Section 8.4
Volume II

SELF-CONSOLIDATING CONCRETE FOR PRECAST/PRESTRESSED CONCRETE PRODUCTS

8.4.1 PURPOSE

This procedure provides guidance to the precast/prestressed concrete fabrication facilities (Plants) that are involved in the manufacturing of the products using Self-Consolidating Concrete. The procedure includes requirements related to the Plants' quality control plans, the submittal of the mix designs, laboratory and field trial batches of the concrete mixes, and inspection and testing of production concrete. The procedure includes self-consolidating concrete related changes in the Specifications and Materials Manual.

Section 8.4, Volume I of the Materials Manual includes guidelines to the Florida Department of Transportation (Department) personnel related to the review of the Plants' quality control plans, mix design verification and approval process, and quality assurance inspection and testing of self-consolidating concrete.

8.4.2 AUTHORITY

Sections 20.23(3) (a) and 334.048(3), Florida Statutes (F.S.).

8.4.3 REFERENCES

Manual for Quality Control for Plants and Production of Structural Precast Concrete Products, Precast/Prestressed Concrete Institute (PCI), Manual MNL 116.

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

American Concrete Institute, Publication 237R-07, Self-Consolidating Concrete, Farmington Hills, Michigan, April 2007.

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

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

8.4.4 SCOPE

This procedure establishes guidelines for the Plants that are involved in the utilization of the self-consolidating concrete for the manufacturing of the precast/prestressed concrete products. The Plants shall comply with the requirements of the Specifications**,** except as modified herein.

8.4.5 SELF-CONSOLIDATING CONCRETE RELATED QUALITY CONTROL PLANS

The Plants' quality control plans should address the following items in addition to /or in lieu of the items that are included for conventional concrete mixes:

(1) Mix design qualification process.
(2) Routine quality control tests.
(3) Concrete batching sequence, mixing methods and duration, delivery, placement, finishing, and curing methods.
(4) The proposed concrete materials ingredient sources.
(5) Concrete delivery and placement times. It is the responsibility of the producer to utilize the appropriate self-consolidating concrete delivery and placement pattern and methods, including selection of the number of layers for the manufacturing of each product.
(6) Prepare self-consolidating concrete delivery, placement, finishing, and curing guidelines for the training of personnel who are involved in these activities. Include the Plant's self-consolidating concrete related guidelines as part of the quality control plan.
(7) The proposed inspection and test methods for the laboratory and field trial batches.
(8) The verification method and frequency of the aggregate moistures content test.
(9) Adequacy of the forming strength to support the pressure of the self-consolidating concrete during placement. Provide information about form joint sealing method to prevent paste leakage.
(10) For self-consolidating concrete, considering the weather condition, include guidelines in the quality control plan regarding the starting time of finishing, application of water fog mist, evaporation reducer or finishing aid if needed, and finishing methods for each type of product.
(11) The strand lift loops placement method and capacity to handle the self-consolidating concrete products.

(12) The qualification and familiarity of the personnel performing the required mixing, delivery, placement, inspection, and testing of self-consolidating concrete.

8.4.6 PROPOSED SELF-CONSOLIDATING CONCRETE MIX DESIGN REQUIREMENTS

8.4.6.1 Specified 346 Class Concrete

Self-consolidating concrete is allowed for the fabrication of precast prestressed concrete as a replacement for the ASTM, AASHTO, or ***Florida Department of Transportation Specification, Section 346*** class of concrete. The Plant shall submit the proposed mix design with test data and other supporting documents to the Department for review. Upon the Department's approval of the mix design, the use of self-consolidating concrete will be allowed for the fabrication of the precast concrete products.

The proposed self-consolidating concrete mixes require the State Materials Office's approval. The District Materials Offices review the proposed concrete mix designs and verify if they meet the requirements of the ***Florida Department of Transportation Specifications, Section 346***, including the following:

(1) Concrete mix ingredients are from Department approved sources.
(2) The high range water reducing admixture meets Type F, Type I or Type II admixture requirements of the ***Florida Department of Transportation Specifications, Section 924***. For self-consolidating concrete, the Type F, Type I or II admixtures are added at the concrete production facility. The addition of the admixtures shall comply with the recommendation of the manufacturer of the admixtures.
(3) Viscosity modifying admixtures shall be evaluated in accordance with the test methods and mixture proportions referenced in ***ASTM C 494*** with the following modification of ***Table 1***, physical requirements:
    (a) For initial and final set times, the allowable deviation of the test concrete from the reference concrete shall not be more than 1.0 hour earlier or 1.5 hours later.
    (b) For compressive and flexural strengths, the test concrete shall be a minimum of 90 percent of the reference concrete at 3, 7 and 28 days.
    (c) The length change of the test concrete shall be a maximum 135 percent of the reference concrete. However, if the length

change of the reference concrete is less than 0.030 percent, the length change of the test concrete shall be a maximum 0.010 percentage units greater than the reference concrete.

(d) The relative durability factor of the test concrete shall be a minimum 80 percent.

The viscosity modifying admixture shall be compatible with other admixtures used in the self-consolidating concrete mixture proportions.

(4) For the self-consolidating concrete, replace the term slump with the slump flow in the Specifications and related sections of the Materials Manual. Instead of slump, the slump flow will be measured in accordance with ***ASTM C 1611***. The proposed target slump flow after the addition of all material ingredients, including admixtures, shall be less than or equal to 27.0 inches for non-prestressed precast concrete products and less than or equal to 25.0 inches for prestressed concrete products.

(5) The volume ratios of fine-to-total aggregates in a mix design shall not exceed 50%.

(6) For mixes with the ratio of fine aggregate-to-total aggregates of less than 45%, the viscosity modifying admixture shall be used, unless the concrete tests have demonstrated that the desired stability and flow characteristics can be achieved without its use.

(7) The water-to-cementitious materials ratio of the concrete mix shall not exceed the allowable value that is specified for the class of concrete or 0.45, whichever is lower.

(8) The laboratory and field demonstration of the proposed mixes shall meet the requirements of the Specifications, Plans, and Materials Manual.

8.4.6.2 ASTM or AASHTO Class of Concrete

The District Materials Offices review and approve the mix designs for the precast concrete products that require ASTM or AASHTO class concrete with specified strength requirements. The proposed self-consolidating concrete mix design shall meet the requirements of Item Numbers (1) to (8) of ***Materials Manual Section 8.4.6.1***.

8.4.7 LABORATORY TRIAL BATCH OF THE PROPOSED MIX DESIGN

The requirements of ***ASTM C 192*** are modified to allow the laboratory performance based batching and mixing time and sequence that produce the required properties.

During the trial batch process, determine the acceptable batching sequence and the mixing time associated with this batching sequence. During the production of the self-consolidating concrete, use the same batching sequence and proper mixing time determined during the prerequisite, satisfactory laboratory and field demonstration process.

(1) Perform the trial batch in accordance with the proposed batching sequence and mixing time that are included in the quality control plan. Note any deviation from the proposed sequence.

(2) Determine the concrete mix properties, including slump flow, T_{50}, Visual Stability Index (VSI) in accordance with ***ASTM C 1611***. The allowable tolerance of the slump flow for the laboratory verification is ± 3.0 in. The Visual Stability Index (VSI) shall not exceed a value of 2. Perform the second test when the VSI of the first test exceeds a value of 2. Reject the proposed mix if the second VSI test exceeds a value of 2. The T_{50} shall be recorded for information only and its recommended range is 2- 7 Sec.

(3) Perform the passing ability of the self-consolidating concrete mix by using J-Ring test method in accordance with ***ASTM C 1621***. The passing ability of the mix shall not exceed 2.0 inches.

(4) Determine the static segregation of the mix in accordance with **ASTM C 1610**. The maximum allowable static segregation limit is 15%.

(5) Perform the air content, density, temperature, and any other test that is required for the class of concrete and any other tests that the Plant has proposed to use for the quality control of the production concrete. Take concrete samples for surface resistivity tests, when it is required for the class of concrete.

(6) Make and cure concrete test cylinders in accordance with ***ASTM C 192***.

8.4.8 FIELD DEMONSTRATION OF THE SELF-CONSOLIDATING CONCRETE

8.4.8.1 General

Subsequent to the satisfactory laboratory trial batch, perform a field demonstration of the proposed mix design. Perform the field trial batches by casting partial or full scale mockup of the proposed precast concrete products.

Dispose of concrete produced for demonstration purposes at no expense to the Department.

Ensure that the demonstration concrete is mixed, delivered, placed, consolidated and cured in accordance with the proposed method and sequence that are addressed in the quality control plan. Produce the self-consolidating concrete batches at the proposed target slump flow of ± 3.0 inches.

Perform inspection and testing of the demonstration concrete during batching, delivery, placement, and post placement. Observe the placement sequence and method of the self-consolidating concrete. 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. Observe the finishing and curing method of the concrete.

8.4.8.2 Number and Quantity of Batch Sizes

For the field demonstration, produce and place at least three batches, each a minimum of 3 yd^3, of self-consolidating concrete with Type F, Type I, or II admixture. Plants that are producing concrete with batch sizes of less than 3 yd^3 are required to produce and place a minimum total amount of 9 yd^3 and perform the aforementioned tests on at least three randomly selected batches.

8.4.8.3 Sampling and Testing of Field Demonstration Concrete

Take representative samples from each batch and perform slump flow, air content, density (unit weight), J-Ring, and temperature tests on these samples. Cast specimens from each sample for compressive strength tests. Take samples of concrete for the surface resistivity tests when it is required for the mix design. For self-consolidating concrete, modify the consolidation method of the ***ASTM C 31, ASTM C 138, ASTM C 173, and ASTM 231*** tests by placing the concrete in the molds in one layer without vibration or tamping.

For each field trial batch, record the slump flow, T_{50}, VSI, air content, concrete and ambient air temperatures, density, and passing ability of the mix by using the J-Ring test. Ensure that the concrete properties are within the required Specification limits. Perform the slump flow loss test as described in ***Materials Manual Section 8.4.8.4.***

Perform the strength tests of the concrete cylinders at the specified ages. Ensure that the surface resistivity tests, ***FM 5-578,*** of the sampled concrete are performed, when the tests are required for the class of concrete.

8.4.8.4 Slump Flow Loss Test of the Field Demonstration Concrete

(1) Determine the workability of the demonstration concrete batches by performing the slump flow tests. Take the samples at 15-minute intervals from each batch.
(2) Continue sampling and testing until the slump flow measures 20.0 inches or less.
(3) From the plot of slump flow versus time, determine the time for each batch of concrete to reach its [proposed target slump flow minus 3.0 inches].
(4) The shortest time period determined from three demonstrated batches to reach the [proposed target slump flow minus 3.0 inches] is considered the cutoff time of the proposed concrete mix. The time for each batch is counted from the time that the concrete is batched at the concrete fabrication facility.
(5) 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 ***Florida Department of Transportation Specifications, Section 346***.

8.4.8.5 Post Placement Inspection

After removal of the forms, perform the post-placement inspection of the in-place mockup concrete. Observe for any signs of honeycombs, cracks, aggregate segregation, sedimentation, cold joints, or any other surface defects and ensure that the hardened concrete is free from these deficiencies. Perform saw cutting of the mockup products when demonstrating the use of self-consolidating concrete for the first time at the Plant. Perform the visual inspection of the saw-cut section and observe the distribution of the aggregates within the saw cut surfaces and around the reinforcing steel and prestressing strands. Verify that the concrete is free from any sign of honeycombs, cracks, aggregate segregation, and any other defects.

Ensure that surface resistivity tests on the core samples or test cylinders are performed, when the Specification requires the test for the class of concrete.

The District Materials Engineer may waive the saw cutting of the mockup for routine mix design approvals of the self-consolidating concrete, when the Plant has satisfactorily performed the saw cutting of the previous mockups and has demonstrated that concrete has been placed without any visible sign of defects during the approval of the previous mix designs.

8.4.8.6 Aggregate Distribution of Hardened Concrete Products

Perform the aggregate distribution test in accordance with ***Mujtaba and Bühler test method,*** presented during the 2003 International Symposium on High Performance Concrete, Orlando, Florida, and as modified herein.

Select six locations along the elevation view of the mockup product. For the slab products, the selected area may be from the plan view of the product, in lieu of its elevation view and the cores may be taken from these selected areas. The aggregate distribution test may be performed by measuring the aggregate content of the concrete directly at each of the selected saw-cut areas of the mockup. The second option is to obtain core samples from six locations of these selected areas of the mockup product. The core samples may be taken from saw-cut section or uncut areas. The concrete quality of each core sample should represent the concrete quality of the selected area.

The aggregate content of each location of the mockup will be determined and compared with the aggregate content of other locations.

A brief outline of the aggregate distribution test of the selected locations of the saw cut surfaces is as follows:

(1) Select 6 locations along the saw cut surface of the mockup and designate them as A, B, C, D, E, and F. Locate A and B on the upper part, C and D at the middle, and E and F at the bottom part of the elevation view of the mockup.
(2) For each test location, select an area of about 8 in x 8 in.
(3) For location, A, draw a vertical or horizontal line along the surface of the selected saw cut area, A-1.
(4) By placing the ruler on the line A-1, measure the size of each piece of aggregate, along the line, greater than or equal to 0.1 in.
(5) Determine the total length of the aggregates along the straight line A-1 by adding the measured sizes of all pieces.
(6) Determine the coarse aggregate (C.A.) content of A-1 along the straight line by calculating the ratio of the total length of aggregates along the line- to- the length of the drawn line.
(7) Draw a total of 7 more parallel lines for A-2 to A-8, as described in items (3) - (6). Report the average C.A. ratio of the location, A, by adding the results of the C.A. content of A-1 through A-8 lines and dividing the summation of the results by eight.
(8) Follow the same procedure as described in Item numbers (3)-(7) for locations B through F.

(9) Calculate the average C.A. content of the mockup by adding the average C.A. contents of locations A through F and dividing the summation of the average C.A. content of all locations by six.
(10) Report the C.A. contents in percent, each as a whole number.

A brief outline of the aggregate distribution test of the core samples is as follows:

For C.A. content of the core samples, follow the same procedure as it is described for the location of the elevation view of the saw cut surfaces. The core samples shall be taken from the selected areas. Draw 8 parallel lines along the longitudinal axis of the surface area of the core sample and measure its C.A. content. The C.A content of each core represents the C.A. content of the selected area.

Report the C.A. contents of the selected locations and their average values in percentages of total volume of the concrete. The absolute value of the difference between the average C.A. content of each location and average C.A. content of all samples should not exceed 15%. Also, the difference, between the average C.A. content of the mockup and the calculated values of the mix design should not differ by more than 15 %.

There is an indication of the segregation problem, at any location where the difference between the C.A. content of that location and the average C.A. content of the mockup exceeds 15%. Determine the cause of the problem and submit a corrective action plan to prevent the recurrence of the problem during the production. The District Materials Office will review the plan and decide if the demonstration trial batch should be repeated or the approval process should be continued as submitted.

8.4.9 SUBMITTAL OF THE VERIFIED MIX DESIGN

Submit the results of the laboratory trial batch tests and field demonstration of verified test data and inspection reports, along with certification, to the District Materials Office. The certification shall state 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 the Plant’s certification statement, the Department will approve the proposed mix design.

8.4.10 SUBMITTAL OF THE PROPOSED LABORATORY VERIFIED MIX DESIGN AND HISTORICAL PRODUCTION TEST DATA

The Plant may propose the approval of the self-consolidating concrete mixes, centrally mixed at the placement site, without the production of field demonstration batches, provided that the proposed mix meets the following two criteria:

(1) A previously approved self-consolidating concrete mix of the same class has demonstrated satisfactory performance under the proposed job placing conditions with a minimum of fifteen Department-accepted consecutive quality control or verification tests, which have met all plastic and hardened concrete test requirements.

(2) The cementitious materials and chemical admixtures, used in the proposed mix, are the same materials from the same source used in the previously approved mix. The mix proportions of the proposed mix are similar to the proportions of the previously approved self-consolidating concrete mix.

8.4.11 PRODUCTION BATCH VERIFICATION

(1) Unless moisture meters are used, for self-consolidating concrete mixes, determine free moisture content of aggregates within two hours prior to each day's batching operations, at 4-hour intervals during continuous batching operations, and at any time a change in moisture content becomes apparent.

(2) Check that the forms are stable and leak proof. Forming materials shall be strong enough to withstand the concrete pressure and prevent any material leakage.

(3) Ensure that the Plant's proposed self-consolidating concrete mix has been approved prior to the production of concrete.

(4) Ensure that the Plant has a proper plan for the continuous mixing, delivery, and placement of concrete to prevent excessive slump flow loss or cold joints.

(5) For continuous placement of more than 3 batches, at the beginning of production of self-consolidating concrete, perform slump flow tests on at least three batches to ensure that the delivered concrete meets the requirement of the Specifications. In addition to the

random sampling and testing, visually check every batch before the concrete is transported to the placement area.

(6) Concrete shall stay plastic and within slump-flow tolerance range during placement.

(7) Ensure that the self-consolidating concrete is delivered in a continuous and timely manner and within the time limit that is allowed by the Specifications and trial batch verification.

(8) Ensure that the following plastic properties are measured for every Lot of the ***Florida Department of Transportation Specifications, Section 346*** class of concrete.

(a) Slump Flow
(b) Air Content
(c) Temperature

The slump flow tolerance is ± 3.0 inches and target range is ± 2.50 inches. Reject any Lot of concrete that does not meet specified plastic property requirements.

The same test requirements and tolerances are applicable to the ASTM and AASHTO class of concrete, except for the air content test. The air content test is waived for ASTM and AASHTO class of concrete, unless the project Specification requires the test.

(9) Place self-consolidating concrete in a continuous and timely manner to maintain its workability and specified slump flow during placement and to minimize the possibility of segregation and cold joints.

(10) Place the self-consolidating concrete without any vibrations, unless unexpected delays occur between different batches.

(11) Ensure that concrete maintains its workability during the entire placement time. Place self-consolidating concrete without any vibration or other consolidation efforts, unless it is determined that minimal vibration efforts result in a better consolidation.

(12) The Plant should have vibrating equipment available to consolidate the concrete, if needed.

(13) The free fall distance of self-consolidating concrete shall not exceed the allowable limit that is specified in the Specifications.

(14) Ensure that the concrete does not overflow.

(15) Do not add water to re-temper the concrete.

(16) Apply the appropriate curing method as soon as practical.

(17) Perform the finishing of concrete to prevent the occurrence of the cracks, honeycombs, voids, and lack of bonding between the concrete and reinforcing steel.

8.4.12 TRAINING

The Plant shall include necessary guidelines to the production and quality control personnel related to the production and quality control inspection and testing of the self-consolidating concrete. The guidelines should be included as part of the Plant's quality control plan.

8.4.13 FORMS

None needed.