ORIGINATION FORM
Proposed Revisions to the Specifications
(Please provide all information - incomplete forms will be returned)

Date: 4/26/2019

Office: State Materials Office

Originator: Jose L. Armenteros

Specification Section: 346

Telephone: (352) 955-6666

Article/Subarticle: The entire Section

email: Jose.Armenteros@dot.state.fl.us

Will the proposed revision require changes to:

Publication	Yes	No	Office Staff Contacted
Standard Plans Index	○	◉	
Traffic Engineering Manual	○	◉	
FDOT Design Manual	○	◉	
Construction Project Administration Manual	◉	○	John Westphal
Basis of Estimate/Pay Items	○	◉	
Structures Design Guidelines	○	◉	
Approved Product List	○	◉	
Materials Manual	◉	○	Jose Armenteros

Will this revision necessitate any of the following:

Design Bulletin ☐ **Construction Bulletin** ☐ **Estimates Bulletin** ☐ **Materials Bulletin** ☐

Are all references to external publications current? **Yes** ◉ **No** ○

If not, what references need to be updated? (Please include changes in the redline document.)

Why does the existing language need to be changed?

The resolution process for acceptability of non-comparison concrete test results requires clear action process. Also, structural adequacy investigation of concrete requires detailed process.

Summary of the changes:

The Section title have been modified. The concrete resolution process have been simplified. A request for an extra “hold cylinder” lessens the liability of the Contractor. The structural adequacy process of the in-place concrete in accordance ACI requirements have been included, providing a wider acceptance ranges for all classes of concrete greater than 5,000 psi.

Are these changes applicable to all Department jobs? **Yes** ◉ **No** ○

If not, what are the restrictions?

Contact the State Specifications Office for assistance in completing this form.
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KEVIN J. THIBAULT
SECRETARY

M E M O R A N D U M

DATE: June 20, 2019

TO: Specification Review Distribution List

FROM: Stefanie D. Maxwell, Manager, Program Management Office

SUBJECT: Proposed Specification: **3460000 Portland Cement Concrete.**

In accordance with Specification Development Procedures, we are sending you a copy of a proposed specification change.

This change was proposed by Jose Armenteros of the State Materials Office (SMO) to modify the language.

Please share this proposal with others within your responsibility. Review comments are due within four weeks and should be sent to Mail Station 75 or online at http://www2.dot.state.fl.us/ProgramManagement/Development/IndustryReview.aspx . Comments received after **July 18, 2019,** may not be considered. Your input is encouraged.

SM/dt
Attachment

PORTLAND CEMENT CONCRETE.
(REV ~~6-13-6-17-19~~6-20-19)

SECTION 346 is deleted and the following substituted:

SECTION 346
STRUCTURAL PORTLAND CEMENT CONCRETE

346-1 Description.

Use ~~structural portland cement~~ concrete composed of a mixture of portland cement, aggregates, water, and, where specified, admixtures, and ~~other~~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 ~~affected~~ 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 or completion dates. Bear all delay costs and other costs associated with the concrete production facility's QC Plan acceptance or reacceptance.

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
~~Pozzolans and Slag~~Supplementary Cementitious MaterialsSection 929

*Use only silica sand except as provided in ~~Section~~ 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 ~~dissimilar~~ materials exceeding the ~~in excess of that~~ specified limits in the above listed Sections.

346-2.2 Types of Cement: Unless a specific type of cement is designated ~~elsewhere~~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.

~~Do not use high alkali cement in extremely aggressive environments or in mass concrete~~.

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

TABLE 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 ~~Pozzolans and Slag~~Supplementary Cementitious Materials: ~~Fly ash or slag~~Supplementary cementitious materials are required to produce binary or ternary concrete mixes~~,~~ in all classes of concrete except for the following ~~classes~~ when used in slightly aggressive environments: Class I 3,000 psi, Class I 3,000 psi (Pavement), and Class II 3400 psi. The quantity of portland cement replaced with supplemental cementitious materials must be on an equal weight replacement basis of the total cementitious materials with the limitations, shown in Table 2.

346-2.3.1 Highly Reactive Pozzolans: ~~Supplementary cementitious m~~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: ~~A c~~Concrete mixes containing ~~two types of cementitious materials:~~ portland cement and one supplementary cementitious material~~, either fly ash or slag~~.

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

Table 2
~~Required Percentages of Cement and Supplementary Cementitious Materials in Concrete Mixes~~Cementitious Materials Concrete Mix Proportions (%)
(Environmental ~~exposures~~ classification is~~are~~ 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	

Table 2
Required Percentages of Cement and Supplementary Cementitious Materials in Concrete MixesCementitious Materials Concrete Mix Proportions (%)
(Environmental exposures classification isare extremely aggressive, unless otherwise noted.)

Application	Portland Cement	Fly Ash Type F	Slag	Highly Reactive Pozzolans[(4)]		
				Silica Fume	Metakaolin	Ultra-Fine Fly Ash
	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

(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. Testing in accordance with AASHTO T358 is not required.

346-2.4 Coarse Aggregate Gradation: Produce all concrete using Size No. 57, 67 or 78 coarse aggregate. With the Engineer's approval and input from the District Materials Office with Producer QC Plan acceptance authority, Size No. 8, Size No. 89, 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. A~~Furnish a~~ggregate gradations sized larger than nominal maximum size of 1.5 inch may be used blended with smaller size coarse aggregate as two components.

~~For concrete Class I and Class II, excluding Class II (Bridge Deck), the coarse and fine aggregate gradation requirements set forth in Sections 901 and 902 are not applicable and the aggregates may be blended; however, the aggregate sources must be approved by the Department. Do not blend the aggregate if the size is smaller than Size No. 78.~~

346-2.5 Admixtures: Use admixtures in accordance with the requirements of this subarticle. ~~Chemical admixtures not covered in this subarticle may be approved by the Department. Submit statistical evidence supporting successful laboratory and field trial mixes which demonstrate improved concrete quality or handling characteristics.~~

Use admixtures in accordance with the manufacturer’s recommended 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~~, in reinforced concrete~~.

~~**346-2.5.1 Water-Reducer/Water-Reducer Retardant Admixtures:** When a water-reducing admixture is used, meet the requirements of a Type A. When a water-reducing and retarding admixture is used, meet the requirements of a Type D.~~

346-2.5.~~2~~ 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.~~3~~ 2 High Range Water-Reducing and Plasticizing Admixtures:

~~**346-2.5.3.1 General:** When a high range water-reducing admixture is used, meet the requirements of a Type F or Type I. When a high range water-reducing and retarding admixture is used, meet the requirements of a Type G or Type II.~~ When a highly reactive pozzolan~~silica fume or metakaolin~~ is incorporated into a concrete mix design, use a high range water-reducing admixture Type I, II, F or G.

346-2.5.3.~~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.~~4~~ 3 Corrosion Inhibitor Admixtures: Use ~~only with concrete containing Type II cement, or Type II (MH) cement, and~~ a water-reducing and retarding~~ant~~ admixture, Type D, or a high range water-reducing and~~er~~ retarding~~er~~ admixture, Type G, to normalize the setting time of concrete.

346-2.5.~~5~~ 4 Accelerating Admixture for Precast Drainage and Incidental Concrete Products: U~~The u~~se ~~of~~ non-chloride accelerating admixtures, Type C or accelerating and water-reducing, Type E, only ~~is allowed~~ in the manufacturing of precast drainage and incidental concrete products.

~~**346-2.5.6 Type S Admixtures:** When a workability retention, shrinkage reducing or a rheology modifying admixture is used, meet the requirements of a Type S 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 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. Strength and slump are specified in Table 3. The required air content for all classes of concrete is less than or equal to 6.0%.

Substitution of a higher class concrete in lieu of a lower class concrete may be allowed 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 lower class concrete and both classes must contain the same types of mix ingredients. When the compressive strength acceptance data is less than the minimum compressive strength of the higher design mix, notify the Engineer. Acceptance is based on the requirements in Table 3 for the lower 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 3.

When a highly reactive pozzolan, or a ternary blend cement is used in Class IV, Class V, Class V (Special), Class VI, or Class VII concrete, ensure that the concrete meets or exceeds a resistivity of 29 k~~Ω~~Ohm-cm at 28 days, when tested in accordance with AASHTO T358. Submit three 4 x 8 inch cylindrical test specimens to the Engineer for resistivity testing before mix design approval. Take the resistivity test specimens from the concrete of the laboratory trial batch or from the field trial batch of at least 3 cubic yards. Verify the mix proportioning of the design mix and take representative samples of trial batch concrete for the required plastic and hardened property tests. Cure the field trial batch specimens according to the standard laboratory curing methods. Submit the resistivity test specimens at least 7 calendar days prior to the scheduled 28 day test. The average resistivity of the three cylinders, eight readings per cylinder, is an indicator of the permeability of the concrete mix.

TABLE 3
Structural Concrete Class, Compressive Strength, and Slump

Class of Concrete	28-day Specified Minimum Compressive Strength (f_c' ~~28-day~~) (psi)	Target Slump Value (inches) (c)
~~Structural Concrete~~		
I (a)	3,000	3 (b)
I (Pavement)	3,000	2
II (a)	3,400	3 (b)
II (Bridge Deck)	4,500	3 (b)
III (d~~e~~)	5,000	3 (b)
III (Seal)	3,000	8
IV ~~(d)(f)~~	5,500	3 (b)
IV (Drilled Shaft)	4,000	8.5
V (Special) ~~(d)(f)~~	6,000	3 (b)
V ~~(d)(f)~~	6,500	3 (b)
VI ~~(d)(f)~~	8,500	3 (b)
VII ~~(d)(f)~~	10,000	3 (b)

(a) 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 (b). The Contractor is permitted to use concrete meeting the requirements of ASTM C478 4,000 psi in lieu of Class I or Class II concrete for precast endwalls, inlets, manholes and junction boxes.
(b) 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, the target slump is 9 inches.
(c) 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.
~~(d) When silica fume, ultrafine fly ash, metakaolin, or a ternary blend cement is used in Class IV, Class V, Class V (Special), Class VI, or Class VII concrete, ensure that the concrete meets or exceeds a resistivity of 29 KOhm-cm at 28 days, when tested in accordance with AASHTO T358. Submit three 4 x 8 inch cylindrical test specimens to the Engineer for resistivity testing before mix design approval. Take the resistivity test specimens from the concrete of the laboratory trial batch or from the field trial batch of at least 3 cubic yards. Verify the mix proportioning of the design mix and take representative samples of trial batch concrete for the required plastic and hardened property tests. Cure the field trial batch specimens similar to the standard laboratory curing methods. Submit the resistivity test specimens at least 7 calendar days prior to the scheduled 28 day test. The average resistivity of the three cylinders, eight readings per cylinder, is an indicator of the permeability of the concrete mix.~~
(d~~e~~) 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 (b).
~~(f) Highly reactive pozzolans may be used outside the lower specified ranges to enhance strength and workability. Testing in accordance with AASHTO T358 is not required.~~

346-3.2 Drilled Shaft Concrete: Notify the Engineer at least 48 hours before placing drilled shaft concrete. Obtain slump loss tests 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. Ambient temperature conditions for placement of drilled shaft concrete for summer condition is 85°F or higher, and below 85°F for normal condition.

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.~~ Technicians performing the slump test must be ACI Field Grade I qualified.~~

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 the slump is within the limits of this Section. Initially cure acceptance cylinders for 48 hours before transporting 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.

346-3.3 Mass Concrete: When mass concrete is designated in the Contract Documents, use a Specialty Engineer to develop and administer a Mass Concrete Control Plan (MCCP). Develop the MCCP in accordance with section 207 of the ACI Manual of Concrete Practice to ensure concrete core temperatures for any mass concrete element do not exceed the maximum allowable core temperature of 180°F and that the temperature differential between the element core and surface do not exceed the maximum allowable temperature differential of 35°F. Submit the MCCP to the Engineer for approval at least 14 days prior to the first anticipated mass concrete placement. Ensure the MCCP includes and fully describes the following:

1. The Financial Project Identification Number (FPID).
2. Contact names and numbers for project information.
3. Names and qualifications of all designees who will inspect the installation of and record the output of temperature measuring devices, and who will implement temperature control measures directed by the Specialty Engineer.
4. The number, type, and dimensions of each mass concrete element to be constructed.
5. A sequential ID number assigned to each element indicating bridge number, element type, element size, element location.
6. The concrete mix design number used to construct each element.
7. Indicate which mass concrete elements will be monitored, or will be candidates for reduced or omitted monitoring.
8. Casting procedures,
9. Insulating systems,
10. Type and placement of temperature measuring and recording devices, as well as any remote monitoring devices and software.
11. Analysis of anticipated thermal developments for the various mass concrete elements for all anticipated ambient temperature ranges.
12. Measures to prevent thermal shock.
13. Active cooling measures, if used.

Fully comply with the approved MCCP. The Specialty Engineer or approved designee shall personally inspect and approve the installation of temperature measuring devices and verify that the process for recording temperature readings is effective for the first placement of each size and type mass component. The Specialty Engineer shall be available for immediate consultation during the monitoring period of any mass concrete element. Record temperature measuring device readings at intervals no greater than six hours, beginning at the completion of concrete placement and continuing until decreasing core temperatures and temperature differentials are confirmed in accordance with the approved MCCP. Leave temperature control mechanisms in place until the concrete core temperature is within 50°F of the ambient temperature. Within three days of the completion of temperature monitoring, submit a report to the Engineer which includes all temperature readings, temperature differentials, data logger summary sheets and the maximum core temperature and temperature differentials for each mass concrete element.

Upon successful performance of the MCCP, reduced monitoring of similar elements may be requested. Submit any such requests to the Engineer for approval at least 14 days prior to the requested date of reduced monitoring. If approved, the Specialty Engineer may monitor only the initial element of concrete elements meeting all of the following requirements:

1. All elements have the same least cross sectional dimension,
2. All elements have the same concrete mix design,
3. All elements have the same insulation R value and active cooling measures (if used), and

4. Ambient temperatures during concrete placement for all elements is within minus 10°F or plus 5°F of the ambient temperature during placement of the initial element.

Install temperature measuring devices for all mass concrete elements. Resume the recording of temperature monitoring device output for all elements if directed by the Engineer. The Department will make no compensation, either monetary or time, for any impacts associated with reduced monitoring of mass concrete elements.

Mass concrete control provisions are not required for drilled shafts supporting sign, signal, lighting or intelligent transportation (ITS) structures. At the Contractor’s option, instrumentation and temperature measuring may be omitted for any mass concrete substructure element meeting all of the following requirements:

1. Least cross sectional dimension of six feet or less,

2. Insulation R value of at least 2.5 provided for at least 72 hours following the completion of concrete placement,

3. The environmental classification of the concrete element is slightly aggressive or moderately aggressive,

4. The concrete mix design meets the mass concrete proportioning requirements of 346-2.3, and

5. The total cementitious content of the concrete mix design is 750 pounds per cubic yard or less.

6. Temperature of the concrete is 95°F or less at placement.

If either the maximum allowable core temperature or temperature differential of any mass concrete element is exceeded, implement immediate corrective action as directed by the Specialty Engineer to remediate. The approval of the MCCP shall be revoked. Do not place any mass concrete elements until a revised MCCP has been approved by the Engineer. Submit an Engineering Analysis Scope in accordance with 6-4 for approval, which addresses the structural integrity and durability of any mass concrete element which is not cast in compliance with the approved MCCP or which exceeds the allowable core temperature or temperature differential. Submit all analyses and test results requested by the Engineer for any noncompliant mass concrete element to the satisfaction of the Engineer. The Department will make no compensation, either monetary or time, for the analyses and tests or any impacts upon the project.

346-3.4 Flowing Concrete for Precast/Prestressed Concrete: Produce flowing concrete mix with target slump of 9 inches.

Subsequent to the laboratory trial batch, perform a field demonstration of the proposed mix design by production and placement of at least three batches, 3 cubic yards minimum size each, of concrete containing flowing concrete high range water reducing admixture. Take representative samples from each batch and perform slump, air content, density (unit weight), and temperature tests on these samples. Cast specimens from each sample for compressive strength tests to verify the design mix trial. Record the ambient air temperature during the test. Ensure that the concrete properties are within the required specification limits. The plants that are producing concrete with batch sizes of less than 3 cubic yards are required to produce and place at least a total amount of 9 cubic yards and perform the aforementioned tests on at least three randomly selected batches.

Determine the workability of the demonstration concrete batches by performing the slump tests on the samples taken at 15 minute intervals from each batch. Continue sampling and testing until the slump measures 6 inches or less. From the plot of slump versus time, determine the time for each batch when the slump is at 7.5 inches. The shortest time period determined from three consecutive batches, at 7.5 inches slump, is considered the cutoff time of the proposed concrete mix. For production concrete, ensure that the time between the batching and depositing of each load of concrete is less than the cutoff time of the mix and also does not exceed the allowable time limit specified in this Section.

Ensure that the demonstration concrete is mixed, delivered, placed, consolidated and cured in accordance with the proposed method and sequence. Produce the flowing concrete batches at slumps between 7.5 inches to 10.5 inches.

Perform inspection of the demonstration concrete during batching, delivery, placement and post placement. During placement, ensure that the concrete batches meet all plastic property requirements of the Specifications and maintain their cohesive nature without excessive bleeding, segregation, or abnormal retardation.

Dispose of concrete produced for demonstration purposes at no expense to the Department. Subject to the Engineer’s approval, the Contractor may incorporate this concrete into non-reinforced concrete items and may be included for payment, provided it meets Contract requirements for slump, entrained air, and strength.

After removal of the forms, perform the post-placement inspection of the in-place concrete. Observe for any signs of honeycombs, cracks, aggregate segregation or any other surface defects and ensure that the hardened concrete is free from these deficiencies. The Engineer may require saw cutting of the mock-up products to verify the uniform distribution of the aggregates within the saw cut surfaces and around the reinforcing steel and prestressing strands. The Engineer will require saw cutting of the demonstration mock-up products for plants that are demonstrating the use of the flowing concrete for the first time. Obtain core samples in accordance with FM 5-617, section 7 to inspect the aggregate distribution.

Submit the results of the laboratory trial batch tests and field demonstration of verified test data and inspection reports to the Engineer, along with certification stating that the results of the laboratory trial batch tests and field demonstration tests indicate that the proposed concrete mix design meets the requirements of the specifications. For the proposed mix design, state the anticipated maximum time limit between the batching and when the concrete of each batch is deposited during the production.

Upon the review and verification of the laboratory trial batch, field demonstration test data, inspection reports and contractor’s certification statement, the Department will approve the proposed mix design.

The Department may approve proposed flowing concrete mixes, centrally mixed at the placement site, without the production of demonstration batches, provided that the proposed mix meets the following two criteria:

1. A previously approved flowing concrete mix of the same class has demonstrated satisfactory performance under the proposed job placing conditions with a minimum of fifteen consecutive Department acceptance tests, which met all plastic and hardened concrete test requirements.

2. The cementitious materials and chemical admixtures, including the flowing concrete high range water reducing admixture, used in the proposed mix are the same materials from the same source used in the previously approved mix, (1) above.

Do not produce or place concrete until the design mixes have been approved.

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 4:

TABLE 4 Concrete Master Proportions		
Class of Concrete	Minimum Total Cementitious Materials Content pounds per cubic yard	Maximum Water to Cementitious Materials Ratio pounds per pounds*
I	470	0.53
I (Pavement)	470	0.50
II	470	0.53
II (Bridge Deck)	611	0.44
III	611	0.44
III (Seal)	611	0.53
IV	658	0.41**
IV (Drilled Shaft)	658	0.41
V (Special)	752	0.37**
V	752	0.37**
VI	752	0.37**
VII	752	0.37**

*The calculation of the water to cementitious materials ratio (w/cm) is based on the total cementitious material including cement and any supplementaryl cementitious materials that are used in the mix.
** When silica fume or metakaolin is used, the maximum water to cementitious material ratio will be 0.35. When the use of ultrafine fly ash is usedrequired, the maximum water to cementitious material ratio will be 0.30.

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 and/or exposure environment shown:

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

346-4.2.2 Control Level for Corrective Action: If chloride test results exceed the limits of Table 5, suspend concrete placement immediately for every mix design 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.

346-5 Sampling and Testing Methods.

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

TABLE 6 Sampling and Testing Methods	
Description	Method
Slump of Hydraulic Cement Concrete	ASTM C143
Air Content of Freshly Mixed Concrete by the Pressure Method*	ASTM C231
Air Content of Freshly Mixed Concrete by the Volumetric Method*	ASTM C173
Making and Curing Test Specimens in the Field**	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***~~*~~	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 R81
Fabricating Test Specimens with Self-Consolidating Concrete	ASTM C1758
Concrete Resistivity as an Electrical Indicator of its Permeability	AASHTO T358

*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.
** Provide curing facilities that have the capacity to store all QC, Verification, and Resolution~~"hold" and Independent Verification~~ 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.
~~***The Verification technician will use the same size cylinders as the Quality Control technician.~~
***~~*~~ 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.

346-6 Quality Control.

346-6.1 General: Perform QC activities to ensure materials, methods, techniques, personnel, procedures and processes utilized during production meet the specified requirements. For precast/prestressed concrete operations, ensure that the QC testing is performed by the producer.

Accept the responsibility for QC inspections on all phases of work. Ensure all materials and workmanship incorporated into the project meet the requirements of the Contract Documents.

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

For slump target values in excess of 6 inches, including flowing and ~~or~~ self consolidating concrete, 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 or 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 k~~ΩK~~Ohm-cm or below and one with higher than 29 k~~ΩK~~Ohm-cm values in a continuous placement. Produce these concretes using 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 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.

346-6.3 Delivery Certification: Ensure that an electronic delivery ticket is furnished with each batch of concrete before unloading at the placement site. The delivery ticket may be proprietary software or in the form of an electronic spreadsheet, but shall be printed. Ensure that the materials and quantities incorporated into the batch of concrete are printed on the delivery ticket. Include the following information on the delivery ticket:

1. Arrival time at jobsite,
2. Time that concrete mix has been completely discharged,
3. Number of revolutions upon arrival at the jobsite,
4. Total gallons of water added at the jobsite,
5. Additional mixing revolutions when water is added,
6. Total number of revolutions.

Items (3) through (6) do not apply to non-agitating concrete transporting vehicles.

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 design mix 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 Plastic Property Tolerances: Reject concrete with slump or air content that does not fall within the specified tolerances and immediately notify the concrete production facility that an adjustment of the concrete mixture is required. If a load does not fall within the tolerances, test each subsequent load and the first adjusted load. If failing concrete is not rejected or adjustments are not implemented, the Engineer may reject the concrete and terminate further production until the corrections are implemented.

Do not allow concrete to remain in a transporting vehicle to reduce slump. Water may be added only upon arrival of the concrete to the jobsite and not thereafter.

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 Truck Mixing: Produce a completely uniform mixed concrete in a truck mixer for 70 to 100- revolutions at the mixing speed designated by the truck manufacturer.

Prior to starting the discharge of the concrete at the jobsite, wWhen water is added at the jobsite, record the added quantity and mix the concrete 30 additional drum mixing revolutions. Do not add water after the total number of drum mixing revolutions exceeds 130, do not make more than twoadditional mix adjustments. Discharge all concrete from truck mixers before total drum revolutions exceed 300, unless the approved mix design allows for an extended transit time. Seek approval from the Engineer prior to using a central mixer and depositing the batch into a truck mixer.

346-7.2.1 Transit Time: Ensure compliance with Table 7 between the initial introduction of water into the mix and completely discharging all of the concrete from the truck. Reject concrete exceeding the maximum transit time. For critical placements, with the Engineer's approval and input from the District Materials Office, the transit time may be extended to the allowable mixing time shown in the mix design.

TABLE 7	
Maximum Allowable Transit Time	
Non-Agitator Trucks	Agitator Trucks
45 minutes	60 minutes
75 minutes*	90 minutes*
*When a water-reducing and retarding admixture (Type D, Type G, or Type II) is used.	

346-7.2.2 Placement Time: All the concrete in a load must be in its final placement position a maximum of 15 minutes after the transit time has expired unless a time extension is approved by the Engineer

346-7.3 On-site Batching and Mixing: 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 or place concrete when the air temperature is below 40ºF. Protect the fresh concrete from freezing in accordance with Section 400. The requirements of concreting in cold weather are not applicable to precast concrete mixing and placement operations occurring in a temperature controlled environment.

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 but is 100ºF or less.

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

346-7.6 Adding Water to Concrete at the Placement Site: Water may be added at the placement site provided the addition of water does not exceed the water to cementitious materials ratio as defined by the mix design. After adding water, perform a slump test to confirm the concrete is within the slump tolerance range;. iIf the slump is outside the tolerance range, reject the load. If an adjustment is made at the concrete production facility, perform a slump test on the next load to ensure the concrete is within the slump tolerance range. Do not place concrete represented by slump test results outside of the tolerance range. Include water missing from the water storage tanks upon arrival at the project site in the jobsite water added.

346-7.7 Sample Location: Obtain acceptance samples from the point of final placement.

Where concrete buckets are used to discharge concrete directly to the point of final placement or into the hopper of a tremie pipe, samples will be obtained from the discharge of the bucket. When the concrete is discharged directly from the mixer into the bucket and the bucket is discharged within 20 minutes, samples may be obtained from the discharge of the mixer.

Where conveyor belts, troughs, pumps, or chutes are used to transport concrete directly to the point of final placement or into the hopper of a tremie pipe, samples will be obtained from the discharge end of the entire conveyor belt, trough, pump, or chute system.

Where concrete is placed in a drilled shaft or other element using a tremie pipe and a concrete pump, samples will be obtained from the discharge of the pump line at the location of the tremie hopper.

For all other placement methods, prior to each placement, obtain Department approval for sampling at the discharge of the mixer in lieu of sampling at the point of final placement. Submit the sampling correlation procedure to the Engineer for approval prior to the placement of the concrete. Once the comparative sampling correlation is approved by the Engineer, apply this correlation to the plastic properties tolerances for samples obtained from the discharge of mixer.

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, or other applications as approved by the Engineer, ensure the discharge end of the pump line remains immersed in the concrete at all times after starting concrete placement.

346-8 Plastic Concrete Sampling and Testing.

QC tests include air content, temperature, slump, and preparing compressive strength cylinders for testing at later dates. In addition, calculate the water to cementitious materials ratio in accordance with FM 5-501 for compliance to the approved mix design.

Ensure that each truck has a rating plate and a valid mixer identification card issued by the Department. Ensure that the revolution counter on the mixer is working properly, and calibration of the water dispenser has been performed within the last twelve months. Reject any concrete batches that are delivered in trucks that do not have mixer identification cards. Remove the mixer identification card when a truck mixer is discovered to be in noncompliance and the mixer deficiencies cannot be repaired immediately. When the mixer identification card is removed for noncompliance, make note of the deficiency or deficiencies found, and forward the card to the District Materials and Research Engineer who has Producer QC Plan acceptance authority.

Perform plastic concrete tests on the initial delivery from each plant of each concrete design mix each day. Ensure QC technicians meeting the requirements of Section 105 are present and performing tests throughout the placement operation. Ensure one technician is present and performing tests throughout the placement operation at each placement site. If a project has multiple concrete placements at the same time, identify the technicians in the QC Plan to ensure minimum sampling and testing frequencies are met. Ensure that the equipment used for delivery, placement and finishing meets the requirements of this Specification.

When a truck designated for QC testing arrives at the discharge site, a subsequent truck may also discharge once a representative sample has been collected from the QC truck and while awaiting the results of QC testing. Reject non-complying loads at the jobsite. Ensure that corrections are made on subsequent loads. Immediately cease concrete discharge of all trucks if the QC truck has failing test. Perform plastic properties tests on all trucks prior to the first corrected truck and the corrected truck. When more than one truck is discharging into a pump simultaneously, only the truck designated for QC testing may discharge into the pump to obtain a representative sample of concrete from the QC truck only.

Furnish sufficient concrete of each design mix as required by the Engineer for verification (VT) testing. When the Engineer's ~~verification~~VT test results do not compare with the QC plastic properties test results, within the limits defined by the Independent Assurance (IA) checklist comparison criteria, located in Materials Manual Chapter 5, disposition of the concrete will be at the option of the Contractor.

On concrete placements consisting of only one load of concrete, perform initial sampling and testing in accordance with this Section. The acceptance sample and plastic properties tests may be taken from the initial portion of the load.

If any of the QC plastic properties tests fail, reject the remainder of that load, and any other loads that have begun discharging, terminate the LOT and notify the Engineer. Make cylinders representing that LOT from the same sample of concrete.

Following termination of a LOT, obtain samples from a new load, and perform 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.

Suspend production when any five loads in two days of production of the same design mix are outside the specified tolerances. Increase the frequency of QC testing to one per load to bring the concrete within allowable tolerances. 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.

When the Department performs Independent Verification (IV), the Contractor may perform the same tests on the concrete at the same time. The Department will compare results based on the Independent Assurance (IA) Checklist tolerances.

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 ~~verification~~ VT plastic properties tests and cast a set of ~~verification~~ VT cylinders. The ~~verification~~ 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 ~~one~~ two additional cylinders from the same sample, and identify ~~it~~them as the quality control resolution (QR) test~~QC "hold"~~ cylinders. The Department will also cast ~~one~~ two additional ~~"hold"~~verification resolution (VR) test cylinders from each ~~Verification~~ 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 ~~QC "hold"~~QR cylinders to the final curing facility in accordance with ASTM C31. ~~At this same time~~Concurrently, the Department will deliver the ~~Verification~~ VT samples, including the ~~Verification~~ VR~~"hold"~~ 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.

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

The Department will compare the ~~Verification~~ VT sample compressive strength test results with the corresponding QC sample test results. ~~In the event that one set of compressive strength data for a set of cylinders falls outside the range of the other set of cylinders, use the lower range of average compressive strength to determine the comparison criteria. Based on this comparison, the Department will determine if the comparison criteria as shown in Table 8 has been met. When the difference between QC and Verification is less than or equal to the comparison criteria, the QC data is verified. When the difference between QC and Verification data exceeds the comparison criteria, the data is not verified and the Engineer will initiate the resolution procedure.~~

~~Table 8~~
~~Comparison Criteria~~

~~Range of Average Compressive Strength~~	~~Comparison Criteria~~
~~Less than 3500 psi~~	~~420 psi~~
~~3,501 – 4,500 psi~~	~~590 psi~~
~~4,501 – 6,500 psi~~	~~910 psi~~
~~6,501 – 8,500 psi~~	~~1,275 psi~~
~~8,501 – 10,500 psi~~	~~1,360 psi~~
~~Greater than 10,500 psi~~	~~*~~
~~* Consider the quality control and verification tests as favorable when the results of both tests are either passing or failing. The test results are not favorable when one of the test result passes and the other one fails. Proceed to the resolution inspection and~~	

~~testing if the comparison is not favorable.~~

346-9.2 Sampling Frequency: As a minimum, sample and test concrete of each design mix for water to cementitious materials ratio, air content, temperature, slump and compressive strength once per LOT as defined by Table ~~9~~8. The Engineer will randomly verify one of every four consecutive LOTs of each design mix 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 ~~9~~8
Sampling Frequency

Class Concrete*	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 ~~two hours between the end of~~ one day's production ~~placement and the start of the next placement~~, whichever is less**
III (Seal)	Each Seal placement

*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.
**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 compressive strength is equal to or greater than ~~two~~ 2.33 standard deviations minus 500 psi above the specified minimum compressive strength ~~(f'_c)~~ for that class of concrete.

2. Every average of three consecutive strength test equals or exceeds the specified minimum compressive strength ~~(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 ~~60~~ calendar ~~days~~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 LOT's.

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 is less than the specified minimum plus two standard deviationsdoes not conform to the above conditions, return to the maximum production quantity representedfrequency represented by the LOT as defined in Table 98. Notify the Engineer that the maximum production rateinitial 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: Ensure that the hardened concrete strength test results are obtained in accordance with 346-9.3.

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

1. Verification of QC and VT data.
2. Resolution of QR and VR data.
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. Acceptance of LOT may be based on verificationVT 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 QC hold 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 verificationVT 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.

346-9.5 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%.

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

Where:

Difference (%) is the absolute percentage difference between QC and Verification Test.

The procedure consists of verifying if the QC and Verification Test 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 Verification Test is less than or equal to 14%, the

~~When~~ QC 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 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 Verification Test data exceeds 14%, the QC data is not verified and the Engineer will initiate the resolution procedure.

~~When QC compressive strength test results are not verified,~~ T ~~t~~he resolution procedure will be used to accept or reject the concrete. Maintain the ~~"hold"~~ VR cylinders until the verification of the compressive strength test results, but no more than one month after the age of the specified strength test.

~~When QC 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 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.~~

346-9.~~5~~ 6 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 to cementitious materials ratio, handling of cylinders, curing procedures and compressive strength testing.

Compare the ~~Verification~~ VT sample results with the ~~verification hold~~VR cylinders results. Compare the QC sample results with the ~~QC hold~~QR cylinders results. Comparison results must not be greater than ~~the comparison requirements in Table 8~~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.

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

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

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 ~~verification~~VT strength test are deemed to be the most accurate, LOTS 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 the ~~"hold"~~QR and VR cylinders to the resolution laboratory. The QC and ~~Verification~~VT laboratories will transport their own ~~QR and VR~~hold cylinders to the resolution testing laboratory within ~~72 hours~~three calendar days after the Engineer notifies the Contractor that a resolution procedure is required. In addition, the Engineer will ensure that the Q~~C~~R and ~~verification "hold"~~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 ~~resolution investigation will determine the strength test results for each of the four or less LOTs. When the QC strength test results are deemed to be the most accurate, the QC strength test results will represent the four or less consecutive LOTs and the Department will pay for the resolution testing and investigation. When the verification strength test results are deemed to be the most accurate, 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 District Materials Office, 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.

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

346-9.~~6~~ 7 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. 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.

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

346-10.1 General: 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 ~~(f_c')~~ by more than:

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

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

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

The Engineer ~~with input from the District Materials Office,~~ will consider the concrete for a given LOT as structurally adequate and coring will not be allowed ~~W~~when a concrete ~~acceptance~~compressive strength test result falls ~~500 psi or less~~ below the specified minimum strength ~~(f_c'),~~ but has met the above conditions~~, coring will not be allowed and the concrete will be considered structurally adequate~~.

When a concrete acceptancecompressive strength test result falls more than 500 psi below the specified minimum strength, and does not meet the above conditions, perform one of the following options:

1. sSubmit an Engineering Analysis Scope in accordance with 6-4 to establish strengthstructural 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. or; aAt the Engineer's discretion, obtain 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. The Engineer will determine whether to allow coring or require an engineering analysis.

When the concrete is deemed to have low strength, oObtain and test the cores in accordance with ASTM C42. Test the cores after obtaining the samples within seven calendar days and report the data to the Engineer within 14 calendar days of the 28-day compressive strength tests.

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. Obtain the Engineer's approval before taking any core samples.

346-10.2 Investigation and Determination of Structural Adequacy: When 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 testing as necessary to determine structural adequacy of the concrete.

If core strength test results are 500 psi or less below the specified minimum strength, consider the concrete represented by the cores structurally adequate. If the core strength test results are more than 500 psi below the specified minimum strength, submit an Engineering Analysis Scope 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.

346-10.3 Coring for Determination of Structural Adequacy: Notify the Engineer 48 hours prior to taking core samples. 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. 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.

346-10.4 Core Conditioning and Testing: Test the cores in accordance with ASTM C42. Test the cores after obtaining the samples within seven calendar days.For cores tested no later than 42 calendar 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.

For cores tested later than 42 calendar days after the concrete was cast, the Engineer will establish the equivalency between 28-day strength and strength at ages after 42 calendar days. 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.

The Engineer with input from the District Materials Office, will consider the concrete as structurally adequate, in area represented by core tests at the actual test age, if the average compressive strength of cores is not less thandoes not fall below the specified minimum compressive strength by more than:

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

b. 10% of $f_c'$the specified minimum compressive strength when $f_c'$the 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.

346-11 Pay Adjustments for Low Strength Concrete.

346-11.1 General: For 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 500 psithe limits established in 346-10.1 below the specified minimum strength (f_c'), core samples may be obtained in accordance with ASTM C42 from the respective LOT of concrete represented by the low acceptance strength test result for determining pay adjustments. A price adjustment will be applied to the certified invoice price the Contractor paid for the concrete or the precast product.

Do not core hardened concrete for determining pay adjustments when the 28 day acceptance cylinder strength test results fall below $f_c'$the specified minimum strength by no are lessmore than 500 psi below the specified minimum strengththe limits established in 346-10.1.

The results of strength tests of the drilled cores, subject to 346-11.5 and 346-11.6this Section, will be used as the acceptance results and will be used in place of the cylinder strength test results for determining pay adjustments.

In precast operations, excluding prestressed, ensure that the producer submits acceptable core sample test results to the Engineer. The producer may elect to use the products in accordance with 346-11this 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 Coring for Determination of Pay Adjustments: Obtain the cores in accordance with 346-10.3.

346-11.4 Core Conditioning and Testing: 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 calendar 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 calendar days after the concrete was cast, the Engineer will establish the equivalency between 28 day strength and strength at ages after 42 calendar days. The Engineer will relate the strength at the actual test age to 28 day strength for the design mix represented by the cores using the following relationship:

346-11.6.1 Portland Cement Concrete without Pozzolan or Slag:

Equivalent 28 Day Strength, f'c (28) = 1/F (Average Core Strength) x 100

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

346-11.6.2 Pozzolanic Cement Concrete:

Equivalent 28 day compressive strength = $f'_c(28)$, where:

$$f'_c(28) = 0.490\, f'_c(t) e^{\left(\frac{8.31}{t}\right)^{0.276}}$$ (Type I Cement)

$$f'_c(28) = 0.730\, f'_c(t) e^{\left(\frac{2.89}{t}\right)^{0.514}}$$ (Type II Cement)

$$f'_c(28) = 0.483\, f'_c(t) e^{\left(\frac{5.38}{t}\right)^{0.191}}$$ (Type III Cement)

$f'_c(t)$ = Average Core Strength at time t (psi)

t = time compressive strength was measured (days)

346-11.6.3 Slag Cement Concrete:

Equivalent 28 day compressive strength = $f'_c(28)$, where:

$$f'_c(28) = 0.794\, f'_c(t) e^{\left(\frac{7.06}{t}\right)^{1.06}}$$ (Type I Cement)

$$f_c'(28) = 0.730\, f_c'(t) e^{\left(\frac{6.02}{t}\right)^{0.747}}$$ (Type II Cement)

$$f_c'(28) = 0.826\, f_c'(t) e^{\left(\frac{2.36}{t}\right)^{0.672}}$$ (Type III Cement)

$f'_c(t)$ = Average Core Strength at time t (psi)

t = time compressive strength was measured (days)

346-11.6.4 Flyash-Slag-Cement Concrete (W/CM>0.41):

Equivalent 28 day compressive strength = $f'_c(28)$, where:

$$f_c'(28) = 0.80\, f_c'(t) e^{\left(\frac{3.14}{t}\right)^{0.72}}$$ (Type I/II Cement)

$f'_c(t)$ = Average Core Strength at time t (psi)

t = time compressive strength was measured (days)

346-11.6.5 Flyash-Slag-Cement Concrete (W/CM<0.41):

Equivalent 28 day compressive strength = $f'_c(28)$, where:

$$f_c'(28) = 0.88\, f_c'(t) e^{\left(\frac{1.86}{t}\right)^{0.90}}$$ (Type I/II Cement)

$f'_c(t)$ = Average Core Strength at time t (psi)

t = time compressive strength was measured (days)

346-11.6.6 Flyash-Silica Fume-Cement Concrete (W/CM<0.41):

Equivalent 28 day compressive strength = $f'_c(28)$, where:

$$f_c'(28) = 0.84\, f_c'(t) e^{\left(\frac{0.92}{t}\right)^{0.50}}$$ (Type III Cement)

$f'_c(t)$ = Average Core Strength at time t (psi)

t = time compressive strength was measured (days)

346-11.6.7 Flyash-Silica Fume-Cement Concrete (W/CM<0.41):

Equivalent 28 day compressive strength = $f'_c(28)$, where:

$$f_c'(28) = 0.86\, f_c'(t) e^{\left(\frac{0.53}{t}\right)^{0.47}}$$ (Type III Cement)

$f'_c(t)$ = Average Core Strength at time t (psi)

t = time compressive strength was measured (days)

346-11.37 Calculating Pay Adjustments: The Engineer will determine payment reductions for low strength concrete accepted by the Department. The 28-day strength is and represented by either cylinders or correlated cores strength test results below the specified minimum strength, in accordance with the following:.

Reduction in Pay is equal to the reduction in percentage of concrete compressive cylinder strength below the specified minimum strength (f_c'):

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

~~(specified minimum strength minus actual strength divided by specified minimum strength).~~

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.

346-12 Pay Reduction for Plastic Properties

A rejected load in accordance with 346-6.4 is defined as the entire quantity of concrete contained within a single ready mix truck or other single delivery vehicle regardless of what percentage of the load was placed. If concrete fails a plastic properties test and is thereby a rejected load but its placement continues after completion of a plastic properties test having a failing result, payment for the concrete will be reduced.

The pay reduction for cast-in-place concrete will be twice the certified invoice price per cubic yard of the quantity of concrete in the rejected load.

The pay reduction for placing a rejected load of concrete into a precast product will be applied to that percentage of the precast product that is composed of the concrete in the rejected load. The percentage will be converted to a reduction factor which is a numerical value greater than zero but not greater than one. The precast product payment reduction will be twice the Contractor’s billed price from the producer for the precast product multiplied by the reduction factor.

If the Engineer authorizes placement of the concrete, even though plastic properties require rejection, there will be no pay reduction based on plastic properties failures; however, any other pay reductions will apply.