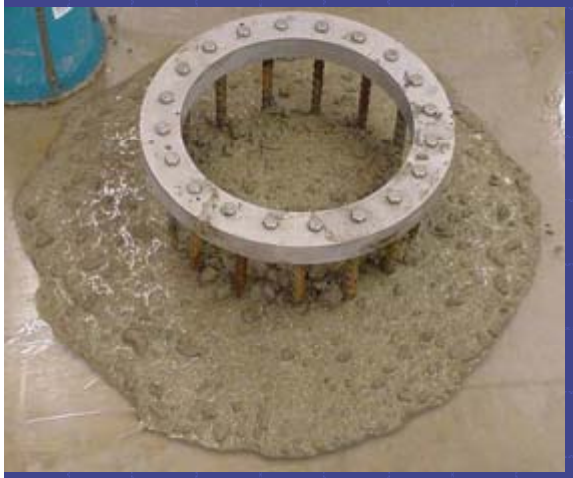
Self-Consolidating Concrete for Precast Elements

November 3, 2010



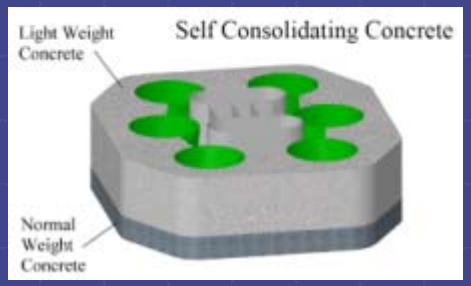
Agenda

- Review of Self-Consolidating Concrete
- Overview of Caltrans Self-Consolidating Concrete Testing Requirements
- Current/Proposed Changes to SCC Mock-Up Requirement
- Questions and Discussion

Self Consolidating Concrete (SCC) and Caltrans

- **Caltrans was one of the first DOTs to encourage the use of SCC in their Spec**
- Caltrans used SCC on new SFOBB Elements in 2003-04 *(prior to the creation of some SCC ASTM Standards)*
- Working with National Organizations (such as ACI and PCI) to develop Specs for SCC use

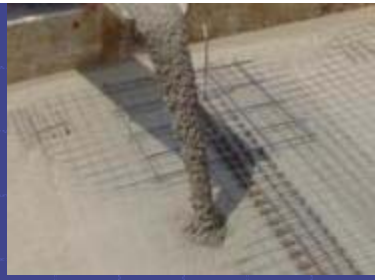
SCC Use on W2



SCC Use on Footing Boxes

SCC Use on Pier E2 (80% of concrete was SCC)

SCC - Caltrans Specifications



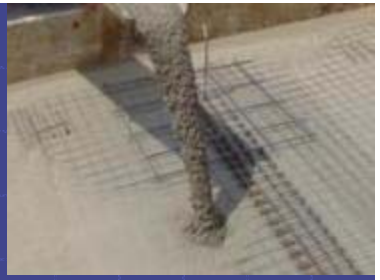
- From ***Special Provisions 8-2.__ Self-Consolidating Concrete for Precast Elements***
- **<u>Prequalification</u> of SCC Mix Designs**
  - Prequalify the SCC mix design with a trial batch using the same materials, mix proportions, mixing equipment, procedures, and size of batch to be used in the production of SCC. **<u>The trial batch test report for the SCC mix design must include the following test results</u>**:

SCC Mix Design Requirements

Property	Requirement	Test Method
Slump Flow	At least 20 inches	ASTM C 1611
Flow Rate - T_{50}	Between 2 and 7 seconds	ASTM C 1611
Visual Stability Index	1.0 or less	ASTM C 1611
J-Ring Flow	The difference between J-Ring flow and the slump flow must not exceed 2 inches	ASTM C 1621
Column Segregation	Static segregation must not exceed 15%	ASTM C 1610
Bleeding	Bleeding capacity must not exceed 2.5%	ASTM C 232
Compressive Strength	The average of 5 test cylinders must be at least 580 psi greater than the specified strength.[a]	California Test 521
Minimum Compressive Strength	The minimum for an individual test cylinder must not be less than the specified strength.[a]	California Test 521

Note:

SCC - Prequalification of SCC Requirements



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Note:

SCC - Slump Flow Test – ASTM C1611

- Used to determine the horizontal free flow characteristics of SCC in the absence of obstructions.
- Used to Monitor the consistency of fresh, unhardened, SCC and its unconfined flow potential.
- The mean spread is measured horizontally to determine the slump flow value.

Slump Flow Test

SCC - Slump Flow Test – ASTM C1611

- **Caltrans Spec requires at least 20 inches**
- *Based on feedback from industry, Caltrans settled on the minimum 20” requirement*
- *ACI 237 Committee indicates a common range of slump flow for SCC is 18” to 30”*

Slump Flow Test

SCC - Flow Rate (T_{50}) Test – ASTM C1611

- Used to determine the horizontal free flow characteristics of SCC in the absence of obstructions.
- Record of the time it takes for the outer edge of the concrete mass to reach a diameter of 20”
- Gives an indication of the relative viscosity

Flow Rate Test

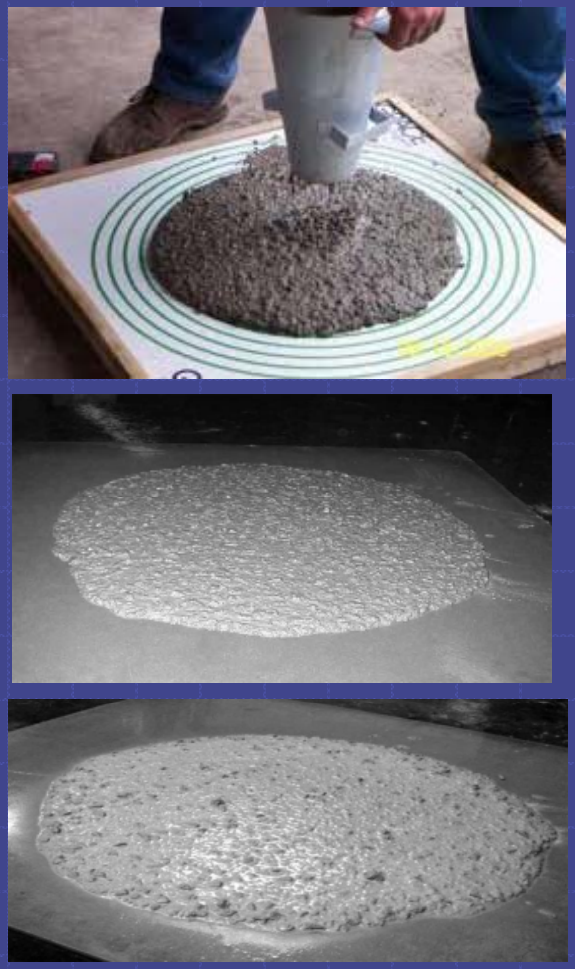
SCC - Flow Rate (T_{50}) Test – ASTM C1611

Flow Rate Test

- **Caltrans Spec requires between 2 and 7 seconds**
- *PCI TR-6-03 references the Brite-eurRam Programme: BE96 – 3801/BRPR-CT96-0366, which states 3 to 7 seconds is acceptable for civil engineering applications*
- *ACI 237 Committee states a time of 2 seconds or less characterizes a SCC with a low viscosity, and greater than 5 seconds characterizes high viscosity*

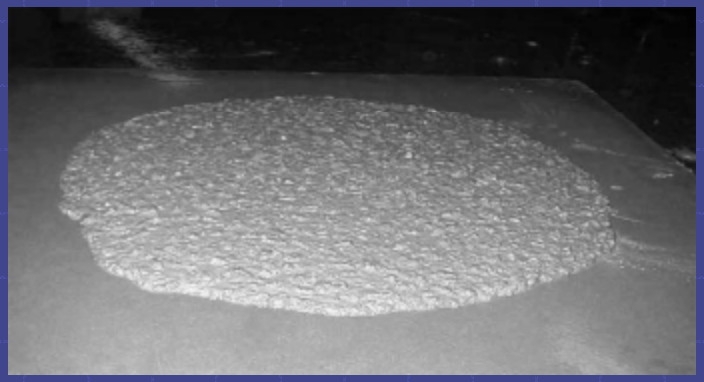
SCC – Visual Stability Index (VSI) Test – ASTM C1611

- Used to qualitatively assess the stability of SCC
- Stability is measured based on evidence of segregation and bleeding
- *Caltrans Spec requires VSI = 0 or 1 (which is consistent with the ACI 237 Committee)*



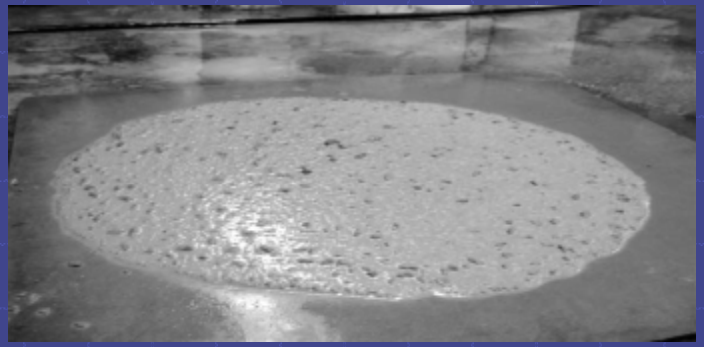
VSI Index Test

SCC – Visual Stability Index (VSI) Test – ASTM C1611

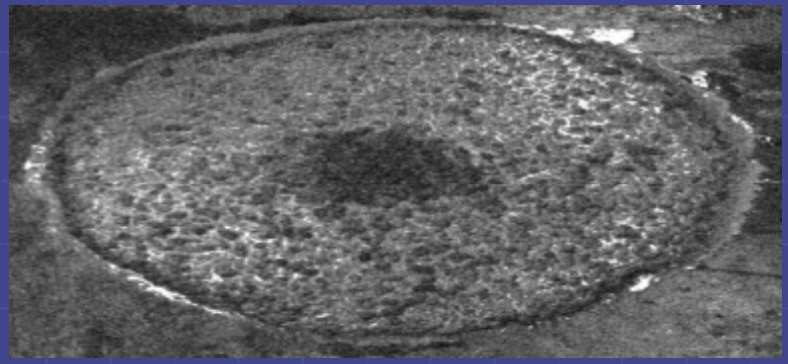


VSI = 0 – Concrete mass is homogenous and no evidence of bleeding

VSI = 1 – Concrete shows slight bleeding, observed as a sheen on the surface



VSI = 2 – Evidence of a mortar halo and water sheen



VSI = 3 – Concrete of coarse aggregate at center of concrete mass and presence of a mortar halo

SCC - J-Ring Test – ASTM C1621

- Used to determine the passing ability of SCC concrete.
- The difference between the slump flow and the J-Ring flow is an indication of the passing ability of the concrete.
- **Difference must not exceed 2 inches**

J-Ring Test

SCC - J-Ring Test – ASTM C1621

- A difference of greater than 2 inches indicates poor ability.
- For Example:

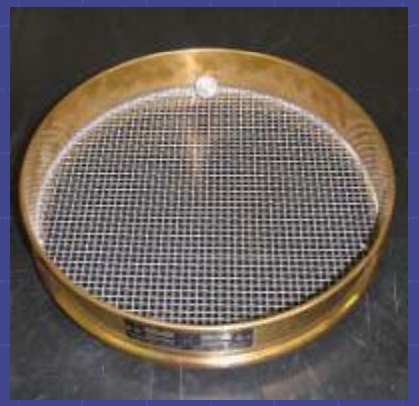
Slump Flow Test value:	23”
J-Ring Test value:	- 21”
Difference:	*2”*

J-Ring Test

- *Multiple Trial Tests were done on SFOBB, and experience led Caltrans to the 2” requirement*
- *Originally, 1” was desired by Caltrans; 2” was result of a compromise with industry*

SCC – Column Segregation Test – ASTM C1610

- Used to develop SCC mixtures with segregation within specified limits.
- The column is filled and allowed to sit 15 minutes.
- Concrete **within each section** is washed over a # 4 sieve, and the retained aggregate is weighed.
- A non-segregating mixture will have consistent aggregate mass distribution



Column Segregation Test

SCC – Column Segregation Test – ASTM C1610

$$S = 2\left[\frac{(CA_B - CA_T)}{(CA_B + CA_T)}\right] * 100, \quad if\ CA_B > CA_T$$

$$S = 0, \quad if\ CA_B \leq CA_T$$

where:

S = static segregation, percent

CA_T = mass of coarse aggregate in the top section of the column

CA_B = mass of coarse aggregate in the bottom section of the column

- "S" in above equation must not exceed 15%
- *15% requirement came from interaction with industry*
- *ACI 237 says SCC percent segregation shall be less than 10%.*

Column Segregation Test

SCC – Column Segregation Test – ASTM C1610

$$S\% = [(CA_B - CA_T)/((CA_B + CA_T)/2)] \times 100, \text{ if } CA_B > CA_T$$

$$S\% = 0, \text{ if } CA_B < CA_T$$

ACI Equation

$$S = 2\left[\frac{(CA_B - CA_T)}{(CA_B + CA_T)}\right] * 100, \quad \text{if } CA_B > CA_T$$

$$S = 0, \quad \text{if } CA_B \leq CA_T$$

where:

S = static segregation, percent

CA_T = mass of coarse aggregate in the top section of the column

CA_B = mass of coarse aggregate in the bottom section of the column

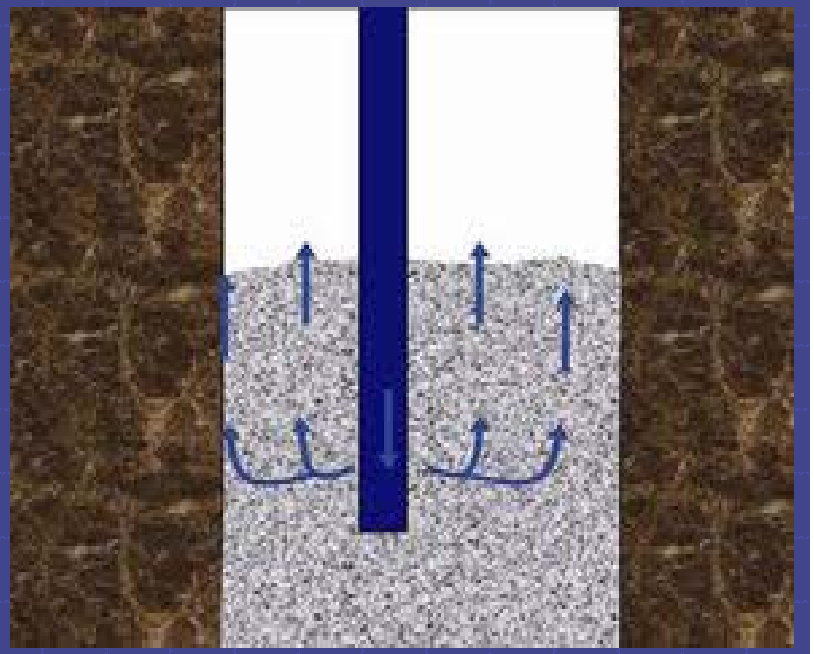
Caltrans Equation

CA_T = Mass of Coarse aggregate in the Top Section

CA_B = Mass of Coarse aggregate in the Bottom Section

SCC - Bleeding Test – ASTM C232

- Used for determining the effect of variables of composition, treatment, environment, or other factors in the bleeding of concrete
- Simulates condition in which the concrete, after placement, is not subjected to intermittent vibration



Bleeding Test

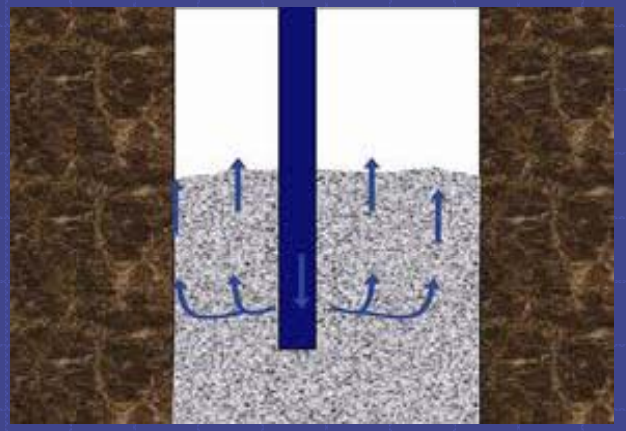
SCC - Bleeding Test – ASTM C232

$$C = (w/W) \times S \quad (2)$$

$$\text{Bleeding, \%} = (D/C) \times 100$$

where:

C = mass of the water in the test specimen, g,
W = total mass of the batch, kg,
w = net mixing water (the total amount of water minus the water absorbed by the aggregates), kg,
S = mass of the sample, g, and
D = mass of the bleeding water, g, or total volume withdrawn from the test specimen in cubic centimeters multiplied by 1 g/cm^3.



Bleeding Test

- "Bleeding %" in above equation must not exceed 2.5%
- *Test was added based on past bleeding-related concerns*
- *Caltrans SFOBB concrete experts proposed 2.5% requirement to industry based on SCC experiences – No industry concerns were noted*

SCC – Compressive Strength Test – California Test 521

- Determines compressive strength of cylindrical concrete specimens such as molded cylinders and drilled cores.

Compressive Strength Test

SCC – Compressive Strength Test – California Test 521

- The average of 5 test cylinders must be at least 580 psi greater than the specified strength at the max age specified/allowed
- The minimum for an individual test cylinder must not be less than the specified strength at the max age specified/allowed
- *Caltrans is open to substituting the use of CTMs with ASTMs whenever possible*

Compressive Strength Test

SCC – Caltrans Mock-Up Requirement

- Clause was added to Design Plans & Quantities memo, stating requirement limited to complicated structures (structures not on standard plans)
- Construct a mock-up **similar to the production element including reinforcement and embedments.**
- Determine the coarse aggregate content using California Test 529. The samples must not differ from each other by more than 8 lbs/ ft^3.
- Saw-cut the mock-up full depth in the transverse direction 2 feet from the termination of the pour.
- Inspect for voids, honeycombing, in the SCC and around embedded items.

SCC Mock-up Inspection

Rejected SCC Mock-up

Mock-up after Transverse Saw Cut

SCC – Proposed Changes to Mock-Up Requirement

- Include **"…encapsulate the reinforcement and embedments without developing excessive rock pockets, voids, or other detrimental effects. "**
- Include "…**The concrete as placed will be required to be tested to determine the presence of voids, rock pockets, mix segregation, and or other inclusions developed during placement**."
- Replace "…**Engineer will be the sole judge as to the acceptance**…" with "…**The acceptance of the completed element or section of the element prior to the casting of the production units is the prerogative of the Engineer**…"

SCC Mock-up Inspection

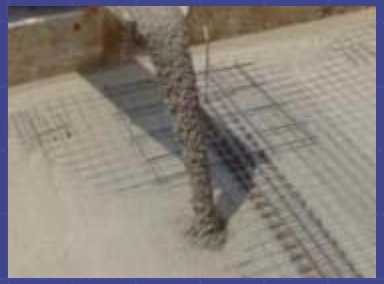
Rejected SCC Mock-up

Mock-up after Transverse Saw Cut

SCC - Caltrans Specifications – Quality Control Requirements

- From ***Special Provisions 8-2.__ Self-Consolidating Concrete for Precast Elements***

- **<u>Quality Control</u> (Production Tests) for SCC Mix Designs:**
  - Determine the **fine aggregate moisture content** for each batch
  - Determine **Slump Flow** at the beginning of SCC placement and whenever a set of concrete cylinders is prepared
  - Determine **Visual Stability Index (VSI)** at the beginning of SCC placement and whenever a set of concrete cylinders is prepared



Questions and Discussion

Thank you for your time

References

- ASTM Standards – C39, C232, C1610, C1611, C1621
- ACI 237R-07, American Concrete Institute
- California Test 521
- Caltrans SSP S8-C20 – Self Consolidating Concrete for Precast Bridge Elements
- NCHRP Report 62P – Self Consolidating Concrete for Precast Bridge Elements
- Proceedings of the Fifth International RILEM Symposium on SCC – Sept. 2007
- Mass Concrete for Bridges – Portland Cement Assoc. 2007
- ACI 207 Mass Concrete – 207 IR-96
- Controlling Temperature in Mass Concrete Concepts Concrete International ,Vol 24 No.1

Example – Slump Flow Determination from ACI 237 Committee Report

- *Slump flow target is determined based on Member Characteristics (shaded blocks are to be avoided)*
- *In general, the lowest slump flow consistency should be chosen to reduce the potential for instability and optimize the performance/cost relationship*
- *Once the initial slump flow target is set, trial mixtures should be proportioned with those materials that will be used for the intended project*

Member characteristics			Slump flow		
			<22 in. (<550 mm)	22 to 26 in. (550 to 650 mm)	>26 in. (>650 mm)
	Reinforcement level	Low			
		Medium			
		High			
	Element shape intricacy	Low			
		Medium			
		High			
	Element depth	Low			
		Medium			
		High			
	Surface finish importance	Low			
		Medium			
		High			
	Element length	Low			
		Medium			
		High			
	Wall thickness	Low			
		Medium			
		High			
	Coarse aggregate content	Low			
		Medium			
		High			
	Placement energy	Low			
		Medium			
		High			

Note: SCC mixtures with slump flows less than 22 in. (550 mm) may require minor vibration.

Table 2.5 from ACI 237

New Test Under Consideration: ASTM C1712

- **Bottom Line: <u>C1712 Test may be included in addition to Column Segregation Test</u>**
- Rapid assessment of static segregation resistance of normal-weight SCC
- **Provides an assessment of whether static segregation is likely to occur.**

$$Pd = d_2 - d_1$$

TABLE X1.1 Degree of Static Segregation Resistance[A]

Penetration depth (*Pd*)	Degree of static segregation resistance
$Pd \leq 10$ mm	Resistant
10 mm < Pd < 25 mm	Moderately resistant
$Pd \geq 25$ mm	Not resistant

Penetration Test