# Section 8.4
# Volume II

# SELF-CONSOLIDATING CONCRETE (SCC) 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 manufacture of the products using SCC. The procedure includes requirements related to the Plants' quality control (QC) plans, the submittal of the mix designs, laboratory and field trial batches of the concrete mixes, and inspection and testing of production concrete. Produce SCC at an approved on-site facility, or off-site ready-mixed concrete facility with an accepted QC plan.

***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' QC plans; mix design verification and approval process; and quality assurance (QA) inspection and testing of SCC.

## 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 (ACI), Publication 237R-07, Self-Consolidating Concrete, Farmington Hills, Michigan, April 2007.

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

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

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 Plants that are involved in the utilization of SCC for the manufacturing of the precast/prestressed concrete products. The Plants shall comply with the requirements of ***FDOT Specifications*****,** except as modified herein.

## 8.4.5 SCC RELATED QUALITY CONTROL PLAN PROVISIONS

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

(1) The mix design qualification process.
(2) Routine quality control tests.
(3) The 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 SCC delivery and placement pattern and methods, including selection of the number of layers for the manufacturing of each product.
(6) The preparation of guidelines regarding SCC delivery, placement, finishing, and curing for the training of personnel who are involved in these activities.
(7) The proposed inspection and test methods for the laboratory and field trial batches.
(8) The verification method and frequency of the aggregate moisture content test.
(9) The adequacy of the forming strength to support the pressure of the SCC during placement. Provide information about form joint sealing method to prevent paste leakage.
(10) For SCC, 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 SCC products.
(12) The qualification and familiarity of the personnel performing the required inspection, and testing of SCC.

## 8.4.6 SCC MIX DESIGN REQUIREMENTS

**Table I**

| SCC Properties | Test | Standard Method | Acceptance Criteria |
|---|---|---|---|
| **Filling Ability** | Slump Flow<br>See 8.4.6.1 (4) and 8.4.7 (4) | ASTM C1611 | Minimum Target = 27.0 in<br>Tolerance= ± 2.5 in |
| | Relative Viscosity ($T_{50}$)<br>See 8.4.7 (5) | ASTM C1611 | 2 sec ≤ $T_{50}$ ≤ 7 sec |
| **Passing Ability** | J-Ring (Δ Flow)<br>See 8.4.7 (6) | ASTM C1621 | Δ Flow ≤ 2.0 in. |
| **Static Segregation** | Column Segregation (S)<br>See 8.4.7 (7) | ASTM C1610 | S ≤ 15% |
| | Rapid Assessment of Static Segregation (Pd)<br>See 8.4.7 (8) | ASTM C1712 | Pd ≤ 25 mm |
| | Visual Stability Index (VSI)<br>See 8.4.7 (9) | ASTM C1611 | VSI ≤ 1 |
| | Aggregate Distribution of Hardened SCC<br>See 8.4.8.4 | FM 5-617 | C.A.I. ≤ 15% |
| | Hardened Visual Stability Index (HVSI)<br>See 8.4.8.5 | AASHTO R 81 | HVSI ≤ 1 |
| **Compressive Strength** | Compressive Strength | ASTM C39 | Depends on the application |
| **Assessment of Durability** | Surface resistivity (when it is required for the class of concrete) | AASHTO T358 | Depends on the application |

### 8.4.6.1 SPECIFIED 346 CLASS CONCRETE

SCC is allowed for the fabrication of precast prestressed concrete as a replacement for the ASTM, AASHTO, or ***FDOT Specifications, 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 SCC will be allowed for the fabrication of the precast/prestressed concrete products.

The proposed SCC mixes require State Materials Office (SMO) approval. The District Materials Research Offices (DMRO) review the proposed concrete mix designs and verify they meet the requirements of the ***FDOT Specifications, Section 346***, including the following:

(1) Concrete mix ingredients are from Department approved sources.

(2) Admixtures shall meet the requirements of the ***FDOT Specifications, Section 924***. For SCC, the Type F or Type I admixtures shall be added at the concrete production facility. The addition of the admixtures shall comply with the recommendation of the manufacturer of the admixtures.

(3) Specific performance admixtures shall meet the requirements of ***ASTM C494 Type S.*** During the review of any proposed Type S admixture, the SMO will verify the admixture properties by reviewing the test data and verification testing to ensure that the concrete containing the specific performance admixture meets the claimed performance characteristics. The SMO may require additional testing of admixture or concrete containing the specific performance admixture. The approval of Type S admixtures is mix design specific. Upon the approval of the mix designs, the Plant shall include specific performance Type S as part of the approved quality control plan. The approval of Type S admixture as part of the Plant's quality control plan indicates that the admixture has been given contingent approval, as evidenced by previous tests and its apparent effectiveness under field conditions. This approval will continue as long as the admixture performs as claimed.
The Type S admixtures shall be compatible with other admixtures used in the SCC mixture proportions and shall not contain calcium chloride or calcium chloride based ingredients.

(4) For the SCC, replace the term "slump" with "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 C1611***. The minimum proposed target slump flow after the addition of all material ingredients, including admixtures, shall be 27.0 inches. There is no maximum proposed target slump limit,

provided the concrete meets the testing criteria in Table I. The tolerance on the proposed target slump flow is ± 2.5 inches. Therefore, the absolute minimum slump flow for the concrete to be acceptable as SCC is 24.5 inches.

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

(6) For mixes with the ratio of fine aggregate to total aggregates of less than 45 percent, the viscosity modifying admixture shall be used, unless the concrete tests have demonstrated that the segregation and flow characteristics, as defined by Table I 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 proposed ASTM or AASHTO class of SCC mix design shall meet the requirements of ***Materials Manual Section 8.4.6.1*** with the exception of the mix design approval process. The DMO will review and approve the mix designs for the precast concrete products that require ASTM or AASHTO class concrete with specified strength requirements.

## 8.4.7 LABORATORY TRIAL BATCH OF THE PROPOSED MIX DESIGN

The requirements of ***ASTM C192*** may be modified to allow the laboratory performance-based batching, mixing time, and sequence that produces the required properties.

In the trial batch process, determine the acceptable batching sequence and the mixing time associated with this batching sequence. During the production of the SCC, use the same batching sequence and adjust the mixing time determined in the batch process. Likewise, if the producer uses a different dosage of admixture, the trial batch time is invalid and shall be adjusted.

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

(2) Obtain a sample of freshly mixed SCC in accordance with test method ***ASTM C172***.

(3) Test SCC concrete in accordance with test method ***ASTM C1758***.

(4) Determine the filling ability of the concrete mix with the slump flow test, in accordance with ***ASTM C1611***.

(5) The relative viscosity ($T_{50}$) is the time taken for any part of the concrete to reach a spread of 20 inches in accordance with ***ASTM C1611***. It can primarily be used as an indication of the production uniformity of a given SCC mix. The ($T_{50}$) test should be performed whenever changes in SCC viscosity are noted visually, or at the discretion of QC or the Department. This test will not be used as a factor in rejection of a batch of SCC but rather as a quality control diagnostic test.

(6) Perform the passing ability of the SCC mix by using the J-Ring Test Method in accordance with ***ASTM C1621***.

(7) Determine the static segregation of the mix in accordance with ***ASTM C1610***.

(8) Determine the rapid assessment of static segregation resistance of the mix in accordance with ***ASTM C1712***.

(9) Determine the Visual Stability Index (VSI) in accordance with ***ASTM C1611***. The VSI shall not exceed a value of 1. Perform a second test when the VSI of the first test exceeds a value of 1. The SCC mix design will not be approved if VSI of the second test exceeds 1 during mix design phase.

(10) 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.

(11) Make and cure concrete test cylinders in accordance with ***ASTM C192***.

## 8.4.8 FIELD DEMONSTRATION OF SCC

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

### 8.4.8.1 NUMBER AND QUANTITY OF BATCH SIZES

For the field demonstration, produce and place a volume of 9 cubic yards in a minimum of three batches of at least 3 cubic yards each. Plants that are producing concrete with batch sizes of less than 3 cubic yards are required to produce the necessary batches to reach the required volume of 9 cubic yards.

### 8.4.8.2 SAMPLING AND TESTING OF FIELD DEMONSTRATION CONCRETE

For each batch, verify the slump flow, and perform the Field Demonstration tests in accordance with Section 8.4.12 (Table II). If more than 3 batches are necessary to reach the required volume, randomly select 3 and follow the same procedure.

Take representative samples at the point of final concrete placement and perform the tests prescribed in Table I and Table II as appropriate.

For SCC, modify the consolidation method of the ***ASTM C31, ASTM C 138, ASTM C173, and ASTM C231*** test following ***ASTM C1758***.

Ensure that the concrete properties are within the required ***Specification*** limits. Perform the slump flow loss test as described in ***Materials Manual Section 8.4.8.5.***

### 8.4.8.3 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 2.5 inches.
(4) The shortest time period determined from three demonstrated batches to reach the proposed target slump flow minus 2.5 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 that it does not exceed the allowable time limit specified in ***FDOT Specifications, Section 346****.*

### 8.4.8.4 The field demonstration shall include the manufacture and evaluation of a mockup product following *FM 5-617* when:

(1) The plant produces SCC for the first time. The mockup product shall be a partial or full scale representation of the proposed precast concrete products. It shall contain reinforcing steel typical

of those products, and shall and use the same mix design. In this case, saw cutting of the cross-section is required for visual inspection.

(2) A new SCC mix design is used in the plant. The mockup can be any shape that meets the dimensional requirements of ***FM 5-617***, section 4.1.1. Reinforcing steel is optional in this case.

**8.4.8.5 The mockup is not required, and the assessment of static segregation shall be verified following *AASHTO R 81* when:**

(1) The target slump flow of the previously approved SCC mix design has been increased by less than or equal to 2.5 inches.

(2) The DMRO/SMO determine that the mockup test is not required for a particular mix.

(3) Permissible adjustments to previously approved mix design have been made as referenced below:

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

b) Admixtures: Should be within the admixture manufacturer's technical data sheet range. Dosage rates outside of this range may be used with written recommendation from the admixture producer’s technical representative. Mixes with adjustments falling outside the technical data sheet range shall be suspended when written recommendation from the admixture producer’s technical representative has not been obtained.

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

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

The District Materials Research Engineer (DMRE) will be advised of any adjustments to the concrete mix design. Batch adjustments shall not be used for batch tolerances of aggregate and cementitious materials. The adjustments shall be noted on the concrete delivery tickets.

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 SCC batches at the proposed target slump flow ± 2.5 inches. The minimum slump flow will be greater than or equal to 24.5 inches.

Perform inspection and testing of the demonstration concrete during batching, delivery, placement, and post placement. Observe the placement sequence and method of the SCC. 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 methods of the concrete.

After performing the aggregate distribution test in accordance with ***FM 5-617***, or ***AASHTO R 81*** as appropriate, if there is an indication of a segregation problem, reject the proposed mix design, determine the cause of the segregation and submit a corrective action plan to prevent the recurrence of the problem during production. The DMRO will review the plan and will require retesting the mix until the aggregate distribution reaches the required values.

#### 8.4.8.6 POST PLACEMENT INSPECTION

After the 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 SCC for the first time at the Plant. Visually inspect 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.

The DMRE may waive the saw cutting of the mockup for routine mix design approvals of the SCC. A waiver will only be granted 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.

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

## 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 DMRO. 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 satisfactory 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 SCC 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 SCC 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.

In any of the previous cases, the slump flow loss test as described in 8.4.8.3 shall be verified.

## 8.4.11 PRODUCTION BATCH VERIFICATION

(1) Unless moisture meters are used, for SCC mixes, determine the 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.

Ensure that the Plant's proposed SCC mix has been approved prior to the production of concrete.

(3) 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. The plan must provide for actions in case of mechanical failures, or other unforeseen incidents.

(4) Minimal mechanical vibration (no more than 3 seconds) of the concrete is allowed under the following circumstances with DMRO approval:

a) If the geometry of the product requires it to fully consolidate the concrete.
b) In the presence of highly reinforced sections.
c) An unforeseen incident occurs during mixing, delivery, and placement.

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

(6) For continuous placement of more than 3 batches, perform slump flow tests on at least three batches at the beginning of the production of SCC 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 to ensure that there is no indication of any excessive variation in the concrete plastic properties within the batches.

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

(8) Ensure that the SCC is delivered in a continuous and timely manner and within the time limit that is allowed by the ***Specifications*** and trial batch verification.

(9) Perform SCC tests at the point of placement or testing station established for that express purpose, provided that a correlation between the plastic properties of the point of placement and testing station has been established.

(10) Ensure that the following plastic properties are measured for every Lot of concrete per class as defined in the ***FDOT Specifications, Section 346***.

a) Slump Flow
b) Relative Viscosity (T50)

c) Visual Stability Index (VSI)
d) Rapid Assessment of Static Segregation Resistance (Pd)
e) Density (Unit Weight)
f) Air Content
g) Temperature

(11) Reject any Lot of concrete that does not meet specified plastic property requirements, with the exceptions described below:
a) SCC should not be rejected on the basis of Slump Flow test, if it has passed the rapid assessment of static segregation resistance test (Pd). Notify the DMRO personnel and take corrective actions if the Slump Flow is out of the established tolerance of Table I.
b) SCC shall not be rejected on the basis of Visual Stability Index (VSI) if it has satisfactorily passed the rapid assessment of static segregation resistance test (Pd).
c) If the rapid assessment of static segregation resistance test (Pd) is greater than 25 mm, and the VSI is greater than 1, the concrete load shall be rejected, and the LOT terminated.
d) If previous load(s) belonging to the terminated LOT have already been discharged into the product, the producer may choose to reject the terminated LOT or re-evaluate it.
e) For re-evaluating the terminated LOT, the Producer shall cast two 6x12 inch concrete cylinders for ***AASHTO R 81***, Hardened Visual Stability Index (HSVI). Invite the DMRO personnel to witness the evaluation. If the HVSI test results are greater than 1, the SCC is considered segregated and the LOT shall be rejected.

(12) 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.

(13) Place SCC 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.

(14) Ensure that concrete maintains its workability during the entire placement time.
If two successive batches are delayed even less than 20 minutes, the surface of the underlying layer might manifest premature stiffness. In such cases, use a rake or a hoe to break the superficial stiffness providing appropriate adhesion between the two layers to avoid any cosmetic issue at the formed surface of the element.

(15) Use methods of placement that prevent segregation or other detrimental effects. These methods must be identified in the QC Plan.

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

(17) Apply the appropriate curing method in accordance with the ***FDOT Specifications Sections 400 or 450***.

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

## 8.4.12 SUMMARY OF TEST METHODS

| TABLE II | | | |
|---|---|---|---|
| **Test Method** | **Mix Design** | **Field Demonstration** | **Production (Every Lot)** |
| Slump Flow (Spread) | **X** | **X** | **X** |
| Relative Viscosity ($T_{50}$) | **X** | **X** | **X** |
| J-Ring (Δ Flow) | **X** | **X** | |
| Column Segregation (S) | **X** | | |
| Rapid Assessment Static Segregation (Pd) | **X** | **X** | **X** |
| Visual Stability Index (VSI) | **X** | **X** | **X** |
| Aggregate Distribution (CAI) | | **X** | |
| Hardened Visual Stability Index (HVSI) | | **X** | **When required** |
| Compressive Strength | **X** | **X** | **X** |
| Surface Resistivity | **X** | | |
| Density (Unit Weight) | **X** | **X** | **X** |
| Air Content | **X** | **X** | **X** |
| Temperature | **X** | **X** | **X** |

## 8.4.13 TRAINING

The Plant shall provide necessary guidelines to the production and quality control personnel related to the production and quality control inspection and testing of SCC. The guidelines should be included as part of the Plant's quality control plan.

## 8.4.14 FORMS

None needed.