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Bulb-T Beams with Self Consolidating Concrete on the Route 33 Bridge Over the Pamunkey River in Virginia

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16. Abstract

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Based on the positive results, beams with SCC were cast and placed in the Route 33 Bridge. The study found that SCC yielding adequate slump flow can be prepared without segregation and with satisfactory strength and acceptably low permeability. However, proper attention must be devoted to mixture proportioning, workability, stability, and air content to ensure the quality of the product.

The use of SCC in beams will have two major benefits: (1) expedited construction at the plant, a savings that is difficult to estimate at this time, and (2) improved quality. If the second benefit provides a 10 percent increase in service life, which is a reasonable expectation; given a typical $10.68 million yearly expenditure for prestressed concrete beams, this could lead to a cost savings for the Virginia Department of Transportation of close to $1 million per year.

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INTRODUCTION

The Virginia Department of Transportation (VDOT) routinely uses high performance concrete (HPC) in its structures. *HPC* may be defined as any concrete that provides enhanced performance characteristics for a given application.[1] Improvement in concrete properties such as workability, durability, strength, and dimensional stability should result in long-lasting, safe, and economical structures. Durability is the most important property in transportation structures.

One method of improving durability is to lower the permeability of the concrete.[2] VDOT has a special provision for low permeability. Permeability is determined using the rapid permeability test in accordance with AASHTO T 277 or ASTM C 1202. Low-permeability concretes contain pozzolans or slag, generally have a low water–cementitious material ratio (w/cm), and are very effective at attaining high durability. These modifications also result in concrete with high strength (above 6,000 psi), which could result in more economical structures by allowing for an increase in prestress force and section shear capacity. Improved economy is realized though increased span lengths; a reduction in the number of beam lines; and a reduction in substructure, transportation, and erection costs.[3,4]

Standard high-strength concrete mixtures have a low w/cm and therefore require high-range water-reducing admixtures (HRWRA). Slump loss problems and stiff concretes can lead to consolidation problems when many strands and conventional reinforcement are placed in forms. Self-consolidating concrete (SCC) provides very high workability, generally because of more fine material and admixtures compared to conventional concrete. SCC easily fills the congested spaces between the reinforcement (both mild reinforcement and prestressing steel) and in the formwork under the influence of its own mass without any additional consolidation. Easy flowing SCC would permit convenient and fast placement of concrete in beams. Eliminating the consolidation problem would enhance the strength and reduce the permeability of concretes, which is essential for longevity, and reduce repairs after casting because of poor consolidation, resulting in better quality prestressed concrete girders.

SCC has been used in Japan and Europe advantageously since the early 1990s.[5] Some of its benefits are decreased labor requirements and increased construction speed, improved mechanical properties and durability characteristics, ability to be used in heavily reinforced and congested areas, consolidation without vibration, and a reduced noise level at manufacturing plants and construction sites. However, there are concerns with its use: segregation, a poor air-void system, shrinkage, and reduced bond strength between strands and concrete. VDOT is interested in using SCC in bridge elements to achieve a higher level of structural performance, durability, and quality of castings than is currently attainable using conventional concrete.

VDOT has built bridges containing standard beams constructed in accordance with AASHTO I-beam shapes. However, these beams are not very efficient for long spans or a wide beam spacing. Therefore, engineers have introduced prestressed bulb-T beams with large bottom flanges that include more prestressing strands per foot of bridge width. Generally, bulb-T beams are more efficient for longer spans with high strength concretes (strengths exceeding 6,000 psi) when compared to standard AASHTO beams.[6] The bulb-T beams have the potential to increase the prestressed concrete girder span limits to 175 ft and provide a competitive alternate design to steel plate girders in the 120 to 175 ft span range. For these reasons, VDOT decided to use bulb-T beams in a new bridge where SCC was also to be evaluated.

PURPOSE AND SCOPE

The purpose of this study was to evaluate the construction and overall performance of SCC in bulb-T beams in the Route 33 Bridge over the Pamunkey River at West Point, Virginia. The field evaluations included the fabrication and placement of SCC and conventional non-SCC concrete having a minimum 28-day compressive strength of 8,000 psi, the instrumentation of bridge beams with strain gages and thermocouples, the testing of specimens cast during placement, and the measurement of strain and camber over time.

Before the construction of the bridge beams, two full-scale test beams were prepared and tested for transfer and development length and shear and flexural strength. Fresh and hardened properties of the SCC were also determined. This test program was designed to evaluate the performance of the SCC concrete and provide properties for future bridge designs.

METHODS

The Route 33 Bridge was designed for normal weight concrete beams in some spans including the control (non-SCC) and SCC spans. The 45-in bulb-T beams in these spans had draped strands with no debonding. Eight beams in one span were made using SCC, and the beams in the adjacent span were made from concrete with conventional workability (less than 7-in slump when an HRWRA is used) and used as controls. Initially, two test beams similar in cross section to the actual beams in the bridge were constructed and then loaded to failure at the Federal Highway Administration’s (FHWA) Turner-Fairbank Highway Research Center in McLean, Virginia. The following sections describe the test program for the experimental beams, bridge beams, and long-term instrumentation.

The specification required for conventional concrete[7] was also used for the SCC except that the slump flow (ASTM C 1611) rather than slump was included. The slump flow value was also determined using a J-ring (ASTM C 1621), which restrains concrete flow. In this procedure, an inverted slump cone is placed at the center of the J-ring. Slump flow with a J-ring that exceeded 22 in was desired in this project. Upon lifting of the cone, the time it took the concrete to reach a 20-in diameter was recorded. A U-box filling height in excess of 10 in, which is 70 percent of the maximum filling height, was assumed satisfactory.[8] The concrete was also tested for air content (ASTM C 231) and unit weight (ASTM C 138). The hardened specimens were subjected to the tests listed in Table 1. Table 1 also shows the specimen size and the number of specimens per batch. To determine if the concrete was actually SCC, hardened concrete samples from the same batch were prepared with and without rodding and were then compared.

The test and bridge beams were steam cured. The samples were placed in the recesses of the beam molds during steam curing. After steam curing, the beams and samples were left to dry in air.

Table 1. Test and Specimen Sizes for Hardened Concrete

Tests	Specifications	Size, in	Number
Compressive strength	AASHTO T 22	4 x 8	8
Elastic modulus	ASTM C 469	4 x 8	8
Splitting tensile strength	ASTM C 496	4 x 8	6
Permeability[a]	AASHTO T 277	2 x 4	4
Drying shrinkage[b]	ASTM C 157[b]	6 x 6 x 14	2
Freeze-thaw durability[c]	ASTM C 666	3 x 4 x 16	2

[a] Cured 1 week in moist room at 73 °F and 3 weeks in water at 100 °F.

[b] Specimens were removed from the molds within 24 hours; immediately, the two opposite sides were coated with epoxy to enable moisture loss from only two sides as in the web of the beams. Afterward, the specimens were left outdoors.

[c] Procedure A except that the test solution contained 2% NaCl.

Test Beams

Two test beams with SCC were cast on August 28, 2003. These beams were 45-in bulb-T beams and were 60 ft long. The beams were prestressed with 0.5-in-diameter strands draped at the 40 percent and 60 percent points of the beam length. The mixture proportions and the hardened concrete properties of SCC in test beams are summarized in Tables 2 and 3, respectively. A commercially available air-entraining admixture (AEA), a polycarboxylate-based HRWRA, and a small amount (1 fl oz/cwt) of an acrylic-based viscosity-modifying admixture were used. A concrete slab (9 in by 3 ft 11 in by 60 ft) was placed on top of the test beams. The partial width deck slabs were cast on September 9, 2003. The slabs contained a total cementitious materials content of 658 lb/yd^3, and 40 percent was slag. The w/cm was 0.43. The properties of the deck slabs are given in Table 4. The test beams were tested for transfer and development length and flexural and shear strength under various loadings.[9]

Table 2. Mixture Proportions for Test Beams

Materials	lb/yd^3
Cement (Type III)	480
Slag	320
Coarse aggregate	1430
Fine aggregate	1430
Water	267
Admixtures	**fl oz/cwt**
AEA	0.25
HRWRA	11.0
VMA	1.0

AEA = air-entraining admixture, HRWRA = high-range water-reducing admixture, VMA = viscosity-modifying admixture.

Table 3. Properties of Self-Consolidating Concrete Used in Test Beams

Fresh	Beam 1	Beam 2	
Slump flow (in) with J-ring	24	20	
T-20 in[a] (sec)	4.0	6.8	
Unit weight (lb/ft^3)	142.4	142.0	
Air (%)	7.4	7.4	
U-box (in)	13	12.8	
Hardened at 28 days	**Beam 1**	**Beam 2**	**Beam 2 Rodded**
Compressive strength (psi)	8,340	8,800	8,520
Permeability (coulombs)	750	533	664

[a] Time it takes for the outer mass of concrete mass to reach 20 in indicates relative viscosity.

Table 4. Properties of Concrete in Deck Slab on Test Beams

Property	Age (days)	Beam 1	Beam 2
Slump (in)		3.75	6.25
Air (%)		5.8	5.6
Concrete temperature (°F)		76	74
Unit weight (lb/ft^3)		148.0	145.2
Compressive strength (psi)	1	910	830
	3	1,890	1,720
	7	3,820	3,650
	28	6,260	5,690
Elastic modulus (10^6 psi)	28	4.90	4.63
Permeability (coulombs)	28	1702	1857

Bridge Beams

The Route 33 Bridge has 49 spans identified alphabetically from west to east. The SCC span, which is the second span from the east abutment, has eight 45-in bulb-T beams spanning about 74 ft. Each beam was cast with about 14 yd^3 of SCC. The two middle beams, SCC 4 and SCC 5, contain vibrating wire gage (VWG) and thermocouple instrumentation. The beam identification starts from the north edge of the span. On August 15, 2005, the two beams were cast and instrumented with the mixture proportions shown in Table 5.

On the same day and in the same precasting bed, beams with conventional concrete were cast for the control span, which is the third span from the east abutment and is adjacent to the SCC span. Two of the beams, Control 4 and Control 5, were instrumented for comparison with

Table 5. Mixture Proportions of Concretes

Material	SCC	Control
Portland cement (lb/yd^3)	480	510
Slag (lb/yd^3)	320	340
Coarse aggregate size	No. 78	No. 68
Coarse aggregate (lb/yd^3)	1451	1731
Fine aggregate (lb/yd^3)	1411	1029
Water (lb/yd^3)	272	336
w/cm	0.34	0.40
VMA (fl oz/yd^3)	16	----
Retarding admixture (fl oz/yd^3)	24	27
HRWRA (fl oz/yd^3)	96	66
Calcium nitrite (gal/yd^3)	2	2

SCC = self-consolidating concrete, VMA = viscosity-modifying admixture, HRWRA = high-range water-reducing admixture.

the corresponding SCC beams: SCC 4 and SCC 5. The mixture proportions of SCC and control concretes are given in Table 5. The SCC mixtures had less cementitious materials and a lower w/cm. To minimize segregation, a higher percentage of fine aggregate, a smaller maximum size aggregate, and a viscosity-modifying admixture (VMA) were used in the SCC mixtures. The aggregate gradings are shown in Figure 1. Concretes were tested in the fresh and hardened states. The tests in the hardened state and the number of specimens are shown in Table 1.

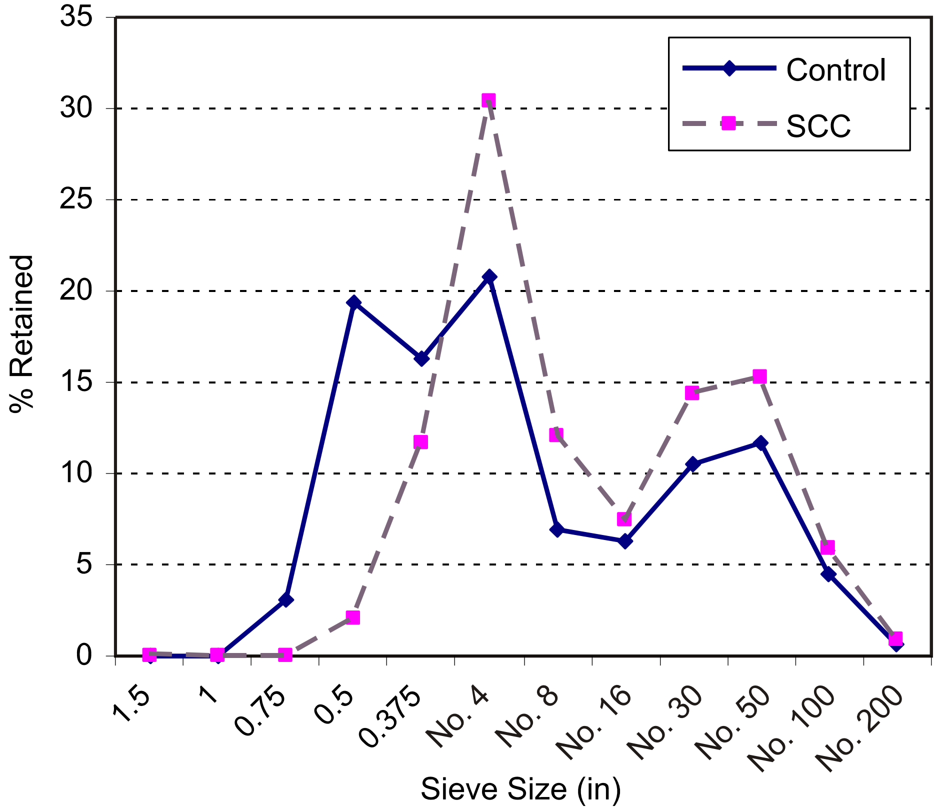

Figure 1. Aggregate Gradings for Self-Consolidating Concrete and Control Mixtures

Instrumentation

VWGs were installed near prestressing strands in the top and bottom flanges of the bridge beams to monitor strains and temperatures continuously from the time of concrete placement. Type T thermocouples were placed at mid-depth in the web of the bridge beams to measure the temperature of the concrete during the steam cure.

The test beams were instrumented with Whittemore gauge studs at the ends of the test beams at the time of fabrication to determine transfer lengths. Test beams were instrumented with strain gauges on the deck concrete and with linear potentiometers to measure beam deflection and strand slip during the load tests.

RESULTS AND DISCUSSION

Test Beams

SCC with a high flow rate was obtained. The SCC leveled itself and did not require consolidation or surface finishing. However, upon stripping of the forms, bugholes (surface air voids) were observed, especially on the top of the bottom flange and the side of the top flange.

The fresh and hardened properties of the test beams were given in Table 3. The SCC had an average compressive strength of 8,570 psi at 28 days and a permeability value of 642 coulombs, much lower than the specified 1500 coulombs. The similar strengths for the rodded and unrodded cylinder specimens indicated that the concrete was self-consolidating. The deck concrete cast on the test beams was vibrated. The fresh and hardened concrete properties of the deck concrete given in Table 4 indicated satisfactory workability, air content, strength, and permeability.

The two test beams were shipped to the FHWA’s Turner-Fairbank Structures Laboratory for testing. During testing, the average compressive strength of the concrete specimens for the beams was 9,580 psi and the splitting tensile strength was 820 psi; for the deck, the values were 8,360 psi and 690 psi, respectively. The transfer lengths measured were less than predicted by theoretical calculations and are summarized in Table 6. The two test beams were tested in four combinations of moment and shear to force various modes of failure, including shear, flexure, and flexure-shear failures. A strand development failure was never realized even when the test load was placed near the beam end. The strands were well bonded to the concrete near the beam end, and strand slip was minimal. These structural tests indicated that the test beams could reach nominal flexural capacity as determined by sectional analysis. Shear failures caused by web crushing occurred at a shear load (pounds) very close to that in Eq. 1.

Table 6. Transfer Length Before and After Placement of Slab

Batch	Before (in)	After (in)
B1A	24	25
B1B	23	18
B1C	---	---
B1D	14	13
B2A	12	12
B2B	20	34
B2C	23	18
B2D	26	16
Average	20.3	19.4
SD	5.3	7.7

$$\text{Shear load} = 10(f'_c)^{0.5} b_w d_v \qquad \text{(Eq. 1)}$$

where

f'_c = actual strength of concrete at time of testing (psi)
b_w = web width (in)
d_v = structural depth of composite beam (in).

The calculations also indicated that the tensile capacity of the concrete in the beam web was 5.3 times the square root of the compressive strength. This is slightly less than the capacity usually assumed by bridge designers when checking principal tensile service load stress in the beam web. In summary, the test beams behaved as would be expected for normally consolidated concrete beams. These positive results from the test program justified the use of SCC in eight beams of the second span from the east abutment of the bridge. The producer was paid a delta cost for the beams used in this span. The producer then requested to be allowed to cast the remaining 32 girders for the bridge using SCC without an increase in cost, which VDOT and FHWA supported. This demonstrates the benefits the producer recognized in using SCC.

Bridge Beams

Placement

The first day of SCC casting started with difficulties. In the same bed, two SCC and two control beams with gages were prepared. The first four batches were rejected. The first batch did not have sufficient flow, since the concrete just reached the J-ring circle (12 in). The second batch was marginal in flow and air content. The third and the fourth batches were unsatisfactory because they had 2.5 percent to 2.6 percent air content, which was less than the required minimum of 4 percent. These last two mixtures had a high slump flow and were unstable, exhibiting segregation and air popping on the surface. Segregating mixtures have difficulty maintaining the desired air content. Moisture in aggregates was more closely checked, and the amount of AEA was increased. As a consequence, the following concrete batches flowed well without segregating and had sufficient air content, as represented by Batch B1 as shown in Table 7. The grading of the aggregates is shown in Figure 1, indicating that adjustments are needed to obtain well-graded aggregates since deficiencies were evident on particular sieves.

Table 7. Fresh Concrete Properties of Bridge Beams

Batch	Date (2005)	Concrete	Slump Flow with J-ring (in)	T20[a] (sec)	Slump (in)	Air (%)	U-Box Flow (in)	Concrete Temperature (°F)
B1	08/15	SCC	22	2.8	--	5.3	12.0	88
B2	08/15	SCC	23.7	3.2	--	5.6	9.8	86
B3	08/15	Control	--	--	8.0	4.2	--	86
B4	08/15	Control	--	--	6.3	4.5	--	87
B5	08/17	SCC	27	--	--	4.5	13.3	82
B6	08/17	SCC	21	--	--	5.0	13.3	84
B7	08/17	SCC	23	--	--	5.2	12.8	84
B8	08/19	SCC	19.5	--	--	4.5	10.8	--
B9	08/19	SCC	27	--	--	4.5	13.3	--

[a] Time it takes for the outer mass of concrete mass to reach 20 in indicates relative viscosity.

Each batch of SCC was 4 yd^3 and was delivered in trucks with an auger (Tuckerbuilt units), which placed concrete near one end of the beam and then slowly moved it toward the other end to minimize the distance the concrete had to flow. SCC that must travel long distances tends to lose stability (segregate) because of the restraint provided by the reinforcement.

During casting of the second beam, coarse aggregates in the bin had been depleted. Unfortunately, coarse aggregate brought in from the stockpiles did not have a uniform moisture content, thus causing inconsistency in the mixtures. Some delivery vehicles had concrete segregating, especially at the beginning and end of the load. The sensitivity of SCCs to moisture content was evident; some batches were wet, and others were dry. Typically, SCC does not need vibration; however, the concrete in this second beam was not flowing well, especially in the top flange region. Therefore, a minimal amount of internal vibration was used in the upper flange. In these two beams, water and very fine material seeped through the spaces around the strands in the bulkheads. Foam was sprayed to close the void spaces around the strands to prevent the mortar from escaping.

On the bed, there were two additional beams cast with conventional 8,000-psi concrete. The mixture proportions of these control beams are given in Table 5. These two beams, designated Control 4 and Control 5, are the middle beams and correspond with SCC beams SCC 4 and SCC 5 in the adjacent span. Each of these four beams was instrumented to enable comparison of the behavior of SCC and conventional concrete.

Upon removal of the formwork the next day, bugholes were evident on all four beams. However, the SCC beams had fewer and shallower bugholes. Nevertheless, the casting did not achieve the desired smooth surface finish, especially on the top of the bottom flange and the sides of the top flange. Therefore, the research team and the contractor planned a few changes for the next set of four SCC beams cast on August 17, 2005. First, the contractor used 1 to 2 sec of external vibration along the sides of the forms to expel the trapped air to give a smoother surface finish. In addition, 1 to 2 sec of internal vibration was applied in the top flange when the SCC was not flowing well because of the lack of a pressure head. The coarse aggregate stockpile was kept wet with sprinklers to ensure a uniform moisture content. The fine aggregate content and the amount of AEA and VMA were increased and the coarse aggregate content was reduced to obtain more stable mixtures. The new fine aggregate content was 1,477 lb/yd^3, the coarse aggregate content 1,382 lb/yd^3, and the VMA content 24 oz/yd^3. When stripped of the formwork the next day, the beams had fewer bugholes than with the initial SCC beams. On August 19, the last two beams were cast, with results similar to those for the previous set.

After these 8 beams for the control span were cast, 32 more SCC beams were cast for the Route 33 Bridge. Similar issues were encountered. At low slump flow, bugholes were evident even on the web, as shown in Figure 2. When the slump flow was high, the number of bugholes was reduced, but fine material rose to the surface, indicating some loss of stability. A frothy-looking surface layer was evident, as shown in Figure 3. Loss of stability results in loss of air

Figure 2. Bugholes on Web and Top of Bottom Flange

Figure 3. Frothy Look on Top in Concrete With High Flow Rate

voids. A high level of quality control is necessary to ensure stable SCC with the proper air-void system. To obtain robust SCC, proper attention should be given to using well-graded combined aggregates; using fine aggregate with a lower void content; using more fine material; minimizing the specific gravity difference between the coarse and fine aggregate; and using VMA with the appropriate dosage.

Properties

Four batches of concrete were tested: two each of SCC and control concrete. The fresh concrete properties summarized in Table 7 indicate that a U-box filling height of about 10 in and more was obtained in SCC. The slump flow values were above 22 in except in one batch; however, the filling height was high in that case. Air contents were within the specified limits. There was variability in flow, indicating the need for better quality control, especially with regard to the moisture content of the aggregates. Conventional concretes were workable and had the proper air content.

The specimens were steam cured with the beams. SCC attained 5,780 psi the next morning, exceeding the specified release strength of 5,000 psi. The control had 4,920 psi the next morning, close to the release strength. The remaining results of tests on hardened concrete given in Table 8 indicate that SCC had a high compressive strength exceeding 10,000 psi and a high splitting tensile strength averaging 788 psi at 28 days. The conventional concrete did not reach the compressive strength of 8,000 psi specified at 28 days, and the splitting tensile strength was lower, 620 psi at 28 days. At 1 year, the compressive strength of conventional concrete was close to or higher than 9,000 psi. The 1 year splitting tensile strengths exceeded 800 psi. The average elastic modulus values exceeded 5,000 ksi at 28 days and later. The strength of the SCC was higher than that of the conventional concrete; however, the elastic modulus values were equal or lower.

The permeability values were low for both concretes. The results of the testing for resistance to freezing and thawing in accordance with the severe test procedure (ASTM C 666,

Table 8. Hardened Concrete Properties of Bridge Beams

Property	Age (day)	B1 (SCC)	B2 (SCC)	B3 (Control)	B4 (Control)
Compressive strength (psi)	2	7,470	6,650	6,270	5,790
	7	9,170	8,860	7,760	6,960
	28	10,110	10,700	7,960	7,610
	1 year	11,230	10,940	9,750	8,730
Elastic modulus (10^6 psi)	2	5.07	4.54	4.99	4.52
	7	5.1	5.06	5.45	5.15
	14	5	5.19	5.69	5.16
	28	4.86	5.35	5.26	4.98
	1 year	5.44	5.16	5.8	5.33
Splitting tensile strength (psi)	7	760	695	715	650
	28	820	755	675	565
	1 year	840	895	805	810
Permeability (coulombs)					
Dry	28	869	996	1,011	985
Wet	28	1195	1487	--	--
Shrinkage (microstrain)	112	295	255	328	320

Procedure A) indicated poor performance in all concretes, as shown in Table 9. The acceptance criteria at 300 cycles are a weight loss of 7 percent or less, a durability factor of 60 or more, and a surface rating (ASTM C 672) of 3 or less. SCC and the conventional concrete had low durability factors. The weight loss and surface rating were higher in SCC. It appears that the use of polycarboxylate HRWRA led to coarser bubbles in the concrete, and for the given air contents, the number and distribution of voids were not sufficient. Such occurrences at the low air content ranges used in precast prestressed concrete with HRWRA are common.[10] However, it is difficult for these beams to become critically saturated, and poor field performance is not expected. The shrinkage values at 112 days were lower for the SCC, which was attributed to the lower water content.

The camber values for the instrumented beams are shown in Figure 4. The strain values as an average of the two gages at each location are displayed in Figures 5 and 6 for the SCC and control beams, respectively. The average camber for SCC was slightly higher than for the conventional concrete at an early age, but cambers and strains for all beams have been similar in service.

Table 9. Freeze-Thaw Data

Batch	Concrete	Weight Loss (%)	Durability Factor	Surface Rating
B1	SCC	20.1	13	1.7
B2	SCC	13.7	7	2.7
B3	Control	1.7	37	0.8
B4	Control	5.5	16	1.4

SCC = self-consolidating concrete.

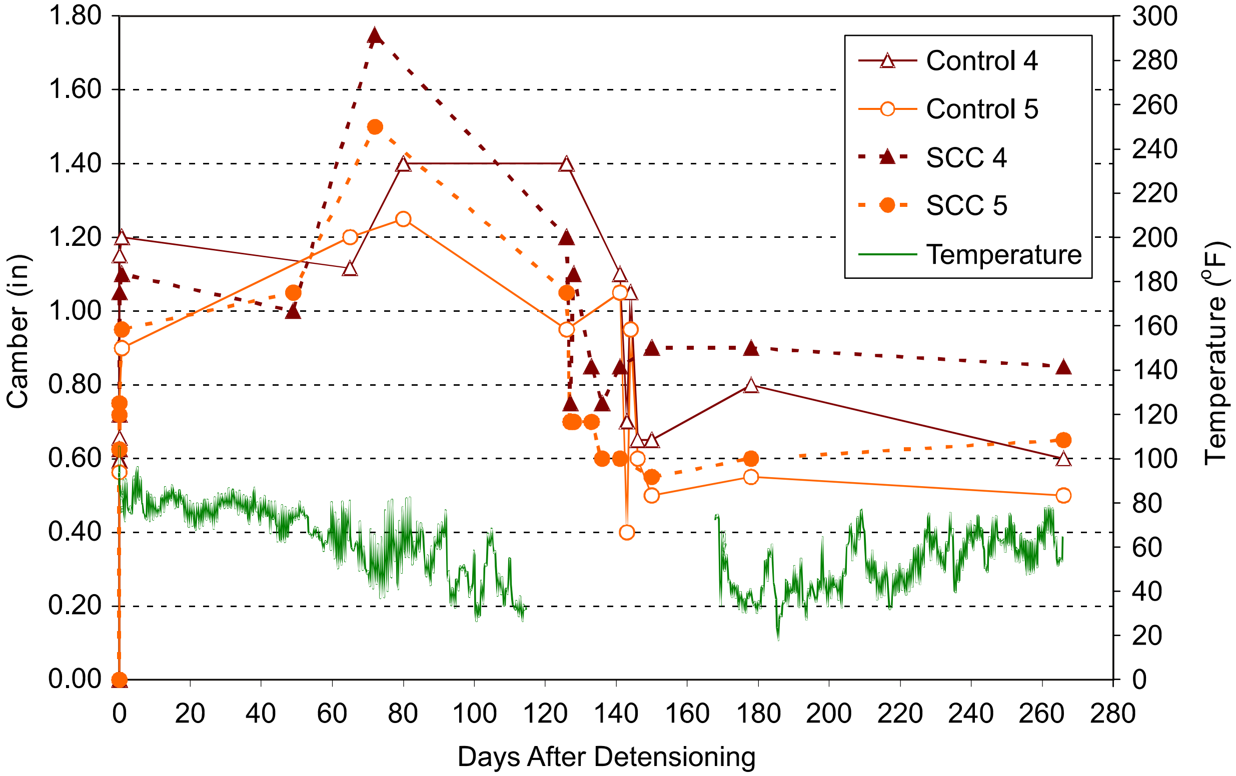

Figure 4. Camber of Self-Consolidating Concrete (SCC) and Control Beams

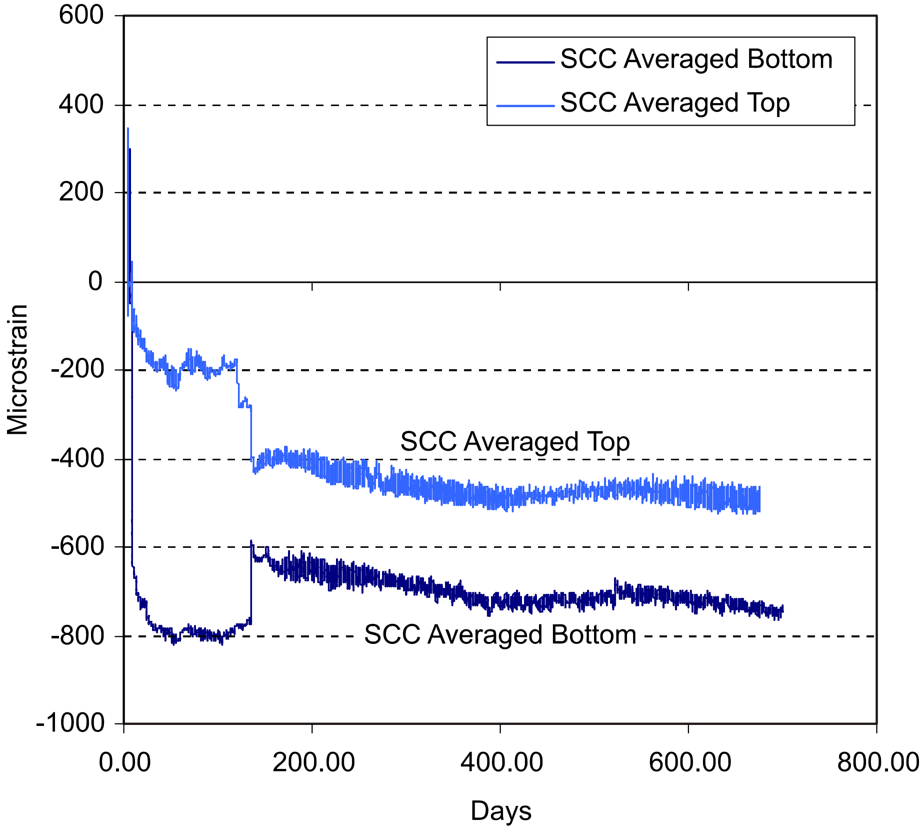

Figure 5. Strain in Self-Consolidating Concrete (SCC) Beams (microstrain versus days)

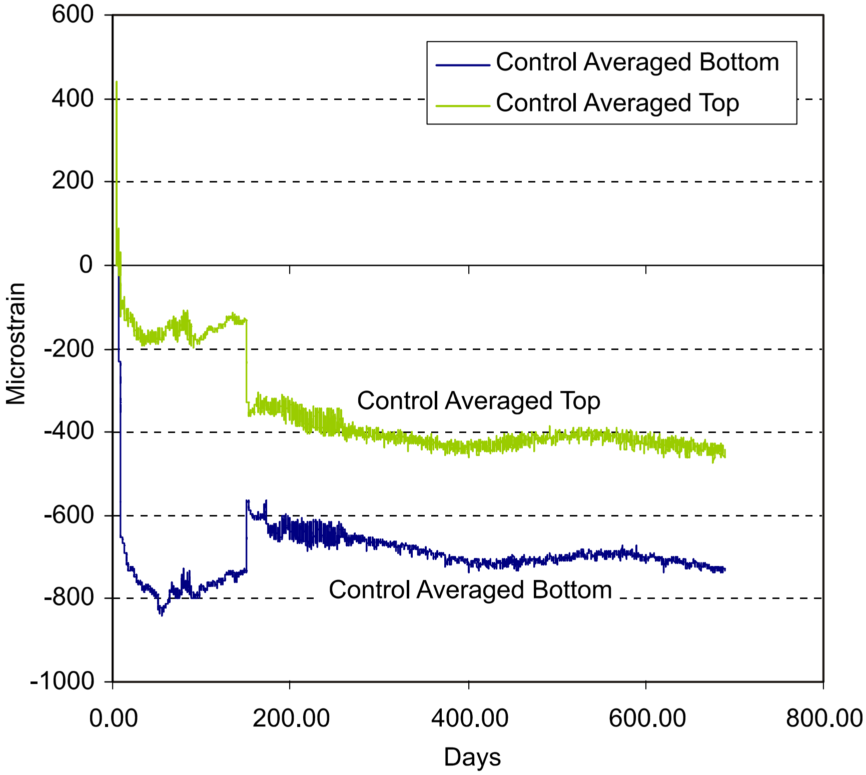

Figure 6. Strain in Control Beams (microstrain versus days)

CONCLUSIONS

- *SCC can be placed successfully, and beams with SCC behave successfully:*

- *SCC yielding adequate slump flow without segregation and with satisfactory strength and permeability can be prepared.* However, proper attention must be devoted to mixture proportioning, workability, stability, and air content to ensure a quality product.

- *SCC is very sensitive to water content.*

- *A low slump flow does not lead to self-consolidation, and SCC with a low slump flow may require mechanical vibration.* Slump loss with time and the short height of concrete discharge as in the top flange of the beam may necessitate minimal vibration for proper consolidation.

- *A high slump flow may lead to segregation and loss of air voids.*

- *Concrete with polycarboxylate-based HRWRA at the low air contents given in the specifications may not have the proper resistance to freezing and thawing when tested in accordance with ASTM C 666, Procedure A.* Satisfactory freeze-thaw resistance is critical in elements that are critically saturated since the expansion of water during freezing generates high stresses. However, satisfactory field performance of the concrete investigated in this study is expected because of the lack of critical saturation.

- *Strand slip measured at the end of the beams was minimal, indicating satisfactory bond between the concrete and the strand.*

- *SCC members can be designed using the same methods, assumptions, and limiting values as used for normally consolidated concrete.*

RECOMMENDATIONS

1. *VDOT's Materials Division and Structure & Bridge Division should permit the use of SCC in beams.* However, the casting procedures should be closely monitored to ensure a quality product.

2. *The Virginia Transportation Research Council should work with VDOT's Materials Division and Structure & Bridge Division to develop a special provision for SCC to be used in future prestressed concrete girder projects.* The goal is for the use of SCC to be standard practice for prestressed concrete girders and probably for most other precast elements.

COSTS AND BENEFITS ASSESSMENT

The use of SCC in beams may have two benefits: expediting construction at the plant and improving quality. No estimate of the personnel-hours saved during fabrication at the plant was attempted in this study. Given the attention to mixture proportions, water content, and air content that SCC requires, the net cost savings during fabrication is difficult to predict.

The cost savings from improved quality is more certain and more predictable. Consolidation problems in beams are common because of the geometry and the amount of reinforcement. Further, replacing and repairing beams are difficult and costly because of the deck structure above them. It is reasonable to expect that the better consolidation that results from the use of SCC will increase the service life of bridge beams by about 10 percent. If better consolidation results in a 10 percent increase in service life, a large savings would occur. In fiscal years 2003 through 2008, VDOT spent an average of $10.68 million per year on prestressed concrete beams. Thus, VDOT could save close to $1 million each year through the use of SCC in beams.

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