Concrete Batch Plant Operator

Study Guide

Developed by the

FLORIDA DEPARTMENT OF TRANSPORTATION

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STATE MATERIALS OFFICE

1. General Production Requirements

Although all orders for concrete are placed with the Producer by the Contractor, all structural concrete produced for Department projects must come from a plant that is currently on the List of Producers with accepted quality control program. The concrete must be produced by qualified personnel, it must be a Department approved design mix and it must be produced, transported, handled, sampled and tested in accordance with the current version of the Department's Standard Specifications for Road and Bridge Construction (hereafter called the specifications) governing the project and the Section 9.2 of the Materials Manual Volume I & II.

2. General Concrete Information

In very broad terms, concrete can be considered as the combination of aggregates and paste. The aggregates consist of fine and coarse aggregate. In combination, they make up approximately 75 to 85% of the volume of concrete with the coarse aggregate taking up the majority of this volume. The paste is a combination of cement, water, admixtures, and entrained air, and comprises approximately 15 to 25% of the volume of concrete.

The cement and water combine in a chemical reaction called hydration. Hydration is what causes the concrete to set and is also what causes the heat in the curing process. The ratio of water to all cementitious materials in the paste is the key factor in determining the strength and quality of concrete. In general, the lower the water cementitious materials ratio, the stronger and more durable the concrete will be.

The characteristics of a batch of concrete can be catered to specific environments, conditions and intended uses with the careful addition of pozzolans and admixtures. Workability, durability, strength and temperature can be greatly affected by how the concrete is batched, mixed, placed and cured.

3. Initial Plant Approval

A plant must submit a proposed quality control plan to the District Materials Office (DMO) in accordance with the specifications. Upon the plant's submittal of a quality control plan, the DMO will review the proposed quality control plan and make the necessary arrangements for the initial plant qualification review and inspection.

The DMO or SMO personnel will perform an initial inspection of the plant using the Example Structural Concrete Production Facility Inspection Guide, Appendix D. Upon completion of the inspection, the inspector shall make recommendations to the District Materials and Research Engineer (DMRE) or their representative regarding the quality control plan acceptance status and the plant's qualifications based on the results of the inspection. The DMRE or their representative will investigate the plant and its quality control (QC) procedures related to areas of non-compliance and/or unacceptable materials.

With acceptance of the quality control plan the plant number will be placed on the Departments Production Facility Listing. The plant and/or its quality control procedures may be inspected at any time.

4. Normal Operation

While the plant is actively supplying concrete to Department projects, it will be re-inspected by Department personnel every three months or as approved. If discrepancies are found during the inspection, the plant may be removed from the approved status and placed in a suspended status.

5. Plant Personnel Requirements

Concrete production facilities supplying concrete to Department projects shall have adequate Construction Training and Qualification Program (CTQP) qualified personnel. Batch Plant Operator, qualified technicians, and Manager of Quality Control are required positions for an approved concrete production facility and shall be CTQP or ACI qualified. At the discretion of the Department, certain functions of the above positions may be combined when it can be demonstrated that the plant operation and quality of the concrete will not be detrimentally affected. The qualification of any personnel shall be made available upon request.

a. Batch Plant Operator

Personnel who have quality control functions or who sign concrete delivery tickets must demonstrate, through examination, adequate concrete related knowledge. Batch Plant Operator/s shall be present during batching operations. The Plant Operator shall be qualified by CTQP or an equivalent training program as defined in Florida Department of Transportation specifications.

6. Material Information and Requirements

a. Portland Cement

Acceptance of the cement at the plant shall be based upon the delivery ticket and Mill Certificate. As a check on current quality, samples may be obtained and tested by the Producer or the Department.

The Mill Certificate must meet the requirements of Section 921 of the Standard Specifications. Unless specifically designated elsewhere, use one of the following types of cement:

1) **Type I**. For use when the special properties specified for any other type are not required.

2) **Type II.** For general use, especially when moderate sulfate resistance is desired. Suggested for mass placements.

3) **Type II (MH).** For use in all mass concrete elements and all elements in extremely aggressive environments.

4) **Type III.** For use when higher early strength is desired.

5) **Type IP.** Suitable for general construction.

6) **Type IS.** The portland blast-furnace slag cement shall consist of an intimate and uniform blend of portland cement and fine granulated blast-furnace slag produced either by intergrinding portland cement clinker and granulated blast-furnace slag, by blending portland cement and finely ground granulated blast-furnace slag, or a combination of intergrinding and blending, in which the slag constituent is up to 95 percent of the mass of portland blast-furnace slag cement. Suitable for general construction.

   Plants must provide a separate and clearly labeled weather-proof facility to store each brand or type of cement available during production. The cement bins must have a vibratory system or other equipment to aid the flow of cement from the bins. There must be a suitable, safe and convenient means of collecting samples. Samples will be taken periodically from the plant and tested by the Department.

   Cement quantity must be determined by weight. Weigh cementitious materials separately from other materials. When weighing cement, other pozzolans and slag in a cumulative weigh hopper, weigh the cement first.

   If bagged Cementitious material or Highly Reactive Pozzolans is permitted, proportion the batch to use only whole bags.

   Cement trivia: one bag of cement weighs 94 pounds, and equal approximately one cubic foot in volume. This applies to a bag of Portland cement in the United States.

b. Pozzolans and Slag

Acceptance of the pozzolans or slag at the plant shall be based upon the delivery ticket and Mill Certificate. As a check on current quality, samples may be obtained and tested by the Producer or the Department.

The Mill Certificate must meet the requirements of Section 929 of the Standard Specifications. The quantities of pozzolans and slag must be determined by weight. When weighing pozzolans and/or slag in a cumulative weigh hopper with cement, the cement must be weighed first.

Plants must provide a separate and clearly labeled weatherproof facility to store each brand or type of pozzolan on hand. There must be a suitable, safe and convenient means of collecting samples. Samples will be taken periodically from the plant and tested by the Department.

c. Aggregate

General - All aggregate used on Department projects shall be obtained from Department approved sources. A list of approved sources will be maintained by the Department and made available from the SMO.

As a minimum, each plant must provide suitable bins, stockpiles or silos to store and identify aggregates without mixing, segregating, degregating, or contaminating the different sources or grades. Identification shall include DOT designated, approved pit number and aggregate grade. Measure aggregates by weight or volume within an accuracy of 1% of the required amount. Apply aggregate surface moisture corrections.

The Producer shall be responsible for handling the aggregates so as to minimize segregation and recover material from the stockpile for use in the mix so it will remain within specification limits. Stockpiles shall be maintained in a well drained condition to minimize free water content and to not promote algae/fungal growth. The Producer shall make available to the Department, from the recovery side of the stockpile where feasible, the quantities of aggregate necessary for sampling and testing to ensure compliance with project specifications.

The minimum sampling frequency for each source of coarse and fine aggregate, when producing concrete for FDOT, is thirty (30) days.

Gradations - Coarse aggregate must meet the requirements of Section 901 of the Standard Specifications. Produce all concrete using Size No. 57, 67, or 78 coarse aggregate. The Engineer may approve the use of Size No. 8 or 89, either alone or blended, with Size No. 57, 67, or 78 coarse aggregate. Do not blend the aggregate if the size is smaller than Size No. 78.

Fine aggregate must meet the requirements of Section 902 of the Standard Specifications.

Wetting Coarse Aggregate - The entire surface of the coarse aggregate shall be continuously and uniformly sprinkled with water for a minimum period of 24-hours immediately preceding introduction into the concrete. Any request for deviations from the 24-hour sprinkling requirement should be addressed in the Producer's Quality Control Plan for consideration by the DMRE.

d. Water

Water must meet the requirements of Section 923 of the Standard Specifications.

If water is from a city source and approved for public use, it does not need to be sampled. If water is from a well or is reclaimed, it must be sampled prior to use on a Department project and every three months thereafter. If water comes from an open body of water or is recycled, it must be sampled and tested prior to use and then monthly.

Water trivia: one gallon weighs 8.33 pounds, one cubic foot contains 7.49 gallons which weighs 62.4 pounds. Water is used as the base substance for determining specific gravity so its specific gravity equals 1.

e. Admixtures

Admixtures will meet the requirements of Section 924 of the Standard Specifications. The admixture dosage rate of the product to be used should be within the range of the 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. Admixtures shall be stored in accordance with the manufacturer’s recommendation.

1) **Air Entraining Admixtures**
Air entraining admixtures are used to introduce microscopic air bubbles into a concrete mix. The benefits include improved workability, increased freeze-thaw resistance and improved durability. Entrained air can slightly reduce the strength of the concrete.

2) **Water-Reducing Admixtures (Type A)**
Water-reducers are used to reduce the amount of water in a mix while maintaining a certain workability or consistency. For a given water content in a mix, water reducers will increase the slump. When a water-reducing admixture is used it must meet the requirements of a Type A admixture.

   Concrete must contain either a water-reducing (Type A) or water-reducing and retarding (Type D) admixture.

3) **Water Reducing and Retarding Admixtures (Type D)** Retarders are used to delay the set time of concrete and reduce the amount of water in a mix while maintaining a certain workability or consistency. It may be used to offset the effects of hot weather or to provide sufficient time before setting in difficult placement or finishing operations. When a water-reducing and retarding admixture is used it must meet the requirements of a Type D admixture.

Concrete must contain either a water-reducing (Type A) or water-reducing and retarding (Type D) admixture.

4) **High Range Water Reducing (HRWR) (Type F or G, or Class I, or II)**
When a high range water-reducing admixture is used it must meet the requirements of a Type F or Type I admixture. When a high range water-reducing and retarding admixture is used it must meet the requirements of a Type G or Type II admixture.

HRWR will provide significantly increased slump with reduced water requirements. This has the benefit of providing high slump, high strength concrete that has a low water cementitious materials ratio. The latest HRWRs will provide a flow able concrete that does not segregate, has water cementitious materials ratios below 0.30, and results in a very strong finished product.

If the design mix uses silica fume or metakaolin, the concrete must contain an approved high range water reducer. If the proper approval has been obtained, HRWR may be used in other applications, as well. Do not use a Type F, G, I, or II admixture in drilled shaft concrete.

5) **Flowing Concrete Admixtures for Precast/Prestressed Concrete**
Use a Type I, II, F, or G admixture for producing flowing concrete.

6) **Corrosion Inhibitors - Calcium Nitrite**
Calcium Nitrite is a chemically reactive admixture used in concrete to inhibit the corrosion of embedded reinforcing steel and other metallic components. It is generally used in projects in extremely aggressive environments.

Calcium nitrite must be stored in accordance with the manufacturer's recommendation. The accelerator should be added at the jobsite. The total batch water of a concrete mix must be adjusted when using calcium nitrite. For example if the mix is in English units, each gallon of calcium nitrite may add 7.0 lbs or 0.84 gallons of water to the mix.

7. Scales and Meters

All scales, meters and other weighing or measuring devices, excluding admixture dispensers, shall be checked for accuracy by a qualified representative of a scale company registered with the Bureau of Weights and Measures, Division of Standards of the Florida Department of Agriculture and Consumer Services prior to production of concrete. Scales, meters and other weighing or measuring devices, excluding admixture dispensers, shall be checked once every three months thereafter. The Department reserves the right to be present during all scale checks.

The Bureau of Weights and Measures may be reached at the following link:
http://www.freshfromflorida.com/Divisions-Offices/Consumer-Services/Business-Services/Standards/Weights-and-Measures

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*** shall be included in the report provided by the qualified company performing the check. A copy of the report corresponding with the current certificate of inspection shall be available at the plant where the device is located.

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

a. Water Measuring Devices

Water measuring devices used during batching operations at concrete plants are to be checked for accuracy at least quarterly. Accuracy of these devices is checked by weight or volume. Any container used for accuracy verification must be capable of holding the maximum quantity of water normally used during batching sequence.

If accuracy is checked by volume, the maximum capacity of the container used must be known in gallons. Graduation marks must be readily visible on the container at each level checked, ensuring accurate volume determination to the nearest 0.5 gallon]. Accuracy of these graduation marks must be documented by a scale company registered with the Bureau of Weights and Measures, Division of Standards of the Florida Department of Agriculture and Consumer Services.

Use of a flow meter mounted in series is acceptable provided the accuracy of the flow meter is traceable to the National Institute of Standards and Technology. The accuracy of the calibration device should be checked annually.

Measure water by volume or weight. Whichever method is used, construct the equipment so 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 to 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% of the quantity of water required as total mixing water for the batch. The total mixing water shall include: water added to the batch, ice added to the batch, water occurring as surface moisture on the aggregates, and water introduced in the form of admixtures.

b. Admixture Measuring Dispensers

Admixture measuring dispenser accuracy shall be certified annually by the admixture supplier. Calibrate the dispensing equipment for calcium nitrite quarterly.

c. Recorders

Plants equipped with recording mechanisms must provide records that are clear, complete and permanent indications of plant performance. Where necessary, recorder information may be supplemented by the batcher during the batching operation. The Department shall be allowed to review recorder history at any time.

8. Batching Accuracy

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 producer. Failure to immediately investigate and implement corrective measures may be cause for suspension of the quality control plan.

Admixture measuring equipment (whether volume or weight) must have an accuracy, under all operating conditions, within 3% of the quantity required for any potential batch size produced at the plant.

Graduated weigh beams or dials must be able to read to 0.1% of the scale's capacity.

Scales to weigh cements, pozzolans, slag, coarse and fine aggregates must be maintained to an accuracy of 0.5% of the maximum load it normally handles.

9. Required Plant Records

All records shall be kept on file for five years at each plant and made available upon request by the Department. The Federal Poster shall be posted so as to be visible to all employees. The following updated information shall be available at each plant:

a. Accepted quality control plan for the concrete production facility.

b. Approved concrete design mixes by financial project numbers.

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

d. Quality control data (aggregate gradation worksheets, absorption worksheets, and concrete chloride test data).

e. Aggregate moisture control records including date and time of test. The accuracy of the moisture test method verified at least weekly. The scale is calibrated annually and covers the full weighing range.

f. Annual calibration records for water measuring devices on trucks or other water sources for concrete water adjustments.

g. Manufacturer's design data and approved modifications for the mixer.

h. Federal Poster

i. The scale company's report corresponding with the current certificate of inspection showing the date of inspection, signature of the scale company representative, the observed scale deviations for the loads checked.

j. Certification documents for admixture weighing and measuring dispensers.

k. Weekly mixer inspection reports.

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

m. Recorder history.

n. Chloride tests shall represent one per design mix in use from the first day of production and every 30 calendar days or less thereafter.

10. <u>Design Mixes</u>

Use only design mixes approved by the SMO for Department use.

11. <u>Batching Tolerances</u>

Concrete must be batched within the following tolerances.

a. Cementitious materials (batch size over 3 yd^3) must be within 1% of the required batch quantity.

b. Cementitious materials (batch size of 3 yd^3 or less) must be within 2% of the required batch quantity.

c. Fine and Coarse Aggregates must be within 1% of their respective required batch quantity.

d. Admixtures must be within 3% of the required batch quantity.

e. Water must be within 1% of the required batch quantity.

Failure to maintain the batching operations of the plastic concrete within the tolerance for each component material requires immediate investigation and corrective action by the concrete producer. Failure to immediately investigate and implement corrective measures may be cause for suspension of the quality control plan.

12. Batch Adjustments for Aggregate Moisture

Within two hours prior to each day's batching, free moisture shall be determined for the coarse and fine aggregates. 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. The concrete producer shall use these values for adjustment of batch proportions.

One or more of the following methods shall determine aggregate free moisture:

a. Using 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. The accuracy of the moisture probe shall be verified at least weekly by the manufacturer's recommended method and by method (b) below. The Chapman flask and speedy moisture tester shall be verified at least weekly by method (b) below.

b. Calculate both coarse and fine aggregate free moisture based upon dry sample weights and adjusting for absorption per AASHTO T 255. The following minimum sample sizes shall be used in lieu of the sample sizes required in AASHTO T 255 Table 1: Fine Aggregate – 500 grams, Coarse Aggregate – 1500 grams

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

d. The comparison criteria between any of these methods shall be no more than 0.5%.

13. Mixers

a. General Requirements

Provide mixers that are capable of combining the components of the concrete into a thoroughly mixed and uniform mass, free from balls or lumps, which are capable of discharging the concrete with a satisfactory degree of uniformity.

Inspect all mixers at least once each week for changes due to accumulation of hardened concrete or to wear of blades.

b. Design

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

Make available at the plant at all times a copy of the manufacturer's design, showing dimensions and arrangement of blades. The concrete producer may use mixers that have been altered from such design in respect to blade design and arrangement, or to drum volume, when concurred by the 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 ID numbers or part number may or may not compare with the serial number on the rating plate. Should the drum be replaced, documentation from the manufacturer must identify any deviations from the rating plate.

c. Truck Mixers

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. Ensure that either system provides control of the rotation of the drum within the limits specified on the manufacturer's rating plate, regardless of the speed of the truck. Use truck mixers of the revolving drum type 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 approved water meter in operating condition. Annually calibrate water measuring devices on truck mixers or other water sources used for concrete water adjustments.

Where a truck mixer volumetric gauge controls job site water additions, ensure the truck mixer is parked in a level condition during on-site water adjustments so that the gauge is indicating a specific tank volume before and after the concrete adjustment. Ensure that the water measuring equipment has an accuracy of within 3% of the indicated quantity.

Truck mixers meeting these requirements will be issued an identification card by the DMRE upon request from the concrete producer. Identification cards shall be displayed in the truck cab when delivering concrete for Department use. Failure to present the identification card upon request shall be cause for rejection of the delivered concrete. The Contractor will 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 forward the identification card to the DMRE in the District with Quality Control Plan acceptance authority

The producer shall inspect all truck mixers at least once each week for changes due to accumulation of hardened concrete or to wear of blades (which may cause inadequate mixing) or chutes. The blades or chutes shall be repaired 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 available upon request.

d. 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. The mixer shall be operated at the speed recommended by the manufacturer.

e. Cleaning and Maintenance of Mixers

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% of the design radial height. Repair or adjust mixers of other designs per manufacturer's instructions. Resolve questions of performance through mixer uniformity tests as described in *ASTM C 94*.

14. <u>Mixing and Delivering Concrete</u>

a. General Requirements

Operate all concrete plant mixers at speeds per the manufacturer's design or recommendation. Do not allow the volume of mixed batch material to exceed the manufacturers rated mixing capacity. Mix concrete containing silica fume, metakaolin or ultra fine fly ash in accordance with their supplier's recommendations.

Account for all water entering the drum as batch water.

When necessary during cold weather conditions, heat either the mix water or 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 is heated to over 100° F, mix them together prior to the addition of the cement. The cement must not come in contact with the materials, which are in excess of 100° F. Include in the quality control plan measures to maintain free moisture in a well drained condition when heating aggregates.

b. Central Mixing

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

c. Transit Mixing

Initially mix each batch between 70 and 100 revolutions of the drum at mixing speed, at the batch plant. All concrete from truck mixers must be discharged before total drum revolutions exceed 300. Count all revolutions of the drum in the total number of revolutions. The number of initial mixing revolutions may be modified when using specialty ingredients (silica fume, metakaolin, ultra fine fly ash, corrosion inhibitor 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.

d. 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. Admixtures such as air-entrainment, water reducers and retarders shall be added with the mixing water.

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. The concrete producer may use other time intervals for the introduction of materials into the mix when the concrete producer demonstrates; using test requirements specified in *ASTM C 94*, that he can achieve uniformity of the concrete mix.

For concrete mixes containing specialty ingredients (Highly Reactive Pozzolans) charge the batch materials into the mixer in a sequence recommended by the supplier 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 manufacture's technical data sheet.

15. Transit Time (per Specification Section 346, dated January 2015)

The maximum allowable time between initial introduction of water into the mix and completely depositing the concrete in place is given below.

Table 4		
	Non-Agitating Trucks	Agitating Trucks
No water reducing and retarding admixture (Type D, Type G or Type II) is used in the mix.	45 minutes	60 minutes
Water reducing and retarding admixture (Type D, Type G or Type II) is used in the mix.	75 minutes	90 minutes

16. Delivery Ticket

The following information is required information for each concrete delivery. All information shown on the delivery ticket must be furnished with each load. The information contained within Materials Manual Section 9.2 Volume II and Florida Department of Transportation Specifications, Section 346 is required information on each delivery ticket. The original signature on the delivery ticket shall certify to the accuracy of the recorded information and compliance with the approved design mix. A sample of a delivery ticket is provided in Appendix "B", and must contain:

a. Serial number of delivery ticket.
b. Plant number assigned by the Department.
c. Date of batching.
d. Contractor's name.
e. FDOT Financial Project Number.

- **f.** Truck number making the concrete delivery shall match the truck number on the delivery ticket.
- **g.** Class of concrete.
- **h.** Design mix number
- **i.** Time all materials are introduced into mixer.
- **j.** Cubic yards in this load.
- **k.** Cumulative total cubic yards batched for job on date of delivery.
- **l.** Maximum allowable water addition at the job site. Unit of measure must be indicated
- **m.** Number of revolutions at mixing speed before leaving for job site.
- **n.** Amount of mixing time for central mixer.
- **o.** Coarse and fine aggregate sources (Department assigned Pit No.).
- **p.** Actual amount of coarse and fine aggregates batched in pounds.
- **q.** Percent of free moisture in coarse and fine aggregates.
- **r.** Cement producer and type.
- **s.** Total amount of cement batched in pounds.
- **t.** Producer, brand name and class (whichever might apply) of Pozzolan or Slag.
- **u.** Total amount of Pozzolan or Slag batched in pounds.
- **v.** Manufacturer total amount of air entraining agent used.
- **w.** Manufacturer and total amount of admixtures used.
- **x.** Total amount of water batched at the plant in gallons or pounds before leaving for the job site. Unit of measure must be indicated.
- **y.** Statement of compliance with the Contract documents.
- **z.** Original signature of Batch Plant Operator and technician identification number.

Note: Items "l" and "m" do not apply to non-agitating concrete transporting vehicles.

Note: Items "a, b, d, f", and "l" through m" do not apply to precast operations with onsite production facilities.

Batch adjustment made in accordance with Materials Manual Volume II Section 9.2 shall be noted on the delivery ticket.

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. 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.

17. Cold Weather Concreting

Do not mix concrete when the air temperature is below 45ºF and falling.

18. Hot Weather Concreting

Hot weather concreting is defined as the production, placing and curing of concrete when the concrete temperature at placing exceeds 85ºF but is less than 100ºF. 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.

19. Acceptance/Rejection of Delivered Concrete

The acceptance or rejection of a load of concrete is based on many criterion. 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, so that it will fall within specified tolerances. If a load does not fall within the tolerances, test each subsequent load until a load falls within the tolerances and the first adjusted load. If adjustments are not implemented for failing concrete, the Engineer may reject the concrete and terminate further production until the corrections are implemented. The following list is by no means all-inclusive.

a. Slump. The following applies to non-Drill Shaft and non-HRWR concrete.

The tolerance range is ±1.5" of the target slump value listed in Specification Section 346 Table 2 based on the class of concrete. The tolerance range will also be shown on the design mix.

1) Out of tolerance range. If the slump differs more than 1.5" from the target slump value, high or low, the load will be rejected. Do not allow concrete to remain in a transporting vehicle to reduce slump.
2) Adjusting out of range. If a load that was initially acceptable and in tolerance is adjusted out of tolerance, it will be rejected.
3) A load of concrete that arrives within target slump value range and has job site water available that load may be adjusted by adding water provided the addition of water does not exceed the water to cementitious materials ratio as defined by the mix design. Adjustments are not permitted after placement of the load has begun.

b. Air Content. If the air content is outside of the ranges listed in Specification Section 346Table 2, the load will be rejected.

c. Water Cementitious Materials Ratio. If the water cementitious materials ratio of the class of concrete or the design mix is exceeded, the load will be rejected.

d. Total Revolutions. If total revolutions of the mixer exceed 300, the load will be rejected.

e. **Transit Times.** Any transit times exceeding those shown in Specification Section 346 Table 6 may result in rejection of the load. 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 in advance by the Engineer.

f. **Concrete Temperature.** Any concrete exceeding 100°F will be rejected. Any concrete that is not from an approved hot weather design mix will be rejected when it exceeds 85°F

20. Calculations and Examples

Note: Use appendix C to solve the following example problems

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A. Calculating aggregate moisture from the cook-out method. Information you will need to be able to collect:

1. W_{wet} = weight of the wet aggregate and weighing pan (lbs).
2. W_{dry} = weight of oven dried aggregate and weighing pan (lbs).
3. P_{tw} = tare weight of the weighing pan

Determine the moisture content as a percent of the aggregate dry weight:
$100 * [(W_{wet} - W_{dry})/(W_{dry} - P_{tw})]$ = moisture content (%)

Example (1):
A sample of course aggregate is taken, weighed (W_{wet}), dried, then re-weighed (W_{dry}). The weights measured are given below. What is the moisture content of the stockpile represented by the sample?

W_{wet} = 3.64 lbs
W_{dry} = 3.45 lbs
P_{tw} = 0.54 lbs

Calculate total moisture content of the sample:
Moisture content (%) = 100 * [(3.64 – 3.45)/(3.45 – 0.54)] = 100 * [0.19/2.91] = 6.53%

Example (2):
W_{wet} = 1,509.6 g
W_{dry} = 1,476.4 g
P_{tw} = 295.3 g

Calculate total moisture content of the sample:
Moisture content (%) = 100 * [(1,509.6 - 1,476.4)/(1,476.4 - 295.3)] = 100 * [33.2/1181.1] = 2.81%

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B. Calculating free moisture in aggregate. Information you will need to be able to collect:

1. Moisture content (see examples (1) & (2)).
2. Aggregate absorption.
   Total Moisture content (%) - absorption (%) = free moisture (%)

Example (3):

The total moisture content is determined to be 6.53% for a stockpile of coarse aggregate. This same aggregate has an absorption of 2.5%. What is the free moisture?

Free moisture = 6.53 – 2.50 = 4.03%

Example (4):

The total moisture content is determined to be 2.81% for a stockpile of fine aggregate. This same aggregate has an absorption of 1.4%. What is the free moisture?

Free moisture = 2.81 - 1.40 = 1.41%

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C. Determine the adjustment to batch water quantity and aggregate quantity due to aggregate moisture. Information you will need to be able to collect:

1. Free moisture (see examples (3) and (4)).
2. Weight of SSD aggregate used per yd^3 from the design mix.

   a. This calculation takes moisture content as a percentage of aggregate weight and turns it into a measurable quantity (lbs, gal) to be used in the adjustment of both batch water and aggregate quantities. Convert the free moisture percent to a numeric value by dividing by 100. For example, in Example (4), the free moisture was determined to be 1.41%. The value used in calculating adjustments is 1.41/100 = 0.0141.

   Adjustment = aggregate weight x converted free moisture

   When the moisture content is greater than the absorption (usual case), the aggregate will give up water to the mix. The aggregate quantity must be increased by the adjustment and the water quantity must be reduced by the adjustment.

b. The water adjustment can be left in terms of pounds or can easily be converted to gallons. One gallon of water weighs 8.33 lbs.

Water adjustment (gal) = [Water adjustment (lbs)]/8.33

Example (5):

The example design mix calls for 1620 lbs of coarse aggregate and 267 lbs (32.0 gal) of water per yd³. The aggregate has an absorption of 2.50% and the total moisture content is determined to be 6.53%. Calculate the adjustments to batch quantities per yd³. Figure the water adjustment in pounds and gallons.

Free moisture = 6.53 - 2.50= 4.03%
Free water = (free moisture/100) + 1.00 = 1.0403
Adjusted aggregate quantity: 1620x1.0403 = 1685.286 lbs
Determine the adjustment in pounds: = 1685.286 – 1,620 = 65.286 (Free Moisture)

Adjusted water quantity (lbs) = 267 - 65.286 = 201.714 = 202 lbs
Determine water adjustment in gallons: 65.286/8.33 = 7.84
Adjusted water quantity (gal) = 32.0 - 7.84 = 24.16 = 24.2 gal

Example (6):

The example design mix calls for 1366 lbs of fine aggregate and 267 lbs (32.0 gal) of water per yd³. The aggregate has an absorption of 1.40% and the total moisture content is determined to be 2.81%. Calculate the adjustments to batch quantities per yd³. Figure the water adjustment in pounds and gallons.

Free moisture = 2.81 - 1.40 = 1.41%
Free water = (free moisture/100) + 1.00 = 1.0141
Adjusted aggregate quantity: 1366x1.0141 = 1385.2606 lbs
Determine the adjustment in pounds: = 1385.2606 – 1,366 = 19.2606 (Free Moisture)

Adjusted water quantity (lbs) = 267 - 19.2606 = 247.7394. = 248 lbs
Determine water adjustment in gallons: 19.2606/8.33 = 2.31 gal
Adjusted water quantity (gal) = 32.0 - 2.31 = 29.69 = 29.7 gal

Example (7):

The following data applies to the design mix. Calculate the adjusted aggregate and water quantities.

Moisture Absorption Quantity / yd³

Coarse Aggregate	Fine Aggregate	Water
1620	1366	267 lbs (32.0 gal)

Coarse aggregate free moisture = 3.5% = (3.5/100) + 1.00 = 1.035
Adjustment due to extra water in the coarse aggregate = 1620x1.035 = 1676.7000 = 1676.7000 – 1620 = 56.7000 lb (Free Moisture)

Fine aggregate free moisture = 2.9% = (2.9/100) + 1.00 = 1.029
Adjustment due to extra water in the fine aggregate = 1366x1.029 = 1405.6140 = 1405.6140 – 1366 = 39.6140 lb (Free Moisture)

Adjustment to the batch water = 56.7000 + 39.6140 = 96.3140 lb

Adjusted aggregate and water quantities are:
Coarse aggregate: 1620 + 56.7000 = 1676.70 = 1677 lb
Fine aggregate: 1366 + 39.6140 = 1405.61 = 1406 lb
Water: 267 – 96.31 = 170.686 = 171 lb = 171/8.33 = 20.5 gal

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D. Determine water cementitious materials ratio and/or batch quantities based on a given water cementitious materials ratio.

1. The water cementitious materials ratio is simply the total weight of all water in a batch divided by the total weight of all cementitious materials (cement, fly ash, slag, etc.) in the batch.

water cementitious materials ratio (w/cm) =

$$\frac{\textbf{(weight of all water in a batch)}}{\textbf{(weight of all cementitious material in a batch)}}$$

Example (8):

The example design mix contains 545 lbs cement, 140 lbs fly ash and 32.0 gal water per cubic yard. What is the water cementitious materials ratio for this mix?

Convert batch water from gallons to pounds: 32.0 x 8.33 = 266.56 lbs.
Calculate water cementitious materials ratio: w/cm = 266.56/(545 + 140) = 266.56/685 = 0.389 = 0.39

Example (9):

A 5 yd³ batch is called for that requires 685 lbs/ yd³ cementitious and a maximum water cementitious materials ratio of 0.39. It is to be batched to allow 15 gal of job site allowable water addition. How much water per cubic yard should be used in the initial batching?

Figure total water required from w/c and cement requirements:
0.39 = (weight of water)/685 = weight of water = 0.39 x 685 = 267.15 = 267 lbs.
Convert to gallons→ 267.15/8.33 = 32.07 = 32.1 gal/ yd³

Since 15 gallons are to be held back from the entire load for allowable job site addition, the hold back per yd³ is 15/5 = 3.0 gal/ yd³.
The load should be batched with 32.1 – 3.0 = 29.1 gal/ yd³ to allow 15 gallon addition at the job site and a maximum water cementitious materials ratio of 0.39.

Example (10):

A 1 yd³ batch was delivered to the job site which called for 545 lbs/ yd³ cement; 140 lbs/yd³; 21.00 gallons of batch water; 1620 lbs/yd³ coarse aggregate with a free moisture of 1%; 1366 lbs/yd³ fine aggregate with a free moisture of 6%; 0.000 gallons added at the job site. Determine water cementitious materials ratio of the 1 yd³ delivery to the job site:

Coarse aggregate: 1,620/1.00+1/100 = 1603.800; 1620 – 1604.000 = 16.000 lbs fee moisture
Fine aggregate: 1,366/1.00+6/100 = 1,288.679 = 1,366 – 288.679 = 77.321 lbs free moisture
Convert gallons of Water to lbs: 21.00 x 8.33 = 174.930 lbs of batch water
Total water in batch: 16.00 + 77.321 + 174.930 + 0.000 = 268.251 lbs
Total Water: 268.251 lbs Total Cementitious: 685 lbs = 268.251/685 = .392
w/cm ratio = 0.39

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E. Specific gravity, unit weight, absolute volume, yield.

1. When talking about specific gravity, everything is compared to water. Water is considered to have a specific gravity of 1 and has a unit weight of 62.4 lbs/ ft^3. If something has a specific gravity greater than 1, it is more dense (weighs more per ft^3) than water. Specific gravities have no units of measure (ft^3, lb, etc.).

2. To determine the unit weight of a material with a known specific gravity, multiply the material's specific gravity by 62.4 lb/ft^3.
unit weight of a material (lb/ ft^3) = (material's specific gravity) x 62.4

Example (11):

Determine the unit weight of cement (specify gravity = 3.15):

3.15x62.4 = 196.56 lbs/ ft^3.

3. To determine the absolute volume of a certain amount of a material, divide its weight by its unit weight.

$$\text{absolute volume} = \frac{\text{weight of material}}{\text{Specific gravity of material x 62.4}}$$

Example (12):

Determine the absolute volume of 1,366 lbs of fine aggregate with a specific gravity of 2.61:

1,366/(2.61 x 62.4) = 1,366/162.864 = 8.39 ft^3

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4. To determine the yield of the example design mix, total the absolute volumes of all the ingredients (including air and, in general, disregarding admixtures). To determine the unit weight of a mix, divide the yield by the total weights of all the ingredients.

Example (13):

Determine the yield and unit weight of the example design mix:

Ingredient	Weight	SG	Calculation	Absolute Volume
Cement	545	3.15	545/(3.15x62.4)	2.773
Fly Ash	140	2.43	140/(2.43x62.4)	0.923
Coarse Aggregate	1620	2.64	1620/(2.64 x 62.4)	9.834
Fine Aggregate	1366	2.61	1366/(2.61x62.4)	8.387
Air	3.5%		0.035 x 27	0.945
Water	267	1	267/(1 x 62.4)	4.279

Yield = 2.773 + 0.923 + 9.834 + 8.387 + 0.945 + 4.279 = 27.141 ft^3

Unit Weight = (545 + 140 + 1,620 + 1,366 + 267)/27.141 = 3938/27.14 = 145.1 lbs/ft^3

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5. When the specific gravity (SG) of one of the batch materials changes by more than 0.08, adjustments need to be made to the mix design quantities to prevent over or under yielding. To calculate the necessary adjustment, determine the volume of the original specific gravity. Using the new specific gravity, determine the weight required to fill the volume that was just calculated. You will find that if the SG goes up (more dense), it will take more weight of the material to fill a given volume and if the SG goes down (less dense), it will take less weight of the material to fill a given volume.

[original mix quantity (lbs)]/[original SG x 62.4] = volume from original SG (ft^3)

[volume from original SG (ft^3)] x (new SG) x 62.4 = new mix quantity (lbs)

Example (14):

The example design mix calls for 1,620 lbs of coarse aggregate with a specific gravity of 2.64. It is determined that the specific gravity of that aggregate is now 2.60. Determine the new design mix quantity for this coarse aggregate.

1,620/(2.64 x 62.4) = 1,620/164.736 = 9.834 (ft^3) = 9.834 x (2.60 x 62.4) = 9.834 x 162.240 = 1,595.47 = 1,595 lbs

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21. Appendix

Appendix A, Definitions
Appendix B, Example Delivery Ticket for Structural Concrete
Appendix C, Example Concrete Design Mix
Appendix D, Example Structural Concrete Production Facility Inspection Guide
Appendix E, Standard Specification Section 346, dated January 2015

Appendix "A"
Definitions

Absolute volume	The volume of a material in a voidless state. This means that the absolute volume of a granular material like cement or aggregate is the volume of the solid matter in the material only, it does not include the volume of the voids between particles.
Absorbed moisture	The moisture in the pores and capillaries of a material. If an aggregate has all the moisture it is capable of absorbing (SSD), it will not give or take any water from the batch water. If an aggregate has not absorbed all the moisture it is capable of absorbing (less than SSD), it will pull batch water from the mix resulting in a drier than anticipated mix. If an aggregate has more moisture than it is capable of absorbing (more than SSD), it has free moisture it will contribute to the batch water resulting in a wetter than anticipated mix (total moisture minus the free moisture).
Absorption	The ability to take moisture into pores or capillaries. For aggregate, it is the moisture content, given as a percent of the aggregate's weight, when it has reached a saturated surface dry condition. For example, if an aggregate has an absorption of 1.0%, it will absorb a weight of water equal to 1.0% of its own weight.
Accelerator	An admixture designed to accelerate strength gain of concrete at an early age. It should be noted that any admixture containing calcium chloride is prohibited from use in any reinforced concrete application.
Admixtures	Ingredients other than cement, water and aggregates that are added to a concrete mix for any or all of the following reasons: reduce construction costs; alter plastic properties; alter curing characteristics; improve inclement weather concrete quality; improve durability; etc.
Air entraining admixture	Admixtures designed to purposely distribute microscopic air bubbles throughout a batch of concrete. Air entrainment significantly improves the durability of concrete to freeze-thaw cycles, improves workability, and reduces segregation and bleeding. All FDOT concrete is required to have an air entraining admixture, except counter weight concrete.
Air dry aggregate	Aggregate that is dry at the surface but contains some interior moisture. Aggregate that is air dry is considered somewhat absorbent because it does not contain all the moisture it is capable of holding (less than SSD).
Approved Products List	The Department generated list of all products suitable for immediate use in Department projects.
Approved status	Fully approved plant status that is the normal operating status for concrete plants which meet the requirements of Department specifications and requirements.
Batch Plant Operator	The Department approved individual responsible for certifying the delivery ticket with his original signature. Shall be present during all batching operations for Department concrete. Department approval is currently obtained by passing the Batch Plant Operator Exam conducted by Construction Training Qualification Program and the required experience.
Bleed water	Water that has migrated to the surface of freshly placed concrete. It is

	caused by the settlement and consolidation of the solids in the mix due to vibration and gravity.
Cement	The bonding agent of concrete. All cements are hydraulic which set and harden due to a chemical reaction with water called hydration.
Cementitious materials	Substances that have hydraulic cementing properties. Although pozzolans have little or no cementitious value, they are included in the total weight of cementitious material in a mix design.
Certified Technician	An individual with a current ACI and/or a Construction Training Qualification Program certification. As required by the current Florida Department of Transportation specifications.
Chloride content	The water soluble chloride-ion content in concrete measured in weight/volume of concrete.
Coarse aggregate	Aggregate substantially retained on the No. 4 sieve. There is a wide range of grading in classifying coarse aggregates.
Concrete	A basic mixture of two components: aggregates and paste. Aggregates are generally divided into two groups: fine and coarse. The paste is comprised of cement and water and binds the aggregates into a hardened mass due to the chemical reaction of the cement and water (see hydration).
Consistency	Measured with the slump test, it refers to the wetness, flowability, stiffness and cohesion of the plastic concrete.
Cookout method	The method of determining aggregate moisture by cooking out all the moisture in an oven. Total moisture is determined by subtracting the oven dry weight from the wet weight of the aggregate.
Corrosion inhibitor	An admixture used to chemically arrest the corrosion reaction caused when chloride ions reach the reinforcing steel in concrete structures. Calcium nitrite is the most commonly used corrosion inhibitor.
Deleterious substances	Generally refers to undesirable substances that may be found in aggregates and water. These may include clay, soft particles, salt, alkali, organic matter, loam, oil, acid, chlorides, etc.
Delivery ticket	Paperwork required to accompany every load of concrete delivered to the Department. All information required on the delivery ticket may be obtained from the Florida Department of Transportation Section 346 and the Materials Manual Volume II Section 9.2. An original signature from a certified Batch Plant Operator is required on each delivery ticket to certify to the accuracy of the information and compliance with the approved design mix and other contract documents.
Dry aggregate weight	Total weight of an aggregate with zero moisture content. Generally determined by cooking the aggregate in an oven until it reaches a stabilized weight.
Durability	A broad term referring to the ability of concrete to withstand the environment and service conditions in which it is placed. It encompasses the following and more: freeze/thaw resistance, abrasion resistance, chemical resistance, permeability, control of cracking, etc.
Entrained air	Microscopic air bubbles purposely trapped in the concrete mix for improved properties and characteristics. See air entraining admixture.
Entrapped air	“Large” air bubbles trapped in the concrete mix - as opposed to microscopic entrained bubbles. Also known as bug holes.
False set	A significant loss of plasticity shortly after mixing. If this occurs, remix the concrete without additional water before it is placed.

Fineness modulus (FM)	A general indication of the fineness or coarseness of an aggregate. It is determined by a specific sieve analysis procedure.
Fine aggregate	Natural sand or crushed stone substantially passing the No. 4 sieve, with most particles less than 0.2".
Fly ash	It is the finely divided residue of the coal burning process in power plants. This pozzolan contributes to the concrete's long-term strength and durability.
Free moisture	The moisture on the surface of an aggregate that is above and beyond the absorbed moisture in an aggregate. It is expressed as a percentage of the weight of the aggregate. Free moisture = Total moisture - absorbed moisture
Fully absorbent aggregate	Aggregate that has been oven dried removing all free and absorbed moisture.
Grading	See sieve analysis.
Heat of hydration	The heat generated by the chemical reaction between water and cement. The amount of heat produced is primarily a function of the chemical make-up of the cement but is also affected by such things as water cementitious materials ratio, cement fineness and temperature of curing.
High Range Water Reducer (HRWR)	See water reducing admixture. Reduces water by 12% to 30%.
Hot weather concreting	Defined as the production, placing and curing of concrete when the concrete temperature at placing is above 85°F but below 100°F.
Hot weather design mix	A design mix that has been batched to satisfy the temperature, slump loss, plastic and hardened properties, and maximum water cementitious materials ratio requirements of the specifications to be designated a hot weather mix. See hot weather concreting for definition.
Hydration	The chemical reaction between the hydraulic calcium silicates of cement and water. Hydration begins as soon as cement comes in contact with water. Hydration will stop when there is insufficient moisture available in the concrete to support the reaction.
Concrete Production Facility Quality Control Plan (QCP)	The concrete producer's plan delineating all actions to be carried out to ensure the produced concrete maintains the required properties from point of production to the point of delivery. The required format for the Concrete Production Facility QCP is available in Chapter 9.2 of the Materials Manual located on the State Materials Office website.
Contractor's Quality Control Plan	The contractor's plan delineating all actions to be carried out to ensure the concrete maintains specified quality and properties from the point of delivery to the point of placement. The required format for the Contractor's QCP may be obtained from Section 105 of the Standard Specifications and is located on the Specifications Office website.
Manager of Quality Control	A required individual in any plant producing concrete for the Department. Requires previous quality control experience and demonstrated proficiency in managing a quality control program. Responsibilities include, but are not limited to, implementing QC policies, maintaining communications with Project Managers and Engineers, supervising QC technicians, and ensuring QC records are properly prepared, maintained and filed.
Mass concrete	Defined as any volume of cast-in-place concrete large enough to

	require measures to deal with large temperature differentials within the mass of concrete and the inherent cracking problems associated with those temperature differentials. For Department projects, mass concrete will be designated in the contract documents. A mass concrete mix design and a proposed plan to monitor and control temperature differential is required for Department projects. Temperature differentials must be kept at or below 35°F between internal and external portions of the mass.
Mixing revolutions	Generally refers to transit truck mixers. Each batch must be initially mixed between 70 - 100 revolutions at mixing speed. If water is added at the job site, an additional 30 mixing revolutions is required. The total mixing speed revolutions is not to exceed 160 and the total drum revolutions is not to exceed 300 prior to total discharge of the load.
Moisture probe	Generally an electrical resistance type meter used to determine the moisture content of aggregates. The probes require periodic calibration and their accuracy shall be verified at least weekly by the manufacturer's recommended method.
Non-approved plant status	Not qualified to supply concrete to the Department.
Oven-dried aggregate weight	The weight of aggregate that has had all its moisture dried out by oven cooking. Aggregate in this condition is considered fully absorbent because of its potential to absorb water.
Plant Batcher	Individuals who perform only the function of batching concrete. They do not have to pass an exam to be Department approved but demonstrated proficiency is required. A Batch Plant Operator must be present during batching and to sign the delivery ticket.
Pozzolanic Materials	Materials which have little or no cementitious value by themselves but, in a finely divided form, have cementitious properties when mixed with water and the byproduct of cement hydration.
Re-tempered concrete	Concrete that has initially started to set and water has been added to it to provide additional workability.
Retarding admixture	Admixtures designed to slow the rate of setting of concrete. These may be used to counteract the accelerating effects of hot weather or delay set for unusual placements like drilled shafts.
Saturated surface dry (SSD)	Refers to aggregate that has absorbed all the moisture it is capable of absorbing and is dry on the outside. All design mix aggregate quantities refer to SSD aggregate. SSD aggregate can neither absorb water from nor contribute water to the concrete mix.
Sieve Analysis	A process used to determine the particle size distribution of an aggregate. The aggregate is sieved through several screens of known size to determine the size distribution and grading of an aggregate.
Slag	Ground granulated blast-furnace slag is a nonmetallic byproduct of iron blast-furnace operations. This material is cementitious and will hydrate with the addition of water. Only Grade 100 or better is allowed in Department projects.
Specific gravity	The relative density of a material compared to water. It is the ratio of the material's weight to the weight of an equal absolute volume of water. Aggregates generally run between 2.4 and 2.9; cement is 3.15.
Superplasticizer	See High Range Water Reducer
Surface moisture	See free moisture.

Tare	A deduction from gross weight made to allow for the weight of a container. For example, the tare weight of a pan is subtracted from the gross weight of the pan and aggregate to get the net weight of the aggregate.
Target slump value	Each class of concrete has a specified target slump value. See Table 1.
Target slump value range	Refers to slump range. For all concrete the tolerance range is ±1.5" of the specified target slump value. Concrete delivered within the target slump value range is accepted on the job site. However, if the concrete is outside the target slump value range, the concrete producer must make immediate corrections to bring the slump back within the target slump value range.
Total aggregate moisture	Absorbed plus free moisture.
Unit weight	The weight of a given unit of concrete is a measure of its density. Generally expressed in pounds per cubic foot or kilograms per cubic meter. Standard weight concrete has a unit weight between 140 and 150 lbs/ft^3. (weight of one cubic foot of concrete)
Unmetered water	Any water added to a batch that is unaccounted for. This is strictly prohibited in FDOT mixes,
Water reducing admixture	Admixtures designed to reduce the water required to produce concrete at a given slump, to reduce the water cementitious materials ratio of a given slump mix, or to increase the slump of a mix with a set amount of batch water. Reduces water by 5% to 12%.
Water cementitious materials ratio (w/cm)	Total weight of all water in a mix divided by the total weight of all cementitious materials in the mix. Water total must include contributions/deductions for aggregate moistures (above or below SSD), contributions from any admixtures or silica fume slurry etc. Cementitious materials must include all cement plus any fly ash, slag, silica fume, metakaolin or any other pozzolan used in the mix design.
Wet aggregate weight	Total weight of an aggregate including any absorbed and free moisture it has.
Yield	The volume of concrete produced in a batch. The yield is determined by dividing the total weight of all the component materials batched by the unit weight of the concrete.

APPENDIX "B"
Example Delivery Ticket for Structural Concrete

Financial Project No.: ______________________ Serial No.: ______________________

Plant No.: ______________________ Date: ______________________

Concrete Supplier: ______________________ 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. Pit Num. / Moisture (%) / Amount	Air Entrainment Admixture Source / Brand / Type / Amount
Fine Agg. Pit 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	Total number of revolutions	
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 “C”
EXAMPLE CONCRETE MIX DESIGN

Class: IV | Mix Design Number: XX-4321 | Minimum Strength: 5500 psi

FDOT Approval Date: 06/02/2014 | *Hot Weather?* Yes | *Issuer's Name:*

Status: APPROVED | *Slip Form?:* No | *Project #:*

Producer : Alpha Concrete | *Plant #:*

Source of Materials

Product *Product Name*	*Quantity*		*Producer* *Plant #*	*QPL #* *Spec:*	*SSD*	*FM*	*Geological Type*
Cement: Type II MH Cement	545	LB	SUMTERVILLE CEMENT COMPANY CMT74	AASHTO M85 II (MH)	3.15		
Fly Ash: Class F Fly Ash	140	LB	APOLLO TECH.-BIG BENDBEACH FA00	ASTM C 618 - Class F	2.43		
Coarse Aggregate: # 89 Stone	1620	LB	SEPARATION INDUSTRIES INC. 03717		2.64		Limestone
Fine Aggregate: Silica Sand	1366	LB	CARIBE INDUSTRIES INC. 66108		2.61	2.16	Silica Sand
Air Ent Admixture: MasterAir AE 90	2.0	OZ	LOST AIR CHEMICAL	S924-1400 AASHTO M 154 - AEA			
Type D Admixture: MasterSet R 961	31.0	OZ	CONSTRUCTION CHEMICALS, LLC	S924-1103 AASHTO M 194 - Type D			
Type F Admixture: MasterGlenium 7500	48.0	OZ	WAIT AWHILE CHEMICALS	S924-6005 AASHTO M 194 - Type F			
Water: Water for Concrete	32.0	GA					
Water: Water for Concrete	267	LB					

Specification Limits

ROLL-A-METER Air Content	1.00to 6.00	percent
Pressure Meter Air Content	1.00to 6.00	percent
Compressive Strength	Greater than or equal to 5500	avgpsi
Slump	5.00to 8.00	inches
Temperature	Less than or equal to 100	degree F
W/CM Ratio	Less than or equal to 0.39	LB per LB

Producer Data

W/cm Ratio	0.39	LB per LB
Theoretical Yield	27.14	CF
Temperature	97	degree F
Slump	5.50	inches
Heat of Hydration	66	cal/g
Unit Weight (Wet)	145.1	LB per CF
Chloride Content	0.084	LB per CY
Air Content	3.5	percent
Compressive Strength	7220	avgpsi 28 DAYS
Aggregate Correction Factor	0.6	

Comments:

Appendix "D"
Example Structural Concrete Production Facility Inspection Guide

<table>
<tr><td>PLANT NUMBER:</td><td colspan="3"></td><td colspan="2">INSPECTION DATE:</td><td colspan="2"></td></tr>
<tr><td>Today's Inspection:</td><td>Initial</td><td></td><td>Routine</td><td></td><td>Re-Inspection</td><td colspan="2"></td></tr>
<tr><td>Concrete Producer:</td><td colspan="7"></td></tr>
<tr><td colspan="7">PLANT PERSONNEL</td><td>Compare</td></tr>
<tr><td>1</td><td colspan="6">Plant personnel are identified in the Quality Control Plan?</td><td>Choose an item.</td></tr>
<tr><td>2</td><td colspan="4">Concrete Production Facility Manager of Quality Control:</td><td colspan="3"></td></tr>
<tr><td>3</td><td colspan="2">Batch Plant Operator:</td><td colspan="5"></td></tr>
<tr><td colspan="2">AREA</td><td colspan="6">SUMMARY OF REMARKS OR DEFICIENCY</td></tr>
<tr><td colspan="2">Personnel</td><td colspan="6"></td></tr>
<tr><td colspan="2">Cementitious Materials</td><td colspan="6"></td></tr>
<tr><td colspan="2">Coarse/Fine Aggregate</td><td colspan="6"></td></tr>
<tr><td colspan="2">Admixtures</td><td colspan="6"></td></tr>
<tr><td colspan="2">Water</td><td colspan="6"></td></tr>
<tr><td colspan="2">Plant Records/Scales</td><td colspan="6"></td></tr>
<tr><td colspan="2">Mixing Concrete</td><td colspan="6"></td></tr>
<tr><td colspan="2">Mixers</td><td colspan="6"></td></tr>
<tr><td colspan="7">The plant inspector discussed today's inspection with the plant representative?</td><td>Choose an item.</td></tr>
<tr><td colspan="7">Based on today's inspection, this plant is recommended to be placed in the following status:</td><td>Choose an item.</td></tr>
<tr><td colspan="4"></td><td colspan="4"></td></tr>
<tr><td colspan="4">FDOT PLANT INSPECTOR</td><td colspan="4">PLANT REPRESENTATIVE</td></tr>
</table>

CEMENTITIOUS MATERIALS		
1	The delivery ticket and mill certificate for cementitious materials comply with the specifications.	Choose an item.
2	The cementitious materials (source, type, class or grade) are identified in the quality control plan.	Choose an item.
3	Each type or class of cementitious materials is stored in a separate weatherproof facility that is clearly labeled.	Choose an item.
4	For the cementitious materials, there is a suitable, safe and convenient means of collecting samples.	Choose an item.
5	Highly reactive pozzolans were stored in accordance with the manufacturer's recommendation.	
6	Cementitious materials are measured within an accuracy of 1% of the required amounts.	Choose an item.

Material	Type	Brand	Source	Delivery Date	Mill Cert Date
Remarks and Deficiency:					

COARSE/FINE AGGREGATE		
1	The aggregate sources are indicated in the quality control plan.	Choose an item.
2	The aggregate Gradation, Absorption and Total Minus 200 tests are performed (at least one every 30 days). Gradation and Total Minus 200 test data shall meet the specification requirements.	Choose an item.
3	The Free Moisture test is performed by an approved method.	Choose an item.
4	The concrete production facility is verifying the accuracy weekly, if the towel drying method is used. The accuracy was verified within 0.5%.	Choose an item.
5	Aggregates are handled and stored in silos, ground storage, or batch bins, free of contamination and segregation, and clearly labeled.	Choose an item.
6	Aggregates are in a well-drained condition.	Choose an item.
7	Aggregates stockpiles are formed properly.	Choose an item.
8	The coarse aggregate is continuously and uniformly sprinkled with any source of water 24 hours immediately preceding introduction into the concrete mix (unless otherwise identified in the quality control plan).	Choose an item.
9	The concrete production facility is verifying the accuracy weekly if the speedy moisture tester or Chapman flask method is used. The accuracy was verified within 0.5%.	Choose an item.
10	The concrete production facility is verifying the accuracy weekly if the moisture probe is used by the recommendation of the manufacturer. The accuracy was verified within 0.5%.	Choose an item.
11	Aggregates are measured within an accuracy of 1% of the required amounts.	Choose an item.

Pit No.	Grade	FDOT Code	Delivery Date

Remarks and/or Deficiency:	

ADMIXTURES		
1	Admixtures are indicated in the quality control plan.	Choose an item.
2	Admixture dispensers are certified annually.	Choose an item.
3	Dispensing equipment for calcium nitrite is calibrated quarterly.	Choose an item.
4	A certificate of conformance was on file.	Choose an item.

Material Identification (Brand)	Delivery Date	Dispenser Calibration Date

Remarks and/or Deficiency:	

WATER		
1	The source of the water is indicated in the quality control plan.	Choose an item.
2	The source of batch water is from the city and approved by a public health department (no testing needed).	Choose an item.
3	The source of batch water is from a well and tested once every three months. If the past eight consecutive tests pass, only one test every six months is required.	Choose an item.
4	The source of batch water is from an open body of water and tested monthly.	Choose an item.
5	The source of water used for sprinkling the coarse aggregate stockpile is reclaimed water and tested once every three months. If the past eight consecutive tests pass, only one test every six months is required if the sampling frequency was reduced.	Choose an item.
6	The source of water used for sprinkling the coarse aggregate stockpile is recycled water and tested monthly.	Choose an item.
7	Water is measures within an accuracy of 1% of the required total mixing water for the batch.	Choose an item.

Remarks and/or Deficiency:	

PLANT RECORDS/SCALES		
1	Accepted quality control plan for the concrete production facility was on file.	Choose an item.
2	Approved concrete mix designs were on file.	Choose an item.
3	Materials source/specification compliance (delivery tickets, certifications, miscellaneous test reports) were on file.	Choose an item.
4	Concrete chloride test data (from initial or last inspection until present) was on file.	Choose an item.
5	Aggregate moisture control records including date and time of test were on file. The scales are calibrated annually and covers the full weighing range, the report was on file.	Choose an item.
6	Annual calibration records for water measuring devices on trucks or other water sources for concrete water adjustments were on file.	Choose an item.
7	Annual calibration records for the Automated Slump Monitoring System and system records were on file.	Choose an item.
8	Manufacturer's design data and approved modifications for the mixer were on file.	Choose an item.
9	Federal poster is displayed.	Choose an item.
10	A scale company registered with the Bureau of Weights and Measures of the Department of Agriculture checked the scales and water meters for accuracy.	Choose an item.
11	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 scaled deviations for the loads checked was on file.	Choose an item.
12	All weighing devices are clean, adequately protected from the element, and in view of the operator.	Choose an item.
13	Certification documents for admixture weighing and measuring dispensers was on file.	Choose an item.
14	Weekly mixer inspection reports were on file.	Choose an item.
15	A daily record of all concrete batched for delivery to Department projects, including respective design mix numbers and quantities of concrete batched was on file.	Choose an item.
16	Recorder history (if plant is equipped) was available.	Choose an item.

FIN #	Mix #	Date Cast	Chloride Results
Remarks and/or Deficiency:			

MIXING CONCRETE		
1	The batching sequence is in accordance with the specifications.	Choose an item.
2	The mixing is at proper drum speed.	Choose an item.
3	The mixer rated capacity was not exceeded.	Choose an item.
4	All water going into the mixer is metered or weighed.	Choose an item.
5	When a central mixer is used, the concrete is mixed a minimum of two minutes or as accepted in the quality control plan.	Choose an item.
6	Admixtures are measured separately.	Choose an item.
7	Admixtures are added with the mixing water.	Choose an item.
8	Cementitious materials are weighed independently from other materials.	Choose an item.
9	Cement is weighed first when using a cumulative weigh hopper.	Choose an item.
Remarks and/or Deficiency:		

MIXERS / MAINTENANCE OF MIXERS		
1	Mixers are free of hardened concrete.	Choose an item.
2	All blades are greater than 90% of design height.	Choose an item.
3	Mixers with approved modification conducted uniformity tests as needed in accordance with ASTM C-94.	Choose an item.
4	The manufacturer's metal rating plate (consisting of mixing speed, agitation speed, rated capacity and unit serial number) is attached, and legible on each mixer.	Choose an item.
5	The mixer is equipped with a hatch in the periphery of the drum, revolution counter, and a clean operating water gauge (calibrated annually) that are all in good operation.	Choose an item.
6	**Central** or **truck** (circle one) mixers demonstrate the capability to combine the concrete component materials into a thoroughly mixed and uniform mass.	Choose an item.
7	**Central** or **truck** (circle one) mixers demonstrate the capability to discharge the concrete with a satisfactory degree of uniformity.	Choose an item.
Remarks and/or Deficiency:		

APPENDIX "E"
SECTION 346
PORTLAND CEMENT CONCRETE

346-1 Description.

Use concrete composed of a mixture of portland cement, aggregate, water, and, where specified, admixtures, pozzolan and ground granulated blast furnace slag. 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 list of Producers with Accepted Quality Control Programs. Producers seeking inclusion on the list shall meet the requirements of 105-3. If the concrete production facility's Quality Control Plan is suspended, the Contractor is solely responsible to obtain the services of another concrete production facility with an accepted Quality Control Plan or await the re-acceptance of the affected concrete production facility's Quality Control 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 Quality Control Plan acceptance or re-acceptance.

346-2 Materials.

346-2.1 General: Meet the following requirements:

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

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

**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 material in excess of that specified in the above listed Sections.

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

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

TABLE 1			
BRIDGE SUPERSTRUCTURES			
Component	Slightly Aggressive Environment	Moderately Aggressive Environment	Extremely Aggressive Environment
Precast Superstructure and Prestressed Elements	Type I or Type III	Type I, Type II, Type III, Type IP, or Type IS	Type II (MH)
Cast In Place	Type I	Type I, Type II, Type IP, or Type IS	Type II (MH)
BRIDGE SUBSTRUCTURE, DRAINAGE STRUCTURES AND OTHER STRUCTURES			
All Elements	Type I or Type III	Type I, Type II, Type IP, or Type IS	Type II (MH)

346-2.3 Pozzolans and Slag: Fly ash or slag materials are required in all classes of concrete. Use fly ash or slag materials as a cement replacement, on an equal weight replacement basis with the following limitations:

(1) Mass Concrete:

a. Fly Ash **-** Ensure that the quantity of cement replaced with fly ash is 18% to 50% by weight, except where the core temperature is expected to rise above 165°F. In that case, ensure that the percentage of fly ash is 35% to 50% by weight.

b. Slag **-** Ensure that the quantity of cement replaced with slag is 50% to 70% by weight. Ensure that slag is 50% to 55% of total cementitious content by weight when used in combination with silica fume, ultrafine fly ash and/or metakaolin.

c. Fly Ash and Slag - Ensure that there is at least 20% fly ash by weight and 40% portland cement by weight for mixes containing portland cement, fly ash and slag.

(2) Drilled Shaft:

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

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

c. Fly Ash and Slag (Ternary Blend) - Ensure that there is 10% to 20% fly ash, 50% to 60% slag by weight, and 30% portland cement by weight for mixes containing portland cement, fly ash and slag.

(3) Precast Concrete **–** Ensure that the precast concrete has a maximum of 25% fly ash or a maximum of 70% slag. In extremely aggressive environments, ensure that the precast concrete has a minimum of 18% fly ash or a minimum of 50% slag.

For fly ash and slag (ternary blend), ensure that there is 10% to 20% fly ash, 50% to 60% slag by weight, and 30% portland cement by weight for mixes containing portland cement, fly ash and slag.

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

a. Fly Ash **-** Ensure that the quantity of cement replaced with fly ash is 18% to 30% by weight.

b. Slag **-** Ensure that the quantity of cement replaced with slag is 25% to 70% for slightly and moderately aggressive environments and 50% to 70% by weight when used in extremely aggressive environments. Ensure that slag is 50% to 55% of total cementitious content by weight when used in combination with silica fume, ultra fine fly ash and/or metakaolin.

c. Fly Ash and Slag (Ternary Blend) - Ensure that there is 10% to 20% fly ash, 50% to 60% slag by weight, and 40% portland cement by weight for mixes containing portland cement, fly ash and slag.

(5) Blended Cements:

a. Type IS **-** Ensure that the quantity of slag in Type IS is less than or equal to 70% by weight.

b. Type IP - Ensure that the quantity of the pozzolan in Type IP is less than or equal to 40% by weight.

(6) Highly Reactive Pozzolans: Highly reactive pozzolans are considered to be silica fume, metakaolin and ultrafine fly ash. When silica fume, metakaolin or ultrafine fly ash is used, it must be used in combination with fly ash or slag and cured in accordance with the manufacturer's recommendations and approved by the Engineer.

a. Silica Fume **-** Ensure that the quantity of cement replaced with silica fume is 3% to 9% by weight of the total cementitious material.

b. Metakaolin **-** Ensure that the quantity of cement replaced with metakaolin is 8% to 12% by weight of the total cementitious material.

c. Ultrafine Fly Ash - Ensure that the quantity of cement replaced with ultrafine fly ash is 8% to 12% by weight of the total cementitious material.

346-2.4 Coarse Aggregate Gradation: Produce all concrete using Size No. 57, 67 or 78 coarse aggregate. With the Engineer's approval, Size No. 8 or Size No. 89 may be used either alone or blended with Size No. 57, 67 or 78 coarse aggregate. The Engineer will consider requests for approval of other gradations individually. Submit sufficient statistical data to establish production quality and uniformity of the subject aggregates, and establish the quality and uniformity of the resultant concrete. Furnish aggregate gradations sized larger than nominal maximum size of 1.5 inch as two components.

For 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 (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 Air Entrainment Admixtures: Use an air entraining admixture in all concrete mixes except counterweight concrete. For precast concrete products, the use of air entraining admixture is optional for Class I and Class II concrete.

346-2.5.3 High Range Water-Reducing 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 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 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 C 1610 except allow for minimal vibration for consolidating the concrete. The maximum allowable difference between the static segregation is less than or equal to 15 percent. Add the flowing concrete admixtures at the concrete production facility.

346-2.5.4 Corrosion Inhibitor Admixture: Use only with concrete containing Type II cement, or Type II (MH) cement, and a water-reducing retardant admixture, Type D, or High Range Water-Reducer retarder admixture, Type G, to normalize the setting time of concrete. Ensure that all admixtures are compatible with the corrosion inhibitor admixture.

346-2.5.5 Accelerating Admixture for Precast Drainage and Incidental Concrete Products: The use of non-chloride admixtures Type C or Type E is allowed in the manufacturing of precast concrete products.

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

346-3.1 General: The separate classifications of concrete covered by this Section are designated as Class I, Class II, Class III, Class IV, Class V and Class VI. Strength and slump are specified in Table 2. The air content range for all classes of concrete is 1.0 to 6.0%, except for Class IV (Drilled Shaft) which is 0.0 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 Contractor’s Quality Control Plan, or for precast concrete, the Precast Concrete Producer’s Quality Control 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 2 for the lower class concrete.

TABLE 2		
Class of Concrete	Specified Minimum Strength (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 (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)

(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 C 478 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 higher target slump when a Type F, G, I or II admixture is used, except when flowing concrete is used. The maximum target slump shall be 7 inches.

(c) For a reduction in the target slump for slip-form operations, submit a revision to the mix design to the Engineer.

(d) When the use of silica fume, ultrafine fly ash, or metakaolin is required as a pozzolan in Class IV, Class V, Class V (Special) or Class VI concrete, ensure that the concrete meets or exceeds a resistivity of 29 KOhm-cm at 28 days, when tested in accordance with FM 5-578. 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.

(e) When precast three-sided culverts, box culverts, endwalls, inlets, manholes or junction boxes require a Class III concrete, the minimum cementitious materials 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 FM 5-578 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.

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.

Ambient temperature conditions for placement of drilled shaft concrete for summer condition is 85° or higher, and below 85° for normal condition. Perform the slump loss test in one of the above ambient temperature conditions.

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 346. Initially cure acceptance cylinders for 48 hours before transporting to the laboratory.

If the elapsed time during placement exceeds the slump loss test data, provide an engineering analysis preformed by a Professional Engineer, registered in the State of Florida, and knowledgeable in the area of foundations, to determine if the shaft is structurally sound and there are no voids in the drilled shaft concrete. 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, provide an analysis of the anticipated thermal developments in the mass concrete elements for all expected project temperature ranges using the selected mix design, casting procedures, and materials.

Use a Specialty Engineer competent in the design and temperature control of concrete in mass elements. The Specialty Engineer shall follow the procedure outlined in Section 207 of the ACI Manual of Concrete Practice to formulate, implement, administer and monitor a temperature control plan, making adjustments as necessary to ensure compliance with the Contract Documents. The Specialty Engineer shall select the concrete design mix proportions that will generate the lowest maximum temperatures possible to ensure that a 35°F differential temperature between the concrete core and the exterior surface is not exceeded. The mass concrete maximum allowable temperature is 180°F. If either the differential temperature or the maximum allowable temperature is exceeded, the Specialty Engineer shall be available for immediate consultation.

Describe the measures and procedures intended for use to maintain a temperature differential of 35°F or less between the interior core center and exterior surface(s) of the designated mass concrete elements during curing. Submit both the mass concrete mix design and the proposed mass concrete plan to monitor and control the temperature differential to the Engineer for acceptance. Provide temperature monitoring devices to record temperature development between the interior core center and exterior surface(s) of the elements in accordance with the accepted mass concrete plan.

The Specialty Engineer, or a person designated by the Specialty Engineer, must personally inspect and approve the installation of monitoring devices and verify that the process for recording temperature readings is effective for the first placement of each size and type mass component. Submit to the Engineer for approval the qualification of all technicians employed to inspect or monitor mass concrete placements. Designate an employee(s) approved by the Specialty Engineer, as qualified to inspect monitoring device installation, to record temperature readings, to be in contact at all times with the Specialty Engineer if adjustments must be made as a result of the temperature differential or the maximum allowable temperature being exceeded, and to immediately implement adjustments to temperature control measures as directed by the Specialty Engineer. Read the monitoring devices and record the readings at intervals no greater than 6 hours. The readings will begin when the mass concrete placement is complete and continue until the maximum temperature differential and the temperature is reached and a decreasing temperature differential is confirmed as defined in the temperature control plan. Do not remove the temperature control mechanisms until the core temperature is within 50°F of the ambient temperature. Furnish a copy of all temperature readings to the Engineer. Provide determined temperature differentials, the summary sheet from the data logger, which includes the maximum temperature, the maximum temperature differential and a final report within three calendar days of completion of monitoring of each element.

Request approval of reduced monitoring of same least dimensioned mass concrete elements containing the same mix design, concrete placement temperatures (within plus 3°F), and insulation thermal resistance value. The Specialty Engineer may monitor and record the temperature for the first element only. Each subsequent element must be started within one hour of the first placement and be completed within one hour of the completion of the first element. Each mass concrete element must be instrumented with monitoring devices in case of failure in meeting the one hour time limit.

Changes or adjustments made to the monitored element must be made to all elements. Failure to follow this will require an Engineering Analysis Report (EAR) for the elements not monitored even if the element that was monitored had a temperature differential well below the maximum allowed. The reduced monitoring option will not be allowed by the Engineer if the Contractor fails to comply with these requirements.

If the 35°F differential or the 180°F maximum allowable temperature has been exceeded, take immediate action as directed by the Specialty Engineer to retard further growth of the temperature differential. Describe methods of preventing thermal shock in the temperature control plan. Use a Specialty Engineer to revise the previously accepted plan to ensure compliance on future placements. Do not place any mass concrete until the Engineer has accepted the mass concrete plan(s). When mass concrete temperature differentials or maximum allowable temperature has been exceeded, provide all analyses and test results deemed necessary by the Engineer for determining the structural integrity and durability of the mass concrete element, to the satisfaction of the Engineer. The Department will make no compensation, either monetary or time, for the analyses or tests or any impacts upon the project.

346-3.4 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 yard minimum size each, of concrete containing flowing concrete HRWR 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. 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 from different locations of mock-up products to inspect the aggregate distribution in each sample and compare it with the aggregate distribution of other core samples. Perform surface resistivity tests on the core samples or test cylinders at 28 days.

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 HRWR 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 3:

TABLE 3		
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**
*The calculation of the water to cementitious materials ratio (w/cm) is based on the total cementitious material including cement and any supplemental cementitious materials that are used in the mix. **When the use of silica fume or metakaolin is required, the maximum water to		

TABLE 3		
Class of Concrete	Minimum Total Cementitious Materials Content pounds per cubic yard	Maximum Water to Cementitious Materials Ratio pounds per pounds*
cementitious material ratio will be 0.35. When the use of ultrafine fly ash is required, 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 4		
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 4, suspend concrete placement immediately for every mix design represented by the failing test results, until corrective measures are made. Perform an engineering analysis to demonstrate that 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. Supply this information within 30 business days of the failing test results from a Professional Engineer registered in the State of Florida, and knowledgeable in the areas of corrosion and corrosion control.

346-5 Sampling and Testing Methods.

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

TABLE 5	
Description	Method
Slump of Hydraulic Cement Concrete	ASTM C 143
Air Content of Freshly Mixed Concrete by the Pressure Method*	ASTM C 231
Air Content of Freshly Mixed Concrete by the Volumetric Method*	ASTM C 173
Making and Curing Test Specimens in the Field**	ASTM C 31

TABLE 5	
Description	Method
Compressive Strength of Cylindrical Concrete Specimens***	ASTM C 39
Obtaining and Testing Drilled Core and Sawed Beams of Concrete	ASTM C 42
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 C 138
Temperature of Freshly Mixed Portland Cement Concrete	ASTM C 1064
Sampling Freshly Mixed Concrete****	ASTM C 172
Static Segregation of Self Consolidating Concrete using Column Techniques	ASTM C 1610
Slump Flow of Self Consolidating Concrete	ASTM C 1611
Passing Ability of Self Consolidating Concrete by J-Ring	ASTM C 1621
Concrete Resistivity as an Electrical Indicator of its Permeability	FM 5-578
*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, “hold” and Independent Verification cylinders simultaneously for the initial 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 Control of Quality.

346-6.1 General: Develop a Quality Control Plan (QCP) as specified in Section 105. Meet the requirements of the approved QCP and Contract Documents. Ensure the QCP includes the necessary requirements to control the quality of the concrete.

Perform QC activities to ensure materials, methods, techniques, personnel, procedures and processes utilized during production meet the specified requirements. For precast/prestressed 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.

Ensure the QCP includes any anticipated requirements for adjusting and controlling the concrete at the placement site. Include the testing procedures that will be implemented to control the quality of the concrete and ensure that concrete placed is within the tolerance range. Also, include provisions for the addition of water to concrete delivered to the placement site at designated level areas, to ensure the allowable amount of water stated on the concrete delivery ticket is correct and the maximum water to cementitious materials ratio on the approved design mix is not exceeded. Ensure the anticipated ranges of jobsite water additions are described and the proposed methods of measuring water for concrete adjustments are included.

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

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

For slump target values in excess of 6 inches 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 both with and without silica fume, ultrafine fly ash, metakaolin or calcium nitrite 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 compatible admixtures. Submit both mixes for approval as separate mix designs, both meeting all requirements of this Section. Ensure that the redesigned mix exhibits plastic and hardened qualities which are additionally approved by the Engineer as suitable for placement with the original mix. The Engineer will approve the redesigned mix for commingling with the original mix and for a specific project application only. Alternately, place a construction joint at the location of the change in concretes.

346-6.3 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: Do not place concrete with a slump more than plus or minus 1.5 inches from the target slump value specified in Table 2.

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: When water is added at the jobsite, 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 additional mix adjustments. Discharge all concrete from truck mixers before total drum revolutions exceed 300. 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 6 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, the Engineer may authorize the placement of the concrete.

TABLE 6	
Maximum Allowable 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 in advance by the Engineer.

346-7.3 On-site Batching and Mixing: Include provisions in the QCP for the mixing at the site. Use a mixer of sufficient capacity to prevent delays that may be detrimental to the quality of the work. Ensure that the accuracy of batching equipment is in accordance with requirements of this Section.

346-7.4 Concreting in Cold Weather: Do not mix 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 less than 100ºF.

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: If the slump, as delivered, is outside the tolerance range, reject the load. If the slump is within the tolerance range, that load may be adjusted by adding water 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. 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. Describe in the QCP the method to sample the plastic concrete at 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. Describe the sampling correlation procedure in the QCP.

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 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 number of technicians in the Quality Control 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 testing. When the Engineer’s verification 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. Make the necessary revisions to concrete operations and increase the frequency of QC testing in the QCP to bring the concrete within allowable tolerances. Obtain the Engineer's approval of the revisions before resuming production. After production resumes, obtain the Engineer's approval before returning to the normal frequency of QC testing.

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

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

When the Department's Independent Verification test results do not meet the requirements of this Section, the Engineer may require the Contractor to revise the QCP.

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 plastic properties tests and cast a set of verification cylinders. The verification 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 additional cylinder from the same sample, and identify it as the QC "hold" cylinder. The Department will also cast one additional "hold" cylinder from each Verification sample. All cylinders will be 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" cylinder to the final curing facility in accordance with ASTM C 31. At this same time, the Department will deliver the Verification samples, including the Verification "hold" cylinder, to their final curing facility.

Test the QC laboratory cured samples for compressive strength at the age of 28 days, or any other specified age, 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 within 24 hours. When the QC testing laboratory cannot input the compressive strength test results into the Department's sample tracking database within 24 hours, the QC testing laboratory will notify the Verification testing laboratory within 24 hours of testing the cylinder and provide the

Verification testing laboratory the compressive strength test results. Ensure the compressive strength results are input into the Department's sample tracking database within 72 hours of determining the compressive strength of the cylinders.

The Department will compare the Verification sample results with the corresponding QC sample 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 7 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 7	
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
Greater than 8,500 psi	1,360 psi

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 8. When a mix design is used for a different application, the LOT is defined by the application. When more than one concrete production facility is used for the same mix design, describe the method of sampling, testing and LOT numbering in the QC Plan. 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 testing to verify compliance with specification requirements. All QC activities, calculations, and inspections will be randomly confirmed by the Department.

TABLE 8	
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	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 placement and the start of the next placement, whichever is less

TABLE 8	
Class Concrete*	LOT Size
III (Seal)	Each Seal placement
*For any class of concrete used for roadway barrier wall, the lot size is defined as 100 cubic yards, or one day's production, whichever is less.	

346-9.2.1 Reduced Frequency for Acceptance Tests: The LOT size may represent 100 cubic yards when produced at the same mix design at the same concrete production facility for the same prime contractor and subcontractor on a given Contract. Submit test results indicating the average compressive strength is greater than two standard deviations above the specified minimum strength for that class of concrete. 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 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 deviations, return to the maximum production quantity represented by the LOT as defined in Table 8. Notify the Engineer that the maximum production rate 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. 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 verification 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 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 verification 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.

When QC compressive strength test results are not verified, the resolution procedure will be used to accept or reject the concrete. Maintain the “hold” cylinders until the verification of the compressive strength test results.

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 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 sample results with the verification hold cylinders results. Comparison results must not be greater than 14%. Compare the QC sample results with the QC hold cylinders results. Comparison results must not be greater than the comparison requirements in Table 7. Core samples of the hardened concrete may be required.

The Engineer will determine through the resolution procedure whether the QC strength test results or the verification 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 Verification lab within three calendar days of the acceptance compressive strength test to transport their “hold” cylinders to the resolution lab. The QC and Verification laboratories will transport their own hold cylinder to the resolution testing laboratory within 72 hours after the Engineer notifies the Contractor that a resolution is required. In addition, the Engineer will ensure that the QC and verification “hold” cylinders are tested within seven calendar days of the acceptance strength tests.

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.

The results of the resolution procedure will be forwarded to the Contractor within five working days after completion of the investigation. If the Department finds deficiencies based on the Contractor’s QCP, the Engineer may suspend that part of the QCP. When the QC plan is suspended, submit corrective actions for approval to the Engineer. The Engineer may take up to five working days to review corrective actions to the QCP. The Engineer will not allow changes to contract time or completion dates. Incur all delay costs and other costs associated with QC plan suspension and re-approval.

346-9.6 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. Provide certification to the Engineer that the concrete was batched and placed in accordance with the Contract Documents. Submit a quality control plan for the concrete placement operation in accordance with Section 105. In addition, the Engineer may conduct Independent Verification (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 for Structural Adequacy.

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

Furnish either a structural analysis performed by the Specialty Engineer to establish strength adequacy or drilled core samples as specified in 346-10.3 to determine the in-place strength of the LOT of concrete in question at no additional expense to the Department. Obtain the Engineer’s approval before taking any core samples. When the concrete is deemed to have low strength, obtain and test the cores 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.

346-10.2 Determination of Structural Adequacy: If core strength test results are less than 500 psi 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, the Department will consider the concrete represented by the cores structurally questionable. Submit a structural analysis performed by the Specialty Engineer. If the results of the structural analysis indicate adequate strength to serve its intended purpose with adequate durability, and is approved by the Department, 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.

346-10.4 Core Conditioning and Testing: Test the cores in accordance with

ASTM C 42. Test the cores after obtaining the samples within seven calendar days.

346-11 Pay Adjustments for Low Strength Concrete.

346-11.1 General: Any LOT of concrete failing to meet the specified minimum strength as defined in 346-3, 346-9, 346-10 and satisfactorily meeting all other requirements of the Contract Documents, including structural adequacy, the Engineer will individually reduce the price of each low strength LOT in accordance with this Section.

346-11.2 Basis for Pay Adjustments: When an acceptance strength test result falls more than 500 psi below the specified minimum strength, core samples may be obtained in accordance with ASTM C 42 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 are less than 500 psi below the specified minimum strength.

The results of strength tests of the drilled cores, subject to 346-11.5 and 346-11.6, will be used as the acceptance results and will be used in lieu 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 346-11. 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)

346-11.7 Calculating Pay Adjustments: The Engineer will determine payment reductions for low strength concrete accepted by the Department and represented by either cylinder or core strength test results below the specified minimum strength, in accordance with the following:

Reduction in Pay is equal to the reduction in percentage of concrete cylinder strength (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.