall not be buried in the concrete.

The slope of chutes for concrete placement shall allow the concrete to flow slowly without segregation. The delivery point of the chute shall be as close as possible to the point of deposit. Chutes and spouts shall be kept clean and shall be thoroughly flushed with water before and after each run. The flush water shall be discharged outside the forms.

Free fall of concrete shall not exceed five feet (1.5 meters). In thin walls or columns where the reinforcement prohibits the use of chutes the method of placement shall prevent objectionable separation of coarse aggregate.

The sequence of placing concrete, including the location of construction joints, shall be as specified. Concrete shall be placed in continuous horizontal layers. Each layer shall be placed before the preceding layer has attained its initial set.

The concrete shall be consolidated by vibrating internally or externally, or both without displacement of reinforcing or forms. The vibration shall be of sufficient duration and intensity to thoroughly consolidate the concrete without causing segregation, localized areas of grout or damage to concrete, forms, and reinforcement.

Vibration shall not be applied directly to reinforcement which extends into sections or layers of concrete which are not plastic under vibration. Vibrators shall not be used to move concrete over distances or to transport concrete in the forms.

Accumulations of mortar splashed upon the reinforcing steel and the surfaces of forms shall be satisfactorily removed. Care shall be exercised not to injure or break the concrete to steel bond at and near the surface of the concrete while cleaning the reinforcing steel. Dried mortar chips and dust shall be removed and not left in the unset concrete.

**L. Underwater Concrete Placement:** Concrete placed under water shall be placed as per Section 465.3.M.

**M. Surface Finish:** The surfaces of all concrete masonry shall be worked during placing. The working shall force all coarse aggregate from the surface and thoroughly work the mortar against the forms to produce a smooth finish relatively free of water, air pockets, and honeycombing.

As soon as the concrete has set sufficiently, the forms on all exposed surfaces shall be carefully removed and all depressions resulting from the removal of metal ties or other causes shall be carefully pointed with a mortar of sand and cement in the same proportions as the concrete being treated. All fins and rough corners on the surfaces shall be removed to present a neat and uniform appearance.

Additional finishing will be required as follows:

**1. Rubbed, Brushed, and Commercial Texture Finishes:** One of these three finishes will be required for all railing, curbs, parapets, wings, and other surfaces not subject to wear which are visible to the traveling public unless otherwise designated in the plans. The selected finish shall be used throughout the entire structure, except the finish for the top and inside of the curb may be different than that used for the other parts of the structure. These finishes will not be required on wing walls and parapets of box culverts and wingwalls and backsides of curbs on bridges which do not have traffic passing beneath them, provided the forms result in a smooth unblemished surface.

**a. Rubbed Finish:** As soon as the pointing has set sufficiently, the surfaces to receive a rubbed finish shall be thoroughly wetted with a brush and rubbed with a medium coarse carborundum stone or an abrasive of equal quality using a small amount of mortar on stone face. The rubbing shall be continued until all form marks and projections are removed, producing a relatively smooth clean surface free from pits or irregularities.

The final finish shall be obtained by rubbing with a fine carborundum stone or an abrasive of equal quality. This rubbing shall continue until the entire surface has a smooth texture and a uniform color.

**b. Brushed Finish:** This finish will be permitted only if it is accomplished within 12 hours of concrete placement. The forms shall be removed as soon as the concrete is able to stand firm without slumping. The surface shall be worked with a rubber float which may be dipped in a very wet three to one fine sand and cement grout mixture. Immediately after the surface is worked into a lather, a soft bristle brush shall be used to smooth the surface, leaving a fine grained, smooth, but sanded texture. A "plastering" job resulting from the use of an excess of grout on the surface will not be permitted.

**c. Commercial Texture Finish:** The objective is to obtain a surface that is reasonably smooth and uniform in texture and appearance. Repairing surface blemishes (bug holes, form lines, etc.) to prevent "show through" prior to application of the commercial texture finish is required. The commercial texture finish shall be performed using an approved

system from a list of approved materials/mixes maintained by the Department. The approved list contains two separate classes (Class A and Class B) for commercial texture finish. Unless otherwise specified on the plans, Class A systems shall be used. The Contractor is required to provide a copy of the manufacturer's recommendations to the Engineer prior to performing any commercial texture finish work.

Unless provided in the manufacturer's recommendations, Class B commercial texture finish shall not be applied to any surface until the concrete is a minimum of 28 days old. The surfaces to receive Class B commercial texture finish shall be abrasive blast cleaned to break the surface film, to remove all laitance and other foreign material, and to provide an absorptive surface. When allowed in the manufacturer's recommendations, powerwashing may be used to prepare the surface in lieu of abrasive blast cleaning.

The surfaces shall be flushed with water not more than 24 hours prior to applying the finish. Unless specified in the manufacturer's recommendations, the concrete surface shall not be wet or damp when the commercial texture finish mixture is applied.

The commercial texture finish mixture shall be mixed in accordance with the method specified in the approved list for the system being used. The same materials and application method shall be used for all surfaces on any one structure.

Commercial texture finish mixtures may be applied by a brushing, rolling, or by spraying, as per the manufacturer's recommendations. The mixture shall cover the original surface with a one coat application. The one coat application shall not be too thick to cause runs, sags, or a plastered effect. After drying, the final surface shall be uniform in color and texture with no laps or breaks in continuity. The color of Class A systems shall closely simulate the color of the original concrete. Unless otherwise specified on the plans, the color of Class B systems shall be a pearl gray color (Federal Standard No. 26622) that is lighter than the color of the original concrete but is not white.

The application of the commercial texture finish shall not be started until all other work that could damage the finish has been completed. The finishing operations shall be continuous until completion of the finish application on any one surface. Corrective work, at the Contractor's expense, will be required on any surfaces which have not been satisfactorily finished or on finished surfaces that have been damaged during subsequent work. The repair work will include as much adjacent surface area as necessary to achieve a uniform appearance.

- 2. Special Surface Finish:** Special surface finish will be required on the concrete surfaces designated on the plans. These surfaces may be newly constructed concrete surfaces and/or older in-place concrete surfaces. The Special Surface Finish shall be performed using an approved Class B system from the approved list of materials/mixes for commercial texture finish.

Surface preparation shall be in accordance with the requirements of Section 460.3.M.1.c except that abrasive blast cleaning is required for all older in-place concrete surfaces. Powerwashing is not an acceptable method of surface preparation on these surfaces.

Mixing and application of the special surface finish shall be in accordance with Section 460.3.M.1.c for Class B commercial texture finish.

- 3. Float Finish:** Unformed surfaces, except bridge decks, shall be given a float finish. After the concrete has been struck off, the surface shall be thoroughly worked and floated with a suitable floating tool. Before the finish has set, the surface cement film shall be removed with a fine brush in order to have a fine-grained, smooth but sanded texture.
- 4. Bridge Deck and Approach Slab Finish:** The concrete shall be placed slightly higher than the finished surface of the deck or approach slab. Immediately after the concrete has been placed and consolidated as required by Section 460.3.K, the surface shall be struck off and finished with an approved finishing machine. For bridge decks the finishing machine shall meet the following minimum requirements:
  - a.** The finishing machine shall be a self-propelled rotating cylinder type, with one or more rotating steel cylinders and augers. The machine shall span the concrete placement width. The cylinders and augers shall spread and consolidate the concrete to the established profile by traversing the placement width, transverse to the roadway centerline. The machine shall be capable of forward and reverse motion under positive control, and be capable of raising all cylinders and augers to clear the surface when traveling in reverse. Any modifications to the factory product will require approval by the Engineer. The portion of the deck adjacent to curbs shall be neatly finished to a true surface with a wooden hand float.
  - b.** Before the concrete has attained its initial set it shall be given a final finish by transverse brooming or carpet drag to provide a surface micro texture.
  - c.** The surface of the concrete bridge deck and approach slab shall be given a transverse metal-tine finish. The metal-tine finish shall provide a groove width of 1/8" and a groove depth of 3/16 inch (5 mm)  $\pm$  1/16 (3 mm). The spacing between the individual grooves shall be randomly spaced and shall vary between 5/8 inches (16mm) to 1-5/8 inches (41 mm) with 50% of the spaces being 1 inch (25 mm) or less. The repeating random pattern on the tining device shall be avoided. Successive passes of the tining shall not overlap. The 12 inch width of the deck next to curb shall be left ungrooved.
  - d.** After the concrete has hardened, the surface and joints shall be tested for smoothness in accordance with SD 417. The permissible longitudinal and transverse surface deviation shall be 1/8 inch (3 mm) in 10 feet (three meters). Any portion of the deck and approach slab showing variation from the template of more than 1/8 inch (3 mm) shall be either ground to an elevation that will be within the permissible deviation or be accepted under the provisions of Section 5.3.

Necessary grinding shall be accomplished with specially prepared circular diamond blades mounted on a horizontal shaft.

Areas that have been ground shall not be left smooth or polished, but shall have a uniform texture equal in roughness to the surrounding unground concrete.

**N. Curing Concrete:** Concrete surfaces shall be kept continuously wet by ponding, spraying or covering with materials that are kept continuously and thoroughly wet. Such materials shall consist of a double layer of burlap or other materials, as approved by the Engineer, which do not discolor or damage the concrete. Forms shall be considered as adequate cover for curing the formed surface as long as the forms remain in place without loosening. Curing shall continue for not less than seven days after placing the concrete. Other precautions to ensure development of strength shall be taken as the Engineer may direct.

In lieu of the above method of curing, membrane curing compound may be used. The compound shall be uniformly applied immediately after the final finishing operations are completed and the free water has left the surface. The curing compound may be applied in one or two applications in accordance with the directions of the manufacturer. If applied in two coatings, the second shall be applied within 30 minutes of the first.

Equipment, workmen, and materials will not be allowed on the surface for a minimum of seven days after application of the curing compound, unless the surface is adequately protected with an approved material. This protection shall not be applied for at least eight hours after application of the curing compound. If the membrane film is broken or damaged within the seven day curing period, the areas affected shall be given a duplicate treatment of the curing material, at the same application rate as the first treatment.

Surfaces which are to receive a finish as per Section 460.3.M.1. and 460.3.M.2 shall not be treated with curing compound, curing shall be accomplished with a double layer of burlap mats and polyethylene sheeting. Membrane curing compound will not be allowed on any surface to which concrete is to be bonded.

Bridge decks and approach slabs shall be cured as follows:

As soon as bridge deck and approach slab concrete has received the final surface finish, linseed oil base emulsion curing compound shall be uniformly applied at the specified rate. This application is not a substitute for curing with burlap mats and polyethylene sheeting but is required for moisture retention until the burlap mats and polyethylene curing materials can be placed. The burlap mats and polyethylene sheeting curing materials shall be in place not later than four hours after completion of deck finishing. The concrete surfaces which are to have superimposed concrete placed upon or against them shall be protected from the curing compound and shall be cured with cotton or burlap mats and white polyethylene sheeting. All reinforcing steel shall be protected from the compound application.

**1. Application of Curing Compound:** Application of linseed oil base emulsion curing compound shall conform to the following requirements:

**a.** Prior to and during application, the material shall be mixed to a uniform consistency without the use of air, violent agitation, or thinning.

- b. The material shall be maintained above 50° F (10° C) during application.
  - c. The material shall be applied, with a spray applicator of sufficient capacity and with spray nozzles of proper size and design to provide a uniform application at the specified rate, immediately after the concrete has received the final finish.
  - d. The minimum application rate shall be as follows:
    - 1) Carpet drag or broom finish - 1 gallon per 150 square feet (1 liter per 4 square meters).
    - 2) Groove finish - 1 gallon per 125 square feet (1 liter per 3 square meters).
- 2. Mats and Polyethylene:** Surfaces cured with burlap mats and polyethylene sheeting shall be cured in the following manner:
- a. The surface to be cured shall be entirely covered with a double layer of burlap mats. The mats shall cover the entire surface with sufficient material beyond the periphery of the area to assure adequate curing of the edges. The mats shall be thoroughly saturated with water and shall be placed with the wettest side down.  
  
Combination burlap-polyethylene sheets may be substituted for one layer of burlap and the polyethylene film with the Engineer's approval
  - b. Immediately after placement, the mats shall be entirely covered with white polyethylene sheeting. Adjacent sheets shall be lapped at least 18 inches (450 mm). The sheeting shall be placed and weighted down to assure contact with the surface.
  - c. Curing shall be maintained for seven days. The mats shall be kept moist by periodic applications of water.
- O. Protection of Concrete:** The following provisions apply to all Class A concrete in addition to the requirements for curing contained in Section 460.3.N.

Concrete for sidewalks, curb and gutter, drop inlets, manholes, ditch checks, pipe headwalls, sleeper slabs, approach slabs, pavement, etc. shall be maintained above 32° F (0° C) until it has attained 1500 psi (11 MPa) compressive strength. The compressive strength will be checked according to SD 409 (SD 409M).

Enclosures for protection of concrete shall be capable of maintaining the temperature specified and permit free circulation of artificial heat. The use of salamanders or other types of open flame heating unit is prohibited.

Form insulation shall be bats of fiberglass, rockwool, balsam wool, or similar commercial insulation material. Insulation shall remain in place for the full protection period. The forms may be loosened slightly to control the temperature of the concrete below the maximum value specified.

The Contractor shall drill holes in the forms and provide thermometer wells ½ inch (13 mm) to one inch (25 mm) in depth at locations established by the Engineer, to determine the temperature of the concrete.

Concrete for bridges, box culverts, retaining walls, anchor blocks, median barriers, light and signal footings, and other structures shall be maintained at a temperature of 50° F (10° C) or above for the first 72 hours after the concrete has been placed. The concrete shall be maintained at a temperature of 40° F (4° C) or above for the next 48 hour period. If low temperatures are recorded during this protection period, one extra day of protection time above 40° F (4° C) shall be added to the original five days of protection for each day that the minimum concrete temperature falls below the specified temperature.

If an additional bag of cement per cubic yard (56 kilograms of cement per cubic meter) is used, or if high early strength cement is permitted, the concrete shall be maintained at a temperature of 60° F (16° C) or above for 72 hours. If temperatures less than 60° F (16° C) are recorded during this protection period, the protection time required shall revert back to that in the preceding paragraph with its provision for low temperatures also being applicable.

Until one of the protection periods have been satisfied, cold weather protection shall continue, falsework shall remain in place, live loads shall not be applied and the concrete temperature shall be maintained above 35° F (2° C).

At the end of the protection period, the concrete temperature shall not be permitted to fall more than 40° F (4° C) for each 24 hour period.

The surface temperature of concrete protected by housing and heating or insulated forms shall not exceed 100° F (38° C) during the protection period.

It will be permissible to flood concrete to a minimum depth of one foot (300 mm) for 10 days after the concrete is placed maintaining a water temperature which prevents freezing of the water in contact with the concrete.

**P. Removal of Temporary Works and Construction of Superimposed Elements:** Methods of removal of temporary works likely to cause overstressing of the concrete shall not be used. Temporary works shall be removed such that the concrete gradually and uniformly takes stresses due to its own weight.

Falsework, forms and other temporary works shall not be removed and superimposed elements shall not be placed without the approval of the Engineer. Falsework and forms may be removed from the affected concrete and placement of superimposed elements may proceed when the concrete reaches the strength specified in Table 1. Concrete compressive strength shall be used as the basis for falsework removal, form removal, and placement of superimposed elements whenever possible. Falsework removal, form removal, and superimposed element placement may be allowed on the basis of time only when concrete compressive strength is not able to be determined and shall be exclusive of periods of time when the temperature is below 40° F (4° C).

**Table 1**  
**Formwork/Form**                      **Placement of Superimposed**  
**Removal**                                      **Elements**

Structural Elements	Concrete		Concrete	
	Strength psi (MPa)	Time	Strength psi (MPa)	Time
Footings/Sleeper Slabs	800 (6)	24 hrs.	1600 (11)	72 hrs.
Columns/Pier Walls	800 (6)	24 hrs.	2000 (14)	12 days
Abutment/Sills	800 (6)	24 hrs.	3000 (21)	20 days
Bent Caps/Pier Caps	2400 (17)	15 days	3000 (21)	20 days
Grout Pads	800 (6)	24hrs.	2000 (14)	12 days
Concrete Diaphragms	800 (6)	24 hrs.	2000 (14)	12 days
Bridge Decks:				
Girder Bridges	2000 (14)	12 days	1200 (8)	48 hrs.
Continuous Conc. Bridges	2400 (17)	15 days	1200 (8)	48 hrs.
Rigid Frame Bridges	2400 (17)	15 days	1200 (8)	48 hrs.
Other Deck Slabs	2000 (14)	12 days	1200 (8)	48 hrs.
Box Culvert:				
Floor, Wingwall Footings	800 (6)	24 hrs.	1600 (11)	72 hrs.
Walls	800 (6)	24 hrs.	3000 (21)	20 days
Top Slab	2000 (14)	12 Days	1200 (8)	48 hrs.
Other Vertical Surfaces not Carrying Load	800 (6)	24 hrs.		

**Q. Backfilling and Application of Liveload:** All concrete shall attain full design strength and all falsework shall be removed prior to backfilling and applying highway live loads to the structure. Construction vehicles, materials, and equipment weighing less than 4,000 pounds (1,800 kg) in total will be allowed on any span, provided the most recently placed concrete has attained a compressive strength of 2,400 psi (17 MPa). Loads over 4,000 pounds (1,800 kg) will not be allowed until the concrete has attained design strength and all falsework has been removed.

The only exceptions are that footings, columns, curb and gutter, and sidewalks (sidewalks on bridge decks are not included) shall not be backfilled until permission has been given by the Engineer. The approach slabs may be opened to traffic when they have attained a compressive strength of 4000 psi (28 MPa).

Luminaires, sign poles, signals and sign bridges shall not be installed on the footings until the concrete has reached full design strength.

**R. Joints:** Surfaces of fresh concrete at horizontal joints shall be rough floated sufficiently to consolidate the surface. All construction joints shall be cleaned of surface laitance, curing compound, and other foreign materials prior to placing fresh concrete against the joint. Drainage fabric shall be placed around construction joints on cast-in-place box culverts in accordance with Section 422.

**S. Grout:** Grout shall be a commercially available non-metallic, non-shrink grout capable of attaining a minimum compressive strength of 4500 psi (31MPa).

#### 460.4 METHOD OF MEASUREMENT

Structural concrete will be measured in accordance with the neat line dimensions shown on the plans to the nearest 0.1 cubic yard (0.1 cubic meter), unless changes are ordered in writing.

Deductions will not be made for the volume of concrete occupied by utility conduit, six inch (150 mm) or smaller drainage pipe, reinforcing steel, encased structural steel, pile heads, anchors, sleeves and encased grillage, or for volume of concrete displaced by weep holes, joints, drains and scuppers or for fillets, chamfers or scorings, one inch square (10 square centimeters) or less in cross section.

Concrete approach and sleeper slabs will be measured to the nearest 0.1 square yard (0.1 square meter).

Concrete used for foundation seals will not be measured for payment.

Commercial texture finish will not be measured for payment.

The special surface finish will be measured along the neat line dimensions shown in the plans for the surfaces designated. The special surface finish will be computed to the nearest square foot (0.1 square meter).

#### 460.5 BASIS OF PAYMENT

The accepted quantities of concrete will be paid for at the contract unit price per cubic yard (cubic meter).

Concrete approach and sleeper slabs will be paid for at the contract unit price per square yard (square meter).

Payment will be full compensation for labor, equipment, tools, materials and all other items of work required in furnishing, forming, placing, finishing, curing, protecting and all other items incidental to the structural concrete.

Reinforcing and structural steel will be paid for separately.

When a bid item for concrete is provided, it will be considered full compensation for excavation necessary to construct the structure, unless a separate item is provided for such excavation.

Commercial texture finish will be incidental to the unit bid price for structural concrete.

Special surface finish will be paid for at the contract unit price per square foot (0.1 square meter).