TRANSPORTATION LEARNING NETWORK

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Welcome!

Self-Consolidating Concrete for Prestressed Bridge Girders

Junwon Seo

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Self-Consolidating Concrete for Prestressed Bridge Girders

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Presentation Outline

1. Project Objectives
2. Project Tasks
3. Conclusions
4. Recommendations
5. Future Work

Project Objectives

1. To develop a SCC mix design guideline for the use of SCC in PSC girders on WisDOT bridge projects
2. To examine effects of various SCC mixture constituents on the material characteristics
3. To investigate structural behavior of a full-scale prestressed SCC girder

Project Tasks

1) Task 1: Literature Review (DOTs' Survey)
2) Task 2: SCC Material Supplier Identification
3) Task 3: SCC Material Testing
4) Task 4: SCC Mix Design Guideline Development
5) Task 5: SCC Girder Implementation

Task 1

Fresh Properties

Fresh Properties

- Stability
  - Dynamic stability describes the resistance of the concrete to the separation of the constituents during transport, placement, and spread into the formwork
  - Static stability is the resistance of the concrete to bleeding, segregation, and surface settlement.
- Passing and Filling Ability
  - Abilities to flow through tight openings, such as spaces between reinforcing bars, under its own weight.
- Segregation
  - Distribution of aggregate particles is relatively equal at all locations of the mix.

Task 1

Strength

Strength Features:

- SCC has shown higher strength than normal concrete.
- Cement content, w/c ratio, and coarse aggregate are the constituents that have more influence on the compressive strength.
- SCC mixtures using limestone fillers have shown substantial higher strength than other mixtures.
- SCC shows a slower growth on strength compared to normal concrete.

Task 1
Shrinkage

Shrinkage Features:

- Several studies have shown that normal concrete exhibits higher strain changes than SCC.
- Types of Shrinkage:
  - Plastic shrinkage.
  - Autogenous shrinkage (lower for SCC).
  - Drying shrinkage (higher for SCC).
- Causes of Shrinkage:
  - Low aggregate content.
  - High water cement ratio.
  - Usage of HRWR.

Task 1
Creep

Creep Features:

- Studies show that SCC may experience 10-20% more strain than high performance concrete.
- Creep behavior is affected by the compressive strength, coarse aggregate and cement type.
- W/c ratio does not seem to have an effect on creep.
- Reasons:
  - SCC with high paste volumes.
  - Low stiffness from aggregates.
  - Binder content and binder type.
  - Loading applied at sample age.

Task 1
DOTs' Survey

State	Survey Y/N	SCC Specifications	Research Report
Alabama	Y	Y	
Florida		Y	Y
Georgia		Y	Y
Illinois		Y	Y
Iowa	Y		
Kentucky		Y	
Louisiana		Y	
Michigan		Y	Y
Minnesota	Y	Y	Y
Nebraska	Y	Y	Y
New York		Y	
North Carolina	Y	Y	Y
Ohio	Y		
Pennsylvania	Y	Y	
Rhode Island	Y	Y	
South Carolina	Y	Y	Y
South Dakota	Y	Y	Y
Texas	Y	Y	Y
Utah	Y	Y	
Washington	Y	Y	

Task 1
DOT Survey

Q1: Does your state have specific mix parameters for the application of Self-Consolidating Concrete (SCC)? If yes, for what applications have SCC been used? (E.g. girders, box culverts, etc.)

Q2: Describe the following materials if used:

a. Type of cement used

b. Cementitious materials used:

c. Coarse Aggregate/Size

d. Fine Aggregate/Size:

e. Admixtures Used.

Q3: Select Test Methods used and include accepted range of values.

Q4: Does your state have either past or ongoing research on SCC.

Q5: What is research plan for SCC characteristics and applications?

Task 1

DOT Survey-Example (Virginia DOT)

Q1: The mix parameters shall be designed with the same parameters as the class of concrete, with a different slump requirement and different admixtures. It is used currently in bridges, beams, drilled shafts, prestressed beams, and precast items.

Q2: a. Type of cement: Type III.

b. Other cementitious materials: None.

c. Coarse aggregate: Max ¾". Not < ¾ minimum clear space.

d. Fine aggregate: no requirements.

e. Admixtures:-VMA: Must meet ASTM C494.

-Shrinkage reducing admixture.

f. Max w/c: 0.45.

Task 1

DOT Survey-Example (Virginia DOT)

Q3: **a.** Slump Flow: 26 +/- 3 in (ASTM C1611).

b. J-Ring Flow: <= 2 in difference from slump flow.

c. Column Segregation: 15% max.

d. VSI: <= 1.

e. Compressive Strength: 4000 psi at release. 6000 psi at 28 days.

f. Permeability: Coulomb requirements depend on the design.

Q4: Yes, our research council (VCTIR) at the University of Virginia uses SCC on several projects.

Q5: VCTIR recently used SCC in pier caps for bridges. The research project has been successfully done thus far at Nimmo Parkway in Virginia Beach.

Task 1

DOTs' Survey

State	Slump Flow	J-RIng	VSI	L-Box	Column Segregation
Alabama	25-29"	±3"	0-1	NA	NA
Florida	27 ±2.5"	±2"	0-1	NA	Max 15%
Georgia	Min 20"	NA	Na	Min 0.8	NA
Illinois	20-28"	Max 4"	0-1	Min 0.6	Max 15%
Iowa	Max 27"	NA	NA	NA	NA
Kentucky	Provide Spread Limits, Production Records and Quality Control Procedures.				
Louisiana	20"-28"	Provide Aggregate Gradations			
Michigan	27" ±1"	±0.6"	0-1	Min 0.8	NA
Minnesota	Max 28"	±2"	0-1	NA	NA
Nebraska	ASTM C1611	NA	ASTM C1611	NA	NA
Nevada	No specific guidelines.				
New York	±2" Target	±2"	0-1	NA	Max 15%
North Carolina	24"-30"	±2"	NA	Min 0.8	NA
Ohio	27±2"	NA	NA	NA	NA
Pennsylvania	20"-30"	±2"	0-1	NA	NA
Rhode Island	20"-26"	±2"	NA	NA	NA
South Carolina	Precasters in the state are hesitant in using SCC.				
South Dakota	20"-28"	±2"	0-1	NA	NA
Texas	22"-27"	±2"	0-1	NA	Max 10%
Utah	18"-32"	±1"	0-1	NA	Max 10%
Virginia	26"±3"	±2"	0-1	NA	Max 15%
Washington	±2" Target	±1.5"	0-1	NA	Max 10%

Task 1

Requirements for SCC Mix

1) Strength [WisDOT]:
- Initial: 6800 psi
- 28 days: 8000 psi

2) Cement [DOT Surveys]
- Portland Cement Type III (Minimum 720 lbs/cubic yards)

3) Aggregates [WisDOT]:
- Maximum content of sand is 50% of coarse total aggregate.
- Aggregate gradation: AASHTO No. 67 Stone.

4) Water Cement Ratio [DOT Surveys]:
- Less than 0.40.

5) Air-Entraining [DOT Surveys]:
- Air entrainment of 6%(± 2%).

6) Other Requirements:
- Transport, placement and finishing requirements.

Task 2

- **Overview:**

County Materials Roberts	• Cement Type I/II • Crushed limestone aggregate • Grace Admixtures
County Materials Janesville	• Cement Type III • Crushed limestone aggregate • Grace admixtures
Spancrete	• Cement Type III • River Gravel • SIKA admixtures

Task 2

Material Identification

Supplier I: County Materials in Wisconsin

1. Contact Person: Ziad Sakkal/Brian Rowekamp
2. Materials to be used:
   - LaFarge Type III LA Cement (Janesville)
   - LaFarge Davenport Type I/II (Roberts)
   - Aggregates:
     - ❑ Fine Aggregate: Glacier Sand.
     - ❑ Coarse Aggregate: ¾" and 3/8" limestone
   - Admixtures provided by Grace:
     - ❑ VMA
     - ❑ HRWR

Task 2
Material Identification

Supplier 2: Spancrete in Wisconsin

1. Contact Person: Paul Staroszczyk and Forrest Brunette.
2. Materials to be used:
   - St. Marys Type III.
   - Aggregates:
     - ❑ Fine Aggregate: Evenson Sand.
     - ❑ Coarse Aggregate: Evenson Stone (River Gravel).
   - Admixtures provided by SIKA:
     - ❑ VMA
     - ❑ HRWR

Task 3

- **Phase 1: Lab Testing**
  - ❑ Fresh Properties: Slump Flow, J-Ring and Column Segregation
  - ❑ Compressive Strength: 18 hours and 28 days of curing
- **Phase 2: Plant Testing**
  - ❑ Creep Test
  - ❑ Shrinkage Test

SDSU

Phase 1
Test Methods

Slump Flow Set up

Slump Spread

SDSU

Phase 1
Test Methods

J-Ring Set Up

J-Ring Spread

Phase 1
Test Methods

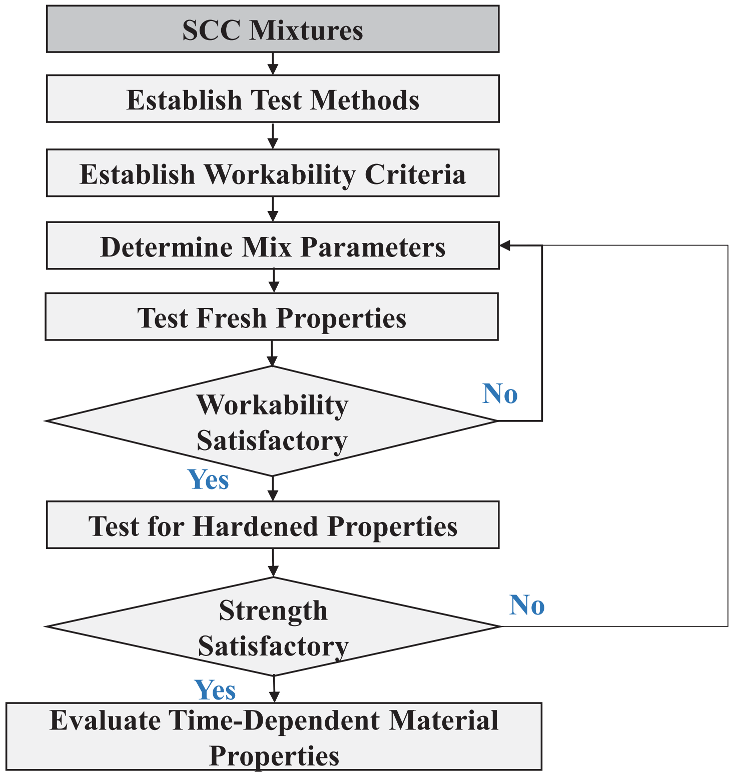
Column Segregation Set Up

Sliding Board to Collect Top Part

Phase 1
Test Methods

Phase 1

Protocol



Phase 1

Mixture Requirements

1. Cement Content: 800 lbs. per cubic yard
2. S/Agg: 0.5
3. Water cement ratio: 0.35
4. Blend ¾″ and 3/8″ coarse aggregates.
   - Find optimum blending configuration.
   - 20% variation of 3/8″
5. Cement Type
   - Type I/II: County Materials Roberts
   - Type III: County Materials Janesville

Note that mixtures of Spancrete were not used for the initial investigation due to a lack of materials from the precastor.

Phase 1
Criteria

Fresh Properties Tests	Acceptable Range	Target Value
Slump Flow	22" – 28"	25"
J-Ring	Max 2"	Max 2"
Column Segregation	≤ 15 %	Close to 10 %
T_{20}	3-10 sec	<6 sec
VSI	≤ 1	≤ 1
Compressive Tests	Target strength	
Strength	6800 psi (18 hours)	
	8000 psi (28 days)	

Phase 1
Test Matrix

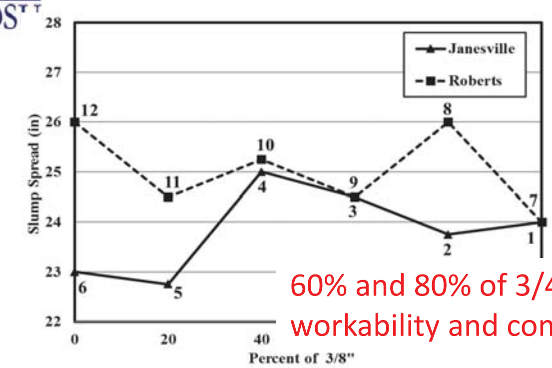
Plant	Mixture No	Aggregate Size (3/8")						Cement Type		w/c	S/Agg
		100%	80%	60%	40%	20%	0%	Type III	Type I/II	0.35	0.50
Janesville	1	X						X		X	X
	2		X					X		X	X
	3			X				X		X	X
	4				X			X		X	X
	5					X		X		X	X
	6						X	X		X	X
Roberts	7	X							X	X	X
	8		X						X	X	X
	9			X					X	X	X
	10				X				X	X	X
	11					X			X	X	X
	12						X		X	X	X

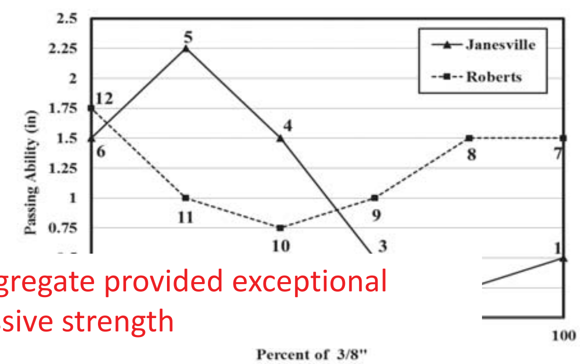
Phase 1
Results

No.	Percent of 3/8"	HRWR oz/cwt	VMA oz/cwt	Slump (in)	T20 (s)	J-Ring (in)	Column Segregation (%)	18hrs Compressive Strength (psi)
	Janesville Type III (Cement Content 800lbs)							
1	100	5	1	24	9.4	24.5	2.76	6442
2	80	5.5	1	24	7.54	24	6.32	7027
3	60	6	0	24.5	12	25	6.47	6756
4	40	5	1	25	9	23.5	8.17	7658
5	20	5.5	1	22.75	10.6	25	9.18	8432
6	0	5	2	23	7.32	24.5	10.1	7049

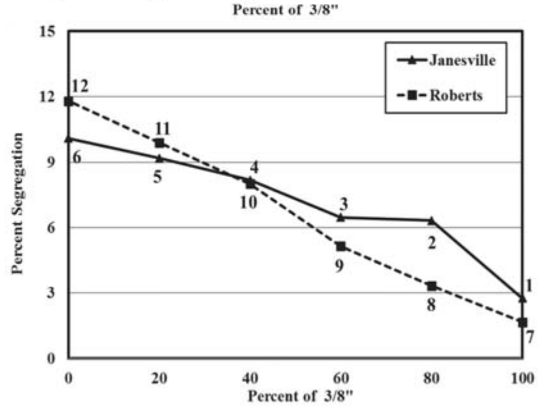
No.	Percent of 3/8"	HRWR (cwt)	VMA (cwt)	Slump (in)	T20 (s)	J-Ring (in)	Column Segregation (%)	18hrs Compressive Strength (psi)
	Roberts Type I/II (Cement Content 800lbs)							
7	100	5	0	24.5	10	22.5	1.67	5221
8	80	6	0	26	7	24.5	3.33	5521
9	60	5	0	24.5	9	23.5	5.15	6187
10	40	6	1.5	24.75	3.4	23.5	8.01	7113
11	20	5	1.5	24.5	4.9	24	9.9	5918
12	0	5	2	26	5.71	24.25	11.8	5870

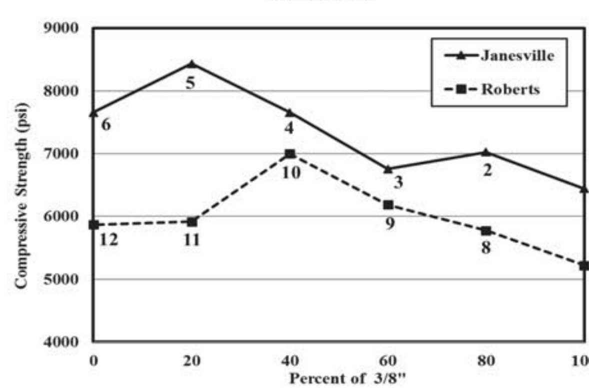
Phase 1
Results





60% and 80% of 3/4” aggregate provided exceptional workability and compressive strength





Phase 1

Additional Testing Results

No.	Mixture Code	%= 3/4"	HRWR Oz/cwt	VMA Oz/cwt	Slump Flow (in)	T20 (s)	J-Ring (in)	Column Segregation (%)	Air %	Temp. (F°)	Compressive strength (psi) 18 hr.	Compressive strength (psi) 28 days
Roberts												
1	CR-800-0.50-0.33	60	6	1.5	24.75	3.4	23.50	2.1	2.2	83	7113	8750
2	CR-800-0.45-0.33	60	5	2	24.6	3.6	23.75	10.2	1.9	80	6959	10393
3	CR-800-0.50-0.33	80	5	1.5	24.5	4.9	24.00	9.9	1.8	82	7135	9994
Janesville												
4	CJ-800-0.50-0.35	60	3.5	3	24.75	3.9	23.50	2.8	2.2	87	6932	10164
5	CJ-750-0.45-0.35	60	4.5	2.3	24.75	5.2	24.00	4.8	2.1	82	6957	9877
6	CJ-800-0.50-0.35	80	3.5	3.5	25.25	4.8	24.50	4.3	1.9	84	7049	9427
7	CJ-800-0.45-0.35	80	4	2.5	25.00	4.6	24.00	6.4	1.8	76	6994	9242
Spancrete												
8	SP-800-0.50-0.35	60	3	1.5	25.75	6.11	23.5	2.3	2.1	81	6736	8307
9	SP-800-0.45-0.35	60	4	2	25.25	5.83	23.75	5.7	2.0	81	6923	8931
11	SP-750-0.45-0.35	60	3	2	24.5	5.34	22.25	2.5	2.1	82	6709	8516
12	SP-800-0.50-0.35	80	3	2	26.25	3.11	24.5	12.1	2.4	84	6862	9076

Phase 2

- **Overview:**

a) Each plant tested the mixtures selected (1, 2, 4, 6 and 9) and adjusted the admixtures dosage to improve the workability between December, 2015 and January, 2016.

b) We visited each plant on February 9-12, 2016. Fresh properties tests were performed at each plant for the selected mixtures.

c) Creep and shrinkage samples were cast and transported to SDSU facilities to monitor changes in strain for a period of a year.

Phase 2

- **Roberts:**


a) SCC Placing


b) Slump Spread


c) Column Segregation


d) SCC Cylinders


e) J-Ring Test

Phase 2

- **Janesville:**


a) Slump Spread


b) J-Ring Test


c) Column Segregation


d) Aggregate washing


e) SCC showing segregation

Phase 2

- **Spancrete:**

a) J-Ring Test

b) Column Segregation

e) Shrinkage Prisms

c) Drying the aggregate

d) Preparing Shrinkage Prisms

Phase 2

- **Result Summary:**

No.	Mixture Code	%= 3/4"	HRWR Oz/cwt	VMA Oz/cwt	Slump Flow (in)	VSI	T20 (s)	J-Ring (in)	Column Segregation (%)	Air %	Temp. (F°)	Unit Weight	Compressive strength (psi)	
													18 hr.	28 days
County Materials Roberts														
1	CR-800-0.50-0.33	60	10	2.5	28.5	1	2.2	28.5	4.15	0.9	80	151.0	4293	11619
2	CR-800-0.45-0.33	60	10	3	25.5	0.5	2.8	24.75	0.85	1.7	78	151.4	5915	13050
County Materials Janesville														
4	CJ-800-0.50-0.33	60	7.40	3.20	25.5	1	2.4	24.75	10.8	1.6	69	147.8	6095	12445
6	CJ-800-0.50-0.33	80	7.50	3.75	26.25	1.5	2.0	26.12	7.7	1.1	70	149.4	4740	12697
Spancrete														
9	SP-800-0.45-0.33	60	14	0	23	0	4.96	20	5.6	2.6	65	156.2	9149	11720

Phase 2

- **Shrinkage (30 prisms):**



Phase 2

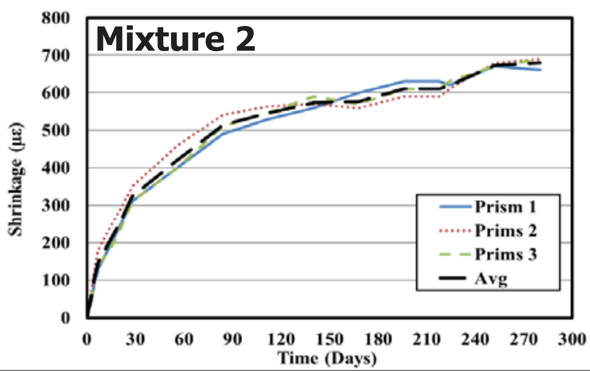
- **Creep (15 cylinders):**

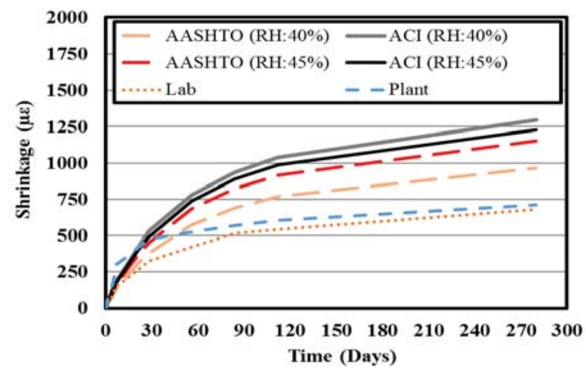


Phase 2

- **Shrinkage results at 28 and 280 days:**

Mixture	28 Days Measurement ($\mu\varepsilon$)		280 Days Measurement ($\mu\varepsilon$)	
	Plant	Lab	Plant	Lab
1	527	267	850	573
2	473	323	710	680
4	519	310	729	643
6	327	347	567	700
9	400	350	635	697

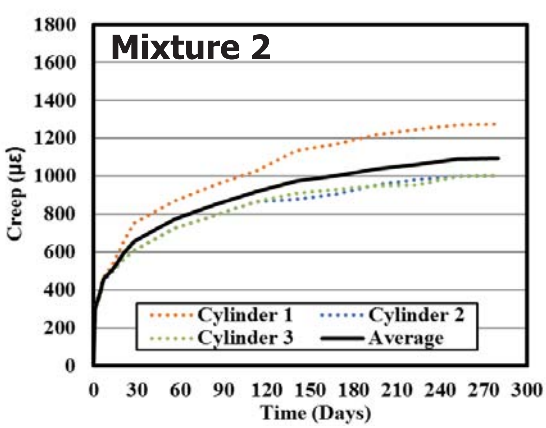


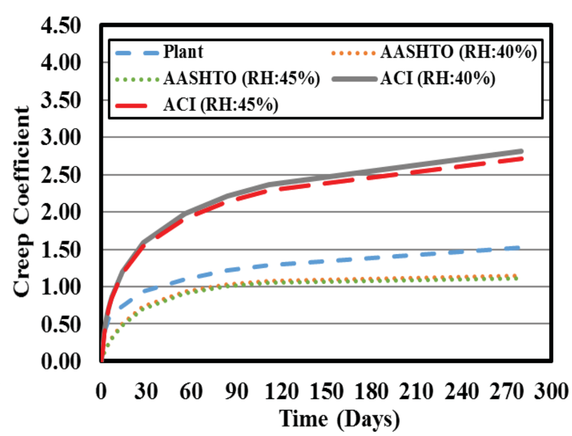


Phase 2

- **Creep results up to 280 days:**

Time	Creep strain on SCC mixtures (με)				
	Mixture 1	Mixture 2	Mixture 4	Mixture 6	Mixture 9
28	700	670	861	832	875
56	836	789	973	947	1012
84	920	876	1064	1066	1107
112	1001	925	1117	1144	1180
280	1203	1094	1278	1306	1440





Task 4
SCC Mix Design Specification

1. Self-Consolidating Concrete (SCC) Specification

1.1 Description: This section consists of requirements regarding SCC mixture design and test methods for prestressed bridge girders fabrication.

1.2 Materials: Materials shall follow section 501.2 of the Wisconsin DOT standard specifications. A proposed mix design should be submitted for approval before application. The contractor should determine the proportions of the mix with the following limitations:

Water cementitious material ratio, w/cm .... 0.35 or less
Cement content .... 800 pounds per cubic yard
Sand to Aggregate ratio, S/Agg .... 0.50 or less
Coarse Aggregate:
  Size .... Max of 3/4"
  Blending .... 3/8" gradation is allowed up to 40% of total coarse aggregate
Admixtures .... WisDOT approved Portland Cement Concrete Admixtures
Air content:
Prestressed bridge girders .... 2.0-4.0 percent maximum

1.3 Test Methods: To approve a new SCC mixture test Slump Flow, J-Ring, Visual Stability Index (VSI), T50, and Column Segregation. Once a mixture has been approved, record Slump Flow, J-Ring and VSI values for every batch to ensure consistency.

1.3.1 New Mixtures

(1) Slump Flow Test: Perform Slump Flow Test following ASTM C1611. Target spread diameter should be between 25"-28". If slump flow value is above 28" reject the mixture. The target value of the contractor for slump flow shall be limited to ±2 variation". T50 value is recommended to range between 2-7 seconds.

(2) VSI: 0 - 1.

(3) J-Ring: Perform the J-Ring Test in accordance to ASTM C1621. J-Ring spread diameter should be within ±2" difference compared to slump flow diameter.

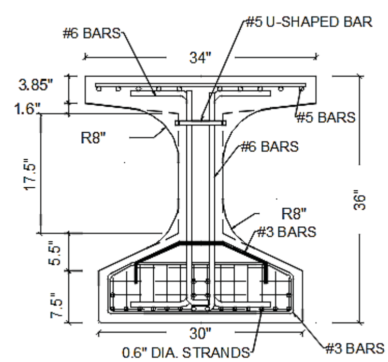
(4) Column Segregation: Perform the Column Segregation Test according to ASTM C1610 guidelines. The percent segregation should not exceed 15%. This test should be performed twice allowing the concrete to sit on the cylinder for both 10 and 40 minutes.

1.3.2 Approved Mixtures

The contractor shall submit Slump Flow, J-Ring and Column Segregation to the DOT quality control office.

Task 5
Overview

- Mixture 4 selected amongst mixtures 1, 2, 4, 6, and 9.
- Bridge (B-40-858) selected for SCC girder implementation. This bridge has girders 36W.



Task 5

Final Mixture Selection

- The table were combined creep and shrinkage from the creep testing
- Selecting Mix 4 and 9 was a reasonable choice for full-scale testing because the first and second highest creep and shrinkage strains, resulting in the significant amount of prestress losses (CMJ offered to fabricate the girder, so final selection should be between mix 4 and 6.)

Creep and shrinkage at 28 days

No	Creep (με)				Shrinkage (με)			
	Cylinder 1	Cylinder 2	Cylinder 3	Ave.	Prism 1	Prism 2	Prism 3	Ave.
1	817	666	616	700	560	440	580	527
2	756	612	620	670	460	500	460	473
4	831	814	939	861	525	580	450	519
6	793	765	919	832	280	400	305	327
9	797	762	1065	875	430	370	-	400

Task 5

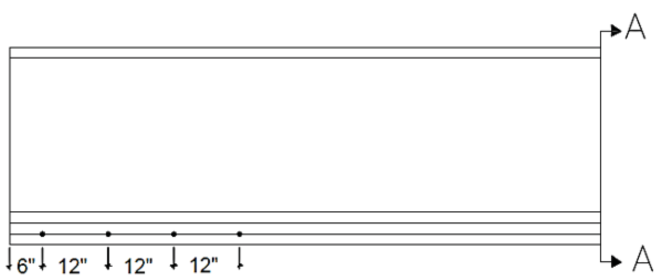
Girder Mixture Details

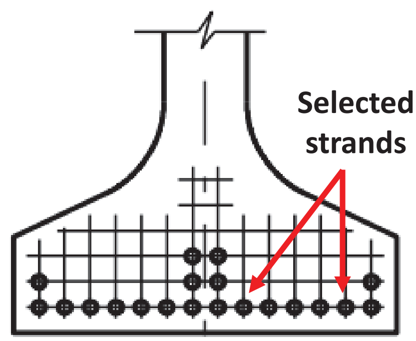
Material Constituent	CC Girder	SCC Girder
Cement (lbs/yrd^3)	752	800
Fine Aggregate (lbs/yrd^3)	1402	1503
Coarse Aggregate (3/8) (lbs/yrd^3):	-	616
Coarse Aggregate (3/4) (lbs/yrd^3):	1831	905
Water (Gallons):	29	31.6
ADVA Cast 575 (oz/cwt):	-	12.5
VMA-3R (oz/cwt):	-	4.1

Task 5
Structural Behavior

- Measure transfer length in a SCC and normal concrete girder.
- Measure prestress losses induced by creep and shrinkage effects.
- Measure camber changes.

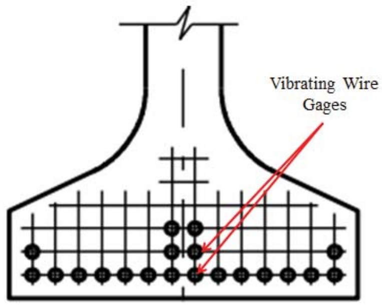
Task 5
Gage Installation for Transfer Length

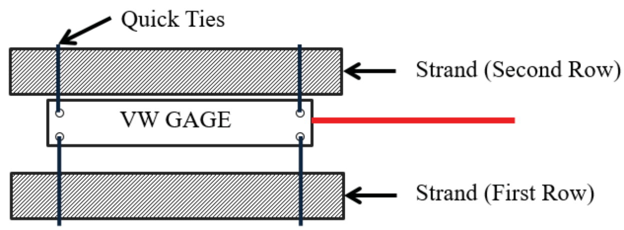




Task 5

Gage Installation for Prestress Losses





Task 5

SCC Mix Quality Control

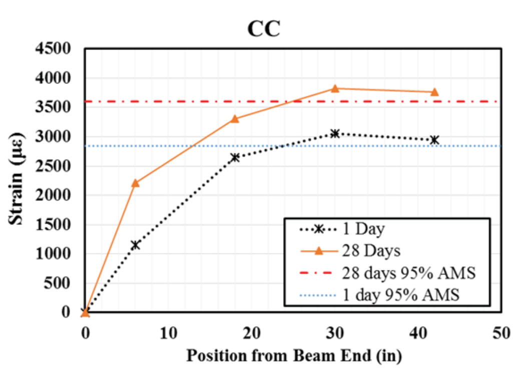
Task 5

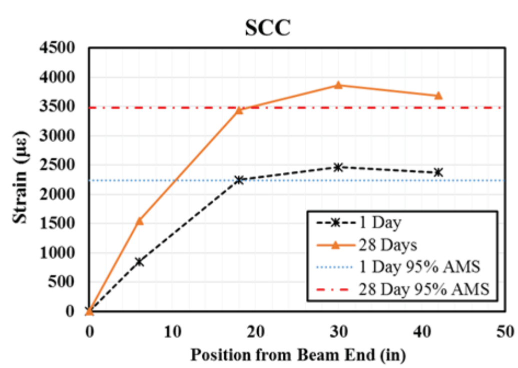
Girder Implementation

Task 5

Transfer Length Result

Time	South End CC (in)	North End SCC (in)	AASHTO ($60d_b$) (in)	ACI ($50d_b$) (in)
1 Day (After release)	24.0	19.0	36	30
28 Days	24.5	20.0		

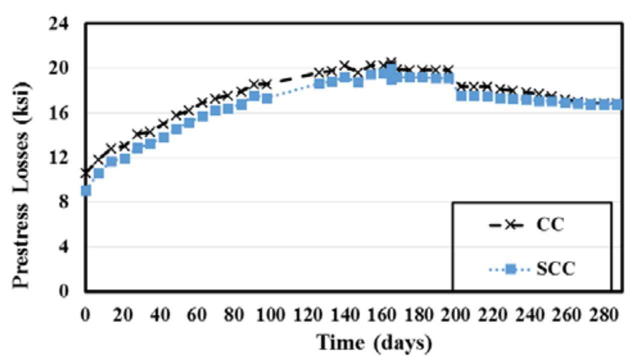


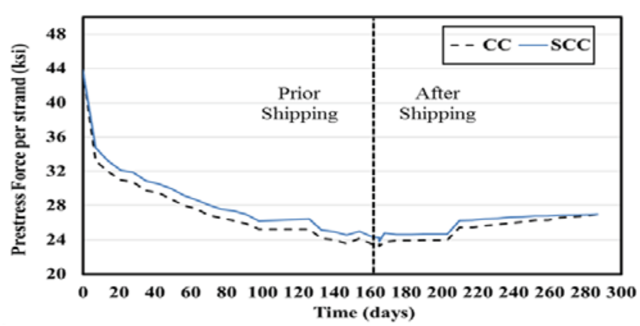


Task 5
Prestress Losses

Time	CC (ksi)	SCC (ksi)	Type of Losses
1 Day (Immediately after release)	10.61	9.07	Elastic Shortening
Day 7	11.85	10.59	Creep, Shrinkage and Relaxation of the Strands (component-level)
Day 161	20.29	19.55	
Before Shipping	20.26	19.76	During Construction
After Shipping	20.58	19.97	
After Placement	20.03	18.97	
After Deck Placement	18.36	17.54	
Day 203	18.34	17.49	Creep, Shrinkage and Relaxation of the Strands (bridge system-level)
Day 287	16.87	16.82	

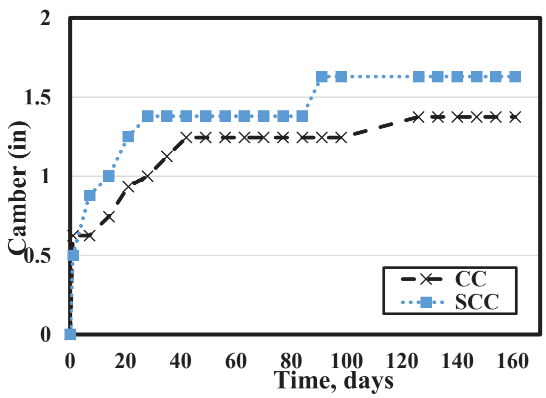
Task 5
Prestress Losses



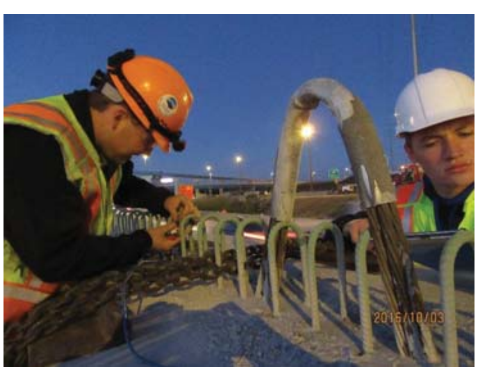


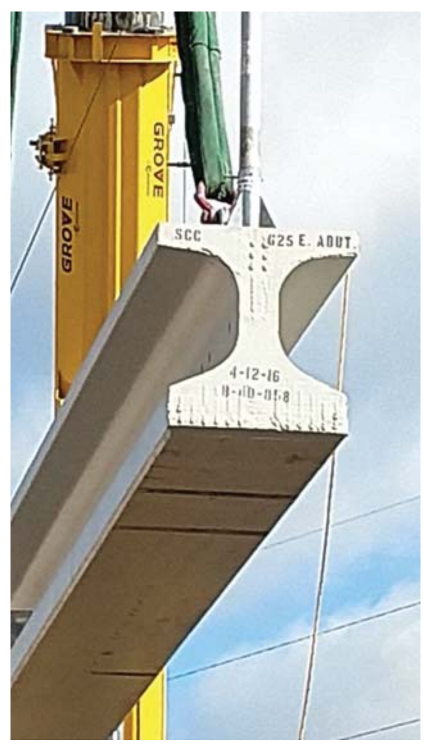
Task 5
Camber

Time	CC Girder (in)	SCC Girder (in)
Day 1	0.62	0.50
Day 28	1.0	1.25
Day 91	1.25	1.63
Day 161	1.38	1.63



Task 5
Girder Implementation





Task 5

Deck Placement

Conclusions

Material Lab Testing

- Slump flow results showed that, between all twelve mixtures, a range of 22.8 in to 26 in was found.
- The majority of the mixtures were less than the maximum passing ability (2 inch), excluding mixture 5 consisting of 20% of 3/8 in coarse aggregate.
- All the mixtures satisfied the required segregation percentage (15%), and the percent segregation decreased as the percentage of 3/8” coarse aggregate increased.
- Compressive strength of all the mixtures ranged from 5221 psi to 8432 psi where one half of the mixtures (mixtures 2, 4, 5, 6, 10, and 11) exceeded the required compressive strength.

Conclusions
Material Plant Testing

- The fresh and hardened properties of all the mixtures for Roberts are acceptable based on the requirements.
- The performance was consistently acceptable among all Janesville mixtures in terms of the fresh and hardened properties.
- Passing ability of all the Spancrete mixtures were not as optimal as those obtained from the mixtures from Roberts and Janesville plants. For hardened property, mixtures 8 and 10 did not reach the required compressive strength at 18 hours.

Conclusions
Creep Testing

- Creep behavior for the three cylinders of each mixture was generally similar, although each mixture had different creep values.
- Mixture 9 exhibits the highest creep strain with a value of 1440 microstrain, while mixture 2 exhibited the lowest creep showing 1094 microstrain.
- The creep model specified by the ACI code overestimated creep coefficients for all the five mixtures, while the AASHTO model slightly underestimates them.

Conclusions
Shrinkage Testing

- The shrinkage values for all the mixtures ranged from 470 to 900 microstrain at 280 days.
- The AASHTO model provided a more accurate prediction of shrinkage at the end of 280 days for all the mixtures compared to the ACI model.

Conclusions
Prestress Losses

- Elastic shortening for the SCC girder was 9.07 ksi, while the CC girder was approximately 17% larger with a value of 10.61 ksi.
- The final prestress loss for the SCC girder was 8.53 ksi, a near 33% higher value than that of CC girder equal to 6.42 ksi.
- Construction losses were 2.22 ksi for the SCC girder and 1.90 ksi for the CC girder.
- The total prestress losses experienced by each girder were 16.89 ksi for the SCC girder, and 17.03 ksi for the CC girder.
- The prestress losses continued to climb until day 161, which is when the girders were shipped and placed on site, at which point the losses slowly started to decline until the final recording day 287.

Conclusions
Transfer Length

- Immediately after release, the transfer length was 19.0 inches for the SCC girder and 24.0 inches for the CC girder.
- At 28 days, the transfer length increased for both girders. The SCC girder increased 1 inch to a final value of 20.0 inches, while the CC girder increased 0.5 inches to a final value of 24.5 inches.
- Because the AASHTO and ACI specified a transfer length of 36.0 and 30.0 inches, respectively, both the codified formulas to determine the transfer length for each of the test girders were considered sufficiently conservative.

Conclusions
Camber

- The variation in camber was 1.63 inches for the SCC girder and 1.38 inches for the CC girder.
- A final reading for each girder was recorded at 4.5 inches, however this value for the SCC girder at day 91, while the CC girder didn't reach this until day 126.
- The SCC girder climbed to a peak camber faster than the CC girder, which started with a higher value, but took longer to reach its peak.

Recommendations

- WisDOT should allow the implementation of prestressed SCC bridge girders.
- Mixture 4, where its material and structural performance was validated throughout this project, should be accepted by WisDOT for girder production without repeating all the testing provided in the proposed SCC mixture design specification.
- Special provisions should be developed to set performance requirements for the fabrication of prestressed bridge girders.

Recommendations (Cont.)

- Investigation of the implementation of supplemental cementitious materials to reduce the costs of SCC mixtures should be made to make it more feasible for local producers.
- Monitoring of larger full-scale SCC girders is recommended to obtain valuable information of long-term structural behavior of SCC girders.

Future Work

- Modifying SCC mixture designs for a better control of creep and shrinkage.
- Investigating shear strength of prestressed SCC bridge girders with different prestressing forces and making relevant design recommendations.
- Establishing a comprehensive prestressed SCC bridge girder design guideline by performing representative load testing on a full-scale SCC girder and a parametric study with variation in girder size, strength, prestressing force, and loss.

Future Work (Cont.)

- Examining long-term structural behavior of prestressed SCC girder bridges under service loads using a structural monitoring system.
- Determining live load distribution factors (LLDFs) of prestressed SCC girders considering its prestress loss over time and developing reliable LLDFs formulas that are compatible to those specified by the AASHTO.

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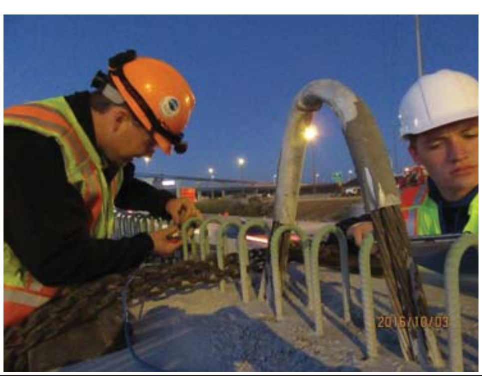
- Collaboration: County Materials and Spancrete

Questions/Suggestions



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