



# HPC Bridge Views

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SCC was used in the inclined pylons of the cable-supported pedestrian bridge, VA.  
Photos: Virginia Department of Transportation.

## Self-Consolidating Concrete Bridge Applications are Expanding

*M. Myint Lwin, Federal Highway Administration*

Self-consolidating concrete (SCC) has generated worldwide interest in research and applications in precast and cast-in-place highway construction. SCC has many engineering, architectural, economic, and environmental benefits. Eliminating the need for concrete vibration reduces the noise level in the plants and at the construction sites, resulting in improved environmental and working conditions. SCC cuts down on the labor needed and wear and tear on equipment and formwork because internal and external vibrators are not used. This, in turn, accelerates concrete placement and results in cost savings, less traffic disruption, and safer work zones. SCC has the ability to flow into and completely fill intricate and complex formwork and to pass through and bond to congested reinforcement without segregation. The formed surfaces of SCC take on the textures of the formwork with little or no defects to repair. SCC contributes to the construction of "Green Bridges."

SCC facilitates the use of creative ways to prefabricate precast, prestressed concrete elements to achieve high production, while increasing plant safety and workers' health and job satisfaction. Prefabricated SCC elements of different shapes and sizes have been produced economically and successfully in plants and then brought to the job site for safe and speedy construction.

Cast-in-place SCC was used in the construction of the inclined pylons of a cable-supported pedestrian bridge in Virginia. Because of the congestion caused by the heavy reinforcement and the cable anchorages, it would have been very difficult to obtain quality concrete in the inclined pylons with conventional concrete.

### **FHWA's Role**

The Federal Highway Administration (FHWA) continues to work with the states, researchers, concrete industry, admixture suppliers, and other partners in advancing SCC technology through research, development, deployment, and construction projects. Many states are using SCC in beams and girders, bridge piers and pile caps, columns, walls, and drilled shafts. SCC is also used in repair of concrete members with limited access for conventional placement and vibration techniques.

The FHWA offers a one-day SCC workshop to the state departments of transportation (DOTs). The workshop is generally held at the request of a state and at a state-furnished facility. The states are encouraged to have projects ready to use the technology before requesting workshops. The FHWA finds that it is most cost effective to use the information and lessons from a workshop right away. For example, the Nevada DOT requested a workshop on SCC for an awarded project, which specified SCC for drilled shafts. The Nevada DOT involved the state laboratory technicians, construction quality control and quality assurance personnel, and the contractor's crew in the workshop. The SCC workshop laid the groundwork for successful application for SCC in drilled shafts. For more information on the SCC workshop program, contact [Antonio.Nieves@dot.gov](mailto:Antonio.Nieves@dot.gov) or [Lou.Triandafilou@dot.gov](mailto:Lou.Triandafilou@dot.gov).

The Innovative Bridge Research and Deployment (IBRD) Program is the successor to the Innovative Bridge Research and Construction (IBRC) Program. The main objectives of the IBRD program are to promote, demonstrate, evaluate, and document the application of innovative designs, materials, and construction methods in the construction, repair, and rehabilitation of bridges and other highway structures. Under the IBRC and IBRD programs, over 20 SCC projects have been awarded and constructed. The projects cover a wide range of applications, including beams and girders, bridge piers and pile caps, columns, abutment walls, retaining walls, drilled shafts, traffic barriers, bridge rails, bridge repairs, and prefabricated elements and systems. Many states, including Florida, Illinois, New Jersey, Nevada, Ohio, and Virginia, have developed SCC construction specifications that allow SCC as an option to the contractors.

## **Research**

States, in collaboration with the universities, have conducted studies to determine the feasibility and practicality of using locally available materials for developing SCC mixes for construction of highway projects. The studies provide guidance for the design and testing of SCC mixes, prediction of time-dependent properties, and constructability considerations.

A National Cooperative Highway Research Program (NCHRP), Project 18-12 Self-Consolidating Concrete for Precast, Prestressed Concrete Bridge Elements is scheduled for completion in 2008. The main objectives of this research are to develop guidelines for the use of self-consolidating concrete in precast, prestressed concrete bridge elements and to recommend relevant changes to the AASHTO LRFD Bridge Design and Construction Specifications.

## **Drilled Shafts**

Researchers at Auburn University, AL, investigated the use of SCC in drilled shafts in 2003 and put SCC into practice in 2005 with the construction of drilled shafts for the U.S. 76/SC 9 bridge replacement over Lumber River in South Carolina. The project started out with the experimental use of SCC in one of the drilled shafts under the IBRC program. The experiment was so successful that the South Carolina Department of Transportation decided to use SCC for production of the five remaining drilled shafts.

The high flowability through congested reinforcement, reduced amount of bleed water, more resistance to segregation, and extended workability (6 to 10 hours) combine to make SCC ideally suitable for drilled shaft construction. SCC can overcome some of the problems encountered in the past in using high-slump conventional concrete.

Under an IBRC grant, the Hawaii DOT is conducting a pre-construction study on the use of SCC in drilled shafts for the replacement of the North Kahana Bridge. The study is targeted to develop SCC specifications and mix design guidelines for using locally available aggregates in Hawaii. The Alabama DOT is conducting a similar study on the use of SCC in drilled shaft construction.

More recently, the contractor for the I-35W replacement bridge in Minneapolis, MN, selected SCC for the drilled shaft construction. Test shafts were constructed to gain valuable lessons in planning, designing, and placing the SCC in over 80 drilled shafts with 7 and 8 ft ( 2.1 and 2.4 m) diameters. In addition, SCC drilled shafts have been constructed in New Jersey and Virginia.

## **Recommendations**

SCC has many technical, economical, and environmental advantages. It can help solve some difficult and costly field problems and should be given consideration when the concrete work involves:

- Intricate and complex formwork;

- Congested steel reinforcement;
- Architectural features;
- Precast elements;
- Need for quality, speed, and high productivity; and
- Limited access for proper vibration.

Overall, SCC demands more diligent planning, engineering, and execution than conventionally vibrated concrete. The beginning users of SCC will benefit greatly from the construction of mockups prior to the production of the final members. Mockups are cost effective ways for owners and contractors to gain experience and assure quality and speed in the final production work.

### **Conclusion**

SCC has high potential for wider applications and larger payoffs. By requiring little or no vibration, its use results in less noise, less labor, faster construction, healthier working conditions, improved concrete quality, and better durability.

### **Further Information**

For further information, contact the author at [myint.lwin@dot.gov](mailto:myint.lwin@dot.gov).

## **Self-Consolidating Concrete for Beams Speeds Biloxi Bay Bridge Construction**

*Mitchell K. Carr, Mississippi Department of Transportation and Bruce Strickland, Sika Corporation*



Self-consolidating concrete was used in the precast, Prestressed concrete beams of the new Biloxi Bay Bridge.

One of the South's most traveled scenic highways and a major Gulf Coast artery is U.S. Route 90. When Hurricane Katrina destroyed the existing four-lane bridge across Biloxi

Bay between Biloxi and Ocean Springs, the Mississippi Department of Transportation (MDOT) realized that the bridge had to be rebuilt quickly and be as durable as possible. The new bridge would need to have sufficient elevation to clear water levels expected from a catastrophic hurricane. The services of an ocean engineering firm were used to develop a computer model to predict future storm surges plus maximum wave height.

With this information in hand, MDOT advertised the project and subsequently awarded a \$338 million design-build contract to GC Constructors, a joint venture of Massman Construction Co., Kansas City, MO; Traylor Bros., Inc., Evansville, IN; and Kiewit Southern Co., Fort Worth, TX; Standard Concrete Products of Columbus, GA, was contracted to supply the precast, prestressed concrete beams for the project.

### **The New Bridge**

At the highest point above the navigation channel, the new 1.66-mile (2.67-km) long bridge rises 95 ft (29 m) above the normal high tide level, affording unobstructed views to travelers while allowing large ships to pass beneath without lowering their masts. Constructed as two side-by-side superstructures, each structure carries three lanes of traffic. In addition, the eastbound structure has a 12-ft (3.7-m) wide path for cyclists and pedestrians. The project also included twin 800-ft (244-m) long bridges over the railroad in Ocean Springs. Awarded in June 2006, the project proceeded at a very fast pace with the north lanes for westbound traffic opening just 16 months later and 12 days ahead of schedule. At its peak, the project employed 450 people and required 18 floating cranes.

Span lengths for the bridge vary from about 86 ft (26 m) at the low level approaches to 250 ft (76.2 m) for the navigation channel span. The superstructure utilizes precast, prestressed concrete bulb tees at a typical spacing of 12 ft (3.7 m). The bulb-tee depths are 54 in. (1.37 m) for 86-ft (26-m) spans, 72 in. (1.83 m) for 120-ft (36.6-m) spans, and 78 in. (1.98 m) for 150-ft (45.7-m) spans. The navigation span of 250 ft (76.2 m) is flanked by two spans of 200 ft (61.1 m). Each line of girders for these three spans was constructed as a five-segment, post-tensioned, spliced girder unit consisting of haunched girders over the piers adjacent to the navigation channel, two end span segments, and a main span drop-in segment. The end span and drop-in segments utilize 78-in. (1.98-m) deep bulb tees, while the haunched segment varies in depth from 78 in. (1.98 m) at the ends to 144 in. (3.66 m) over the piers. To accommodate the posttensioning ducts, the web thickness of the bulb tees was increased from 7 to 9 in. (178 to 229 mm).

### **Self-Consolidating Concrete**

“Two major factors contributed to the speed with which we were able to complete this project,” said Peter Pieterse, division manager for Standard Concrete Products. “MDOT accepted our recommendation to use self-consolidating concrete to cast the beams. A debonded rather than draped strand pattern for the prestressing strands allowed much faster production so the beams could be ready for delivery as needed.”

Polycarboxylate technology was utilized to produce the self-consolidating concrete. This provided a number of benefits including extended slump retention, higher concrete strengths for greater design flexibility and structural economies, more durability, lower permeability, and fewer surface defects.

The use of self-consolidating concrete reduced the time required to cast the beams by approximately 50%, virtually eliminated the need for vibration equipment, reduced associated noise, and reduced the costs of final finishing by an estimated 60%. The specified concrete compressive strengths were 6500 psi (45 MPa) at release of the strands and 8500 psi (59 MPa) at 28 days. Actual average strengths were 7000 psi (48 MPa) within 15 to 18 hours of being placed, and 13,000 psi (90 MPa) at 28 days. The specifications required a slump flow of 24 to 28 in. (610 to 710 mm), an air content of 3 to 6%, and a maximum temperature at placement of 95 °F (35 °C). The average measured slump flow was 25 in. (635 mm) and the average measured air content was 4%.

Static-segregation and J-Ring tests were conducted for every 1000 yd<sup>3</sup> (765 m<sup>3</sup>) of concrete. The concrete and strand also easily passed the specified strand-bond test often called the Moustafa Test.

“The concrete met all of the specifications, and the beams looked great,” concluded Pieterse. “As a result of the reduced concrete waste, speed of construction, and increasing acceptance of self-consolidating concrete, we’re using it whenever and wherever possible.”

### **Lessons Learned**

The use of self-consolidating concrete not only reduced production costs through faster placement but it also allowed for placement with less skilled workers. Concrete was deposited at fewer points along the forms and flowed approximately 35 ft (10.7 m). Placing self-consolidating concrete in this manner created a smooth surface without signs of bleeding or discoloration. When producing self-consolidating concrete, slump flow and visual stability index (VSI) testing should be performed on the first few batches at the beginning of the placement. Further slump flow tests and VSI testing were done per the specifications. It should also be noted that moisture content of the aggregate and variations in aggregate gradations have a greater impact on self-consolidating concrete than conventional concrete.

Typically, self-consolidating concrete requires a higher cementitious materials content. The requirement to be highly flowable dictated the use of a high-range water-reducing admixture. The lower water content and higher cement content resulted in higher compressive strengths than conventional concrete.

## Further Information

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## Implementing SCC Technology in Nebraska—All About Working Together

*Mark D. Lafferty, Concrete Industries, Inc.*



Self-consolidating concrete with a compressive strength of 12,000 psi (83 MPa) was used in the beams of the Harris Overpass, Lincoln, NE.

In October 2001, Concrete Industries, Inc. (CI) was working with its admixture supplier to improve our form finish for precast concrete products. They brought us a new product and before long the concrete slump became a 26-in. (660-mm) diameter circle. Obviously, this generated a lot of excitement with our production personnel, but we also had to consider what it would take to get architects and engineers comfortable with using it.

Two significant changes happened between then and now. First, the admixture and cement companies promoted the advancement of self-consolidating concrete (SCC). Second, CI—through the Prestressed Concrete Association of Nebraska (PCAN)—developed a strong partnership with the University of Nebraska and the Nebraska Department of Roads. Looking back, this partnership was the key to getting things done quickly. By mid-January 2002, in addition to studying a vast amount of information from Japan and Europe, we had determined that, by going to a smaller limestone coarse aggregate and finer sand, we could make a more consistent concrete. The smaller aggregate size and the use of a viscosity modifying admixture (VMA) allowed us to use a smaller cementitious materials content. The final cementitious materials content, water-cementitious materials ratio, and air content were not significantly different from our conventional slump concrete. This was a very important consideration for us. Because the final hardened concrete looked the same as our conventional slump concrete, it reduced concerns about the use of SCC. It allowed us to focus on segregation, the issue

everyone (including CI) was concerned about. All we needed to do was make sure we had no segregation and we would be successful.

### **From Parking Structures to Bridges**

Our first commercial project using SCC was a 275,000 ft<sup>2</sup> (25,500 m<sup>2</sup>), five-level, totally precast, concrete parking structure with nine different precast products totaling more than 6300 yd<sup>3</sup> (4810 m<sup>3</sup>) of concrete. We approached the contractor and architect with a proposal to use SCC. We attended a jobsite meeting to explain the technology, show our development data, and answer any questions. At the end of this meeting, it was stated that the concrete specification for this project was performance based. As long as the concrete performed per the specifications, CI could use this new material. In order to meet the delivery schedule, we had started this project by casting prestressed concrete double tees with conventional slump concrete. However, on February 28, 2002, we switched all production to self-consolidating concrete.

From the very beginning, we knew we wanted to use SCC in Nebraska bridge girders, so PCAN approached Lyman Freemon, the Nebraska State Bridge Engineer. After reviewing what CI had learned up to that point and considering any issues that might impact bridge design, Freemon gave PCAN his department's support. Each precaster would need to develop its own mix design and get the Nebraska Department of Roads (NDOR) approval. We then started working with the NDOR Materials and Testing Division. NDOR set up the design framework and had oversight of all phases of concrete production and placement. During this time, NDOR personnel would make unannounced inspections, do comparison tests, and review our concrete mixing and testing procedures.

We started testing SCC mixtures in January 2002. By March, CI had approval for initial testing of concrete in non-NDOR products. We needed to gather information about properties such as modulus of elasticity, shrinkage, and flexural strength. We knew the compressive strength and durability were going to be satisfactory, so we used our commercial projects to facilitate this testing. Towards the end of April, we had gathered enough data to settle on a final mix design. Once that happened, we started our work with Dr. Maher Tadros at the University of Nebraska at Lincoln (UNL). In addition to segregation, the biggest NDOR concern was strand bond. UNL verified the strand bond by doing full-scale testing for transfer and development length using NU Girders with many strands. They also used the Moustafa pullout test. We finished in May 2002, with NDOR giving CI approval to use SCC in all bridge products.

Our first project was a single-span bridge north of Crofton, NE. This bridge consisted of five NU1100, 43-in. (1100-mm) deep girders that were 104 ft (31.7 m) long. The design called for forty-four 0.6-in. (15-mm) diameter strands and concrete compressive strengths of 7500 psi (52 MPa) at release of the strands and 8500 psi (59 MPa) at 28 days. We made our first casting on May 13, 2002. Our actual concrete strengths were 7870 psi (54.3 MPa) at release of the strands and 9230 psi (63.6 MPa) at 28 days. From that time, the use of SCC for NDOR precast products became standard practice for CI. Our best performing mix shown in the table below achieved an average strength of 8800 psi (61 MPa) at 14 to 16 hours after casting and 12,000 (83 MPa) at

28 days. The admixture quantities were selected within the ranges listed to achieve the proper set control, slump flow, and cohesion.

### Further Information

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Material <sup>(1)</sup>	Quantities (per yd <sup>3</sup> )	Quantities (per m <sup>3</sup> )
Cement, Type III	800 lb	475 kg
Fly Ash, Class C	150 lb	89 kg
Fine Aggregate	1295 lb	768 kg
Coarse Aggregate <sup>(2)</sup>	1431 lb	849 kg
Water	292 lb	173 kg
Retarding Admixture	0 to 5 fl oz	0 to 193 mL
High-Range Water-Reducing Admixture	2 to 14 fl oz	77 to 542 mL
Mid-Range Water-Reducing Admixture	4 to 8 fl oz	155 to 309 mL
Viscosity Modifier	2 to 10 fl oz	77 to 387 mL
Water-Cementitious Materials Ratio	0.31	0.31

1. An air entrainment admixture was also used to achieve a total air content of 2 to 5%.
2. 1/2 in. (13 mm) maximum size limestone.

The above table lists the concrete mix proportions for the Harris Overpass beams as 800 lb of Type III cement, 150 lb of Class C fly ash, 1295 lb of fine aggregate, 1431 lb of coarse aggregate, 292 lb of water, 0 to 5 fl oz of retarding admixture, 2 to 14 fl oz of high-range water-reducing admixture, 4 to 8 fl oz of mid-range water-reducing admixture, and 2 to 10 fl oz of viscosity modifier for a total water-cementitious materials ratio of 0.31.

## ASTM Test Methods for Self-Consolidating Concrete

*Henry G. Russell, Henry G. Russell, Inc.*

Self-consolidating concrete (SCC) must have the ability to flow under its own weight, to pass reinforcing bars or other obstacles without segregation, and not segregate during or after

casting. The following ASTM standard test methods have been developed to address these fresh concrete properties.

### **ASTM C1611—Slump Flow of Self-Consolidating Concrete**

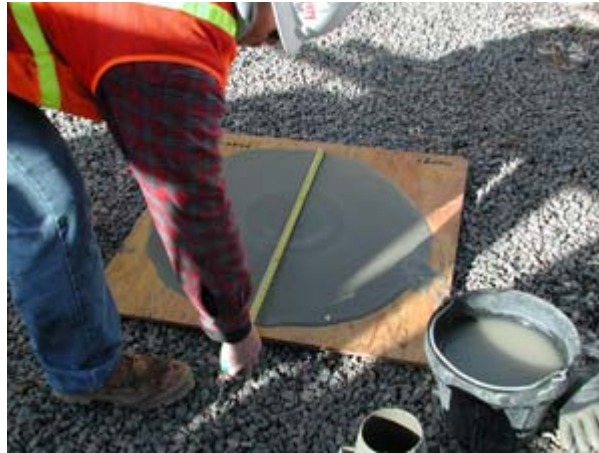


Photo: PCA

This test is performed in a similar manner and with similar equipment as the conventional slump test—ASTM C143. The slump cone can be either used the same way up or inverted. A sample of freshly mixed concrete is placed in the cone in one lift without tamping or vibration. The mold is lifted and the concrete allowed to spread. After spreading ceases, two orthogonal diameters of the concrete patty are measured. The slump flow is the average of the two diameters.

The slump flow test allows a comparison of the lateral flow and filling potential of different SCC mixtures. A common range of slump flow for SCC is 18 to 30 in. (450 to 750 mm). The slump flow test can be used in production to assess the consistency of SCC. According to ACI 237R-07, the slump flow should not differ by more than 2 in. (50 mm) from batch to batch.

A nonmandatory appendix of ASTM C1611 provides a procedure for a relative measurement of flow rate, viscosity, and stability. The flow rate is determined by measuring the time it takes for the outer edge of the concrete to reach a diameter of 20 in. (500 mm). The flow rate is influenced by the concrete's viscosity. The stability can be observed by visually examining the concrete patty for evidence of segregation.

## ASTM C1621—Passing Ability of Self-Consolidating Concrete by J-Ring

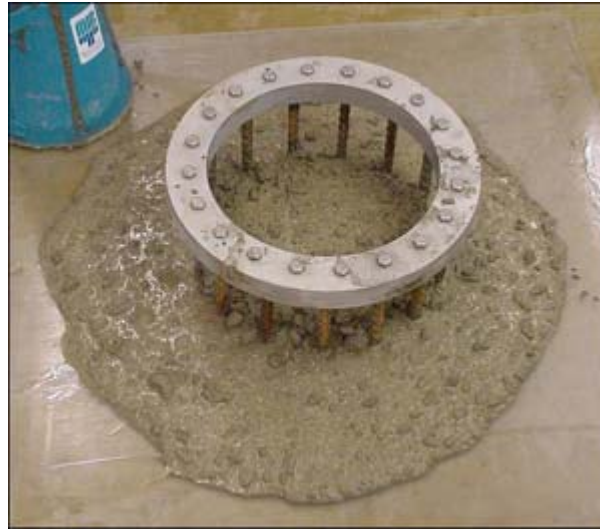


Photo: BASF Construction Chemicals

This test method provides a procedure to determine the passing ability of concrete by using a J-Ring in combination with the ASTM C1611 slump flow test. The J-Ring is placed outside the slump cone so that the concrete flows through the legs of the ring when the cone is lifted. The slump flow with and without the J-Ring is measured. A difference of less than 1 in. (25 mm) indicates good passing ability. A difference greater than 2 in. (50 mm) indicates poor passing ability. The test method is suitable for use in the laboratory and in the field.

## ASTM C1610—Static Segregation for Self-Consolidating Concrete Using Column Technique



Photo: BASF Construction Chemicals

In the test method, a sample of freshly mixed concrete is placed in a cylindrical mold without tamping or vibration. After 15 minutes, the mold is separated into three sections representing the top, middle, and bottom of the cylinder. Each section is removed individually and the concrete in the top and bottom sections washed over a No. 4 (4.75 mm) sieve. The retained aggregate from each section is weighed and the static segregation calculated as the difference between the bottom and top sections divided by the average weight. The test method is a laboratory procedure to determine the potential static segregation. An SCC mixture is generally considered to be acceptable if the percent segregation is less than 10% (ACI 237R-07).

### **Further information**

ACI 237R-07, Self-Consolidating Concrete, American Concrete Institute, Farmington Hills, MI, 2007, 30 pp.

[www.selfconsolidatingconcrete.com](http://www.selfconsolidatingconcrete.com).