Section 9.2
Volume II

STRUCTURAL CONCRETE PRODUCTION FACILITIES GUIDE

9.2.1 PURPOSE

This guide establishes policies that govern the production of structural concrete used by the Florida Department of Transportation (FDOT), herein after called the Department. The guide also provides the Concrete Production Facility (Plant) with information related to the methods and the minimum requirements for Quality Control (QC) Plan, and criteria by which the Department will review the QC Plan for acceptance.

9.2.2 AUTHORITY

Sections 20.23(3)(a), 334.044(2), 334.044(10)(a), and 334.048(3) Florida Statutes.

9.2.3 SCOPE

The principal user of this document is a structural concrete Plant.

9.2.4 REFERENCES

Code of Federal Regulations (CFR), Federal-Aid Policy Guide (FAPG), Subchapter G – Engineering and Traffic Operations, Part 637 – Construction Inspection and Approval, Subpart B – Quality Assurance Procedures for Construction

American Society for Testing and Materials (ASTM) Standard Test Methods and Specifications, Philadelphia, Pennsylvania.

American Association of State Highway and Transportation Officials (AASHTO), Part II Tests, Washington, D.C.

American Concrete Institute (ACI), Farmington Hills, Michigan. Reports of the Technical Committees 211, 214, 301 and 318.

Florida Department of Transportation Standard Specifications for Road and Bridge Construction (Specifications).

Florida Department of Transportation Approved Products List (APL).

Florida Department of Transportation Sampling and Testing Methods (FSTM).

9.2.5 GENERAL INFORMATION

Plants that supply concrete to Department projects must have a Producer QC Plan accepted by the Department in accordance with ***Specifications Section 105***. The Department will maintain a list of Plants with accepted QC Plans that meet the requirements of this guide.

When the concrete producer has multiple Plants located in the same physical address:

a. Each Plant is required to have a separate QC Plan and Plant Number, provided that concrete mixers are fed by independent processing lines, including aggregates and cementitious materials silos, set of scales, and conveyors.

b. The Plants may have separate or combined batch house and control center.

c. The same Concrete Batch Plant Operator can simultaneously control the Plants.

Concrete produced in accordance with ***Specifications Section 346*** and this guide will be accepted based on the proper certification and verification of project compressive strength acceptance criteria.

Perform materials sampling and testing in accordance with the ***Specifications Section 6***.

The Department will inspect the Plants at least once every three months.

The Plants may request a reduced scheduling frequency for the Plant inspections from the District Materials and Research Engineer (DMRE). The reduced inspection scheduling frequency will be based on the following items:

(1) When the specified 28-day compressive strength (***f'c***) is equal to or less than 5,000 psi.

a. The Plant QC standard deviation (***S***) of the compressive strength tests shall be equal to or less than 600 psi.

b. The Plant QC within-batch coefficient of variation (CV_1),

$CV_1 = \frac{S_1}{\overline{X}}(100\%)$, shall be equal to or less than 5%, where:

$S_1 = \frac{\overline{R}}{d_2}$ = Within-batch standard deviation.

$\overline{R}$ = Average range of at least 10 same age strength test results.

d_2 = Factor for computing within-batch standard deviation (***ACI 214R*** Table 4.1).

$\overline{X}$ = mean.

(2) When the specified strength (***f’c***) is greater than 5,000 psi.

a. The Plant QC coefficient of variation (***CV***), $CV = \frac{S}{\overline{X}}(100\%)$, shall be equal to or less than 11%, where:

S = standard deviation.

$\overline{X}$ = mean.

b. The Plant QC within-batch coefficient of variation shall be equal to or less than 5%.

(3) Previous Plant inspections, correction of any deficiencies noted, failing samples attributed to the Plant.

(4) Request from the Producer.

The evaluation of the above statistical parameters will be performed in accordance with ***ACI 214R Guide to Evaluation of Strength Test Results of Concrete***. The Department Materials Acceptance and Certification system (MAC) will provide a complete report of this information.

Upon meeting all criteria, the Plant may be changed to a reduced inspection frequency if approved by the DMRE. The inspection frequency shall be a minimum of once every six (6) months or less. These inspections will assist in ensuring that the Plant continues to produce material in accordance with the Plant’s accepted QC Plan, ***Specifications*** and other ***Contract Documents***.

9.2.6 CONCRETE PLANT ROLES AND RESPONSIBILITIES

9.2.6.1 Material Requirements

Meet the requirements of ***Specifications Section 346***.

9.2.6.1.1 Cementitious Materials

Acceptance of the cementitious materials at the Plant shall be based upon the delivery ticket and mill certificate.

Clearly label each cementitious material with its Production Facility ID and type. Store them in a separate weatherproof facility.

Measure the mass of the cementitious materials within an accuracy of 1 percent of the required total amount. For concrete batches of 3 cubic yards or less, an accuracy of 2 percent is allowed. Weigh the cementitious materials separately from other materials. When weighing the cementitious materials in a cumulative weigh hopper, weigh the cement first.

If bagged highly reactive pozzolans (silica fume, metakaolin, ultra-fine fly ash) or other cementitious materials are permitted, proportion the batch to use only whole bags. Store the highly reactive pozzolans in accordance with the manufacturer's recommendation.

9.2.6.1.2 Aggregates

Aggregates used in Department projects must meet the requirements of ***Florida Administrative Code Rule 14-103***. A list of approved sources will be maintained by the Department and made available from the State Materials Office (SMO).

Coarse aggregates size No. 8, and size No. 89 used alone in concrete mix designs are project specific.

As a minimum, provide suitable bins, stockpiles or silos to store and identify aggregates without mixing, segregating, degradation or contamination of the different sources or grades. Each source must be properly marked and identified. Department designated, approved source number and aggregate grade shall be included in the identification.

Aggregates shall be measured by mass or volume within an accuracy of 1 percent of the required amount.

The concrete Plant is responsible for handling the aggregates by minimizing their segregation and obtaining them from the stockpile for use in the mix so it will remain within the requirement of the Specification limits. Stockpiles shall be maintained in a well-drained condition to minimize their free water contents and algae/fungal growth. Quantities of aggregates necessary for sampling and testing shall be obtained from the recovery side of the stockpile, where feasible, to ensure compliance with the ***Specifications*** and other ***Contract Documents***.

9.2.6.1.2.1 Wetting Coarse Aggregate Stockpiles, Storage Bins and Silos

For a period of 24 hours immediately preceding introduction into concrete, the coarse aggregate shall be continuously and uniformly sprinkled with water, meeting the requirements of ***Specifications Section 923***. Address in the Plant's QC Plan any request for deviations from the 24-hour sprinkling requirement.

9.2.6.1.3 Admixtures

Use only admixtures approved by the Department in the concrete mixes. A certification from the admixture supplier that the admixture meets the requirements of ***Specifications Section 924*** is required. The admixture dosage rate of the product to be used should be within the range of the admixture manufacturer's technical data sheet. Dosage rates outside of this range may only be used with written recommendation from the admixture producer's technical representative.

(1) The use of air entrainment admixtures is optional in all concrete mixes. Do not use it in counterweight and dry cast concrete.

(2) When a highly reactive pozzolan is incorporated into a concrete, use a high range water-reducing admixture Type I, II, F or G.

(3) When a corrosion inhibitor admixture is incorporated into a concrete, 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.

(4) 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.

Measure the admixtures by mass or volume. Use measuring equipment that has accuracy (under all operating conditions) within 3 percent of the quantity of admixture required for the batch. Measure each admixture separately, and add it to the batch in accordance with the admixture manufacturer's recommendation.

Store the admixtures in accordance with the admixture manufacturer's recommendation.

9.2.6.2 Scales, Meters, and other Weighing or Measuring Devices

9.2.6.2.1 General Requirements

Check the accuracy of all scales, meters, and other weighing or measuring devices, excluding admixture dispensers, prior to the production of concrete and, at a minimum, once every three months thereafter.

Ensure that a qualified representative of a scale company registered with the Bureau of Weights and Measures, under the Division of Standards of the Florida Department of Agriculture and Consumer Services, checks the accuracy of the above listed equipment. The Department reserves the right to be present during all equipment accuracy checks.

Ensure that the report provided by the qualified company performing the check includes the date of inspection, signature of the company representative, observed deviations for each quantity checked and a statement that the device conforms to the ***Specifications*** and other ***Contract Documents***. Maintain a copy of the report corresponding with the current certificate of inspection at the Plant.

Affix a certificate of inspection bearing the date of the certification showing signature of the company representative to each weighing or measuring device.

9.2.6.2.2 Scales

Maintain scales to an accuracy of 0.5 percent of the maximum load normally handled.

9.2.6.2.3 Water Measuring Devices

The check for accuracy will be by weight or volume. Whichever method is used, ensure that the accuracy of measurement is not affected by variations in pressure in the water supply line. Use a meter or weighing device capable of being set to deliver the required quantity and automatically cut off the flow when the required quantity has been discharged. Ensure that the measuring equipment has accuracy, under all operating conditions, within 1 percent of the quantity of water required as total mixing water for the batch. Ensure that the total mixing water shall include water added to the batch, ice added to the batch, free water occurring as surface moisture on the aggregates, and water introduced in the form of admixtures.

Use of flow meters mounted in series is acceptable provided that the accuracy of the flow meters is traceable to the National Institute of Standards and Technology.

9.2.6.2.4 Admixture Measuring Dispensers

Ensure that the admixture supplier complete the annual certification of admixture measuring dispenser accuracy. Calibrate the dispensing equipment for calcium nitrite quarterly.

9.2.6.2.5 Recorders

Plants equipped with recording mechanisms must provide records that are clear, complete, and with permanent indications of the Plant's performance. Recorder information may be supplemented by the batcher during the batching operation. Allow Department inspectors to review the recorder history at any time.

9.2.6.2.6 Concrete Equipment

Use equipment that has no detrimental effect on the plastic concrete for handling of concrete mix ingredients; and mixing, handling, transporting, and depositing of the mixed concrete. Do not use equipment with aluminum surfaces in physical contact with the mixed product. As an exception, aluminum chutes, not longer than 20 feet, may be used for ready mixed concrete trucks.

9.2.6.3 Batching Accuracy

The failure to maintain batching operations of the plastic concrete within the tolerance for each component material requires immediate investigation and corrective action by the concrete Plant. A failure to immediately investigate and implement corrective measures may be cause for suspension of the Plant's QC Plan.

9.2.6.3.1 Batch Adjustments for Materials

Permissible adjustments to previously approved mix designs that may be made without a new mix design request are as follows:

(1) Allowable variation of Coarse or Fine Aggregate: The variation for each aggregate can be ±75 pounds per cubic yard of concrete.

(2) Admixtures dosage should be within the admixture manufacturer's technical data sheet range. Dosage rates outside of this range may be used only after obtaining written recommendation from the admixture manufacturer's technical representative.

(3) Allowable variation of total Cementitious Materials: ±6.5 percent per cubic yard but not less than the specified minimum for that class of concrete.

The adjusted mix must meet the theoretical yield requirements of the approved mix design.

Inform the DMRE of any adjustments made to the concrete mix design. Do not use batch adjustments for batch tolerances of aggregate and cementitious materials. Note the adjustments on the concrete delivery tickets.

At the Producer’s option, submit the adjusted mix design for approval based on satisfactory field demonstration of at least 4 lots of production. Provide documentation of batch adjustments and field performance data.

9.2.6.3.2 Batch Adjustments for Moisture

Determine the free moisture of coarse and fine aggregates within two hours prior to each day's batching, unless moisture meters are used. Determine the free moisture content of aggregates at 4-hour intervals during continuous batching operations, and at any time a change in moisture content becomes apparent. Adjust batch proportions using these values.

Use the following methods to determine aggregate free moisture:

(1) Use moisture meter readings, speedy moisture tester or Chapman flask for fine aggregate moisture. The moisture meter readings may be used for coarse or fine aggregate moistures. Verify the accuracy of the moisture meter at least weekly by the moisture meter manufacturer's recommended method and by method (2) below. Verify the accuracy of the Chapman flask and speedy moisture tester at least weekly by method (2) below.

(2) Calculate the coarse and fine aggregate free moisture based upon dry sample weights and adjusting for absorption per ***AASHTO T 255***. Use the following minimum sample sizes in lieu of the sample sizes required in ***AASHTO T 255*** Table 1.
    Fine Aggregate – 500 grams
    Coarse Aggregate – 1500 grams

(3) Towel dry coarse aggregate to calculate free moisture on saturated surface dry aggregate. The accuracy of towel drying shall be verified weekly by method (2) above.

(4) The comparison criteria between any of these methods must be no more than 0.5 percent.

9.2.6.4 Optimized Aggregate Gradation

Meet the requirements of Appendix “B” on the methods used to produce combined aggregate gradations of fine, intermediate and coarse aggregate sizes for the concrete mixes.

9.2.6.5 Substitution of Materials

Obtain the Department’s approval for portland cement, aggregates, and supplementary cementitious materials substitutions before placing concrete.

Ensure that the substituted mix meets the theoretical yield requirements, does not exceed the maximum allowable water to cementitious materials ratio, and the cementitious materials content of the mix equals the approved base mix design. The theoretical unit weight of the proposed mix design shall be within 2.0 pounds per cubic foot of the originally approved theoretical mix design unit weight. The substitution of materials does not require chloride testing for mix design approval.

The Department may require a single 3.0 cubic yards minimum test batch at the Plant to demonstrate that the properties of the adjusted mix design are within the slump, air, compressive strength and chloride tolerances provided in ***Specifications Section 346***.

9.2.6.5.1 Aggregates

Aggregate sources may be substituted within an approved base mix design provided that the aggregates are the same geological type, same size, and are from an approved source. The new aggregate must have a saturated surface dry (SSD) specific gravity within 0.08 of the SSD specific gravity of the original aggregate source.

9.2.6.5.2 Portland Cement

At the discretion of the SMO Concrete Materials Engineer, cement substitutions may be considered to prevent concrete placement delays on ongoing construction projects. The Department may take up to five working days to review any material substitution request. Ensure that the concrete producer submits the proposed material substitution to the appropriate DMRO for verification.

Cement sources may be substituted within an approved mix design provided that the cements are the same type. The District Materials and Research Office (DMRO) will ensure the replacement mix contains the same component materials as the replaced mix and only cement substitution is permitted. At the first jobsite placement of the new mix, the Plant’s certified ***ACI Concrete Field Testing Technician – Grade I***, or the

Contractor's ***CTQP Concrete Field Technician – Level 1*** will cast three – 4 by 8 in. cylinders to be tested by the Plant's or the Contractor's qualified laboratory. The compressive strength of the cylinders shall be tested at 28 days. The DMRO will submit the 28-day test results to the SMO.

9.2.6.5.3 Supplementary Cementitious Materials

Fly ash from an approved source may be substituted within an approved base mix design. The mix design may contain only one fly ash source. When a fly ash is substituted in the mix design, a new mix number will be issued for that mix.

At the discretion of the SMO Concrete Materials Engineer, slag substitutions may be considered to prevent concrete placement delays on ongoing construction projects. The Department may take up to five working days to review any material substitution request. The concrete producer must submit the proposed material substitution to the appropriate DMRO for verification.

9.2.7 MIX DESIGNS

9.2.7.1 General

Concrete mix designs shall meet the requirements of ***Specification Section 346***. Follow ACI 301 Section 4, and ACI 211 as guidelines to design the concrete mixes.

When the Engineer determines that unsatisfactory results are obtained during production, the mix design approval will be rescinded.

Design a concrete mix to provide a required compressive strength (***f'cr***) that exceeds the specified minimum compressive strength (***f'c***) by the overdesign value in Table 1.

$$\boldsymbol{f'cr = f'c + Overdesign}$$

Proceed as follows to select the overdesign value in concrete mixes:

(1) Use Table 1 at the concrete producer's option, or when the concrete producer has no records of field strength tests performed within the past 24 months and spanning no less than 45 calendar days for a class of concrete within 1,000 psi of that ***f'c***.

TABLE 1 – Overdesign requirements for establishing ***f'cr*** when data is not available				
Class of Concrete	28-day ***f'c*** (psi)	Overdesign (psi)	28-day ***f'cr*** (psi)	Maximum Allowable 28-day Compressive Strength (psi)
I	3,000	1,200	4,200	4,600
I Pavement	3,000	1,200	4,200	5,200
II	3,400	1,200	4,600	5,700
II Bridge Deck	4,500	1,200	5,700	6,750
III	5,000	1,200	6,200	6,750
III Seal	3,000	1,200	4,200	5,200
IV	5,500	1,250	6,750	7,850
IV Drilled Shaft	4,000	1,200	5,200	6,200 (1)
V Special	6,000	1,300	7,300	7,850
V	6,500	1,350	7,850	10,050
VI	8,500	1,550	10,050	11,700
VII	10,000	1,700	11,700	13,000
(1) A higher maximum allowable 28-day compressive strength may be approved.				

(2) As an option, for a class of concrete, submit compressive strength field test data for the past 24 months and spanning no less than 45 calendar days, to determine the standard deviation. The ***f'c*** is required to be within 1,000 psi. The strength test data represents either a group of at least 30 consecutive tests or a statistical average for two groups totaling 30 or more tests.

Design a concrete mix for a class of concrete specified in ***Specifications Section 346***. When the concrete mix meets the overdesign requirements of a higher class, classify the mix design as per Table 1.

9.2.7.2 Surface Resistivity Test

For all concrete mixes, cast three – 4 by 8 in. cylinders from the laboratory trial batch or from the field trial batch of at least 3 cubic yards. Test the cylinders at 28-day by an accredited laboratory in accordance to ***AASHTO T 358***. Submit the results to the Department for mix design approval.

9.2.7.3 Mix Design Submittal

Submit the mix design verification requests directly to the DMRO in the District where the mix design will be verified. If a mix design is to be verified at a location that is out-of-state, submit the mix design verification request to the DMRO closest to that location.

Ensure that the preparation and testing of the trial batch mixes are performed by a laboratory that is inspected and meets the requirements of ***ASTM C1077***. Personnel performing plastic or hardened concrete testing shall be qualified as described in ***Specifications Section 105***.

Slab replacement mixes do not require hot weather verification for mix design approval. Use only mix designs approved by the SMO for Department projects.

Ensure that the 28-day compressive strengths of all trial batch mixes meet the requirements of Table 1.

At the discretion of the SMO Concrete Materials Engineer, the mix design may be tentatively approved at an earlier date (e.g. 14-day). If the 28-day compressive strength does not meet the requirements of Table 1, the mix design will be disapproved.

Submit the proposed mix designs in MAC. The actual proportions of raw materials intended to be combined to produce the concrete with a theoretical yield of 27 ± 0.02 cubic foot.

Attach the following supporting documentation with each new mix design submittal:

(1) A current material certificate (less than one-year from submittal date) for all cementitious materials to include specific gravity.

(2) A current material certificate (less than one-year old from submittal date) for all aggregate materials, to include SSD specific gravity, gradation, absorption and fineness modulus (for fine aggregates).

(3) A certification statement from the admixture manufacturer's technical representative that the proposed admixture is compatible with all other admixtures to be included in the concrete mix design.

(4) Laboratory trial batch and testing documentation including constituents, batch weights, trial batch size, date batched, time batched, time sampled, plastic properties, hardened properties, chloride contents and written recommendations for admixture dosage (if required per 9.2.6.1.3).

(5) A copy of the contract documents that specifies the concrete mix design requirements. Examples are ***Special Provisions***, ***Technical Special Provisions***, ***Developmental Specifications***, ***Plan Notes*** or ***Supplemental Agreements***.

(6) Laboratory slump loss test data, if performed, for drilled shaft mixes with an elapsed time of 5 hours or less as described in ***Specification Section 455***, and 30 cubic yards of concrete or less.

For material substitutions, attach the following supporting documentation with each submittal:

(1) A current material certificate (less than one-year old from submittal) for all cementitious material, to include specific gravity.

(2) A current (less than one-year old from submittal) material certificate for all aggregate materials, to include SSD specific gravity, gradation, absorption and fineness modules (for fine aggregates).

9.2.7.4 Standard Concrete Trial Batch Mix (mix temperature between 68°F and 86°F)

(1) Ensure that preparation and testing of the trial mix is performed in accordance with ***ASTM C192***. Perform water to cementitious materials ratio calculations in accordance with ***FM 5-501***.

(2) On completion of the mixing period, ensure that the trial batch mix concrete has a slump within ±0.50 inch of the target value (±1.0 inch for mixes utilizing a High Range Water-Reducing admixture), and an air content less than or equal to 6.0 percent.

9.2.7.5 Hot Weather Concrete Trial Batch Mix (mix temperature of 94°F or higher)

(1) Ensure that preparation and testing of the trial batch mixes is performed in accordance with ***ASTM C192***, with the following exceptions:

(2) Perform initial mixing in accordance with ***ASTM C192***, except concrete materials shall be brought to a temperature that will ensure the mix temperature is not less than 94ºF at any time.

(3) Hold the trial batch mix in the mixer for 90 minutes after completion of initial mixing. During the extended mixing period, turn the drum intermittently for 30 seconds every five minutes. Cover the drum with wet burlap or an impermeable cover material during the rest periods. At the end of the 90-minute period, remix the trial batch mix for a minimum of one minute and make a slump test to verify that the concrete is within the specified range for slump. Ensure that the mix temperature is not less than 94ºF at any time.

(4) On completion of the extended mixing period, ensure that the trial batch mix concrete has a slump within ±0.75 inch of the target value (±1.0 inch for mixes utilizing a High Range Water-Reducing admixture), and an air content less than or equal to 6.0 percent. If below the target range, the Plant may adjust the slump by adding water. After the water addition, remix the concrete for a minimum of two minutes and perform slump and air content tests.

(5) The total water used in initial mixing and the final slump adjustment constitutes the mix design water content. Perform water to cementitious materials ratio calculations in accordance with ***FM 5-501***. Ensure that the total water to cementitious materials ratio does not exceed the specified water to cementitious materials ratio in the ***Specifications Section 346***, for the respective class of concrete.

9.2.7.6 Hot Weather concrete trial mix for extended transit time mixes

Ensure that preparation and testing of the trial mixes are performed in accordance with the hot weather procedure, with the following additional requirements.

Upon completion of the hot weather procedure, do not add additional water to the batch. Hold the trial mix in the mixer for the additional time required after completion of the 90-minute mixing period. During the extended mixing period, turn the drum intermittently for 30 seconds every five minutes. Cover the drum with wet burlap or an impermeable cover material during the rest periods. At the end of the required additional time extension period, remix the trial mix for a minimum of one minute and perform a slump test to verify that the concrete is within the specified range for slump. Ensure that the mix temperature is not less than 94ºF at any time.

9.2.7.7 Concrete trial batch mix for *Specifications Section 353* (slab replacement):

Ensure that preparation and testing of the trial batch mix is performed in accordance with ***ASTM C192***. Perform water to cementitious materials ratio calculations in accordance with ***FM 5-501***.

On completion of the mixing period, ensure that the trial batch mix concrete has a slump within ±0.50 inch of the target value (±1.0 inch for mixes utilizing a High Range Water-Reducing admixture), an air content less than or equal to 6.0 percent.

Hold the trial batch mix in the mixer for 60 minutes after completion of initial mixing. During the extended mixing period, turn the drum intermittently for 30 seconds every five minutes. Cover the drum with wet burlap or an impermeable cover material during the rest periods. Forty-five (45) minutes after completion of initial mixing add the required accelerator and cast the compressive strength test specimens.

9.2.7.8 Mix Design Review

Every five years, approved mix designs will be reviewed for compliance with current ***Specifications***. The SMO will track through MAC the concrete mix designs field data and may reclassify the mixes when:

(1) The compressive strength results exceed the required compressive strength (***f'cr***), and the concrete meets the overdesign requirements of a higher class.

(2) The result of the statistical evaluation of the concrete according to 9.2.5, indicate at least a good quality control as specified in ***ACI 214R*** Tables 4.3 and 4.4).

The mix design may be disapproved, reapproved or reclassified.

9.2.8 Drilled Shaft Concrete

Provide drilled shaft concrete meeting the requirements of ***Specifications Section 346***, including the slump loss test data. When concrete is placed in any shaft, provide concrete in accordance with the following specified slump loss requirements.

Ensure that the slump loss is gradual as evidenced by slump loss tests described below. The concrete elapsed time is defined in ***Specifications Section 455***.

Provide slump loss tests before drilled shaft concreting operations begin, demonstrating that the drilled shaft concrete maintains a slump of at least 5 inches throughout the concrete elapsed time. Obtain all other slump loss test results in the field. The slump loss test is performed at an ambient temperature consistent with the summer condition (85°F or higher) or the normal condition (below 85°F).

Inform the DMRE at least 48 hours before performing such tests. Perform slump loss testing of the drilled shaft mix using qualified personnel as defined by this section.

Perform the following procedures for the field slump loss tests, summer condition:

(1) Begin all elapsed times when water is initially introduced into the mixer.

(2) During field slump loss testing for summer condition, the concrete temperature must exceed an average of 90°F.

(3) Ensure that the mix is at least 3 cubic yards and is mixed in a truck mixer with a valid mixer identification card.

(4) After initial mixing, determine the slump, ambient and concrete temperatures and air content. Ensure that the concrete properties are within the required limits as specified in ***Specifications Section 346***.

(5) Verify the water to cementitious materials ratio and other delivery ticket data meet mix design requirements.

(6) When concrete is not being mixed, agitate the mixer at the midrange of the mixer manufacturer's recommended agitating speed. Remix the batch for one minute at the mixing speed of the mixer before determining slump, ambient and concrete temperatures.

(7) Determine slump, ambient and concrete temperatures at 30-minute intervals until the slump is 5 inches or less.

Perform the following procedures for the field slump loss tests, normal condition:

(1) Begin all elapsed times when water is initially introduced into the mixer.

(2) During field slump loss testing for normal condition, the concrete temperature does not exceed an average of 85°F.

(3) Ensure that the mix is at least 3 cubic yards and is mixed in a truck mixer with a valid mixer identification card.

(4) After initial mixing, determine the slump, ambient and concrete temperatures and air content. Ensure that the concrete properties are within the required limits as specified in ***Specifications Section 346***.

(5) Verify the water to cementitious materials ratio and other delivery ticket data meet mix design requirements.

(6) When concrete is not being mixed, agitate the mixer at the midrange of the mixer manufacturer's recommended agitating speed. Remix

the batch for one minute at the mixing speed of the mixer before determining slump, ambient and concrete temperatures.

(7) Determine slump, ambient and concrete temperatures at 30-minute intervals until the slump is 5 inches or less.

During laboratory slump loss testing for summer condition, the concrete temperature shall meet the requirements for hot weather trial batching (94°F).

(1) Begin all elapsed times when water is initially introduced into the mixer.

(2) Follow the procedure for Concrete Trial Mix Temperature of 94°F (hot weather mixes).

(3) At the end of the Concrete Trial Mix Temperature of 94°F (hot weather mixes). Turn the drum intermittently for 30 seconds every five minutes. Cover the drum with wet burlap or an impermeable cover material during the rest periods.

(4) After initial mixing, determine the slump, ambient and concrete temperatures and air content. Ensure that the concrete properties are within the required limits as specified in ***Specifications Section 346***.

(5) Remix the batch for one minute before determining slump, ambient and concrete temperatures at 15-minute intervals until the slump is 5 inches or less.

During laboratory slump loss testing for normal condition, the concrete temperature shall be in the range of 68°F to 86°F.

(1) Begin all elapsed times when water is initially introduced into the mixer.

(2) Ensure that preparation and testing of the trial mix is performed in accordance with ***ASTM C192***.

(3) At the end of the mix procedure, turn the drum intermittently for 30 seconds every five minutes. Cover the drum with wet burlap or an impermeable cover material during the rest periods.

(4) After initial mixing, determine the slump, ambient and concrete temperatures and air content. Ensure that the concrete properties

are within the required limits as specified in ***Specifications Section 346***.

(5) Remix the batch for one minute before determining slump, ambient and concrete temperatures at 15-minute intervals until the slump is 5 inches or less.

Submit slump loss test results to the DMRO for obtaining the approval in terms of elapsed time before concrete placement.

Mix designs approved based on aggregate substitution shall not require a new slump loss test. However, drilled shaft mix designs with cement or fly ash substitutions will require a new slump loss test to be performed.

9.2.9 PLANT BATCHING REQUIREMENTS

9.2.9.1 Bins

Provide bins of adequate capacity for the required concrete production. Support the bins upon a rigid framework founded upon a stable foundation capable of holding them in a safe and secure position. Design each compartment to discharge efficiently and freely into the weigh hopper. Provide positive means of control so that as the quantity desired in the weigh hopper is approached, the material can be added slowly, and the addition of further material can be stopped precisely. Use a discharging mechanism that prevents loss of material when it is closed. Construct aggregate storage bins sufficiently tight to prevent leakage of material, and divide them into at least one compartment for the fine aggregate and one compartment for each size of coarse aggregate to be used. Provide compartment partitions that are sufficiently tight and high enough to prevent intermingling of the different materials. Construct leak-proof and moisture-proof cementitious bins, and provide them with vibrators or other means to aid the flow of cement from the bin.

9.2.9.2 Weigh Hoppers

Provide weigh hoppers consisting of suitable containers freely suspended from scales and protected from the elements so that accuracy is not adversely affected. Equip the hoppers with a discharge mechanism that prevents leakage or loss of material when closed. Vent hoppers to permit air to escape and equip them with vibrators or other equipment that ensures complete and efficient discharge of materials.

9.2.9.3 Scales

Provide either beam type or springless dial type scales, or electronic devices such as load cells. Where using beam type scales, provide suitable means to hold poises securely in position after they are set. Keep scales clean and in good operating condition. Provide the scale operator with an unobstructed view of all indicating devices and convenient access to all controls. Use graduated weigh beam or dials to permit reading to 0.1 percent of the capacity of the scales. Check scales up to at least the maximum load normally handled on each respective scale.

9.2.10 MIXERS

9.2.10.1 General Requirements

Provide mixers that can combine the components of the concrete into a thoroughly mixed and uniform mass, free from balls or lumps, and which can discharge the concrete with a satisfactory degree of uniformity.

Inspect all mixers at least once each week.

9.2.10.2 Design

Use inclined axis revolving drum type truck mixers, or concrete Plant central mixers of the non-tilting, tilting, vertical or horizontal shaft types.

Make always available at the Plant a copy of the mixer manufacturer's design, showing dimensions and arrangement of blades. The concrete Plant may use mixers that have been altered from such design in respect to blade design and arrangement, or to drum volume, when authorized by the mixer manufacturer and approved by the DMRE. For initial design changes, provide uniformity test data, based on ***ASTM C94*** testing.

The metal rating plates must be attached to each mixer to specify its mixing speed, agitating speed, rated capacity and unit serial number. The unit serial number represents the entire mixing system. The metal rating plate may be located on the inside of the driver’s door. Mixer drum identification numbers or part numbers may or may not compare with the serial number on the rating plate. Should a drum be replaced, documentation from the mixer manufacturer must identify any deviations from the rating plate.

9.2.10.3 Truck Mixers Description

Use truck mixers with a drum that is actuated by a power source independent of the truck engine or by a suitable power take-off. Either system must provide control of the rotation of the drum within the limits specified on the mixer manufacturer's rating plate, regardless of the speed of the truck. Use truck mixers that are equipped with a hatch in the periphery of the drum shell which permits access to the inside of the drum for inspection, cleaning and repair of the blades.

Use truck mixers equipped with revolution counters and mounting, by which the number of revolutions of the drum may be readily verified.

Ensure that the water supply system mounted on truck mixers is equipped with a volumetric water gauge or a water meter in operating condition. Annually calibrate water measuring devices on truck mixers or other water sources used for concrete water adjustments.

Ensure truck mixers equipped with a volumetric water gauge are parked in a level condition during on-site water adjustments and for calibration. Ensure that the water measuring equipment has an accuracy of within 3 percent of the indicated quantity.

Truck mixers meeting these requirements shall be issued a mixer identification card by the DMRE upon request from the Plant. Failure to present the identification card upon request shall be cause for rejection of the delivered concrete. The Contractor shall remove the identification cards when a truck mixer is discovered to be in noncompliance and the deficiency cannot be repaired immediately. When the identification card is removed for noncompliance, the Contractor shall note the deficiency on the identification card and forward the identification card to the DMRE in the District with QC Plan acceptance authority.

The concrete Plant shall inspect all truck mixers at least once each week for changes due to accumulation of hardened concrete or to wear of blades or chutes. The blades or chutes shall be repaired or replaced as necessary to meet these requirements. Any appreciable accumulation of hardened concrete shall be removed before any mixer may be used.

Copies of the most recent water measuring equipment calibration shall be kept in the truck cab and made available upon request.

9.2.10.4 Automated Slump Monitoring System

Proposed automated slump monitoring system include the following items:

(1) Slump is measured by the ready-mixed concrete truck.

(2) Slump is adjusted and controlled by the ready-mixed concrete truck.

(3) All water additions and slump adjustments are recorded.

The Plant’s QC Plan shall include:

(1) Automated slump monitoring system information.

(2) Provisions for training on the proposed automated slump monitoring systems. As a minimum, the Plant shall provide training on the automated slump monitoring system for drivers, QC personnel, and verification inspection personnel.

(3) Calibration procedures.

Calibration of the automated slump monitoring system shall be done on an annual basis, or when a truck is rejected in accordance with ***Specifications Section 346***. All system records including calibration records shall be made available at the Plant to the Department upon request.

Mix concrete at speeds and number of revolutions as recommended by the mixer manufacturer, when water is added enroute to the project site. Automatic introduction of water will be disabled when entering the project site or when the maximum water to cementitious materials ratio for the mix design is reached. If the system adds water in transit, the concrete shall be re-mixed at mixing speed upon arrival to the project for an additional 30 revolutions. Water shall not be added during the discharge of the batch.

9.2.10.5 Central Mixers

Use stationary type mixers equipped with a timing device which will automatically lock the discharge lever when the drum is charged and release it at the end of the mixing period. In the event of failure of the timing device, the Department may allow operations to continue during the day that failure was noticed for the first time. Do not extend such operations beyond the end of that working day. Operate the mixer at the speed recommended by the central mixer manufacturer.

9.2.10.6 Mixer Cleaning and Maintenance

Repair or replace mixer blades of revolving drum type mixers when the radial height of the blade at the point of maximum drum diameter is less than 90 percent of the design radial height. Repair or adjust mixers of other designs per mixer manufacturer's instructions. Resolve questions of performance by performing mixer uniformity tests as described in ***ASTM C94***.

9.2.11 MIXING AND DELIVERING CONCRETE

9.2.11.1 General Requirements

Operate all Plant mixers at speeds per the mixer manufacturer's design or recommendation. Do not allow the volume of mixed batch material to exceed the mixer manufacturer's rated mixing capacity. Mix concrete containing highly reactive pozzolans in accordance with the supplier's recommendations.

Wash-out water left in the drum prior to batching and account for all water entering the drum as batch water.

When necessary, during cold weather conditions, heat either the mix water, the aggregates or both prior to batching. Apply the heat uniformly in a manner which is not detrimental to the mix. Do not heat the aggregates directly by gas or oil flame or on sheet metal over fire. Do not heat the aggregates or water to a temperature of over 150° F. If either component is heated to over 100° F, mix them together prior to the addition of the cement. The cement must not be in contact with the materials at temperatures exceeding 100° F. Include in the Plant's QC Plan measures to maintain free moisture in a well-drained condition when heating aggregates.

9.2.11.2 Central Mixing

After all materials are in the mixer, mix the concrete a minimum of two minutes or the central mixer manufacturer's recommended minimum mixing time, whichever is longer.

9.2.11.3 Transit Mixing

Initially mix each batch between 70 and 100 revolutions of the drum at mixing speed. The number of initial mixing revolutions may be modified when using specialty ingredients (highly reactive pozzolans, corrosion inhibitors calcium nitrite, accelerators, high range water reducers, etc.), as recommended by the specialty ingredients supplier.

Do not haul concrete in mixer trucks loaded with more than the rated capacity shown on their attached plates.

The water storage tanks on the truck shall be filled after reporting all water used and the delivery ticket is printed, before leaving for the project site. Water missing from the water storage tanks upon arrival at the project site shall be included in the jobsite water added.

9.2.11.4 Charging the Mixer

Charge each batch into the drum so that some water enters both in advance of and after the cementitious material and aggregates. If using fly ash (other than ultra-fine fly ash) in the mix, charge it into the drum over approximately the same interval as the cement. Other time intervals introducing materials into the mix may be used after demonstrating uniformity of the concrete mix using the test requirements specified in ***ASTM C94***.

For concrete mixes containing specialty ingredients, charge the batch materials into the mixer in a sequence recommended by the mixer manufacturer of the specialty ingredients. Adjust the weight of mixing water for a concrete mix containing a corrosion inhibitor and/or accelerator admixture. Account for water in the corrosion inhibitor and/or accelerator as described in the admixture manufacturer's technical data sheet.

9.2.12 QUALITY CONTROL PROGRAM

The QC Plan of any concrete Plant shall meet the requirements of ***Specifications Sections 105***. The Plant's QC Plan shall also address the following items:

(1) Describe how the concrete Plant will maintain the properties of concrete to the point of discharge at the project site.

(2) Describe how the water to cementitious materials ratio and the plastic properties tests of concrete will be controlled to meet ***Specification*** requirements.

(3) Describe the action that will be taken when batching high slump concrete to prevent lumps and balls shall also be addressed.

(4) Describe personnel qualification, source of materials, and equipment used to produce concrete shall be addressed in the Plant's QC Plan.

(5) Describe the action that will be taken when there is a concern with a material or product at the Plant which may be in violation of the ***Contract Documents*** and notify the DMRO.

When more than two trucks from a Plant delivering high slump concrete (6" slump or higher) is found to contain lumps and balls, the Department will notify the Plant that the Department will not accept high slump concrete from the Plant on any Department projects. To resume production of high slump concrete, the Plant must demonstrate the ability to batch a full-size load as defined by the Plant's QC Plan of high slump concrete free of lumps and balls. In addition, the Plant must revise that portion of its QC Plan that addresses batching of high slump concrete to reflect QC improvements made.

The Plant shall be on the Department's Production Facility Listing prior to production of concrete for Department projects. The accepted Plant's QC Plan shall be the minimum required control of concrete on all Department projects.

9.2.13 PERSONNEL

Plants supplying concrete to Department projects shall have adequate qualified personnel. Concrete Batch Plant Operator, qualified technicians and Plant Manager of QC are required positions for a Plant.

The Plant QC personnel shall meet the Structural Concrete Production Facility QC Personnel requirements of ***Specification Section 105***.

9.2.13.1 Concrete Batch Plant Operator

The duties and responsibilities of the Concrete Batch Plant Operators include but are not limited to the following:

(1) Sign concrete certification/delivery tickets.

(2) Must be present during concrete batching operations.

9.2.13.2 Qualified Technicians

The duties and responsibilities of the Qualified Technicians include but are not limited to the following:

(1) The ACI Concrete Field Testing Technician - Grade 1 performs concrete plastic properties test, such as slump, temperature, air content, making and curing concrete cylinders, and calculating the water to cementitious materials ratio.

(2) The ACI Concrete Strength Testing Technician performs tests on hardened properties of concrete.

(3) The ACI Self-Consolidating Concrete Testing Technician performs the self-consolidating concrete tests.

9.2.13.3 Plant Manager of Quality Control

Personnel who perform the duties of managing the QC of the Plant shall have the duties, responsibilities, and be qualified as follows:

Duties and responsibilities:

(1) Implement policies and procedures of the Plant's QC Plan.

(2) Maintain liaison with the Department on all activities related to QC.

(3) Supervise the activities of all QC technicians, ensuring sufficient manpower is available in all areas related to QC testing and inspection.

(4) Review all QC procedures to ensure compliance with the ***Specifications*** and other ***Contract Documents***.

(5) Ensure all QC records are properly prepared and reviewed.

(6) Ensure that QC activities are performed in accordance with documented instructions and procedures.

(7) Develop and maintain a filing, storage, and retrieval system for QC records.

(8) QC Plant Manager or his/her qualified designee must be daily on-site at the Plant or always available on-site upon a four-hours' notice.

9.2.13.4 Concrete Mix Designer

The Concrete Mix Designer is responsible for the QC functions of designing the required concrete mixes.

9.2.14 RECORDS

All records shall be kept on file and made available at each Plant upon request by the Department. The following updated information shall be available at each Plant:

(1) Accepted concrete Plant QC Plan.

(2) Approved concrete mix designs.

(3) Materials source/specification compliance (delivery tickets, certifications, miscellaneous test reports).

(4) Concrete chloride test data.

(5) Aggregate moisture control records including date and time of test.

(6) Manufacturer’s mixer information.

(7) Federal Highway Administration poster shall be posted to be visible to all employees.

(8) A copy of the scale company’s report corresponding with the current certificate of inspection, showing the date of inspection, signature of the scale company representative, and the observed scale deviations for the loads checked.

(9) Certification documents for admixture weighing and measuring dispensers.

(10) Weekly mixer inspection reports.

(11) A daily record of all concrete batched for delivery to Department projects, including respective mix design numbers and quantities of batched concrete.

9.2.15 SAMPLING AND TESTING OF MATERIALS

9.2.15.1 General

Sampling and testing of materials and concrete for QC purposes is the responsibility of the concrete Plant. The frequency of sampling must be designed to provide adequate data to operate within the Plant’s QC Plan for each mix design. ***Table 2*** designates the minimum sampling and testing frequencies that shall be performed in a well-controlled Plant. The Plant’s QC Plan shall indicate an increased sampling rate when any of the Plant’s testing results of the QC Plan items reach their maximum allowable limits.

All sampling and testing shall be conducted in accordance with the Department’s current ***Florida Sampling and Testing Methods***, ***AASHTO***, or ***ASTM*** sampling and testing methods. Obtain SSD specific gravity and absorption values for both coarse and fine aggregate.

The Plant shall submit a corrective action plan to prevent the recurrence of the problem when evidence shows that the Plant has failed to sample within the required frequencies.

TABLE 2 – Concrete Material Components Sampling and Testing	
Material and Required Tests	Minimum Sampling Frequency for Each Source and Grade
Coarse Aggregate Gradation (**AASHTO T 27**) Total Minus 200-mesh (**FM 1-T011**)	Certification

TABLE 2 – Concrete Material Components Sampling and Testing

Material and Required Tests	Minimum Sampling Frequency for Each Source and Grade
Fine Aggregate Gradation (**FM 1-T 027**) Total Minus 200-mesh (**FM 1-T011**)	Certification
Cementitious Materials	Delivery Ticket and Mill Certificate
Admixtures	Certification
Water (1)	As required in ***Specification Section 923***
Chlorides (**FM 5-516**)	1 every 30 days or in accordance with this guide

(1) The corrective action plan requires that open bodies of water and recycled water shall be tested every 15 days during production. Well and other sources of water shall be tested every 45 days during production, until approval to return to the normal sampling frequency is given by the DMRE for the District which has Plant QC Plan acceptance responsibility. Failure to comply with the sampling frequency shall be cause for suspension of the Plant's QC Plan.

9.2.15.2 Chloride Testing

It is the responsibility of the Plant to make sure chloride content of all reinforced concrete produced for the Department does not exceed the maximum allowable limits indicated in ***Specifications Section 346***. The Plant shall use a qualified laboratory, from the Department's Qualified Labs Report, for all chloride testing. The laboratory shall meet the requirements of ***Specifications Section 105-7***.

Obtain the chloride test report. Enter the test results and attach the chloride test report in MAC within 17 calendar days of sampling. Failure to comply with the time frame for data entry may result in suspension of the Plant's QC Plan.

Determine the chloride content of each mix design produced every calendar month at the Plant, as necessary to produce concrete meeting ***Specification Section 346***. When more than one mix design uses the same cementitious materials and aggregate source, the Plant has the option to test for chlorides on the mix design with the highest cementitious content to represent all such mixes. The chloride test report shall clearly indicate all mix designs covered by the test.

An increased sampling frequency shall be implemented when evidence shows the concrete Plant has failed to sample for chlorides within the required frequency. The increased sampling frequency requires that the concrete for chloride testing shall be sampled once per week during production, until approval to return to the normal sampling frequency is given by the DMRE of the District that has Plant QC Plan acceptance responsibility. Failure to comply with the sampling frequency shall result in suspension of the Plant's QC Plan.

If chloride test results exceed the limits shown in ***Specifications Section 346***, suspend concrete production immediately for every mix design represented by the failing chloride test results until corrective measures are made. Notify the DMRE and the SMO Structures Corrosion Laboratory as soon as the test results are available. Notify all customers on affected FDOT projects and request from them all the Contract and Financial Project numbers impacted.

Submit the following documentation to the DMRE. A Materials Acceptance Resolution (MAR) for each FDOT project affected by failing chloride test results will be issued.

(1) Engineering Analysis Report (EAR) Scope.

(2) The ***FM 5-516*** Chloride test results.

(3) Date(s) of production represented by failing test results.

(4) Mix design(s) represented by failing test results.

(5) Contract and Financial Project number(s).

Disposition of concrete represented by the MAR will be documented for each affected FDOT project, in accordance with the requirements of ***Specifications Section 6*** and ***Section 346****.*

When the source of any component material, including admixtures, for the concrete is changed, sampling for chloride determination shall restart the first day of production of the mix with the new component material.

In addition to the testing frequency required in ***Table 2***, the DMRO will collect the chloride split samples from the Plant once per year for testing at SMO. The DMRO will compare the test results as follows:

(1) If the average chloride test results are within 0.092 pounds per cubic yard of concrete, and at least one test passes, no further action is necessary.

(2) If the average chloride test results are within 0.092 pounds per cubic yard of concrete, and both results fail, resolve as per ***Specifications Section 346***.

(3) If the average chloride test results are not within 0.092 pounds per cubic yard of concrete, DMRO will notify SMO and the SMO will send the sample to third-party laboratory for resolution.

If third-party laboratory agrees with Plant results, no further action is required. If third-party laboratory agrees with SMO results, resolve as per ***Specifications Section 346***.

9.2.16 DELIVERY TICKET/CERTIFICATION

The following information is required information for each concrete delivery and must be furnished with each load. The information contained within ***Specifications Section 346*** is required information on each delivery ticket/certification. The original signature on the delivery ticket shall certify to the accuracy of the recorded information and compliance with the approved mix design. A sample of a delivery ticket is provided in ***Appendix "A".*** Use this form or a similar form containing the same information:

(1) Serial number of delivery ticket.

(2) The Plant number as assigned by the Department.

(3) Date of batching.

(4) Contractor's name.

(5) FDOT Financial Project Number.

(6) Truck number making the concrete delivery shall match the truck number on the delivery ticket.

(7) Class of concrete.

(8) Mix design number.

(9) Time all materials are introduced into mixer.

(10) Cubic yards in this load.

(11) Cumulative total cubic yards batched for job on date of delivery.

(12) Maximum allowable water addition at the job site. Unit of measure must be indicated.

(13) Number of revolutions at mixing speed before leaving for job site.

(14) Amount of mixing time for central mixer.

(15) Coarse and fine aggregate sources (Department assigned Source No.).

(16) Actual amount of coarse and fine aggregates batched in pounds.

(17) Percent of free moisture in coarse and fine aggregates.

(18) Cement producer’s name and type of cement.

(19) Total amount of cement batched in pounds.

(20) Producer’s name, brand name and class (whichever might apply) of supplementary cementitious material used.

(21) Total amount of each supplementary cementitious material batched in pounds.

(22) Admixture manufacturer, type and total amount of each admixture used.

(23) Total amount of water batched and added after the truck leaves the Plant in gallons or pounds before leaving for the job site. Unit of measure must be indicated.

(24) Statement of compliance with the ***Contract Documents.***

(25) Original signature of Batch Plant Operator and technician identification number.

Notes:
- Items 12 and 13 do not apply to non-agitating concrete transporting vehicles.
- Items 1, 2, 4, 6, and 9 through 13 do not apply to precast operations with onsite Plants.

9.2.17 TRAINING

Training will be in accordance with ***Specifications Section 105***.

9.2.18 FORMS

Example Concrete Delivery Ticket – Appendix A, ***Materials Manual Volume II, Section 9.2***

APPENDIX "A"
Sample Delivery Ticket for Structural Concrete

Financial Project No.: ______________________ Serial No.: ______________________

Plant No.: ______________________ Date: ______________________

Concrete Plant: ______________________ Delivered to: ______________________

Phone Number: ______________________ Phone Number: ______________________

Address: ______________________ Address: ______________________

Truck No.	DOT Class	DOT Mix No.	Cubic Yards This Load
Allowable Jobsite Water Addition (gal. or lbs.)	Time Loaded	Mixing revolutions or time	Cubic Yards Total Today

Cement Source / Type / Amount	Fly Ash: Source / Grade / Amount Slag: Source / Class / Amount
Coarse Agg. Source Num. / Moisture (%) / Amount	Air Entrainment Admixture Source / Brand / Type / Amount
Fine Agg. Source Num. / Moisture (%) / Amount	Admixture Source / Brand / Type / Amount
Batch Water (gals. or lbs.) Amount	Admixture Source / Brand / Type / Amount

Issuance of this ticket constitutes certification that the batched concrete was produced and is in compliance with the ***Contract Document*** requirements for Structural Concrete.

Technician Identification Number Signature of Batch Plant Operator

Arrival time at job site		Number of revolutions upon arrival at job site	
Total Water added at job site (gallons)	Admixtures added at the job site (ounces)	Additional mixing revolutions with added water	
Time concrete completely discharged	Time admixture added		
Initial Slump	Initial Air	Initial Concrete Temp.	Initial w/cm Ratio
Acceptance Slump	Acceptance Air	Acceptance Concrete Temp.	Acceptance w/cm Ratio

Signature on this ticket constitutes certification that the maximum specified water cementitious materials ratio was not exceeded and the batch was delivered and placed in compliance with the ***Contract Document*** requirements.

Technician Identification Number Signature of Contractor's Representative

APPENDIX "B"

Optimized Combined Aggregate Gradation (OCAG) Method Using the Modified Coarseness Factor Chart (MCFC)

1. Scope

1.1. The Modified Coarseness Factor Chart (MCFC) was developed to empirically design concrete pavement mixes that had good workability and placement properties. The mixes had improved aggregate packing densities and lower cementitious paste volumes. Since thermal and shrinkage stresses are directly related to cementitious paste content, concretes with reduced paste contents have lower tendencies to crack. For constant water-to-cementitious materials ratio (w/cm), concrete with higher paste contents have higher initial porosities that result in higher permeabilities that reduce durability.

1.2. The MCFC is used as a guide to combine coarse, intermediate, and fine aggregates to produce an optimized combined aggregate gradation (OCAG). The denser particle packing obtained with an OCAG enables a reduction in the volume of cementitious paste needed to produce concrete with the required plastic and hardened properties. References are given at the end of this appendix that provide more detail on the method and the interpretation of the results.

1.3. Optimization of the CAG refers to providing the lowest overall paste content that can produce the desired plastic and hardened properties. Lower cementitious paste contents may require relatively high admixture additions to attain desired slumps/flows. Placement methods that require higher concrete slumps/flows, such as for pumping, may limit the reduction of total cementitious paste volume.

2. Significance and Use

2.1. Research has shown that using a reduced cementitious paste content in combination with optimized CAG can significantly increase the durability of concrete. Advantages include lower shrinkage and thermal cracking tendencies, lower permeability, lower maximum temperatures for mass concrete, lower material costs, and an environmental benefit due to the reduction in use of portland cement, the production of which releases significant quantities of carbon dioxide into the atmosphere.

2.2. Normal concrete typically contains coarse aggregates that are mostly larger than 3/16 in. (No. 4 sieve size) and fine aggregates that are mostly smaller than 3/16 in. The combined aggregate size distributions are normally deficient in the No. 4 to No. 16 aggregate sizes (3/16 in. to 3/64 in.) and are referred to as gap-graded distributions. Gap-graded aggregate distributions do not pack as densely as wellgraded distributions, resulting in a greater volume of void space between larger particles (aggregate void volume). To produce adequate workability of the concrete, the volume of cementitious paste (cementitious materials and water) must be sufficient to fill all the interparticle voids (aggregate void volume) and to coat all the aggregate surfaces. An excess volume of paste is needed to separate the aggregates and greatly reduce interparticle friction, enabling the concrete to flow. The volume of excess cementitious paste needed depends on the desired workability and typically ranges from 1.25 to 1.75 times the aggregate void volume.

3. Materials

3.1. Coarse Aggregates: Obtain two coarse aggregates meeting ***Specifications Section 901***, one large-sized coarse aggregate such as Size No. 57 and one intermediate-sized coarse aggregate such as Size No. 89.

3.2. Fine Aggregate: Use silica sand meeting ***Specifications Section 901***.

3.3. Cementitious Materials: Specific to concrete mix design.

3.4. Admixtures: Specific to mix design.

4. Aggregate Characterization

4.1. Aggregate size distributions: Determine aggregate size distributions using the procedures specified in ***ASTM C136/C136M***. The sieve series should be comprised of the following sieves: 1 1/2 in., 1 in., 3/4 in., 1/2 in., 3/8 in., No. 4, No. 8, No. 16, No. 30, No. 50, No. 100, and No. 200.

4.2. Aggregate specific gravities: Aggregate specific gravities shall be measured using the procedures specified in ***FM 1-T 084*** and ***FM 1-T 085***, respectively.

4.3. Aggregate packing densities: Determine aggregate packing densities (volume fractions of aggregate) of combined aggregate gradations as specified in ***ASTM C29/C29M***.

5. Optimization of the CAG Using the MCFC Process

5.1. The CAG shall consist of the following aggregate sizes:

5.1.1. A large-sized coarse limestone aggregate, No. 57.

5.1.2. An intermediate-sized coarse limestone aggregate, No. 89.

5.1.3. A fine aggregate (silica sand).

5.2. Determine the specific gravities of the limestone aggregates and the silica sand (***FM 1-T 085*** and ***FM 1-R 084***, respectively).

5.3. Determine the aggregate size distributions for the No. 57 and No. 89 coarse aggregates and the silica sand (***ASTM C136***).

5.4. Use a spreadsheet to calculate a series of combined aggregate gradations by varying the proportions of each type of aggregate using the individual aggregate size gradations.

5.5. Evaluate the quality of each CAG using the MCFC (Figure 1).

5.5.1. The coarseness factor (CF) is defined as follows:

$$CF = \left(\frac{Q}{Q+I}\right)100$$

where: *Q* = Percent of combined aggregates retained on the 3/8 in. sieve.

I = Percent of combined aggregates passing the 3/8 in. sieve and retained on the No. 4 and No. 8 sieves.

5.5.2. The workability factor (WF) is defined as follows:

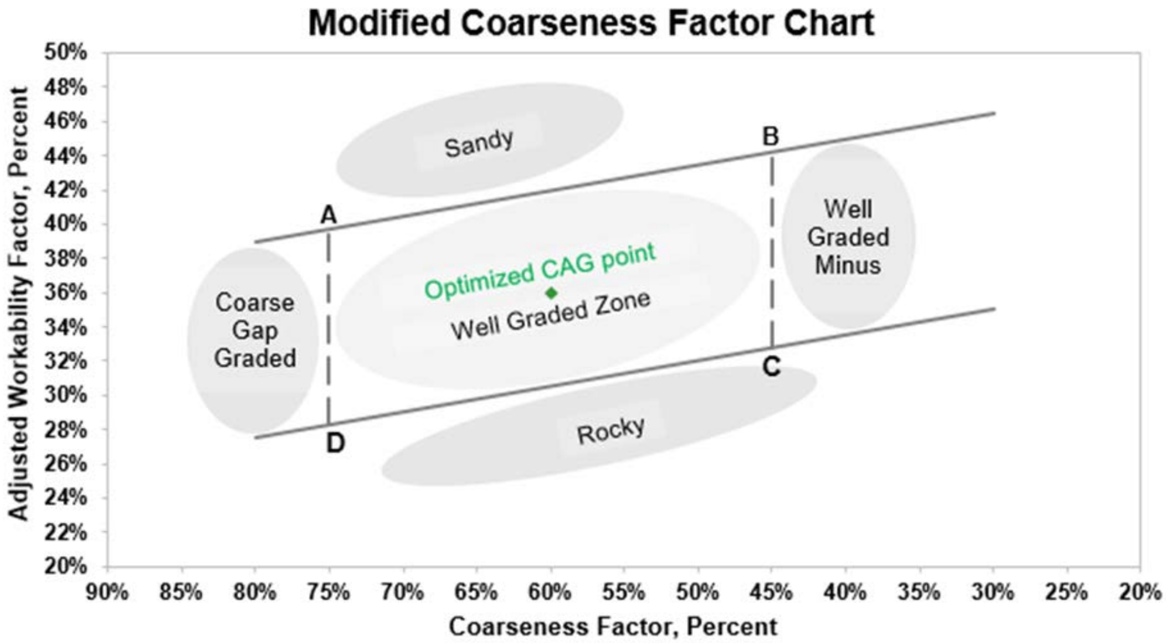
$$WF = \left(\frac{W}{Q+I+W}\right)100$$

where: *W* = Percent of combined aggregates passing the No. 8 sieve.

5.5.3. When the cementitious material content of a concrete mix is other than 564 lb/ft^3 (equivalent to six sacks of cement), WF has to be adjusted by plus or minus 2.5% per sack of cement (94 lb) that is over or under 564 lb.

$$WF_{adj} = \left(\frac{W}{Q+I+W}\right)100 + 2.5\left(\frac{W_{cm}}{94} - 6\right)$$

where: W_{cm} = Mass of total cementitious material content in lb/yd^3



5.6. Perform checks on the CAG packing densities by measuring their compacted bulk densities and void fractions (***ASTM C29***).

5.7. Choose an initial low cementitious paste volume (start around 26 vol% paste) for each mix design and perform laboratory trials to evaluate the plastic properties. Use water-reducing admixtures to adjust workability. Adjust paste content and admixtures to get desired plastic properties.

5.8. For each promising mix design, make samples for plastic and hardened property testing. Properties must meet the requirements of ***Specifications Section 346*** and the performance requirements of the intended use.

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