Self-Consolidating Concrete (SCC): Today and Tomorrow

By William S. Phelan

Self-Consolidating Concrete (SCC) originated and gained initial acceptance in Japan in the late 1980s. It is used successfully today throughout the world in both precast and cast-in-place concrete. It is increasingly being specified and used in North America.

SCC is a highly flowable, non-segregating concrete with a slump/flow of 20 inches to 30 inches that can be easily placed and completely fills forms under its own weight, without mechanical vibratory consolidation. It is produced using high-range water-reducing admixtures (HRWRA, also known as superplasticizers), viscosity-modifying admixtures (VMA), and well-graded aggregates.

Polycarboxylate-based HRWRAs are the typical type used; they are significantly different from the older naphthalene-based HRWRAs. HRWRAs and VMAs provide the required fluidity and viscosity. VMAs are commonly used in mixes with slump/flows above 24 inches, and in mixes with less than optimum combined aggregate gradation. Mix designs are initially prepared in accordance with the project specifications, expected slump/flow range, and a setting time based on climatic conditions at the time of placement. The proposed mix must be verified by a successful onsite placement to confirm the optimum slump/flow, pumpability, finish, and setting time. Excessive form pressure can result from retarded concrete, too rapid placement of concrete, or both.

Formwork must be designed with slump/flow, rate of placement, and setting time established. SCC has thixotropic properties which tend to minimize form pressures. Thixotropy is the property of certain gels or fluids that are thick (viscous) under normal conditions, but flow (become thin, less viscous) over time when shaken, agitated, or otherwise stressed. The proceedings from SCC 2010, *Design, Production and Placement of Self-Consolidating Concrete*, held September 26-29, 2010 in Montreal, Canada, provide valuable information on slump/flow, setting time, and resulting form pressure.

Slump/Flow of 28 inches.

SCC is currently used in precast concrete, architectural concrete, heavily reinforced concrete and formed repairs. SCC in the plastic state offers the benefits of speed of placement, ease of consolidation, deformability,

Successful SCC Mix Designs.

	Freedom Tower 1,776 Feet High New York, NY	301 Mission Street San Francisco, CA 60 Stories	Michigan State University Arts Center	LNG Storage Tanks Freeport, Texas	US Mission @ The United Nations
Cement	300 lbs.	470 lbs.	560 lbs.	582 lbs.	550 lbs.
Microsilica	25 lbs.				
Fly Ash Class F	65 lbs. (Class C)		240 lbs. (Class C)	190 lbs.	
Slag (Grade 120)	483 lbs.	470 lbs.			250 lbs.
Sand	1370 lbs.	1417 lbs.	1374 lbs.	1404 lbs.	
Coarse Aggregate	1640 lbs., ¾”	1417 lbs., ½”	1597 lbs., 3/8”	1439 lbs., 1”	1550 lbs., 3/8”
Water	270. lbs.	292 lbs.	272 lbs.	294 lbs.	275 lbs.
Air-Entraining Admixture	–	–	As required	–	4.0 oz.
HRWR	70 oz.	94 oz.	34 oz.	108 oz.	49.0 oz.
Viscosity Modifier	10 oz.	25 oz.	2 oz.	4 oz.	2.0 oz.
Hydration Control Admixture	30 oz.				
Site added Admixture, HRWR	As required	As required	As required	As required	30.0 oz.
Air Content	< 3%	< 3%	3% – 6%	2%	3% – 6%
Slump Flow	23” – 27”	20” – 24”	28” – 30”	29” +/- 2”	24” +/- 2”
Water/Cementitious Ratio	0.27	0.31	0.34	0.38	0.34
Compressive Strength , f'c	14,000 psi @ 56 days	10,000 psi @ 56 days	6,000 psi @ 28 days	5,000 psi @ 28 days	8,000 psi @ 28 days
Average Strength	16,149 psi + @ 56 days		10,000 psi +		11,000 psi +

University of California, Merced, CA. Mirror Finish Wall.

Architectural Concrete. SCC is pumped from the bottom in this wall.

and resistance to bleeding and segregation in both the dynamic and static states. The hardened concrete benefits include improved appearance and finish, as well as higher early strength than conventional superplasticized concrete, with slumps of 7 to 10 inches when a polycarboxylate admixture is used. SCC has higher bond strengths to steel because vibration in conventional concrete can cause bleeding that result in some voids under reinforcement. SCC can also achieve these additional benefits:

- Faster placing, finishing, and stripping of forms.
- Reduced equipment costs.
- Faster turnaround time of concrete trucks.
- Significant cost savings because of the elimination of vibration and increased rate of placement.
- Reduction in patching and repair.
- Increased safety for the work force with the elimination of vibration.

The benefits of SCC are recognized by many owners, designers, and concrete producers throughout the country. Most structural engineering firms today include SCC in their master specifications. The following mix designs have been used successfully.

University of California, Merced, CA.
Architectural Concrete Measured for Slump/Flow.

Successful SCC Mix Designs

Successful SCC concrete projects have the following characteristics:

- The specification is clear as to usage, water/cementitious ratio, air content, the necessity for a pre-placement conference, and successful test placement onsite.
- The pre-placement conference agenda requires representatives from the designers, contractors, concrete producers, admixture manufacturers, and testing lab personnel to discuss thoroughly the mix design requirements in both the plastic and hardened state, climatic conditions, form design, form release agent, schedule, rate of placements, test placement location (s), and target slump-flow.

When the planning and preparation are thorough, and appropriate Quality Assurance/Quality Control (QA/QC) procedures are followed, very successful projects are the result.

Key requirements for SCC include:

- Acceptable slump/flow range based on the successful test placement onsite.
- Testing procedures at the concrete plant and in the field with respect to water and air content.
- Acceptable architectural finish requirements regarding uniformity of finish, color and limits on "bug hole" size and number. A bug hole is a small void generally resulting from air trapped on the form surface. ACI describes them in Sections 3.7 and 4.9.6 of its *Guide to Cast-In-Place Architectural Concrete Practice*.

Major Projects in the US

The United States Mission at the United Nations was the Grand Award Winner at the Concrete Industry Board awards dinner in 2009. This structure is 28 stories of buff-colored, architectural SCC concrete (8000 psi @ 28 days).

The Freedom Tower (Tower 1) at the World Trade Center site is 1,776 feet tall. Concrete is above 60 stories now. The shear walls were 16,149 psi @ 56 days (modulus of elasticity of 7,700,000 psi) from the foundation to 70 feet above street level. 12,000 psi concrete was used for the next 330 feet. (*Modulus of elasticity is a key requirement for high-strength concrete used for construction of tall buildings*).

The Trump Tower in Chicago, Illinois was a major user of SCC. It is a 92-story reinforced concrete project that required 4,600 cubic yards of SCC to be cast-in-place continuously for 22 hours to construct the mat foundation that supports the finished structure. The mix had a 7-day compressive strength of 9,950 psi and a 28-day strength of 12,000 psi. This single pour is the largest ever recorded to date in North America using SCC.

Major Projects around the World

The Burj Khalifa is the tallest building in the world. SCC was used throughout the building and was pumped 166 stories above the ground. The slump/flow was 24 to 28 inches.

The Mori Tower in Shanghai, China used SCC for its structural frame. The foundation is composed of 48,000 cubic yards of SCC. It was cast-in-place in three phases, with the last phase made up of 36,000 cubic yards being poured continuously for 40 hours using 19 pumps. This 1,614-foot tall, 101-floor building consumed over 390,000 cubic yards of concrete before completion.

Architectural Concrete with knife edge corners and openings

Architectural Concrete. Close up of knife edge openings.

In Neuchatel, Switzerland, the La Maladiere Football Stadium was made up of 78,000 cubic yards of SCC placed in 10 months. The slump flow required was 26 inches, with a 28-day compressive strength of 6,400 psi. This development contains a football stadium with 11,500 seats, a mall with 270,000 square feet of retail space and a parking structure with 930 spaces. The structure was completed in 2007.

Summary

SCC greatly expands the possibilities of successful high-performance concrete placements with difficult and demanding requirements. In fact, the goal in North America is "15 by 15" – to have SCC become 15% of all ready-mixed concrete by 2015.▪

William S. Phelan is Senior Vice President of Marketing & Technical Services for the Euclid Chemical Company. He is an Honorary Member and Fellow of ACI. ACI 212.3R-10, Report on Chemical Admixtures for Concrete, was chaired by William S. Phelan. He may be reached at ***euclidchem@att.net****.*