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Design and Performance of Self-Consolidating Concrete for Connecting Precast Concrete Deck Panels and Bridge I-Girders

by

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16. Abstract

Existing full-depth precast concrete deck systems use either open channels or pockets to accommodate the shear connectors of supporting girders for achieving composite systems. The use of open channels or pockets requires cast-in-place concrete/grout to fill these channels/pockets and deck overlay to cover the exposed surface. These operations negatively affect the quality of precast concrete decks and their speed of construction, which are the expected benefits of using precast concrete deck systems. Recent developments in full-depth precast concrete deck systems include using covered individual pockets at large spacing to simplify construction and eliminate the need for deck overlays to cover exposed surfaces. This requires flowable concrete/gout to completely fill deck pockets and gaps between the precast concrete deck panels and bridge girders (i.e. haunches). The high cost of commercial grouts and their strict requirements of surface preparation and application procedures reduce the constructability and cost-effectiveness of precast concrete deck systems.

The objective of this project is to investigate the constructability of using self-consolidating concrete (SCC) to fill the gap between precast concrete deck panels and bridge girders as well as covered deck pockets. This includes developing SCC mixture(s) with specific requirements in terms of flowability, passing ability, stability, workability retention, and pumpability and evaluating the performance of these novel construction materials in small–scale and full-scale specimens. Sequence of pouring/pumping SCC as well as its quality control and quality assurance procedures are also determined. This experimental investigation is crucial for the success of the new generation of full-depth precast concrete deck systems and improving its competitiveness against cast-in-place deck systems.

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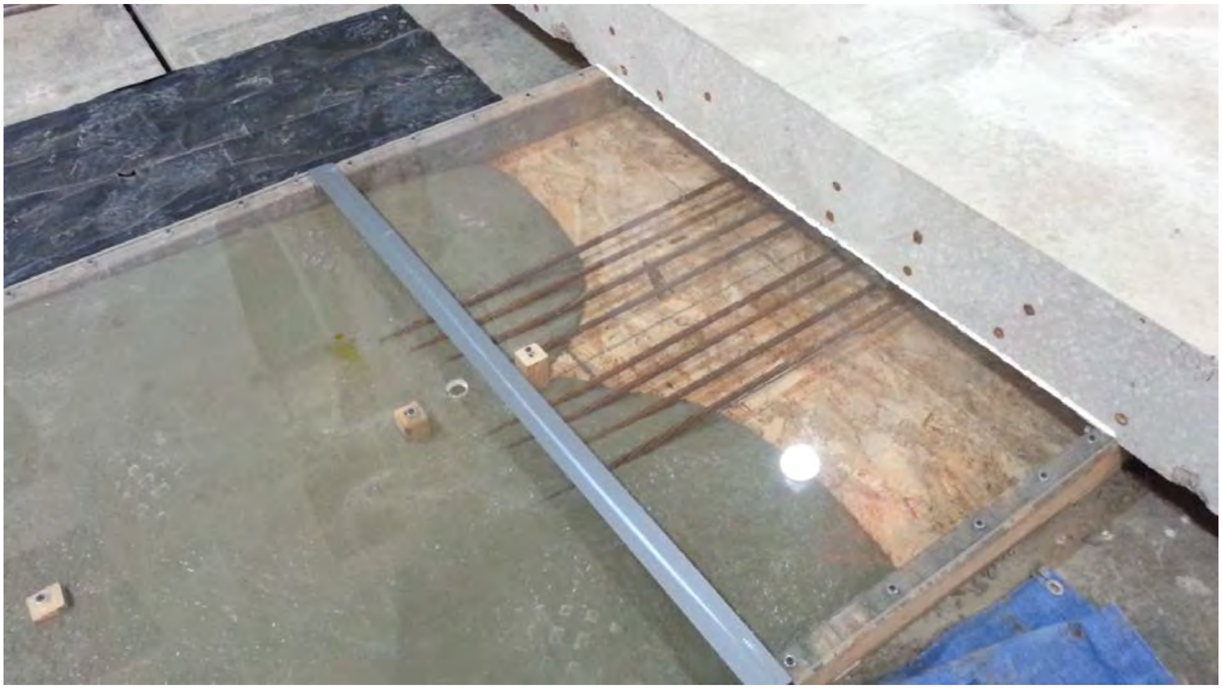

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FINAL REPORT

Investigators

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and
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ABSTRACT

Existing full-depth precast concrete deck systems use either open channels or pockets to accommodate the shear connectors of supporting girders for achieving composite systems. The use of open channels or pockets requires cast-in-place concrete/grout to fill these channels/pockets and deck overlay to cover the exposed surface. These operations negatively affect the quality of precast concrete decks and their speed of construction, which are the expected benefits of using precast concrete deck systems. Recent developments in full-depth precast concrete deck systems include using covered individual pockets at large spacing to simplify construction and eliminate the need for deck overlays to cover exposed surfaces. This requires flowable concrete/gout to completely fill deck pockets and gaps between the precast concrete deck panels and bridge girders (i.e. haunches). The high cost of commercial grouts and their strict requirements of surface preparation and application procedures reduce the constructability and cost-effectiveness of precast concrete deck systems.

The objective of this project is to investigate the constructability of using self-consolidating concrete (SCC) to fill the gap between precast concrete deck panels and bridge girders as well as covered deck pockets. This includes developing SCC mixture(s) with specific requirements in terms of flowability, passing ability, stability, workability retention, and pumpability and evaluating the performance of these novel construction materials in small–scale and full-scale specimens. Sequence of pouring/pumping SCC as well as its quality control and quality assurance procedures are also determined. This experimental investigation is crucial for the success of the new generation of full-depth precast concrete deck systems and improving its competitiveness against cast-in-place deck systems.

1 INTRODUCTION

a. Background

Full-depth precast concrete deck systems have several advantages, such as improved construction quality, reduced construction time and impact on traveling public, possible weight reduction, and reduction of total project life-cycle cost. The quality of precast deck systems is superior to field-cast concrete bridge decks because production occurs in a controlled plant environment. The variability of construction due to environmental conditions is eliminated in the plant that uses consistent casting operations and curing techniques. Moreover, there is a major weakness of cast-in-place (CIP) decks for which a solution has not been found. When concrete is placed over relatively stiff girders, it becomes part of the girder/deck composite system as soon as it begins to harden—several hours after placement. At that time, its tensile capacity is small. Shrinkage in the first few hours after setting as the heat of cement hydration dissipates causes a reduction in concrete volume that cannot be accommodated by the restraint of the supporting girders. This often results in cracking, especially in the transverse direction, that continues to develop as concrete shrinks, most of which occurs in the first 60 days of age. Shrinkage and cracking can be eliminated by using precast concrete deck systems[1].

The size of precast concrete deck panels is smaller than the full bridge deck, thereby reducing the concrete mixing, placing, and finishing variability that exists in the field. Also, because the panels are small, curing is easily controlled and applied immediately to achieve the best material performance characteristics. High-performance concrete (HPC) is recommended for all bridge decks to repeated load cycles in severe environmental conditions. Plant casting provides greater assurance that the performance characteristics of HPC will be achieved. For example, plant-produced 8,000 psi concrete panels are just as easily produced as 4,000 psi concrete panels, while a CIP concrete deck is hard to consistently produce at a strength higher than 4,000 or 5,000 (witch one?) psi [Reference to support the comment?]. More important than strength in bridge decks, shrinkage and the associated cracking are greatly controlled. A two-way prestressed concrete deck is expected to be crack-free for the service life of the bridge, an advantage that is not practical to achieve on CIP decks. The construction method becomes more critical as available field labor decreases or labor turnover for contractors persists.

Precast concrete deck panels can be designed as composite or non-composite with the supporting girders. A non-composite panel is less complicated and more cost efficient to fabricate. Elimination of the shear connectors simplifies forming the panel and reduces work during post-tensioning operations. This, however, requires that relatively large girders be used to carry traffic loads without aid from the deck as in composite systems. The more common composite system is structurally superior and overall is much more cost-effective[2].

b. Problem Statement

Projects constructed using full-depth composite precast concrete deck systems in the U.S. have used either continuously open channel along the girder lines, such as Skyline Bridge, Omaha, NE, or open individual pockets at maximum spacing of 2 ft, such as US-24 Mississippi River Bridge, Quincy, IL. These channels/pockets had to be filled with CIP concrete/grout and overlaid with wearing surface before being open to traffic. These operations increase the construction cost and duration significantly and reduce the attractiveness of full-depth precast concrete deck systems as deck overlay needs to be replaced several times during the service life of the bridge.

Recent developments in full-depth precast concrete deck systems include using covered individual pockets at 4 ft spacing, eliminating deck overlay, and placing post-tensioning strands in the gap between precast panels and supporting girders (i.e. haunch)[3]. These developments reduce construction cost and duration significantly and increase the deck service life to match the service life of other bridge components. However, for implementing these developments, a flowable concrete/gout is required to completely fill deck pockets and the gap between the precast concrete deck panels and bridge girders (i.e. haunch). The high cost of commercial grouts and their strict requirements of surface preparation and application procedures hinder their use in this application.

Self-consolidating concrete (SCC) is proposed as a cost-effective and efficient option for connecting full-depth precast concrete deck panels and bridge girders. SCC is a specially proportioned hydraulic cement concrete that enables the fresh concrete to flow easily into the forms and around the steel reinforcement without segregation. Use of SCC with the newly developed precast concrete deck systems improves their constructability, cost-effectiveness, their competitiveness against CIP concrete deck systems. In addition, the use of SCC to fill the deck shear pockets is expected to result in higher interface shear capacity for the deck-girder connection than that of grout-filled pockets due to the effect of aggregate interlock.

The new generation of full-depth precast concrete deck system (known as 2nd generation of NUDECK) is being implemented in the construction of the Kearney East Bypass Bridge project. The bridge connects 11th street to the 56th street over the US-30 and Union Pacific Rail Road in Kearny, NE. The project consists of twin bridges: the south bound bridge will be constructed using conventional CIP deck; and the north bound bridge will be constructed using the 2nd generation NUDECK system. Each bridge is a two-span continuous bridge that is 41 ft 8 in. wide and 332 ft long. Each span is 166 ft long and consists of five precast/prestressed concrete girders (NU1800) at 8 ft 6 in. spacing as shown in Figure 1.1. Each bridge has a 14° skew and 2% cross slope. Figure 1.2 shows a plan view of all deck panels, dimensions and reinforcement of one typical panel, and cross sections of typical panel-to-girder connections. For more details on the implementation of this project, refer to the final report titled “Implementation of Precast Concrete Deck System NUDECK (2nd Generation)”[4]. The following YouTube link shows animation of bridge construction: http://www.youtube.com/watch?v=FOqcmkik_4Y

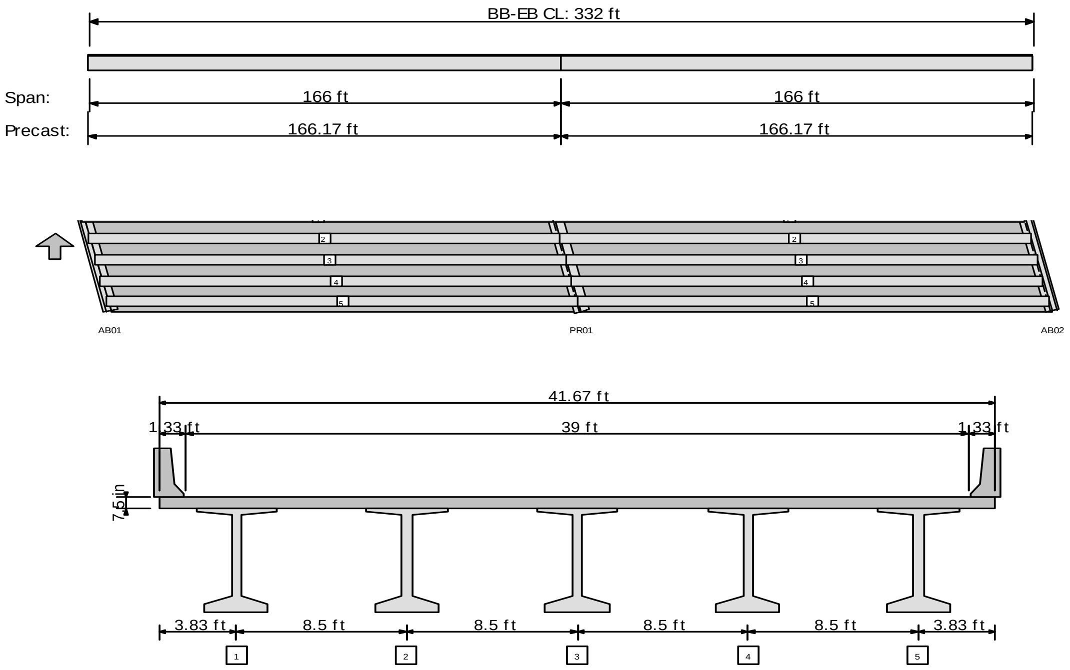
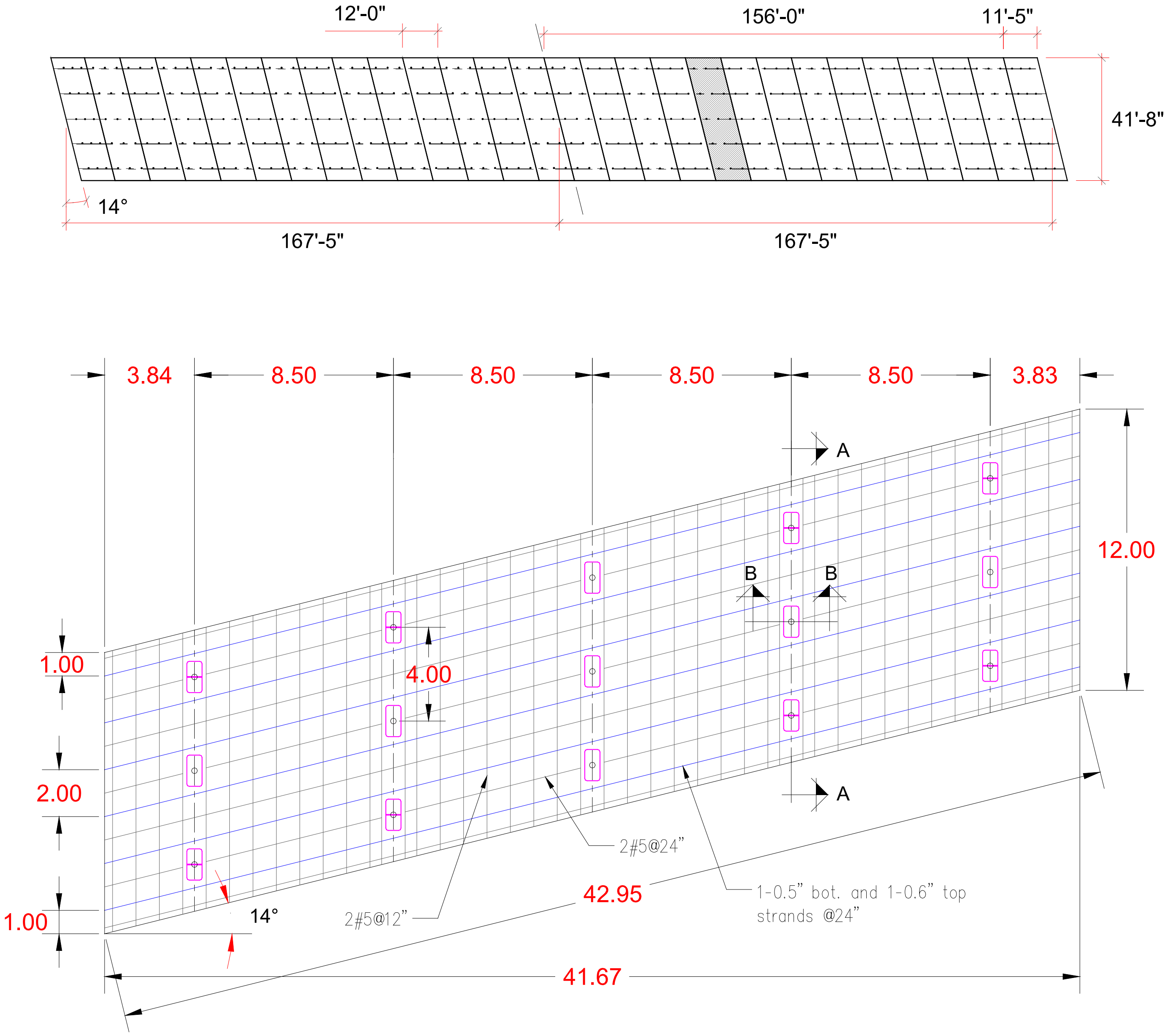
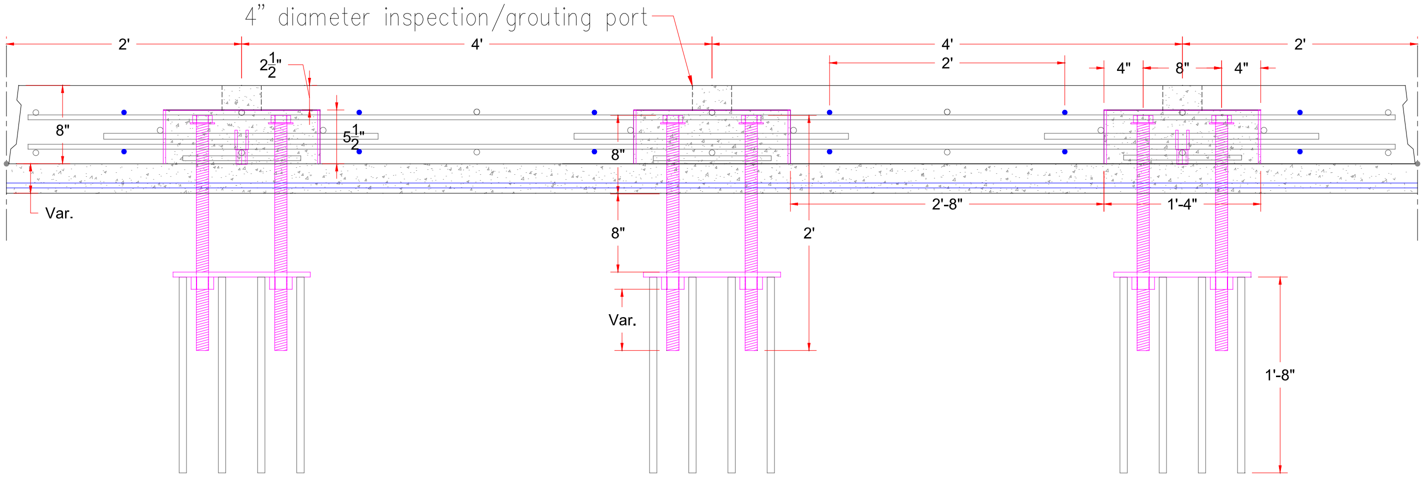


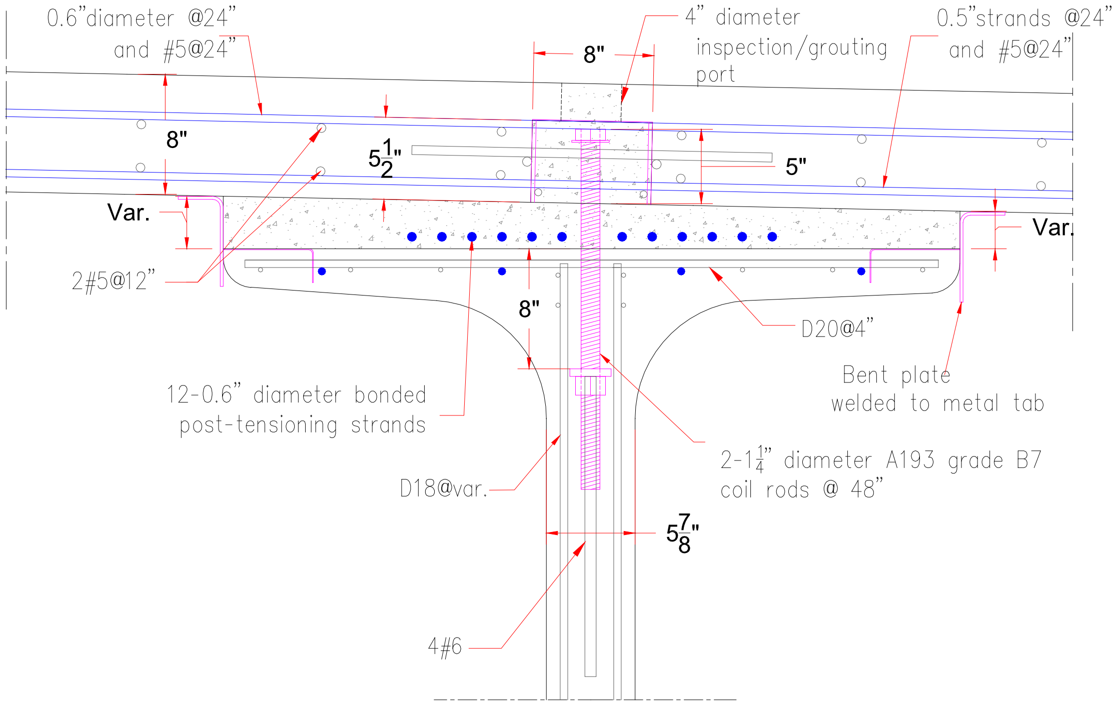
Figure 1.1 – Bridge elevation, plan, and cross section


12'-0"
156'-0"
11'-5"
41'-8"
14°
167'-5"
167'-5"
3.84
8.50
8.50
8.50
8.50
3.83
A
A
B
B
12.00
1.00
4.00
2.00
1.00
14°
2#5@24"
2#5@12"
42.95
1-0.5" bot. and 1-0.6" top
strands @24"
41.67

a) Plan views



b) Section A-A



c) Section B-B

Figure 1.2 – Precast concrete deck panel: a) plan views; b) elevation sectional view; and c) cross sectional view (hatched areas are to be filled with SCC).

NOTE: The shaded areas in sections A-A and B-B represent the haunch and pockets that need to be grouted for connecting precast concrete deck panels to the supporting girders.

c. Objective

The objective of this project is to experimentally investigate the feasibility and constructability of using SCC to fill gaps between precast concrete deck panels and bridge girders as well as covered deck pockets. This includes the following specific goals:

- Develop SCC mixture(s) with specific requirements in terms of flowability, passing ability, stability, workability retention, and pumpability that are needed for this application.
- Evaluate the fresh and hardened properties of the developed SCC mixture(s) batched in small quantity (i.e. using laboratory mixer), and large quantity (i.e. using plant mixer).
- Evaluate the pumpability of the developed SCC mixture(s) using mockup and full-scale pumping tests.
- Develop special provisions for the SCC mixing, pouring, and quality control/assurance procedures in this specific application.

2 DEVELOPMENT OF SCC MIXTURES

For all the investigated mixtures, Type I Portland cement with specific gravity of 3.15 was used. Either Type F or Type C Fly ash was employed at 20% substitution of total cementitious materials, by mass. Either CTS Komponent or Conex supplied from Euclid chemicals was used to reduce and/or control of shrinkage of the concrete. Dosage rates of these expansive agents were varied during the optimization process and are presented in Section of test results and findings. Natural sand with specific gravity of 2.53 and absorption of 0.62% was used as fine aggregate. Pea gravel of MSA of 3/8 in. was used as coarse aggregate. Specific gravity and absorption values of the gravel were 2.54% and 2.7%, respectively. It is important to note that the natural sand and Pea gravel used in this project meets sieve gradation limits elaborated in ASTM C 33, “Standard Specification for Concrete Aggregates”, as presented in Figures 2.1 and 2.2, respectively. Technical data of the materials used for laboratory and mockup test investigation are listed in Appendix A.

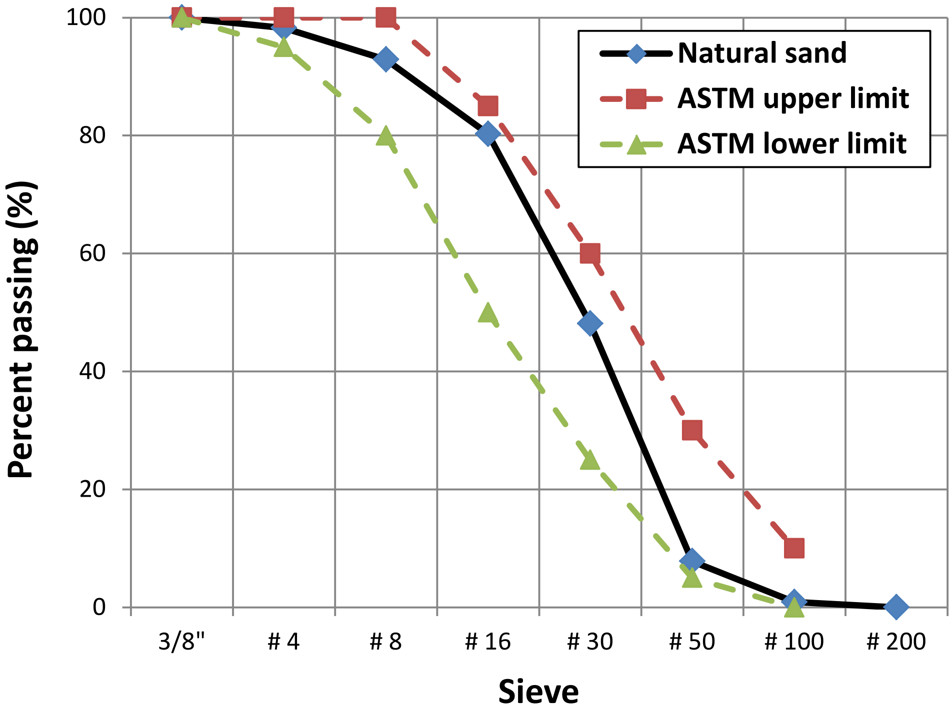


Figure 2.1 – Sieve analysis results of sand and ASTM limits

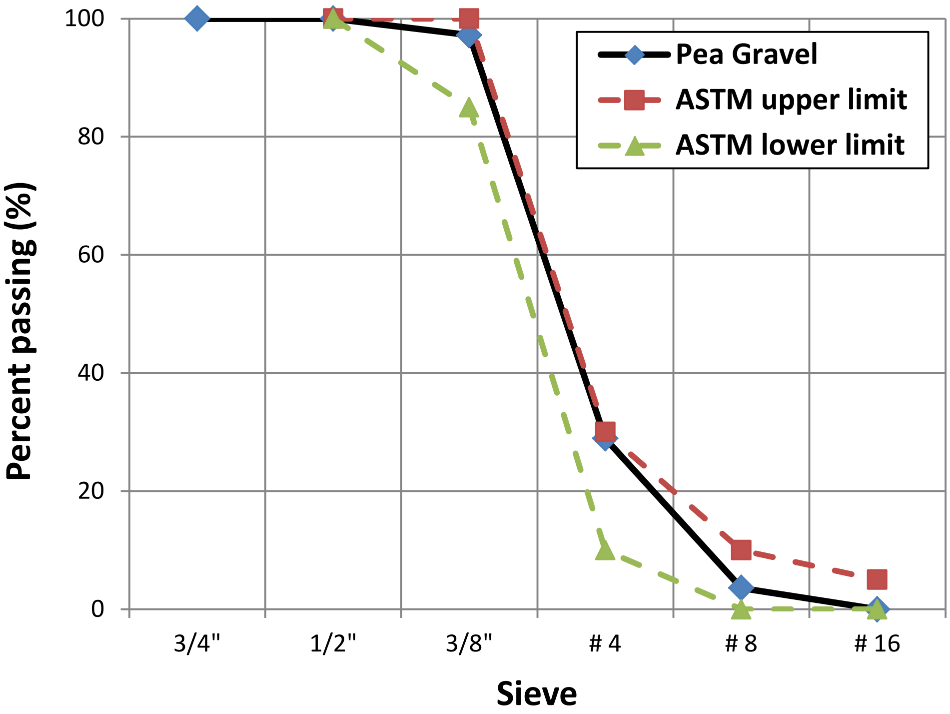


Figure 2.2 – Sieve analysis results of Pea gravel and ASTM limits

Conex is an expansive Type G component, which produces a calcium hydroxide platelet crystal system based on calcium aluminate/calcium hydroxide, as specified in ACI 223. On the other hand, CTS Komponent is an expansive cement which when added to regular Portland cement, produces ASTM C845 Type-K cement. Typically, about 15% of the cement is replaced with Komponent to meet the requirements of ASTM C845 Type-K cement.

Two types of superplastizers were introduced to the SCC mixtures. Plastol 5000 was used to secure initial slump flow and Plastol 6200 EXT was introduced to maintain the flow consistency. The specific gravity values of Plastol 5000 and Plastol 6200 EXT are 1.07 and 1.09, respectively. In addition, Eucon retarder 100 and Visctrol were used to control the setting time and to enhance stability, respectively. Both admixtures have specific gravity of 1.2. For a stable air-void system, Eucon AEA 92 was introduced to the mixer before adding cement and cementitious materials.

The slump flow (T-50, VSI), V-funnel, air content, J-ring, column segregation, sieve stability, and static bleeding test were conducted for the development of optimized SCC mixtures. The slump flow (ASTM C 1611) test was used to evaluate the filling ability of SCC. The V-funnel test and J-ring test were conducted to evaluate the passing ability. The column segregation (ASTM C 1610) and sieve stability tests were used to evaluate the stability of SCC. The SR index in the sieve stability test refers to mass percentage of mortar pass through the 5-mm sieve to initial concrete sample mass. A static bleeding test (ASTM C 940) was used to determine static bleeding as well as volume change during 3 hours after cement and water contact. In addition to workability and stability aspects, compressive strength (ASTM C 39) and shrinkage (drying and autogenous) were determined. Several 4 x 8 in. cylindrical specimens were sampled to determine compressive strength at 1, 7, and 28 days of age. Drying shrinkage was conducted according to ASTM C 157 using digital comparator. Autogenous shrinkage was monitored using vibrating wire gauges embedded in concrete prisms measuring 3 x 4 x 16 in. Autogenous shrinkage prisms were completely sealed with adhesive aluminum tape to prevent any moisture loss.

Several stages of trial batches were made to optimize the SCC mixtures that meet the target performance of the project specification. Details of each stage are shown below.

a. Stage 1: Optimization of SCC mixture proportioning

In order to fill deck pockets and gaps between the precast concrete deck panels and bridge girders, SCC mixtures should have high flowability, high passing ability, as well as high resistance to bleeding and segregation. Therefore, such novel construction materials need to secure both high slump flow of 25.5 to 29.5 in. and excellent J-ring passing ability (difference between slump flow and J-ring values less than 2 in.), as presented in Table 2.1. In addition, the SCC mixtures should be stable (high resistance to bleeding and segregation) in order to minimize any gap in the dockets and gaps, which should be prevented to secure shear capacity of bridge structure.

For the first stage of the optimization, the Komponent expansive agent was used at the dosage of 15%, by total mass of cementitious materials. The mixture composition of the optimized SCC is given in Table 2.2. All fresh properties of the optimized SCC mixtures were within the targeted performance ranges, as presented in Table 2.1. In addition, 28-day compressive strength of the optimized concrete was 8,840 psi, which is higher than the targeted strength of 6,000 psi.

Table 2.1 – Target performance ranges and properties of SCC optimized with Komponent expansive agent

Properties	**Testing age (min.)**				**Target Value/Range**
	10	**60**	**120**	**180**	
Slump flow (in.)	29.5	27.2	23.5	27	25.5 – 29.5
V-funnel flow (sec)	5.5	5.5	4.5	7	≤ 12
Air content (%)	8	7	6	5.5	5 – 9
L-box ratio (h_2/h_1)	1.0	-	-	-	0.8 to 1.0
J-ring (in.)	29.5	-	-	-	Slump flow J-ring spread diff. ≤ 2
Column segregation (%)	0.41%	-	-	-	≤ 10
Static bleeding	0	0	0	0	-
Compressive strength at 1 day (psi)	3,140 (mean of 2 out of 3)				-
Compressive strength at 7 days (psi)	5,140 (C.O.V. of 6%)				3,500
Compressive strength at 28 days (psi)	8,840 (C.O.V. of 4%)				6,000

Table 2.2 – Mixture composition of the SCC optimized with Komponent expansive agent

Materials	**Imperial unit (lb/yd^3 or $fl.oz/yd^3$)**	**SI unit (kg/m^3 or mL/m^3)**
Type I Portland cement	570	338
Class F fly ash	145	86
Expansive agent (Komponent)	125	74
Total binder materials	840	498
Water	295	175
w/b	0.35	0.35
Sand	1340	795
3/8 in. Pea gravel (coarse agg.)	1390	824
Superplasticizer 1 (Plastol 6200 EXT)	75.0	2,900
Superplasticizer 2 (Plastol 5000)	142.0	5,500
Set-retarder (Retarder 100)	33.0	1,277
VEA (Visctrol)	11.5	445
Air-entraining agent (AEA92)	1.4	54

b. Stage 2: Performance comparison of SCC made with different expansive agents

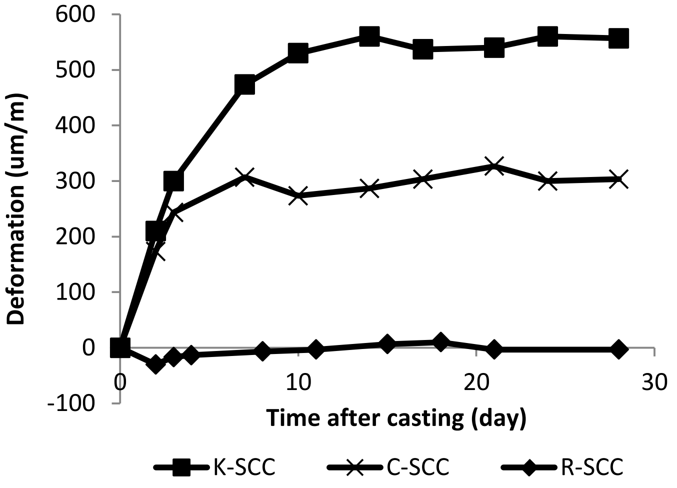
An experimental work was undertaken to compare the effect of different expansive agents on deformation and compressive strength development of corresponding concrete. Three concrete mixtures were prepared with Komponent, Conex, and without any expansive agent. For each concrete, after demolding, prismatic samples were subjected to different exposure conditions, which included specimens stored at a temperature of 73.4 ± 3.5°F (23 ± 2°C) and a relative humidity of 50% ± 4%, sealed specimens stored at 73.4 ± 3.5°F (23 ± 2°C), and immersed specimens in lime-saturated water at 73.4 ± 3.5°F (23 ± 2°C). Similarly, cylindrical samples were exposed to water-curing (lime-saturated) and sealed-curing.

In total, three SCC mixtures were optimized. Fresh properties of the three mixtures are presented in Table 2.3. All three optimized mixtures met the targeted performance range set for this project, which include high flowability, high passing ability, and adequate static stability. Among the three mixtures, the SCC made with Komponent expansive agent exhibited slightly greater slump flow and higher passing ability compared to the other two mixtures, as presented in Table 2.3. There was no clear difference in compressive strength results of the various mixtures made with different the expansive agents and curing conditions.

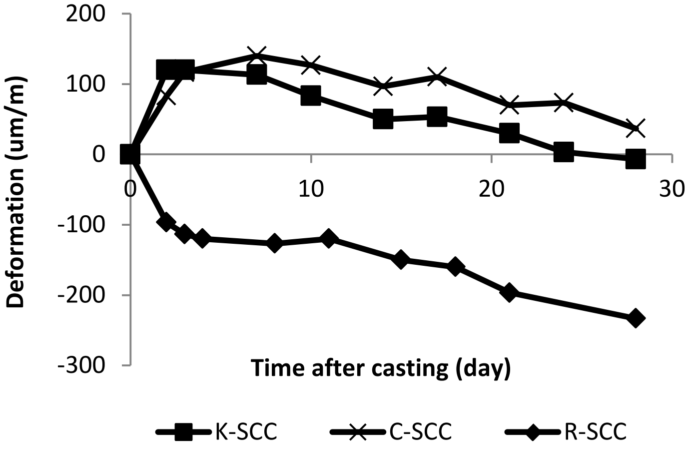
Table 2.3 – Fresh properties and compressive strength of SCC made with different expansive agent

Expansive Agent	**Komponent**		**Conex**		**Reference (without any expansive agent)**	
Testing time (min)	10	70	15	75	15	75
Slump flow (in.)	31.5	30.7	30	28.3	29.7	29
V-funnel flow (sec)	5.1	5.5	3.3	4.0	4.2	4.6
Air content (%)	5.2	6.5	5.5	3.5	5.0	5.5
L-box ratio (h_2/h_1)	1.0	1.0	0.89	0.86	0.93	0.86
J-ring (in.)	30.5	26	29.3	27.8	27.5	27
Static bleeding	0	-	0	-	0	-
Curing condition	water	sealed	water	sealed	water	sealed
1 day compressive strength	2,825	2,420	2,445	2,430	1,905	2,130
7 day compressive strength	4,600	4,500	4,785	4,905	4,290	4,410
28 day compressive strength	6,185	5,825	5,580	5,560	5,500	6,165

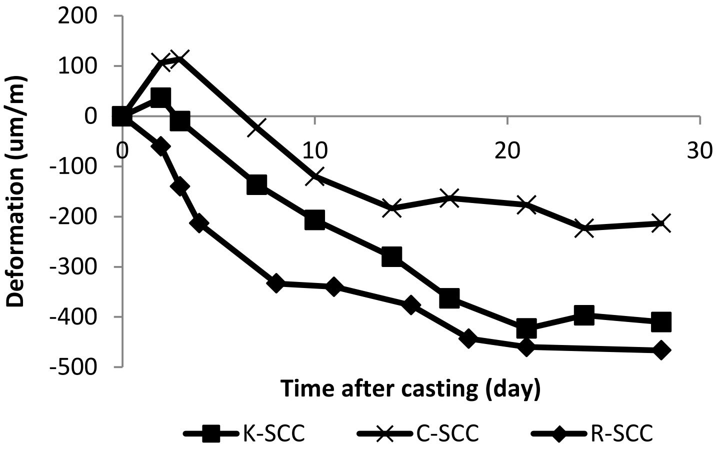
The effect of different expansive agents on deformation of the concrete is compared in Figure 2.3. The K-SCC, C-SCC, and R-SCC mixtures refer to the concrete mixtures made with the Komponent, Conex, and reference concrete without any expansive agent, respectively. It is interesting to note that the influence of expansive agents on the deformation differs with the curing condition. For example, in the case of water-curing, concrete containing the Komponent at the 15% replacement ratio had almost 200% higher expansion than similar mixture containing the Conex admixture at the dosage rate of 10%, by mass of binder. On the other hand, the air-dried samples of the Komponent mixture had 200% higher shrinkage at 28 days compared to those made with the Conex expansive agent (-410 vs. -210 μm/m). Similarly, under the sealed condition, concrete made with Conex had relatively higher expansion than similar concrete containing Komponent.



(a) Water-cured



(b) Sealed



(c) Air-drying

Figure 2.3 – Deformation of concrete mixtures made with different expansive agents and subjected to different curing conditions

c. Stage 3: Batching sequence comparison and robustness evaluation

Different batching sequences were applied to a given concrete. As presented in Table 2.4, sequence A was used to simulate the situation where all chemical admixtures are introduced on site upon concrete delivery. On the other hand, sequence B involves the incorporation of all chemical admixtures at the batching plant. Different batching sequences were applied to both SCC mixtures that were optimized using the Komponent expansive agent and similar concrete made with the Conex expansive agent. For both cases, 30-minute mixing time was applied to simulate the transportation of the concrete to the job site.

The mixture compositions of the two optimized mixtures are presented in Table 2.5. It should be noted that all chemical admixtures were fixed, except for the SP2 (Plastol 5000) which was adjusted to secure initial target slump flow of 28.5 ± 0.4 in. (725 ± 10 mm) for the different batching sequences.

Performance of highly flowable concrete is in general more sensitive to the variations in concrete temperature, SP dosage, and water content. Therefore, an experimental work was undertaken to evaluate the influence of concrete temperature (59 vs 95^{o}F (15 vs 35^{o}C)), SP dosage (±10% from the optimum dosage of SP1), and mixing water content (±10% from optimum water content). This analysis is important to evaluate the robustness of the proposed SCC mixture.

Table 2.4 – Details of batching and mixing used for different batching sequences

Batching sequence A		**Batching sequence B**	
Time (min)	**Action**	**Time (min)**	**Action**
Pre-mixing of 5 minutes: - Coarse aggregate and sand, mix for 1 minute at 12 rpm - Add ½ of mixing water and mix for 1 minute at 12 rpm - Add cement, fly ash, and expansive agents and mix for 3 minutes at 12 rpm			
30	Mix for 30 minutes at 8 rpm to simulate transport to job site	3	Add AEA and retarder and mix for 3 minutes
30 + 3	Add AEA and retarder and mix for 3 minutes	6	Add SP1 and mix for 3 minutes
30 + 6	Add SP1 and mix for 3 minutes	9	Add VMA and mix for 3 minutes
30 + 9	Add VMA and mix for 3 minutes	12	Add SP2 and mix for 3 minutes
30 + 12	Add SP2 and mix for 3 minutes	12 + 30	Mix for 30 minutes at 8 rpm to simulate transport to job site
12 + 120	Agitate until 2 hours at 2 rpm to simulate casting period	12 + 120	Agitate at 2 rpm until 2 hours to simulate casting period

Table 2.5 – Mixture composition of mixtures made with Komponent and Conex admixtures

Materials	SCC with Komponent		SCC with Conex	
	(lb/yd^3)	(fl.oz/yd^3)	(lb/yd^3)	(fl.oz/yd^3)
Type I Portland cement	570		600	
Class F fly ash (20% of total binder)	170		179	
Expansive agent (Komponent)	125		-	
Expansive agent (Conex)	-		87	
Total binder materials	865		866	
Water	285		285	
w/b	0.33		0.33	
Sand	1615		1615	
3/8 in. Pea gravel (coarse agg.)	1077		1077	
Superplasticizer 1 (Plastol 6200 EXT)		103.0		75.0
Superplasticizer 2 (Plastol 5000)		23.0		69.0
Set-retarder (Retarder 100)		33.0		33.0
VEA (Visctrol)		0		33.9
Air-entraining agent (AEA92)		1.4		1.4

Variations of slump flow values for mixture made with the Komponent expansive agent are presented in Figure 2.4. Komponent mixture prepared with the batching sequence A (admixtures added at job site) exhibited sudden decrease in slump flow beyond 40 minutes. The slump flow values at 40 and 130 minutes were 30.3 and 20.3 in. (770 and 515 mm), respectively, as presented in Figure 2.4. However, the same mixture prepared with the batching sequence B (admixtures added at the batching plant) had adequate slump retention with values of 31 and 28 in. (785 and 710 mm) at 40 and 130 minutes, respectively. This indicates that SCC containing the Komponent expansive agent is more sensitive to changes in batching sequence. This makes the quality control more difficult at batching plant and job site.

On the other hand, mixtures made with the Conex exhibited similar slump flow retention with respect to time, regardless of the batching sequence, A or B (Figure 2.5). Therefore, all the mixtures used for robustness evaluation were prepared with Conex expansive agent. It is important to note that for a given concrete, SCC prepared with the batching sequence B exhibited significantly higher stability compared to similar concrete made with sequence A. The Conex mixture prepared with sequence B had 60% lower SR index from sieve stability test and 75% lower percent static segregation from column segregation test, as presented in Figure 2.6. Therefore, batching sequence B is used for further experimental work, including robustness study.

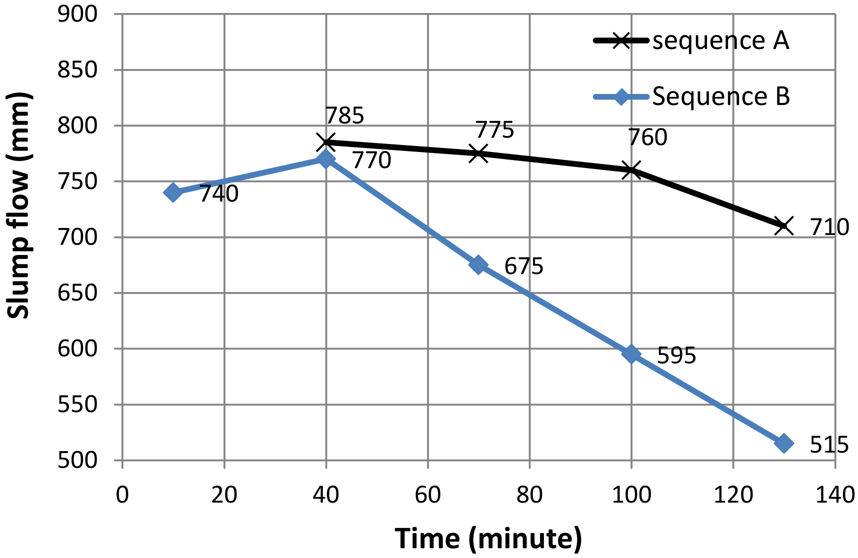


Figure 2.4 – Variations of slump flow with respect to time for the Komponent SCC mixtures prepared with different batching sequences

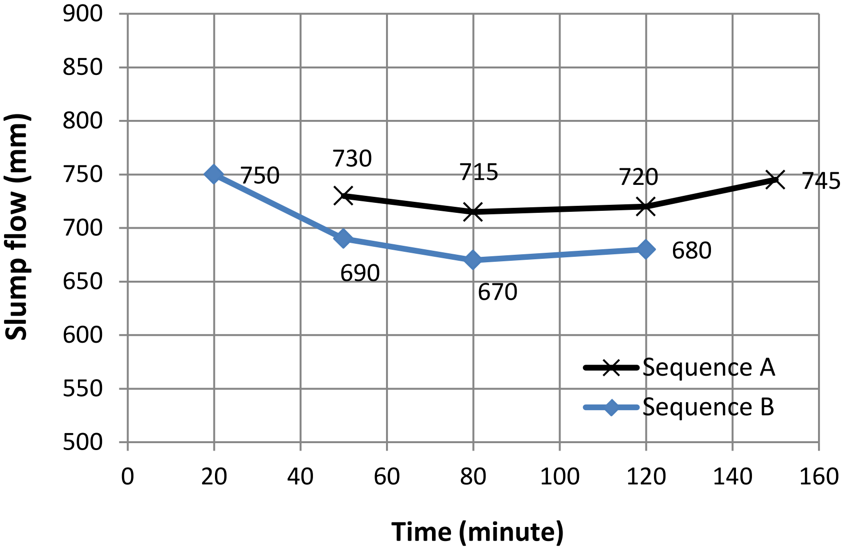


Figure 2.5 – Variations of slump flow with respect to time for the Conex SCC mixtures prepared with different batching sequences

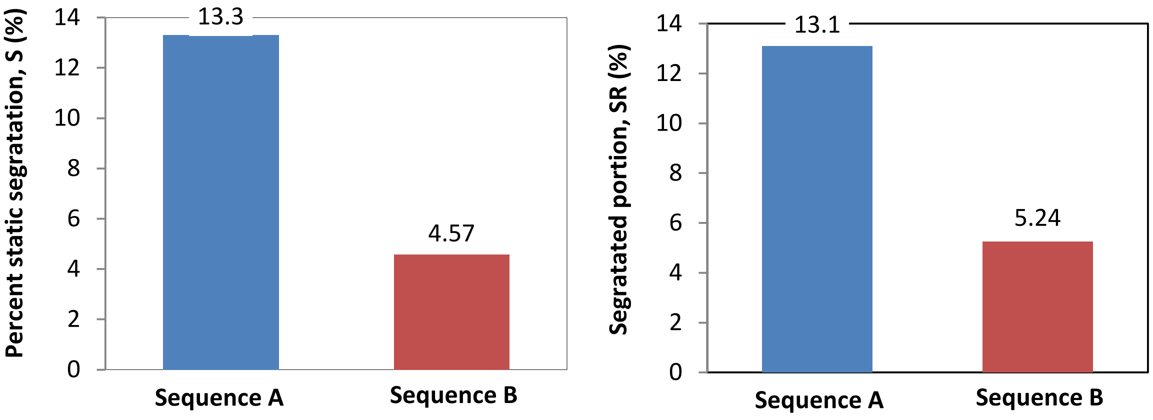


Figure 2.6 – Comparison of static segregation resistance of the Conex mixtures made with different batching sequences

Fresh properties of the SCC mixtures made with relatively small variations in SP dosage, water content, and concrete temperature are summarized in Table 2.6. Sieve stability tests were carried out only once for each mixture. In the case of slump flow and V-funnel time, water content and concrete temperature had more significant effect on the initial value, and its variation with respect to time. On average, the mixture made with 10% higher water content had 6% greater initial slump flow compared to that prepared with 10% lower water content. However, the slump retention of the two mixtures was similar. It should be noted that the SCC with 10% higher water content led to significant increase in segregation index determined from the sieve stability test compared to the SCC with 10% lower water content (21% vs. 2%). On the other hand, the SCC with ±10% SP1 dosage spread did not result in clear difference in sieve segregation index (4.4% vs. 5.6%). The SP1 dosage variation of ±10% affected slump retention ability. For example, SCC containing 10% higher SP1 had only 2.2 in. (55 mm) slump loss between 20 and 120 minutes, compared to 4.3 in. (110 mm) for the SCC with (-) 10% SP1.

Table 2.6 – Fresh properties of mixtures made with different SP dosages, water contents, and initial concrete temperatures (Conex expansive agent) (25.4 mm = 1 in.)

Parameter	Time after cement-water contact (min)			
	20	50	80	120
Slump flow (mm)				
Reference at 73.4°F (23°C)	740	685	660	688
(+) 10% SP1	755	710	695	700
(-) 10% SP1	743	673	668	635
(+) 10% water	810	750	745	775
(-) 10% water	765	745	725	720
95°F (35°C)	715	645	540	515
59°F (15°C)	765	735	740	710
V-funnel (sec)				
Reference at 73.4°F (23°C)	4.39	4.34	5.35	5.87
(+) 10% SP1	4	3.56	5	5.37
(-) 10% SP1	3.75	3.59	4.37	4.63
(+) 10% water	2.22	2.54	3.69	4.22
(-) 10% water	6.6	4.38	6.68	6.5
95°F (35°C)	4.85	4.32	5.72	8.25
59°F (15°C)	4.13	4.38	5.18	5.57
Air content (%)				
Reference at 73.4°F (23°C)	7.7	6.8	5	6
(+) 10% SP1	8	9.5	6.6	6.2
(-) 10% SP1	7	6.7	5.8	4.8
(+) 10% water	7	6.2	5.5	4
(-) 10% water	7	7.6	6.6	4.5
95°F (35°C)	6	6.5	5.6	5
59°F (15°C)	8	5.5	6.5	5.5
Sieve stability (SR in %)				
Reference at 73.4°F (23°C)	4.9	-	-	-
(+) 10% SP1	4.4	-	-	-
(-) 10% SP1	5.6	-	-	-
(+) 10% water	20.6	-	-	-
(-) 10% water	1.9	-	-	-
95°F (35°C)	1.0	-	-	-
59°F (15°C)	9.6	-	-	-

In general, slump flow or flowability of concrete at high temperature decreases faster with respect to time. As presented in Table 2.6, concrete at 35°C (95°F) had lower initial slump flow of 28.1 in. (715 mm) compared to 30 in. (765 mm) for the similar concrete at 15°C (59°F). In addition, the former concrete exhibited significantly higher slump flow loss between 20 and 120 minutes than the latter one (8 in. (200 mm) at 95°F (35°C) vs. 2.2 in. (55 mm) at 59°F (15°C)). Similar tendency was found for the V-funnel flow results. Therefore, additional dosage of set-retarder or superplasticizer may be needed to secure workability retention for concrete subjected to high temperature.

3. PUMPING MOCKUP FIELD TESTS

Three mockup pumping campaigns were carried out in this project and are described below.

a. Pumping Mockup Field Test No. 1

In this test, SCC was optimized with the Komponent expansive agent for the placement of an element measuring 2 in. thick, 48 in. wide, and 48 ft long. The mockup simulates the haunch area between precast concrete girders and precast concrete deck panels that needs to be filled with SCC. The concrete was pumped using 2 in. diameter hose from one end of the test setup, as shown in Figure 3.1. The dimensions of this specimen are shown in Figure 3.2. This field test was conducted on May 24th, 2013 at the HyPoint laboratory at Missouri S&T. The SCC mixture had high flowability and adequate stability which is necessary for the challenging casting condition. At the beginning of pumping, concrete flowed very smoothly into the formwork without any signs of blockage or segregation. Yield stress and plastic viscosity rheological parameters determined using the ICAR rheometer were 7 Pa and 14 Pa.s, respectively, which indicate excellent flowability. However, due to the high pressure exerted by pumping, the formwork started to open and leak during pumping, as shown in Figure 3.3. The pumping process was then stopped without completing the test.

Figure 3.1 – Photo of the formwork and pump connection at one end

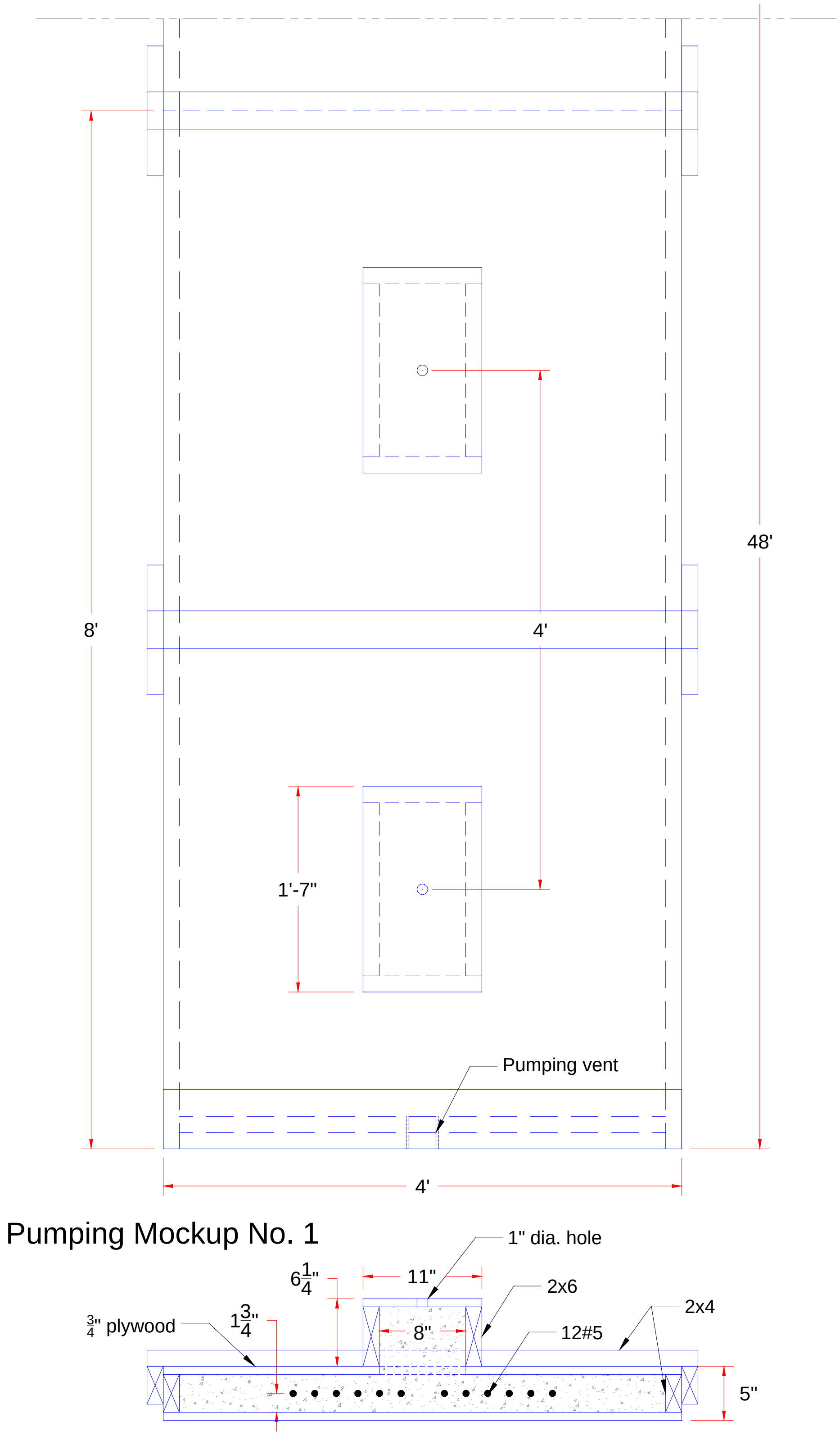


Figure 3.2 – Dimensions and reinforcement of the field test No. 1 specimen

Figure 3.3 – Leakage of concrete after formwork failure due to high concrete pressure at one end

The concrete was sampled to determine hardened properties in addition to workability and rheology. Fresh properties up to 90 minutes and compressive strength values at 1, 7, and 28 days of ages are summarized in Table 3.1. The optimized SCC mixture exhibited adequate slump flow and its retention up to 90 minutes and excellent resistance to bleeding which is required for static stability of the concrete. In addition, the optimized mixture had the spread difference between slump flow and J-ring flow of 0.4 to 0.5 in. and L-box ratio of 1 and 0.89 at 30 and 90 minutes, respectively. These values indicate excellent passing ability of the SCC mixture. The compressive strengths of the optimized mixture were greater than the targeted values, as presented in Table 3.1.

Table 3.1 – Fresh properties and compressive strength of SCC used for field test No. 1 (Komponent expansive agent)

Properties	Time after cement-water contact (min)				Target Value/Range
	30	90	120	180	
Slump flow (in.)	30.7	28.3	Due to the high pressure exerted by pumping, the test was stopped.		25.5 – 29.5
V-funnel (sec)	4.0	4.3			≤ 12
Air content (%)	3.6	2.1			-
L-box ratio (h_2/h_1)	1.0	0.89			0.8 to 1.0
J-ring (in.)	30.3	27.8			Diff. ≤ 2
Static bleeding	0	0			-
Yield stress (Pa)	7	-			-
Plastic viscosity (Pa.s)	14	-			-
Compressive strength at 1 day (psi)	3,340				-
Compressive strength at 7 days (psi)	5,960				3,500
Compressive strength at 28 days (psi)	8,060				6,000

Autogenous shrinkage of cast prism (3 x 4 x 16 in.) was monitored using vibrating wire gauges. Prismatic specimens sampled for autogenous shrinkage were demolded at 1 day and then, were completely sealed using adhesive aluminum tape to prevent any moisture flow between the concrete and atmosphere. The shrinkage samples were stored at a temperature of 73.4 ± 3.5°F (23 ± 2°C). The data are presented in Figure 3.4. The optimized SCC mixture exhibited about 30 μm/m of expansion at the age of 7 days, which reached to null (zero) at approximately 25 days of age. Such expansion seems to be low to compensate shrinkage of the concrete with respect to time. Additional photos of the first field test are given in Appendix B.

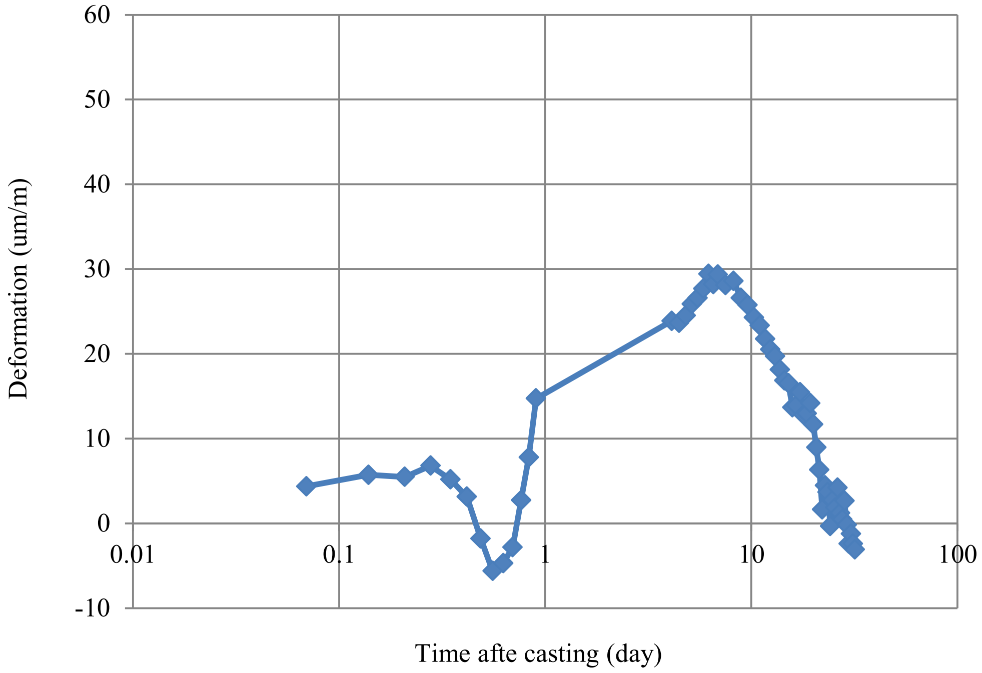


Figure 3.4 – Autogenous deformation of SCC used for field test No. 1

b. Pump Mockup Field Test No. 2

From the lessons learned from the first mockup test, a more rigid formwork was designed to sustain the high pumping pressure for the second field testing. In this test, the wooden form was reinforced with many 2 x 4 in. lumbers, as shown in Figure 3.5. As in the case of the first field testing, the concrete was pumped from the one end point. A pressure indicator was installed to the form to evaluate the concrete rise in a chimney type of set-up, as shown in Figure 3.6. The mixture composition of the SCC used in the second field testing is summarized in Table 3.2.

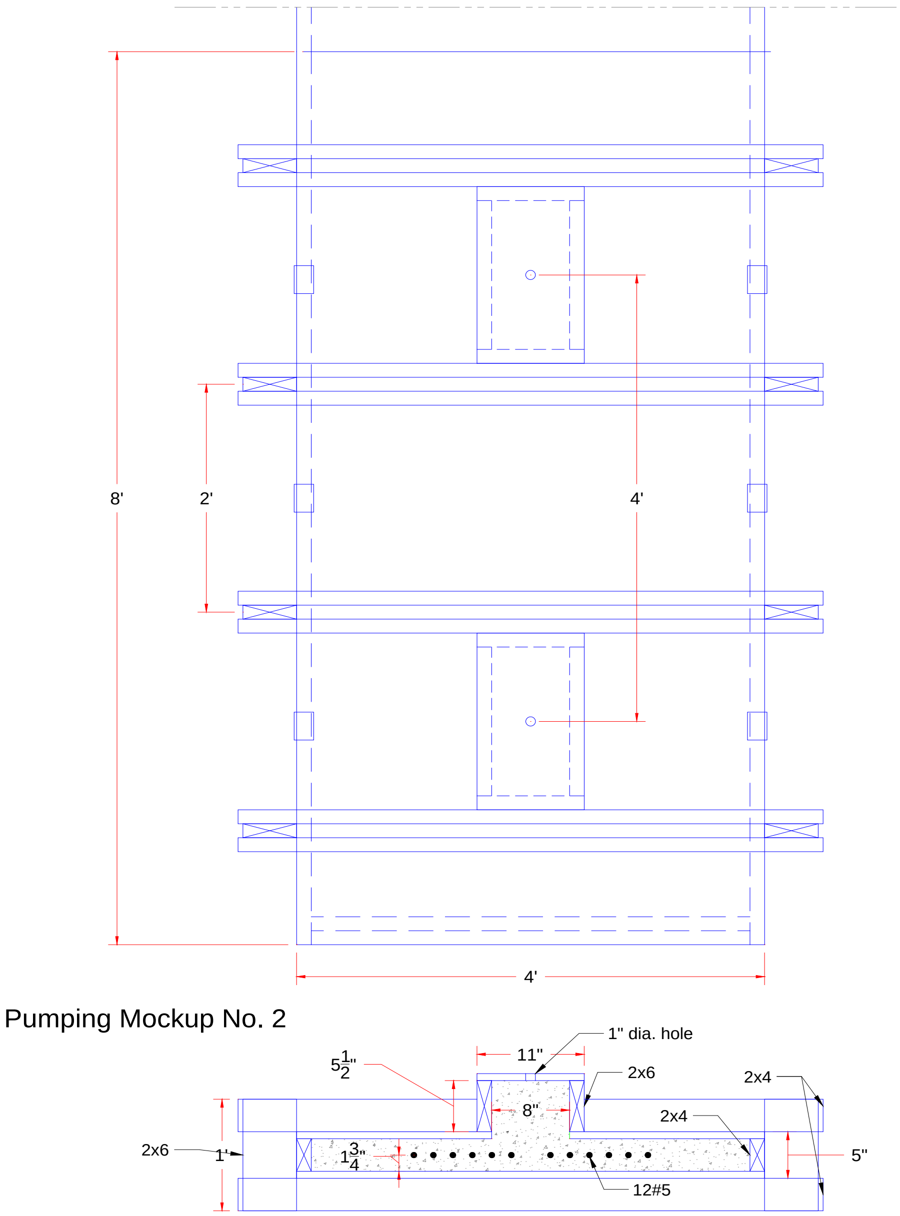


Figure 3.5 – Dimensions and reinforcement of the field test No. 2 specimen

Figure 3.6 – Photo of the formwork, pump connection, and pressure indicator at one end

Table 3.2 – Mixture composition of SCC used for the second field testing (Komponent)

Materials	Imperial unit		SI unit	
	(lb/yd^3)	(fl.oz/yd^3)	(kg/m^3)	(mL/m^3)
Type I Portland cement	570		338	
Class C fly ash	170		101	
Expansive agent (Komponent)	125		74	
Total binder materials	865		513	
Water	285 + 20		181	
Sand	1615		958	
3/8 in. Pea gravel (coarse agg.)	1077		640	
Superplasticizer 1 (Plastol 6200 EXT)		103.0		3,985
Superplasticizer 2 (Plastol 5000)		23.0		890
Set-retarder (Retarder 100)		33.0		1,277
VEA (Visctrol)		0		0
Air-entraining agent (AEA92)		1.4		54

Table 3.3 summarizes the fresh and hardened properties of the SCC mixtures. The slump flow of the concrete at the beginning of pumping was 26.5 in. (670) mm, which is within the acceptable range of the targeted values of 25.5 to 29.5 in. (650 to 750 mm). The flow value was lower than

that of the first field testing. However, a sudden set took place, and then the slump flow of the concrete at 60 minutes dropped to 19.3 in. (490 mm), which is not adequate to pump the concrete into the very restricted and long formwork. The concrete placement was stopped without the completion. The form was barely one third of the total length, as shown in Figure 3.7.

Table 3.3 – Fresh properties and compressive strength of SCC used for field test No. 2

Properties	**Time after pumping started (min)**				**Target Value/Range**
	0	**60**	**120**	**180**	
Slump flow (in.)	26.5	19.3	Placement was stopped due to sudden workability loss		25.5 – 29.5
V-funnel (sec)	4.2	6.3			≤ 12
Air content (%)	-	4.5			-
L-box ratio (h_2/h_1)	0.78	-			0.8 to 1.0
J-ring (in.)	27.5	17.7			Diff. ≤ 2
Static bleeding	0	0			-
Compressive strength at 1 day (psi)	3,840				-
Compressive strength at 7 days (psi)	6,410				3,500
Compressive strength at 28 days (psi)	7,895				6,000

Figure 3.7 – Photo of concrete flow in the field test No. 2 (sudden loss of workability)

Such sudden loss of workability is attributed to the fact that high temperature condition significantly accelerated the ettringite formation of Komponent which also consume considerable amount excess water that can contribute the flowability of the concrete. In addition, such high rate of ettringite formation may be speeded up in the presence of Class C fly ash at the high temperature. It is important to note that all the chemical admixtures were added to the mixture at the job site and the set-retarder may not be effective in controlling setting and workability retention, specifically at the high temperature. The concrete temperature of the second field test was higher than 95°F (35°C). More photos of the second field test are given in Appendix B. Deformations of concrete prisms subjected to different curing conditions (air-drying, sealed, and water-cured) were monitored and given in Figure 3.8. The SCC used for the second field test had about 150 µm/m of shrinkage at the age of 28 days under sealed conditions, which is similar to the exposure condition of actual concrete placed between the deck slab and bridge girder. In addition, the second field test revealed that control of concrete temperature is very critical especially for this type of SCC made with various chemical admixtures. Performance of such type of concrete is more sensitive to some variations in temperature, SP dosage, and water content. It is important to verify the robustness of this type of concrete.

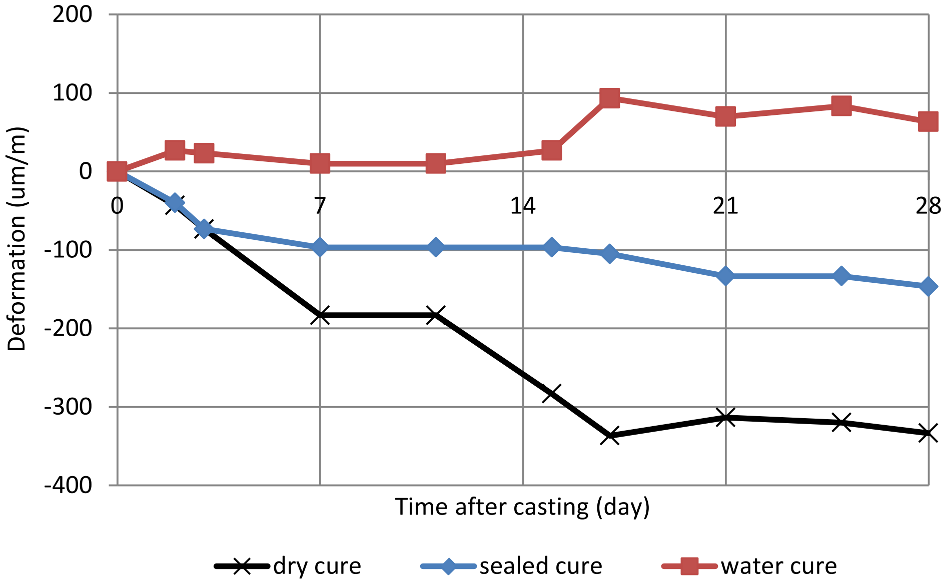


Figure 3.8 – Deformation of SCC used in field test No. 2 under different curing conditions

c. Pumping Mockup Field Test No. 3

For the field test No. 3 that was carried out on August 19th, 2013, the Conex expansive agent was used. Unlike the first and second field tests, all chemical admixtures were added at the batching plant, and additional adjustment of the SP1 was carried out at the job site to secure adequate slump flow. Concrete arrived at the job site approximately 30 minutes after the contact of the cement and water. After SP adjustment, the pumping of the concrete started from the one end point and was gradually continued to push the concrete to the other end of the form. Figures 3.9 and 3.10 show photo and schematic of the pumping line connection to the form as well as a detailed drawing of this connection.

Figure 3.9 – Pumping line connected to the one end of the formwork and concrete pressure indicator tower to monitor pressure build-up exerted on the formwork

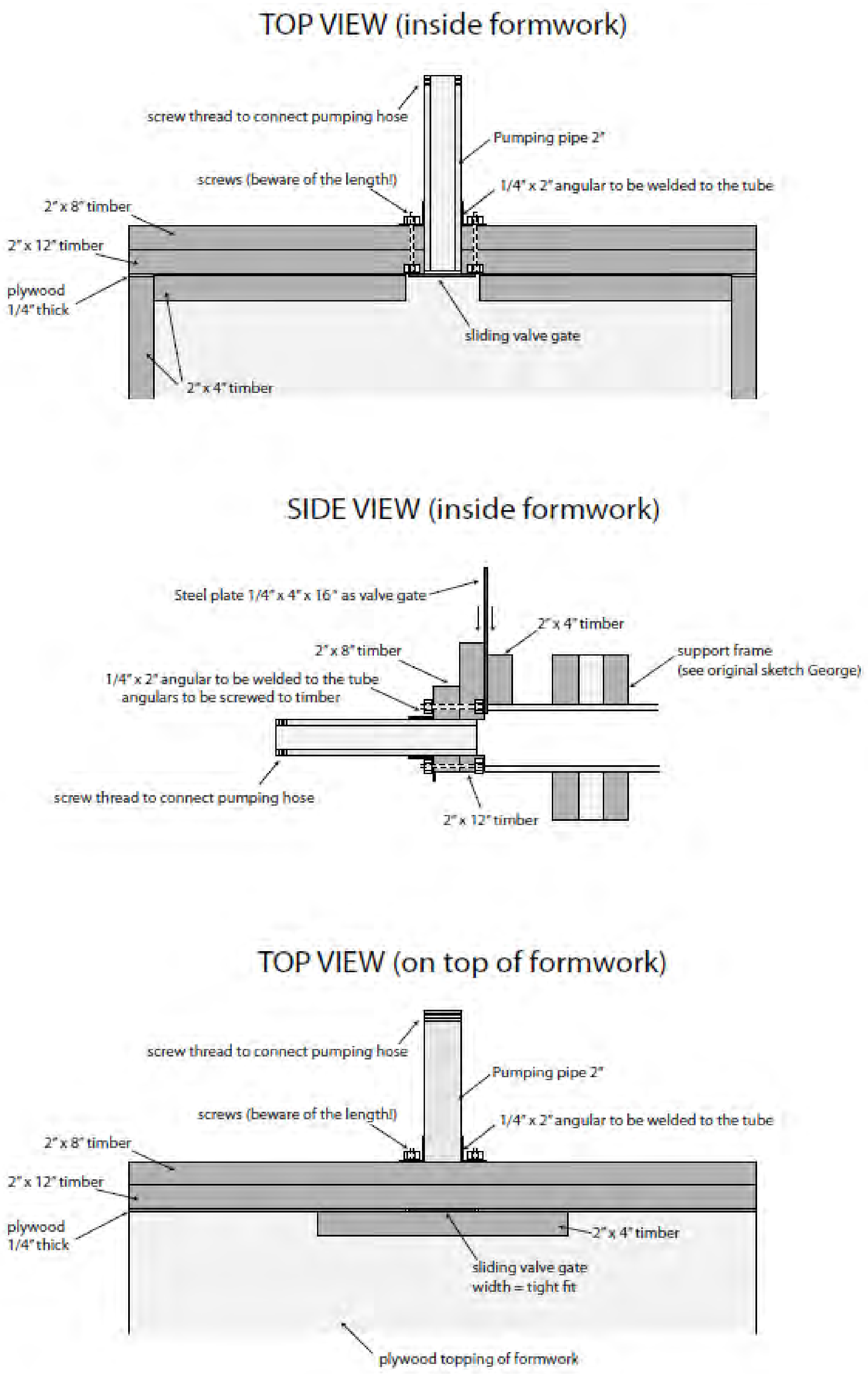


Figure 3.10 – Schematic of the pumping line connected to the one end of the formwork

The mixture compositions and test results of the SCC used in the third field test are summarized in Tables 3.4 and 3.5, respectively. A total of 4 yd^3 of concrete was arrived at the job site (HyPoint laboratory). After the first SP adjustment, slump flow and J-ring flow values of the concrete were 30.7 and 29.7 in. (780 and 755 mm), respectively. The pumping of the concrete started from the one end at the age of 40 minutes. At the initiation of the pumping, the concrete had excellent slump flow of 29.1 in. (740 mm), high passing ability of J-ring flow diameter of 29.5 in. (750 mm), and high resistance to segregation (sieve stability, SR index of 4.3% and static segregation of 3.5%). Concrete flowed smoothly into the form without any leakage or major problem.

Table 3.4 – Mixture composition of SCC used for field test No. 3 (Conex)

Materials	**Imperial unit**	
	(lb/yd^3)	**(fl.oz/yd^3)**
Type I Portland cement	600	
Class F fly ash (20% of total binder)	179	
Expansive agent (Conex)	87	
Total binder materials	866	
Water, initial	292	
Sand	1615	
3/8 in. Pea gravel (coarse agg.)	1077	
Superplasticizer 1 (Plastol 6200 EXT)		75 (initial)
Superplasticizer 2 (Plastol 5000)		6.8
Set-retarder (Retarder 100)		33.0
VEA (Visctrol)		33.9
Air-entraining agent (AEA92)		1.4

Table 3.5 – Fresh properties and compressive strength values of SCC used for field test No. 3 (Conex expansive agent)

Time after cement-water contact (min)	**25**	**40**	**60**	**70**	**75**	**80**	**120**
Real time (hour:min)	9:25	9:40	10:00	10:10	10:15	10:20	11:00
Observation			Slump loss and high pumping pressure		Pumping stopped	Recovery of slump flow	
Action taken	Accepted	Start 1st pumping	Testing	Testing	½ gallon of water added to 2 yd^3 of concrete	½ gallon-water & 250 ml-SP1 added then start 2nd pumping	Testing
Concrete temperature (^{o}F)	82.6	79.2	-	-	-	86.4	83.3
Slump flow (in.)	30.7	29.1	26	25.6	28	31.5	26.2
T-50 (sec)	0.59	1.09	1.10		0.84	0.4	1.47
V-funnel flow (sec)	-	3.94	-	-	-	3.0	3.46
Air content (%)	-	9	-	-	-	8	9
Unit weight (kg/m^3)	-	2180	-	-	-	2165	2175
L-box ratio (h_2/h_1)	-	0.86	-	-	-	0.86	0.88
J-ring (in.)	29.7	29.5	-	-	-	26.8	25.2
Column segregation, static segregation (%)*	-	3.5%					
Sieve stability, SR (%)	-	4.3%	-	-	-	-	-
VSI	1	0	0	0	0	1	0
Yield stress (Pa)	-	-	13	-	-	-	42
Plastic viscosity (Pa.s)	-	-	28	-	-	-	20
Compressive strength at 1 day (psi)	-						
Compressive strength at 7 days (psi)	3,760						
Compressive strength at 28 days (psi)	5,360						

* Static segregation was determined on the top and bottom sections in accordance with ASTM C 1610.

Slump flow determined at 60 and 70 minutes were 26 and 25.6 in. (660 and 650 mm), respectively. Due to the high loss of the slump flow, pumping pressure increased rapidly and reached to nearly the maximum allowable level before opening of the enclosed section, as presented in Figure 3.11. On the first pumping stage, the concrete flew up to about half of the total length of the element (24 ft out of the total length of 48 ft), as presented in Figure 3.12. The pumping process stopped, and ½ gallon of water was added to remaining concrete of approximately 2 yd^3. After the addition of another ½ gallon of water and 250 ml of SP1, slump flow of the SCC backed to 31.5 in. (800 mm) at 80 minutes, which was 40 minutes from the initiation of the first pumping. The pumping line was connected to the other end of the form. The second pumping process started at 80 minutes of age (Figure 3.13). The form was completely filled by the age of 100 minutes (Figure 3.14). It should be noted that there were few minor leaks on the form due to high pumping pressure.

Figure 3.11 – Photo of indication of nearly maximum pumping pressure on the formwork

Figure 3.12 – Photo of center of the form after the first pumping stage

Figure 3.13 – Photo of the second pumping stage

Figure 3.14 – Photo after the completion of casting from both ends

After 1 week from the casting, the forms were stripped, and visual inspection was carried out. As presented in Figure 3.15, the concrete slab did not have any visible voids or any major issue with the surface finish. In addition, all the chimneys that represent the pockets in the pre-fabricated bridge panels (see Figure 4.3) were completely filled, which indicates that the SCC can indeed fill all the shear keys between bridge decks and girder connections. There were some air pockets at the interface between the connects and the wooden form.

The cast slab was cut into sic separate sections in order to verify the aggregate distribution of each section. All cut sections exhibited very homogenous distribution of coarse aggregate without any segregation or defects. Detail photos of the visual inspections, including top, side, and section views are presented in Appendix B.

The concrete used for the third filed test exhibited higher expansion compared to the two previous field test mixtures. The concrete exhibited about 250 μm/m of expansion (isothermal) at

7 days, which reached to the peak and will be reduced with respect to time due to autogenous shrinkage (Figure 3.16). The concrete deformation was monitored up to 45 days. The concrete still had an expansion of 220 μm/m at 45 days of age, as shown in Figure 3.16.

Figure 3.15 – Photo of overall appearance of the cast element

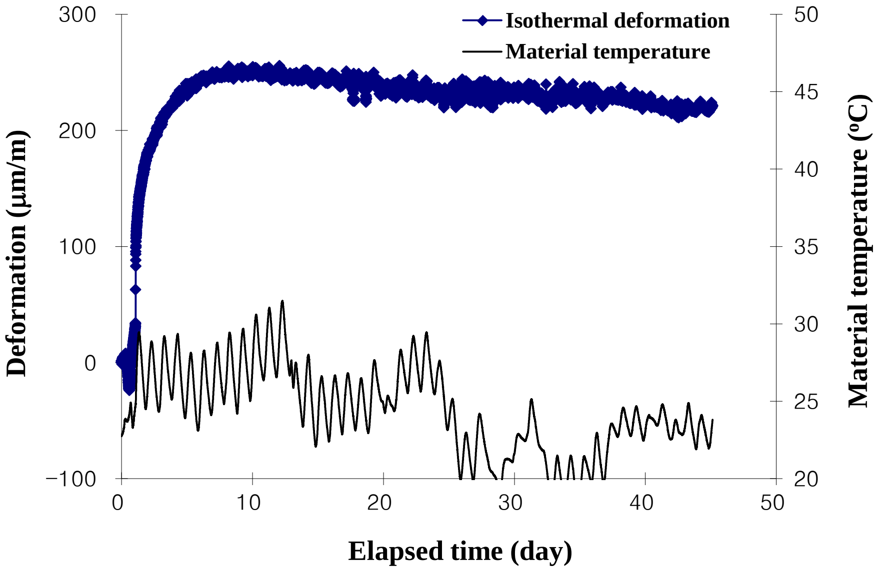


Figure 3.16 – Isothermal deformation of concrete used for the third field test

The optimized SCC mixture has high flowability, adequate stability, and no shrinkage. The optimized SCC was used to cast an element measuring 2 in. thick, 48 in. wide, and 48 ft long. The thin and long element was successfully filled using the developed SCC mixture made with w/cm of 0.34 and Conex expansive agent (10% by total mass of binder). However, the three field tests revealed that sharp reduction in flowability or slump flow with respect to time should be prevented in order to reduce high pumping pressure. In addition, viscosity of the concrete should be reduced to increase the flow rate of the concrete on the form and to prevent rapid structural build-up (thixotropy) which may cause sharp increase in pumping pressure with rest time.

d. Further optimization of SCC mixture

In order to improve the flow properties of the concrete, the following approaches can be applied for further optimization of the SCC mixture composition:

- Use of Class F fly ash instead of Class C fly ash
- Reduction of VMA dosage (1/4 of the current dosage)
- Use of self-consolidating mortar (absence of coarse aggregate reduces viscosity), if needed

Based on these suggestions, a self-consolidating mortar was developed using Class F fly ash and reduced amount of VMA (1/4 of current dosage). Mixture composition and fresh properties of the mortar are presented in Tables 3.6 and 3.7, respectively. The prepared self-consolidating mortar had excellent initial slump flow of 31 in. (790 mm) without any bleeding (0.12% bleeding) and good retention of the slump flow for 3 hours (28.3 in. (720 mm) at 180 minutes). In addition, the mortar mixture had V-funnel flow time values of 3.3 to 3.8 seconds, thus indicating good passing ability and dynamic stability. The mortar mixture developed approximately 20% higher compressive strength compared to that of optimized SCC mixture (5,360 vs. 6,350 psi) at 28 days.

Table 3.6 – Mixture composition of self-consolidating mortar mixture

Materials	**Mortar with Class F Fly ash**	
	(lb/yd^3)	**(fl.oz/yd^3)**
Type I Portland cement	808	
Class F fly ash (20% of total binder)	241	
Expansive agent (Conex)	117	
Water	393	
Sand	2175	
Superplasticizer 1 (Plastol 6200 EXT)		45.5
Superplasticizer 2 (Plastol 5000)		9.2
Set-retarder (Retarder 100)		44.4
VEA (Visctrol)		11.4
Air-entraining agent (AEA92)		1.4

Table 3.7 – Fresh properties and compressive strength of self-consolidating mortar mixture

Time (min)	**10**	**60**	**120**	**180**
Slump flow (in.)	31	28.7	29.5	28.3
T-50 (sec)	1.4	1.28	1.22	1.2
Air content (%)	5.0	3.1	4.6	3.5
Temperature (^{o}F)	73.2	74.3	73.8	73.4
V-funnel flow (sec)	3.44	3.78	3.32	3.4
Unit weight (kg/m^3)	2234	2275	2248	2265
Static bleeding (%)	0	0	0	0.12
Compressive strength at 28 days (psi)	6,350			

4. FULL-SCALE PUMPING TEST

In order to evaluate the constructability of pumping the developed SCC mixture for connecting precast concrete deck panels and I-girder, a full-scale pumping testing was conducted. The full-scale specimen consisted of 58 ft 10 in. long NU900 (3 ft deep) precast/prestressed concrete I-girder and five precast concrete deck panels (three typical panels + two end panels). The specimen was designed and detailed using the same procedures and details proposed for the construction of Kearney East bypass bridge project presented earlier. Figure 4.1 shows the concrete dimensions and reinforcing details of the NU900 girder specimen fabricated by Concrete Industries Inc., Lincoln, NE on June, 20, 2013. Figure 4.2 shows photos of girder fabrication presenting the shear connectors, post-tensioning deviators, and metal tabs similar to those designed for the Kearney East Bypass bridge project.

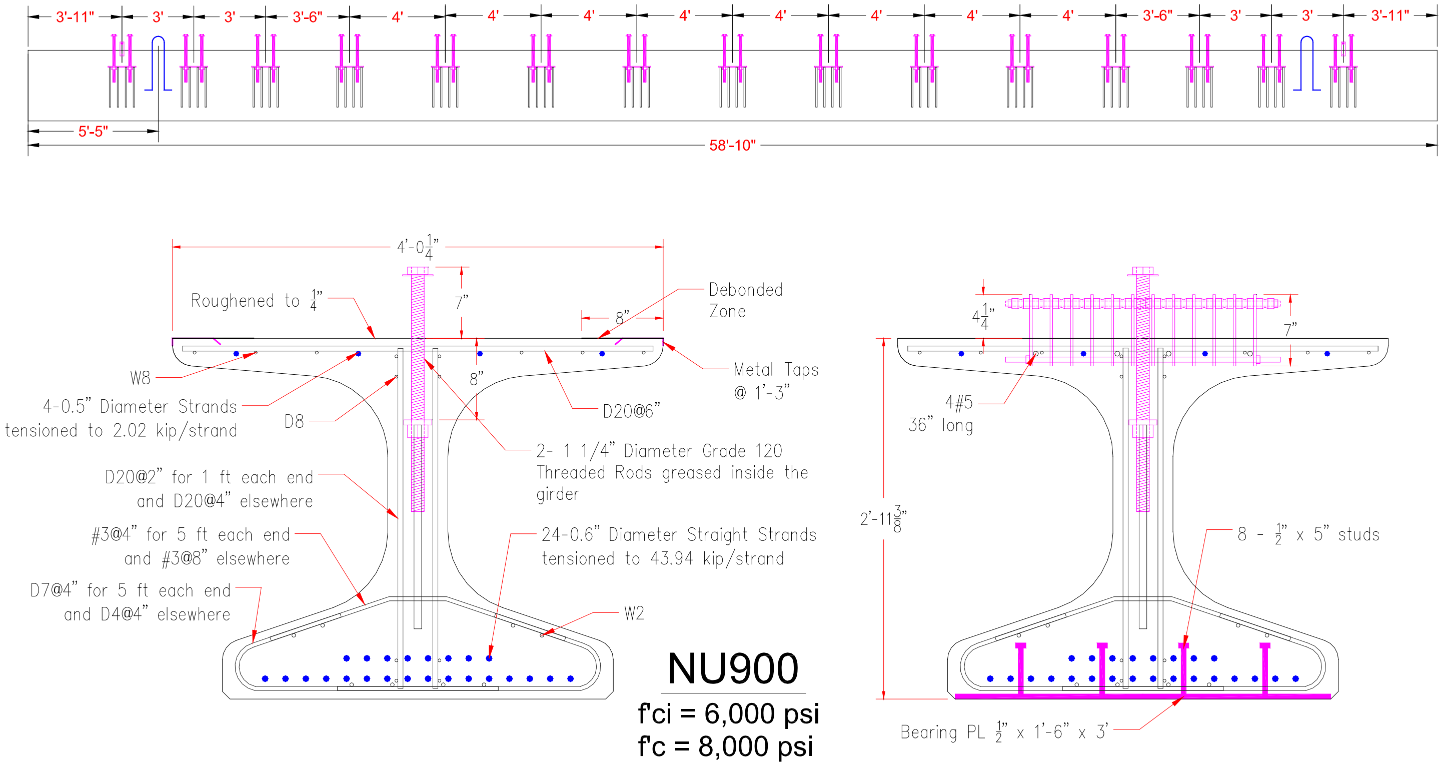


Figure 4.1 – Elevation view, middle cross section (left), and end cross section (right) of NU900 girder specimen

Figure 4.2 – Photos of girder fabrication

A total of five precast concrete deck panels were also fabricated to erect the full-scale specimen: three typical panels and two end panels to simulate actual bridge construction. The three typical panels were obtained by saw cutting a full size demonstration panel fabricated by Concrete Industries Inc., Lincoln, NE on April 25, 2013 as shown in Figure 4.3. The cutting layout resulted in three skewed panels that are 8 in. think, 12 ft long and 7 ft 8.25 in. wide as shown in Figure 4.4. Each panel has three pockets at 4 ft spacing: two pockets with lifting inserts (type A), and one pocket without lifting inserts (type B). The two end panels were also fabricated by Concrete Industries, Inc. in Lincoln, NE in a later date. Each end panel is 8 in. thick, 11 ft 4.75 in. long, and 7 ft 8.25 in. wide with 14^{o} skew. End panels contain embedded anchor blocks for deck post-tensioning. Figure 4.5 shows the concrete strength of the specimen girder and deck components. Curing compounds were sprayed to the pre-fabricated girder and decks for curing.

Figure 4.3 – Photo of full size demonstration deck panel showing panel soffit and shear pockets

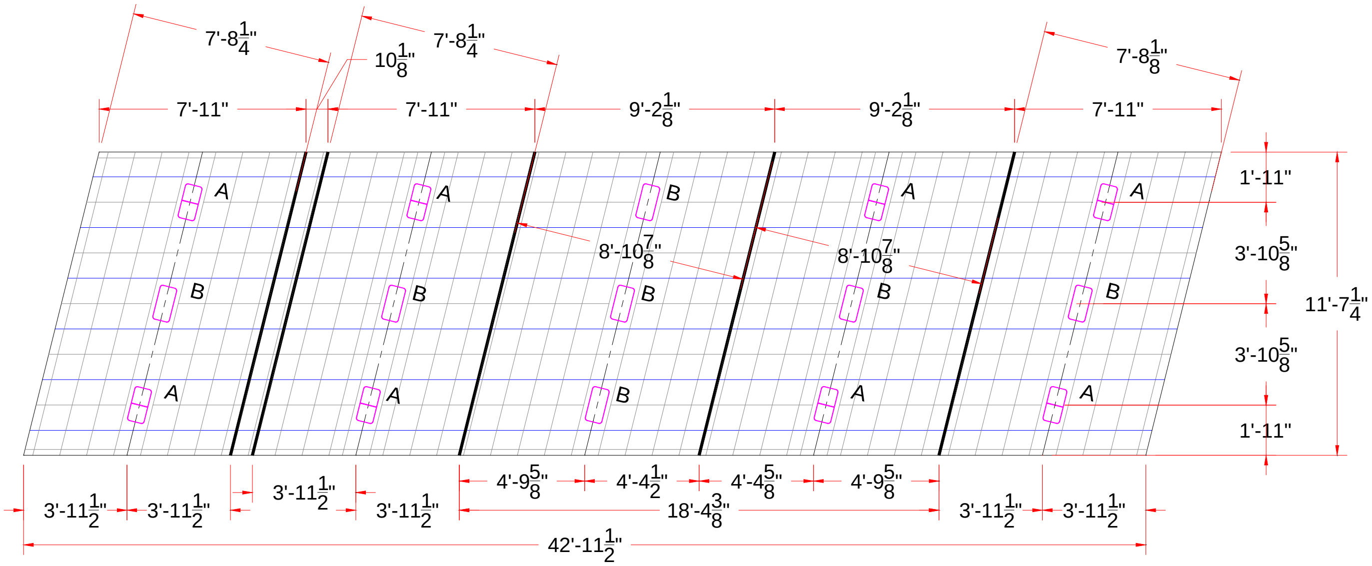


Figure 4.4 – Layout of panel saw cutting

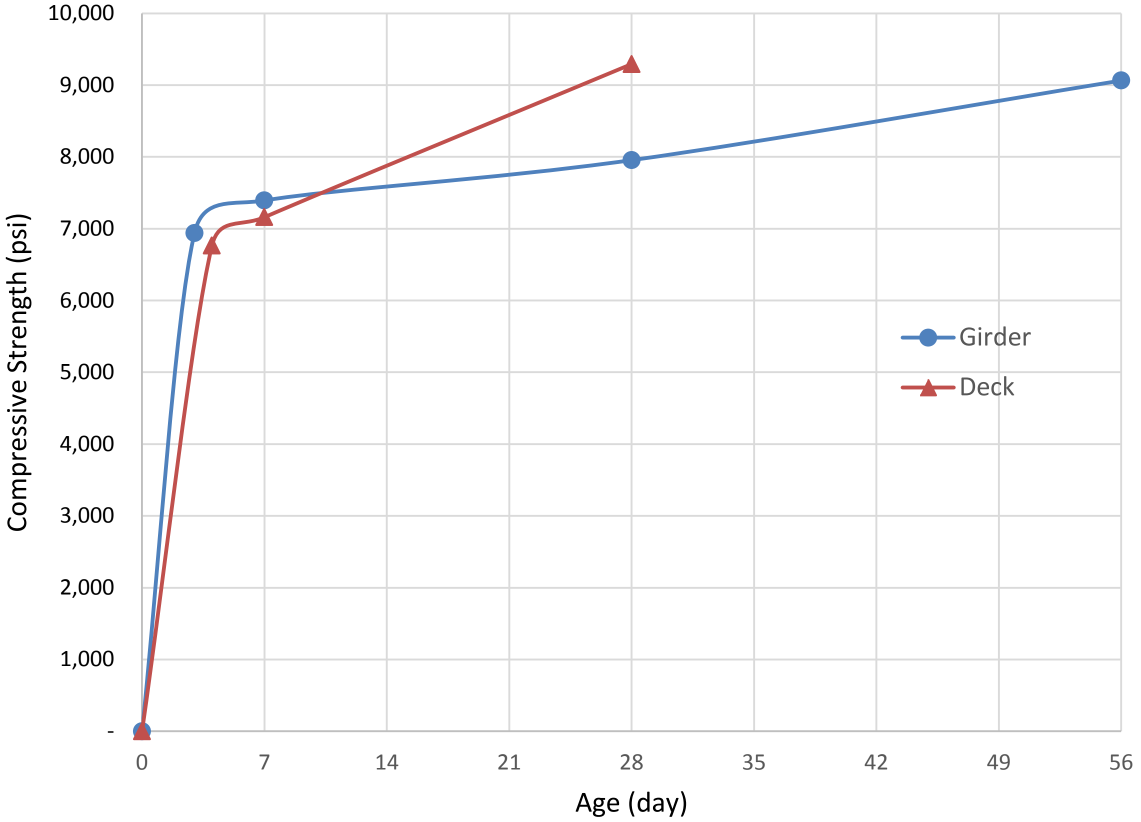


Figure 4.5 – Concrete strength of precast girder and deck panels

The NU900 girder specimen and the five deck panel specimens were shipped to UNL Structural Laboratory in Omaha for erection and testing. The steps followed in the specimen erection are shown below. Photos of these steps are shown in Appendix C, and a video of specimen erection can be seen at the following YouTube link: http://www.youtube.com/watch?v=Jky8gpaGhRc.

1. Place the girder on roller supports located at the girder ends to create a simple span of 57 ft 10 in.
2. Lay down 12-0.6 in. diameter post-tensioning strands on the top flange and thread the ends through the deviators at girder ends. Strands were 4 ft longer than the girder.
3. Install steel bent plates (or angles) used as deck support system by welding them to the metal tab inserts on the girder top flange. The height of the bent plates was adjusted to achieve at least 3 in. thick haunch and provide the required deck profile after considering deck deflection. These bent plates are also acting as side forms for haunch concrete.
4. Adjust the height of shear connectors to have an embedment in the deck of at least 5 in.
5. Attach compressive material (backer rod) to the top of the bent plates to prevent leakage.

6. Place precast concrete deck panels on the deck support system staring from the middle and moving outward.
7. Form the sides and bottom of transverse joints between adjacent deck panels using backer rod and wood forms.
8. Place the specified SCC mixture into transverse joints after cleaning and moistening them.
9. Place anchor plates, post-tensioning chucks, and bearing/bulkhead plates at the two end panels.
10. Post-tension the strands using mono-strand jack starting from the middle strands and moving outward in a symmetrical manner to minimize the eccentricity.
11. Pump the specified SCC from the pump sleeves welded to the bulkhead plate provided at girder ends until concrete overflows from the inspection vents.

The developed SCC mixture for connecting precast girder and deck panels was slightly revised to accommodate material availability in the state of Nebraska. Table 4.1 lists the composition and proportions of the revised SCC mixture that consists of 1PF cement (Type I cement pre-blended with 23% ± 2% Class F fly ash), 3/8" limestone aggregate, C33 natural sand (called 4110), and BASF admixtures. Technical data of these admixtures are shown in Appendix D.

Table 4.1 – Composition and proportions of the revised SCC mixture

Component	Quantity	US Units
IPF Cement	866	lb/yd^3
Water	285	lb/yd^3
w/c	**0.33**	**N/A**
4110 Sand	1615	lb/yd^3
3/8 in. Limestone	1077	lb/yd^3
TOTAL AGG.	**2692**	**lb/yd^3**
HRWR (Glenium 3030)	4	oz/cwt
Retarder (Delvo)	4	oz/cwt
VMA (Rheomac 362)	4	oz/cwt
AEA (MB-AE 90)	0.2	oz/cwt
WRA (RheoTEC Z-60)	4	oz/cwt

A trial batch was conducted on September 27, 2013 to evaluate the performance of the revised SCC mixture and pour the transverse joints between adjacent deck panels shown in Figure 4.6.

The mixture achieved an average slump flow of 29 in. (735 mm), as shown in Figure 4.7, J-ring slump difference less than 1 in., and VSI = 1.0. These values indicate that the revised SCC mixture has adequate flowability, passingability, and resistance to segregation. Several 4 x 8 in. cylinders were taken to evaluate the compressive strength and hardened visual stability index (HVSI) shown in Figure 4.8. The same mixture with no modifications will be used in the pumping test to fill the gap between the precast girder and deck panels of the same specimen.

Figure 4.6 – Transverse joint between adjacent deck panels.

Figure 4.7 – Slump flow of the SCC mixture used in filling transverse joints (VSI = 1.0)

Figure 4.8 – Coarse aggregate distribution in joint concrete (HVSI = 1)

Pumping test was conducted on October 18, 2013 using ready mixed concrete from Lyman Richey Co. and Hotz concrete pumping Co. Concrete was delivered with low flowability, therefore, several dosages of HRWRA were added to achieve an average slump flow of 27.8 in. as shown in Figure 4.9. Other workability properties are summarized in Table 4.2.

Figure 4.9 – Slump flow of the SCC mixture used in the pumping test (VSI = 0)

Table 4.2 – Workability properties of the pumped SCC

Test	Criteria	Time (min)		
		30	60	90*
Slump flow (in.)	26 - 30	27.75	25	30.5
Visual stability index (VSI)	0 - 1	0	0	1
J-ring slump spread difference (in.)	0 - 2	1		
Penetration (in.)	0 - 1	0.75		
Filling capacity (%)	80 - 100	96		
Column segregation (%)	0 - 10	5.2		
Long through segregation (%)	0 - 30	16.1		
Air content (%)	5 – 9			
Static yield stress (Pa)	N/A			49
Dynamic yield stress (Pa)	N/A			22
Plastic viscosity (Pa.s)	N/A			3.3

* Another dosage of HRWRA was added to an assumed quantity of concrete

Pumping started by using a ½ cubic yard of slurry to lubricate the hose and haunch area, then SCC was pumped from one end, and the flow of concrete from the 1 in. diameter holes at 4 ft spacing was monitored to ensure the filling of shear pockets. Pumping continued until the accumulated pressure caused uplifting of the specimen panels. Pumping stopped and proceeded from the other end until the haunch and pockets were completely filled, and vents were plugged. Below is a detailed sequence of events recorded in this investigation:

- 1:42 PM: 5 yd^3 of concrete arrived. Initial slump flow = 18 in.
- 1:52 PM: 1.5 fl.oz/cwt of HRWRA was added. Slump flow = 24 in.
- 1:56 PM: 1 fl.oz/cwt of HRWRA was added. Slump flow did not change significantly.
- 2:02 PM: 1 fl.oz/cwt of HRWRA was added. Slump flow = 27.75 in. Accepted.
- 2:05 PM: Pumping started at 35 to 50 bars in concrete pressure as shown in Figure 4.10. Concrete overflow from vents was stopped using plugs, as shown in Figure 4.11.
- 2:15 PM: Concrete leaked after reached 29.5 ft from the pumping point due to the high pumping pressure that cause uplifting of deck panels, as shown in Figure 4.12. Pumping stopped.
- 2:37 PM: Pumping resumed from the other end as shown in Figure 4.13.
- 2:50 PM: 1.5 fl.oz/cwt of HRWRA was added to the remaining amount of concrete. Slump flow = 30.5 in.

- 3:04 PM: Pumping was completed.

A YouTube presentation of the pumping test can be seen at: http://www.youtube.com/watch?v=8kLjKAfsylY

Figure 4.10 – Pumping SCC using 2 in. diameter hose

Figure 4.11 – Plugging 1 in. diameter vents

Figure 4.12 – Concrete leakage during pumping due to deck uplift

Figure 4.13 – Pumping concrete from the other end of the specimen

Figure 4.14 presents the compressive strength of the lab-mixed and ready-mixed SCC used in pouring the transverse joints and haunch respectively. The plot indicates the reproducibility of the proposed mixture. Figure 4.15 shows a cross section of the hardened haunch concrete after specimen testing, which presents the coarse aggregate distribution. This figure indicates the pumped SCC has adequate resistance to segregation.

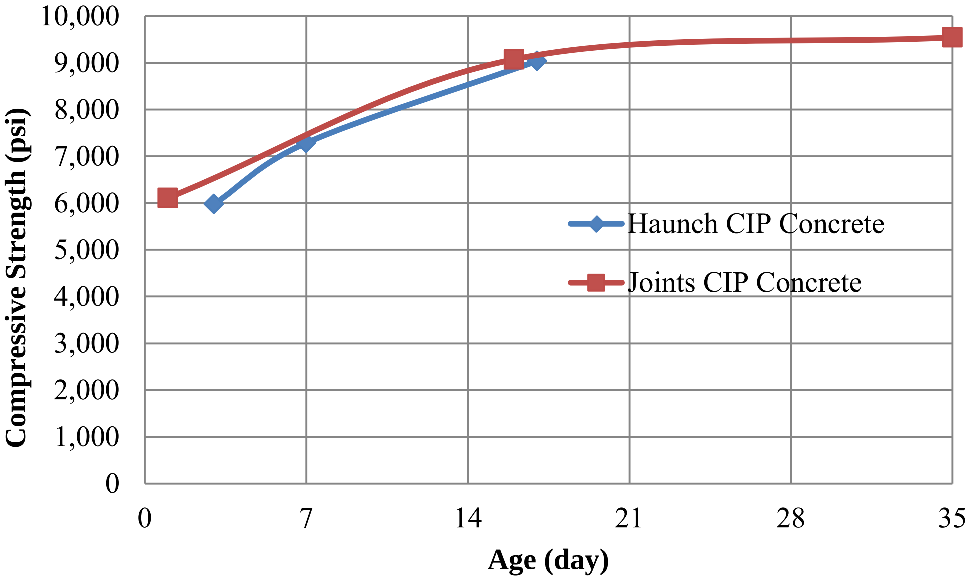


Figure 4.14 – Concrete compressive strength for CIP transverse joints and haunch

Figure 4.15 – Coarse aggregate distribution in haunch concrete (HVSI = 1.0)

To evaluate the structural performance of the precast concrete girder-to-deck connection capacity, the full-scale specimen was tested in flexure using a concentrated load at the mid-span section, as shown in Figure 4.16. This testing setup generates a uniform interface shear force on all the shear connectors. Several linear variable differential transformers (LVDTs) were used to monitor the horizontal and vertical displacements of the precast deck relative to the CIP haunch; and string potentiometer was used to measure the specimen deflection at the mid-span section.

Figure 4.16 – Test setup

Testing was conducted by loading the specimen at 50 kip increments. After each loading increment, the specimen was visually inspected for cracking, and cracks were marked to evaluate their propagation. This process was repeated until the load reached 200 kip. Then, the specimen was loaded continuously to failure, which occurred at a load of 380 kip with a maximum deflection of 8.4 in. The load was released, and the specimen maintained a permanent deflection of 3.6 in. Figure 4.17 plots the load-deflection relationship of the specimen, which represents its behavior while testing. This straight line relationship at the beginning indicates that the specimen remained un-cracked up to a load of 200 kips, which is higher than the calculated cracking load of 161 kip for a fully composite section. Table 4.3 lists the demand, theoretical capacity and measured capacity for both cracking and ultimate loads. These results indicate that the tested specimen outperformed the predicted capacities for a fully composite section.

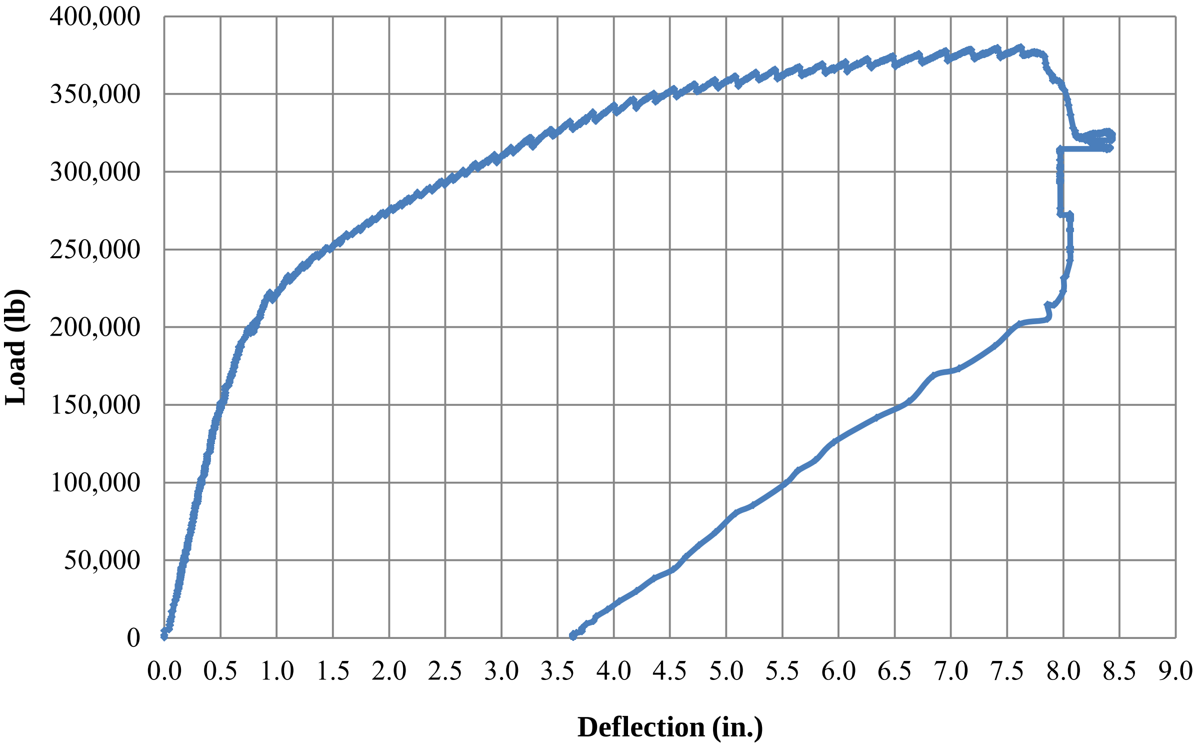


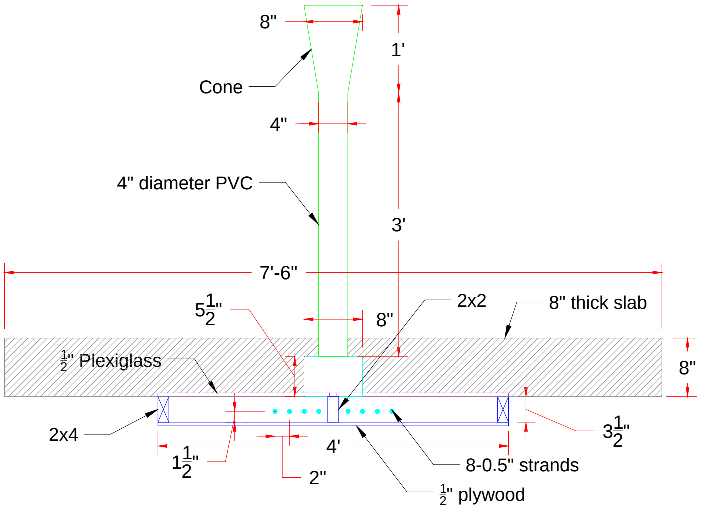
Figure 4.17 – Load-deflection relationship of the specimen

Table 4.3 – Comparing theoritical and measured capacities

Load Type	Cracking Load (kip)	Ultimate Load (kip)
Theoretical capacity	161	338
Measured capacity	200	380
Ratio of measured-to-theoretical	1.24	1.12

5. MOCKUP POURING TEST

The challenge of pumping SCC into the haunch area from one end to the other one has indicated that it is not practical to pump SCC for a 334-ft long girder line. Despite the optimized rheological properties of the SCC, high pumping pressure would be required to ensure proper filling of the haunch and pocket areas. This conclusion resulted in proposing a new approach, which will be tested in this chapter. Testing was performed to evaluate the constructability of the new full-depth precast concrete deck system by pouring SCC from a 4-in. diameter pouring port located in the middle of a 12 ft long deck panel. The goal is to completely fill the haunch area between precast deck panel and the supporting girder as well as the shear pockets within the deck panel without pumping SCC. The mockup test aims to determine whether pouring every 12 ft (using only one pouring port per panel) is adequate to ensure a complete and efficient filling of the haunch and pockets. Figure 5.1 shows the cross section and plan views of the mockup specimen, which consists of: a) wood formed channel that is 16 ft long, 4 ft wide, and 3.5 in. thick; b) two deck panels with two shear pockets spaced at 12 ft; c) ½ in. plexiglass sheets covering the top of the channel between the panels to allow observing the concrete flow; d) 8-0.5 in. diameter strands lightly tensioned and located in the mid-height of the channel to simulate the post-tensioning strands used underneath the deck; e) several 2x2 lumber pieces to support the plexiglass and simulate the shear connectors located every 4 ft along the specimen; and f) 1 in. diameter vents to allow the air to escape while filling the haunch and pockets. Photos of the pouring mockup test specimen are presented in Figure 5.2.



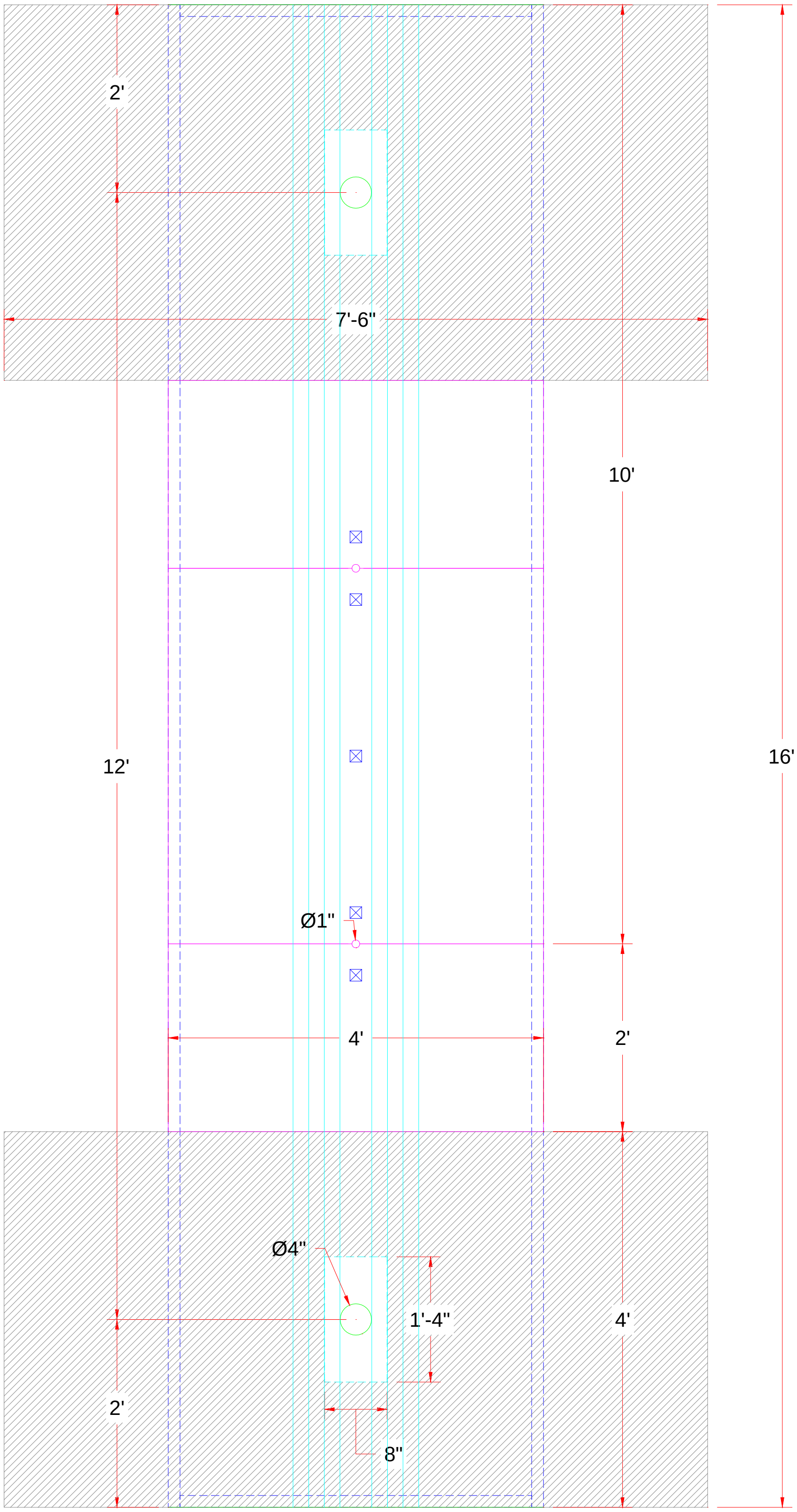


Figure 5.1 – Section and plan views of the mockup test specimen

Figure 5.2 – Photos of the pouring mockup test specimen

Table 5.1 lists the proportions of the SCC mixture delivered by ready mix on Nov. 18, 2013 at 11:30 am. The mixture initially had very low flowability, which required several additional dosages of HRWR and WRA as shown in Table 5.1 in order to achieve the required flowability. Table 5.2 lists the tests performed and the results of workability tests. Photos of slump flow and J-ring tests are shown in Figure 5.3 and photos of penetration resistance and air content tests are shown in Figure 5.4.

Table 5.1 – SCC mixture proportions

Component	**Quantity per 1 cy**	**Units**	**Quantity per 3 cy**
IPF Cement	866	lb/yd^3	2598
Water	285	lb/yd^3	855
w/c	**0.33**	**N/A**	**0.33**
Sand	1615	lb/yd^3	4845
3/8 in. Limestone	1077	lb/yd^3	3231
TOTAL AGG.	**2692**	**lb/yd^3**	**8076**
HRWR (Glenium 3030)	6	oz/cwt	156
AEA (MB-AE 90)	0.25	oz/cwt	6
WRA (RheoTEC Z-60)	0	oz/cwt	0
Added at the site			
HRWR (Glenium 3030)	5	oz/cwt	130
WRA (RheoTEC Z-60)	4	oz/cwt	104

Table 5.2 – Tests performed and their results

Conducted Test	**ASTM/AASHTO Standard**	**Measured Parameter**	**Value**	**Criteria**	**Decision**
Slump flow	C 1611 / TP 73	Average diameter (in.)	27.8	26 - 30	OK
Slump flow	C 1611 / TP 80	Visual stability index (VSI)	0	0 - 1	OK
J-ring	C 1621 / TP 74	Difference in slump flow and J-ring flow diameter (in.)	0.5	< 2 in.	OK
Penetration resistance	C 1712	Penetration (in.)	0.25	< 0.5	OK
Air content	C 231 / T 152	Percentage of air (%)	3.8%	5%-9%	Add more AEA
Static segregation	PP 58	Hardened visual stability index (HVSI)	0	0 - 1	OK
Compressive strength	C 39 / T22	Average 3-day strength (psi)	6,520	> 3,500	OK
	C 39 / T22	Average 28-day strength (psi)	11,860	> 6,000	OK

Figure 5.3 – Slump flow (top) and J-ring (bottom) tests (VSI = 0)

Figure 5.4 – Penetration resistance (top) and air content (bottom) tests

Concrete was poured using a large bucket and a custom-made 8 in. diameter chute, as shown in Figure 5.5, to easily pour the concrete into the cone/funnel used on top of the 4 in. diameter pipe. Figure 5.6 shows photos of the concrete flowing from one pouring port to the other, completely filling the channel and pockets, and encapsulating the strands in a very short time without trapping any air pockets. By the end of the test, concrete overflow at one of the transverse joints between Plexiglass sheets, as shown in Figure 5.7, because one of the screws holding the sheets was pulled out due to concrete pressure causing a gap between adjacent sheets. This was not a concern as it is not the case when adjacent deck panels are used. Table 5.3 shows the revised SCC mixture to account for the lack of entrained air and the need for a retarder. Figure 5.8 shows a photo of the hardened concrete after form stripping and cylinder testing. These photos show a uniform distribution of coarse aggregate across the section, which indicates a hardened visual stability index (HVSI) of 0. Figure 5.9 shows the compressive strength gain with time for SCC cylinders. A video of the mockup pouring test is posted in YouTube at: http://www.youtube.com/watch?v=85pAU3yFs9s

Figure 5.5 – The bucket and chute used in pouring SCC

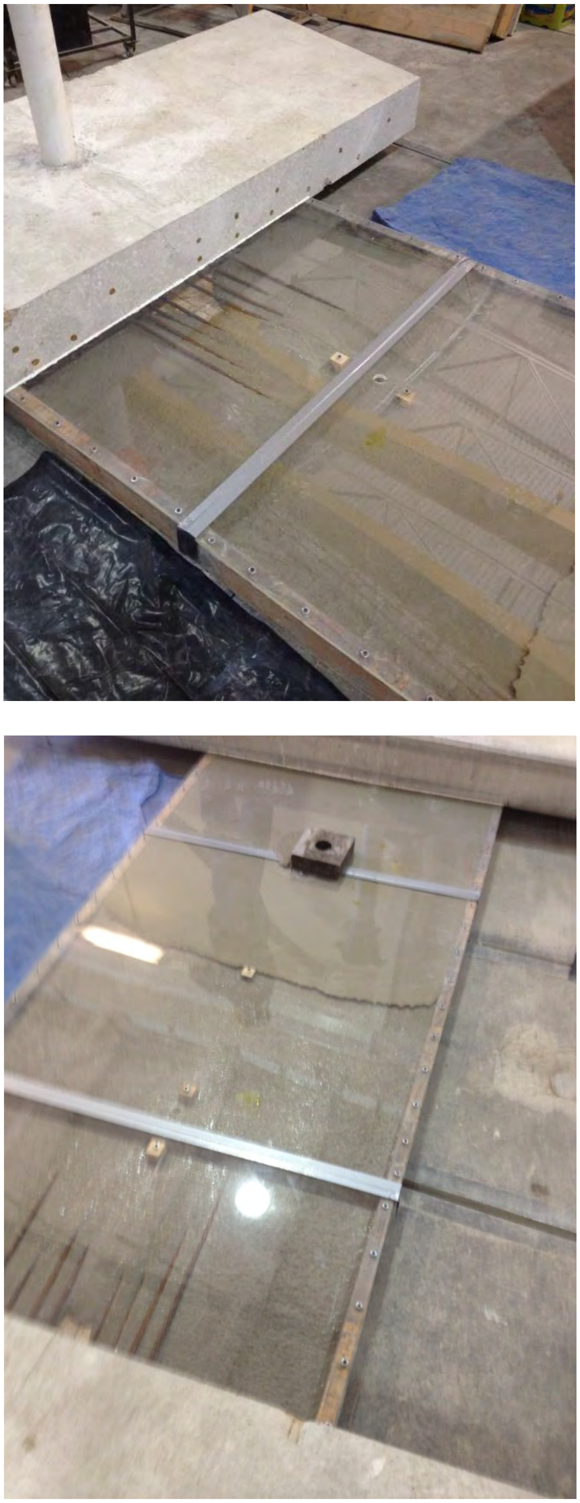


Figure 5.6 – SCC flowing from one port to the other and completely filling the channel

Figure 5.7 – Concrete overflowing at one of the joints between Plexiglass sheets

Table 5.3 – Revised SCC mixture proportions

Component	Quantity per 1 cy	US Units
IPF Cement	866	lb/yd^3
Water	285	lb/yd^3
w/c	**0.33**	**N/A**
Sand	1615	lb/yd^3
3/8 in. Limestone	1077	lb/yd^3
TOTAL AGG.	**2692**	**lb/yd^3**
HRWR (Glenium 3030)	6	oz/cwt
Retarder (Delvo)	4	oz/cwt
VMA (Rheomac 362)	0	oz/cwt
AEA (MB-AE 90)	0.4	oz/cwt
WRA (RheoTEC Z-60)	4	oz/cwt

Figure 5.8 – Coarse aggregate distribution in hardened concrete (HVSI = 0)

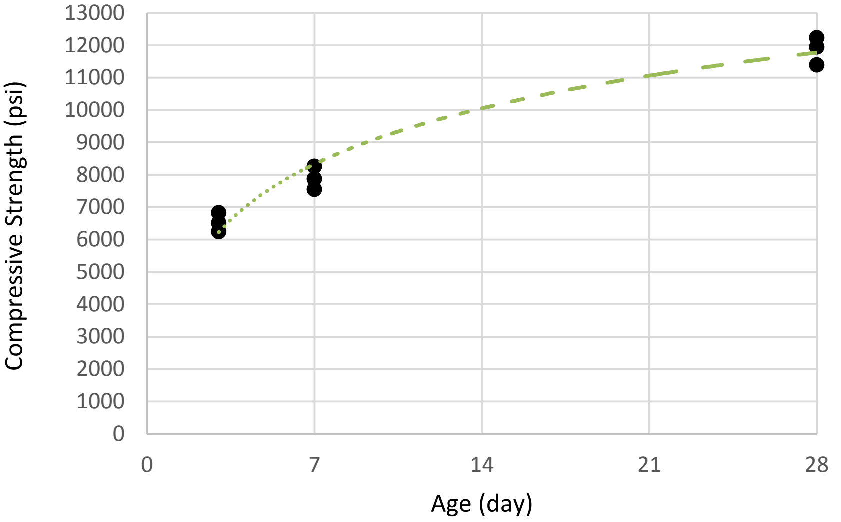


Figure 5.9 – Compressive strength test results of SCC

6. PUSH-OFF TESTS

The purpose of this investigation is to evaluate the interface shear capacity of the girder-to-deck connection using the proposed SCC mixture. A total of eight push-off test specimens were fabricated and tested for the four different groups listed in Table 6.1 (i.e. two specimens per group). Each specimen consists of a T-girder with pre-installed shear connector assembly similar to the one used in the full-scale specimen and a 8 in. thick precast concrete deck panel with one shear pocket similar to the one used in the full-scale specimen. Table 6.1 shows that group A specimens used self-consolidating grout (i.e. no coarse aggregate) to fill the haunch and pocket areas. Table 6.2 lists the proportions of that grout. All other specimens (groups B, C, and D) used SCC similar to the one used earlier in the full-scale pumping test and pouring mockup test (refer to Table 5.3 for mixture proportions). Group C specimens had 8#5 Grade 60 bars placed longitudinally around the shear connectors (4#5 bars on each side) at 2 in. spacing. These bars are located at the mid-height of the haunch to evaluate the effect of the post-tensioning strands used in the Kearney East Bypass project (refer to Figure 1.2). Group D specimens had smaller dimensions for the haunch area to evaluate the effect of the cohesion between the haunch concrete and precast deck soffit. This condition also simulates the cases where narrow flange I-girders (e.g. AASHTO girders) or isolated haunches are used. Appendix E shows the photos of specimen fabrication and tested for all the four groups.

Table 6.1 – Description of push-off test specimens

Group ID	Specimen ID	Haunch Concrete	Haunch Dimensions	Haunch Reinforcement
A	A1	Grout	48” x 41”	none
	A2	Grout	48” x 41”	none
B	B1	SCC	48” x 41”	none
	B2	SCC	48” x 41”	none
C	C1	SCC	48” x 41”	8#5
	C2	SCC	48” x 41”	8#5
D	D1	SCC	24” x 16”	none
	D2	SCC	24” x 16”	none

Table 6.2 – Proportions of the grout used in Group A specimens

Material	Quantity (lb/cy)
Cement I/II	602
Class F fly ash	180
Expansive agent	0
Coarse aggregate	-
Fine aggregate	2,672
Water	315
HRWRA	5.9 oz/cwt
VMA	1.0 oz/cwt
AEA	0.2 oz/cwt
Retarder	2.9 oz/cwt

Figure 6.1 shows the dimensions and reinforcing details of the T-girders used in the 8 push-off specimens. In all these specimens, the top of the shear connectors was maintained at 9 in. from the top of the T-girder flange to ensure an embedment of 5.25 in. in the pocket after subtracting 3.75 in. that represents the haunch thickness. Figure 6.2 plots the compressive strength of the concrete used in casting the T-girders up to the time of testing. This plot indicates that concrete compressive strength of T-girders ranged from 8,000 – 12,000 psi at the time of testing. Precast deck panels were placed after forming the haunch area using 4x4 lumber and adding ½ in. backer rod on top of it to prevent haunch concrete from leaking as shown in Appendix E. The two concrete deck panels used in group A specimens were formed and cast in the UNL structural laboratory as shown in Appendix E. The remaining six deck panels used in all other specimens were saw cut from the full-scale demonstration deck panel produced by Concrete Industries, Inc. and shown earlier in Figure 4.4. The concrete compressive strength of all the deck panels was approximately 9,000 psi at the time of structural testing. The haunch and pocket areas were then filled with grout (for group A specimens) and SCC (for groups B, C, and D specimens) using a 4 in. diameter holes in the precast deck panel. The overflow of the concrete/grout was an indication that the entire space was completely filled. Figure 6.3 shows the compressive strength of the haunch grout/concrete at various ages. This figure indicates that grout had a significantly lower compressive strength (approximately 3.8 ksi) than SCC (approximately 6.5 ksi) at a given age of testing. It should be noted that the grout was mixed using lab drum mixer, while SCC was provided using a local ready mix supplier.

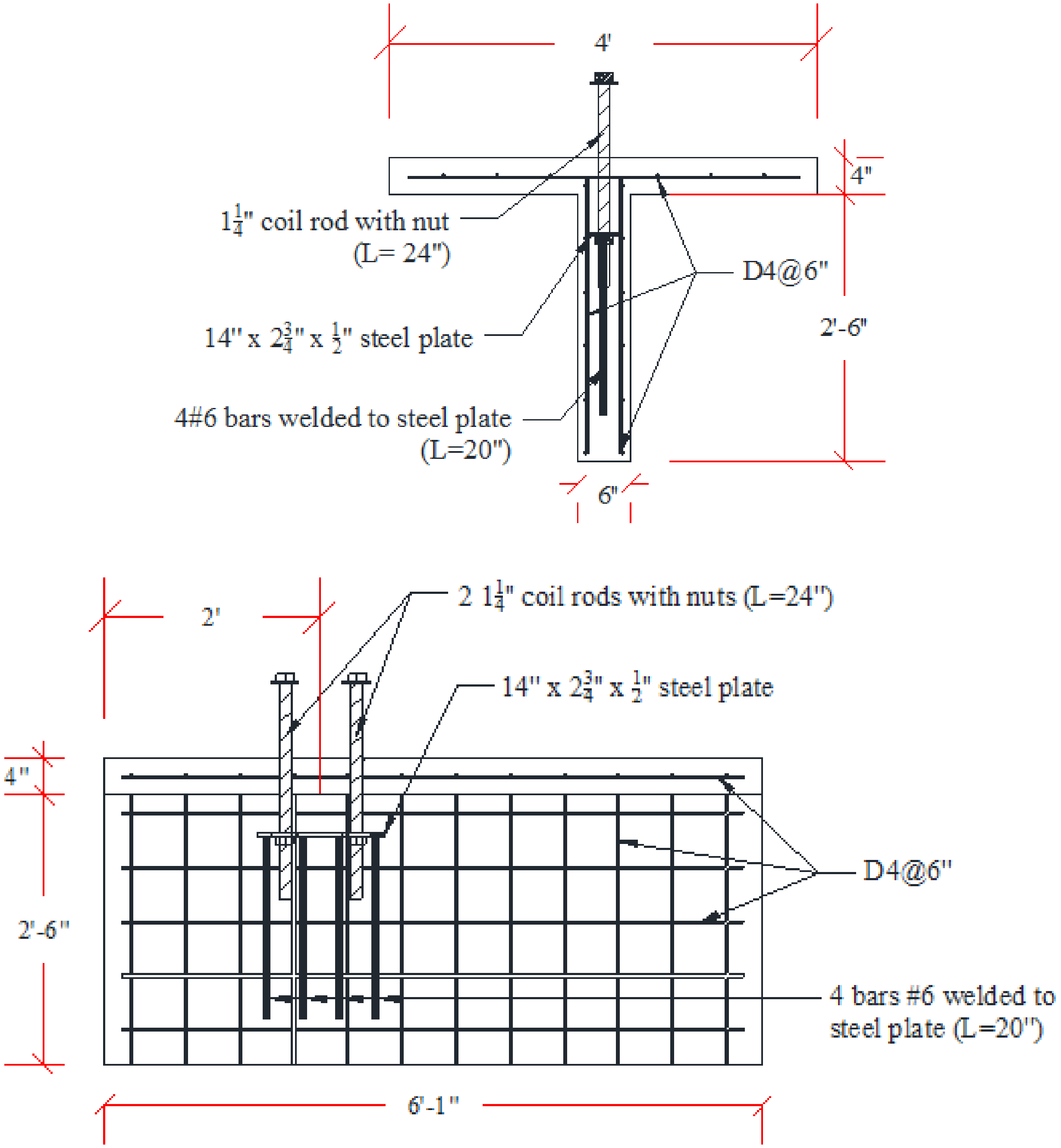


Figure 6.1 – T-girder dimensions and reinforcement

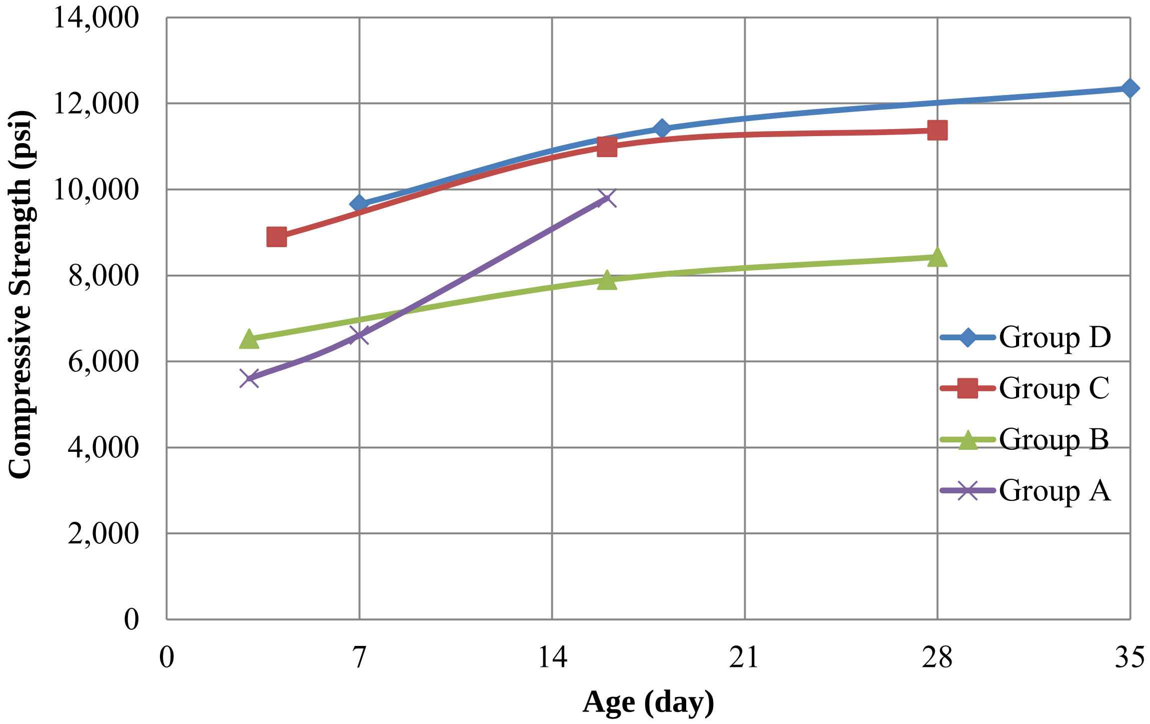


Figure 6.2 – Concrete strength of the T-girders

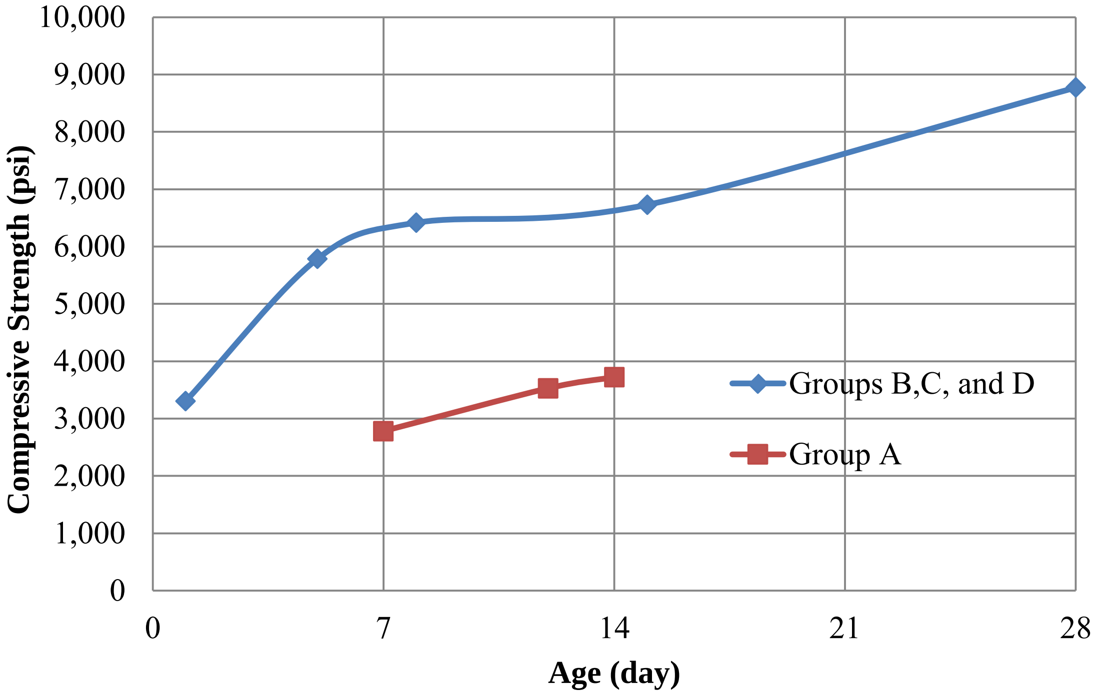


Figure 6.3 – Compressive strength of grout and SCC used in filling the haunch and pocket

The grout used in group A specimens had an average spread of 29 in. with VSI = 1.0. No further workability tests were conducted. The SCC used in groups B, C, and D specimens had low flowability (average spread = 22.5), however, it was decided not to add extra dosage of HRWRA to evaluate the structural performance of the connection when low flowability SCC is used, which is more critical. Table 6.3 lists all the tested workability properties of SCC mixtures. Figure 6.4 compares the rheological properties of the same SCC mixture when used for the pumping test (high flowability) and for pouring the haunch in groups B, C, and D specimens (low flowability).

Table 6.3 – Workability properties of the SCC mixture used for filling haunches and pockets

Test	Criteria	Time (min)	
		15	30
Slump flow (in.)	**26 - 30**	22.5	
Visual stability index (VSI)	**0 - 1**	0	
Slump flow J-ring Spread Difference (in.)	**0 - 2**	1	
Penetration (in.)	**0 - 1**	0.25	
Filling capacity (%)	**80 - 100**		85
Column segregation (%)	**0 - 10**		2.4
Long through segregation (%)	**0 - 30**		14.5
Air content (%)	**5 - 9**		4

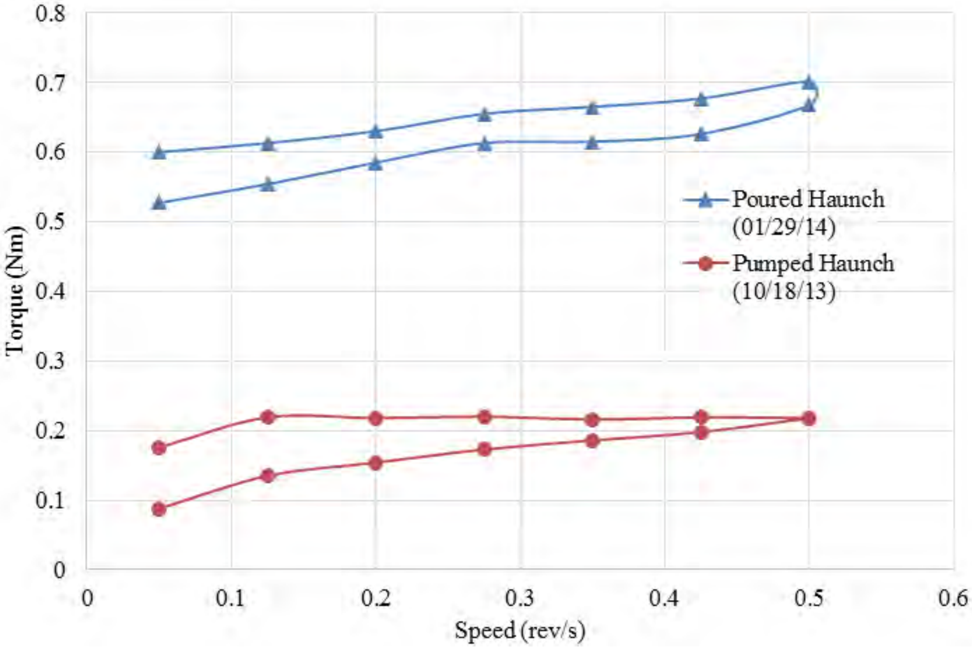


Figure 6.4 – Comparing rheological properties

Figure 6.5 shows the setup of the push-off testing conducted on all the eight specimens. It should be noted that a strap was added to groups C and D specimens at the girder end facing the wall to prevent its rotation under elevated loads.

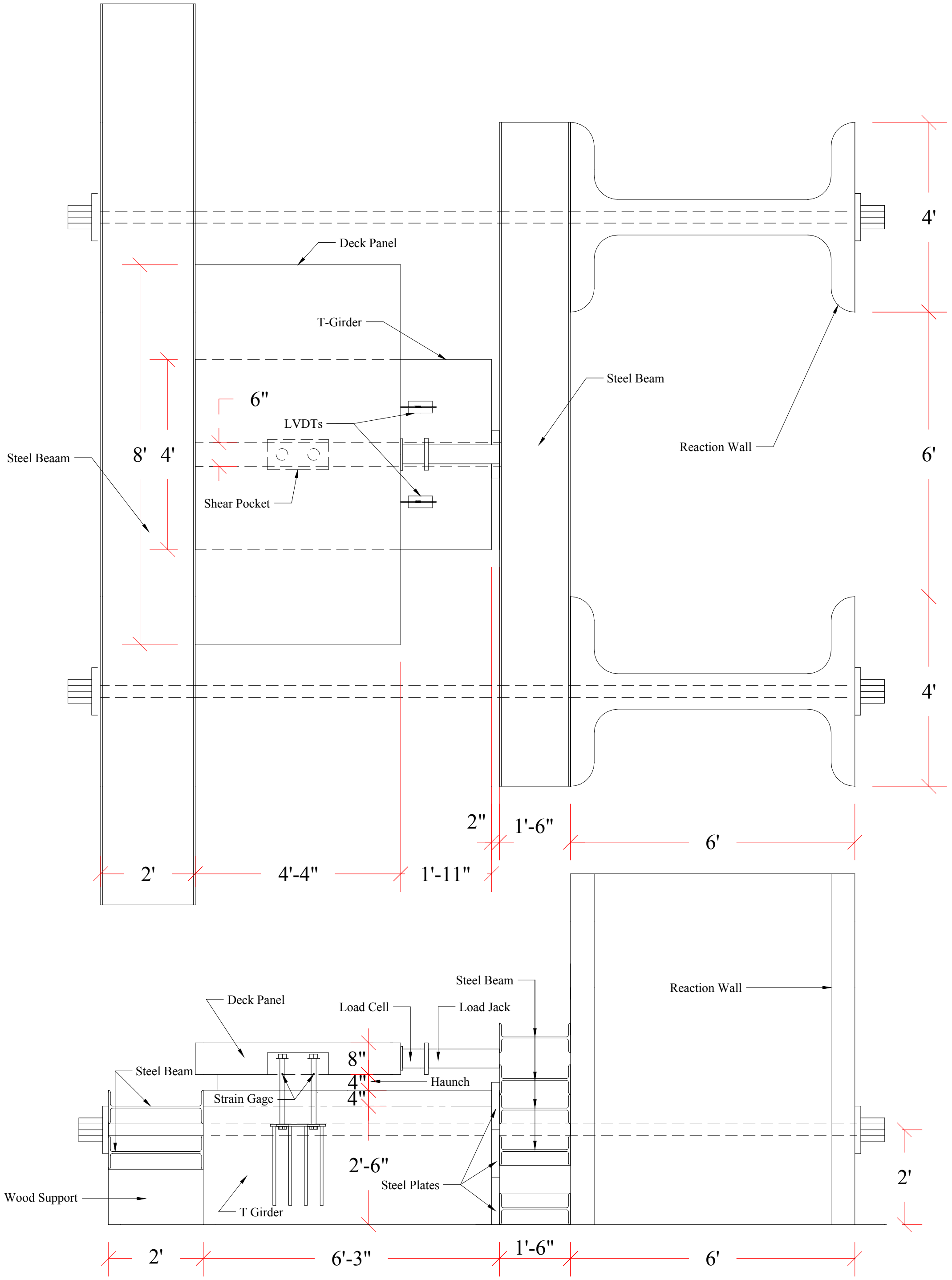


Figure 6.5 – Push-off test setup

Figure 6.6 plots the load-displacement relationships for the eight push-off tests. This figure indicates that all connections had an increased resistance until an initial slippage occurred (< 0.2 in.), where a significant drop in the connection capacity took place. By loading the connection further, additional resistance was developed due to the dowel action of the shear connectors. Ultimate capacity of the connection was reached at significantly higher displacement (> 1.5 in.) only in groups C and D specimens, which were restrained from rotation. Figure 6.7 summarizes push-off testing results by plotting the load at initial displacement and ultimate load. This figure indicates that groups B, C, and D specimens have higher capacity than group A specimens due to the high strength and presence of coarse aggregate in SCC mixture. The figure also indicates that the dimensions of the haunch (group D) do not have negative effect on the connection capacity. The presence of longitudinal reinforcement in the haunch (group C) has positive effect on the ultimate capacity of the connection.

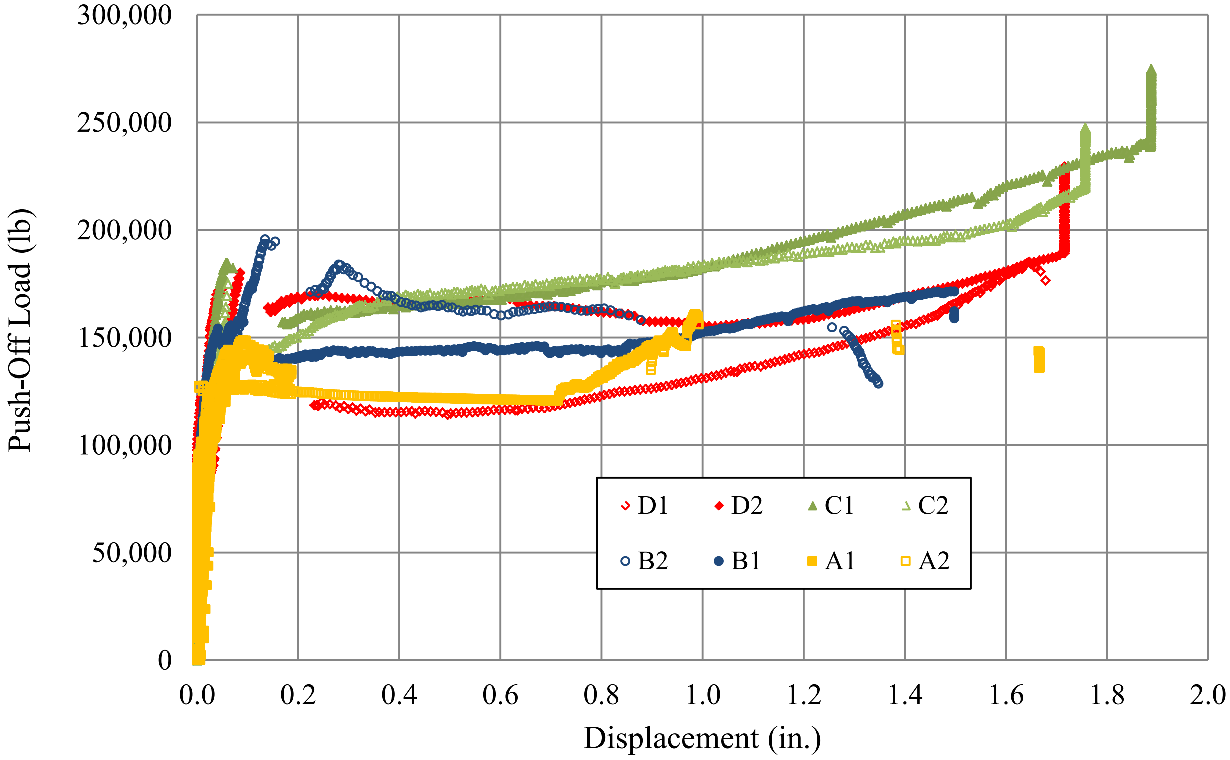


Figure 6.6 – Push-off test results

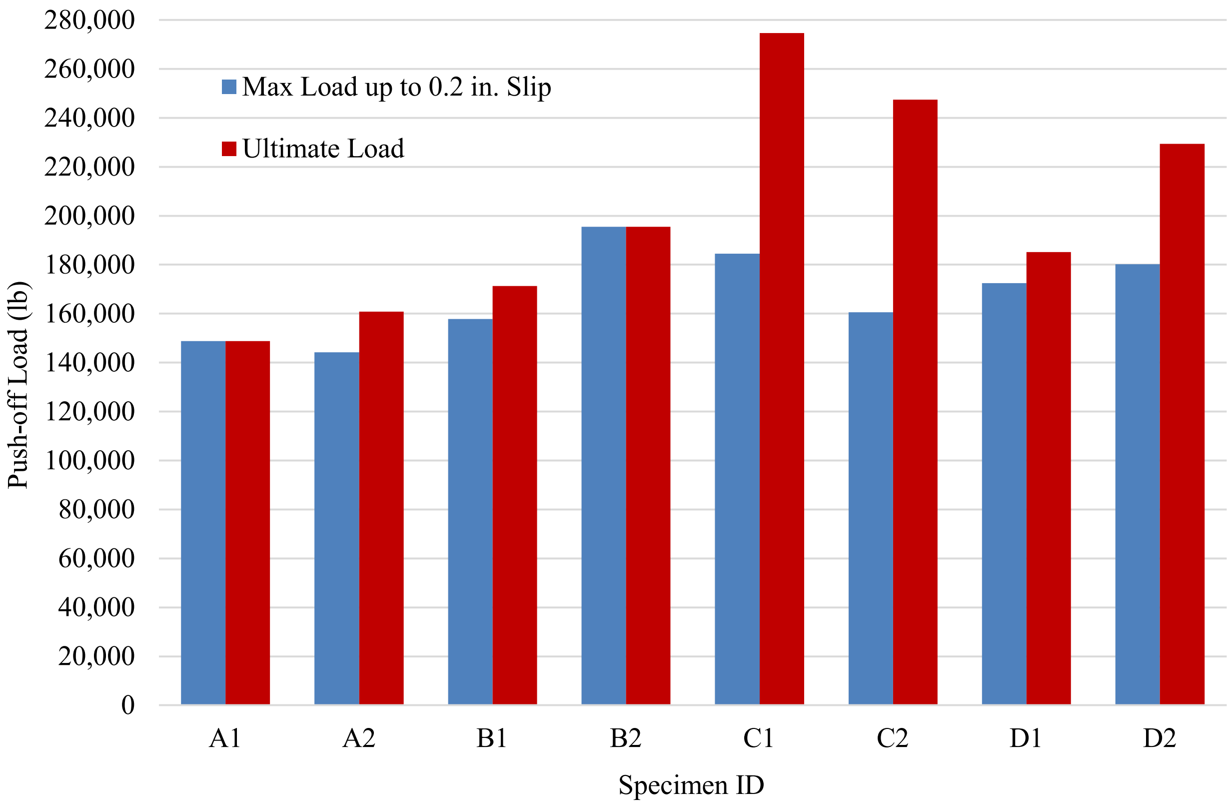


Figure 6.7 – Summary of push-off test results

7. CONCLUSIONS

This study is an integral part of another research project that aims at evaluating the constructability of a newly developed precast concrete bridge deck system (2nd generation NUDECK system). In this project, the development and use of SCC for connecting precast concrete deck panels and bridge I-girders is vital to the success of the new deck system. Therefore, the scope of this study includes the optimization of a specific SCC mixture for this special application and evaluating its flowability and pumpability experimentally in small–scale and full-scale specimens, as well as its hardened properties including strength and shrinkage. Also, quality control and quality assurance procedures are investigated and presented to bridge owners/contractors as special provisions. Based on the outcomes of the several experimental investigations conducted in this study and the associated constructability experience, the following conclusions can be made:

- A highly flowable and economical SCC mixture can be developed to fill the gap between precast concrete deck panels and bridge I-girders (haunch) as well as the shear pockets in deck panels while satisfying all workability and strength requirements. This development eliminates the need for special expensive grouts that negatively affect the cost effectiveness of precast concrete deck systems.
- The developed SCC mixture performs better than grout with respect to interface shear capacity due to its high strength and presence of coarse aggregates in the optimized SCC. Interface shear is an important design criteria for precast concrete bridge deck systems.
- Pumping SCC from one end of the bridge along the girder lines results in a significant increase in concrete pressure with distance due to the geometric complexity of volume that needs to be filled. The accumulated pressure could result in blow out of side forms or uplift of deck panels. Therefore, pumping should be restricted to short span bridges or when multiple pumping vents can be provided along the girder line.
- Pouring SCC from 4 in. diameter holes spaced at 12 ft is a simple, efficient, and economical method for filling the haunch and shear pockets along each girder line.
- Special provisions for the use of SCC in this application were developed for NDOR, as shown in Appendix F.

8. REFERENCES

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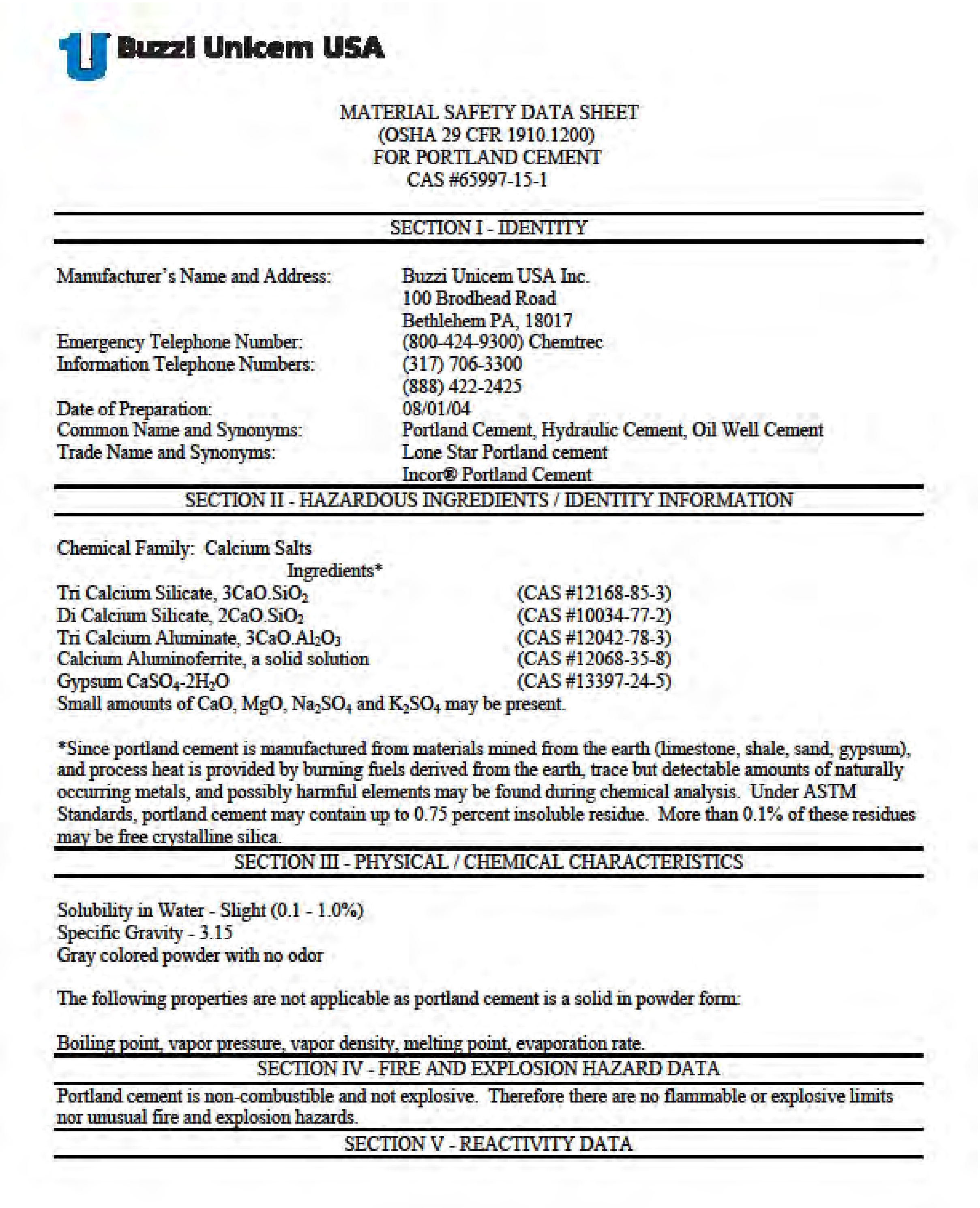
4. Morcous, G., Tadros, M. K., Hatami, A. (2013) "Implementation of Precast Concrete Deck System NUDECK (2nd Generation)" NDOR Technical Report M323, Dec.

9. APPENDICES

APPENDIX A: Materials Used in Pumping Mockup Testing



Buzzi Unicem USA

MATERIAL SAFETY DATA SHEET
(OSHA 29 CFR 1910.1200)
FOR PORTLAND CEMENT
CAS #65997-15-1

SECTION I - IDENTITY

Manufacturer's Name and Address:	Buzzi Unicem USA Inc. 100 Brodhead Road Bethlehem PA, 18017
Emergency Telephone Number:	(800-424-9300) Chemtrec
Information Telephone Numbers:	(317) 706-3300 (888) 422-2425
Date of Preparation:	08/01/04
Common Name and Synonyms:	Portland Cement, Hydraulic Cement, Oil Well Cement
Trade Name and Synonyms:	Lone Star Portland cement Incor® Portland Cement

SECTION II - HAZARDOUS INGREDIENTS / IDENTITY INFORMATION

Chemical Family: Calcium Salts

Ingredients*	
Tri Calcium Silicate, $3CaO.SiO_2$	(CAS #12168-85-3)
Di Calcium Silicate, $2CaO.SiO_2$	(CAS #10034-77-2)
Tri Calcium Aluminate, $3CaO.Al_2O_3$	(CAS #12042-78-3)
Calcium Aluminoferrite, a solid solution	(CAS #12068-35-8)
Gypsum $CaSO_4$-$2H_2O$	(CAS #13397-24-5)

Small amounts of CaO, MgO, Na_2SO_4 and K_2SO_4 may be present.

*Since portland cement is manufactured from materials mined from the earth (limestone, shale, sand, gypsum), and process heat is provided by burning fuels derived from the earth, trace but detectable amounts of naturally occurring metals, and possibly harmful elements may be found during chemical analysis. Under ASTM Standards, portland cement may contain up to 0.75 percent insoluble residue. More than 0.1% of these residues may be free crystalline silica.

SECTION III - PHYSICAL / CHEMICAL CHARACTERISTICS

Solubility in Water - Slight (0.1 - 1.0%)
Specific Gravity - 3.15
Gray colored powder with no odor

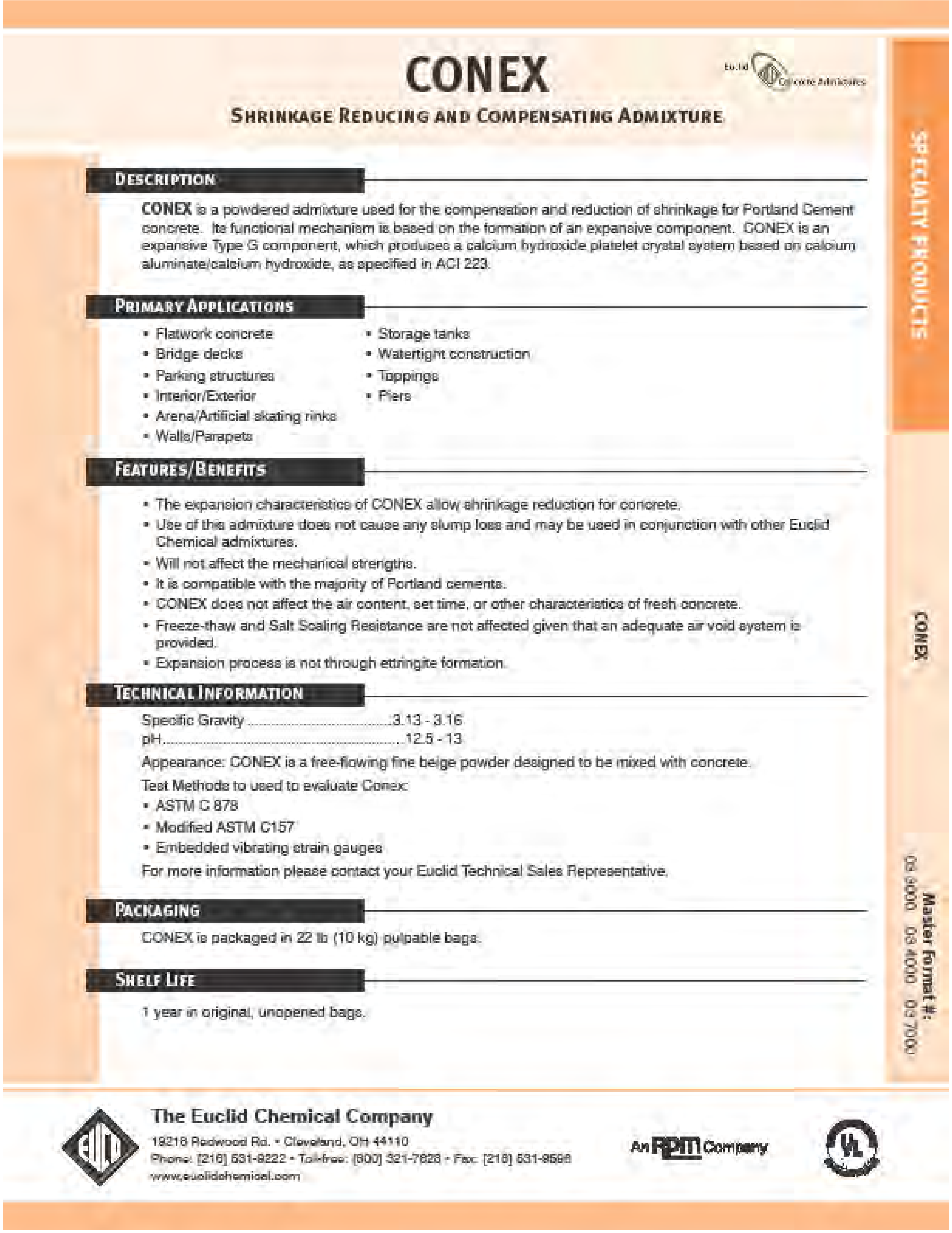
The following properties are not applicable as portland cement is a solid in powder form:

Boiling point, vapor pressure, vapor density, melting point, evaporation rate.

SECTION IV - FIRE AND EXPLOSION HAZARD DATA

Portland cement is non-combustible and not explosive. Therefore there are no flammable or explosive limits nor unusual fire and explosion hazards.

SECTION V - REACTIVITY DATA



CONEX

SHRINKAGE REDUCING AND COMPENSATING ADMIXTURE

SPECIALTY PRODUCTS

DESCRIPTION

CONEX is a powdered admixture used for the compensation and reduction of shrinkage for Portland Cement concrete. Its functional mechanism is based on the formation of an expansive component. CONEX is an expansive Type G component, which produces a calcium hydroxide platelet crystal system based on calcium aluminate/calcium hydroxide, as specified in ACI 223.

PRIMARY APPLICATIONS

- Flatwork concrete
- Bridge decks
- Parking structures
- Interior/Exterior
- Arena/Artificial skating rinks
- Walls/Parapets
- Storage tanks
- Watertight construction
- Toppings
- Piers

FEATURES/BENEFITS

- The expansion characteristics of CONEX allow shrinkage reduction for concrete.
- Use of this admixture does not cause any slump loss and may be used in conjunction with other Euclid Chemical admixtures.
- Will not affect the mechanical strengths.
- It is compatible with the majority of Portland cements.
- CONEX does not affect the air content, set time, or other characteristics of fresh concrete.
- Freeze-thaw and Salt Scaling Resistance are not affected given that an adequate air void system is provided.
- Expansion process is not through ettringite formation.

CONEX

TECHNICAL INFORMATION

Specific Gravity ....3.13 - 3.16
pH...12.5 - 13

Appearance: CONEX is a free-flowing fine beige powder designed to be mixed with concrete.

Test Methods to used to evaluate Conex:

- ASTM C 878
- Modified ASTM C157
- Embedded vibrating strain gauges

For more information please contact your Euclid Technical Sales Representative.

PACKAGING

CONEX is packaged in 22 lb (10 kg) pulpable bags.

SHELF LIFE

1 year in original, unopened bags.

Master Format #:
03 3000 03 4000 03 7000

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www.euclidchemical.com

An RPM Company

CTS Cement Cement Manufacturing Corporation
11065 Knott Avenue, Suite A
Cypress, CA 90630
Phone: (800) 929-3030 • Fax: (714) 379-8270
info@ctscement.com
www.ctscement.com

CTS Komponent® — DATASHEET

Additive for Non-Shrink and Low-Shrinkage Concrete

RECOMMENDED SPECIFICATIONS FOR CTS KOMPONENT® CONCRETE

CEMENT:
Shall be normal portland cement Type I or II conforming to ASTM C150.

EXPANSIVE COMPONENT:
Shall be CTS Komponent®, an expansive Type-K component manufactured by CTS Cement Manufacturing Corporation. It shall be added to the concrete mix at the batch plant or at the jobsite.

AGGREGATES:
Shall be clean, well graded and conform to ASTM C33.

WATER:
Shall be clean and potable.

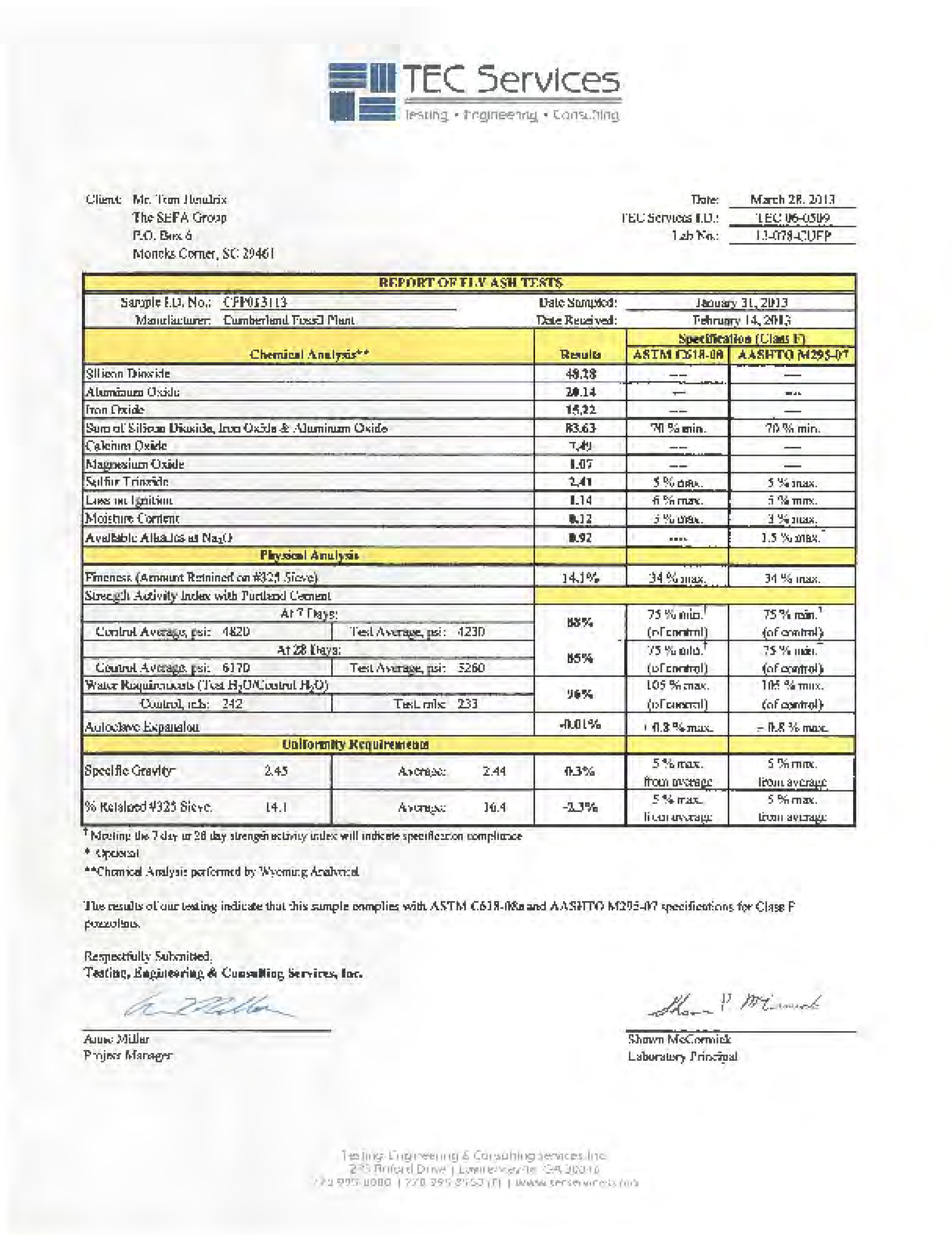
ADMIXTURE:
Most admixtures are compatible with shrinkage-compensating concrete. (Check with CTS Cement on experience with a given admixture.)

RECOMMENDED PROCEDURE FOR BATCHING AND MIXING CTS KOMPONENT® CONCRETE:
Sufficient mixing of concrete to obtain a uniform mix is important for any concrete construction project and is required for CTS Komponent® concrete. The addition of CTS Komponent® dry powder is similar to the addition of fly ash to a concrete mix where special batching and mixing procedures are used to assure a uniform product.

BATCHING AND MIXING PROCEDURES:
The ingredients for shrinkage-compensating concrete can be batched or put into a truck mixer in various ways. The preferred batching procedure is: 1. Charge the mixer with approximately 80% of the mixing water and air-entraining admixture per the mix design. 2. Ribbon feed the CTS Komponent® and portland cement in with coarse aggregate and sand with the mixer drum turning at mixing speed. 3. Add the remainder of aggregates and sand. 4. Mix for 5 minutes at mixing speed. 5. Check the slump of the mix. A slump of 5" ± 1" is recommended for most work.

JOBSITE CONDITIONS:
Pre-Pour Meeting: A Pre-Pour Meeting is recommended to coordinate the work.
Slump Loss: A slump loss during transit is to be expected and the amount of loss depends on the length of haul and temperature.

REINFORCEMENT:
Accepted engineering practices for structural elements provide sufficient reinforcement for Komponent® Cement Concrete. However, in non-load-bearing members such as slabs on grade, for non-shrink cement the minimum amount of reinforcement should be about 0.15% of the gross cross-sectional area of the concrete in each direction. For low-shrinkage concrete a smaller amount of reinforcement may be used. Reinforcement should be placed about 1" to 2" from the top allowing for



TEC Services
Testing • Engineering • Consulting

Client: Mr. Tom Hendrix
The SEFA Group
P.O. Box 6
Moncks Corner, SC 29461

Date: March 28, 2013
TEC Services I.D.: TEC 06-0509
Lab No.: 13-078-CUFP

REPORT OF FLY ASH TESTS

Sample I.D. No.: CFP013113
Manufacturer: Cumberland Fossil Plant
Date Sampled: January 31, 2013
Date Received: February 14, 2013

Chemical Analysis**	Results	Specification (Class F) ASTM C618-08	 AASHTO M295-07
Silicon Dioxide	48.28	---	---
Aluminum Oxide	20.14	---	---
Iron Oxide	15.22	---	---
Sum of Silicon Dioxide, Iron Oxide & Aluminum Oxide	83.63	70 % min.	70 % min.
Calcium Oxide	7.49	---	---
Magnesium Oxide	1.07	---	---
Sulfur Trioxide	2.41	5 % max.	5 % max.
Loss on Ignition	1.14	6 % max.	5 % max.
Moisture Content	0.12	3 % max.	3 % max.
Available Alkalies as Na_2O	0.92	----	1.5 % max.*
Physical Analysis			
Fineness (Amount Retained on #325 Sieve)	14.1%	34 % max.	34 % max.
Strength Activity Index with Portland Cement			
At 7 Days: Control Average, psi: 4820 / Test Average, psi: 4230	88%	75 % min.† (of control)	75 % min.† (of control)
At 28 Days: Control Average, psi: 6170 / Test Average, psi: 5260	85%	75 % min.† (of control)	75 % min.† (of control)
Water Requirements (Test H_2O/Control H_2O) Control, mls: 242 / Test, mls: 233	96%	105 % max. (of control)	105 % max. (of control)
Autoclave Expansion	-0.01%	± 0.8 % max.	± 0.8 % max.
Uniformity Requirements			
Specific Gravity 2.45 / Average: 2.44	0.3%	5 % max. from average	5 % max. from average
% Retained #325 Sieve 14.1 / Average: 16.4	-2.3%	5 % max. from average	5 % max. from average

† Meeting the 7 day or 28 day strength activity index will indicate specification compliance

* Optional

**Chemical Analysis performed by Wyoming Analytical

The results of our testing indicate that this sample complies with ASTM C618-08a and AASHTO M295-07 specifications for Class F pozzolans.

Respectfully Submitted,
Testing, Engineering & Consulting Services, Inc.

Anne Miller
Project Manager

Shawn McCormick
Laboratory Principal

Testing, Engineering & Consulting Services, Inc.
235 Buford Drive | Lawrenceville, GA 30046
770.995.8000 | 770.995.8550 (f) | www.tecservices.com

PLASTOL 6200EXT

EXTENDED WORKABILITY HIGH-RANGE WATER REDUCING ADMIXTURE

DESCRIPTION

PLASTOL 6200EXT high-range water-reducing admixture is formulated using advanced polycarboxylate technology, specifically engineered for concrete to provide extended workability retention minimizing the need for jobsite slump adjustments while maintaining consistent air contents from batching to placing of concrete. In addition, Plastol 6200EXT maintains the typical benefits of polycarboxylate technology of high compressive strengths, flexural strength, and excellent setting characteristics. Plastol 6200EXT can be used to reduce the total cement content and used with supplementary cementitious materials. Plastol 6200EXT does not contain added chlorides or chemicals known to promote the corrosion of steel.

PRIMARY APPLICATIONS

- Ready-mix concrete with maximum water reduction requirements
- Excellent workability retention without set retardation
- Self-Consolidating Concrete (SCC)
- Low w/c concrete
- High-performance concrete
- Precast/pre-stressed concrete
- Flatwork and mass concrete
- Pervious concrete

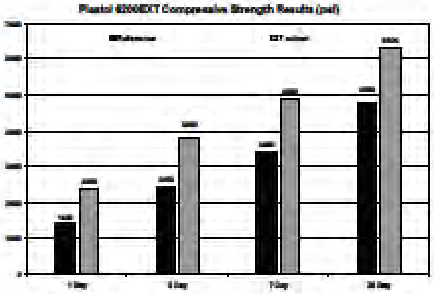
FEATURES/BENEFITS

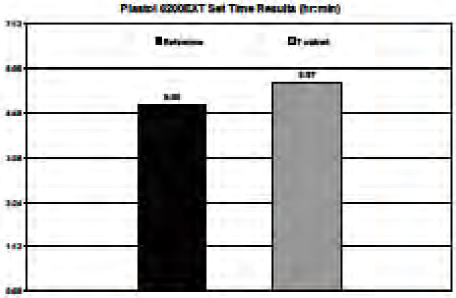
- Provides exceptional workability
- Consistent control of air content
- Higher early and ultimate strengths
- Reduces or eliminates job-site addition of HRWR
- Lowers number of rejected concrete loads
- Aids in concrete placement and reduces labor cost

TECHNICAL INFORMATION

Performance Data:

The following test results were achieved using typical ASTM C 494 mix design requirements, 517 lb/yd³ (307 kg/m³) cement content and similar (± 0.5)% air content. These results were obtained under laboratory conditions with materials and mix designs meeting the specifications of ASTM C 494. Changes in materials and mix designs can affect the dosage response of PLASTOL 6200EXT.





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www.euclidchemical.com
An RPM Company

PLASTOL 5000

HIGH RANGE WATER REDUCING ADMIXTURE

HIGH-RANGE WATER REDUCERS

DESCRIPTION

PLASTOL 5000 is a ready to use polycarboxylate based, high range water-reducing admixture for concrete. PLASTOL 5000 increases early concrete strength as well as ultimate strength. PLASTOL 5000 can be used to produce increased concrete slump or to significantly reduce water demand for a specific slump. PLASTOL 5000 can be added at the plant or jobsite and is compatible with other admixtures. PLASTOL 5000 contains no added chlorides.

PRIMARY APPLICATIONS

- High performance concrete
- Self-compacting concrete
- Precast concrete
- Low water/cement ratio concrete
- High early strength applications

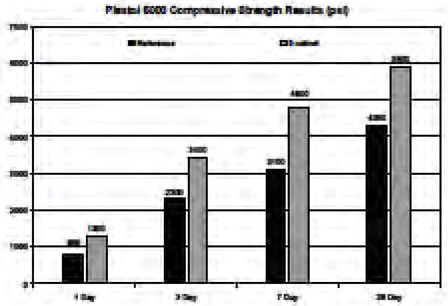
FEATURES/BENEFITS

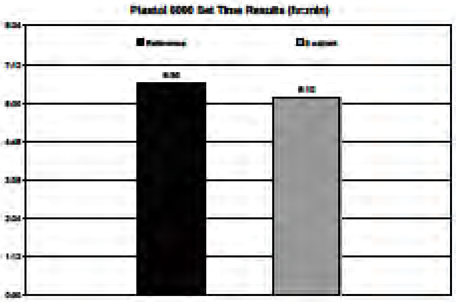
- Low water/cement ratio reduces water demand
- Self-compacting concrete reduces labor costs
- High early strength reduces energy costs
- Controlled setting times reduces labor costs

TECHNICAL INFORMATION

Performance Data:

The following test results were achieved using typical ASTM C 494 mix design requirements, 517 lb/yd³ (307 kg/m³) cement content and similar (± 0.5)% air content. These results were obtained under laboratory conditions with materials and mix designs meeting the specifications of ASTM C 494. Changes in materials and mix designs can affect the dosage response of PLASTOL 5000.





PLASTOL 5000

Master Format #:
03 3000 03 4000 03 7000

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EUCON RETARDER 100

WATER REDUCING - EXTENDED SET CONTROLLING RETARDER

DESCRIPTION

EUCON RETARDER 100 is a synthetically produced liquid water-reducing and set retarding admixture for concrete. It is a modified sodium gluconate. EUCON Retarder 100 does not contain calcium chloride or other potential corroding materials and may be used in the presence of aluminum or zinc embedments. EUCON Retarder 100 may be used at varying dosage rates to achieve extended set times compared to a control mix of up to 30 hours. It is compatible with air-entraining agents, water reducers and calcium chloride.

PRIMARY APPLICATIONS

- Prestressed concrete
- Concrete requiring water reduction and set time control
- Architectural concrete
- Hot weather concrete placement

FEATURES/BENEFITS

Plastic Concrete

- Retards setting characteristics
- Improves finishability
- Improves workability
- Reduces water requirements
- Reduces segregation

Hardened Concrete

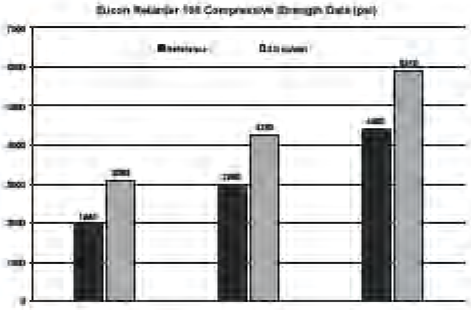
- Increases strengths
- Improves finished appearance
- Reduces cracking
- Reduces permeability
- Non staining

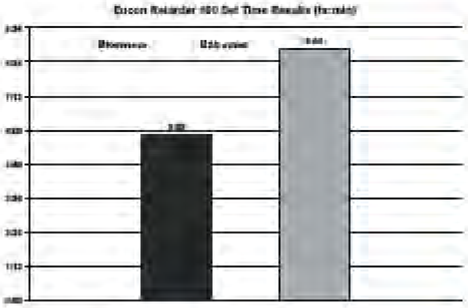
TECHNICAL INFORMATION

Perfomance Data

The following test results were achieved using typical ASTM C 494 mix design requirements, 517 lb/yd³ (307 kg/m³) cement content and similar (± 0.5)% air content.

These results were obtained under laboratory conditions with materials and mix designs meeting the specifications of ASTM C 494. Changes in materials and mix designs can affect the dosage response of EUCON RETARDER 100.





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EUCON AEA-92

AIR ENTRAINING AGENT FOR CONCRETE

DESCRIPTION

EUCON AEA-92 is formulated for use as an air entraining admixture for concrete of all types and is manufactured under rigid control which assures uniform and precise performance. It should be added to the mix independently and not with other admixtures.

PRIMARY APPLICATIONS

- Ready mix concrete
- Structural concrete
- Mass concrete
- Paving concrete
- All exterior concrete

FEATURES/BENEFITS

- Provides a stable air void system with proper bubble size and spacing. This air void system protects concrete against damage caused by repeated freeze/thaw cycles
- Concrete is made more resistant to de-icing salts, sulfate attack and corrosive water
- Less mixing water can be used per yard (meter) of concrete and placeability is improved
- Minimizes bleeding and segregation of the concrete

TECHNICAL INFORMATION

EUCON AEA-92 is an aqueous solution compound of synthetic organic chemicals. It is compatible with concrete mixes containing calcium chloride, water reducing admixtures, retarding admixtures, or high range water reducers.

PACKAGING

EUCON AEA-92 is packaged in bulk, 275 gal (1041 L) totes, 55 gal (208 L) drums and 5 gal (18.9 L) pails.

SHELF LIFE

2 years in original, unopened package.

SPECIFICATIONS/COMPLIANCES

EUCON AEA-92 meets or exceeds the requirements of the following specifications:

- Corps of Engineers Specification CRD C-13
- ASTM Specification C 260
- AASHTO Specification M 154
- ANSI/NSF STD 61

Master Format #:
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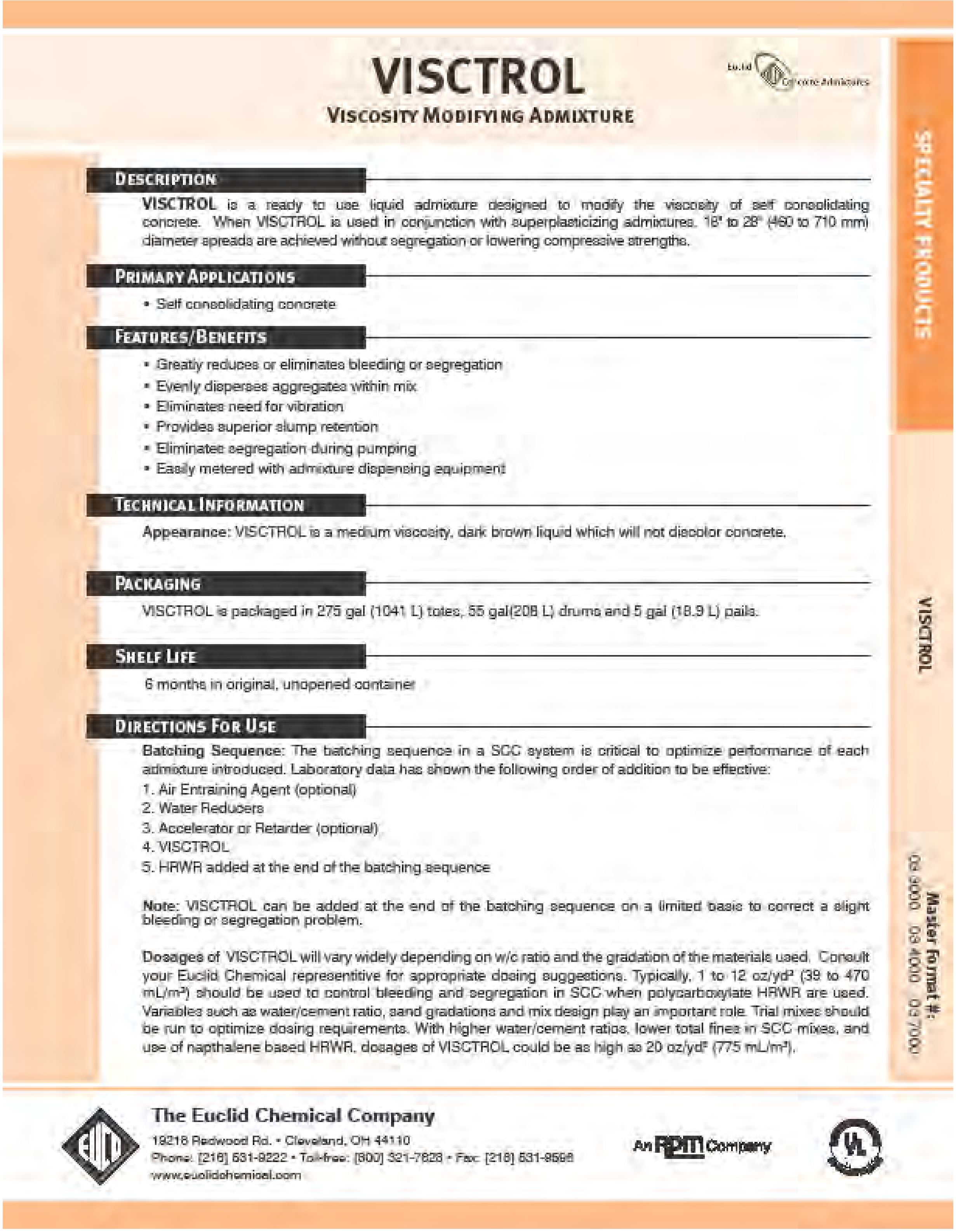

VISCTROL

Viscosity Modifying Admixture

Description

VISCTROL is a ready to use liquid admixture designed to modify the viscosity of self consolidating concrete. When VISCTROL is used in conjunction with superplasticizing admixtures, 18" to 28" (460 to 710 mm) diameter spreads are achieved without segregation or lowering compressive strengths.

Primary Applications

- Self consolidating concrete

Features/Benefits

- Greatly reduces or eliminates bleeding or segregation
- Evenly disperses aggregates within mix
- Eliminates need for vibration
- Provides superior slump retention
- Eliminates segregation during pumping
- Easily metered with admixture dispensing equipment

Technical Information

Appearance: VISCTROL is a medium viscosity, dark brown liquid which will not discolor concrete.

Packaging

VISCTROL is packaged in 275 gal (1041 L) totes, 55 gal(208 L) drums and 5 gal (18.9 L) pails.

Shelf Life

6 months in original, unopened container

Directions For Use

Batching Sequence: The batching sequence in a SCC system is critical to optimize performance of each admixture introduced. Laboratory data has shown the following order of addition to be effective:

1. Air Entraining Agent (optional)
2. Water Reducers
3. Accelerator or Retarder (optional)
4. VISCTROL
5. HRWR added at the end of the batching sequence

Note: VISCTROL can be added at the end of the batching sequence on a limited basis to correct a slight bleeding or segregation problem.

Dosages of VISCTROL will vary widely depending on w/c ratio and the gradation of the materials used. Consult your Euclid Chemical representitive for appropriate dosing suggestions. Typically, 1 to 12 oz/yd^3 (39 to 470 mL/m^3) should be used to control bleeding and segregation in SCC when polycarboxylate HRWR are used. Variables such as water/cement ratio, sand gradations and mix design play an important role. Trial mixes should be run to optimize dosing requirements. With higher water/cement ratios, lower total fines in SCC mixes, and use of napthalene based HRWR, dosages of VISCTROL could be as high as 20 oz/yd^3 (775 mL/m^3).

SPECIALTY PRODUCTS

VISCTROL

Master Format #:
03 9000 03 4000 03 7000

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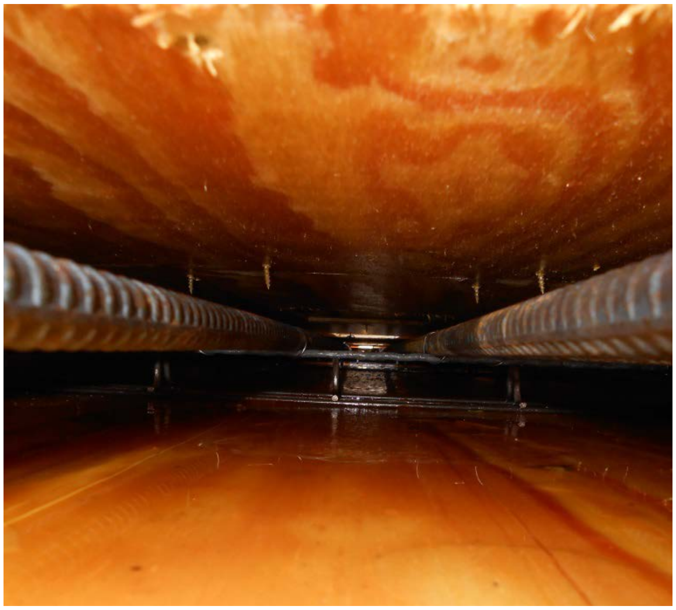
APPENDIX B: Pumping Mockup Tests

First Pumping Mockup Test

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26

Second Pumping Mockup Test

Third Pumping Mockup Test

Section A)

Section B)

Section C)

Section D)

Section E)

Section F)

Section A)

Section B)

Section C)

Section D)

Section E)

Section F)

Section A)

Section B)

Section C)

Section D)

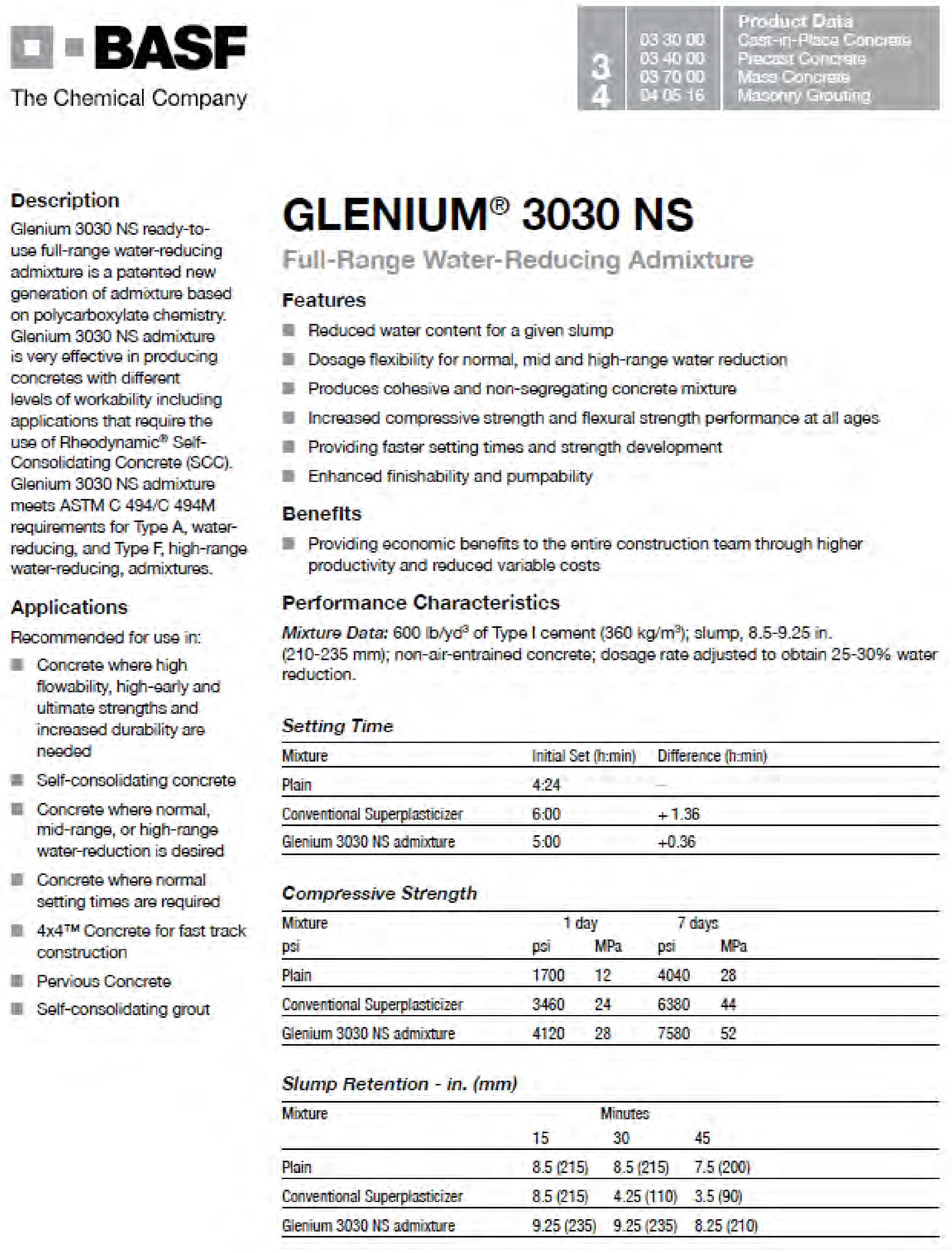
Section E)

Section F)

APPENDIX C: Fabrication of Full-Scale Specimen


F11243

APPENDIX D: Materials Used in Full-Scale Testing



BASF
The Chemical Company

		Product Data
3	03 30 00	Cast-in-Place Concrete
	03 40 00	Precast Concrete
	03 70 00	Mass Concrete
4	04 05 16	Masonry Grouting

GLENIUM® 3030 NS

Full-Range Water-Reducing Admixture

Description

Glenium 3030 NS ready-to-use full-range water-reducing admixture is a patented new generation of admixture based on polycarboxylate chemistry. Glenium 3030 NS admixture is very effective in producing concretes with different levels of workability including applications that require the use of Rheodynamic® Self-Consolidating Concrete (SCC). Glenium 3030 NS admixture meets ASTM C 494/C 494M requirements for Type A, water-reducing, and Type F, high-range water-reducing, admixtures.

Applications

Recommended for use in:

- Concrete where high flowability, high-early and ultimate strengths and increased durability are needed
- Self-consolidating concrete
- Concrete where normal, mid-range, or high-range water-reduction is desired
- Concrete where normal setting times are required
- 4x4™ Concrete for fast track construction
- Pervious Concrete
- Self-consolidating grout

Features

- Reduced water content for a given slump
- Dosage flexibility for normal, mid and high-range water reduction
- Produces cohesive and non-segregating concrete mixture
- Increased compressive strength and flexural strength performance at all ages
- Providing faster setting times and strength development
- Enhanced finishability and pumpability

Benefits

- Providing economic benefits to the entire construction team through higher productivity and reduced variable costs

Performance Characteristics

Mixture Data: 600 lb/yd^3 of Type I cement (360 kg/m^3); slump, 8.5-9.25 in. (210-235 mm); non-air-entrained concrete; dosage rate adjusted to obtain 25-30% water reduction.

Setting Time

Mixture	Initial Set (h:min)	Difference (h:min)
Plain	4:24	–
Conventional Superplasticizer	6:00	+ 1:36
Glenium 3030 NS admixture	5:00	+0:36

Compressive Strength

Mixture	1 day		7 days	
psi	psi	MPa	psi	MPa
Plain	1700	12	4040	28
Conventional Superplasticizer	3460	24	6380	44
Glenium 3030 NS admixture	4120	28	7580	52

Slump Retention - in. (mm)

Mixture	Minutes		
	15	30	45
Plain	8.5 (215)	8.5 (215)	7.5 (200)
Conventional Superplasticizer	8.5 (215)	4.25 (110)	3.5 (90)
Glenium 3030 NS admixture	9.25 (235)	9.25 (235)	8.25 (210)

Product Data: GLENIUM® 3030 NS

Rate of Hardening: Glenium 3030 NS admixture is formulated to produce normal setting characteristics throughout its recommended dosage range. Setting time of concrete is influenced by the chemical and physical composition of the basic ingredients of the concrete, temperature of the concrete and ambient conditions. Trial mixtures should be made with actual job materials to determine the dosage required for a specified setting time and a given strength requirement.

Guidelines for Use

Dosage: Glenium 3030 NS admixture has a recommended dosage range of up to 3 fl oz/cwt (195 mL/100 kg) for Type A applications, 3-6 fl oz/cwt (195-390 mL/100 kg) for mid-range use and up to 18 fl oz/cwt (1,170 mL/100 kg) for Type F applications. The dosage range is applicable to most concrete mixtures using typical concrete ingredients. However, variations in job conditions and concrete materials, such as silica fume, may require dosages outside the recommended range. In such cases, contact your local BASF Construction Chemicals representative.

Mixing: Glenium 3030 NS admixture can be batched with the initial mixing water or as a delayed addition. However, optimum water reduction is generally obtained with a delayed addition.

Product Notes

Corrosivity – Non-Chloride, Non-Corrosive: Glenium 3030 NS admixture will neither initiate nor promote corrosion of reinforcing steel embedded in concrete, prestressed concrete or of galvanized steel floor and roof systems. Neither calcium chloride nor other chloride-based ingredients are used in the manufacture of Glenium 3030 NS admixture.

Compatibility: Glenium 3030 NS admixture is compatible with most admixtures used in the production of quality concrete, including normal, mid-range and high-range water-reducing admixtures, air-entrainers, accelerators, retarders, extended set control admixtures, corrosion inhibitors, and shrinkage reducers.

Do not use Glenium 3030 NS admixture with admixtures containing beta-napthalene-sulfonate. Erratic behaviors in slump, slump flow, and pumpability may be experienced.

For directions on the proper evaluation of Glenium 3030 NS admixture in specific applications, contact your BASF Construction Chemicals representative.

Storage and Handling

Storage Temperature: If Glenium 3030 NS admixture freezes, thaw at 45 °F (7 °C) or above and completely reconstitute by mild mechanical agitation. ***Do not use pressurized air for agitation.***

Shelf Life: Glenium 3030 NS admixture has a minimum shelf life of 12 months. Depending on storage conditions, the shelf life may be greater than stated. Please contact your BASF Construction Chemicals representative regarding suitability for use and dosage recommendations if the shelf life of Glenium 3030 NS admixture has been exceeded.

Packaging

Glenium 3030 NS admixture is supplied in 55 gal (208 L) drums, 275 gal (1040 L) totes and by bulk delivery.

Related Documents

Material Safety Data Sheets: Glenium 3030 NS admixture.

Additional Information

For additional information on Glenium 3030 NS admixture or its use in developing concrete mixes with special performance characteristics, contact your BASF Construction Chemicals representative.

The Admixture Systems business of BASF Construction Chemicals is a leading provider of innovative additives for specialty concrete used in the ready mix, precast, manufactured concrete products, underground construction and paving markets throughout the NAFTA region. The Company's respected Master Builders brand products are used to improve the placing, pumping, finishing, appearance and performance characteristics of concrete.

BASF
The Chemical Company

3	03 30 00 03 40 00 03 70 00	**Product Data** Cast-in-Place Concrete Precast Concrete Mass Concrete

MB-AE™ 90

Air-Entraining Admixture

Description

MB-AE 90 air-entraining admixture is for use in concrete mixtures. It meets the requirements of ASTM C 260, AASHTO M 154 and CRD-C 13.

Applications

Recommended for use in:

- Concrete exposed to cyclic freezing and thawing
- Production of high-quality normal or lightweight concrete (heavyweight concrete normally does not contain entrained air)
- All paving-related concrete exposed to freezing and thawing cycles

Features

- Ready-to-use in the proper concentration for rapid, accurate dispensing

Benefits

- Improved resistance to damage from cyclic freezing and thawing
- Improved resistance to scaling from deicing salts
- Improved plasticity and workability
- Reduced permeability – increased watertightness
- Reduced segregation and bleeding

Performance Characteristics

Concrete durability research has established that the best protection for concrete from the adverse effects of freezing and thawing cycles and deicing salts results from: proper air content in the hardened concrete, a suitable air-void system in terms of bubble size and spacing, and adequate concrete strength, assuming the use of sound aggregates and proper mixing, transporting, placing, consolidation, finishing and curing techniques. MB-AE 90 admixture can be used to obtain adequate freeze-thaw durability in a properly proportioned concrete mixture, if standard industry practices are followed.

Air Content Determination: The total air content of normal weight concrete should be measured in strict accordance with ASTM C 231, "Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method" or ASTM C 173/C 173M, "Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method."
The air content of lightweight concrete should only be determined using the Volumetric Method. The air content should be verified by calculating the gravimetric air content in accordance with ASTM C 138/C 138M, "Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete." If the total air content, as measured by the Pressure Method or Volumetric Method and as verified by the Gravimetric Method, deviates by more than 1-1/2%, the cause should be determined and corrected through equipment calibration or by whatever process is deemed necessary.

Guidelines for Use

Dosage: There is no standard dosage for MB-AE 90 admixture. The exact quantity of air-entraining admixture needed for a given air content of concrete varies because of differences in concrete-making materials and ambient conditions. Typical factors that might influence the amount of air entrained include: temperature, cementitious materials, sand gradation, sand-aggregate ratio, mixture proportions, slump, means of conveying and placement, consolidation and finishing technique.The amount of MB-AE 90 admixture used will depend upon the amount of entrained air required under actual job conditions. In a trial mixture, use 1/4 to 4 fl oz/cwt (16-260 mL/100 kg) of cementitious material. Measure the air content of the trial mixture, and, if needed, either increase or decrease the quantity of MB-AE 90 admixture to obtain the desired air content.

In mixtures containing water-reducing or set-control admixtures, the amount of MB-AE 90 admixture needed may be somewhat less than the amount required in plain concrete.

Product Data: MB-AE™ 90

Due to possible changes in the factors that can affect the dosage of MB-AE 90 admixture, frequent air content checks should be made during the course of the work. Adjustments to the dosage should be based on the amount of entrained air required in the mixture at the point of placement.

If an unusually high or low dosage of MB-AE 90 admixture is required to obtain the desired air content, consult your Local sales representative. In such cases, it may be necessary to determine that, in addition to a proper air content in the fresh concrete, a suitable air-void system is achieved in the hardened concrete.

Dispensing and Mixing: Add MB-AE 90 admixture to the concrete mixture using a dispenser designed for air-entraining admixtures, or add manually using a suitable measuring device that ensures accuracy within plus or minus 3% of the required amount.

For optimum, consistent performance, the air-entraining admixture should be dispensed on damp, fine aggregate. If the concrete mixture contains fine lightweight aggregate, field evaluations should be conducted to determine the best method to dispense the air-entraining admixture.

Precaution

In a 2005 publication from the Portland Cement Association (PCA R&D Serial No. 2789), it was reported that problematic air-void clustering that can potentially lead to above normal decreases in strength was found to coincide with late additions of water to air-entrained concretes. Late additions of water include the conventional practice of holding back water during batching for addition at the jobsite. Therefore, caution should be exercised with delayed additions of water to air-entrained concrete. Furthermore, an air content check should be performed after any post-batching addition to an air-entrained concrete mixture.

Product Notes

Corrosivity – Non-Chloride, Non-Corrosive: MB-AE 90 admixture will neither initiate nor promote corrosion of reinforcing and prestressing steel embedded in concrete, or of galvanized floor and roof systems. No calcium chloride or other chloride-based ingredients are used in the manufacture of this admixture.

Compatibility: MB-AE 90 admixture may be used in combination with any BASF admixture, unless stated otherwise on the data sheet for the other product. When used in conjunction with other admixtures, each admixture must be dispensed separately into the concrete mixture.

Storage and Handling

Storage Temperature: MB-AE 90 admixture should be stored and dispensed at 31 °F (-0.5 °C) or higher. Although freezing does not harm this product, precautions should be taken to protect it from freezing. If MB-AE 90 admixture freezes, thaw at 35 °F (2 °C) or above and completely reconstitute by mild mechanical agitation. ***Do not use pressurized air for agitation.***

Shelf Life: MB-AE 90 admixture has a minimum shelf life of 18 months. Depending on storage conditions, the shelf life may be greater than stated. Please contact your Local sales representative regarding suitability for use and dosage recommendations if the shelf life of MB-AE 90 admixture has been exceeded.

Safety: Chemical goggles and gloves are recommended when transferring or handling this material.

Packaging

MB-AE 90 admixture is supplied in 55 gal (208 L) drums, 275 gal (1040 L) totes and by bulk delivery.

Related Documents

Material Safety Data Sheets: MB-AE 90 admixture.

Additional Information

For additional information on MB-AE 90 admixture, or its use in developing a concrete mixture with special peformance characteristics, contact your Local sales representative.

The Admixture Systems business of BASF's Construction Chemicals division is a leading provider of innovative admixtures for specialty concrete used in the ready-mixed, precast, manufactured concrete products, underground construction and paving markets throughout the North American region. The Company's respected Master Builders brand products are used to improve the placing, pumping, finishing, appearance and performance characteristics of concrete.

BASF
The Chemical Company

3 4	03 30 00 03 40 00 03 70 00 04 05 16	Product Data Cast-in-Place Concrete Precast Concrete Mass Concrete Masonry Grouting

Description

Rheomac VMA 362 viscosity-modifying admixture (VMA) is a ready-to-use, liquid admixture that is specially developed for producing concrete with enhanced viscosity and controlled rheological properties. Concrete containing Rheomac VMA 362 admixture exhibits superior stability, thus increasing resistance to segregation and facilitating placement and consolidation. Rheomac VMA 362 admixture meets ASTM C 494/C 494M requirements for Type S, Specific Performance, admixtures.

Applications

Recommended for use in:

- Concrete containing "gap-graded" aggregates
- Lean concrete mixtures
- Concrete containing manufactured sand
- Concrete as a pumping aid
- Concrete as a finishing aid
- Concrete mixtures requiring "more body"
- Rheodynamic® Self-Consolidating Concrete (SCC)
- Liquid Sand™ program
- Pervious Concrete
- Self-Consolidating Grout

RHEOMAC® VMA 362

Viscosity-Modifying Admixture

Features

- Modifies viscosity of concrete
- Thixotropic properties

Benefits

- Controls bleeding
- Provides flexibility in mixture proportioning and batching
- Provides concrete stability during transport and placement
- Reduces segregation, even with highly fluid concrete mixtures
- Enhances pumping and finishing
- Enhances surface appearance
- Provides superior and predictable in-place concrete properties
- Facilitates production of highly fluid concrete mixtures such as Rheodynamic Self-Consolidating Concrete (SCC)

Performance Characteristics

Setting Time: Rheomac VMA 362 admixture has little to no impact on concrete setting time within the recommended dosage range of 2-14 fl oz/cwt (130-920 mL/100 kg) of cementitious materials.

Compressive Strength: Rheomac VMA 362 admixture does not affect the compressive strength of concrete.

Viscosity: Concrete containing Rheomac VMA 362 admixture will exhibit an increase in viscosity with increasing dosage of the admixture. This desirable characteristic facilitates concrete placement, consolidation and finishing and provides stability to very fluid concrete mixtures.

Workability: Because of its thixotropic properties, concrete containing Rheomac VMA 362 admixture can increase in viscosity if left in a mixing vessel without agitation. Workability can be restored by simply remixing the concrete mixture.

Air Content: Rheomac VMA 362 admixture does not affect the air content in either air-entrained or non-air-entrained concrete. Typical dosages of air-entraining admixtures may be used to achieve the desired air content.

Product Data: RHEOMAC® VMA 362

Guidelines for Use

Dosage: The recommended dosage range for Rheomac VMA 362 admixture is 2-14 fl oz/cwt (130-910 mL/100 kg) of cementitious materials. A dosage of 2-6 fl oz/cwt (130-390 mL/100 kg) is recommended for typical concrete mixtures requiring "more body" to facilitate pumping and finishing procedures. A dosage of up to 14 fl oz/cwt (910 mL/100 kg) is recommended to provide stability in self-consolidating concrete mixtures. Because of variations in concrete materials, job site conditions and/or applications, dosages outside of the suggested range may be required.

Mixing: Rheomac VMA 362 admixture is typically added with the initial mix water. Alternately, Rheomac VMA 362 admixture may be added after all other concreting ingredients have been batched and thoroughly mixed, either at the batch plant or at the jobsite.

Product Notes

Compatibility: Rheomac VMA 362 admixture is compatible with most admixtures used in the production of quality concrete including normal, mid-range and high-range water-reducing admixtures and air entrainers. Rheomac VMA 362 admixture is also compatible with typical accelerators, retarders, extended set-control admixtures, corrosion inhibitors, and shrinkage reducers. However, a field trial mixture is recommended to ensure appropriate performance.

Storage and Handling

Storage Temperature: Rheomac VMA 362 admixture must be stored at temperatures above 32 °F (0 °C) and below 130 °F (54 °C). Protect Rheomac VMA 362 admixture from freezing because it cannot be reconstituted after thawing.

Shelf Life: A product stability evaluation has shown that Rheomac VMA 362 admixture has a shelf life of 8 months. Please contact your local sales representative regarding suitability for use and dosage recommendations if the stated minimum shelf life of Rheomac VMA 362 admixture has been exceeded.

Dispensing: Rheomac VMA 362 admixture should be dispensed using direct-feed dispensing systems. It is recommended that fail-safe features must be included in this dispenser application for potential meter malfunctions. Consult your local sales representative for the proper dispensing equipment for Rheomac VMA 362 admixture.

Packaging

Rheomac VMA 362 admixture is supplied in 55 gal (208 L) drums, 275 gal (1040 L) totes, and by bulk delivery.

Related Documents

Material Safety Data Sheets: Rheomac VMA 362 admixture.

Additional Information

For additional information on Rheomac VMA 362 admixture or its use in developing concrete mixtures with special performance characteristics, contact your local sales representative.

The Admixture Systems business of BASF Construction Chemicals is a leading provider of innovative admixtures for specialty concrete used in the ready mix, precast, manufactured concrete products, underground construction and paving markets throughout the North American region. The Company's respected Master Builders brand products are used to improve the placing, pumping, finishing, appearance and performance characteristics of concrete.

BASF
The Chemical Company

3/4 | 03 30 00
03 40 00
03 70 00
04 05 16 | **Product Data**
Cast-in-Place Concrete
Precast Concrete
Mass Concrete
Masonry Grouting

RheoTEC™ Z-60

Workability-Retaining Admixture

Description

RheoTEC Z-60 admixture is a revolutionary new technology based on significant advances in admixture chemistry. RheoTEC Z-60 admixture is used as part of an admixture system to provide customized admixture solutions for a wide range of concrete applications. RheoTEC Z-60 admixture is a workability-retaining admixture that provides flexible degrees of slump retention without retardation.

RheoTEC Z-60 admixture provides the concrete producer with the ability to immediately create the optimal admixture system for changing and fluctuating regional raw materials, environmental conditions and project requirements. RheoTEC Z-60 admixture gives the concrete producer the ability to consistently produce and deliver quality concrete mixtures.

RheoTEC Z-60 admixture meets the interim requirements of ASTM C 494/C 494M Type S, Specific Performance, admixtures.

Applications

Recommended for use in:

- Concrete with varying slump requirements
- Concrete mixtures utilizing supplementary cementitious materials
- Concrete where high flowability, increased stability and durability are needed
- Production of self-consolidating concrete (SCC) mixtures
- Ready-mixed and precast concrete

Features

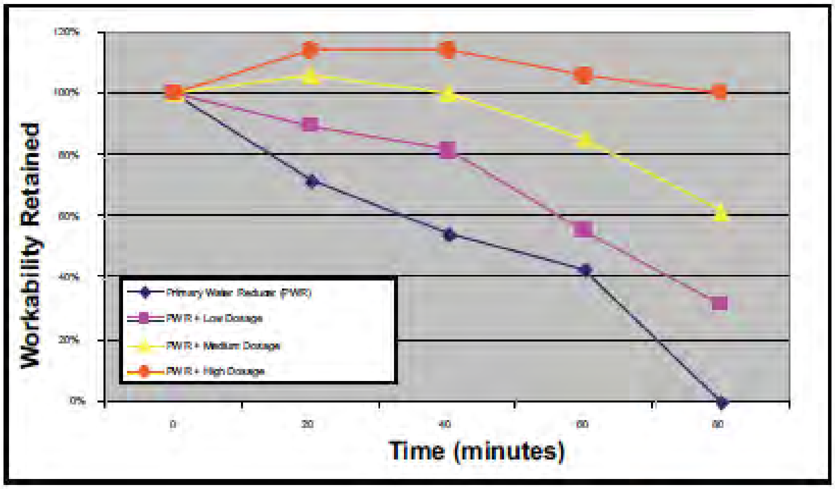
- Workability retention without retardation
- Flexible levels of workability retention by adjusting dosage
- Improved early- and late-age compressive strengths

Benefits

- Promotes greater consistency of concrete workability at the jobsite
- Promotes consistency in compressive strengths via minimized jobsite addition of water
- Minimizes re-dosing of high-range water-reducing admixture at the job site
- Consistent air-entrainment
- Fewer rejected loads and better customer satisfaction due to consistent quality of concrete
- Faster truck turn-around time
- Expanded concrete delivery range

Performance Characteristics

The data in the following graph represents the dramatic performance achievable through the use of RheoTEC Z-60 admixture. Represented in the graph are four mixtures. The first mixture utilized a primary water reducer without RheoTEC Z-60 admixture. The three remaining mixtures utilized the same primary water reducer with a low, medium and high dosage of the RheoTEC Z-60 admixture. These mixtures had concrete temperatures of 90 °F (32 °C) and contained 600 lb/yd^3 (356 kg/m^3) of cement with a w/c of 0.40.



Master Builders

Product Data: RheoTEC Z-60

Guidelines for Use

Dosage: RheoTEC Z-60 admixture has a recommended dosage range of 3-12 fl oz/cwt (195-750 mL/100 kg) of cementitious materials.

Mixing: RheoTEC Z-60 admixture can be added with the initial batch water or as a delayed addition.

Product Notes

Corrosivity – Non-Chloride, Non-Corrosive: RheoTEC Z-60 admixture will neither initiate nor promote corrosion of reinforcing steel embedded in concrete, prestressing steel or of galvanized steel floor and roof systems. Neither calcium chloride nor other chloride-based ingredients are used in the manufacture of RheoTEC Z-60.

Compatibility: RheoTEC Z-60 admixture is compatible with most admixtures used in the production of quality concrete, including normal, mid-range and high-range water-reducing admixtures, air-entrainers, accelerators, retarders, extended set control admixtures, corrosion inhibitors, and shrinkage reducers.

Do not use RheoTEC Z-60 admixture with admixtures containing beta-naphthalene sulfonate. Erratic behaviors in slump, workability retention and pumpability may be experienced.

RheoTEC Z-60 admixture has only been tested with admixtures manufactured by BASF Construction Chemicals. As a result, use of RheoTEC Z-60 admixture with non-BASF admixtures may produce unpredictable results. BASF denies any warranty expressed or implied with respect to any application using a non-BASF admixture in connection with the use of RheoTEC Z-60 admixture.

Storage and Handling

Storage Temperature: RheoTEC Z-60 admixture must be stored at temperatures above 40 °F (5 °C). If RheoTEC Z-60 admixture freezes, thaw and reconstitute by mechanical agitation. **Do not use pressurized air for agitation.**

Shelf Life: RheoTEC Z-60 admixture has a minimum shelf life of 6 months. Depending on storage conditions, the shelf life may be greater than stated.

Packaging

RheoTEC Z-60 admixture is supplied in 55 gal (208 L) drums, 275 gal (1040 L) totes and by bulk delivery.

Related Documents

Material Safety Data Sheets: RheoTEC Z-60 admixture.

Additional Information

For additional information on RheoTEC Z-60 admixture or on its use in developing concrete mixtures with special performance characteristics, contact your local sales representative.

BASF Construction Chemicals is a leading provider of innovative chemical admixtures and silica fume for specialty concrete used in the ready-mixed, precast, manufactured concrete products, underground construction and paving markets in the North American region. The Company's respected Master Builders brand products are used to improve the placing, pumping, finishing, appearance and performance characteristics of concrete.

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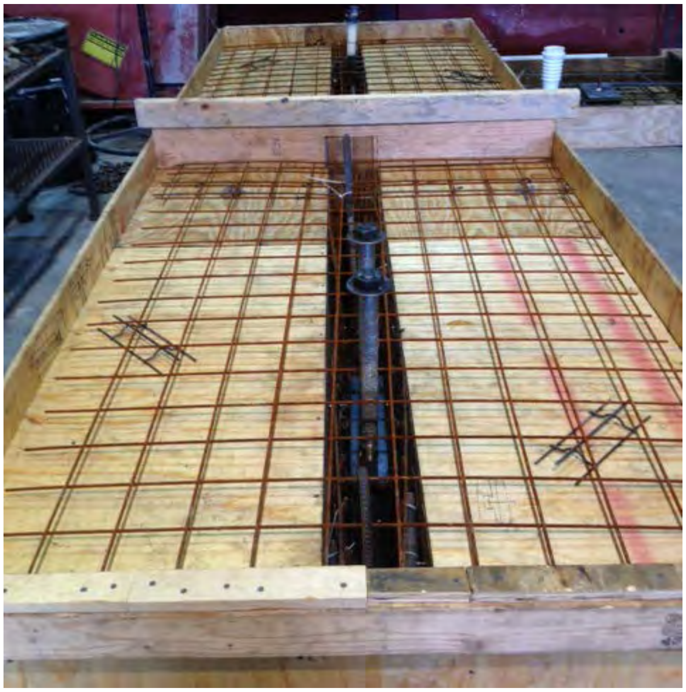
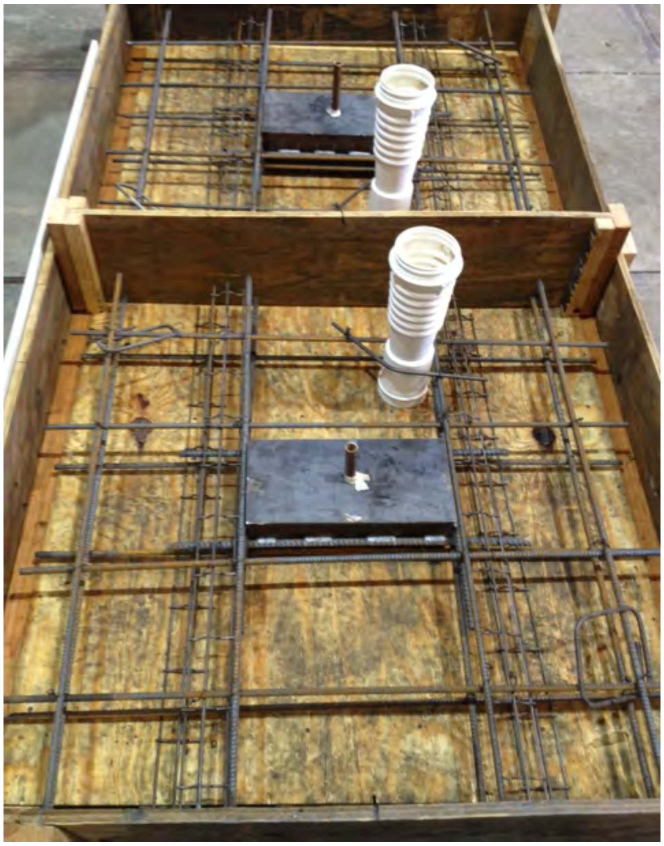
APPENDIX E: Fabrication and Testing of Push-off Specimens

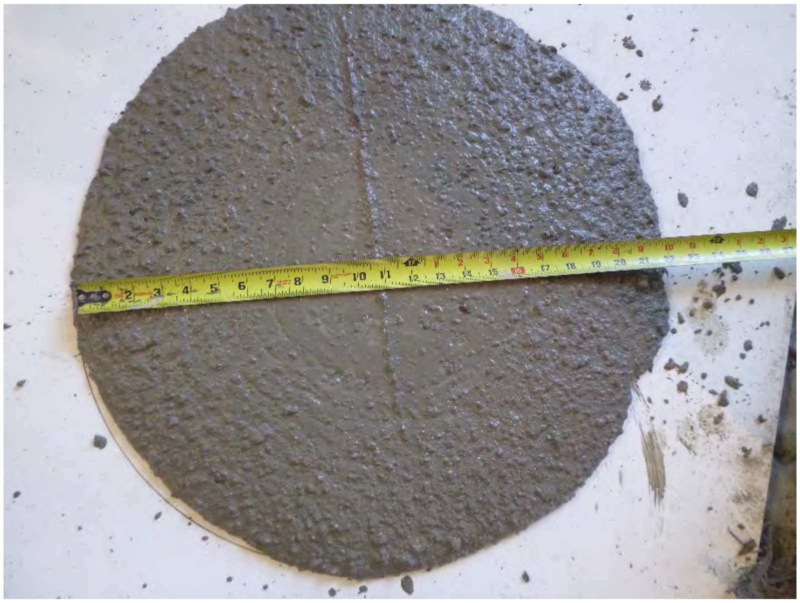
GROUP A

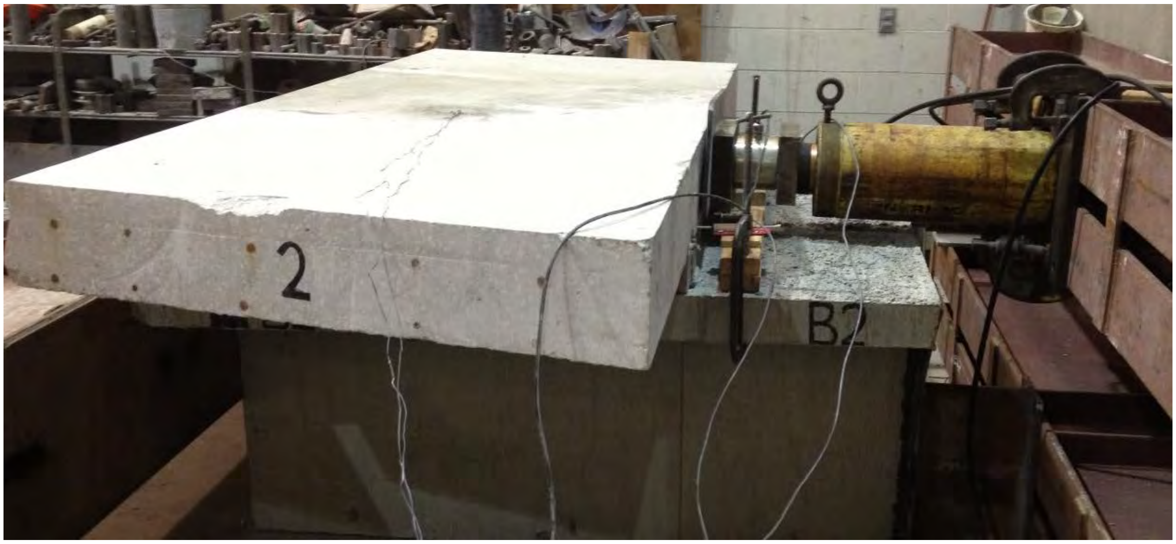





ENERPAC
Girder 1

GROUP B

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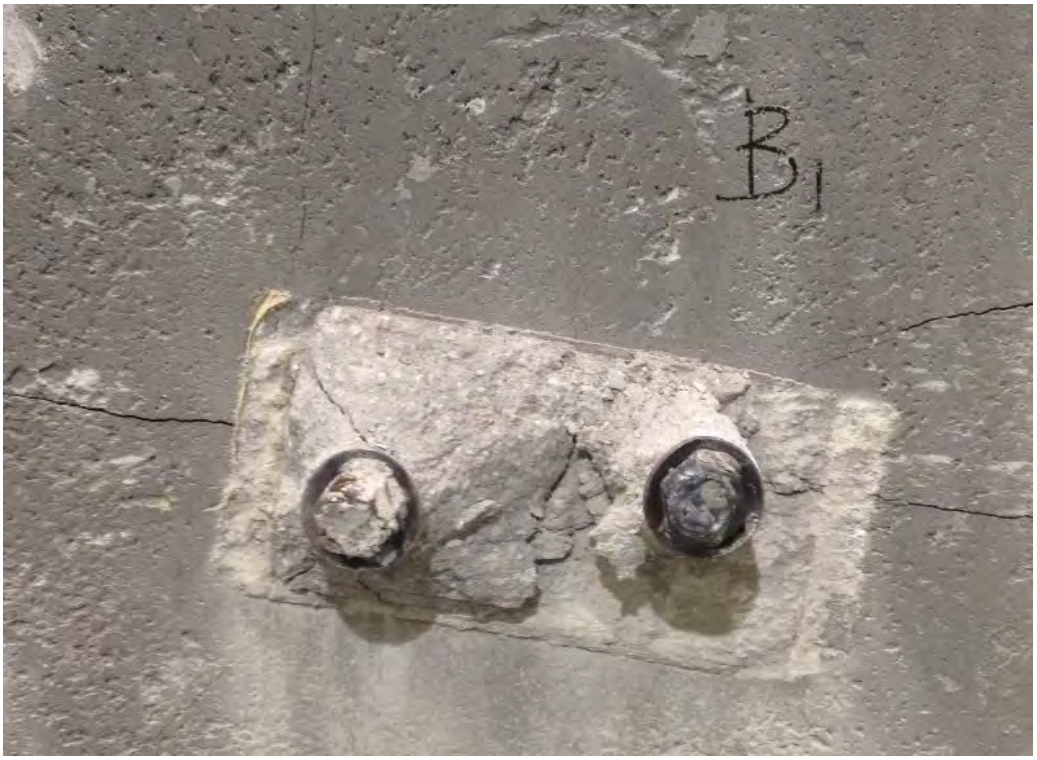
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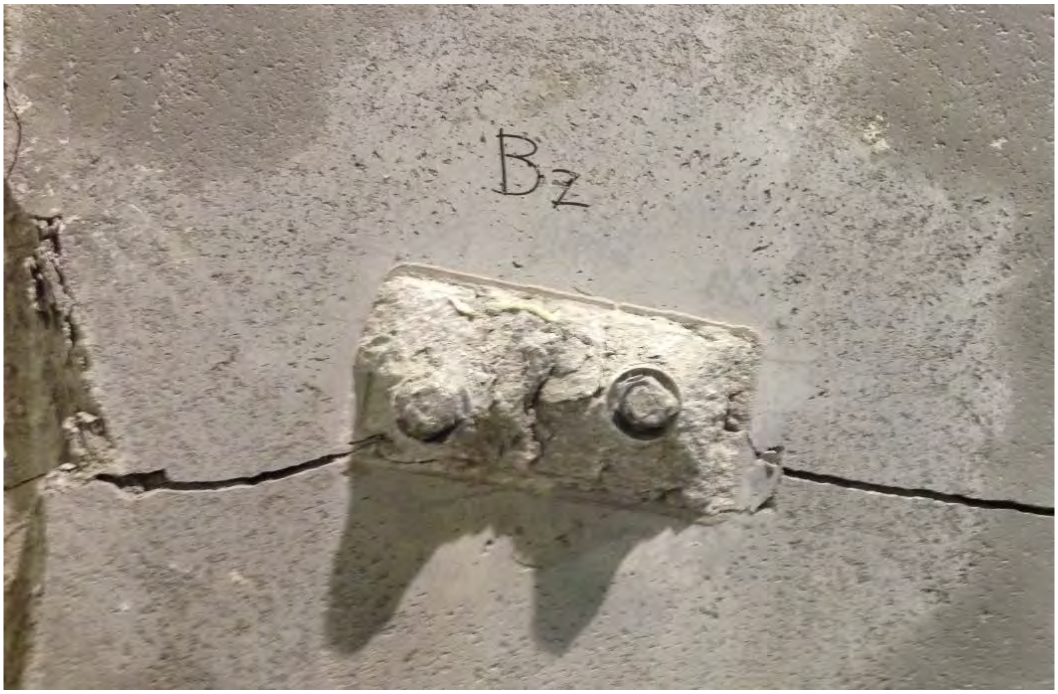
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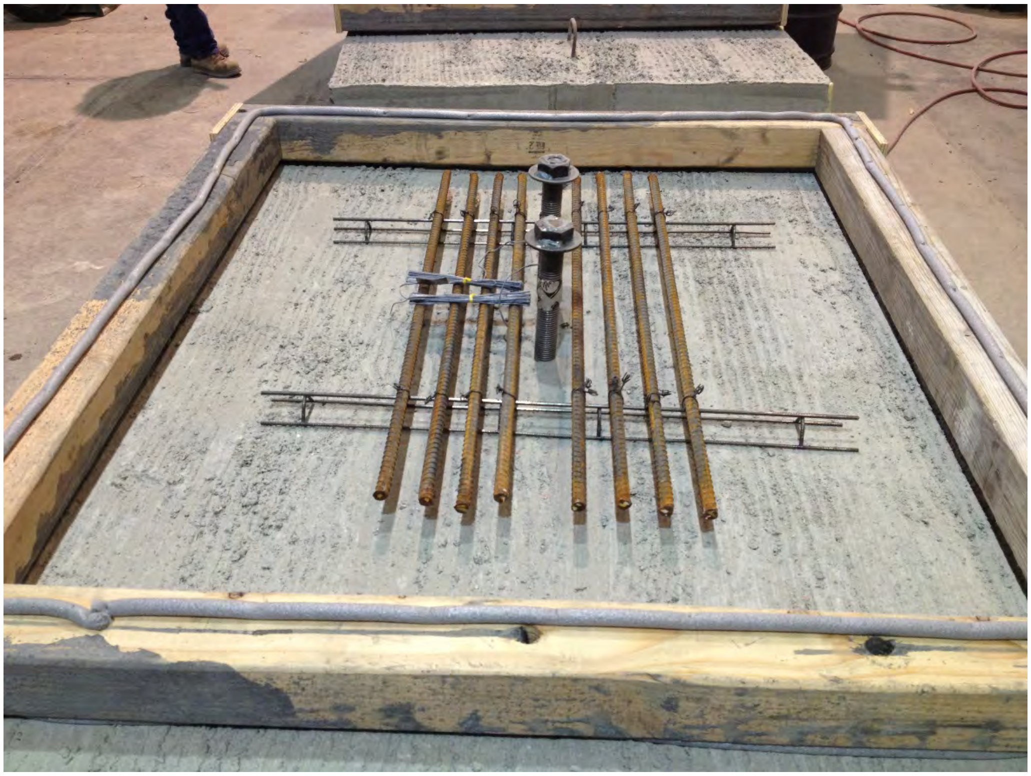
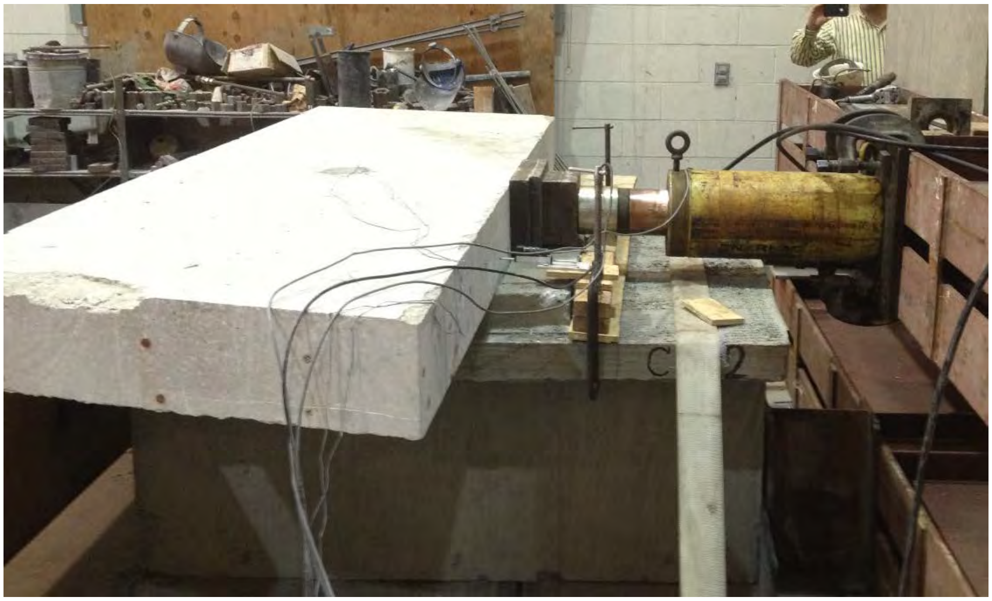
GROUP C






C1


C2


C2

GROUP D


D2


D1


C C2
D2

APPENDIX F: NDOR Draft Special Provisions

SELF-CONSOLIDATING CONCRETE

Section 1002 in the Standard Specification is amended to include the following:

Description

Self-Consolidating Concrete (SCC) is defined as a highly workable concrete that can be placed under its own weight and adequately fill all voids without segregation. SCC is placed without the need for vibration or other mechanical consolidation.

Materials Requirements

a. The material shall be SCC and shall consist of the following:
    (1) Cementitious materials Type 1PF and Class F fly ash designation are pre-blended or Interground with Class F fly ash by the cement mill producer at a rate of 25% ± 2%. No additional Class F fly ash will be added at the batch plant. Type 1PF cement shall meet all requirements of ASTM C 595.
    (2) Fine Aggregate shall meet the specification AASTHO M 6.
    (3) Coarse Aggregate shall meet AASTHO M 43 Size (No. 3/8 to No. 8).
    (4) SCC shall consist of superplasticizer, accelerators, and air admixtures and water. All admixtures shall meet the specifications in accordance with Section 1007 of this specification.
b. No change shall be made to the approved SCC mix design during the progress of work without the prior written permission of the Portland Cement Concrete (PCC) Engineer.
c. The SCC fresh, mechanical and permeability properties shall conform to the requirement in Table 1. The Contractor shall provide from a NDR Approved Independent Certified laboratory the testing data within the last 5 years and be submitted with tests as specified in Table 1.

Table 1. Test and Criteria for evaluating the acceptance of SCC.

Self-Consolidating Concrete (SCC)	
Slump Flow – ASTM C 1611	Range. 26 – 30 inches
Passing Ability by J-Ring Method – ASTM C 1621	Range. 0 – 2 inches
Visual Stability Index (VSI) – Appendix of ASTM C 1611 is required. VSI.	0 – 1
Air Content (ASTM C 231)	6.0 – 8.5%
Compressive Strength (ASTM C39)	Min. 6 ksi at 28 days
Freeze-Thaw Resistance (ASTM C666-B; 600 cycles)	RDM > 70%

Mix Design Approval Requirements:

a. The Contractor shall submit a pre-test trial of SCC Mix Design consisting of a minimum 4 cubic yards.
b. The pre-test trial SCC Mix Design shall be submitted to the Engineer 5-6 weeks prior to any SCC being placed on the project.
c. The SCC pre-test trial shall not be paid for directly by the Department and shall be subsidiary to items which direct payment is made.
d. Concrete shall not be placed on the project before the SCC testing has been reviewed and approved by the Engineer.
e. Material shall be produced by a NDR's approved Ready Mix Plant for SCC.
f. A SCC pre-test trial shall be tested at the project site and delivered by a NDR's Approved ready mix plant. SCC shall be sampled and tested by Material and Research Central Laboratory.
   (1) Air Content of Freshly Mixed Concrete by Pressure Method – ASTM C 231.
   (2) Temperature of Fresh Concrete at the time of casting.
   (3) Compression Strength – ASTM C 39.
   (4) Slump Flow – ASTM C 1611.
   (5) Passing Ability by J-Ring Method – ASTM C 1621.
   (6) Visual Stability Index (VSI) – Appendix of ASTM C 1611 is required.
   (7) Any changes to the mix design require the approval of the Concrete Engineer and a batch trial will be required.
   (8) The contractor shall submit batching sequence as specified recommendation to the Engineer.

Project Requirements

a. Materials & Research personal will be on-sight to perform the quality assurance of SCC for the following tests.
   (1) Air Content of Freshly Mixed Concrete by Pressure Method – ASTM C 231
   (2) Compression Strength – ASTM C 39.
   (3) Slump Flow – ASTM C 1611.
   (4) Passing Ability by J-Ring Method – ASTM C 1621.
   (5) Visual Stability Index (VSI) – Appendix of ASTM C 1611 is required.
b. Concrete quality control shall be the responsibility of the Contractor.