SECTION 551
PORTLAND CEMENT
CONCRETE

551.01 DESCRIPTION. These are the general requirements for designing portland cement concrete mixtures, the ingredients, mixing, placing, curing, testing and acceptance for all classes and uses of portland cement concrete.

Additional requirements and exceptions to these specifications may be found in other sections concerning the specific use of the portland cement concrete.

551.02 MATERIALS.

551.02.1 Cement. Furnish low-alkali portland cement meeting the requirements of AASHTO M 85 or ASTM C 150, Type I,II, III, IV, or V, as specified.

Furnish Type I,II, or III cement for Class "Pre" concrete.

Do not use Type II-A cement.

Use Type II cement when the type or types is not specified.

Furnish Portland cement meeting the following requirements:

1. A total alkali content not exceeding 0.6 percent, calculated as the percentage of sodium oxide (NaO) plus 0.658 times the percentage of potassium oxide (K_2O);
2. Use only one brand of any one type of cement on the Contract except by written approval from the Engineer. Different brands or grades, if approved, cannot be used alternately in any one pour;
3. Store all bulk cement in metal silos, bins, or other approved storage. Assure storage permits convenient sampling and inspection. Store all sack cement in weatherproof buildings or, if approved, in the open on raised platforms with waterproof covering. Partially set, caked or lumpy cement will be rejected.

551.02.2 Air-Entraining Agents. Add an air-entraining agent to the concrete mixture unless otherwise specified.

Obtain the Engineer's written approval for changes to the air-entraining agent.

Add an air-entraining agent to prestressed concrete when specified or directed.

A. **Testing.** Before using any air-entraining agent, submit test results from a certified laboratory documenting that the agent meets the requirements of AASHTO M 154 (ASTM C 260) for 7 and 28 day compressive strengths and provides freeze-thaw resistance. Tests for bleeding, bond strength, and volume change are not required.

   Tests may be taken on material samples submitted by the Contractor for use on the project or on samples submitted and certified by the manufacturer as representing the air-entraining agent to be supplied.

B. **Certification.** The Contractor may, instead of meeting Subsection 551.02.2(A) requirements, submit certification from the manufacturer attesting that the proposed material meets AASHTO M 154 (ASTM C 260) requirements.

The Department will keep on file, the original certification, giving approval of the material for individual projects by memorandum. Submit a signed statement attesting that the product furnished is the product represented by the manufacturer's certificate. List the name of the product in each certification and Contractor's statement.

The Contractor is responsible for unacceptable results caused by the air-entraining agent.

An air-entraining agent proposed for use or previously approved for other projects, may be used after Department acceptance of the Contractor's certification stating the name of the approved agent.

A proposed air-entraining agent may be used as an approved agent if it has minor differences in concentration and after the Department's acceptance of a Contractor's certification stating the name of the agent and that no other admixture or chemical agent is present.

C. Re-testing. The air-entraining agent may re-tested as necessary.

When re-tested, the concrete cylinders with air entraining agent must reach at least 88% of the compressive strength of the concrete without the air-entraining agent.

The percent strength reduction is calculated from the average strength of at least 5 standard 6 by 12-inch (152 mm X 305 mm) cylinders of each concrete type made and cured using MT-101 and tested under AASHTO T 22.

The percentage of entrained air is determined by MT-102.

Air-entraining agents failing these requirements will be rejected.

D. Addition of Air-Entraining Agent. Add the approved agent or agents to the mixing water.

If an approved metering device is used, its use to control the quantity of air-entraining agent added is acceptable.

E. Adjustments. The aggregate weight specified in the mix design is adjusted for increased yield resulting from air-entrainment. No field adjustment can be made.

The Department's laboratory will make any adjustments required.

551.02.3 Admixtures. Use admixtures only with the Project Manager's written permission.

Admixtures are only approved with certified laboratory test results or satisfactory field performance records to support product claims.

Furnish admixtures meeting ASTM C 494 requirements.

Use admixtures as follows:

1. When a water-reducing admixture is used, the cement content may be reduced not exceeding 10% for all concrete classes except Class "AS", "DS", or "BD Modified". The resulting water cement ratio must not exceed 0.49 or 5½ gallons (21 L) per sack of cement. Compressive strengths must meet Table 551-01 requirements;
2. No admixtures containing calcium chloride are permitted;
3. Notify the Engineer of the type of admixture to be used. Mix designs will not be furnished until this information is received;

4. Introduce admixtures and air-entraining agents separately into the mix water. Do not combine these agents before introducing them into the mixing unit.

551.02.4 Epoxy Adhesives. Furnish epoxy adhesives meeting ASTM C 881 or AASHTO M 234 and ASTM C 883 requirements.

Paragraph 1.4.8 of AASHTO M 234 is amended to permit thinning of epoxy for use in sealing ground deck slab areas only.

Furnish coal tar epoxy coating meeting AASHTO M 200 requirements.

551.02.5 Water. Obtain the Engineer's approval of the water to be used in the concrete. Assure the water does not contain oil, acid, alkali, vegative substances and is not brackish or salty.

Questionable water will be tested by comparing the compressive strength of concrete cubes made with the water in question, against those of concrete cubes made with water of known quality.

The concrete cubes will be cast, cured, and tested for compressive strength under ASTM C 109.

551.02.6 Aggregate. Furnish aggregates meeting Subsection 701.01 requirements.

Store aggregates in compartmented bins, or other methods that separate the different aggregate sizes to prevent contamination. Suspend work for aggregate contamination until corrected.

Build up coarse aggregate stockpiles in successive horizontal layers not exceeding 3 feet (0.9 m) thick. Complete each layer before starting the next one. Re-mix segregated aggregate to the grading requirements at Contractor expense.

When ready-mixed concrete is furnished, the ready-mix company's stockpiled aggregates must meet the aggregate specifications. The Company must establish separate stockpiles for Department work if existing stockpiles do not meet specifications.

Do not use contaminated aggregate removed from stockpiles in the work.

551.02.7 Curing Compounds and Protective Coatings. Furnish concrete curing compounds and protective coatings and combination curing-protective coating compounds meeting Subsection 713.07 requirements.

551.02.8 Preformed Expansion Joint Fillers For Concrete. Furnish preformed expansion joint fillers meeting Subsection 707.01 requirements.

551.03 CONSTRUCTION REQUIREMENTS.

551.03.1 Classification. Concrete is classified as follows:

1. Concrete mixtures with prefixes "A" contain 1½"-inch (37.5 mm) size aggregate;
2. Concrete mixtures with prefixes "D" contain 3/4-inch (19 mm) size aggregate.

   Concrete with prefixes "D" may be substituted for concrete with prefixes "A" when the mix design has been approved by the laboratory.

The following requirements govern:

A. Classes "A" and "D" Concrete. Classes "A" and "D" concrete are used for sidewalks, curbs, and slope protectors.

B. Classes "AD" and "DD" Concrete. Classes "AD" and "DD" concrete are used for all structural concrete.

Class "DD" concrete may be substituted for Class "AD" concrete with the Project Manager's written approval. Bid all structural concrete as Class "AD". If a substitution is made, changing back to Class "AD" must be requested in writing and receive the Project Manager's written approval.

C. Class "BD Modified" Concrete. Class "BD Modified" concrete is used for all superstructure concrete including deck slabs and barriers.

D. Classes "AP" and "DP" Concrete. Classes "AP" and "DP" concrete are used for concrete pavement on streets and highways.

E. Classes "AS" and "DS" Concrete. Classes "AS" and "DS" concrete are used for concrete deposited underwater that does not contain an air-entraining agent.

F. Class "Pre" Concrete. Class "Pre" concrete is used in all prestressed items.

G. Class "F" Concrete. Class "F" concrete is used for setting metal fence posts and braces and similar uses where high quality concrete is not necessary.

Obtain the Project Manager's approval for aggregates for Class "F" concrete.

H. Classes "AC" and "DC" Concrete. Classes "AC" and "DC" concrete are used for erosion control devices.

I. Class "NS" Concrete. Class "NS" concrete is used as a non-shrink backfill for utility cuts in paved roadway sections.

J. Air-Entrained Concrete. Use air-entrained concrete in all parts of structures, except for Classes "AS", "DS", and Pre" concrete.

Do not use an air-entrained portland cement.

1. **Air-Entraining Agents.** Add the approved air-entraining agent to produce an entrained air content within the specified limits for the particular class of concrete.
2. **Entrained Air.** Provide the required air content for each class of concrete shown in Table 551-1.

   Testing for the percent entrained air will be by MT 102 using concrete samples taken just before incorporation in the work.

551.03.2 Composition of Concrete. Furnish the Project Manager with the names of proposed suppliers and locations of proposed aggregate sources upon receipt of the Notice of Contract Award. This information is not required for Class "F", "AC", or "DC" concrete.

Coordinate with the Project Manager for submitting samples for testing.

A. Design. Design the concrete mix as follows:

1. Follow the laboratory mix design for measuring the coarse aggregate, fine aggregate, and the minimum allowable cement volumes into each batch.

2. The Department will furnish a laboratory mix design for each class of concrete, specifying the minimum cement content, the quantity of fine and coarse aggregate, and the maximum quantity of mixing water, as shown in Table 551-1. Make written requests to the Project Manager to increase the cement content in the mix designs.

   The Contractor may submit concrete mix designs to the Project Manager for approval rather than using the Department-furnished mix designs. Have Contractor furnished mix designs be developed by qualified persons following procedures published by the PCA or ACI. Meet the requirements of Table 551-1 for aggregate sizes, minimum cement content, maximum water content, slump, and entrained air limits. Cement content may be increased above the specified minimum to enhance workability or compressive strength. State the design proportions in terms of aggregates in a saturated, surface dry condition, with batch weights adjusted to account for actual moisture content of the aggregates during use. Submit the proposed aggregate source and proportion computations. Submit contractor-furnished mix designs based on aggregates used on highway projects within 1 year for review and approval at least 14 days before use. Submit mix designs based on aggregates from new sources for review at least 33 calendar days before use.
3. Produce all classes of concrete with the required minimum compressive strengths and the minimum flexural strength for Classes "AP" and "DP" concrete. The cement content may be increased to a maximum of 8 bags per cubic yard (10.5 bags per m^3) if approved.
4. Proportion the materials following the approved mix design. If concrete will be placed by pumping, the Engineer may modify the mix design to aide pumping.
5. Use the approved mix design proportions, if the materials are furnished from the originally named sources and meet the specified requirements. Do not exceed the maximum water-cement ratio specified in Table 551-1 for each class of concrete.
6. Do not change the materials source without the Engineer's approval and an approved mix design.
7. Fly ash or Type IP cement may be substituted for portland cement provided the following requirements are met:
   a. Make the substitution at a minimum ratio of 1.2 parts of the substitute to 1 part of portland cement by weight. Do not exceed 20 percent replacement by weight of the total cement.
   b. Portland Cement meeting AASHTO M 85, Table 1, may be used in place of moderate heat of hydration cement where fly ash is substituted.
   c. Do not exceed a 0.53 percent water-cement ratio by weight for all concrete classes except Class " BD Modified ", which is 0.44 percent. For calculation purposes, the cement weight is the total weight of Type IP cement or Portland Cement and replacement fly ash.

d. The 28-day strength of the substitute mix must equal or exceed the 28-day strength of the original mix design.

The strength is determined by testing cylinders cast from trial batches of concrete produced from the two mix designs. Make 5 batches of concrete for each mix design. One cylinder from each of the 5 trial batches of the two concrete mixes will be tested. Equivalency is based on a Student-t distribution test of the difference between the means of 5 tests of each mix at a significance level of 95 percent.

The slump must be within 1-inch (25 mm) of the target value; the air content within 1 percentage point of the midpoint of the allowable range specified in Section 551.03, Table 551-1. Do not exceed the maximum water-cement ratio specified in **c.**

Provide the concrete testing using a certified independent laboratory at Contractor expense. Furnish the Project Manager the certified test results. The Department has the right to verify all test results before concrete production begins. Department mix design approval does not relieve Contractor responsibility to produce concrete of the specified strength.

Follow the above procedure for each concrete class containing a Portland Cement substitute proposed for use.

Do not begin concrete production of any concrete class until testing and satisfactory results for that concrete is complete.

B. Class "F" Concrete. Class "F" concrete is 1 part portland cement, 2 parts of clean, hard, sharp sand passing a #4 mesh (4.75 mm) screen, and 4 parts of clean, broken stone or gravel uniformly graded between the #4 mesh (4.75 mm) and 1 ½-inch (37.5 mm).

Proportion the materials by weight or volume as approved.

Class "A" or "D" concrete may be substituted for Class "F" concrete.

C. Classes "AC" and "DC" Concrete. Classes "AC" and "DC" concrete is low slump concrete meeting Table 551-1 requirements.

Use broken stone or gravel uniformly graded between the #4 mesh (4.75 mm) and the maximum size sieve and clean, hard, sharp sand passing the #4 mesh (4.75 mm) sieve.

Proportion the materials by weight or volume as approved.

Class "A" or "D" concrete may be substituted for Classes "AC" and "DC" concrete.

D. Class "BD Modified" Concrete. Produce Class "BD Modified" concrete meeting Table 551-1 requirements.

Furnish coarse aggregate meeting the gradation requirements for No. 2 coarse aggregate in Table 701-4 of Subsection 701.01.2, with 5 percent maximum passing the No. 8 (2.36 mm) sieve.

Use an approved water-reducing admixture, and a set-retarding water-reducing admixture in deck slabs when ambient temperatures are expected to exceed +60 °F (15 °C) during the pour. No reduction in cement content is permitted because of using the water-reducing admixture.

The minimum cement content in Table 551-1 may be increased to enhance workability at Contractor expense.

Changes in concrete or material sources to maintain compressive strengths may be made, subject to the Project Manager's approval, at Contractor expense.

E. Class "NS" Concrete. Produce Class "NS" concrete composed of the following:

Material	Weight per cu. yd. (kg)
Cement - 0.45 sack	42 lbs (19 kg)
Water - 39 gallons (147.6 L)	325 lbs (147.5 kg)
Coarse Aggregate	1700 lbs (771.8 kg)
Fine Aggregate	1845 lbs (837.6 kg)

Furnish coarse aggregate meeting Subsection 701.01.2 requirements and the number 2 gradation in Table 701-4. Furnish fine aggregate meeting Subsection 701.01.1 requirements. The fine aggregate has no fineness modulus requirement.

TABLE 551-1
CONCRETE PROPORTIONING TABLE

Class	Size of Coarse Aggregate, Square Mesh, Inches (mm)	Minimum Cement Content, 94-lb. Sacks Per CY (0.76 m³)	Indicated Compres-sive Strength 7-Day, PSI (MPa)	Minimum Required Compres-sive Strength 28-Day, PSI (MPa)	Maximum NetWater Content Per Bag of Cement, Gallons (liters)	Target Value for Slump, Inches (mm)	Tolerance Inches (mm)	Required Air Content, Percent
A	1½ (37.5)	5.5	1600 (11)	2400 (17)	6.0 (22.7)	2½ (60)	±¾ (20)	4-6
D	¾ (19)	5.5	1600 (11)	2400 (17)	6.0 (22.7)	2½ (60)	±¾ (20)	5-7
AD	1½ (37.5)	6.5	2000 (14)	3000[3] (21)	6.0 (22.7)	2½ (60)	±¾ (20)	4-6
DD	¾ (19)	6.5	2000 (14)	3000[3] (21)	6.0 (22.7)	2½ (60)	±¾ (20)	5-7
AS	1½ (37.5)	7.0	1600 (11)	2400 (17)	6.0 (22.7)	6 (150)	±2 (50)	—
DS	¾ (19)	7.0	1600 (11)	2400 (17)	6.0 (22.7)	6 (150)	±2 (50)	—
AP[1]	1½ (37.5)	6.0	2000 (14)	Note 3	6.0 (22.7)	1½ (40)	±¾ (20)	4-6
DP[1]	¾ (19)	6.0	2000 (14)	Note 3	6.0 (22.7)	1½ (40)	±¾ (20)	5-7
Pre[2]	¾ (19)	6.5	—	5000 (34)	—	—	—	—
F	1½ (37.5)	—	—	—	6.0 (22.7)	—	—	—
AC	1½ (37.5)	4.5	—	—	6.0 (22.7)	1½ (40)	±¾ (20)	—
DC	¾ (19)	4.5	—	—	6.0 (22.7)	1½ (40)	±¾ (20)	—
BD Mod	¾ (19)	6.5	—	Note 3	5.0 (19)	2½ (60)	±¾ (20)	5-7

NOTES:

[1] For concrete pavement, the 28-day flexural strength requirement is 500 psi (3.5 MPa) minimum, determined by AASHTO T9 (ASTM C 78).

[2] For prestressed beams, the minimum compressive strength at transfer of pre-stress is 4000 psi (28 MPa). The strength shown at transfer of pre-stress and the 28-day requirement are for standard beams and will vary with beam length and design. Check plans and specifications for each project.

[3] The minimum required compressive strength at 28 days listed in the table does not apply to Classes "AD" and "DD" concrete used in bridges and structures. The compressive strengths for acceptance for Classes "AD" and "DD" concrete used in bridges and for Classes "AP", "DP", and "BD Modified" concrete is that specified in Subsection 551.03.7(C)(1).

[4] The target value for slump may be reduced as necessary for concrete placed using slip-form methods.

551.03.3 Sampling, Handling, Batching, and Mixing. Produce each class of specified concrete from approved material batched in the proportions specified in the approved mix design.

Correct for moisture content variations. The fine and coarse aggregates are sampled using methods described in MT-201 using sample sizes used in MT-202.

The water may be proportioned by weight or volume. Proportion the cement, fine aggregate, and coarse aggregates by weight.

The Contractor may substitute approved volumetric measuring devices for weighing devices when batching aggregates for structures containing less than 10 cubic yards (7.65 m^3) of concrete.

Obtain the Engineer's approval of weighing methods before starting batching operations.

A. Water.

1. **Weigh Measurement.** Assure the weigh equipment measurements are not affected by pressure variations in the water supply lines. The Project Manager may require an auxiliary tank for filling the weighing tank.
2. **Metering.** Measure water volume by metering through a recording water-meter device, accurate to within plus or minus 1 percent of the required volume or plus or minus 1 gallon (3.8 L), whichever is greater.

   Meter water for batching and mixing during warm weather operations.

   The Project Manager may permit alternate methods of water measurement for cold weather work.

   Completely discharge wash water from the mixer before starting any batching operation.

B. Cement and Aggregate. Proportion cement and aggregate by weight on all projects exceeding 50 cubic yards (38 m^3) for all classes of concrete.

Assure equipment for weighing cement and aggregates is accurate to within 0.5 percent of the true weight.

Weigh aggregates to within 1.5 percent of the total aggregate batch weight.

Weigh cement or fly ash to within 1.0 percent of the total cement batch weight. Weigh cement separately.

Equip scales for manual operation with a telltale dial or other device to show at least the last 50 pounds (23 kg) of load.

C. Batching Plant. Equip the batching plant with separate bins, weighing hoppers, and scales for fine aggregate and each size coarse aggregate.

If bulk cement is used, include a bin, hopper, and separate scale for the cement. Seal and vent the cement weighing hoppers to prevent dust escaping to the atmosphere.

Equip the batching plant with a non-resettable batch counter that indicates the number of batches proportioned.

A single weighing hopper with an accumulative scale is permitted if a separate scale is used for weighing the cement.

Batch plants will meet the requirements of having a separate scale for weighing the cement if:

1. The cement is always weighed in a separate inner hopper of standard manufacture design; and
2. The cement is always batched and weighed first in the batching sequence;
3. Batch fly ash separately by weight.

For projects exceeding 20,000 square yards (16,720 m²) of Portland Cement Concrete Pavement, proportion aggregates and cement with equipment that weighs and records batch weights automatically.

Provide the Project Manager a printed record of each batches: weight for aggregate; cement; fly ash; volume of water and admixtures; the time mixing began; time batch discharged; haul unit number; and percent moisture in aggregate. The automatic batching equipment above may be used for smaller concrete volumes.

Provide each scale installation with 10 standard 50 pound (23 kg) test weights.

Locate the aggregate sampling device at the nearest practical point the aggregates enter the batching weigh bins. Obtain the Project Manager's approval of the sampling device before batching operations begin.

D. Mixers. Use mixers that combine cement, aggregates, water, and admixtures within the specified time to form a uniformly mixed mass.

Operate mixers following the manufacturers recommendations.

Assure the manufacturer's plate is prominently displayed on the mixer showing the drum capacity in volume of mixed concrete.

Repair or replace mixer blades worn more than 3/4-inch (19 mm) from the design dimensions.

Clean hardened concrete from the drum. Do not intermingle batches.

Uniformity tests on three consecutive batches will be performed on samples taken after 15% and 85% of the batch is discharged.

Table 551-2 specifies the maximum permissible variations in test results on samples from the two different portions of the same batch.

TABLE 551-2
ALLOWABLE BATCH VARIATIONS

Air Content - Volume, percent of concrete	1.0
Slump - Inches	1.0 (25 mm)
Coarse Aggregate Content - Portion by weight of each sample retained on a No 4 sieve (4.75 mm), Percent	6.0
Average compressive strength at 7 days for each sample based on average strength of all comparative test specimens, Percent (two cylinders will be molded and tested for each sample)	7.5

Concrete is acceptable if test results in 2 out of 3 batches meet the limits for 3 out of the 4 tests.

Provide the facilities for sampling and arrange schedules for the sampling and testing.

Dump all concrete mixed less than the specified time outside the work or remove if incorporated, at Contractor expense.

Do not mix, transport, or place concrete using equipment with aluminum or aluminum parts that contact the concrete.

Concrete may be mixed in central plant mixers or in truck mixers meeting the following requirements:

1. **Central Plant Mixers.** Equip central plant mixers with an approved timing device, that automatically locks the discharge device when the drum is charged and releases the lock at the end of the required mixing period. The lock must have an audible warning device, which signals each time the lock is released.

   If the locking and timing device fails, the mixer may be used temporarily, provided the mixing time is increased 50% by using a clock or watch with a second hand located within full view of the mixer operator. Repair or replace the timing device within 3 working days.

   Equip mixers to have a positive mechanical device to prevent adding aggregate after the drum has been charged and mixing has begun.

   Mixing time for central plants is 90 seconds. The required mixing time may be reduced if the plant is capable of producing a homogeneous mix in a shorter time. Reduced mixing time will be approved only if uniformity tests meet Subsection 551.03.3(D) requirements.

2. **Truck Mixers and Agitators.** Use truck-mounted mixers having a closed, watertight revolving drum fitted with blades that thoroughly mix and completely discharge the concrete without segregation.

   Assure the manufacturer's plate showing the rated mixing, agitating capacity and the rated drum speeds for mixing and agitating is attached to the truck mixer and is legible.

Equip truck mixers with an accurate revolution counter that registers the drum revolutions. Mount the counter so it is easily read by both the operator and inspector.

Equip truck mixers with a water-metering device that is accurate to within plus or minus 1% of the required volume or plus or minus 1 gallon (3.8 L), whichever is greater.

The truck mixer metering device is not required if all batch water is added at the plant or other location through an approved metering device.

Operate the drum at the manufactures recommended speeds.

Introduce water, cement, and aggregates at a central plant and add aggregates into the mixer in any sequence that produces a concrete meeting all Contract requirements. Batch cement and water simultaneously.

Water may be added at the job site provided its introduction is witnessed by an inspector and the specified water-cement ratio is not exceeded.

If water is added at the job site, provide at least 20 additional mixing revolutions each time water is added before discharge.

Begin mixing immediately after introducing the cement and water and continue for at least 70 revolutions at mixing speed.

Assure at least 100 drum revolutions exceed 6 revolutions per minute. All revolutions exceeding 100 must be at agitating speed.

Keep the drum revolving continuously after the cement and water are introduced until it is discharged.

Do not use mixed concrete that has remained in the truck mixer drum longer than 10 minutes without agitation.

Concrete may be partially mixed by central plant mixing and completed by truck mixing. Central plant mixing must meet the requirements of Subsection 551.03.3(D)(1), except that the central plant mixing time may be reduced to 30 seconds. Continue the additional truck mixing between 50 and 80 drum revolutions at mixing speed.

E. Hand Mixing. Approval may be given to hand mix batches not exceeding 1/2 cubic yard (0.4 m^3) provided:

1. The hand mixing is performed on watertight platforms or containers;
2. The sand is spread evenly over the platform;
3. The cement is uniformly distributed over the sand and the two ingredients are thoroughly mixed dry using shovels until the mix is uniform in color.

Form the mix into a "crater", add water, turn and slice the entire mass until a uniform consistency is obtained.

Thoroughly wet the coarse aggregate, add it to the mortar, and turn and re-turn the entire mass at least 6 times until all aggregate is thoroughly covered with mortar and the mix is uniform in color and appearance.

Do not place hand mixed concrete underwater.

551.03.4 Transporting Concrete. Assure that the capacity of the plant and transportation equipment provide a delivery rate to permit handling, placing, and finishing of the work.

Time the delivery of loads to prevent the in-place concrete from taking initial set before succeeding layers or lifts are placed. Do not permit any layer or lift of concrete to remain exposed in excess of 20 minutes before being covered by fresh concrete.

Document the method and time of delivery by plant slips issued to the driver and signed by the Inspector at the plant. Deliver the slip to the Project Inspector upon arriving at the project.

A. Revolving Drum Mixers. Transport concrete in revolving drum mixers meeting Subsection 551.03.3(D)(2) requirements.

Discharge the concrete at the job and place it in final position within 1½ hours after introducing the mixing water and cement.

When the ambient temperature is 85 °F (29 °C) or above, place the concrete in final position within 1 hour after the water and cement are introduced.

B. Non-agitating Transportation Equipment. Do not use non-agitating transport equipment to transport concrete except when placing concrete pavement under Section 501.

551.03.5 Placing Concrete. Assure all reinforcement and other embedded items are clean and free from dried mortar, rust, scale, oil, or foreign matter before placing concrete.

Keep untreated forms and existing concrete in contact with fresh concrete wet at least 1 hour before placing the concrete.

Wash treated forms with a water spray immediately before placing the concrete.

Place concrete meeting the applicable requirements of Sections 501, 552, and 553.

Compact concrete into final position and consolidate it around fittings and embedded items.

Do not place Fly ash or Type IP concrete cement in different parts of the same structure before obtaining the Project Manager's approval. Demonstrate that such use will not result in noticeable color changes or appearance.

551.03.6 Curing Concrete. Protect exposed concrete surfaces from premature drying by covering it with canvas, plastic sheets with sealed joints, burlap, sand, or other materials. Keep the concrete moist. Continually moisten uncovered surfaces by misting.

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

Protect concrete against freezing or other conditions harmful to strength development under the applicable requirements of Sections 501, 552, and 553.

To aid finishing, side forms on ornamental work, curbs and sidewalks, railings, and parapets may be removed between 12 and 48 hours after concrete placement.

Continue moist curing while finishing the concrete.

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.

Cure concrete for at least 7 days after the concrete is placed by either of the following methods.

A. Water Curing. Keep all finished top surface concrete moist with a fine water mist until the concrete has set. Keep the moist concrete wet with water or an approved curing cover.

Cure concrete deck slabs and concrete floors by placing burlap, cotton mats, or other absorptive material behind the finishing operation as soon as possible without marring the finished surface. Keep the absorptive material moist while in place.

The absorptive material may be kept in place for the entire curing period, or it may be removed as soon as practical and the entire surface covered with approximately 1½-inches (40 mm) of sand, kept moist for the entire curing period.

B. Impervious Membrane Curing. Use Type 2 white-pigmented membrane curing compound on deck slabs and portland cement concrete pavements.

Use Type 1-D clear membrane curing compound with a translucent fugitive dye for other surfaces.

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

Furnish clear curing compound, transparent and free from permanent color.

The clear compound must 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.

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 certification.

Pressure apply the curing compound, spraying it over the entire exposed surface in a minimum uniform film of one gallon per 150 square feet (0.27 L per square meter) of concrete surface. Pressurize the curing compound to produce a fine mist on the concrete during application.

Apply the curing compound immediately after the concrete finishing is completed.

If it is necessary that workers or equipment be on the concrete surface before the 7 day curing period is complete, cover the sealed surface with a protective cushion. Use a cushion of moist, 1-inch (25 mm) minimum thick layer of fine sand or sufficient layers of moist burlap to prevent damage to the finished concrete. Cover the cushion with 4 feet by 8 feet (1220 mm by 2440 mm) sheets of ¾-inch (20 mm) plywood. Do not place the cushion material until the final application of curing compound has been in place for 8 hours.

Alternate cushion material may be approved by the Project Manager in writing. Layers of plastic, visqueen, or canvas are not permitted.

C. **Application of Combination Curing and Protective Coating Compounds.** When specified, uniformly apply a combination curing and protective coating compound meeting Subsection 713.07 requirements over horizontal surfaces such as pavements, bridge deck slabs, concrete floors, and sidewalks.

Use white-pigmented compound for pavements or deck slabs.

Use a clear compound containing a fugitive dye on curbs, sidewalks, barrier rail, and other superstructure components.

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 per m^2).

Apply the curing compound immediately after the finishing operation using a self-powered machine with a mechanical pressure distribution system to provide uniform coverage. Equip the spray nozzles with hoods during windy conditions.

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

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

551.03.7 Testing and Acceptance of Concrete.

A. **Compressive Strength Testing.**

1. **General.** A compressive strength sample consists of 3 test cylinders made at the same time from the same batch of concrete.

   The Contractor may make additional cylinders to determine strength gain and to maintain job control.

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

   The compressive strength results from one or a combination of the cylinders tested will determine if the concrete meets the required compressive strength in Table 551-1.

   Test cylinders will be cast and cured using MT-101 and tested under AASHTO T 22.

2. **Prestressed Concrete Members.** Standard compressive strength tests for Class "Pre" concrete will be made at 28 days. The average strengths of the three 28-day cylinders will determine acceptance under Subsection 551.03.7(C)(2).

   The Contractor may make additional cylinders for determining strength gain and to maintain job control.

3. **Class "BD Modified" Concrete.** Standard compressive tests for Class "BD Modified" concrete will be made at 7 and 28 days. The average strengths of two 28-day cylinders will determine acceptance under Subsection 551.03.7(C)(1).

B. **Flexural Strength Testing.** In addition to the above compressive strength requirements, Classes "AP" and "DP" portland cement concrete pavement will 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 one or a combination of the beams tested will be used to determine whether the concrete meets the required flexural strength specified in Table 551-1.

Flexural beams made in the field will be cast and cured using MT-101 and tested under AASHTO T 97 (ASTM C 78).

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

1. **Classes "AD", "DD", "BD Modified", "AP", and "DP" Concrete.** These classes of concrete placed in bridges and in concrete pavement are evaluated for acceptance on a lot-by-lot basis.

The concrete quantity placed in a single day is divided into lots of equal quantity under Table 551-3.

TABLE 551-3
CONCRETE LOT QUANTITIES

Classes "AD", "DD", and "BD Modified"	Classes "AP" and "DP"	No. of Lots
100-199 Cu Yd (76.5-152 m^2)	100- 999 Cu Yd (76.5-152 m^2)	1
200-399 Cu Yd (153-305 m^2)	1000-1999 Cu Yd (765-1529 m^2)	2
400-599 Cu Yd (306-458 m^2)	2000-2999 Cu Yd (1530-2294 m^2)	3
600-799 Cu Yd (459-611 m^2)	3000-3999 Cu Yd (295-3059 m^2)	4
800-999 Cu Yd (612-764 m^2)	4000-4999 Cu Yd (3060-3824 m^2)	5

Lots for concrete volumes less than 100 cubic yards (76.5 m^3) in a single day will be formed by combining the quantities for each 2 successive placements.

Two sets of standard 6 x 12-inch (152 X 305 mm) compressive test cylinders will be made for each lot. Each set will be made from a sample taken from a single batch or load selected at random from all loads or batches in the lot.

Each set will consist of 1 cylinder for Classes "AD", "DD", "AP", and "DP" concrete and 2 cylinders for Class "BD Modified" concrete.

Cylinders will be cast and cured using MT-101 and tested under AASHTO T 22.

Each set of cylinders are tested for compressive strength at 28 days. The test results for 2 cylinder sets will be the average of the strengths of the individual cylinders.

The strengths of other cylinders made from the sample and tested at earlier ages are not considered for acceptance.

The lot acceptance strength is the average of the test results for the lot.

Each lot is accepted or rejected based on the lot acceptance test strength. The pay factor for each lot accepted is determined from the following table.

TABLE 551-4
PAY FACTORS

LOT ACCEPTANCE STRENGTH - PSI (1 psi= 6.9 kPa)

Class	1.0	0.95	0.85	0.70
AP,DP,AD,DD	3400 or >	3100-3399	2900-3099	<2900
BD Modified	3900 or >	3500-3899	3300-3499	<3300

The Contractor may request acceptance of a lot at the 0.95 and 0.85 pay factor in lieu of approved corrective work or removal and replacement.

Acceptance at the 0.70 pay factor instead of approved corrective work or removal and replacement will be based on the Engineer's determination of the effects the defective lot will have on structural integrity and durability specified in Subsection 105.03.

The concrete quantity in each accepted lot is paid for at the contract unit price multiplied by the appropriate pay factor in Table 551-4.

The lot quantity for pay factors less than 1.0 is computed from:

a. Plan neat line dimensions of the portions of the bridge or bridges where the lot was placed; or

b. The plan area in square yards (square meters) of the section of pavement in which the lot was placed.

2. Class "Pre" Concrete. Class "Pre" concrete is evaluated for acceptance on a lot-by-lot basis based on the average of the 28-day compressive strength cylinders and variation in test results as measured by the standard deviation.

Each lot will be judged against the formula, $\overline{X}$ - F'c + 0.35S.

Where:

$\overline{X}$ is the average of three 28-day cylinder strengths.

S is the standard deviation of the strengths for the three 28-day cylinders.

Fcc is the concrete strength required for final acceptance as specified in the Contract.

A lot is defined as all the concrete that is placed in a single pre-cast prestressed member.

Lots with any actual $\overline{X}$ less than $\overline{X}$ calculated from the above formula will be rejected.

Three 28-day compressive test cylinders will be made for each lot, and each 28-day test cylinder sample will be selected on a random basis from all batches or loads.

The strengths of other cylinders made from a sample and tested at an earlier age will not be considered for acceptance purposes.

The cylinders for acceptance will be cast under MT-101, sampled under MT-111 and tested under AASHTO T 22.

The cylinders will be cured within the curing enclosure under the exact conditions and methods used to cure the prestressed member until transfer of pre-stress. After transfer of pre-stress, the cylinders will continue curing under MT-101.

3. **Classes "A", "D", "AS", and "DS" Concrete.**
   a. The average of all the 28-day strength tests representing each class of concrete, as well as the average of any 5 consecutive 28-day strength tests representing each class of concrete, must be equal to or greater than the required compressive strength.
   b. Not more than 1 test in 10 consecutive tests may fall below 90 percent of the required compressive strength.
   c. On projects where less than 10 tests are made, not more than 1 test may fall below the required compressive strength. The average of all tests must be equal to or greater than the required compressive strength, and paragraph (d) below will not apply.
   d. Not more than 10 percent of all compressive strength tests may fall below the required compressive strength for each class of concrete used in each major structure.
   e. Concrete represented by tests that fail to meet the requirements of paragraphs (a), (b), (c), and (d) will be rejected, unless it can be established by other methods that the concrete is acceptable in place in the completed structure. Procedures to evaluate in-place concrete that has failed one of the above requirements will be approved by the Engineer. Submit these procedures in writing within 7 days after the last compression test representing the specific member. Include in the written procedure details of sampling methods, including sample locations, test methods and conditions, and proposed criteria to evaluate test results. Generally, nondestructive test methods such as the Swiss hammer and the Windsor probe will not be considered. The evaluation procedure must be approved in writing before any sampling or testing of concrete in-place.
   f. Unsatisfactory concrete will be rejected. Remove and replace all rejected concrete at Contractor expense.
4. **Small Concrete Quantities.** The Project Manager may accept 7 cubic yards (5.4 cubic meters) or less of 3,000 psi (20.7 MPa) strength concrete without a formal mix design. Submit a batch proportioning sheet to the Project Manager for approval before use. Class "BD" concrete is excluded from this exception. Furnish concrete under this exception meeting the slump requirements in Table 551-1.

551.04 METHOD OF MEASUREMENT. Concrete is measured by the cubic yard (cubic meter) under Subsection 552.04, unless otherwise specified.

Classes "AP" and "DP" concrete is measured for payment under Subsection 501.04.

Concrete used in pre-cast concrete products is measured for payment under Subsection 554.04.

Class "Pre" concrete is measured for payment under Subsection 553.04.

551.05 BASIS OF PAYMENT. Payment for the completed and accepted quantities is made under the following:

Pay Item	Pay Unit
Concrete	Cubic Yard (cubic meter)

Concrete is paid for at the contract unit price per cubic yard (cubic meter) under Subsection 552.05.

Classes "AP" and "DP" concrete is paid for under Subsection 501.05.

Concrete used in pre-cast concrete products is paid for under Subsection 554.05.

Class "Pre" concrete used in prestressed concrete members is paid for under Subsection 553.05.

Payment at the contract unit price is full compensation for all resources necessary to complete the item of work under the Contract.