551.03.2 Composition of Concrete

B. Class Deck and Overlay-SF. Design and produce class Deck and Overlay-SF concrete in accordance with Table 551-3 and the following:

- Use silica fume. Include fly ash and/or GGBFS as SCMs.
- SCMs replacement quantities must meet the requirements of Subsection 551.03.2(A)(5).
- Use compatible air entraining, water reducing and/or super-plasticizing admixtures.
- Mix requires trial batch surface resistivity test results in accordance with AASHTO T 358 greater than 21 kilohm-centimeters at 28 days. Rapid chloride permeability test results in accordance with AASHTO T 277 less than 2000 coulombs at 28 days or 1500 coulombs at 56 days will also be accepted.
- Submit a batching sequence procedure with the mix design including the amount of material charged and the time before the next material will be added. Include approximate mixer revolutions for each stage of the sequence.

Alternative mix designs not in accordance with Table 551-3 may be accepted provided the following requirements are met:

1. Include in the design compressive strength test results according to AASHTO T 22 for 3, 7, and 28 days. The design must produce strengths in accordance with Table 551-3 by the specified age.
2. Include in the mix design shrinkage test results according to AASHTO T 160. The maximum allowed shrinkage for mix design acceptance is .0300% at 28 days.
3. Include in the mix surface resistivity test results in accordance with AASHTO T 358 greater than 21 kilohm-centimeters at 28 days.
4. Include in the mix design creep test results at 28 days according to ASTM C512.
5. Include in the mix design modulus of elasticity (MOE) results according to ASTM C469.
6. Include in the mix design air-void spacing results according to ASTM C457 modified point-count method at 100x magnification. The average of all tests must not exceed 0.009 inches (0.230 mm) with no single test greater than 0.010 inches (0.260 mm). The total air content must exceed 5.5%.
7. Design and produce concrete maintaining a plastic air content of 5.5% - 8.5%.
8. Submit a batching sequence procedure with the mix design including the amount of material charged and the time before the next material will be added. Include approximate mixer revolutions for each stage of the sequence.

E. Controlled Low Strength Material (CLSM).

Furnish aggregates in accordance with Table 551-4 or Table 701-2.

H. Class Pre Concrete. Design and produce Class Pre concrete in accordance with Table 551-3.

Alternative mix designs not in accordance with Table 551-3 may be accepted provided the following requirements are met.

Deleted: batch rapid chloride permeability test results in accordance with AASHTO T 277 less than 1500 coulombs at 28 days or surface

Deleted: TP 95

Deleted: 35

Deleted: .

Deleted: design rapid chloride permeability (RCP) test results according to AASHTO T 277. The design must demonstrate a maximum of 1500 coulombs at 28 days.

Deleted: .

Deleted: Include the following in the mix design.

Formatted: Font: Bold

Formatted: Indent: Left: 0.5", First line: 0.25", No bullets or numbering

Formatted: Font: Not Bold

1. Include in the design compressive strength test results according to AASHTO T 22 for 3, 7, and 28 days. Also include strength tests at intended de-tensioning/release times (e.g. 12 hrs, 16 hrs, 24 hrs, etc.) The 28-day results must exceed specified strength.
2. Include in the mix design shrinkage test results according to AASHTO T 160.
3. Include in the mix design creep test results at 28 days according to ASTM C512.
4. Include in the mix design MOE results according to ASTM C469.

Deleted: The maximum allowed shrinkage for mix design acceptance is .0350% at 28 days.

551.03.3 Batching, Mixing, Handling and Sampling

Produce each class of specified concrete from approved material batched in the proportions specified in the approved mix design.

Correct for moisture content variations. All concrete aggregates are sampled using methods described in MT 201 using sample sizes used in MT 202. MT 122 will be used to calculate combined gradations.

Deleted: 224

The water may be proportioned by weight or volume. Proportion the cement and aggregates by weight.

The temperature of the combined material must be less than 130 °F (54 °C) before the addition of cementitious materials.

Meet the requirements of ASTM C94 for all concrete batch plants and operations prior to and throughout production of concrete for any work, including concrete for any field trial batches. In addition to ASTM C94, meet the following requirements throughout the production of concrete:

551.03.7 Curing Concrete

Continuously water cure any class of concrete used for bridge deck construction for 14 calendar days as specified below.

Continuously water cure class Overlay-SF for 7 calendar days as specified below.

Continuously water cure class Overlay-LM for 72 hours as specified below, followed by a dry cure. Begin the dry cure at the end of the 72-hour wet cure period by removing the burlap and the polyethylene. Allow the concrete to undergo 48 hours of dry cure. Keep the bridge closed to traffic an additional 48 hours if the air temperature falls below 50 °F (10 °C) during the cure. Allow no traffic on the overlay surface until the end of the dry cure and the transverse deck grooving has been completed.

Continuously cure all other concrete surfaces for 7 calendar days by either water curing or liquid membrane-forming curing compound as specified below. Design strength must be verified by field-cured cylinders in accordance with AASHTO T 22.

Do not place curing compounds on concrete that is still bleeding.

Protect freshly placed concrete from freezing, high temperatures, large temperature differentials, premature drying, excessive moisture, and moisture loss for the period of time necessary to develop the desired concrete properties.

Protect exposed concrete surfaces from premature drying by covering with canvas, plastic sheets with sealed joints, burlap, or other approved materials. Keep the concrete moist. Continually moisten uncovered surfaces by fogging. Do not allow water to drip, flow, or puddle on the concrete surface during fog misting, when placing the burlap, or at any time before the concrete has achieved final set. Do not use intermediate monomolecular film curing agents (evaporation retarders) as a method to reduce moisture loss.

The concrete surfaces against forms may be cured by leaving the forms in place for at least 7 calendar days.

Keep the concrete surfaces moist after removing forms until surface repair is completed and one of the final cure methods described below is used. Surface repair includes removal of irregularities and repair of all depressions, voids, and air holes.

After placement, cure concrete surfaces as follows:

A. Water Cure. Keep all finished top surface concrete moist with a fine water mist until the burlap is placed.

Place wet burlap in accordance with Subsection 717.01.2 immediately behind concreting operations no later than 15 minutes after finishing. Do not use products having a laminated moisture barrier. Soak burlap for a minimum of 24 hours before use. Keep the burlap wet until concrete reaches sufficient strength to place soaker hoses or other effective means of providing moisture without marring the surface. Once a watering system is placed, place an approved reflective type sheeting or blanket over the watering system in accordance with Subsection 717.01.1 and cover to reduce evaporation. The entire concrete surface must remain moist throughout the full cure period. Ensure the temperature of all water used in the water cure is within 20 °F (11 °C) of the in-place concrete temperature. Secure covers and sheeting to prevent them from being lifted or displaced.

B. Liquid Membrane-Forming Curing Compound. Furnish and uniformly apply a liquid membrane-forming curing compound in accordance with Subsection 717.01.3 or 717.01.4 over exposed surfaces.

Deliver membrane-curing compound to the job in the manufacturer's original container, clearly labeled with the manufacturer's name and contents.

The compound must be ready to use as shipped by the manufacturer. Do not dilute the compound.

Do not use curing compound without providing the Project Manager a manufacturer's product data sheet.

Use white-pigmented compound for pavements.

Use products in accordance with 717.01.4 on curbs, sidewalks, and barrier rail. Use a product in accordance with 717.01.3 on substructure components, superstructure components other than those requiring a water cure, and all other exposed concrete surfaces. Ensure products furnished in accordance with Subsection 717.01.3 are clear and contain a fugitive dye that makes the film visible on the concrete for at least 4 hours after application but does not affect the concrete surfaces natural color after curing.

Thoroughly mix and apply the compound following the manufacturer's instructions or apply at a rate exceeding 1 gallon per 150 square feet (0.27 L/m^2) and ensure complete coverage with no transparent areas showing obvious color differential.

Apply the curing compound immediately after the finishing operation using a mechanical pressure distribution system to provide uniform coverage. During windy conditions, equip the spray nozzles with hoods.

When concrete is placed in forms, immediately apply the curing compound after form removal if the concrete has not reached its design strength.

A hand-operated sprayer providing uniform coverage may be used to apply liquid curing compound to areas where a mechanical sprayer is impractical.

Deleted: If an intermediate monomolecular film curing agent (evaporation retarder) is used, apply the monomolecular film in a light-fog application, using a pressure spray tank with an adjustable nozzle. Use a water-to-curing agent ratio and rate of application, both according to the manufacturer's recommendations. Agitate the solution before each application.¶
Apply the monomolecular film immediately after the final finishing operation is completed on any area. Do not perform finishing after application of the curing agent.¶
Use of an evaporation retarder must be approved before use by the Project Manager. Furnish a product data sheet to the Project Manager before approval.¶

Deleted: clear compound containing a fugitive dye on curbs, sidewalks, barrier rail,

Deleted: and

Deleted: The

Deleted: compound must

If the curing membrane is damaged from any cause during the curing period, re-coat the damaged areas immediately.

Do not apply membrane-curing compound to construction joint surfaces. Protect exposed steel during application of curing compounds.

551.03.8 Testing and Acceptance of Concrete

A. Pre-testing of Concrete (Classes Structure, Deck and Overlay). Pre-testing is not required for concrete placements smaller than 7 cubic yards (m^3). The Department will perform pre-tests for air content and slump at the start of each concrete production run and any time there is a significant change in the pumping configuration or concrete placement as determined by the Project Manager. Meet the following requirements:

1. Discharge and waste a minimum of 0.25 cubic yards (0.2 cubic meters) of concrete.
2. Collect a sample.
3. If slump and air content pre-tests indicate the sampled concrete meets applicable specifications, placement may begin.
4. If a pre-test produces a failing result, the truck may be dosed with approved admixtures included in the mix design, in accordance with Subsection 551.03.3(H).
5. If the pre-test again produces a failing result, the truck will be rejected. The testing process will be repeated on subsequent trucks until passing air and slump results are achieved. Pre-test results are not used for concrete lot acceptance.

B. **Sampling and Testing.** Furnish an adequate and representative sample of concrete in accordance with MT 105 from the point of placement to an area designated by the Project Manager for testing of concrete properties and molding of test specimens. Do not drop or agitate samples. The sampling and transport must be witnessed by the Department. The Department will take possession of the sample and begin the following applicable tests.

1. **Compressive Strength Testing.** Furnish samples for determining compressive strength following MT 105. Test cylinders will be cast and cured following MT 101 and tested in accordance with AASHTO T 22 at a frequency determined by MT 601**.** Test cylinders for SCC will be cast and cured in accordance with MT 117. Compressive strength tests may be molded at any time if inconsistency between batches is identified or suspected. A compressive strength set consists of 4 test cylinders made at the same time from the same batch of concrete. Tests for plastic properties will also be run from the same sample used for compressive strength tests.

   The Contractor may make additional cylinders to determine strength gain and to maintain job control. Make additional cylinders anytime strengths must be determined before 7 days for cure times, form removal, post-tensioning, or any other scenario requiring field-cured strength tests.

   Standard compressive strength tests will be made at 7 and 28 days, except as specified below for concrete used in prestressed members.

   The compressive strength results of the cylinders tested will determine if the concrete meets the required compressive strength in Table 551-3 or specified in the contract.
2. **Testing of Plastic Concrete.** Perform quality control sampling/testing during the concrete placement, including air content, temperature, and slump to maintain job control.

Furnish samples for determining slump, air, and temperature in accordance with MT 105. Slump will be tested in accordance with MT 104. Air content will be determined in accordance with MT 102. Temperature will be tested in accordance with ASTM C1064 at a frequency determined in accordance with MT 601. Plastic properties tests may be run at any time if inconsistency between batches is identified or suspected.

Slump flow and air content for SCC will be evaluated in accordance with MT 116 and MT 118.

Deleted: 119

Plastic concrete will also be subjected to a visual test for segregation. If segregation is identified by a "halo", bleeding, aggregate agglomerations, or aggregate settlement (identified by a high sheen or bubbling) during the slump test, do not place the concrete. Take immediate steps to resolve the problem. Remove and replace any concrete placed showing signs of segregation at no expense to the department.

3. **Flexural Strength Testing.** In addition to the compressive strength requirements, Class Pave hydraulic cement concrete pavements require beam tests to determine the concretes flexural strength.

   The number of flexural strength tests required for acceptance is determined by the Department on a random basis. The flexural strength results from 1 or a combination of the beams tested will be used to determine whether the concrete meets the required flexural strength specified in Table 551-3.

   Flexural beams made in the field will be cast and cured in accordance with MT 101 and tested in accordance with AASHTO T 97.

4. **Durability Testing.** When applicable, furnish samples for determining permeability following MT 105. Test cylinders will be cast and cured following MT 101 and tested in accordance with AASHTO T 358.

   Deleted: AASHTO T 277 or

   Deleted: TP 95

   The Department may test hardened air content in accordance with ASTM C457 for acceptance.

5. **Gradations.** Samples for determining gradations of aggregates for concrete will be sampled in accordance with MT 201 and tested in accordance with MT 202. Combined gradations are determined in accordance with MT 215.

C. **Acceptance of Concrete.** The concrete must meet all contract specifications and the following:

1. **Classes General, Deck, Pave, Structure, Overlay and Drilled Shaft Concrete.** These classes of concrete are evaluated for acceptance on a lot-by-lot basis.

   An individual lot is defined as a single days pour or every 200 yd^3 (150 m^3) of concrete poured (i.e. 200 yd^3 = 1 lot, 400 yd^3 = 2 lots, etc.) whichever is less, excluding Class Pave. An individual lot of Class Pave concrete is defined as a single day's pour or every 1,000 yd^3 (750 m^3) of concrete poured, whichever is less. Each lot is accepted or rejected based on the lot acceptance air tests, strength tests, gradation tests and when applicable, permeability tests. The pay factors for each lot accepted are determined from Table 551-5, 551-6, 551-7 and 551-8.

   The overall lot pay factor (OLPF) will be calculated for each bid item that has concrete as a component poured on the project and will be applied as a line item adjustment on the estimate.

Except for concrete barrier rail, pay factors will not be calculated for precast items. Concrete barrier rail will be tested and accepted the same as cast in place items.

a. Strength. A minimum of 2 standard compressive strength sets will be made for each lot. Each set will be made from concrete taken from a separate batch or load randomly selected from all loads or batches in the lot. For a lot less than 30 cubic yards (23 m^3), the Project Manager may elect to make 1 set of compressive strength cylinders to represent that lot.

Three cylinders from each set of cylinders are tested for compressive strength at 28 days and the fourth is tested at 7 days. The test result is the average of the strengths of the 3 individual 28 day cylinder specimens unless an outlier is identified.

The Department will analyze the test results for outliers. The results of the 2 specimens with the closest compressive strengths will be averaged. If the strength result of the remaining cylinder differs by more than 10% from that average, it will be considered an outlier. If an outlier is identified, that specimen will be removed and, the average strength of the set will be determined using the remaining 2 specimens.

The lot acceptance strength is the average of all sets for the lot.

TABLE 551-5
CONCRETE STRENGTH PAY FACTORS

Strength Pay Factors Classes Deck, Overlay, Structure, General, Pave, and Drilled Shaft Concrete lot acceptance strength, x psi (1 psi = 6.9 kPa)	
strength, x (psi)	**strength pay factor, PF_S**
x ≥ 4,000	$PF_S = 1.0$
4,000 > x ≥ 3,500	$PF_S = 1.0 - \frac{0.15(4000 - x)}{500}$
3,500 > x ≥ 2,800	$PF_S = 0.85 - \frac{0.85(3500 - x)}{700}$
2,800 > x	PF_S = 0, remove and replace

The pay factors shown will be used when the department determines the concrete is acceptable at less than the specified strength. The Department may require removal and replacement or corrective action for any concrete not in accordance with the required strength.

b. Air Content Concrete air content will be determined in accordance with MT 102 or ASTM C457 on the same sample used to make the compression test cylinders for acceptance and on samples taken according to MT 601. A separate air content pay factor will be computed for each test result and the lot air content pay factor will be the average of the individual test result pay factors. The pay factor for each lot based on air content is determined from Table 551-6.

TABLE 551-6
AIR CONTENT PAY FACTORS

Lot Acceptance, Air Content			
Classes General, Pave, Deck, Overlay, and Structure Concrete		Used when mix design incorporates ≥ 1½-inch nominal maximum aggregate gradation	
Air content, x (%)	Air content pay factor, PF_{AC}	Air content, x (%)	Air content pay factor, PF_{AC}
x ≥ 5.5%	$PF_{AC} = 1.0$	x ≥ 4.5%	$PF_{AC} = 1.0$
5.5% > x ≥ 4.5%	$PF_{AC} = 1.0 - 0.1(5.5 - x)$	4.5% > x ≥ 4.0%	$PF_{AC} = 1.0 - 0.2(4.5 - x)$
4.5% > x ≥ 3.0%	$PF_{AC} = 0.9 - 0.6(4.5 - x)$	4.0% > x ≥ 2.5%	$PF_{AC} = 0.9 - 0.6(4.0 - x)$
3.0% > x	Remove and Replace	2.5% > x	Remove and Replace

The pay factors shown will be used when the department determines the air content of the in-place concrete is acceptable at percentages less than specified. The Department may require removal and replacement or corrective action for any concrete not in accordance with the required air contents.

In addition to the air content pay factor, coating concrete with an approved penetrating epoxy sealer at no cost to the Department will be required any time concrete having an air content less than 4.0% (3.5% for concrete containing 1½-inch nominal aggregate) for Classes Deck, Overlay, and Structure concrete allowed to remain in place.

Air content pay factors will not be used on Class Drilled Shaft concrete.

c. Permeability. Concrete permeability will be determined at 28 days in accordance with AASHTO T 358 (Table 551-7). At least one set of compressive strength cylinders per lot will also be tested for permeability. The lot acceptance permeability is the average of the test results for the lot. The pay factor for each lot based on permeability is determined from Table 551-7.

TABLE 551-7
CONCRETE PERMEABILITY PAY FACTORS (COULOMBS)

Lot Acceptance, Permeability, x (kΩ-cm) Classes Deck and Overlay[1]	
lot chloride permeability test result, x (kΩ-cm)	**permeability pay factor, PF_P**
x ≥ 29	$PF_P = 1.05$
29 > x ≥ 21	$PF_P = 1.05 - \frac{0.05(29 - x)}{8}$
21 > x ≥ 16	$PF_P = 1.00 - \frac{0.30(21 - x)}{5}$
16 > x	0.70

Note 1: If Class Structure is specified for a bridge deck, the incentive may be paid, but no deduction will occur for permeability results.

Deleted: either
Deleted: T 277
Deleted:
Deleted: A minimum of 1 set of 3 cylinders will be cast per lot following MT 101 for testing permeability.
Deleted: coulomb
Deleted: coulombs
Deleted: 1,500 ≥ x
Deleted: $x - 1500$
Deleted: 500
Deleted: 2,000 ≥ x > 1,500
Deleted: $x - 2000$
Deleted: 1000
Deleted: 3,000 ≥ x > 2,000
Deleted: x > 3,000

The pay factors shown will be used when the department determines the permeability of the in-place concrete is acceptable with results less than specified. The Department may require removal and replacement or corrective action for any concrete not in accordance with the required permeability.

d. Gradation. Concrete aggregate gradations will be determined in accordance with MT 202 or MT 215, if applicable. A minimum of one gradation test will be performed per 200 cubic yards (150 m^3) excluding class Pave. The test result will be used in the OLPF calculation for each lot of concrete placed within that 200 cubic yards (150 m^3). For class Pave, a minimum of one gradation test will be performed per 1000 cubic yards (750 m^3).

1) Conventional Gradations. For concrete designed with conventional gradations, the Department will calculate the pay factor for the gradation using the following formula.

$$PF_G = 1.0 - \frac{(x)}{1000}$$

Where:
x = The sum of the individual percentages out of range on each aggregate fraction.
PF = Pay Factor

2) Optimized Gradations. For concrete designed with optimized gradations the Department will calculate the pay factor for the gradation using the following formula

$$PF_G = 1.0 - \frac{0.25(x) + 2(y)}{250}$$

Where:
x = The sum of percentages out of tolerance on each individual aggregate fraction (rounded to the whole number).
y = Percentage out of tolerance on the No. 200 (0.075 mm) sieve fraction (reported to the tenth of a percent).
PF = Pay Factor
If all gradation tests in the lot produce passing results, the following pay factor will be used:

PF_G=1.02

Deleted: reported

The following formulas are used to calculate the OLPF and unit price adjustment ADJ. All pay factors (PF_S, PF_P, PF_{AC}, and PF_G) must be 1.00 or greater for the production lot to be eligible for positive ADJ (incentive). If any individually calculated pay factor (PF_S, PF_P, PF_{AC}, and PF_G) is less than 1.00, the maximum value for its companion pay factor (PF_S, PF_P, PF_{AC}, and PF_G) to be used in the OLPF calculation for the respective production lot will not exceed 1.00. No OLPF can exceed 1.07.

$$OLPF = PF_S \times PF_{AC} \times PF_P \times PF_G$$
$$ADJ = (OLPF - 1) \times Price$$

Where
ADJ = Price adjustment per pay unit to be applied to the production lot quantity
Price = Contract unit price for the pay item

If a pay factor is not applicable to a specific class of concrete, the pay factor (PF) will be 1.00. Use Table 551-9 to determine pay factors applicable to specific classes of concrete.

TABLE 551-9
PAY FACTORS FOR CONCRETE

PF Type	Deck	Overlay	Structure	General	Drilled Shaft	Pave
PF_S	X	X	X	X	X	X
PF_{AC}	X	X	X	X		X
PF_P	X	X				
PF_G	X	X	X	X	X	X

COMMENTS:

1. 551.03.2 B. 3. Says, "Include in the mix surface resistivity test results …"
   It should say, Include in the mix design surface resistivity test results …

   Response: Agreed.

551.03.2 Composition of Concrete

C. Class Deck and Overlay-SF. Design and produce class Deck and Overlay-SF concrete in accordance with Table 551-3 and the following:

- Use silica fume. Include fly ash and/or GGBFS as SCMs.
- SCMs replacement quantities must meet the requirements of Subsection 551.03.2(A)(5).
- Use compatible air entraining, water reducing and/or super-plasticizing admixtures.
- Mix requires trial batch surface resistivity test results in accordance with AASHTO T 358 greater than 21 kilohm-centimeters at 28 days. Rapid chloride permeability test results in accordance with AASHTO T 277 less than 2000 coulombs at 28 days or 1500 coulombs at 56 days will also be accepted.

- Submit a batching sequence procedure with the mix design including the amount of material charged and the time before the next material will be added. Include approximate mixer revolutions for each stage of the sequence.

Alternative mix designs not in accordance with Table 551-3 may be accepted provided the following requirements are met:

1. Include in the design compressive strength test results according to AASHTO T 22 for 3, 7, and 28 days. The design must produce strengths in accordance with Table 551-3 by the specified age.
2. Include in the mix design shrinkage test results according to AASHTO T 160. The maximum allowed shrinkage for mix design acceptance is .0300% at 28 days.
3. Include in the mix design surface resistivity test results in accordance with AASHTO T 358 greater than 21 kilohm-centimeters at 28 days.
4. Include in the mix design creep test results at 28 days according to ASTM C512.
5. Include in the mix design modulus of elasticity (MOE) results according to ASTM C469.
6. Include in the mix design air-void spacing results according to ASTM C457 modified point-count method at 100x magnification. The average of all tests must not exceed 0.009 inches (0.230 mm) with no single test greater than 0.010 inches (0.260 mm). The total air content must exceed 5.5%.
7. Design and produce concrete maintaining a plastic air content of 5.5% - 8.5%.
8. Submit a batching sequence procedure with the mix design including the amount of material charged and the time before the next material will be added. Include approximate mixer revolutions for each stage of the sequence.

F. Controlled Low Strength Material (CLSM).

Furnish aggregates in accordance with Table 551-4 or Table 701-2.

I. Class Pre Concrete. Design and produce Class Pre concrete in accordance with Table 551-3.

Alternative mix designs not in accordance with Table 551-3 may be accepted provided the following requirements are met.

5. Include in the design compressive strength test results according to AASHTO T 22 for 3, 7, and 28 days. Also include strength tests at intended de-tensioning/release times (e.g. 12 hrs, 16 hrs, 24 hrs, etc.) The 28-day results must exceed specified strength.
6. Include in the mix design shrinkage test results according to AASHTO T 160.
7. Include in the mix design creep test results at 28 days according to ASTM C512.
8. Include in the mix design MOE results according to ASTM C469.

551.03.3 Batching, Mixing, Handling and Sampling

Produce each class of specified concrete from approved material batched in the proportions specified in the approved mix design.

Correct for moisture content variations. All concrete aggregates are sampled using methods described in MT 201 using sample sizes used in MT 202. MT 122 will be used to calculate combined gradations.

The water may be proportioned by weight or volume. Proportion the cement and aggregates by weight.

The temperature of the combined material must be less than 130 °F (54 °C) before the addition of cementitious materials.

Meet the requirements of ASTM C94 for all concrete batch plants and operations prior to and throughout production of concrete for any work, including concrete for any field trial batches. In addition to ASTM C94, meet the following requirements throughout the production of concrete:

551.03.7 Curing Concrete

Continuously water cure any class of concrete used for bridge deck construction for 14 calendar days as specified below.

Continuously water cure class Overlay-SF for 7 calendar days as specified below.

Continuously water cure class Overlay-LM for 72 hours as specified below, followed by a dry cure. Begin the dry cure at the end of the 72-hour wet cure period by removing the burlap and the polyethylene. Allow the concrete to undergo 48 hours of dry cure. Keep the bridge closed to traffic an additional 48 hours if the air temperature falls below 50 °F (10 °C) during the cure. Allow no traffic on the overlay surface until the end of the dry cure and the transverse deck grooving has been completed.

Continuously cure all other concrete surfaces for 7 calendar days by either water curing or liquid membrane-forming curing compound as specified below. Design strength must be verified by field-cured cylinders in accordance with AASHTO T 22.

Do not place curing compounds on concrete that is still bleeding.

Protect freshly placed concrete from freezing, high temperatures, large temperature differentials, premature drying, excessive moisture, and moisture loss for the period of time necessary to develop the desired concrete properties.

Protect exposed concrete surfaces from premature drying by covering with canvas, plastic sheets with sealed joints, burlap, or other approved materials. Keep the concrete moist. Continually moisten uncovered surfaces by fogging. Do not allow water to drip, flow, or puddle on the concrete surface during fog misting, when placing the burlap, or at any time before the concrete has achieved final set. Do not use intermediate monomolecular film curing agents (evaporation retarders) as a method to reduce moisture loss.

The concrete surfaces against forms may be cured by leaving the forms in place for at least 7 calendar days.

Keep the concrete surfaces moist after removing forms until surface repair is completed and one of the final cure methods described below is used. Surface repair includes removal of irregularities and repair of all depressions, voids, and air holes.

After placement, cure concrete surfaces as follows:

B. Water Cure. Keep all finished top surface concrete moist with a fine water mist until the burlap is placed.

Place wet burlap in accordance with Subsection 717.01.2 immediately behind concreting operations no later than 15 minutes after finishing. Do not use products having a laminated moisture barrier. Soak burlap for a minimum of 24 hours before use. Keep the burlap wet until concrete reaches sufficient strength to place soaker hoses or other effective means of providing moisture without marring the surface. Once a watering system is placed, place an approved reflective type sheeting or blanket over the watering system in accordance with Subsection 717.01.1 and cover to reduce evaporation. The entire concrete surface must remain moist throughout the full cure period. Ensure the temperature of all water used in the water cure is within 20 °F (11 °C)

of the in-place concrete temperature. Secure covers and sheeting to prevent them from being lifted or displaced.

B. Liquid Membrane-Forming Curing Compound. Furnish and uniformly apply a liquid membrane-forming curing compound in accordance with Subsection 717.01.3 or 717.01.4 over exposed surfaces.

Deliver membrane-curing compound to the job in the manufacturer's original container, clearly labeled with the manufacturer's name and contents.

The compound must be ready to use as shipped by the manufacturer. Do not dilute the compound.

Do not use curing compound without providing the Project Manager a manufacturer's product data sheet.

Use white-pigmented compound for pavements.

Use products in accordance with 717.01.4 on curbs, sidewalks, and barrier rail. Use a product in accordance with 717.01.3 on substructure components, superstructure components other than those requiring a water cure, and all other exposed concrete surfaces. Ensure products furnished in accordance with Subsection 717.01.3 are clear and contain a fugitive dye that makes the film visible on the concrete for at least 4 hours after application but does not affect the concrete surfaces natural color after curing.

Thoroughly mix and apply the compound following the manufacturer's instructions or apply at a rate exceeding 1 gallon per 150 square feet (0.27 L/m^2) and ensure complete coverage with no transparent areas showing obvious color differential.

Apply the curing compound immediately after the finishing operation using a mechanical pressure distribution system to provide uniform coverage. During windy conditions, equip the spray nozzles with hoods.

When concrete is placed in forms, immediately apply the curing compound after form removal if the concrete has not reached its design strength.

A hand-operated sprayer providing uniform coverage may be used to apply liquid curing compound to areas where a mechanical sprayer is impractical.

If the curing membrane is damaged from any cause during the curing period, re-coat the damaged areas immediately.

Do not apply membrane-curing compound to construction joint surfaces. Protect exposed steel during application of curing compounds.

551.03.8 Testing and Acceptance of Concrete

A. Pre-testing of Concrete (Classes Structure, Deck and Overlay). Pre-testing is not required for concrete placements smaller than 7 cubic yards (m^3). The Department will perform pre-tests for air content and slump at the start of each concrete production run and any time there is a significant change in the pumping configuration or concrete placement as determined by the Project Manager. Meet the following requirements:

1. Discharge and waste a minimum of 0.25 cubic yards (0.2 cubic meters) of concrete.
2. Collect a sample.
3. If slump and air content pre-tests indicate the sampled concrete meets applicable specifications, placement may begin.
4. If a pre-test produces a failing result, the truck may be dosed with approved admixtures included in the mix design, in accordance with Subsection 551.03.3(H).

5. If the pre-test again produces a failing result, the truck will be rejected. The testing process will be repeated on subsequent trucks until passing air and slump results are achieved. Pre-test results are not used for concrete lot acceptance.

B. Sampling and Testing. Furnish an adequate and representative sample of concrete in accordance with MT 105 from the point of placement to an area designated by the Project Manager for testing of concrete properties and molding of test specimens. Do not drop or agitate samples. The sampling and transport must be witnessed by the Department. The Department will take possession of the sample and begin the following applicable tests.

1. **Compressive Strength Testing.** Furnish samples for determining compressive strength following MT 105. Test cylinders will be cast and cured following MT 101 and tested in accordance with AASHTO T 22 at a frequency determined by MT 601**.** Test cylinders for SCC will be cast and cured in accordance with MT 117. Compressive strength tests may be molded at any time if inconsistency between batches is identified or suspected. A compressive strength set consists of 4 test cylinders made at the same time from the same batch of concrete. Tests for plastic properties will also be run from the same sample used for compressive strength tests.

   The Contractor may make additional cylinders to determine strength gain and to maintain job control. Make additional cylinders anytime strengths must be determined before 7 days for cure times, form removal, post-tensioning, or any other scenario requiring field-cured strength tests.

   Standard compressive strength tests will be made at 7 and 28 days, except as specified below for concrete used in prestressed members.

   The compressive strength results of the cylinders tested will determine if the concrete meets the required compressive strength in Table 551-3 or specified in the contract.

2. **Testing of Plastic Concrete.** Perform quality control sampling/testing during the concrete placement, including air content, temperature, and slump to maintain job control.

   Furnish samples for determining slump, air, and temperature in accordance with MT 105. Slump will be tested in accordance with MT 104. Air content will be determined in accordance with MT 102. Temperature will be tested in accordance with ASTM C1064 at a frequency determined in accordance with MT 601. Plastic properties tests may be run at any time if inconsistency between batches is identified or suspected.

   Slump flow and air content for SCC will be evaluated in accordance with MT 116 and MT 118.

   Plastic concrete will also be subjected to a visual test for segregation. If segregation is identified by a “halo”, bleeding, aggregate agglomerations, or aggregate settlement (identified by a high sheen or bubbling) during the slump test, do not place the concrete. Take immediate steps to resolve the problem. Remove and replace any concrete placed showing signs of segregation at no expense to the department.

3. **Flexural Strength Testing.** In addition to the compressive strength requirements, Class Pave hydraulic cement concrete pavements require beam tests to determine the concretes flexural strength.

   The number of flexural strength tests required for acceptance is determined by the Department on a random basis. The flexural strength results from 1 or a combination of the beams tested will be used to determine whether the concrete meets the required flexural strength specified in Table 551-3.

   Flexural beams made in the field will be cast and cured in accordance with MT 101 and tested in accordance with AASHTO T 97.

4. **Durability Testing.** When applicable, furnish samples for determining permeability following MT 105. Test cylinders will be cast and cured following MT 101 and tested in accordance with AASHTO T 358.

   The Department may test hardened air content in accordance with ASTM C457 for acceptance.

5. **Gradations.** Samples for determining gradations of aggregates for concrete will be sampled in accordance with MT 201 and tested in accordance with MT 202. Combined gradations are determined in accordance with MT 215.

C. Acceptance of Concrete. The concrete must meet all contract specifications and the following:

1. **Classes General, Deck, Pave, Structure, Overlay and Drilled Shaft Concrete.** These classes of concrete are evaluated for acceptance on a lot-by-lot basis.

   An individual lot is defined as a single days pour or every 200 yd^3 (150 m^3) of concrete poured (i.e. 200 yd^3 = 1 lot, 400 yd^3 = 2 lots, etc.) whichever is less, excluding Class Pave. An individual lot of Class Pave concrete is defined as a single day's pour or every 1,000 yd^3 (750 m^3) of concrete poured, whichever is less. Each lot is accepted or rejected based on the lot acceptance air tests, strength tests, gradation tests and when applicable, permeability tests. The pay factors for each lot accepted are determined from Table 551-5, 551-6, 551-7 and 551-8.

   The overall lot pay factor (OLPF) will be calculated for each bid item that has concrete as a component poured on the project and will be applied as a line item adjustment on the estimate.

   Except for concrete barrier rail, pay factors will not be calculated for precast items. Concrete barrier rail will be tested and accepted the same as cast in place items.

   a. **Strength.** A minimum of 2 standard compressive strength sets will be made for each lot. Each set will be made from concrete taken from a separate batch or load randomly selected from all loads or batches in the lot. For a lot less than 30 cubic yards (23 m^3), the Project Manager may elect to make 1 set of compressive strength cylinders to represent that lot.

      Three cylinders from each set of cylinders are tested for compressive strength at 28 days and the fourth is tested at 7 days. The test result is the average of the strengths of the 3 individual 28 day cylinder specimens unless an outlier is identified.

      The Department will analyze the test results for outliers. The results of the 2 specimens with the closest compressive strengths will be averaged. If the strength result of the remaining cylinder differs by more than 10% from that

average, it will be considered an outlier. If an outlier is identified, that specimen will be removed and, the average strength of the set will be determined using the remaining 2 specimens.

The lot acceptance strength is the average of all sets for the lot.

TABLE 551-5
CONCRETE STRENGTH PAY FACTORS

Strength Pay Factors **Classes Deck, Overlay, Structure, General, Pave, and Drilled Shaft Concrete** lot acceptance strength, x psi (1 psi = 6.9 kPa)	
strength, x (psi)	**strength pay factor, PF_S**
x ≥ 4,000	$PF_S = 1.00$
4,000 > x ≥ 3,500	$PF_S = 1.00 - \frac{0.15(4000 - x)}{500}$
3,500 > x ≥ 2,800	$PF_S = 0.85 - \frac{0.85(3500 - x)}{700}$
2,800 > x	PF_S = 0, remove and replace

The pay factors shown will be used when the department determines the concrete is acceptable at less than the specified strength. The Department may require removal and replacement or corrective action for any concrete not in accordance with the required strength.

b. Air Content Concrete air content will be determined in accordance with MT 102 or ASTM C457 on the same sample used to make the compression test cylinders for acceptance and on samples taken according to MT 601. A separate air content pay factor will be computed for each test result and the lot air content pay factor will be the average of the individual test result pay factors. The pay factor for each lot based on air content is determined from Table 551-6.

TABLE 551-6
AIR CONTENT PAY FACTORS

Lot Acceptance, Air Content			
Classes General, Pave, Deck, Overlay, and Structure Concrete		Used when mix design incorporates ≥ 1½-inch nominal maximum aggregate gradation	
Air content, x (%)	Air content pay factor, PF_{AC}	Air content, x (%)	Air content pay factor, PF_{AC}
x ≥ 5.5%	$PF_{AC} = 1.00$	x ≥ 4.5%	$PF_{AC} = 1.00$
5.5% > x ≥ 4.5%	$PF_{AC} = 1.00 - 0.10(5.5 - x)$	4.5% > x ≥ 4.0%	$PF_{AC} = 1.00 - 0.20(4.5 - x)$
4.5% > x ≥ 3.0%	$PF_{AC} = 0.90 - 0.60(4.5 - x)$	4.0% > x ≥ 2.5%	$PF_{AC} = 0.90 - 0.60(4.0 - x)$
3.0% > x	Remove and Replace	2.5% > x	Remove and Replace

The pay factors shown will be used when the department determines the air content of the in-place concrete is acceptable at percentages less than specified.

The Department may require removal and replacement or corrective action for any concrete not in accordance with the required air contents.

In addition to the air content pay factor, coating concrete with an approved penetrating epoxy sealer at no cost to the Department will be required any time concrete having an air content less than 4.0% (3.5% for concrete containing 1½-inch nominal aggregate) for Classes Deck, Overlay, and Structure concrete allowed to remain in place.

Air content pay factors will not be used on Class Drilled Shaft concrete.

c. Permeability. Concrete permeability will be determined at 28 days in accordance with AASHTO T 358 (Table 551-7). At least one set of compressive strength cylinders per lot will also be tested for permeability. The lot acceptance permeability is the average of the test results for the lot. The pay factor for each lot based on permeability is determined from Table 551-7.

TABLE 551-7
CONCRETE PERMEABILITY PAY FACTORS

Lot Acceptance, Permeability, x (kΩ-cm) Classes Deck and Overlay[1]	
lot chloride permeability test result, x (kΩ-cm)	**permeability pay factor, PF_P**
x ≥ 29	$PF_P = 1.05$
29 > x ≥ 21	$PF_P = 1.05 - \frac{0.05(29 - x)}{8}$
21 > x ≥ 16	$PF_P = 1.00 - \frac{0.30(21 - x)}{5}$
16 > x	0.70

Note 1: If Class Structure is specified for a bridge deck, the incentive may be paid, but no deduction will occur for permeability results.

The pay factors shown will be used when the department determines the permeability of the in-place concrete is acceptable with results less than specified. The Department may require removal and replacement or corrective action for any concrete not in accordance with the required permeability.

d. Gradation. Concrete aggregate gradations will be determined in accordance with MT 202 or MT 215, if applicable. A minimum of one gradation test will be performed per 200 cubic yards (150 m^3) excluding class Pave. The test result will be used in the OLPF calculation for each lot of concrete placed within that 200 cubic yards (150 m^3). For class Pave, a minimum of one gradation test will be performed per 1000 cubic yards (750 m^3).

3) Conventional Gradations. For concrete designed with conventional gradations, the Department will calculate the pay factor for the gradation using the following formula.

$$PF_G = 1.00 - \frac{(x)}{1000}$$

Where:
x = The sum of the individual percentages out of range on each aggregate fraction.
PF = Pay Factor

4) **Optimized Gradations.** For concrete designed with optimized gradations the Department will calculate the pay factor for the gradation using the following formula

$$PF_G = 1.00 - \frac{0.25(x) + 2(y)}{250}$$

Where:
x = The sum of percentages out of tolerance on each individual aggregate fraction (each rounded to the whole number).
y = Percentage out of tolerance on the No. 200 (0.075 mm) sieve fraction (rounded to the tenth of a percent).
PF = Pay Factor

If all gradation tests in the lot produce passing results, the following pay factor will be used:

PF_G=1.02

The following formulas are used to calculate the OLPF and unit price adjustment ADJ. All pay factors (PF_S, PF_P, PF_{AC}, and PF_G) must be 1.00 or greater for the production lot to be eligible for positive ADJ (incentive). If any individually calculated pay factor (PF_S, PF_P, PF_{AC}, and PF_G) is less than 1.00, the maximum value for its companion pay factor (PF_S, PF_P, PF_{AC}, and PF_G) to be used in the OLPF calculation for the respective production lot will not exceed 1.00. No OLPF can exceed 1.07.

$$OLPF = PF_S \times PF_{AC} \times PF_P \times PF_G$$
$$ADJ = (OLPF - 1) \times Price$$

Where
ADJ = Price adjustment per pay unit to be applied to the production lot quantity
Price = Contract unit price for the pay item

If a pay factor is not applicable to a specific class of concrete, the pay factor (PF) will be 1.00. Use Table 551-9 to determine pay factors applicable to specific classes of concrete.

TABLE 551-9
PAY FACTORS FOR CONCRETE

PF Type	Deck	Overlay	Structure	General	Drilled Shaft	Pave
PF_S	X	X	X	X	X	X
PF_{AC}	X	X	X	X		X
PF_P	X	X				
PF_G	X	X	X	X	X	X