Florida Department of Transportation

RON DESANTIS
GOVERNOR

605 Suwannee Street
Tallahassee, FL 32399-0450

KEVIN J. THIBAULT, P.E.
SECRETARY

July 21, 2021

Khoa Nguyen
Director, Office of Technical Services
Federal Highway Administration
3500 Financial Plaza, Suite 400
Tallahassee, Florida 32312

Re: State Specifications Office
Section: **346**
Proposed Specification: **3460100 STRUCTURAL PORTLAND CEMENT CONCRETE.**

Dear Mr. Nguyen:

We are submitting, for your approval, two copies of the above referenced Supplemental Specification.

This change was proposed by Jose Armenteros to expand classification, move existing language to the Materials Manual, and clarify existing language in the Standard Specification.

Please review and transmit your comments, if any, within two weeks. Comments should be sent via email to daniel.strickland@dot.state.fl.us.

If you have any questions relating to this specification change, please call me at 850-414-4130.

Sincerely,

Signature on file

Daniel Strickland, P.E.
State Specifications Engineer

DS/dh
Attachment
cc: Florida Transportation Builders' Assoc.
State Construction Engineer

STRUCTURAL PORTLAND CEMENT CONCRETE.
(REV ~~6-3~~7-14-21)

ARTICLE 346-1 is deleted and the following substituted:

346-1 Description.

Use a Department-approved concrete mix design composed of a mixture of portland cement, aggregate, water, ~~and, where specified,~~ admixtures, and supplementary cementitious materials. Deliver the portland cement concrete to the site of placement in a freshly mixed, unhardened state.

Obtain concrete from a plant that is currently on the Department's Production Facility Listing. Producers seeking inclusion on the list shall meet the requirements of Section 105. If the concrete production facility's Quality Control (QC) Plan is suspended, the Contractor is solely responsible to obtain the services of another concrete production facility with an accepted QC Plan or await the reacceptance of the concrete production facility's QC Plan prior to the placement of any further concrete on the project. There will be no changes in the Contract Time because of the suspension, as described. Bear all delay costs and other costs associated with the concrete production facility's QC Plan acceptance or reacceptance.

ARTICLE 346-2 is deleted and the following substituted:

346-2 Materials.

346-2.1 General: Meet the following requirements:

Coarse Aggregate.....Section 901
Fine Aggregate*.....Section 902
Portland Cement and Blended Cement.....Section 921
Water.....Section 923
Admixtures**.....Section 924
Supplementary Cementitious Materials.....Section 929
*Use only silica sand except as provided in 902-5.2.3.
**Use products listed on the Department's Approved Product List (APL).

Do not use materials containing hard lumps, crusts, or frozen matter, or that is contaminated with materials exceeding the specified limits in the above listed Sections.

346-2.2 Types of Cement: Unless a specific type of cement is designated in the Contract Documents, use Type I, Type IL, Type IP, Type IS, Type II, Type II (MH) or Type III cement in all classes of concrete. Use Type IL or Type II (MH) for all mass concrete elements.

Use only the types of cements designated for each environmental classification in structural concrete as shown in Table 346-1. A mix design for a more aggressive environment may be used in a less aggressive environmental condition.

Table 346-1 Cement Use by Environmental Classification			
Component	Slightly Aggressive Environment	Moderately Aggressive Environment	Extremely Aggressive Environment (1)
Bridge Superstructures			
Precast Superstructure and Prestressed Elements	Type I or Type III	Type I, Type IL, Type II, Type III, Type IP, or Type IS	Type II (MH), Type IL, Type III (2) or Ternary Blend
Cast ~~I~~in Place	Type I	Type I, Type IL, Type II, Type IP, or Type IS	Type II (MH), Type IL, or Ternary Blend
Bridge Substructures, Drainage Structures, and other Structures			
All Elements	Type I or Type III	Type I, Type IL, Type II, Type IP, or Type IS	Type II (MH), Type IL, or Ternary Blend

Notes:
(1) Cements used in a more aggressive environment may also be used in a less aggressive environment.
(2) Type III cement may be used in an Extremely Aggressive Environment for precast superstructure and prestressed elements when the ambient temperature at the time of concrete placement is 60°F and below.

346-2.3 Supplementary Cementitious Materials: Supplementary cementitious materials are required to produce binary or ternary concrete mixes in all classes of concrete specified in Table 346-3, except for the following when used in slightly aggressive environments: Class I ~~3,000 psi~~, Class I ~~3,000 psi~~ (Pavement), and Class II ~~3,400 psi~~.

The quantity of portland cement replaced with supplemental~~l~~ry cementitious materials must be on an equal weight replacement basis of the total cementitious materials in accordance with ~~the limitations, shown in~~ Table 346-2.

346-2.3.1 Highly Reactive Pozzolans: Materials that have a very high degree of pozzolanic reactivity due to their very fine particle sizes, including silica fume, metakaolin and ultrafine fly ash.

346-2.3.2 Binary Concrete Mixes: Concrete mixes containing portland cement and one supplementary cementitious material.

346-2.3.3 Ternary Concrete Mixes: Concrete mixes containing portland cement and any two of supplementary cementitious materials, either fly ash, slag, or highly reactive pozzolans.

Table 346-2
Cementitious Materials Concrete Mix Proportions (%)
(Environmental classification is extremely aggressive, unless otherwise noted)

Application	Portland Cement	Fly Ash Type F	Slag	Highly Reactive Pozzolans (4)		
				Silica Fume	Metakaolin	Ultra-Fine Fly Ash
General Use	70-82	18-30				
	66-78	15-25		7-9		
	66-78	15-25			8-12	
	66-78	15-25				8-12
	30-40	10-20	50-60			
	~~30-75~~ (1)		~~25-70~~ (1)			
	30-50		50-70			
	36-43		50-55	7-9		
	33-42		50-55		8-12	
	33-42		50-55			8-12
Precast / Prestressed	70-85 (1)	15-30 (1)				
	70-82	18-30				
	66-78	15-25		7-9		
	66-78	15-25			8-12	
	66-78	15-25				8-12
	30-40	10-20	50-60			
	30-50		50-70			
	36-43		50-55	7-9		
	33-42		50-55		8-12	
	33-42		50-55			8-12
Drilled Shaft	63-67	33-37				
	38-42		58-62			
	30-40	10-20	50-60			
Mass Concrete	50-82 (2)	18-50 (2)				
	50-65 (3)	35-50 (3)				
	66-78	15-25		7-9		
	66-78	15-25			8-12	
	66-78	15-25				8-12
	30-40	10-20	50-60			
	30-50		50-70			
	36-43		50-55	7-9		
	33-42		50-55		8-12	
	33-42		50-55			8-12

Notes:
(1) Slightly Aggressive and Moderately Aggressive environments.
(2) For Concrete with Core Temperature T≤165°F.
(3) For Concrete with Core Temperature T≥165°F.
(4) Highly reactive pozzolans may be used below the specified ranges to enhance strength and workability.

346-2.4 Coarse Aggregate Gradation: Produce all concrete using Size No. 57, 67 or 78 coarse aggregate ~~specified in Section 901~~.

~~-~~ Use~~With the Engineer's approval and input from the District Materials Office with Producer QC Plan acceptance authority,~~ Size No. 8, and Size No. 89 alone, only when approved by the Engineer ~~with input from the District Materials Office (DMO).~~

Use Size No. 4 or larger ~~or other gradations may be used either alone or blended with Size No. 57, 67 or 78 coarse aggregate. Submit sufficient statistical data to establish production quality and uniformity of the subject aggregates, and establish the quality and uniformity of the resultant concrete. Aggregate gradations sized larger than nominal maximum size of 1.5 inch may be used~~ blended with smaller size coarse aggregate as two components.

346-2.4.1 Optimized Aggregate Gradation: Improve the aggregate packing density at the Contractor's option, by adding an intermediate-size coarse aggregate. Meet the requirements of Section 9.2, Volume II of the Materials Manual, on the methods used to produce combined aggregate gradation of fine, intermediate, and coarse aggregate sizes for the concrete mixes.

346-2.5 Admixtures: ~~Use admixtures in accordance with the requirements of this subarticle. Use~~Ensure admixtures are used in accordance with the manufacturer's recommend~~ed~~ations and meeting the requirements of Section 9.2 Volume II of the Materials Manual. ~~dosage rate~~. ~~Dosage rates outside of this range may be used with written recommendation from the admixture producer's technical representative. Do not use admixtures or additives containing calcium chloride in reinforced concrete, either in the raw materials or introduced during the manufacturing process.~~

~~**346-2.5.1 Air Entrainment Admixtures:** Use an air entraining admixture in all concrete mixes except counterweight and dry cast concrete. For precast concrete products, the use of air entraining admixture is optional for Class I and Class II concrete.~~

~~**346-2.5.2 High Range Water-Reducing, Retarding and Plasticizing Admixtures:** When a highly reactive pozzolan is incorporated into a concrete mix design, use a high range water-reducing admixture Type I, II, F or G.~~

~~**346-2.5.2.1 Flowing Concrete Admixtures for Precast/Prestressed Concrete:** Use a Type I, II, F or G admixture for producing flowing concrete. If Type F or G admixture is used, verify the distribution of aggregates in accordance with ASTM C1610 except allow for minimal vibration for consolidating the concrete. The maximum allowable difference between the static segregation is less than or equal to 15 %. Add the flowing concrete admixtures at the concrete production facility.~~

~~**346-2.5.3 Corrosion Inhibitor Admixtures:** Use a water-reducing and retarding admixture, Type D, or a high range water-reducing and retarding admixture, Type G, to normalize the setting time of concrete.~~

~~**346-2.5.4 Accelerating Admixture for Precast Drainage and Incidental Concrete Products:** Use non-chloride accelerating admixtures, Type C or accelerating and water-reducing, Type E, only in the manufacturing of precast drainage and incidental concrete products.~~

ARTICLE 346-3 is deleted and the following substituted:

346-3 Classification of Concrete.

346-3.1 General: The classifications of concrete ~~covered by this Section~~ are designated as Class I, Class I (Pavement), Class II, Class II (Bridge Deck), Class III, Class III (Seal), Class IV, Class IV (Drilled Shaft), Class V, Class V (Special), Class VI, and Class VII. The 28-day specified minimum compressive strength, maximum water to cementitious materials ratio and target slump of each class are ~~specifi~~detailed in Table 346-3. The required air content for all classes of concrete is less than or equal to 6.0%.

For purposes of this Specification the concrete is further classified as follows:

1. Conventional Concrete: The target slump is described in Table 346-3 with a tolerance of ± 1.5 inches.

2. Increased Slump Concrete: The maximum target slump is 7 inches with a tolerance of ± 1.5 inches when a Type F, G, I or II admixture is used.

3. Slip-form Concrete: The target slump is 1.5 inches with a tolerance of ± 1.5 inches.

4. Flowing Concrete: Use flowing concrete only in the manufacturing of precast and prestressed products. Request Engineer's authorization to use flowing concrete for cast-in-place applications. The target slump is 9 inches with a tolerance of ± 1.5 inches. Meet the requirements of Section 8.6 Volume II of the Materials Manual.

5. Self-Consolidating Concrete (SCC): Use SCC only in the manufacturing of precast and prestressed products. The minimum target slump flow is 22.5 inches with a tolerance of ± 2.5 inches. Meet the requirements of Section 8.4 Volume II of the Materials Manual.

346-3.2 Concrete Class Substitutions: The Engineer may allow the substitution of a higher class concrete in lieu of the specified class concrete when the substituted concrete mixes are included as part of the QC Plan, or for precast concrete, the Precast Concrete Producer QC Plan. The substituted higher class concrete must meet or exceed the requirements of the specified class concrete.

When the average 28-day compressive strength ~~acceptance data~~ is less than the 28-day specified minimum compressive strength of the higher class mix design ~~mix~~, notify the Engineer. Acceptance is based on the requirements in Table 346-3 for the specified class concrete. ~~Do not place concrete with a slump more than plus or minus 1.5 inches from the target slump value specified in Table 346-3.~~

346-3.3 Master Proportion Table: Proportion the materials ~~used~~ to produce the ~~various~~ classes of concrete in accordance with Table 346-3.

The calculation of the water to cementitious materials ratio (w/cm) is based on the total cementitious materials including portland cement and any supplementary cementitious materials used in the mix.

Table 346-3 Master Proportion Table			
Class of Concrete	28-day Specified Minimum Compressive Strength (f_c') (psi)	Maximum Water to Cementitious Materials Ratio (pounds per pounds)	Target Slump Value (inches) ~~(3)~~
I (1)	3,000	0.53	3 (2)
I (Pavement)	3,000	0.50	1.5 or 3 (~~5~~3)
II (1)	3,400	0.53	3 (2)
II (Bridge Deck)	4,500	0.44	3 (2)
III (4)	5,000	0.44	3 (2)
III (Seal)	3,000	0.53	8
IV	5,500	0.41(~~6~~4)	3 (2)
IV (Drilled Shaft)	4,000	0.41	8.5
V (Special)	6,000	0.37(~~6~~4)	3 (2)
V	6,500	0.37(~~6~~4)	3 (2
VI	8,500	0.37(~~6~~4)	3 (2)
VII	10,000	0.37(~~6~~4)	3 (2)

Notes:
(1) For precast three-sided culverts, box culverts, endwalls, inlets, manholes and junction boxes, the target slump value and air content will not apply. The maximum allowable slump is 6 inches, except as noted in (2). The Contractor is permitted to use concrete meeting the requirements of ASTM C478 (4,000 psi) in lieu of the specified Class I or Class II concrete for precast endwalls, inlets, manholes and junction boxes.
(2) Increased slump and slip form concrete as defined in 346-3.1~~The Engineer may allow a maximum target slump of 7 inches when a Type F, G, I or II admixture is used. When flowing concrete is used, meet the requirements of Section 8.6 of the Materials Manual.~~
~~(3) For a reduction in the target slump for slip-form operations, submit a revision to the mix design to the Engineer. The target slump for slip-form mix is 1.50 inches.~~
~~(4) When precast three-sided culverts, box culverts, endwalls, inlets, manholes or junction boxes require a Class III concrete, the minimum cementitious materials content is 470 pounds per cubic yard. Do not apply the air content range and the maximum target slump shall be 6 inches, except as allowed in (2).~~
(~~5~~3) Meet the requirements of Section 350.
(~~6~~4) When silica fume or metakaolin is required, the maximum water to cementitious material ratio will be 0.35. When ultrafine fly ash is used, the maximum water to cementitious material ratio will be 0.30.

346-3.4 Durability for Concrete Construction:

346-3.4.1 Minimum Cementitious Materials Content: Ensure that the produced concrete meets the minimum amount of cementitious materials content in Table 346-4.

Table 346-4 Minimum Amount of Total Cementitious Materials Content (pounds per cubic yard of concrete)			
Concrete Class	Environmental Classification		
	Extremely Aggressive	Moderately Aggressive	Slightly Aggressive
I, I (Pavement), II, and III (Seal)	470		
II (Bridge Deck), III (1), IV, IV (Drilled Shaft), V, V(Special), VI and VII	600	550	510

Notes:
(1) When precast three-sided culverts, box culverts, endwalls, inlets, manholes or junction boxes require a Class III concrete, the minimum cementitious materials content may be reduced to 470 pounds per cubic yard.

346-3.4.2 Chloride Content Limits: Use the following maximum allowable chloride content limits for the concrete application and/or exposure environment shown:

Table 346-5
Chloride Content Limits for Concrete Construction

Application/Exposure Environment		Maximum Allowable Chloride Content, (pounds per cubic yard of concrete)
Non-Reinforced Concrete		No Test Needed
Reinforced Concrete	Slightly Aggressive Environment	0.70
	Moderately or Extremely Aggressive Environment	0.40
Prestressed Concrete		0.40

~~If chloride test results exceed the limits of Table 346-5, s~~Suspend concrete placement immediately for every mix design if chloride test results exceed the limits of Table 346-5~~represented by the failing test results,~~ until corrective measures are made. Submit an Engineering Analysis Scope in accordance with 6-4 by a Specialty Engineer knowledgeable in the areas of corrosion and corrosion control, to determine if the material meets the intended service life of the structure on all concrete produced from the mix design failing chloride test results to the previous passing test results.

346-3.4.3 Surface Resistivity Test: Ensure that the Class II (Bridge Deck), Class IV, Class V, Class V (Special), Class VI, or Class VII concrete in extremely aggressive environments meets or exceeds a resistivity of 29 kOhm-cm at 28 days, when a highly reactive pozzolan is used.

SUBARTICLE 346-4.1 is deleted and the following substituted:

346-4 Special Types of Concrete.

346-4.1 Drilled Shaft Concrete: Notify the Engineer at least 48 hours before placing drilled shaft concrete. Obtain slump loss test~~s~~ results demonstrating that the drilled shaft concrete maintains a slump of at least 5 inches throughout the concrete elapsed time before drilled shaft concrete operations begin.

Perform the slump loss test at the anticipated ambient temperature for drilled shaft placements greater than 30 cubic yards and an elapsed time of greater than five hours.

Obtain slump loss test results from an approved laboratory or from a field demonstration. Slump loss test results for drilled shafts requiring 30 cubic yards of concrete or less and a maximum elapsed time of five hours or less may be done in a laboratory. Obtain all other slump loss test results in the field.

The concrete elapsed time is defined in Section 455. Obtain the Engineer's approval for use of slump loss test results including elapsed time before concrete placement begins.

Test each load of concrete for slump to ensure that it~~the slump~~ is within the limits of this Section. Initially cure acceptance cylinders for 48 hours before transporting them to the laboratory.

If the elapsed time during placement exceeds the slump loss test data, submit an Engineering Analysis Scope in accordance with 6-4 by a Specialty Engineer knowledgeable in

~~the area of~~ concrete foundations, to determine if the shaft is structurally sound and free from voids. At the direction of the Engineer, excavate the drilled shaft for inspection. Obtain approval from the Engineer before placing any additional shafts.

ARTICLE 346-5 is deleted and the following substituted:

346-5 Sampling and Testing Methods.

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

Table 346-7
Concrete Sampling and Testing Methods

Description	Method
Slump of Hydraulic Cement Concrete	ASTM C143
Air Content of Freshly Mixed Concrete by the Pressure Method (1)	ASTM C231
Air Content of Freshly Mixed Concrete by the Volumetric Method (1)	ASTM C173
Making and Curing Test Specimens in the Field (2)	ASTM C31
Compressive Strength of Cylindrical Concrete Specimens	ASTM C39
Obtaining and Testing Drilled Core and Sawed Beams of Concrete	ASTM C42
Initial Sampling of 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 C138
Temperature of Freshly Mixed Portland Cement Concrete	ASTM C1064
Sampling Freshly Mixed Concrete (3)	ASTM C172
Static Segregation of Self-Consolidating Concrete using Column Techniques	ASTM C1610
Slump Flow of Self-Consolidating Concrete	ASTM C1611
Relative Viscosity of Self-Consolidating Concrete	ASTM C1611
Visual Stability Index of Self-Consolidating Concrete	ASTM C1611
Passing Ability of Self-Consolidating Concrete by J-Ring	ASTM C1621
Rapid Assessment of Static Segregation Resistance of Self-Consolidating Concrete Using Penetration Test	ASTM C1712
Aggregate Distribution of Hardened Self-Consolidating Concrete	FM 5-617
Hardened Visual Stability Index of Self-Consolidating Concrete	AASHTO R 81
Fabricating Test Specimens with Self-Consolidating Concrete	ASTM C1758
Concrete Resistivity as an Electrical Indicator of its Permeability	AASHTO T 358

(1) The Department will use the same type of meter for Verification testing as used for QC testing. When using 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.
(2) Provide curing facilities that have the capacity to store all QC, Verification, and Resolution cylinders simultaneously for the initial curing. Cylinders will be delivered to the testing laboratory in their molds. The laboratory will remove the specimens from the molds and begin final curing.
(3) Take the test sample from the middle portion of the batch in lieu of collecting and compositing samples from two or more portions, as described in ASTM C172.

SUBARTICLE 346-6.2 is deleted and the following substituted:

346-6.2 Concrete Mix Design: Provide concrete that has been produced in accordance with a Department approved mix design, in a uniform mass free from balls and lumps.

For slump target values in excess of 6 inches, including flowing ~~and self consolidating~~ concrete and SCC, utilize a grate over the conveyance equipment to capture any lumps or balls that may be present in the mix. The grate must cover the entire opening of the conveyance equipment and have an opening that is a maximum of 2-1/2 inches in any one direction. Remove the lumps and balls from the grate and discard them. Discharge the concrete in a manner satisfactory to the Engineer. Perform demonstration batches to ensure complete and thorough placements in complex elements, when requested by the Engineer.

Do not place concretes of different compositions such that the plastic concretes may combine, except where the Plans require concrete with a surface resistivity value of 29 kOhm-cm or below and one with higher than 29 kOhm-cm values in a continuous placement. Produce these concretes using separate mix designs. 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 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 as approved by the Engineer.

ARTICLE 346-9 is deleted and the following substituted:

346-9 Acceptance Sampling and Testing.

346-9.1 General: Perform plastic properties tests in accordance with 346-8 and cast a set of three QC cylinders, for all structural concrete incorporated into the project. Take these acceptance samples randomly as determined by a random number generator acceptable to the Department. The Department will independently perform VT plastic properties tests and cast a set of VT cylinders. The VT cylinders will be the same size cylinder selected by the Contractor, from a separate sample from the same load of concrete as the Contractor's QC sample.

For each set of QC cylinders verified by the Department, cast two additional cylinders from the same sample, and identify them as the quality control resolution (QR) test cylinders. The Department will also cast two additional verification resolution (VR) test cylinders from each VT sample. All cylinders will be clearly identified as outlined in the Sample/Lot Numbering System instructions located on the State Materials Office website. Deliver the QC samples, including the QR cylinders to the final curing facility in accordance with ASTM C31. Concurrently, the Department will deliver the VT samples, including the VR cylinders, to their final curing facility.

Test the QC laboratory cured samples for compressive strength at the age of 28 days, in a laboratory meeting and maintaining at all times the qualification requirements listed in Section 105.

Ensure the QC testing laboratory input the compressive strength test results into the Department's Materials Acceptance and Certification (MAC) system ~~on daily basis~~within 24 hours after testing. Notify the Engineer when results cannot be inputted into MAC.

~~The QC testing laboratory will input the compressive strength test results into the Department's Materials Acceptance and Certification (MAC) system within 24 hours. When the QC testing laboratory cannot input the compressive strength test results into MAC within 24 hours, the QC testing laboratory will notify the VT testing laboratory within 24 hours of testing the cylinder and provide the VT testing laboratory the compressive strength test results. Ensure the compressive strength results are input into MAC within 72 hours of determining the compressive strength of the cylinders.~~

The Department will compare the VT sample compressive strength test results with the corresponding QC sample test results.

346-9.2 Sampling Frequency: As a minimum, sample and test concrete of each mix design for water to cementitious materials ratio, air content, temperature, slump and compressive strength once per LOT as defined by Table 346-9. The Engineer will randomly verify one of every four consecutive LOTs of each mix design based on a random number generator. The Department may perform Independent Verification (IV) testing to verify compliance with specification requirements. All QC activities, calculations, and inspections will be randomly confirmed by the Department.

Table 346-9
Sampling Frequency

Class Concrete (1)	LOT Size
I	one day's production
I (Pavement)	2,000 square yards, or one day's production, whichever is less
II, II (Bridge Deck), III, IV, V (Special), V, VI, VII	50 cubic yards, or one day's production, whichever is less
IV (Drilled Shaft)	50 cubic yards, or one day's production, whichever is less (2)
III (Seal)	Each Seal placement

(1) For any class of concrete used for roadway concrete barrier, the lot size is defined as 100 cubic yards, or one day's production, whichever is less.
(2) Start a new LOT when there is a gap of more than two hours between the end of one drilled shaft placement and the beginning of the next drilled shaft placement.

346-9.2.1 Reduced Frequency for Acceptance Tests: The LOT size may represent 100 cubic yards when produced with the same mix design at the same concrete production facility for the same prime Contractor and subcontractor on a given Contract. As an exception, the requirements for the precast/prestressed production facility will only include the same mix design at the same concrete production facility.

Submit strength test results indicating that the two following criteria are met:

1. The average of the acceptance compressive strengths is equal to or greater than the specified minimum compressive strength (f'c~~f$_e$'~~) plus 2.33 standard deviations minus:

a. 500 psi, if f'c~~f$_e$'~~ is 5,000 psi or less.

b. 0.10 f'c~~f$_c$'~~, if f'c~~f$_c$'~~ is greater than 5,000 psi.

2. Every average of three consecutive strength test equals or exceeds the f'c~~f$_c$'~~ plus 1.34 standard deviations.

Base calculations on a minimum of ten consecutive strength test results for a Class IV or higher; or a minimum of five consecutive strength results for a Class III or lower.

The average of the consecutive compressive strength test results, based on the class of concrete, can be established using historical data from a previous Department project. The tests from the previous Department project must be within the last calendar year or may also be established by a succession of samples on the current project. Only one sample can be taken from each LOT. Test data must be from a laboratory meeting the requirements of Section 105. Obtain Department approval before beginning reduced frequency LOTs.

If at any time a strength test is not verified or the average strength of the previous ten or five consecutive samples based on the class of concrete from the same mix design and the same production facility does not conform to the above conditions, return to the frequency represented by the LOT as defined in Table 346-9. Notify the Engineer that the initial frequency is reinstated. In order to reinitiate reduced frequency, submit a new set of strength test results.

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 Concrete: The Engineer will accept the concrete of a given LOT when the compressive strength test results are verified and ~~it~~ meets the minimum specified compressive strength in~~requirement of~~ Table 346-3. Ensure that the hardened concrete strength test results are obtained in accordance with 346-9.3.

The process of concrete compressive strength verification and acceptance consists of the following steps:

1. Verification of QC and VT data.
2. Resolution of Q~~R~~C and V~~R~~T data if needed.
3. Structural Adequacy determination.

Do not discard a cylinder strength test result based on low strength (strength below the specified minimum strength as per the provisions of this Section).

When one of the three QC cylinders from a LOT is lost, missing, damaged or destroyed, determination of compressive strength will be made by averaging the remaining two cylinders. If more than one QC cylinder from a LOT is lost, missing, damaged or destroyed, the Contractor will core the structure at no additional expense to the Department to determine the compressive strength. Prior to coring, obtain Engineer's approval for coring the structure and its proposed coring location. Acceptance of LOT may be based on VT data at the discretion of the Engineer. ~~Obtain the approval of the Engineer to core, and of the core location prior to coring.~~

For each QC and each QR cylinder that is lost, missing, damaged or destroyed, payment for that LOT will be reduced by $750.00 per 1,000 psi of the specified design strength [Example: loss of two Class IV (Drill Shaft) QC cylinders that has no VT data will require the element to be cored and a pay reduction will be assessed (4,000 psi / 1,000 psi) x $750 x 2 = $6,000]. This reduction will be in addition to any pay adjustment for low strength.

346-9.4.1 Small Quantities of Concrete: When a project has a total plan quantity of less than 50 cubic yards, that concrete will be accepted based on the satisfactory compressive strength of the QC cylinders. Submit certification to the Engineer that the concrete was batched

and placed in accordance with the Contract Documents. Submit a QC Plan for the concrete placement operation in accordance with Section 105. The Engineer may perform IV testing as identified in 346-9 and evaluate the concrete in accordance with 346-9.7.

346-9.5 Verification: The results of properly conducted test by QC and VT laboratories on specimens prepared from the same sample of concrete are not to differ by more than 14%.

$$\text{Difference (\%)} = \text{ABS}\left(\frac{\text{QC}-\text{VT}}{\text{QC}}\right)100$$

Where:

Difference (%) is the absolute percentage difference between QC and V~~erification T~~est average compressive strength.

The procedure consists of verifying if the QC and V~~erification T~~est compressive strengths data meet the established comparison criteria:

1. When the difference between the average compressive strength of QC and the average compressive strength of V~~erification T~~est is less than or equal to 14%, the QC test results are upheld and 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 plastic property results which meet the requirements of the approved mix design and strength test results which equal or exceed the respective specified minimum strength.

2. When the difference between the average compressive strength of QC and the average compressive strength of V~~erification T~~est data exceeds 14%, the compressive strength results are~~QC data is~~ not verified and the Engineer will initiate the resolution procedure. ~~The resolution procedure will be used to accept or reject the concrete.~~

Maintain the QR and VR cylinders for a minimum of 30 days following~~until~~ the ~~verification of the compressive strength test results~~testing date of~~, and may be discarded after about no more than one month after the age of~~ the specified strength ~~test~~ age.

346-9.6 Resolution ~~Procedure~~: ~~The resolution procedure may consist of, but need not be limited to, a review of sampling and testing of fresh concrete, calculation of water to cementitious materials ratio, handling of cylinders, curing procedures and compressive strength testing.~~The Engineer will perform the resolution process to identify the reliability of the compressive strength results when the difference between the average compressive strength of QC and the average compressive strength of VT data exceeds 14% as described in 346-9.5(2).

The Engineer will correlate the 28-day strength (VR_{28} and QR_{28}) for the VR and QR cylinders and will compare:

1. The VT sample results with the VR_{28} cylinders results.
2. The QC sample results with the QR_{28} cylinders results.

~~Compare the VT sample results with the VR cylinders results. Compare the QC sample results with the QR cylinders results.~~ Comparison results must not be greater than 17.5%. Core samples of the hardened concrete may be required. ~~The Engineer will correlate the 28-day strength (VR_{28} and QR_{28}) for the VR and QR cylinders.~~

$$V_D\ (\%) = \text{ABS}\left(\frac{\text{VT} - \text{VR}_{28}}{\text{VT}}\right)100$$

$$Q_D\ (\%) = \text{ABS}\left(\frac{\text{QC} - \text{QR}_{28}}{\text{QC}}\right)100$$

Where:

V_D (%) is the absolute percentage difference between VT and VR_{28}.

Q_D (%) is the absolute percentage difference between QC and QR_{28}.

The resolution procedure will use the above equations. The Engineer will determine through the resolution procedure whether the QC strength test results or the VT strength test are deemed to be the most accurate, LOT~~S~~s will then be considered to be verified. ~~When the Engineer cannot determine which strength test results are the most accurate, the concrete represented by the four consecutive LOTs will be evaluated based on the QC data.~~

The Engineer will inform the QC and VT laboratories within three calendar days of the acceptance compressive strength test to transport their QR and VR cylinders to the resolution laboratory. The QC and VT laboratories will transport their own hold cylinders to the resolution testing laboratory within three calendar days after the Engineer notifies the Contractor that a resolution procedure is required. In addition, the Engineer will ensure that the QR and VR cylinders are tested within 14 calendar days of the acceptance strength tests.

The Engineer will determine the most accurate strength test result to represent the four or fewer consecutive LOTs as follows:

1. When both results meet the established comparison criteria, both are deemed accurate and the QC strength will represent the LOTs. The Department will pay for cost of the resolution testing.

2. When only the QC result is within the established comparison criteria, the QC strength is deemed as most accurate and will represent the LOTs. The Department will pay for the cost of the resolution testing.

3. When only the VT result is within the established comparison criteria, the VT strength is deemed as most accurate and will represent the LOTs. The Department will assess a $1,000 pay reduction for the cost of the Resolution Investigation.

4. When both results are outside the established comparison criteria, the Engineer, with input from the D~~istrict~~ M~~aterials~~ O~~ffice~~, will determine if any Department IA evaluations are required and which test results are most accurate. The Department will pay for the cost of the resolution testing.

When the Engineer cannot determine which strength test results are the most accurate, the concrete represented by the four consecutive LOTs will be evaluated based on the QC data.

The results of the resolution procedure will be forwarded to the Contractor within five working days after completion of the investigation.

346-9.7 ~~Small Quantities of Concrete346-10 Investigation of Low Strength Concrete and~~ Structural Adequacy~~:~~: ~~When a project has a total plan quantity of less than 50 cubic yards, that concrete will be accepted based on the satisfactory compressive strength of the QC cylinders. Submit certification to the Engineer that the concrete was batched and placed in accordance with the Contract Documents. Submit a QC Plan for the concrete placement operation in accordance with Section 105. In addition, the Engineer may conduct IV testing as identified in 346-9. Evaluate the concrete in accordance with 346-10 at the discretion of the Engineer.~~ The Engineer will evaluate the structural adequacy ~~**346-10.1 General:** The following applies~~ for verified concrete that does not meet the minimum specified compressive strength of Table 346-3.

For standard molded and cured strength cylinders, the compressive strength of concrete is satisfactory provided that the two following criteria are met:

1. The average compressive strength does not fall below the specified minimum compressive strength by more than:

a. 500 psi if the specified minimum compressive strength is equal to or less than 5,000 psi.

b. 10% of the specified minimum compressive strength if the specified minimum compressive strength is greater than 5,000 psi.

2. The average compressive strength with the previous two LOTs is equal to or exceeds the specified minimum compressive strength. This condition only applies if there are two or more previous LOTs to calculate the average.

The Engineer will consider the concrete for a given LOT as structurally adequate and coring will not be allowed when a concrete compressive strength test result falls below the specified minimum strength but has met the above conditions.

ARTICLE 346-10 is deleted and the following substituted:

346-10 Investigation of Low Compressive Strength Concrete ~~and Structural Adequacy~~.

~~**346-10.1 General:** The following applies for concrete that does not meet the minimum specified compressive strength of Table 346-3.~~

~~For standard molded and cured strength cylinders, the compressive strength of concrete is satisfactory provided that the two following criteria are met:~~

~~1. The average compressive strength does not fall below the specified minimum compressive strength by more than:~~

~~a. 500 psi if the specified minimum compressive strength is equal to or less than 5,000 psi.~~

~~b. 10% of the specified minimum compressive strength if the specified minimum compressive strength is greater than 5,000 psi.~~

~~2. The average compressive strength with the previous two LOTs is equal to or exceeds the specified minimum compressive strength. This condition only applies if there are two or more previous LOTs to calculate the average.~~

~~The Engineer will consider the concrete for a given LOT as structurally adequate and coring will not be allowed when a concrete compressive strength test result falls below the specified minimum strength but has met the above conditions.~~

When a verified concrete compressive strength test result falls below the specified minimum strength, and does not meet the structural adequacy described in 346-9.7~~above conditions~~, perform one of the following options:

1. Submit an Engineering Analysis Scope in accordance with 6-4 to establish structural and durability adequacy. When the scope is approved by the Engineer, submit an Engineering Analysis Report (EAR) in accordance with 6-4 that includes a full structural analysis. If the results of the structural analysis indicate adequate strength to serve its intended purpose with adequate durability, and is approved by the Engineer, 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.

2. At the Engineer's discretion, obtain drilled core samples as specified in this Section to determine the in-place strength of the LOT of concrete in question, at no additional expense to the Department. The Engineer will determine whether to allow coring of

the in-place concrete or require an engineering analysis based on the compressive strength of the test cylinders.

346-10.~~2~~1 Coring for Determination of Structural Adequacy: 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 used in lieu of the cylinder strength test results for determination of structural adequacy. 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.

~~Obtain the Engineer's written approval before taking any concrete core sample. Notify the Engineer 48 hours prior to taking core samples.~~ Obtain and test the cores in accordance with ASTM C42. ~~Report the test results to the Engineer within seven calendar days of the Engineer's written approval.~~ The Engineer will select the size and 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 Engineer's written approval before taking any concrete core sample. Notify the Engineer 48 hours prior to taking core samples.

Sample three undamaged cores taken from the same approximate location where the questionable concrete is represented by the low strength concrete test cylinders. Repair core holes after samples are taken with a product in compliance with Section 930 or 934 and meeting the approval of the Engineer. Report the test results to the Engineer within ~~seven~~two calendar days of ~~obtaining~~testing the core samples.

The Engineer, with input from the D~~istrict~~ M~~aterials~~ O~~ffice~~, will consider the concrete as structurally adequate, in the area represented by core tests at the actual test age, if the average compressive strength of cores does not fall below the specified minimum compressive strength (f'c) by more than:

a. 500 psi when the f'c ~~specified minimum compressive strength~~is equal to or less than 5,000 psi.

b. 10% of the f'c ~~specified minimum compressive strength~~when the f'c ~~specified minimum compressive strength~~is greater than 5,000 psi.

The Engineer may also require the Contractor to perform additional testing as necessary to determine structural adequacy of the concrete.

ARTICLE 346-11 is deleted and the following substituted:

346-11 Pay Adjustments for Low Compressive Strength Concrete.

346-11.1 General: For any LOT of concrete failing to meet the f'c~~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: The Engineer will determine payment reductions based on the 28 day compressive strength, represented by either acceptance compressive strength or correlated cores strength test results based on the following criteria:

1. When the acceptance compressive strength test result falls below the specified minimum compressive strength, but no more than the limits established in 346-~~10.1~~9.7 below the specified minimum strength, do not core hardened concrete for determining pay adjustments. Use the acceptance compressive strength test results.

2. When the acceptance compressive strength test result falls below the specified minimum compressive strength by more than the limits established in 346-~~10.1~~9.7, the structure may be cored for determination of structural adequacy as directed by the Engineer. Use the result of the 28 day correlated core compressive strength or the acceptance compressive strength test, whichever is less.

A price adjustment will be applied to the certified invoice price the Contractor paid for the concrete or the precast product.

The Engineer will relate the strength at the actual test age to the 28 day strength for the design mix represented by the cores using appropriate strength time correlation equations.

In precast concrete operations, excluding prestressed concrete, ensure that the producer submits acceptable core sample test results to the Engineer. The producer may elect to use the products in accordance with this Section. Otherwise, replace the concrete in question at no additional cost to the Department. For prestressed concrete, core sample testing is not allowed for pay adjustment. The results of the cylinder strength tests will be used to determine material acceptance and pay adjustment.

346-11.3 Calculating Pay Adjustments: The Engineer will determine payment reductions for low strength concrete accepted by the Department. The 28-day strength is represented by either cylinders or correlated cores strength test results in accordance with 346-~~-~~11.2.

Reduction in Pay is equal to the reduction in percentage of concrete compressive strength below the specified minimum strength:

$$\text{Reduction in Pay (\%)} = \left(\frac{\text{~~f'c~~f'c} - \text{28 day Strength}}{\text{f'c} - \text{~~f'c~~}}\right) 100$$

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

STRUCTURAL PORTLAND CEMENT CONCRETE.
(REV 7-14-21)

ARTICLE 346-1 is deleted and the following substituted:

346-1 Description.

Use a Department-approved concrete mix design composed of a mixture of portland cement, aggregate, water, admixtures, and supplementary cementitious materials. Deliver the portland cement concrete to the site of placement in a freshly mixed, unhardened state.

Obtain concrete from a plant that is currently on the Department's Production Facility Listing. Producers seeking inclusion on the list shall meet the requirements of Section 105. If the concrete production facility's Quality Control (QC) Plan is suspended, the Contractor is solely responsible to obtain the services of another concrete production facility with an accepted QC Plan or await the reacceptance of the concrete production facility's QC Plan prior to the placement of any further concrete on the project. There will be no changes in the Contract Time because of the suspension, as described. Bear all delay costs and other costs associated with the concrete production facility's QC Plan acceptance or reacceptance.

ARTICLE 346-2 is deleted and the following substituted:

346-2 Materials.

346-2.1 General: Meet the following requirements:

Coarse Aggregate	Section 901
Fine Aggregate*	Section 902
Portland Cement and Blended Cement	Section 921
Water	Section 923
Admixtures**	Section 924
Supplementary Cementitious Materials	Section 929

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

**Use products listed on the Department's Approved Product List (APL).

Do not use materials containing hard lumps, crusts, or frozen matter, or that is contaminated with materials exceeding the specified limits in the above listed Sections.

346-2.2 Types of Cement: Unless a specific type of cement is designated in the Contract Documents, use Type I, Type IL, Type IP, Type IS, Type II, Type II (MH) or Type III cement in all classes of concrete. Use Type IL or Type II (MH) for all mass concrete elements.

Use only the types of cements designated for each environmental classification in structural concrete as shown in Table 346-1. A mix design for a more aggressive environment may be used in a less aggressive environmental condition.

Table 346-1 Cement Use by Environmental Classification			
Component	Slightly Aggressive Environment	Moderately Aggressive Environment	Extremely Aggressive Environment (1)
Bridge Superstructures			
Precast Superstructure and Prestressed Elements	Type I or Type III	Type I, Type IL, Type II, Type III, Type IP, or Type IS	Type II (MH), Type IL, Type III (2) or Ternary Blend
Cast in Place	Type I	Type I, Type IL, Type II, Type IP, or Type IS	Type II (MH), Type IL, or Ternary Blend
Bridge Substructures, Drainage Structures, and other Structures			
All Elements	Type I or Type III	Type I, Type IL, Type II, Type IP, or Type IS	Type II (MH), Type IL, or Ternary Blend

Notes:
(1) Cements used in a more aggressive environment may also be used in a less aggressive environment.
(2) Type III cement may be used in an Extremely Aggressive Environment for precast superstructure and prestressed elements when the ambient temperature at the time of concrete placement is 60°F and below.

346-2.3 Supplementary Cementitious Materials: Supplementary cementitious materials are required to produce binary or ternary concrete mixes in all classes of concrete specified in Table 346-3, except for the following when used in slightly aggressive environments: Class I, Class I (Pavement), and Class II.

The quantity of portland cement replaced with supplementary cementitious materials must be on an equal weight replacement basis of the total cementitious materials in accordance with Table 346-2.

346-2.3.1 Highly Reactive Pozzolans: Materials that have a very high degree of pozzolanic reactivity due to their very fine particle sizes, including silica fume, metakaolin and ultrafine fly ash.

346-2.3.2 Binary Concrete Mixes: Concrete mixes containing portland cement and one supplementary cementitious material.

346-2.3.3 Ternary Concrete Mixes: Concrete mixes containing portland cement and any two of supplementary cementitious materials, either fly ash, slag, or highly reactive pozzolans.

Table 346-2
Cementitious Materials Concrete Mix Proportions (%)
(Environmental classification is extremely aggressive, unless otherwise noted)

Application	Portland Cement	Fly Ash Type F	Slag	Highly Reactive Pozzolans [4]		
				Silica Fume	Metakaolin	Ultra-Fine Fly Ash
General Use	70-82	18-30				
	66-78	15-25		7-9		
	66-78	15-25			8-12	
	66-78	15-25				8-12
	30-40	10-20	50-60			
	30-50		50-70			
	36-43		50-55	7-9		
	33-42		50-55		8-12	
	33-42		50-55			8-12
Precast / Prestressed	70-85 [1]	15-30 [1]				
	70-82	18-30				
	66-78	15-25		7-9		
	66-78	15-25			8-12	
	66-78	15-25				8-12
	30-40	10-20	50-60			
	30-50		50-70			
	36-43		50-55	7-9		
	33-42		50-55		8-12	
	33-42		50-55			8-12
Drilled Shaft	63-67	33-37				
	38-42		58-62			
	30-40	10-20	50-60			
Mass Concrete	50-82 [2]	18-50 [2]				
	50-65 [3]	35-50 [3]				
	66-78	15-25		7-9		
	66-78	15-25			8-12	
	66-78	15-25				8-12
	30-40	10-20	50-60			
	30-50		50-70			
	36-43		50-55	7-9		
	33-42		50-55		8-12	
	33-42		50-55			8-12

Notes:
(1) Slightly Aggressive and Moderately Aggressive environments.
(2) For Concrete with Core Temperature T≤165°F.
(3) For Concrete with Core Temperature T≥165°F.
(4) Highly reactive pozzolans may be used below the specified ranges to enhance strength and workability.

346-2.4 Coarse Aggregate Gradation: Produce all concrete using Size No. 57, 67 or 78 coarse aggregate.

Use Size No. 8, and Size No. 89 alone, only when approved by the Engineer.

Use Size No. 4 or larger blended with smaller size coarse aggregate as two components.

346-2.4.1 Optimized Aggregate Gradation: Improve the aggregate packing density at the Contractor's option, by adding an intermediate-size coarse aggregate. Meet the requirements of Section 9.2, Volume II of the Materials Manual, on the methods used to produce combined aggregate gradation of fine, intermediate, and coarse aggregate sizes for the concrete mixes.

346-2.5 Admixtures: Ensure admixtures are used in accordance with the manufacturer's recommendations and meeting the requirements of Section 9.2 Volume II of the Materials Manual.

ARTICLE 346-3 is deleted and the following substituted:

346-3 Classification of Concrete.

346-3.1 General: The classifications of concrete are designated as Class I, Class I (Pavement), Class II, Class II (Bridge Deck), Class III, Class III (Seal), Class IV, Class IV (Drilled Shaft), Class V, Class V (Special), Class VI, and Class VII. The 28-day specified minimum compressive strength, maximum water to cementitious materials ratio and target slump of each class are detailed in Table 346-3. The required air content for all classes of concrete is less than or equal to 6.0%.

For purposes of this Specification the concrete is further classified as follows:

1. Conventional Concrete: The target slump is described in Table 346-3 with a tolerance of ± 1.5 inches.

2. Increased Slump Concrete: The maximum target slump is 7 inches with a tolerance of ± 1.5 inches when a Type F, G, I or II admixture is used.

3. Slip-form Concrete: The target slump is 1.5 inches with a tolerance of ± 1.5 inches.

4. Flowing Concrete: Use flowing concrete only in the manufacturing of precast and prestressed products. Request Engineer's authorization to use flowing concrete for cast-in-place applications. The target slump is 9 inches with a tolerance of ± 1.5 inches. Meet the requirements of Section 8.6 Volume II of the Materials Manual.

5. Self-Consolidating Concrete (SCC): Use SCC only in the manufacturing of precast and prestressed products. The minimum target slump flow is 22.5 inches with a tolerance of ± 2.5 inches. Meet the requirements of Section 8.4 Volume II of the Materials Manual.

346-3.2 Concrete Class Substitutions: The Engineer may allow the substitution of a higher class concrete in lieu of the specified class concrete when the substituted concrete mixes are included as part of the QC Plan, or for precast concrete, the Precast Concrete Producer QC Plan. The substituted higher class concrete must meet or exceed the requirements of the specified class concrete.

When the average 28-day compressive strength is less than the 28-day specified minimum compressive strength of the higher class mix design, notify the Engineer. Acceptance is based on the requirements in Table 346-3 for the specified class concrete.

346-3.3 Master Proportion Table: Proportion the materials to produce the classes of concrete in accordance with Table 346-3.

The calculation of the water to cementitious materials ratio (w/cm) is based on the total cementitious materials including portland cement and any supplementary cementitious materials used in the mix.

Table 346-3
Master Proportion Table

Class of Concrete	28-day Specified Minimum Compressive Strength (f'c) (psi)	Maximum Water to Cementitious Materials Ratio (pounds per pounds)	Target Slump Value (inches)
I (1)	3,000	0.53	3 (2)
I (Pavement)	3,000	0.50	1.5 or 3 (3)
II (1)	3,400	0.53	3 (2)
II (Bridge Deck)	4,500	0.44	3 (2)
III (4)	5,000	0.44	3 (2)
III (Seal)	3,000	0.53	8
IV	5,500	0.41(4)	3 (2)
IV (Drilled Shaft)	4,000	0.41	8.5
V (Special)	6,000	0.37(4)	3 (2)
V	6,500	0.37(4)	3 (2
VI	8,500	0.37(4)	3 (2)
VII	10,000	0.37(4)	3 (2)

Notes:
(1) For precast three-sided culverts, box culverts, endwalls, inlets, manholes and junction boxes, the target slump value and air content will not apply. The maximum allowable slump is 6 inches, except as noted in (2). The Contractor is permitted to use concrete meeting the requirements of ASTM C478 (4,000 psi) in lieu of the specified Class I or Class II concrete for precast endwalls, inlets, manholes and junction boxes.
(2) Increased slump and slip form concrete as defined in 346-3.1
(3) Meet the requirements of Section 350.
(4) When silica fume or metakaolin is required, the maximum water to cementitious material ratio will be 0.35. When ultrafine fly ash is used, the maximum water to cementitious material ratio will be 0.30.

346-3.4 Durability for Concrete Construction:

346-3.4.1 Minimum Cementitious Materials Content: Ensure that the produced concrete meets the minimum amount of cementitious materials content in Table 346-4.

Table 346-4
Minimum Amount of Total Cementitious Materials Content
(pounds per cubic yard of concrete)

Concrete Class	Environmental Classification		
	Extremely Aggressive	Moderately Aggressive	Slightly Aggressive
I, I (Pavement), II, and III (Seal)	470		
II (Bridge Deck), III (1), IV, IV (Drilled Shaft), V, V(Special), VI and VII	600	550	510

Table 346-4 Minimum Amount of Total Cementitious Materials Content (pounds per cubic yard of concrete)			
Concrete Class	Environmental Classification		
	Extremely Aggressive	Moderately Aggressive	Slightly Aggressive
Notes: (1) When precast three-sided culverts, box culverts, endwalls, inlets, manholes or junction boxes require a Class III concrete, the minimum cementitious materials content may be reduced to 470 pounds per cubic yard.			

346-3.4.2 Chloride Content Limits: Use the following maximum allowable chloride content limits for the concrete application and/or exposure environment shown:

Table 346-5 Chloride Content Limits for Concrete Construction		
Application/Exposure Environment		Maximum Allowable Chloride Content, (pounds per cubic yard of concrete)
Non-Reinforced Concrete		No Test Needed
Reinforced Concrete	Slightly Aggressive Environment	0.70
	Moderately or Extremely Aggressive Environment	0.40
Prestressed Concrete		0.40

Suspend concrete placement immediately for every mix design if chloride test results exceed the limits of Table 346-5 until corrective measures are made. Submit an Engineering Analysis Scope in accordance with 6-4 by a Specialty Engineer knowledgeable in the areas of corrosion and corrosion control, to determine if the material meets the intended service life of the structure on all concrete produced from the mix design failing chloride test results to the previous passing test results.

346-3.4.3 Surface Resistivity Test: Ensure that the Class II (Bridge Deck), Class IV, Class V, Class V (Special), Class VI, or Class VII concrete in extremely aggressive environments meets or exceeds a resistivity of 29 kOhm-cm at 28 days, when a highly reactive pozzolan is used.

SUBARTICLE 346-4.1 is deleted and the following substituted:

346-4 Special Types of Concrete.

346-4.1 Drilled Shaft Concrete: Notify the Engineer at least 48 hours before placing drilled shaft concrete. Obtain slump loss test results demonstrating that the drilled shaft concrete maintains a slump of at least 5 inches throughout the concrete elapsed time before drilled shaft concrete operations begin.

Perform the slump loss test at the anticipated ambient temperature for drilled shaft placements greater than 30 cubic yards and an elapsed time of greater than five hours.

Obtain slump loss test results from an approved laboratory or from a field demonstration. Slump loss test results for drilled shafts requiring 30 cubic yards of concrete or

less and a maximum elapsed time of five hours or less may be done in a laboratory. Obtain all other slump loss test results in the field.

The concrete elapsed time is defined in Section 455. Obtain the Engineer's approval for use of slump loss test results including elapsed time before concrete placement begins.

Test each load of concrete for slump to ensure that it is within the limits of this Section. Initially cure acceptance cylinders for 48 hours before transporting them to the laboratory.

If the elapsed time during placement exceeds the slump loss test data, submit an Engineering Analysis Scope in accordance with 6-4 by a Specialty Engineer knowledgeable in concrete foundations, to determine if the shaft is structurally sound and free from voids. At the direction of the Engineer, excavate the drilled shaft for inspection. Obtain approval from the Engineer before placing any additional shafts.

ARTICLE 346-5 is deleted and the following substituted:

346-5 Sampling and Testing Methods.

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

Table 346-7 Concrete Sampling and Testing Methods	
Description	Method
Slump of Hydraulic Cement Concrete	ASTM C143
Air Content of Freshly Mixed Concrete by the Pressure Method (1)	ASTM C231
Air Content of Freshly Mixed Concrete by the Volumetric Method (1)	ASTM C173
Making and Curing Test Specimens in the Field (2)	ASTM C31
Compressive Strength of Cylindrical Concrete Specimens	ASTM C39
Obtaining and Testing Drilled Core and Sawed Beams of Concrete	ASTM C42
Initial Sampling of 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 C138
Temperature of Freshly Mixed Portland Cement Concrete	ASTM C1064
Sampling Freshly Mixed Concrete (3)	ASTM C172
Static Segregation of Self-Consolidating Concrete using Column Techniques	ASTM C1610
Slump Flow of Self-Consolidating Concrete	ASTM C1611
Relative Viscosity of Self-Consolidating Concrete	ASTM C1611
Visual Stability Index of Self-Consolidating Concrete	ASTM C1611
Passing Ability of Self-Consolidating Concrete by J-Ring	ASTM C1621
Rapid Assessment of Static Segregation Resistance of Self-Consolidating Concrete Using Penetration Test	ASTM C1712
Aggregate Distribution of Hardened Self-Consolidating Concrete	FM 5-617
Hardened Visual Stability Index of Self-Consolidating Concrete	AASHTO R 81
Fabricating Test Specimens with Self-Consolidating Concrete	ASTM C1758
Concrete Resistivity as an Electrical Indicator of its Permeability	AASHTO T 358

(1) The Department will use the same type of meter for Verification testing as used for QC testing. When using 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.
(2) Provide curing facilities that have the capacity to store all QC, Verification, and Resolution cylinders simultaneously for the initial curing. Cylinders will be delivered to the testing laboratory in their molds. The laboratory will remove the specimens from the molds and begin final curing.
(3) Take the test sample from the middle portion of the batch in lieu of collecting and compositing samples from two or more portions, as described in ASTM C172.

SUBARTICLE 346-6.2 is deleted and the following substituted:

346-6.2 Concrete Mix Design: Provide concrete that has been produced in accordance with a Department approved mix design, in a uniform mass free from balls and lumps.

For slump target values in excess of 6 inches, including flowing concrete and SCC, utilize a grate over the conveyance equipment to capture any lumps or balls that may be present in the mix. The grate must cover the entire opening of the conveyance equipment and have an opening that is a maximum of 2-1/2 inches in any one direction. Remove the lumps and

balls from the grate and discard them. Discharge the concrete in a manner satisfactory to the Engineer. Perform demonstration batches to ensure complete and thorough placements in complex elements, when requested by the Engineer.

Do not place concretes of different compositions such that the plastic concretes may combine, except where the Plans require concrete with a surface resistivity value of 29 kOhm-cm or below and one with higher than 29 kOhm-cm values in a continuous placement. Produce these concretes using separate mix designs. 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 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 as approved by the Engineer.

ARTICLE 346-9 is deleted and the following substituted:

346-9 Acceptance Sampling and Testing.

346-9.1 General: Perform plastic properties tests in accordance with 346-8 and cast a set of three QC cylinders, for all structural concrete incorporated into the project. Take these acceptance samples randomly as determined by a random number generator acceptable to the Department. The Department will independently perform VT plastic properties tests and cast a set of VT cylinders. The VT cylinders will be the same size cylinder selected by the Contractor, from a separate sample from the same load of concrete as the Contractor's QC sample.

For each set of QC cylinders verified by the Department, cast two additional cylinders from the same sample, and identify them as the quality control resolution (QR) test cylinders. The Department will also cast two additional verification resolution (VR) test cylinders from each VT sample. All cylinders will be clearly identified as outlined in the Sample/Lot Numbering System instructions located on the State Materials Office website. Deliver the QC samples, including the QR cylinders to the final curing facility in accordance with ASTM C31. Concurrently, the Department will deliver the VT samples, including the VR cylinders, to their final curing facility.

Test the QC laboratory cured samples for compressive strength at the age of 28 days, in a laboratory meeting and maintaining at all times the qualification requirements listed in Section 105.

Ensure the QC testing laboratory input the compressive strength test results into the Department's Materials Acceptance and Certification (MAC) system within 24 hours after testing. Notify the Engineer when results cannot be inputted into MAC.

The Department will compare the VT sample compressive strength test results with the corresponding QC sample test results.

346-9.2 Sampling Frequency: As a minimum, sample and test concrete of each mix design for water to cementitious materials ratio, air content, temperature, slump and compressive strength once per LOT as defined by Table 346-9. The Engineer will randomly verify one of every four consecutive LOTs of each mix design based on a random number generator. The Department may perform Independent Verification (IV) testing to verify compliance with

specification requirements. All QC activities, calculations, and inspections will be randomly confirmed by the Department.

Table 346-9
Sampling Frequency

Class Concrete (1)	LOT Size
I	one day's production
I (Pavement)	2,000 square yards, or one day's production, whichever is less
II, II (Bridge Deck), III, IV, V (Special), V, VI, VII	50 cubic yards, or one day's production, whichever is less
IV (Drilled Shaft)	50 cubic yards, or one day's production, whichever is less (2)
III (Seal)	Each Seal placement

(1) For any class of concrete used for roadway concrete barrier, the lot size is defined as 100 cubic yards, or one day's production, whichever is less.
(2) Start a new LOT when there is a gap of more than two hours between the end of one drilled shaft placement and the beginning of the next drilled shaft placement.

346-9.2.1 Reduced Frequency for Acceptance Tests: The LOT size may represent 100 cubic yards when produced with the same mix design at the same concrete production facility for the same prime Contractor and subcontractor on a given Contract. As an exception, the requirements for the precast/prestressed production facility will only include the same mix design at the same concrete production facility.

Submit strength test results indicating that the two following criteria are met:

1. The average of the acceptance compressive strengths is equal to or greater than the specified minimum compressive strength (f'c) plus 2.33 standard deviations minus:

a. 500 psi, if f'c is 5,000 psi or less.
b. 0.10 f'c, if f'c is greater than 5,000 psi.

2. Every average of three consecutive strength test equals or exceeds the f'c plus 1.34 standard deviations.

Base calculations on a minimum of ten consecutive strength test results for a Class IV or higher; or a minimum of five consecutive strength results for a Class III or lower.

The average of the consecutive compressive strength test results, based on the class of concrete, can be established using historical data from a previous Department project. The tests from the previous Department project must be within the last calendar year or may also be established by a succession of samples on the current project. Only one sample can be taken from each LOT. Test data must be from a laboratory meeting the requirements of Section 105. Obtain Department approval before beginning reduced frequency LOTs.

If at any time a strength test is not verified or the average strength of the previous ten or five consecutive samples based on the class of concrete from the same mix design and the same production facility does not conform to the above conditions, return to the frequency represented by the LOT as defined in Table 346-9. Notify the Engineer that the initial frequency is reinstated. In order to reinitiate reduced frequency, submit a new set of strength test results.

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

346-9.4 Acceptance of Concrete: The Engineer will accept the concrete of a given LOT when the compressive strength test results are verified and meets the minimum specified compressive strength in Table 346-3. Ensure that the hardened concrete strength test results are obtained in accordance with 346-9.3.

The process of concrete compressive strength verification and acceptance consists of the following steps:

1. Verification of QC and VT data.
2. Resolution of QC and VT data if needed.
3. Structural Adequacy determination.

Do not discard a cylinder strength test result based on low strength (strength below the specified minimum strength as per the provisions of this Section).

When one of the three QC cylinders from a LOT is lost, missing, damaged or destroyed, determination of compressive strength will be made by averaging the remaining two cylinders. If more than one QC cylinder from a LOT is lost, missing, damaged or destroyed, the Contractor will core the structure at no additional expense to the Department to determine the compressive strength. Prior to coring, obtain Engineer's approval for coring the structure and its proposed coring location. Acceptance of LOT may be based on VT data at the discretion of the Engineer.

For each QC and each QR cylinder that is lost, missing, damaged or destroyed, payment for that LOT will be reduced by $750.00 per 1,000 psi of the specified design strength [Example: loss of two Class IV (Drill Shaft) QC cylinders that has no VT data will require the element to be cored and a pay reduction will be assessed (4,000 psi / 1,000 psi) x $750 x 2 = $6,000]. This reduction will be in addition to any pay adjustment for low strength.

346-9.4.1 Small Quantities of Concrete: When a project has a total plan quantity of less than 50 cubic yards, that concrete will be accepted based on the satisfactory compressive strength of the QC cylinders. Submit certification to the Engineer that the concrete was batched and placed in accordance with the Contract Documents. Submit a QC Plan for the concrete placement operation in accordance with Section 105. The Engineer may perform IV testing as identified in 346-9 and evaluate the concrete in accordance with 346-9.7.

346-9.5 Verification: The results of properly conducted test by QC and VT laboratories on specimens prepared from the same sample of concrete are not to differ by more than 14%.

$$\text{Difference (\%)} = \text{ABS}\left(\frac{\text{QC}-\text{VT}}{\text{QC}}\right)100$$

Where:

Difference (%) is the absolute percentage difference between QC and VT average compressive strength.

The procedure consists of verifying if the QC and VT compressive strengths data meet the established comparison criteria:

1. When the difference between the average compressive strength of QC and the average compressive strength of VT is less than or equal to 14%, the QC test results are upheld and verified. The Engineer will accept at full pay only LOTs of concrete represented by plastic property results which meet the requirements of the approved mix design and strength test results which equal or exceed the respective specified minimum strength.

2. When the difference between the average compressive strength of QC and the average compressive strength of VT data exceeds 14%, the compressive strength results are not verified and the Engineer will initiate the resolution procedure.

Maintain the QR and VR cylinders for a minimum of 30 days following the testing date of the specified strength.

346-9.6 Resolution: The Engineer will perform the resolution process to identify the reliability of the compressive strength results when the difference between the average compressive strength of QC and the average compressive strength of VT data exceeds 14% as described in 346-9.5(2).

The Engineer will correlate the 28-day strength (VR_{28} and QR_{28}) for the VR and QR cylinders and will compare:

1. The VT sample results with the VR_{28} cylinders results.
2. The QC sample results with the QR_{28} cylinders results.

Comparison results must not be greater than 17.5%. Core samples of the hardened concrete may be required.

$$V_D\ (\%)\ = \mathrm{ABS}\left(\frac{VT - VR_{28}}{VT}\right)100$$

$$Q_D\ (\%)\ = \mathrm{ABS}\left(\frac{QC - QR_{28}}{QC}\right)100$$

Where:

V_D (%) is the absolute percentage difference between VT and VR_{28}.

Q_D (%) is the absolute percentage difference between QC and QR_{28}.

The resolution procedure will use the above equations. The Engineer will determine through the resolution procedure whether the QC strength test results or the VT strength test are deemed to be the most accurate, LOTs will then be considered to be verified.

The Engineer will inform the QC and VT laboratories within three calendar days of the acceptance compressive strength test to transport their QR and VR cylinders to the resolution laboratory. The QC and VT laboratories will transport their own hold cylinders to the resolution testing laboratory within three calendar days after the Engineer notifies the Contractor that a resolution procedure is required. In addition, the Engineer will ensure that the QR and VR cylinders are tested within 14 calendar days of the acceptance strength tests.

The Engineer will determine the most accurate strength test result to represent the four or fewer consecutive LOTs as follows:

1. When both results meet the established comparison criteria, both are deemed accurate and the QC strength will represent the LOTs. The Department will pay for cost of the resolution testing.
2. When only the QC result is within the established comparison criteria, the QC strength is deemed as most accurate and will represent the LOTs. The Department will pay for the cost of the resolution testing.
3. When only the VT result is within the established comparison criteria, the VT strength is deemed as most accurate and will represent the LOTs. The Department will assess a $1,000 pay reduction for the cost of the Resolution Investigation.
4. When both results are outside the established comparison criteria, the Engineer, with input from the DMO, will determine if any Department IA evaluations are

required and which test results are most accurate. The Department will pay for the cost of the resolution testing.

When the Engineer cannot determine which strength test results are the most accurate, the concrete represented by the four consecutive LOTs will be evaluated based on the QC data.

The results of the resolution procedure will be forwarded to the Contractor within five working days after completion of the investigation.

346-9.7 Structural Adequacy: The Engineer will evaluate the structural adequacy for verified concrete that does not meet the minimum specified compressive strength of Table 346-3.

For standard molded and cured strength cylinders, the compressive strength of concrete is satisfactory provided that the two following criteria are met:

1. The average compressive strength does not fall below the specified minimum compressive strength by more than:

a. 500 psi if the specified minimum compressive strength is equal to or less than 5,000 psi.

b. 10% of the specified minimum compressive strength if the specified minimum compressive strength is greater than 5,000 psi.

2. The average compressive strength with the previous two LOTs is equal to or exceeds the specified minimum compressive strength. This condition only applies if there are two or more previous LOTs to calculate the average.

The Engineer will consider the concrete for a given LOT as structurally adequate and coring will not be allowed when a concrete compressive strength test result falls below the specified minimum strength but has met the above conditions.

ARTICLE 346-10 is deleted and the following substituted:

346-10 Investigation of Low Compressive Strength Concrete.

When a verified concrete compressive strength test result falls below the specified minimum strength, and does not meet the structural adequacy described in 346-9.7, perform one of the following options:

1. Submit an Engineering Analysis Scope in accordance with 6-4 to establish structural and durability adequacy. When the scope is approved by the Engineer, submit an Engineering Analysis Report (EAR) in accordance with 6-4 that includes a full structural analysis. If the results of the structural analysis indicate adequate strength to serve its intended purpose with adequate durability, and is approved by the Engineer, 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.

2. At the Engineer’s discretion, obtain drilled core samples as specified in this Section to determine the in-place strength of the LOT of concrete in question, at no additional expense to the Department. The Engineer will determine whether to allow coring of the in-place concrete or require an engineering analysis based on the compressive strength of the test cylinders.

346-10.1 Coring for Determination of Structural Adequacy: 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 used in lieu of the cylinder strength test results for determination of structural adequacy. 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.

Obtain and test the cores in accordance with ASTM C42.The Engineer will select the size and 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 Engineer's written approval before taking any concrete core sample. Notify the Engineer 48 hours prior to taking core samples.

Sample three undamaged cores taken from the same approximate location where the questionable concrete is represented by the low strength concrete test cylinders. Repair core holes after samples are taken with a product in compliance with Section 930 or 934 and meeting the approval of the Engineer. Report the test results to the Engineer within two calendar days of testing the core samples.

The Engineer, with input from the DMO, will consider the concrete as structurally adequate, in the area represented by core tests at the actual test age, if the average compressive strength of cores does not fall below the specified minimum compressive strength (f'c) by more than:

a. 500 psi when the f'c is equal to or less than 5,000 psi.
b. 10% of the f'c when the f'c is greater than 5,000 psi.

The Engineer may also require the Contractor to perform additional testing as necessary to determine structural adequacy of the concrete.

ARTICLE 346-11 is deleted and the following substituted:

346-11 Pay Adjustments for Low Compressive Strength Concrete.

346-11.1 General: For any LOT of concrete failing to meet the f'c as defined in 346-3, 346-9, 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: The Engineer will determine payment reductions based on the 28 day compressive strength, represented by either acceptance compressive strength or correlated cores strength test results based on the following criteria:

1. When the acceptance compressive strength test result falls below the specified minimum compressive strength, but no more than the limits established in 346-9.7 below the specified minimum strength, do not core hardened concrete for determining pay adjustments. Use the acceptance compressive strength test results.

2. When the acceptance compressive strength test result falls below the specified minimum compressive strength by more than the limits established in 346-9.7, the structure may be cored for determination of structural adequacy as directed by the Engineer. Use the result of the 28 day correlated core compressive strength or the acceptance compressive strength test, whichever is less.

A price adjustment will be applied to the certified invoice price the Contractor paid for the concrete or the precast product.

The Engineer will relate the strength at the actual test age to the 28 day strength for the design mix represented by the cores using appropriate strength time correlation equations.

In precast concrete operations, excluding prestressed concrete, ensure that the producer submits acceptable core sample test results to the Engineer. The producer may elect to use the products in accordance with this Section. Otherwise, replace the concrete in question at

no additional cost to the Department. For prestressed concrete, core sample testing is not allowed for pay adjustment. The results of the cylinder strength tests will be used to determine material acceptance and pay adjustment.

346-11.3 Calculating Pay Adjustments: The Engineer will determine payment reductions for low strength concrete accepted by the Department. The 28-day strength is represented by either cylinders or correlated cores strength test results in accordance with 346-11.2.

Reduction in Pay is equal to the reduction in percentage of concrete compressive strength below the specified minimum strength:

$$\text{Reduction in Pay (\%)} = \left(\frac{f'c - 28 \text{ day Strength}}{f'c}\right) 100$$

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