346 PORTLAND CEMENT CONCRETE.

(REV 1-8-02) (FA 1-10-02) (7-02)

SECTION 346 (Pages 321-346) is deleted and the following substituted:

SECTION 346
PORTLAND CEMENT CONCRETE

346-1 Description.

Use concrete composed of a mixture of portland cement, aggregate, water, and, where specified, admixtures and pozzolan. Deliver the portland cement concrete to the site of placement in a freshly mixed, unhardened state.

Obtain concrete from an approved concrete production facility's meeting the production and Quality Control (QC) of concrete provisions of this Section and Chapter 9.2 of the Materials Manual – Concrete Production Facilities Guidelines, which may be view at the following URL: http://www11.myflorida.com/statematerialsoffice/QualitySystems/materialsmanual/section92.pdf . If the concrete production facility's approval is suspended, the Contractor is solely responsible to obtain the services of another approved concrete production facility or await the re-approval of the affected concrete production facility prior to the placement of any further concrete on the project. There will be no changes in the contract time or completion dates. Bear all delay costs and other costs associated with the concrete production facility approval or re-approval.

346-2 Materials.

346-2.1 General: Meet the following requirements:

Coarse Aggregate	Section 901
Fine Aggregate*	Section 902
Portland Cement	Section 921
Water	Section 923
Admixtures	Section 924
Pozzolans and Slag	Section 929

*Use only silica sand except as provided in 902-5.2.3.

Do not use materials containing hard lumps, crusts or frozen matter, or that is contaminated with dissimilar material.

346-2.2 Types of Cement: Unless a specific type of cement is designated elsewhere, use Type I, Type IP, Type IS, Type IP (MS), Type II, or Type III cement in all classes of concrete.

Use only the types of cements designated for each environmental condition in structural concrete. A mix design for a more aggressive environment may be substituted for a lower environmental condition.

TABLE 1

BRIDGE SUPERSTRUCTURES			
Component	Slightly Aggressive Environment	Moderately Aggressive Environment	Extremely Aggressive Environment
Precast Superstructure and Prestressed Elements	Type I, Type II, or Type III	Type I or Type III with Fly Ash or Slag, Type IP, Type IS, or Type IP (MS)	Type II with Fly Ash or Slag
C.I.P. Superstructure Slabs and Barriers	Type I or Type II	Type I with Fly Ash or Slag, Type IP, Type IS, or Type IP (MS)	Type II with Fly Ash or Slag
BRIDGE SUBSTRUCTURE, DRAINAGE STRUCTURES AND OTHER STRUCTURES			
Component	Slightly Aggressive Environment	Moderately Aggressive Environment	Extremely Aggressive Environment
All Structure Components	Type I, Type II, or Type III	Type I with Fly Ash or Slag, Type IP, Type IP (MS), or Type IS	Type II with Fly Ash or Slag

346-2.3 Pozzolans and Slag: Use as desired, on a equal weight replacement basis, fly ash, silica fume, metakaolin, other pozzolans, and slag materials as a cement replacement in all classes of concrete, with the following limitations:

(1) Mass Concrete:

a. Fly Ash-ensure that the quantity of cement replaced with fly ash is 18% to 50% by weight.

b. Slag-ensure that the quantity of cement replaced with slag is 50% to 70% by weight. Ensure that slag is 50% to 55% of total cementitious content by mass of total cementitious materials when use in combination of silica fume and/or metakaolin.

(2) Drilled Shaft:

a. Fly Ash-ensure that the quantity of cement replaced with fly ash is 33% to 37% by weight.

b. Slag-ensure that the quantity of cement replaced with slag is 58% to 62% by weight.

(3) For all other concrete uses not covered in (1) and (2) above,

a. Fly Ash-ensure that the quantity of cement replaced with fly ash is 18% to 22% by weight.

b. Slag-ensure that the quantity of cement replaced with slag is 25% to 70% for Slightly and Moderately Aggressive environments, and 50% to 70% by weight when used in extremely Aggressive environments. Ensure that slag is 50% to 55% of total cementitious content by weight of total cementitious materials when use in combination of silica fume and/or metakaolin.

(4) Type IP (MS): Ensure that the quantity of cement replaced with Type IP (MS) is in the range of 15% to 40% by weight.

(5) Silica Fume and Metakaolin:

a. Cure in accordance with the silica fume or metakaolin manufacturer’s recommendation.

b. Silica Fume-ensure that the quantity of cement replaced with silica fume is 7% to 9% by weight. Use high range water reducing admixtures in concrete mixes incorporating silica fume.

c. Metakaolin-ensure that the quantity of cement replaced with metakaolin is 8% to 12% by weight, and may require a high range water reducing admixture.

346-2.4 Coarse Aggregate Gradation: Produce all concrete using Size No. 57 or Size No. 67 coarse aggregate. With the Engineer's approval, Size No. 8 or Size No. 89 may be used either alone or blended with Size No. 57 or Size No. 67. The Engineer will consider requests for approval of other gradations individually. Submit sufficient statistical data to establish production quality and uniformity of the subject aggregates, and establish the quality and uniformity of the resultant concrete. Furnish aggregate gradations sized larger than nominal maximum size of 1.5 inch [37.5 mm] as two components. Ensure the maximum coarse aggregate size does not violate the reinforcement spacing provisions given for reinforced concrete in the AASHTO Standard Specifications for Highway Bridges.

346-2.5 Admixture Requirements:

346-2.5.1 Chemical Admixtures: Use water-reducing admixture, Type A, or water-reducing and retarding admixture, Type D, that meets the requirements of ASTM C 494 [ASTM C 494M]. Use in accordance with the manufacturer's recommended dosage rate.

The Engineer may approve the use of other admixtures. The Engineer will require the Contractor to submit statistical evidence supporting successful laboratory and field trial mixes which demonstrate improved concrete quality or handling characteristics.

Do not use chemical admixtures or additives containing calcium chloride (either in the raw materials or introduced during the manufacturing process) in reinforced concrete.

346-2.5.2 Air Entrainment Admixtures: Use an air entraining admixture in all concrete mixes except counterweight concrete. Establish dosage rates of air entrainment admixtures by trial mixes, and adjust them based on field conditions to produce workable concrete with the required air content as shown in Table 2.

346-2.5.3 High Range Water Reducing Admixtures: Use high range water reducing admixtures in concrete mixes incorporating silica fume or metakaolin. Use as desired an approved High Range Water Reducer (HRWR) admixture, either Type F or Type G, except for concrete used in drilled shafts.

Perform all testing for plastic concrete properties after the HRWR has been added to the concrete mix.

346-2.5.4 Corrosion Inhibitor Admixture: Use only with concrete containing Type II cement, Class F fly ash or slag, and a water reducing retardant admixture, Type D, to normalize the setting time of concrete. Ensure that all admixtures are compatible with the corrosion inhibitor admixture.

346-3 Classification, Strength, Slump, and Air Content.

346-3.1 General: The separate classifications of concrete covered by this Section are designated as Class I, Class II, Class III, Class IV, Class V, and Class VI. Strength, slump, and air content of each class are specified in Table 2:

TABLE 2

Class of Concrete	Specified Minimum Strength (28-day) (psi) [(MPa)]	Target Slump (inches) [(mm)](c)	Air Content Range (%)
STRUCTURAL CONCRETE			
I (Pavement)	3,000 [21]	2 [50]	1 to 6
I (Special) (a)	3,000 [21]	3 [75] (b)	1 to 6
II (a)	3,400 [23]	3 [75] (b)	1 to 6
II (Bridge Deck)	4,500 [31]	3 [75] (b)	1 to 6
III	5,000 [35]	3 [75] (b)	1 to 6
III (Seal)	3,000 [21]	8 [200]	1 to 6
IV	5,500 [38]	3 [75] (b)	1 to 6
IV (Drilled Shaft)	4,000 [28]	8 [200]	0 to 6
V (Special)	6,000 [41]	3 [75] (b) (d)	1 to 5
V	6,500 [45]	3 [75] (b)	1 to 5
VI	8,500 [59]	3 [75] (b)	1 to 5

(a) For precast drainage products that are manufactured at the precast plant the Contractor is permitted to use concrete meeting the requirements of ASTM C 478 [ASTM C 478M] 4,000 psi [30 MPa] in lieu of Class I or Class II concrete. Apply the chloride content limits specified in 346-4.2 to all precast or cast-in-place box culverts.

(b) The Engineer may allow higher target slump, not to exceed 7 inches [180 mm], when a Type F or Type G admixtures is used.

(c) The Engineer may approve a reduction in the target slump for slip-formed or prestressed elements.

(d) When the use of silica fume or metakaolin is required as a pozzolan in Class V (Special) concrete, ensure that the concrete does not exceed a permeability of 1,000 coulombs at 28-days when tested per AASHTO T 277. Submit 2, 4-inch [102 mm] diameter by 8 inch [203 mm] length cylindrical test specimens to the Engineer for permeability testing before mix design approval. The permeability of the concrete will be taken as the average of two tests, one test per cylinder.

346-3.2 Drilled Shaft Concrete: When drilled shaft concrete is placed in any wet shaft, provide concrete in accordance with the following specified slump loss requirements. When concrete is placed in a dry excavation, do not test for slump loss, except where a temporary removable casing is to be used.

Ensure that drilled shaft concrete has a slump between 7 inches and 9 inches [175 mm and 225 mm] when placed and maintains a slump of 4 inches [100 mm] or more throughout the drilled shaft concrete elapsed time. Ensure that the slump loss is gradual as evidenced by slump loss tests described below. The concrete elapsed time is the sum of the mixing and transit time, the placement time and the time required for removal of any temporary casing that causes or could cause the concrete to flow into the space previously occupied by the temporary casing.

Provide slump loss tests before drilled shaft concrete operations begin, demonstrating that the drilled shaft concrete maintains a slump of at least 4 inches [100 mm] throughout the concrete elapsed time. Inform the Engineer at least 48 hours before performing such tests. Perform slump loss testing of the drilled shaft mix using a laboratory acceptable to the Engineer meeting the requirements of 6-9.

Perform the following procedures for slump loss tests:

(1) Prepare the mix for the slump loss test at a temperature consistent with the highest ambient and concrete temperatures expected during actual concrete placement. Obtain the Engineer's approval of the test temperature.

(2) Ensure that the mix is at least 3 yd^3 [2.3 m^3] and is mixed in a mixer truck.

(3) After initial mixing, determine the slump, concrete temperature, ambient temperature and air content. Ensure that the concrete properties are within the required specification limits.

(4) Mix the concrete intermittently for 30 seconds every five minutes at the mixing speed of the mixer.

(5) Determine slump, concrete temperature, ambient temperature and air content at 30 minute intervals until the slump is 4 inches [100 mm] or less. Remix the mix for one minute at the mixing speed of the mixer before these tests are run.

(6) Begin all elapsed times when water is initially introduced into the mix.

(7) Ensure that the concrete maintains a slump of at least 4 inches [100 mm] for the anticipated elapsed time.

(8) Obtain the Engineer's approval of slump loss test results in terms of elapsed time before concrete placements.

346-3.3 Mass Concrete: When mass concrete is designated in the Contract Documents, provide an analysis of the anticipated thermal developments in the mass concrete elements for all expected project temperature ranges using the proposed mix design, casting procedures, and materials. Use a Specialty Engineer following the procedure outlined in Section 207 of the ACI Manual of Concrete Practice to formulate, implement, administer and monitor a temperature control plan, making adjustments as necessary to ensure compliance with the Contract Documents. Describe the measures and procedures intended for use to maintain a temperature differential of 35ºF [20ºC] or less between the interior core center and exterior surface(s) of the designated mass concrete elements during curing. Submit both the mass concrete mix design and the proposed mass concrete plan to monitor and control the temperature differential to the Engineer for acceptance. The Engineer will review the submittal for acceptance within ten working days of receipt. Provide temperature monitoring devices to record temperature development between the interior core center and exterior surface(s) of the elements in accordance with the accepted mass concrete plan. Read the monitoring devices and record the readings at intervals no greater than 6-hours beginning when the mass concrete placement is complete and continuing until the maximum temperature differential (not maximum temperature) is reached and a decreasing temperature differential is confirmed. Furnish a copy of all temperature readings to the Engineer. If the 35ºF [20ºC] differential has been exceeded, take immediate action, as directed by the Specialty Engineer, to retard further growth of the temperature differential. Use a Specialty Engineer to revise the previously accepted plan to ensure compliance on future placements. Do not place any mass concrete until the Engineer has accepted the mass concrete plans. When mass concrete temperature differentials are exceeded provide all analyses and test results deemed necessary by the Engineer for determining the structural integrity and durability of the mass concrete element, to the satisfaction of the Engineer. The Department will make no compensation, either monetary or time, for the analyses or tests or any impacts upon the project.

346-4 Composition of Concrete.

346-4.1 Master Proportion Table: Proportion the materials used to produce the various classes of concrete in accordance with Table 3:

TABLE 3

Class of Concrete	Minimum Total Cementitious Materials Content lb/yd^3 [kg/m^3]	*Maximum Water Cementitious Materials Ratio lb/lb [kg/kg]
I (Pavement)	508 [300]	0.50
I (Special)	508 [300]	0.50
II	564 [335]	0.49
II (Bridge Deck)	611 [365]	0.44
III	611 [365]	0.44
III (Seal)	611 [365]	0.52
IV	658 [390]	0.41
IV (Drilled Shaft)	658 [390]	0.41
V (Special)	752 [445]	0.37**
V	752 [445]	0.37**
VI	752 [445]	0.37

*The calculation of the water to cementitious materials ratio (w/cm) is based on the total cementitious material including silica fume, slag, fly ash or metakaolin.

**When the use of silica fume or metakaolin is required as a pozzolan, the maximum water cementitious material ratio will be 0.35.

346-4.2 Chloride Content Limits for Concrete Construction:

346-4.2.1 General: Use the following maximum chloride content limits for the concrete application shown:

Table 4

Application	Maximum Allowable Chloride Content lb/yd^3 [kg/m^3]	
	Production	Mix Design
Non Reinforced Concrete	N/A	N/A
Reinforced Concrete that does not require Type II cement plus slag or pozzolan(s)	0.70 [0.42]	0.64 [0.38]
All applications that require Type II cement plus pozzolan(s)	0.40 [0.24]	0.34 [0.20]
Prestressed Concrete	0.40 [0.24]	0.34 [0.20]

Determine the chloride content as the average of three tests on samples taken from the concrete. Ensure that the range of results of the three tests does not exceed a chloride content of 0.08 lb/yd^3 [0.05 kg/m^3] of concrete. When test results are outside of the allowable range, run an additional three tests until the test results are within the allowable range. The Contractor may obtain samples from representative concrete cylinders or cores tested for compressive strength. If the cylinders or cores have been exposed to salt or aggressive environment, discard the outer 1 inch [25 mm] surface of the sample.

346-4.2.2 Sampling and Testing: Determine the chloride content in accordance with FM 5-516 within two weeks of sampling.

(1) For all concrete requiring Type II cement with pozzolan(s) or slag and prestressed concrete, determine the chloride content on a frequency that is in accordance with these Specifications and the following procedures:

(a) When the chloride content is 0.25 lb/yd^3 [0.15 kg/m^3] or less, determine chloride content at a frequency of not less than one for every four weeks of production as long as the test results remain at or below 0.25 lb/yd^3 [0.15 kg/m^3]. As an exception to the aforementioned testing frequency, when eight consecutive tests show chloride content below 0.25 lb/yd^3 [0.15 kg/m^3], the Engineer may reduce the frequency to not less than one for every eight weeks of production.

(b) When the chloride content is greater than 0.25 [0.15] and less than or equal to 0.33 lb/yd^3 [0.20 kg/m^3], determine chloride content at a frequency of not less than one for every two weeks of production, as long as the values remain at or below 0.33 lb/yd^3 [0.20 kg/m^3].

(c) When the chloride content is greater than 0.33 lb/yd^3 [0.20 kg/m^3], make subsequent chloride content tests for each day's production.

(2) For all reinforced concrete other than concrete requiring Type II cement with slag or pozzolan(s) and prestressed concrete, determine the chloride content on a frequency of not less than one test every four weeks. As an exception to the aforementioned testing frequency, when eight consecutive chloride content determinations are below 0.40 lb/yd^3 [0.24 kg/m^3] of concrete, the Engineer may reduce the frequency to not less than one for every eight weeks of production.

For any case listed above, when the source of any concrete component material, including admixtures, is changed, determine the chloride content immediately.

Test results obtained at the frequency provided above represent the chloride content of all concrete placed subsequent to the preceding test for the determination of chloride content.

346-4.2.3 Certification: Determine the chloride content, and certify the test results of chloride determinations to the Department. Include in the certification all pertinent data required by the Department. The Department will require properly executed certifications showing the chloride content within the required limits for acceptance of all concrete produced in accordance with these Specifications.

346-4.2.4 Control Level for Corrective Action: If the test results indicate that the chloride level is greater than the following limits, suspend concrete production until implementing corrective measures acceptable to the Engineer.

(1) Chloride content of 0.65 lb/yd^3 [0.39 kg/m^3] or greater for reinforced concrete that does not require Type II cement plus slag or pozzolan(s).

(2) Chloride content of 0.35 lb/yd^3 [0.21 kg/m^3] or greater for prestressed concrete and all applications that require Type II cement with slag or pozzolan(s).

The Engineer will reject the concrete exceeding the maximum allowable chloride content limits shown in 346-4.2.1.

346-5 Sampling and Testing Methods.

Perform concrete sampling and testing in accordance with the following methods:

Table 5

Description	Method
Slump of Hydralic Cement Concrete	ASTM C 143 [ASTM C 143M]
Air Content of Freshly Mixed Concrete by the Pressure Method*	ASTM C 231
Air Content of Freshly Mixed Concrete by the Volumetric Method*	ASTM C 173 [ASTM C 173M]
Making and Curing Test Specimens in the Field	ASTM C 31 [ASTM C 31M]
Compressive Strength of Cylindrical Concrete Specimens	ASTM C 39 [ASTM C 39M]
Obtaining and Testing Drilled Core and Sawed Beams of Concrete	ASTM C 42 [ASTM C 42M]
Early sampling of fresh concrete from revolving drum truck mixers or agitators	FM 5-501
Low Levels of Chloride in Concrete and Raw Materials	FM 5-516
Density (Unit Weight), Yield and Air Content (Gravimetric) of Concrete	ASTM C 138 [ASTM C 138M]
Temperature of Freshly Mixed Portland Cement Concrete	ASTM C 1064 [ASTM C 1064M]
Sampling Freshly Mixed Concrete	ASTM C 172

Use the same type of meter for QC tests as the Department uses for Verification testing. Where selecting pressure type meters, use an aggregate correction factor determined by the concrete producer for each mix design to be tested. Record and certify test results for correction factors for each type of aggregate at the concrete production facility.

346-6 Control of Quality.

346-6.1 General: Develop a Quality Control Plan (QCP) as specified in 6-8. Assume responsibility for meeting the requirements of the approved QCP and Contract Documents. Ensure the QCP includes the necessary requirements to control the quality of the concrete between the point of delivery at the site and the final placement.

QC activities are performed by the Contractor to ensure materials, methods, techniques, personnel, procedures and processes utilized during production meet the specified requirements.

Accept responsibility for performing QC inspections of all phases of work ensuring all materials and workmanship incorporated into the product meets the requirements of the Contract Documents.

When concrete plastic properties (slump, air content and temperature) could be significantly affected by handling between the point of delivery and the point of final placement, including the use of pumps, conveyor belts, troughs, chutes, barge transport or other means. Provide in the QCP provisions to sample the plastic concrete for all testing at the point of final placement, as a minimum.

Ensure the QCP includes any anticipated requirements for adjusting the concrete at the placement site. Include the testing procedures that will be implemented to control the quality of the concrete and ensure that concrete placed is within the target range. Also, include provisions for the addition of water to concrete delivered to the placement site at designated level

areas, to ensure the allowable amount of water stated on the concrete delivery ticket or the maximum water/cementitious ratio on the approved design mix are not exceeded. Ensure the anticipated ranges of jobsite water additions are described and the proposed methods of measuring water for concrete adjustments are included.

Failure to meet the requirements of this Specification or the QCP will automatically void that portion of the QCP. To obtain QCP re-approval, implement corrective actions as approved by the Engineer. The Engineer may allow the Contractor to continue any ongoing concrete placement but the Engineer will not accept concrete for any new placement until the QCP reapproval is given by the Engineer.

346-6.2 Concrete Design Mix: Provide concrete that has been produced in accordance with a Department approved design mix.

Do not place concretes of different compositions such that the plastic concretes may combine, except where the plans require concrete both with and without silica fume, metakaolin or calcium nitrite in a continuous placement. Produce these concretes using two separate design mixes. For example, designate the mix with calcium nitrite as the original mix and the mix without calcium nitrite as the redesigned mix. Ensure that both mixes contain the same cement, fly ash or slag, coarse and fine aggregates and compatible admixtures. Submit both mixes for approval as separate mix designs, both meeting all requirements of this Section. Ensure that the redesigned mix exhibits plastic and hardened qualities which are additionally approved by the Engineer as suitable for placement with the original mix. The Engineer will approve the redesigned mix for commingling with the original mix and for a specific project application only. Alternately, place a construction joint at the location of the change in concretes.

346-6.2.1 Material Substitutions: Material sources may be substituted within an approved base mix design provided that the materials are the same type, with similar chemical and physical properties and are from an approved source. Obtain the Department's approval for any material substitutions before beginning concrete placement. Provide a new base mix design for any cementitious material or admixture substitution. The Department may take up to five working days to review any material substitution request.

For every material substitution made, perform testing for chlorides and assure compliance with 346-4.2.

Ensure the substituted mix meets the theoretical yield requirements, does not exceed the maximum water to cementitious materials ratio, and the cement content equals or exceeds, the approved base mix design.

The Department may require a single 3.0 yd^3 [2.3 m^3] minimum test batch at the approved concrete production facility to demonstrate that the plastic properties of the adjusted mix design is within the slump and air tolerances provided in Table 2 and the theoretical unit weight of the proposed mix design will be within 2.0 lbs/ft^3 [35 kg/m^3] of the originally approved mix design. Approved adjusted mixes may be transferred.

At any time if the Engineer determines that unsatisfactory results are obtained during production, return to the originally approved base mix design or obtain approval of a new mix design.

346-6.3 Delivery Certification: Ensure that a delivery ticket is furnished with each batch of concrete before unloading at the placement site. Ensure that the materials and quantities incorporated into the batch of concrete is recorded on the delivery ticket. Provide the following information on the Delivery Ticket:

(1.) Arrival time at job site,

(2.) Time that concrete mix has been completely discharged,
(3.) Number of revolutions upon arrival at the job site,
(4.) Total gallons [liters] of water added at the job site,
(5.) Additional mixing revolutions when water is added,
(6.) Total number of revolutions at mixing and agitating speed.

Ensure the batcher responsible for production of the batch of concrete signs the delivery ticket, certifying the batch of concrete was produced in accordance with the Contract Documents.

Sign the delivery ticket certifying that the maximum specified water to cementitious materials ratio was not exceeded due to any jobsite adjustments to the batch of concrete, and that the batch of concrete was delivered and placed in accordance with the Contract Documents.

346-6.4 Tolerances: Meet the following tolerances from target values for plastic concrete properties specified in 346-3.1:

Table 6

Property	Tolerance
Slump (Non-Drilled Shaft Concrete)	± 1.5 inch [±40 mm]
Slump (Drilled Shaft Concrete)	± 1 inch [±25 mm]
Air Content	As shown in the range in Table 2

Reject concrete with slump exceeding the above tolerances or air content exceeding the ranges in Table 2. Do not allow concrete to remain in a transporting vehicle to reduce slump. Water may be added in accordance with the approved QCP.

If the slump of non-drilled shaft concrete varies from the target value in excess of 0.75 inch [20 mm] (1 inch [25 mm] for concrete containing HRWR), immediately adjust the concrete mixture to correct the slump of succeeding batches. The Engineer will allow a reasonable time for adjustment, taking into consideration trucks already in route from the concrete production facility. If the Contractor does not implement adjustments at the earliest possible time, the Engineer will reject the concrete and terminate further production until the Contractor makes corrections.

346-7 Mixing and Delivering Concrete.

346-7.1 General Requirements: Operate all concrete mixers at speeds and volumes per the manufacturer's design or recommendation as stipulated on the mixer rating plate.

346-7.2 Transit Mixing: When water is added at the job site, mix the concrete 30 additional mixing revolutions. When mixing for the purpose of adjusting consistency, do not allow the total number of revolutions at mixing speed to exceed 160. Discharge all concrete from truck mixers before total drum revolutions exceed 300.

346-7.3 Mixing at the Site: Use a mixer of sufficient capacity to prevent delays that may be detrimental to the quality of the work. Ensure that the accuracy of batching equipment is in accordance with requirements of this Section.

346-7.4 Concreting in Cold Weather: Do not mix concrete when the air temperature is below 45ºF [7ºC] and falling. The Contractor may mix and place concrete when the air temperature in the shade, and away from artificial heat, is above 40ºF [4ºC] and rising. Do not

heat aggregates or use salts to reduce the freezing temperature. Protect the fresh concrete from freezing until the concrete reaches a minimum compressive strength of 1,500 psi [10 MPa]. Do not apply this requirement where concrete is to be heat cured.

346-7.5 Concreting in Hot Weather: Hot weather concreting is defined as the production, placing and curing of concrete when the concrete temperature at placing exceeds 85ºF [30ºC] but is less than 100ºF [40ºC].

Unless the specified hot weather concreting measures are in effect reject concrete exceeding 85ºF [30ºC] at the time of placement. Regardless of special measures taken, reject concrete exceeding 100ºF [40ºC]. Predict the concrete temperatures at placement time and implement hot weather measures to avoid production shutdown.

346-7.6 Transit Time: Ensure compliance with the following maximum allowable time between the initial introduction of water into the mix and depositing the concrete in place:

Table 7

Non-Agitator Trucks	Agitator Trucks
45 minutes	60 minutes
75 minutes*	90 minutes*

* When a water reducing and retarding admixture (Type D or Type G) is used.

346-7.7 Adding Water To Concrete at the Placement Site: Perform an initial slump before the addition of water at the job site. After adjusting the slump, perform a test to confirm that the slump of the concrete is within the target range. If the slump exceeds the target range but is within the tolerance range, that load may be accepted, but water added at the site will be reduced to maintain a slump within the target range on successive loads. Confirm with another test that the next load is within the target range after the addition of water at the placement site. Repeated incidents of concrete being placed outside the target range will result in revocation of that portion of the QCP. No concrete represented by plastic test results outside of the tolerance range will be accepted for placement.

346-7.8 Sample Location: Where concrete buckets are used to discharge concrete directly into the forms at the point of final placement or into the hopper of a tremie pipe, all samples will be obtained from the discharge of the bucket; except where the concrete is discharged directly from the mixer into the bucket, with a minimal lapse of time before discharge of the bucket, all samples may be obtained from the discharge of the mixer if identified in the QCP.

Where concrete is placed in a drilled shaft or other element using a tremie pipe and a concrete pump, all QC and Verification samples will be obtained from the discharge of the pump line at the location of the tremie hopper. Obtain comparative samples for use in controlling the mix from the discharge of the mixer delivering concrete to the pump to confirm that the plastic properties are within the tolerance range.

Where a concrete pump is used to deposit concrete directly into a drilled shaft which is a wet excavation without the use of a tremie, ensure the discharge end of the pump line remains immersed in the concrete at all times after starting concrete placement, and the following procedure is followed:

a. Obtain initial samples from the discharge of the pump line using the full length of pump line which will be required to start the placement. Ensure the plastic properties of the concrete sampled from the discharge of the pump line are within the target range. Obtain

comparative initial samples from the discharge of the mixer delivering concrete to the pump in order to control the plastic properties of the mix.

b. Obtain all other samples from the discharge of the mixer delivering concrete to the pump. Ensure the plastic properties of the concrete being delivered to the pump are within the allowable tolerance, except when necessary and approved by the engineer and based on comparative testing, to provide concrete meeting the Specification requirements at the end of the pump line.

346-8 Plastic Concrete Sampling and Testing.

QC tests include water to cementitious ratio calculation, air content, temperature, slump, compressive strength cylinders, and may include plastic unit weight. Perform plastic concrete tests on the initial delivery of each concrete design mix each day. Ensure QC technicians meeting the requirements of 105-2 are present and performing test throughout the placement operation. Ensure one technician is present and performing test throughout the placement operation at each placement site. Ensure all equipment utilized meets this Specification. Do not proceed with the placement operation until the delivered concrete complies with plastic properties specified. After placement begins, perform QC tests to ensure compliance with Specification requirements on each LOT of concrete. Reject non-complying loads which cannot be adjusted at the jobsite. Ensure that corrections are made on subsequent loads.

Furnish sufficient concrete of each design mix as required by the Engineer for verification testing. When the Engineer's verification tests results do not compare with the QC plastic properties tests results, within the limits defined by the Independent Assurance (IA) checklist comparison criteria, disposition of the concrete will be at the option of the Contractor.

If a QC test fails, reject the remainder of that load, terminate the LOT, and notify the Engineer. Make cylinders representing that LOT from the same sample of concrete.

Following termination of a LOT, re-initiate initial plastic properties tests until such time as the water to cementitious materials ratio, air content, temperature and slump comply with the Specification requirements. Initiate a new LOT once the testing indicates compliance with Specification requirements.

When three consecutive LOTs, or when five LOTs in two days of production of the same design mix are outside the specified tolerances, suspend production. Make the necessary revisions to concrete operations and increase the frequency of QC testing in the QCP to bring the concrete within allowable tolerances. Obtain the Engineer's approval of the revisions before resuming production. After production resumes, obtain the Engineer's approval before returning to the normal frequency of QC testing.

If concrete placement stops for more than 90 minutes, perform initial plastic properties testing on the next batch and continue the LOT. Cylinders cast for that LOT will represent the entire LOT.

The Department may perform discretionary verification testing at any time to evaluate the QC of the concrete. The comparison between the discretionary verification testing and the QC testing is identified in the IA Checklist Criteria. When a test does not compare, the Contractor will revise the QCP as deemed necessary by the Engineer. The Department reserves the right to notify the IA to review the testing procedures and equipment.

346-9 Acceptance Sampling and Testing.

346-9.1 General: Perform plastic properties test as per 346-8 and cast a set of three 6 inch x 12 inch QC cylinders for each LOT of structural concrete incorporated into the project. Take these acceptance samples randomly for each LOT as determined by a random number generator. The Department will independently perform plastic properties test and cast a set of verification cylinders from a separate sample from the same load of concrete as the Contractor's QC sample. For each LOT verified by the Department, cast one additional cylinder from the same sample, and identify it as the QC "hold" cylinder. The Department will also cast one additional "hold" cylinder from each verification sample. All cylinders will be initially cured in the same curing facility. Transport the QC cylinders to the testing laboratory in the same time period the Department transports the Verification cylinders.

Test the QC samples for compressive strength at the age of 28 days in a laboratory meeting and maintaining at all times the qualification requirements listed in 6-9.

The Engineer will compare the average 28-day compressive strength of the QC cylinders to the average 28-day compressive strength of the verification cylinders for that LOT. QC and verification test laboratories will provide the Engineer with the compressive strength test results on the first working day after testing and place this information into the Department's sample tracking database within three working days. If the averages of the 28-day compressive strength compare within 750 psi [5.2 MPa], the QC data is verified. If the verification and QC do not compare the Engineer will initiate a resolution procedure in accordance with 346-9.5.

346-9.2 Sampling Frequency for Quality Control Tests:

As a minimum, sample and test concrete of each design mix for water to cementitious ratio, air content, temperature, slump and compressive strength in accordance with Table 8. The Engineer will randomly verify one of every four consecutive LOTS of each design mix based on a random number generator, and may perform additional discretionary verification tests.

Table 8

Class Concrete	Maximum LOT Size
I (Pavement)	one lane mile [1.5 lane km] or one day's production, whichever is less
I (Special)	150 yd^3 [125 m^3] or one day's production, whichever is less
II, II (Bridge Deck), III, IV, IV (Drilled Shaft), V (Special), V, VI	50 yd^3 [40 m^3], or one day's production, whichever is less
III (Seal)	Each Seal placement

346-9.2.1 Reduced Frequency for Acceptance Tests: For all structural concrete except Class I and III (Seal), if the previous 15 consecutive strength test results of the same design mix produced at the same concrete production facility, on a given Contract have all been verified and have attained an average strength greater than 2 standard deviations above the specified minimum, then the maximum LOT size will be increased to 100 yd^3 [80 m^3].

The average of 15 consecutive breaks can be established based on historical data from the previous project. The data must also represent the same prime/sub contractor. The last test from the previous job must be within the last 60 calendar days. Test data must be from a laboratory meeting the requirements of 6-9.

The average of 15 consecutive breaks can also be established by a succession of samples on the current project. Only one sample can be taken from each LOT.

If at any time a strength test is not verified and/or the average strength of the previous 15 consecutive samples is less than the specified minimum plus 2 standard deviations, the maximum LOT size will return to 50 yd^3 [40 m^3]. The maximum LOT size will remain 50 yd^3 [40 m^3] until the thresholds listed above are achieved.

346-9.3 Strength Test Definition: The strength test of a LOT is defined as the average of the compressive strengths tests of three cylinders cast from the same sample of concrete from the LOT.

346-9.4 Acceptance of Hardened Concrete: Hardened concrete will be accepted or rejected on the basis of strength test results as defined in 346-9.3. Do not discard a cylinder strength test result based on low strength (strength below the specified minimum strength as per the provisions of 346-3 and 346-9). When QC strength test results are verified, the Engineer will accept the concrete based on QC test results. The Engineer will accept at full pay only LOTs of concrete represented by strength test results which equal or exceed the respective specified minimum strength.

When one of the three QC cylinders from a non-verified LOT is lost, damaged or destroyed, determination for compressive strength will be made by averaging the remaining two cylinders and payment for that LOT of concrete will be reduced by 10%.

When more than one QC cylinder from a non-verified LOT is lost, damaged, or destroyed, the Contractor, at the discretion of the Engineer, will core the structure at no cost to the Department to determine if the LOT of concrete meets the minimum compressive strength requirements. In addition, no payment will be made for this LOT of concrete.

When QC compressive strength test results are not verified, the resolution procedure will be used to accept or reject the concrete.

346-9.5 Resolution Procedure: The Department may initiate an IA review of sampling and testing methods. The resolution procedure may consist of, but need not be limited to, a review of sampling and testing of fresh concrete, calculation of water cementitious materials ratio, handling of cylinders, curing procedures and compressive strength testing. Cores of the hardened concrete may be required. The Engineer will ensure that the QC and verification “hold” cylinders are tested within 7 days of the 28-day strength tests. The following acceptance procedure will apply.

When the Department determines that either the QC or verification strength test results are in error, the concrete will be accepted based only on the strength test results deemed by the Department to be the most accurate. When the verification strength test results are deemed to be the most accurate, the verification strength test results will represent the four consecutive LOTs, and the Contractor will pay for the resolution testing. When the QC strength test results are deemed to be the most accurate, the QC strength test results will represent the four consecutive LOTs and the Department will pay for the resolution testing.

When the Department cannot determine that either the QC or verification strength test results are in error, the concrete represented by the four consecutive LOTs will be evaluated based on the results of the resolution investigation.

If the Department finds deficiencies based on the Contractor’s QCP, the Engineer may suspend that part of the QCP. When the QC plan is suspended, submit corrective actions for approval of the Engineer. The Engineer may take up to five working days to review corrective

actions to the QCP. The Engineer will not allow changes to Contract Time or completion dates. Incur all delay costs and other costs associated with QC plan suspension and re-approval.

346-10 Investigation of Low Strength Concrete for Structural Adequacy.

346-10.1 General: When a concrete acceptance strength test result falls more than 10% or 500 psi [3.5 MPa] below the specified minimum strength, whichever is the lesser deviation from the specified minimum strength, and the Department determines that an investigation is necessary, make an investigation into the structural adequacy of the LOT of concrete represented by that acceptance strength test result at no additional expense to the Department. The Engineer may also require the Contractor to perform additional strength testing as necessary to determine structural adequacy of the concrete.

Furnish either a structural analysis performed by a Specialty Engineer to establish strength adequacy or drilled core samples as specified in 346-10.3 to determine the in-place strength of the LOT of concrete in question at no additional expense to the Department. Obtain the Engineers approval before taking any core samples. Core strength test results obtained from the structure will be accepted by both the Contractor and the Department as the in-place strength of the LOT of concrete in question. The core strength test results will be final and used in lieu of the cylinder strength test results for determination of structural adequacy and any pay adjustment. The Department will calculate the strength value to be the average of the compressive strengths of the three individual cores, this will be accepted as the actual measured value.

346-10.2 Determination of Structural Adequacy: If core strength test results are less than 10% below the specified minimum strength, and this deviation from the specified minimum strength does not exceed 500 psi [3.5 MPa], consider the concrete represented by the cores structurally adequate. If the core strength test results are more than 10% or 500 psi [3.5 MPa] below the specified minimum strength, whichever is the lesser deviation from the specified minimum strength, the Department will consider the concrete represented by the cores structurally questionable. Submit a structural analysis performed by a Specialty Engineer. If the results of the structural analysis, approved by the Department, indicates adequate strength to serve its intended purpose with adequate durability, the Contractor may leave the concrete in place subject to the requirements of 346-11,otherwise, remove and replace the LOT of concrete in question at no additional expense to the Department.

346-10.3 Coring for Determination of Structural Adequacy: Furnish three undamaged core samples taken from the same approximate location as where the structural questionable concrete represented by the low strength concrete test cylinders was placed. Select the location of the drilled cores so that the structure is not impaired and does not sustain permanent damage after repairing the core holes. Obtain the approval of the Engineer to core, and of the core location prior to drilling.

346-10.4 Core Conditioning and Testing: The Department will test the cores in accordance with ASTM C 42 [ASTM C 42M].

346-11 Pay Adjustments for Low Strength Concrete.

346-11.1 General: Any LOT of concrete failing to meet the specified minimum strength as defined in 346-3, 346-9, 346-10 and satisfactorily meeting all other requirements of the

Contract Documents, including structural adequacy, the Engineer will individually reduce the price of each low strength LOT in accordance with this Section.

346-11.2 Basis for Pay Adjustments: When an acceptance strength test result falls more than 10% or 500 psi [3.5 MPa] below the specified minimum strength, whichever is the lesser deviation from the specified minimum strength, core samples may be obtained from the respective LOT of concrete represented by the low acceptance strength test result for determining pay adjustments.

When the Contractor submits acceptable core samples to the Engineer for testing, the Engineer will determine payment reductions based upon the results of the strength tests. Both the Contractor and the Department shall accept the results of strength tests of the drilled cores, subject to 346-11.5 and 346-11.6, as final and in lieu of the cylinder strength test results for determining pay adjustments.

Do not core hardened concrete for determining pay adjustments when the 28-day acceptance cylinder strength test results are less than 10% below the specified minimum strength, and this deviation from the specified minimum strength does not exceed 500 psi [3.5 MPa].

346-11.3 Coring for Determination of Pay Adjustments: Obtain the cores in accordance with 346-10.3.

346-11.4 Core Conditioning and Testing: The Department will test the cores in accordance with 346-10.4.

346-11.5 Core Strength Representing Equivalent 28-Day Strength: For cores tested no later than 42 days after the concrete was cast, the Engineer will accept the core strengths obtained as representing the equivalent 28-day strength of the LOT of concrete in question. The Engineer will calculate the strength value to be the average of the compressive strengths of the three individual cores. The Engineer will accept this strength at its actual measured value.

346-11.6 Core Strength Adjustments: For cores tested later than 42 days after the concrete was cast, the Department will establish the equivalency between 28-day strength and strength at ages after 42 days based on test data developed by a Department approved testing laboratory to relate strength at the actual test age to 28-day strength for the particular class of concrete and design mix represented by the cores. Obtain such data at no additional expense to the Department. When such data is not available and cannot be produced, as determined by the Department, the Department will determine the equivalent 28-day strength by adjusting the tested core strengths according to the following relationship:

$$\text{Equivalent 28-Day Strength} = \frac{\text{Average Core Strength X 100}}{F}$$

where:

$F = 4.4 + 39.1 (\ln x) - 3.1 (\ln x)^2$ (Type I Cement)

$F = -17.8 + 46.3 (\ln x) - 3.3 (\ln x)^2$ (Type II Cement)

$F = 48.5 + 19.4 (\ln x) - 1.4 (\ln x)^2$ (Type III Cement)

x = number of days since the concrete was placed

ln = natural log

346-11.7 Calculating Pay Adjustments: The Engineer will determine payment reductions for low strength concrete, accepted by the Department and represented by either

cylinder or core strength test results below the specified minimum strength, in accordance with the following:

Reduction in Pay =$0.80/yd ^{3} [$1.05/m^3] for each 10 psi [70 kPa] of strength test value below the specified minimum strength.

For the elements that payments are based on the per foot [meter] basis, the Engineer will adjust the price reduction from cubic yards [cubic meters] basis to per foot [meter] basis, determine the total feet [meter] of the elements that are effected by low strength concrete samples and apply the adjusted price reduction accordingly.