EVALUATION OF SILICA FUME HIGH DENSITY THIN BONDED OVERLAYS

Construction Report
March 2000

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**Abstract**

In September 1999, Bridges "A" and "B" of contract TBOI-0035-1(110)044 were overlaid with a silica fume concrete surface. The bridges are located on Interstate 35 in Carter County, 1.6 km north of State Highway 53. The deteriorated bridge decks were prepared by coldmilling the surface and removing the delaminated areas with jackhammers. Reinforcement bars were cleaned and exposed areas patched.

The mix design was changed several times before a workable mix was developed. Every load was tested at the plant and the job site. Several slump and air content problems were experienced before a consistent mix was finalized. Silica fume concrete was mixed at a batch plant and transported on the job site with ready mix trucks. After each lane was completed, the curing process took another 78 hours.

Post construction testing included skid resistance, compressive strength, bond strength, and chloride permeability testing. All these requirements were met. Recommendations were made to establish the slump and use a high range water reducer for construction ease. Other recommendations were, continue to use ready mix trucks, but fill them to a maximum volume of 60 percent. Establish seasonal limitations to minimize changes of extreme temperatures. Finally, temperature parameters should be developed.
ACKNOWLEDGMENTS

The author would like to express his appreciation to Chuck Donovan and Robert Kenneda, Senior Technicians for the Research & Development Division of the Oklahoma Department of Transportation in the role of monitoring and recording plant data during construction. Mr. Donovan was the principal technician assigned to the project and was a key in calculating tables. Others needing to be acknowledged are Mark Baker and Ute Ganjanathavat, Project Engineers for the Bridge Division with the insight of making sound changes in procedures; Mark Zishka, Rocky Patty and T. J. Jacks for the Ardmore Residency for controlling the field operation; Val Wheelwright of Overland Construction the prime contractor; Dick Pool and Junior Katz of Wildcat Concrete Services for the construction of the overlay; Wayne Brown and Tom Byrd of Joe Brown Concrete Inc. for supplying the silica fume concrete. A special thanks goes to Kimberly Gordon, the Project Manager from Research & Development Division that organized and developed the work plan before leaving for Graduate school.
The contents of this report reflect the views of the author(s) who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the views of the Oklahoma Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation. While trade names may be used in this report, it is not intended as an endorsement of any machine, contractor, process, or products.
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<td>lb/ft²</td>
<td>poundforce per square inch</td>
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<td>7</td>
<td>Bridge ‘B’ Inside Lane Job Site Testing</td>
<td>17</td>
</tr>
<tr>
<td>8</td>
<td>Bridge ‘A’ Inside Lane Job Site Testing</td>
<td>18</td>
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EXECUTIVE SUMMARY

In September 1999, two bridge decks were overlaid with a silica fume concrete surface on Interstate-35 (I-35) in Carter County, 1.6 km (one mile) north of State Highway (SH-53). The deteriorated bridge decks were prepared by cold milling the surface and removing the delaminated areas with jackhammers. Reinforcement bars which were exposed during repair operations, were cleaned and the damaged areas were replaced by patches.

During construction of the overlay, the mix design was altered by agreement between the contractor and Oklahoma Department of Transportation (ODOT). This was done because concrete which apparently met air content and slump requirements at the batch plant (ready-mix), was not meeting these same requirements when it reached the construction site. This situation went on during approximately half of the overlay construction. Changing the mix design appeared to solve these problems. Slump and air were both within specification requirements after the change.

Every truck load was tested for slump, air content and temperature measurements. Additional requirements for a successful overlay included skid resistance, compressive strength, and chloride permeability testing. All of these requirements were met. The extra testing and good construction techniques were instrumental in producing a successful and smooth riding project.
INTRODUCTION

The Oklahoma Department of Transportation (ODOT) has approximately 7,300 bridges throughout the state highway system. Virtually all of these bridges have deicing salts applied to them at some time. Water from melted snow and ice contains chloride ions which penetrate the Portland Cement Concrete (PCC) bridge decks. This eventually results in corrosion of the reinforcing steel. Corrosion of reinforcing steel causes deterioration when the chloride ion content reaches the threshold level of about 0.8 kg/m³ (4 lb/cy)(2).

Rehabilitation of a deteriorating bridge deck generally requires removing and replacing damaged concrete. Restoring smoothness to a repaired deteriorated deck may require an overlay. Silica fume concrete, latex-modified concrete and low-slump dense concrete are some of the products which have been tried on bridge deck overlays(3).

One of the concerns with concrete products overlaying bridge decks is premature cracking. Premature cracking is associated with poor air void content and improper curing. Good pavements and bridge decks, without premature cracking, have a narrow air void content range, between five and nine percent(4).

BACKGROUND

Silica fume is a replacement additive for Portland cement used in bridge decks overlays to increase strength and lower permeability. Silica fume is “a ‘by-product’ material from the production of silicon metal or ferrosilican alloys in an electric arc furnace.” More than 85 percent of the material is amorphous silica (SiO₂), which is a very fine spherical particle. It is two magnitudes finer than ground Portland cement. Silica fume when mixed with water forms calcium silicate hydrates, which fills the spaces in the cement paste matrix, resulting in a more dense, stronger, and relatively impermeable material(5).
Before the contract on this project was let, ODOT retained a private testing lab to evaluate prospective silica fume modified Portland Cement Concrete (PCC) mix design guidelines. A selection was made of specifications that performed best in regards to slump, air content, compressive strength, permeability, drying and shrinkage. Table 1 describes specifications which were used for this project.

Before overlay placement operations began, the contractor had a trial batch mixed which met the requirements of Table 1. ODOT field personnel and the contractor’s employees agreed that changes in the mix were needed to improve workability. A meeting on this was held, and changes in the mix design requirements resulting from this meeting are given in Table 2.

Table 1. Original Mix Design Guidelines

<table>
<thead>
<tr>
<th>Material</th>
<th>Specifications Proportions</th>
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<tbody>
<tr>
<td>Cement Type 1</td>
<td>Minimum 374 Kg per cubic meter</td>
</tr>
<tr>
<td>Silica Fume</td>
<td>7.5 percent of cement weight</td>
</tr>
<tr>
<td>Water/Cement Ratio</td>
<td>0.4 maximum</td>
</tr>
<tr>
<td>Slump</td>
<td>200 mm maximum</td>
</tr>
<tr>
<td>Air Content</td>
<td>6 +/- 2 percent</td>
</tr>
<tr>
<td>Aggregate Size</td>
<td>#7 (ASTM C31)</td>
</tr>
<tr>
<td>Compressive Strength</td>
<td>24 Mpa</td>
</tr>
<tr>
<td>Material</td>
<td>Measurement</td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Cement Type 1</td>
<td>737 lbs</td>
</tr>
<tr>
<td>Silica Fume</td>
<td>62 lbs</td>
</tr>
<tr>
<td>Coarse Aggregate #67</td>
<td>1403 lbs</td>
</tr>
<tr>
<td>Fine Aggregate, Sand Class A</td>
<td>1363 lbs</td>
</tr>
<tr>
<td>Water</td>
<td>32.5 gals</td>
</tr>
<tr>
<td>Air Content</td>
<td>6.5 +/- 1.0 percent</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>27.00</strong></td>
</tr>
<tr>
<td>Superplasticizer</td>
<td>119 oz</td>
</tr>
<tr>
<td>Entrained Air / maximum</td>
<td>8.0 oz</td>
</tr>
<tr>
<td>Target Retarder</td>
<td>35-37 oz</td>
</tr>
<tr>
<td>Water/Cement ratio</td>
<td>0.34 lb/lb</td>
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<tr>
<td>Slump</td>
<td>2-5 inch</td>
</tr>
<tr>
<td>Concrete unit weight</td>
<td>141.2 pcf</td>
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OBJECTIVES

The objectives of this project are as follow:

• Evaluate conditions of each installation before overlaying.

• Document procedures for specification changes in the mix design proportion and other characteristics in the mix.

• Document preconstruction preparation.

• Monitor construction and document procedures.

• Record results of job control testing for each site.

• Evaluate bridge deck placement.

• Perform an annual evaluation of the bridge deck installation.
PROJECT INFORMATION

LOCATION

Project number TBOI-0035-1(110) 044 consisted of placing a silica fume overlay on structure NBI 17229, which is bridge “A” (southbound) and NBI 17255 which is bridge “B” (northbound). The bridges are located on I-35 in Carter County, 32.55 kilometers (20.23 miles) north of the Love County line. Both bridges are over a county road, approximately 1.6 km (one mile) north of SH-53 near mile marker 45 (Figure 1). The two bridges were built in 1979. Average daily traffic at this location is 27,500 vehicles, which includes 21 percent trucks.

Figure 1. Silica Fume Overlay Location Map
MATERIALS

The following mix ingredients (Table 3) were used to construct the silica fume thin overlays. Other materials listed were used to complete the bridge deck overlay surface. See Appendix B for additive specifications.

Table 3. Materials and Sources

<table>
<thead>
<tr>
<th>MATERIALS</th>
<th>SOURCES</th>
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<tr>
<td>Coarse Aggregate (#67)</td>
<td>Dolese -Davis Quarry</td>
</tr>
<tr>
<td></td>
<td>Davis, Oklahoma</td>
</tr>
<tr>
<td>Fine Aggregate (Sand Class A)</td>
<td>TXI</td>
</tr>
<tr>
<td></td>
<td>Ardmore, Oklahoma</td>
</tr>
<tr>
<td>Cement (Type 1)</td>
<td>Holnam, Inc.</td>
</tr>
<tr>
<td></td>
<td>Joe Browns Cement Plant Ardmore, Oklahoma</td>
</tr>
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<td>“Rheomac SF100&quot; (Silica fume mineral admixture)</td>
<td>Master Builders Technologies</td>
</tr>
<tr>
<td></td>
<td>Cleveland, Ohio</td>
</tr>
<tr>
<td>Rheobuild 1000 Superplasticizer (High-range water-reducer)</td>
<td>Master Builders Technologies</td>
</tr>
<tr>
<td></td>
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<tr>
<td>MB VR (Air entraining admixture)</td>
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<tr>
<td>Pozzolith 300-R Set retarder (Reduce water retarding setting time)</td>
<td>Master Builders Technologies</td>
</tr>
<tr>
<td></td>
<td>Cleveland, Ohio</td>
</tr>
<tr>
<td>Pre-cure Compound</td>
<td>Master Builders Technologies</td>
</tr>
<tr>
<td>White Curing Compound</td>
<td>Master Builders Technologies</td>
</tr>
<tr>
<td>890-SL (Single part epoxy)</td>
<td>Dow Corning</td>
</tr>
<tr>
<td>Backer rod</td>
<td>Wildcat Concrete Service</td>
</tr>
<tr>
<td>Elastomeric Joint Sealer</td>
<td>Wildcat Concrete Service</td>
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</tbody>
</table>
EQUIPMENT

Heavy equipment and hand tools were used to construct the silica fume bridge deck overlay. Equipment used on the project is listed.

- Cold Milling Machine
- Jack Hammer
- Air Compressor
- Ready Mix Truck
- Asphalt Laydown Machine
- Dump Truck
- Roller
- CMI Bid-Well Concrete Paver
- Hand Finishing Tools
- Fresno Float
- Tine Float
- Hand Broom
- Wheel Barrel
- Concrete Mixing Machine
- Hand Vibrator
- Hand Concrete Saw
- Self-propelled Concrete Saw
The existing bridges were surveyed in April, 1997. The project was delayed several times before construction was completed in September, 1999. The information below is from the 1997 survey. Approximately 74 m² (800 s.f.) of deck on northbound bridge had been patched. Block cracking could be seen in and around the wheel paths of the outside lane. Delamination sounding showed a total area of deterioration of approximately 102 m² (1100 s.f.). The southbound bridge also had cracking in the wheel paths of the outside lane. Delamination sounding according to ASTM designation: D 4580-86, showed approximately 139 m² (1500 s.f.) of deteriorated deck.

A considerable amount of maintenance patching (Figure 2) had been done on both bridges, and the ride over them were noticeably rough. Cracking in the wheel paths with spalls where cracks met were common (Figure 3). These conditions made the bridges an excellent candidate for a silica fume overlay. Smoothness testing was not done before construction.

Figure 2. Patching on Existing Bridge Deck, Before Overlay.
The engineer's cost estimate was approximately $800,000 for the two bridge deck overlays. See Appendix A for cost details. Repairing the bridge decks before an overlay is important. An extensive evaluation of the two bridge decks was performed to determine the amount of deterioration. A cold milling machine removed 51 mm (2 inches) from the surface of the approaches, bridge decks and leave slabs. Delaminated concrete areas were removed by jackhammer. The corroded reinforcement bars were cleaned, and patches of a Class A concrete and silica fume were poured. Approximately sixty percent of the bridge decks surface area were patched (Figures 4 and 5). After patching was completed, the surfaces were cleaned with a sand blasting and high pressure water operation. The decks were then covered with plastic until placement of the overlay.
Figure 4. Bridge 'B' Patching Diagram

Figure 5. Bridge 'A' Patching Diagram
CONSTRUCTION

The silica fume concrete overlays were constructed in the following order:

- Site 1- Bridge “B,” outside lane.
- Site 2- Bridge “A,” outside lane, bridge approach.
- Site 3- Bridge “A,” bridge deck and leave slab.
- Site 4- Bridge “B,” inside lane.
- Site 5- Bridge “A,” inside lane.

A grout cement paste meeting requirements of ODOT specification 701.10(c) was made with enough water to form a slurry. At the plant, located in Ardmore about 32 km (20 miles) from the construction site, ready mix trucks were being loaded with the silica fume concrete mix. The mix consisted of Portland cement, water, aggregate, sand, silica fume, a high range water reducer and set retarder, when needed. See Appendix B for specifications. Under ODOT specifications, when the temperature of the concrete is greater than 32°C (90°F), it was controlled by watering the aggregate and sand 12 hours before construction. Then during construction, ice was added to the mix as a substitute for water, when needed. Tables 3 - 6 can be reviewed to determine when ice was added. Each truck load was tested for slump, air content, and temperature before leaving the plant site. This information was placed on each load ticket.

When each loaded truck reached the job site, it was backed over a plastic covering to a pouring location. The plastic holds the moisture, and protects the surface from dirt and debris. A visual inspection of the slump was done by the contractor to determine when additional water was needed. Grout was broomed on the deck surface just ahead of the unloaded concrete. As the mix was being discharged, the plastic was rolled back from the deck to the back wheels of the truck. Each load was tested again for slump, air content and temperature by an independent testing firm (Tables 5 - 8).

Several problems relating to air content and slump had occurred on each pour site in the approaches. Site 1 had air content measurements on the lower half of the specification (Table 3). It’s highest
measurement was 6.2%, and the lowest measurement was 3.2% (out of specifications). Fifty percent of its air content tests were out of specification. Site 2 had 60% of its slump measurements out of specifications (Table 5). The bridge deck pour was stopped at that point, due to the contractor's inability to control the mix to specifications. Site 3 had consistent slump and air measurements, with one truck out of specifications in both requirements (slump and air). That load was not accepted by the contractor. Site 4 had two air content measurements out of specification (high). One test showed 10 percent air content measurements. Its air averaged 6.3 percent. Site 5 had three air contents out of specification (high). A nine percent air content measurement was the highest amount measured.

The contractor placed the mix in 50 mm (2 inch) lifts in front of the concrete paver in even arcs across the deck. The concrete paver vibrated the mix as the paver rolled transversely across the lane. Then, dual augers on the paver leveled the material to the designated height. Concrete placed along the walls and the centerline was hand vibrated. A vibra-tamp roller, located on the paver, helped consolidate and seal the overlaid surface. Dual steel rollers (smooth) finished the mat in both directions with each pass. Fog bars, located above the rollers, misted an evaporation prevention film (pre-cure) on the concrete surface. Behind the rollers was a drag pan used for further finishing the surface. Small adjustments or corrections were made by hand finishing, while the Fresno float sealed and smoothed the mat. A tine float placed grooves in the mat for skid resistance. Shoulders on the bridge deck received a broom finish.

White curing compound was applied from a 208 liter (55 gallon) drum with a gasoline powered engine sprayer. The surface was sprayed with the compound as soon as the mat was able to take the mist without marring the concrete. The application rate was not recorded. Two hours after the completion of each silica fume lane, a burlap cover was placed over it. The cover was saturated with water and then covered with plastic for 78 hours.

Calculations were run on each site concrete pour for the evaporation rate of surface moisture. ODOT's specification 504.03(e)5 states, "control evaporation according to the requirements of Article 504.03(c). Limit the evaporation rate of water from the fresh concrete to less than 0.5
kilograms per square meter per hour (0.1 lb/sq ft./hr). Control evaporation adequately to prevent premature crusting of the surface or an increase in drying crack.” Sites 1 and 2 had air temperatures of 28 C (81 F) and 31 C (84 F), relative humidity of 74% and 50%, concrete temperatures of 28 C (81 F) and 33 C (86 F), and wind velocities of 8 km/h (5 mph) and 12 km/h (7 mph). This results in a rate of evaporation of 0.35 kg/m²/h (0.075 lb/sq/hr) and 0.4 kg/m²/h (0.08 lb/sq/hr). Although, these sites met the evaporation requirements (no additional controls required), evaporation control of saturating burlap cloth and covering it with plastic was used. On sites 3, 4 and 5, evaporation rates were more than 0.5 kg/m²/h (0.1 lb/sq ft/hr) and required evaporation control. The following table (Table 8) has completed information on evaporation control under ODOT specification 504.03(c).

Table 4. Evaporation Control

<table>
<thead>
<tr>
<th>Location</th>
<th>Air Temp</th>
<th>Humidity</th>
<th>Concrete Temp</th>
<th>Wind Speed</th>
<th>Rate</th>
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<tr>
<td></td>
<td>F</td>
<td>%</td>
<td>F</td>
<td>mph</td>
<td>lb/sq/hr</td>
</tr>
<tr>
<td>Site 1</td>
<td>81</td>
<td>74</td>
<td>81</td>
<td>5</td>
<td>0.075</td>
</tr>
<tr>
<td>Site 2</td>
<td>89</td>
<td>50</td>
<td>86</td>
<td>7</td>
<td>0.08</td>
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<td>80</td>
<td>42</td>
<td>83</td>
<td>5</td>
<td>0.13</td>
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<td>Site 4</td>
<td>71</td>
<td>79</td>
<td>88</td>
<td>7</td>
<td>0.15</td>
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<tr>
<td>Site 5</td>
<td>60</td>
<td>66</td>
<td>80</td>
<td>10</td>
<td>0.18</td>
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After a 78 hour cure period, the covers were removed. At the existing steel expansion joints, grooves were cut in the overlay, and an elastomeric binder mixed with abrasion and chemical resistant aggregate was poured. Elastomeric mortar and binder met ODOT requirement 701.08(h)2.2. Saw joints were then cut through the overlay over the existing joints. A Backer rod was placed in the joints and self leveling silicon sealant was applied. After all four lanes were completed, the bridge project was striped and opened to traffic. See Appendix C for the construction photo sequence.
## Table 5. Bridge ‘B’ Outside Lane

<table>
<thead>
<tr>
<th>TRUCK NO.</th>
<th>WATER ADDED</th>
<th>SLUMP</th>
<th>% AIR</th>
<th>TEMPERATURE</th>
<th>COMMENTS</th>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>BRIDGE ‘B’ OUTSIDE LANE</td>
</tr>
<tr>
<td>Bridge Approach</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
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</tr>
<tr>
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<td>4.75</td>
<td>4.3</td>
<td>81 F</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>4.75</td>
<td>5.5</td>
<td></td>
<td>80 F</td>
<td></td>
</tr>
<tr>
<td>Bridge Deck</td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
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</tr>
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<td></td>
<td>81 F</td>
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<td></td>
<td>82 F</td>
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</tr>
<tr>
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<td>4.8</td>
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</tr>
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<td>9</td>
<td>3.0</td>
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<td>78 F</td>
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Table 6. Bridge ‘A’ Outside Lane

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<th>TRUCK NO.</th>
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<th>COMMENTS</th>
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<tr>
<td><strong>Bridge Approach</strong></td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>1</td>
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<td>5.1</td>
<td>83°F</td>
<td>20 oz Superplasticizers</td>
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<td></td>
<td></td>
</tr>
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<td>1</td>
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<td>4</td>
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Table 7. Bridge ‘B’ Inside Lane

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<th>% AIR</th>
<th>TEMPERATURE</th>
<th>COMMENTS</th>
</tr>
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<tbody>
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<td></td>
<td></td>
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<td>1</td>
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<td>80 F</td>
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</tr>
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<td>3.0</td>
<td>4.0</td>
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Table 8. Bridge ‘A’ Inside Lane

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<th>COMMENTS</th>
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</thead>
<tbody>
<tr>
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<tr>
<td>1</td>
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<td>5.9</td>
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<td>10 gal</td>
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<td>6.2</td>
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<td>7.2</td>
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<tr>
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<td>3.5</td>
<td>9.0</td>
<td>79 F</td>
<td>Cylinders pulled</td>
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<td>1.5</td>
<td>8.0</td>
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</tr>
<tr>
<td>6</td>
<td></td>
<td>2.25</td>
<td>5.7</td>
<td>81 F</td>
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<tr>
<td>Bridge Deck</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>5 gal</td>
<td>2.5</td>
<td>6.8</td>
<td>81 F</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>15 gal</td>
<td>2.5</td>
<td>6.0</td>
<td>79 F</td>
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</tr>
<tr>
<td>9</td>
<td>10 gal</td>
<td>3.0</td>
<td>7.9</td>
<td>82 F</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>20 gal</td>
<td>3.0</td>
<td>6.5</td>
<td>80 F</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>20 gal</td>
<td>3.5</td>
<td>10.0</td>
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<td></td>
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<td>12</td>
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<tr>
<td>13</td>
<td>10 gal</td>
<td>2.75</td>
<td>6.2</td>
<td>79 F</td>
<td>Cylinders pulled</td>
</tr>
</tbody>
</table>
POST CONSTRUCTION

Post construction activity consisted of several tests used to determine overlay performance were done 30 days after construction. Compressive strength, bond overlay (chain drag), smoothness (profilograph), skid resistance, bond strength, and chloride permeability are the list of tests. See Appendix D for test results.

Compressive strength testing was performed on cylinders made from each overlay mix at 7 and 28 days. Seven day results measured a low of 35,371 kPa (5130 psi), still in specification, and a high of 54,125 kPa (7850 psi). The 28 day strength results measured a low of 42,197 kPa (6120 psi) and a high of 65,847 kPa (9550 psi). The measured strengths meet specification requirements.

The chain drag method was used to determine the amount of bond area between the old bridge deck and the overlay. The results from both bridges were 100 per cent bonded. Smoothness was tested with a profilograph under ODOT specifications. The profilograph reading given for each bridge was recorded in inches of roughness per mile (profile index). Bridge “B” had a profile index average of 5.7 inches of roughness per mile, while Bridge “A” had a profile index average of 16.5 inches of roughness per mile, both meeting specification.

Skid data testing was done by the ODOT Traffic Division. The skid numbers (SN) are derived as the product of a mechanical test wherein a skid trailer tire interfaces with the road surface providing an approximate value which may be converted to a coefficient of friction. The recorded high was 53.4 SN, and the recorded low was 43.4 SN.

Bond strength testing was measured under the rules of the Virginia epoxy concrete overlay for surface preparation and adhesion’s procedures. Three cores were taken from each panel in both the north and south bound bridges, and the inside and passing lanes. The core holes were drilled to approximately 6.4 mm (1/4 inch). Pipe caps were bonded to the cores. A test rig with a dynamometer was attached and a tensile load at 45.4 kg (100 lbs) every 5 seconds was applied to failure.
Five types of failure can occur during bond strength testing, but only two types occurred on this project which satisfied ODOT's Research requirements. Type 1 is a failure in the existing concrete deck at depths greater than or equal to 6.4 mm (1/4 inch) over more than 50% of test area. Type 2 is a failure in the existing concrete deck at a depth less than 6.4 mm (1/4 inch) over more than 50% of test area. A properly applied epoxy overlay on a properly prepared surface should result in a Type 1 failure of the concrete. There were 25 Type 1 and 11 Type 2 failures. The tensile strength was tested 36 times. Twenty-eight times the breaks were 276 kPa (40 psi), six times 138 kPa (20 psi), and one time each at 552 kPa (80 psi) and 414 kPa (60 psi).

According to ASTM C1202, at 28 days after placement, chloride permeability testing could be performed on the bridge deck samples. The silica fume overlay was expected to have a low permeability rating (between 1000 and 2000 coulombs). Chloride ion permeability testing of the concrete was important to the project. Test results showed very low to negligible amounts of chloride ion penetration of the concrete. One test showed a moderate amount of chloride intrusion. The moderate test result was 2379 coulombs. The very low results ranged from a high of 756 coulombs to a low of 145 coulombs, with an average of 308 coulombs. The two negligible measurements were 94 and 90 coulombs. A total of 18 tests were run.
DISCUSSION

Mix design changes were instrumental for an easier and more consistent construction operation. First, changing the mix to a higher slump aided the ease of construction(9). Second, the addition of a set retarder made the mix more consistent.

The percent of silica fume was raised from a 7.0 percent to 7.5 percent. The results of the permeability testing averaged 460 coulombs which is classified as very low. Therefore, there is room in the specification for the percentage of silica fume being substituted for the Type 1 cement to be adjusted to a lower concentration.

A construction group was formed for collaboration on ideas in the "recommendation" phase of the report. The group agreed on the following. A trial mix should be made to establish the range of set retarder and high range water reducer needed for the mix. The ready mix trucks should use less volume in the trucks to leave room for expansion. Moisture content needs to be determined before the water/cement ratio is determined. Temperature and seasonal parameters should be established because of the problems the silica fume overlay had during the hot weather during construction. Recommendations were made to keep the mix at a temperature below 90°F and use ice; and watering of aggregate several hours before mixing.
CONSTRUCTION

Reinforcement and patching repair were performed using standard construction methods. Equipment and manpower used in the building of the overlay was supplied by the subcontractor. The average smoothness index for a new bridge is approximately 67 m/km (27 in/mi) according to a Research & Development field report memo. Profile indexes from smoothness testing on the two overlaid decks indicated smoothness which was considerably better. Factors instrumental in producing the smooth riding surface were changes in the specifications which made the mix more workable, the use of a modified Bid-Well concrete paver, and a large amount of hand work. All of the skid data collected showed satisfactory skid numbers on the silica fume concrete surface.

The mix design was originally specified as "ODOT’s High Density Concrete Overlay" specification (section 505 and 701.10) with 7.5 percent of cement by weight replaced with silica fume (Table 1). During trial mixes, patch work and overlay construction, it was modified to the mix design (Table 2). The use of high range water reducers and set retarders, and specification changes in slump (4 inch maximum to a 5 ½ inch maximum) was instrumental in producing a successful overlay.

The Virginia bond test was developed for adhesion between two epoxy overlays, not between an old standard concrete deck and a silica fume concrete overlay. Therefore, the 1724 kPa (250 psi) tensile rupture strength requirement was probably not the proper value for this overlay. The important requirement from the specification was the type of failure developed during the pull. Type I and II failures are in the old concrete, indicating the bond is stronger than the old concrete deck. Those were the two types of breaks which occurred during the bond tests. Chain drag tests showed no delaminations.

Chloride ion permeability results in the concrete were very low, much lower than the threshold target value of 2,000 coulombs. There is room for changes in the specification on the amount of silica fume additives required in the mix.
RECOMMENDATIONS

The construction group produced the following recommendations:

• A trial mix should be established with a 25 to 51 mm (1 to 2 inch) slump. Then a high range water reducer should be added to achieve a maximum slump of 127 mm (5 inches) for ease of construction.

• Ready mix trucks should be used with the volume of truck being filled to a maximum 60% capacity, or to the resident engineer’s recommendation.

• Moisture content should be determined on the coarse and fine aggregate, and used in the water cement ratio calculations.

• Temperature parameters should be established.

• Seasonal limits should be considered to avoid overlay placement during extreme temperatures.
REFERENCES


9. Miller, Bo. *Microsilica Modified Concrete for Bridge Deck Overlays*, Materials and Research Section Highway Division, Oregon Department of Transportation, October 1990.
APPENDIX A
Oklahoma Department of Transportation Special Provision, Specification and Cost Estimate

Oklahoma Department of Transportation special provision..................................................... A-2
Figure 504-1 Evaporation rate of surface moisture................................................................. A-4
Cost Estimate.......................................................................................................................... A-6
OKLAHOMA DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISION
FOR
SPECIAL CONTRACTOR TESTING
TBOI-00035-1(110)004, Carter County


100.01 DESCRIPTION. This work will consist of testing the Portland Cement Concrete Overlay treated with Silica Fume that the Engineer will specify. Testing shall be performed by an Independent Testing Laboratory acting as a subcontractor to the General Contractor at the times stated herein. A representative from the Oklahoma Department of Transportation Office of Research shall be notified at least forty-eight hours prior to each phase of testing and general construction.

101.02 General. The Contractor shall subcontract an AMRL (AASHTO Material Reference Laboratory) accredited or, Cement and Concrete Reference Laboratory (CCRL) inspected Independent Testing Laboratory with relevant experience to conduct the tests outlined herein. This Independent Testing Laboratory shall provide at least two references to the Engineer to indicate prior experience.

101.02 TESTING. The following tests shall be performed at the site of construction as outlined herein and performed in accordance with the testing standard listed. Testing standards shall be performed as designated in the American Association of State Highway and Transportation Officials (AASHTO), the American Concrete Institute (ACI), the American Society for Testing and Materials (ASTM) or the Virginia Test Method (VTM) listed immediately following the name of the test. Where no testing standard is listed, the Independent Testing Laboratory shall use a testing method approved by the Engineer. The results of each test shall be properly recorded in the standard format and sent to the Engineer within thirty calendar days of testing.

101.02 (a) Chloride Permeability (AASHTO T277). This test shall be performed on three 150 mm cores prior to surface preparation of the bridge decks for construction. Three permeability to chloride ion tests shall also be performed on three 150 mm cores forty calendar days after installation from different sites on the bridge deck to be selected by the Engineer.

101.02 (b) Tensile Adhesion or Bond Strength (VTM-92, ACI 503, or equal). This test shall be performed at the time of construction. Three, reproducible tensile adhesion tests shall also be performed forty calendar days after installation at different sites on the bridge deck.

101.02 (c) Drying Shrinkage (ASTM C157). This test shall be performed at each bridge for the purposes of quality assurance testing during construction.

101.03 SAMPLING METHODS. The Independent Testing Laboratory shall provide a record of the following information based on results from sampling methods. Test methods used to obtain results must be approved by the Engineer.

101.03 (a) Rate of Evaporation
101.03 (b) Actual Mixture Proportions
101.03 (c) Water to Cement Ratio
101.03 (d) Thermal Coefficient of Concrete
101.03 (e) Entrained Air
101.04 METHOD OF MEASUREMENT. Measurement for Special Contractor Testing will be made on a lump sum basis.

101.05 BASIS OF PAYMENT. Special Contractor Testing, measured as provided above, will be paid for at the contract price for:

SPECIAL CONTRACTOR TESTING LUMP SUM

which price will be full compensation for performing the work specified and the furnishing of all materials, labor, tools, equipment and incidentals necessary to sample, test and report the treated concrete.

Payment for this item will be made in one installment after all samples have been obtained and tests performed.
5. Evaporation Control and Curing. Limit moisture loss from fresh concrete by first, controlling evaporation, and then, curing. Begin evaporation control immediately after concrete strike-off, and continue until the concrete is protected from moisture loss by one of the permitted curing methods.

Control evaporation according to the requirements of Article 504.03(c). Limit the evaporation rate of water from the fresh concrete to less than 0.5 kilograms per square meter per hour. Use Figure 504-1, or other approved means, to determine the evaporation rate. Control evaporation adequately to prevent premature crusting of the surface or an increase in drying cracking. If fogging, limit the application of moisture to avoid either disturbing the finish or collecting water in puddles. Do not use water from fogging as an aid to finishing the concrete.

Cure bridge deck and approach slab concrete according to the methods described in Article 509.04(f). Use the water method. The liquid membrane curing compound method may be used, before applying the water method, to shorten the time evaporation control is needed. Discontinue evaporation control after applying the either curing method.

6. Removing Forms. Comply with Article 502.04(c).

(f) Surface Correction through Grinding. Test the hardened driving surfaces after curing for true-ness using a 3-meter straightedge or other specified device before final acceptance. Mark and grind areas having high spots of 3 mm or more, or areas requiring grinding to meet smoothness specifications. Grind after the concrete curing period is completed, and according to Section 425. Discontinue grinding when the out-of-tolerance areas are within specified tolerances. Do not reduce the concrete cover of reinforcing steel to less than 50 mm. Restore the skid-resistant surface in ground areas using saw-cut grooving.

f Remove and replace, at no additional cost, bridge decks and approach slabs which cannot be corrected to specification tolerances.
Example shown by dashed lines is for an air temperature of 18°C, relative humidity of 45%, concrete temperature of 18°C, and a wind velocity of 24 km/h. This results in a rate of evaporation of 0.64 kg/m²/hr, and requires evaporation control to be used.

(g) Transverse Grooving. Provide saw-cut transverse grooving for bridge decks and approach slabs under the following conditions:
- Saw-cut transverse grooving is specified in the contract documents as a pay item.
- Transverse grooving must be replaced after grinding.
- Out-of-tolerance transverse grooving (either finned-float or saw-cut) must be corrected.
## COST ESTIMATE

Contract: 990057, TBOI-35-1(110)044 - BRIDGE REHABILITATION ON I-35

Project: 1625704, BRIDGE REHABILITATION 90% FEDERAL FUNDS (0037K) NOT TO EXCEED 400,000 & 20% MATCH

### Category: 0200, X231-BRIDGE 'A'

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</tr>
<tr>
<td>FLOODLIGHTING</td>
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<td>14,000 DAY</td>
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<td>3,000</td>
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<td>21%</td>
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<td>$4,500.00</td>
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<tr>
<td>MOBILIZATION</td>
<td>641 1399</td>
<td>1,000 LSM</td>
<td></td>
<td>1,000</td>
<td>1,000</td>
<td>100%</td>
<td>70,000.00</td>
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<tr>
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<td>619(O) 4726</td>
<td>1,600,000 SY</td>
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<td>1,668,880</td>
<td>1,668,880</td>
<td>99%</td>
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<td>619(O) 478C</td>
<td>150,000 LF</td>
<td></td>
<td>150,000</td>
<td>150,000</td>
<td>100%</td>
<td>10,000.00</td>
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<tr>
<td>SUBGRADE, METHOD B (2)</td>
<td>310(O) 416</td>
<td>1,669,000 SY</td>
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<td>1,688,890</td>
<td>1,688,890</td>
<td>99%</td>
<td>19,000.00</td>
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<tr>
<td>TACK COAT (F-25)</td>
<td>497 0250</td>
<td>200,000 GAL</td>
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<td>73,000</td>
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<td>37%</td>
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Project: 1625704, BRIDGE REHABILITATION 90% FEDERAL FUNDS (0037K) NOT TO EXCEED 400,000 & 20% MATCH

### Category: 0201, X231-BRIDGE 'B'

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<th>Item Description</th>
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<th>% Cpt</th>
<th>Unit Price</th>
<th>Dollar Amt. Paid To Date</th>
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<tbody>
<tr>
<td>(PL) CONCRETE SAWING</td>
<td>900.10 6141</td>
<td>270,000 LF</td>
<td></td>
<td>423,000</td>
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<td></td>
<td></td>
<td>$10,350.00</td>
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<tr>
<td>(PL) SEAL EXPANSION JOINT</td>
<td>901.14 6264</td>
<td>77,120 LF</td>
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<td></td>
<td></td>
<td></td>
<td>$350,000.00</td>
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<tr>
<td>(SP) ASPH. CONCRETE TYPE A (PG 64-22) (F-66)</td>
<td>411(A) 4302</td>
<td>373,400 TON</td>
<td></td>
<td>421,470</td>
<td>421,470</td>
<td>113%</td>
<td>55,000.00</td>
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<td>(SP) ASPH. CONCRETE TYPE B (PG 64-22) (F-66)</td>
<td>411(B) 4402</td>
<td>272,500 TON</td>
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<td>182,910</td>
<td>182,910</td>
<td>67%</td>
<td>75,000.00</td>
<td>$13,718.25</td>
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<tr>
<td>(SP) ELASTOMERIC MORTAR</td>
<td>504(C) 639X</td>
<td>14,000 CF</td>
<td></td>
<td>23,230</td>
<td>23,230</td>
<td>166%</td>
<td>900,000.00</td>
<td>$20,597.00</td>
<td></td>
</tr>
<tr>
<td>(SP) Q.E.T. GUARD RAIL END SECTION</td>
<td>623(H) 8571</td>
<td>2,000 EA</td>
<td></td>
<td>2,000</td>
<td>2,000</td>
<td>100%</td>
<td>2,000,000.00</td>
<td>$5,000.00</td>
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<tr>
<td>(SP) RAPID CURE JOINT SEALANT (3)</td>
<td>504(B) 637X</td>
<td>360,000 LF</td>
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<td>423,000</td>
<td>423,000</td>
<td>11%</td>
<td>50,000.00</td>
<td>$21,115.00</td>
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<tr>
<td>(SU) PRIME COAT (F-55)</td>
<td>408 5774</td>
<td>157,000 GAL</td>
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<td>2,000</td>
<td>2,000</td>
<td></td>
<td>2,000.00</td>
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<tr>
<td>BRIDGE FLOOR OVERLAY TYPE A</td>
<td>532 6071</td>
<td>1,754,000 SY</td>
<td></td>
<td>2,145,760</td>
<td>2,145,760</td>
<td>122%</td>
<td>52,000.00</td>
<td>$111,580.56</td>
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<tr>
<td>CLASS B BRIDGE FLOOR REPAIR</td>
<td>530 6019</td>
<td>110,000 SY</td>
<td></td>
<td>181,590</td>
<td>181,590</td>
<td>165%</td>
<td>240,000.00</td>
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<tr>
<td>CLASS C BRIDGE FLOOR REPAIR</td>
<td>530 6020</td>
<td>10,000 SY</td>
<td></td>
<td>19,310</td>
<td>19,310</td>
<td>193%</td>
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<td>FLOODLIGHTING</td>
<td>532 6027</td>
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<td></td>
<td>2,000</td>
<td>2,000</td>
<td>14%</td>
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<td>$3,000.00</td>
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<tr>
<td>REMOVAL OF ASPHALT PAVEMENT (1)(F-43)</td>
<td>619(O) 4726</td>
<td>1,115,000 SY</td>
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<td>1,111,110</td>
<td>1,111,110</td>
<td>99%</td>
<td>10,000.00</td>
<td>$11,111.10</td>
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<tr>
<td>REMOVAL OF GUARD RAIL (SP-8)(F-43)</td>
<td>619(O) 478C</td>
<td>150,000 LF</td>
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<td>150,000</td>
<td>150,000</td>
<td>100%</td>
<td>5,000.00</td>
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Project: 1625704, BRIDGE REHABILITATION 80% FEDERAL FUNDS (0037K) NOT TO EXCEED 400,000 & 20% MATCH

Category: 0201, X231-BRIDGE 'B'

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<th>Total Qty. Paid</th>
<th>% Cpt</th>
<th>Unit Price</th>
<th>Dollar Amt. Paid To Date</th>
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<td>SUBGRADE, METHOD B (2)</td>
<td>310(8)</td>
<td>014</td>
<td>1,111,000 SY</td>
<td>761,110</td>
<td>761,110</td>
<td>69%</td>
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<td>TACK COAT (F-25)</td>
<td>407</td>
<td>0250</td>
<td>146,000 GAL</td>
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Project: 1625704, BRIDGE REHABILITATION 80% FEDERAL FUNDS (0037K) NOT TO EXCEED 400,000 & 20% MATCH

Category: 0300, Y008-CONST. TRAFFIC CONTROL

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<th>Qty. Paid To Date</th>
<th>Total Qty. Paid</th>
<th>% Cpt</th>
<th>Unit Price</th>
<th>Dollar Amt. Paid To Date</th>
</tr>
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<tr>
<td>SURVEYANCE OF TRAFFIC CONTROL (TO-39)</td>
<td>850.99</td>
<td>8545</td>
<td>40,000 SD</td>
<td>80,000</td>
<td>80,000</td>
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<tr>
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<td>880(C)</td>
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<td>121,000</td>
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<td>880(F)</td>
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<td>240,000 SD</td>
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<td>8601</td>
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<td>31%</td>
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<td>856(B)</td>
<td>8003</td>
<td>4,000,000 LF</td>
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<td>SAND FILLED IMP. ATTENU. MODULE</td>
<td>870(A)</td>
<td>8011</td>
<td>30,000 EA</td>
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<td>100%</td>
<td>75,000.00</td>
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<tr>
<td>SIGNS 0 TO 6.25 SF</td>
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<td>0018</td>
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<td>SIGNS 15.00 FT TO 32.50 S.F.</td>
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<td>961.11</td>
<td>8635</td>
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<td>800,000 SD</td>
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<td>0,000</td>
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<td>$0.00</td>
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<td>WING BARRIADSES</td>
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Project: 1625704, BRIDGE REHABILITATION 80% FEDERAL FUNDS (0037K) NOT TO EXCEED 400,000 & 20% MATCH

Category: 0301, Y008-TRAFFIC STRIPING

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<th>% Cpt</th>
<th>Unit Price</th>
<th>Dollar Amt. Paid To Date</th>
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<td>PAV. MARKERS CLASS C</td>
<td>867(F)</td>
<td>8242</td>
<td>20,000 EA</td>
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<td>PAVEMENT MRKING REMOVAL STRIP (TO-22)</td>
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<td>8000</td>
<td>2,800,000 LF</td>
<td>3,000,000</td>
<td>3,000,000</td>
<td>107%</td>
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<td>TRAFFIC STRIPE (PLASTIC)(* WIDE)</td>
<td>855(A)</td>
<td>8313</td>
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<td>7,231,000</td>
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Percentage of Contract Completed (curr): 104%

Total Amount Earned This Estimate: $93,328.83

Total Amount Earned To Date: $831,909.08
APPENDIX B
Manufacturer's Literature on Concrete Admixtures used on Project TDOI-35-1(110)044

Pozzolith 300-R ...................................................................................................................... B-2
MB VB ......................................................................................................................................... B-3
Rheobuild 1000 ...................................................................................................................... B-5
Rheomac SF100 ...................................................................................................................... B-7
POZZOLITH® 300-R
Concrete admixture for retarding setting times

DESCRIPTION:
POZZOLITH® 300-R ready-to-use, liquid admixture is for making more uniform and predictable high-performance concrete while retarding its setting time to facilitate placing and finishing operations. It meets ASTM C 494 requirements for Type B retarding and Type D water-reducing and retarding admixtures, specifically:

- Increased strength—compressive and flexural
- Relative durability to damage from freezing and thawing—well above industry standards
- Reduced water content required for a given workability
- Retarded-setting characteristics

ADVANTAGES:
The set-retarding characteristics of POZZOLITH 300-R admixture aid in the production of concrete with the following special qualities:

- Improved workability
- Reduced segregation
- Superior finishing characteristics for flatwork and cast surfaces
- Moderate to extended retardation—depending on the dosage rate
- Provides flexibility in the scheduling of placing and finishing operations
- Offsets the effects of too-early hardening during extended delays between mixing and placing
- Helps eliminate cold joints
- Allows for dead-load deflection to take place (before concrete sets) in extended pours for bridge decks, cantilevers, nonshored structural elements, etc.
- Lowers peak temperature and/or rate of temperature rise in mass concrete—reduces thermal cracking
- Effective as a singular admixture or as a component in a Master Builders Admixture System

WHERE TO USE:
POZZOLITH 300-R admixture is recommended for use in all types of concrete where moderate to extended retardation of set time and improved performance are desired.

- This admixture improves pumped concrete, shotcrete (wet mix) and conventionally placed concretes. It improves plain, reinforced, prestressed, lightweight or standard weight concrete.

POZZOLITH 300-R admixture can be used with portland cements approved under AASHTO, ASTM and CRD specifications. The use of POZZOLITH 300-R and a Master Builders air-entraining admixture is recommended whenever concrete is required to withstand freeze/thaw cycles. When used in conjunction with another admixture, each admixture must be dispensed separately into the mix.

POZZOLITH 300-R admixture will not initiate or promote corrosion of reinforcing steel in concrete. This admixture does not contain intentionally added calcium chloride or chloride-based ingredients. The admixture, due to chlorides originating from all the ingredients used in its manufacture, contributes less than 0.0002% (2.0 ppm) chloride ions by weight of the cement when used at the rate of 1 fl oz per 100 lb (65 mL per 100 kg) of cement.

POZZOLITH 300-R admixture can be used in white or colored concrete and in architectural concrete.

QUANTITY TO USE:
POZZOLITH 300-R admixture is recommended for use at the rate of 3 to 5 fl oz per 100 lb (195 to 326 mL per 100 kg) of cement for most concrete mixes using average concrete ingredients. Because of variations in job conditions and concrete materials, dosage rates other than the recommended amounts may be required. In such cases, contact your local Master Builders representative.

RATE OF HARDENING:
The temperature of the concrete mix and the ambient temperature (forms, earth, reinforcement, etc.) affect the hardening rate of concrete. At higher temperatures, concrete hardens more rapidly which may cause problems with placing and finishing.

One of the functions of POZZOLITH 300-R admixture is to retard the set of concrete. Within the normal dosage range, it will generally extend the working and setting times of concrete containing normal portland cement approximately 1 hour to 5 hours compared to a plain concrete mix, depending on job materials and temperatures. Trial mixes should be made with job materials approximating job conditions to determine the dosage required.

PERFORMANCE CHARACTERISTICS:
Concrete produced with POZZOLITH 300-R admixture will have rapid strength development after initial set occurs. It develops higher early (24 hour) and higher ultimate strengths than plain concrete when used within the recommended dosage range and under normal, comparable curing conditions.

When POZZOLITH 300-R admixture is used in heat-cured concrete, the length of the preheating period should be increased until initial set of the concrete is achieved. The actual heat-curing period is then reduced accordingly to maintain existing production cycles without sacrificing early or ultimate strength.
**MB VR**

Admixture for entraining air in concrete

**REQUIREMENTS/ADVANTAGES:**

MB VR® (Master Builders Neutralized VINSOL® Resin solution) admixture for entraining air in concrete meets the requirements of ASTM C 260, AASHTO M 154, CRD-C 13 and other Federal and state specifications.

The entrainment of optimum air in concrete results in the following improvements in concrete quality:

- Increased resistance to damage from freezing and thawing
- Increased resistance to scaling from deicing salts
- Reduced permeability—Increased watertightness
- Reduced segregation and bleeding
- Improved plasticity and workability
- Improved properties of mixes used for making concrete block, concrete pipe and other precast products

Concrete durability research has established that the best protection for concrete from the adverse effects of freeze/thaw 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, placing, handling and curing techniques.

When unusually low or high amounts of an air-entraining admixture are required to achieve normal air content or if the required amount of air-entraining admixture necessary to achieve required levels of air content is observed to change significantly under given conditions, the reason should be investigated. In such cases, it is especially important to determine: (a) that a proper amount of air is contained in the fresh concrete at the point of placement; and (b) that a suitable air-void system (spacing factor) is being obtained in the hardened concrete.

**FEATURES/BENEFITS:**

- **Ready To Use - Solution** is the proper concentration for rapid, accurate dispensing.
- **Compatible for Use** - MB VR admixture is compatible with concrete containing other admixtures - water-reducers, high-range water-reducers, accelerators, retarders, and water repellents. The use of MB VR air-entraining admixture with Master Builders water-reducing, set-controlling admixtures forms a desirable combination for producing high-quality normal or lightweight concrete. Heavyweight concrete normally does not contain entrained air.

**NOTE:** As stated in ACI 212 and other publications, when two or more admixtures are used, each must be added to the mix separately (through dispensers or manually) and must not be mixed with each other prior to adding to the concrete mix.

For optimum, consistent performance, the air-entraining admixture should be dispensed on damp fine aggregate or with the initial batch water. When using lightweight fine aggregate, field evaluations should be conducted to determine the best method to dispense the air-entraining admixture.

**USAGE INFORMATION:**

Add MB VR admixture to the concrete mix using a dispenser designed for air-entraining admixtures; or add manually using a suitable measuring device that ensures accuracy within plus or minus 0.5% of the required amount. Measure the air content of the trial mix and either increase or decrease the quantity of MB VR admixture to obtain the desired air content in the production mix. Check the air content of the first batch and make further adjustments if needed.

Due to possible changes in the factors that affect the dosage rate of MB VR, frequent checks should be made during the course of the work. Adjustments to the dosage should be based on the amount of entrained air in the mix at the point of placement.

**QUANTITY TO USE:**

There is no standard dosage rate for MB VR admixture. The exact quantity of air-entraining admixture needed for a given air content of concrete is not predictable because of differences in concrete making materials. Typical factors which might influence the amount of entrained air are: temperature, cement, sand grading, mix proportions, slump, means of conveying and placing, use of extra fine materials such as fly ash, etc.

The amount of MB VR admixture used will depend upon the amount of entrained air required under actual job conditions. In a trial mix use 1/4 to 4 fl oz/100 lb (16 to 200 mL/100 kg) of concrete. In mixes containing water-reducing, set-controlling admixtures, the amount of MB VR needed may be somewhat less than the amount required in plain concrete. In mixes requiring a higher or lower dosage to obtain the desired air content, consult your local Master Builders representative.
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, "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, "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.

TEMPERATURE PRECAUTION:
MB-VR admixture should be stored and dispensed at 35°F (2°C) or higher. Although freezing does not harm this product, precautions should be taken to protect it from freezing. If it freezes, thaw and reconstitute by mild mechanical agitation. Do not use pressurized air for agitation.

PACKAGING:
MB-VR admixture is supplied in 55 U.S. gallon (208 liter) drums and by bulk delivery.

CAUTION:
MB-VR admixture is a CAUSTIC solution. Chemical goggles and gloves are recommended if transferring or handling large quantities of material. (See MSDS and/or product label for complete information.)

NON-CHLORIDE, NON-CORROSIVE:
MB-VR admixture will not initiate or promote corrosion of reinforcing steel embedded in concrete, prestressed concrete or concrete placed on galvanized steel floor and roof systems. Calcium chloride is not an added ingredient in the manufacture of MB-VR admixture. Based on the chlorine originating from all ingredients used in manufacture, MICRO-AIR admixture contributes less than 0.0001% (1.0 ppm) chloride ions by weight of the cement when used at the rate of 1 fl oz per 100 lb (65 mL per 100 kg) of cement.

For suggested specification information or for additional product data on MB-VR air-containing admixture, contact your local Master Builders representative.
RHEOBUILD® 1000
For the production of rheoplastic concrete

DESCRIPTION:
RHEOBUILD 1000 high-range, water-reducing admixture, is one of a complete line of RHEOBUILD admixtures formulated to produce rheoplastic concrete. Rheoplastic concrete flows easily, maintaining high plasticity for time periods unmatched by any other superplasticized concrete. Yet it has the low water/cement ratio of no-slump concrete, providing excellent engineering (hardened) properties. The slump-retention characteristics of rheoplastic concrete permit the addition of RHEOBUILD 1000 admixture at the batch plant. This ready-to-use, liquid admixture meets ASTM C 494 requirements for Type A and Type F admixtures.

ADVANTAGES IN THE PLASTIC STATE:
RHEOBUILD 1000 admixture aids in the production of concrete with these special qualities:
- Plasticity range of 8 to 11° (200 to 280 mm)
- Extended slump retention
- Controlled time of set
- Cohesive and non-segregating
- Minimal bleed water

ADVANTAGES IN THE HARDENED STATE:
Through improved cement hydration efficiency, less dependence on consolidation energy and potential mix proportion adjustments, concrete treated with RHEOBUILD 1000 admixture provides the following engineering properties:
- Higher early strengths than can be achieved with conventional superplasticizers
- Increased ultimate compressive strength
- Higher modulus of elasticity
- Improved bond strength to steel
- Low permeability
- High durability
- Reduced shrinkage and creep
- Highly reliable in-place structural integrity

BENEFITS:
The economic benefits are both immediate and long-term, and extend to the total construction team. Use of rheoplastic concrete saves job time and cost through higher productivity rates or reduced labor. The higher early strength achieved with rheoplastic concrete allows for accelerated construction methods, resulting in completion dates ahead of schedule. Also, rheoplastic concrete permits engineering specification changes that allow for greater limits on the free-fall of concrete, lift heights and concrete temperatures, and potential economic mix adjustments.

SLUMP RETENTION VS. TIME

![SLUMP RETENTION VS. TIME](image-url)
WHERE TO USE:
RHEOBUILD 1000 admixture is recommended for use in concrete where high plasticity, normal-setting characteristics and accelerated strengths are desired.

As a result of the preceding advantages and benefits, this admixture will improve performance in prestressed, precast and ready-mixed concrete applications.

RHEOBUILD 1000 admixture can be used with portland cements approved under ASTM, AASHTO or ORO specifications. The use of RHEOBUILD 1000 and a Master Builders air-entraining admixture is recommended whenever concrete is required to withstand freeze/thaw cycles. It is strongly recommended that concrete be properly cured.

RHEOBUILD 1000 admixture can be used effectively as a singular admixture or as a component in a Master Builders admixture system. When used in conjunction with another admixture, each admixture must be dispensed separately into the mix.

DIRECTIONS FOR USE:
Because slump retention is increased using RHEOBUILD 1000 admixture, it may be batched at the ready-mix plant as opposed to jobsite addition often required when using other high-range water-reducers.

NOTE: For directions on the proper evaluation and use of RHEOBUILD 1000 admixture in specific applications, contact your local Master Builders representative.

WORKABILITY:
Concrete containing RHEOBUILD 1000 admixture has the ability to maintain a rheoplastic state (8 to 11° (200 to 280 mm)) for up to two hours, if such workability is required. The precise duration of workability depends not only on temperature, but also on the type of cement, mix proportion, the nature of the aggregates, the method of transport, and the dosage rate of RHEOBUILD 1000 admixture.

For additional information on RHEOBUILD 1000 admixture or on its use in developing a concrete mixture with special performance characteristics, contact your local Master Builders representative.

QUANTITY TO USE:
RHEOBUILD 1000 admixture is recommended for use at a rate of 10 to 25 fl oz per 100 lb (0.65 to 1.5 liters per 100 kg) of cementitious materials, depending upon the application, and the amount of strength acceleration needed or slump increase desired.

This dosage range applies for most concrete mixes using average concrete ingredients. However, variations in job conditions and concrete materials, such as silica fume, may make usage rates outside the recommended dosage range desirable. In such cases, contact your local Master Builders representative.

RATE OF HARDENING:
RHEOBUILD 1000 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 climatic conditions. Trial mixes should be made with job materials to determine the dosage required for a specified setting time and a given strength requirement.

PACKAGING:
RHEOBUILD 1000 admixture is supplied in 55 U.S. gallon (208 liter) drums and bulk delivery.

TEMPERATURE PRECAUTION:
If RHEOBUILD 1000 admixture has frozen, thaw at 45 °F (7 °C) or above and completely reconstitute by mild mechanical agitation. Do not use pressurized air for agitation.

NON-CHLORIDE, NON-CORROSIVE:
RHEOBUILD 1000 admixture will not initiate or promote corrosion of reinforcing steel embedded in concrete, prestressed concrete or concrete placed on galvanized steel floor and roof systems. Neither calcium chloride nor any chloride-based ingredients are used in the manufacture of RHEOBUILD 1000. In all concrete applications, RHEOBUILD 1000 admixture conforms to the most stringent or minimum chloride ion limits currently suggested by construction industry standards and practices.
RHEOMAC® SF100
(Formerly MB SF)
Silica fume mineral admixture

DESCRIPTION:
RHEOMAC SF100 dry compacted silica fume admixture is formulated to produce extremely strong, durable concrete possessing special performance qualities. RHEOMAC SF100 meets ASTM C1240 Standard Specification for Silica Fume for Use in Hydraulic-Cement Concrete and Mortar.

BENEFITS:
RHEOMAC SF100 silica fume is a critical component in the production of high-performance concrete with the following unique engineering properties:
• Dramatically Reduced Permeability that effectively inhibits the ingress of moisture, chlorides and other contaminants into concrete.
• Effective Corrosion Protection of steel-reinforced concrete.
• Highly Durable concrete with increased resistance to:
  • Corrosion
  • Abrasion/erosion
  • Chemical attack
  • Sulfates
  • Freeze/thaw damage
• High-Strength concrete with strengths in excess of 15,000 psi (105 MPa).
• Extremely High Modulus of Elasticity exceeding 6,000,000 psi (41,000 MPa).
• High-Early Strengths that enable more efficient and cost effective production of prestressed and/or precast concrete.

HOW IT WORKS:
RHEOMAC SF100 silica fume is a micro-filling material that physically fills the voids between cement particles. RHEOMAC SF100 silica fume dramatically lowers concrete permeability, and reduces the size and number of capillaries that allow contaminants to enter concrete.

RHEOMAC SF silica fume maximizes concrete service life by providing superior resistance to attack from damaging environmental forces.

As a pozzolan, RHEOMAC SF100 silica fume reacts chemically within concrete to increase the amount of calcium silicate hydrate (CSH) that is formed. CSH is the bonding agent that holds concrete together. The additional CSH significantly increases the compressive strength and decreases the permeability of concrete.

WHERE TO USE:
RHEOMAC SF100 silica fume will improve performance in precast, paving, shotcrete and ready-mixed concrete applications. RHEOMAC SF100 silica fume increases concrete strength and reduces permeability, thereby increasing the concrete's resistance to environmental attack. This makes RHEOMAC SF100 silica fume ideal for use in structures exposed to deicing salts such as parking garages and bridge decks, as well as for marine structures, slabs, and in any construction project requiring the protection provided by highly durable, low permeability concrete.

Typical Compressive Strengths
28 Days

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<th>Strength (psi)</th>
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<th>145</th>
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<tr>
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<td>10</td>
<td>15</td>
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<tr>
<td>STRENGTH</td>
<td>4</td>
<td>8</td>
<td>12</td>
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</table>

* Compressive strengths indicated when silica is optimized regarding binder, aggregate and other factors affecting strength.
RHEOMAC SF100 silica fume's pozzolanic and void-filling properties enable concrete to attain ultra-high compressive strengths. RHEOMAC SF100 silica fume is ideal for use in projects requiring high-strength/high performance concrete for reducing member size, increasing span lengths, improving structural economics, and meeting other high-performance structural requirements.

DRY COMPACTED VS. SLURRY:
The high-performance benefits of silica fume concrete can be achieved by using either dry compacted or slurried forms of silica fume. Dry compacted and slurried forms of silica fume provide identical performance in concrete. Both require effective mixing for maximum results. Master Builders provides both dry compacted and slurried forms of silica fume for the convenience of the concrete producer in storing, handling, and batching.

DIRECTIONS FOR USE:
RHEOMAC SF100 silica fume is batched at the ready-mix plant in a manner similar to cement or other cementitious materials such as fly ash and granulated slag. It may be batched in a central or truck mixer, and may be added at any point in the batching process. Follow ASTM C-94 procedures to ensure effective mixing and distribution throughout the mixer.

QUANTITY TO USE:
RHEOMAC SF100 silica fume is recommended for use at an addition rate of 5 to 15% by weight of cement. Dosage rates may vary according to application and desired concrete properties. For dosages outside the recommended range, contact your local Master Builders representative.

STORAGE/HANDLING/DISPENSING:
RHEOMAC SF100 silica fume stores, handles, and dispenses similar to cement or fly ash. In bulk, RHEOMAC SF100 silica fume may be stored in a silo. Packaged material may be stored indefinitely in a dry area. RHEOMAC SF100 silica fume requires no special dispensing equipment.

PACKAGING:
RHEOMAC SF100 silica fume is available in 25 lb (11.6 kg) shreddable bags, 50 lb (23 kg) bags, 2,000 lb (907 kg) bulk bags or bulk delivery.

SPECIFIC GRAVITY:
The specific gravity of RHEOMAC SF100 silica fume is 2.2.

COMPATIBILITY:
RHEOMAC SF100 silica fume can be used with Portland cements approved under ASTM, AASHTO, or CRD specifications. It is compatible with most concrete admixtures, including all Master Builders admixtures. RHEOMAC SF100 silica fume is recommended for use with high-range water-reducing admixtures, such as RHEOBUILD 1000 admixture, for maximum workability while maintaining a low water-cementitious materials ratio.

RATE OF HARDENING:
Setting time of concrete is influenced by the chemical and physical composition of the cement and/or cement type used to produce the concrete, temperature of the concrete, weather conditions, and the use of chemical admixtures. Trial mixes should be made with job materials to determine the setting time of a specific mixture.

NON-CHLORIDE:
RHEOMAC SF100 silica fume will not initiate or promote corrosion of reinforcing steel embedded in concrete, prestressed concrete, or concrete placed on galvanized steel floor and roof systems. Neither calcium chloride nor any chloride-based ingredients are used in the manufacture of RHEOMAC SF100 silica fume.
PACKAGING:
POZZOLITH 300-R admixture is supplied in 55 US gallon (208 liter) drums and by bulk delivery.

TEMPERATURE PRECAUTION:
If POZZOLITH 300-R admixture has frozen, thaw at 35 °F (2 °C) or above and completely reconstitute by mild mechanical agitation. Do not use pressurized air for agitation.

For additional information on POZZOLITH 300-R admixture or on its use in developing a concrete mix with special performance characteristics, contact your local Master Builders representative.
APPENDIX C
Photographs of Overlay Construction Operation

Figure 1. Calibrating finish grade height ................................................................. C-2
Figure 2. Mixing grout for overlay bond strength ..................................................... C-2
Figure 3. Spreading silica fume concrete for the overlay ............................................ C-3
Figure 4. Spreading silica fume concrete by hand ..................................................... C-3
Figure 5. Concrete paver spreading silica fume concrete ......................................... C-4
Figure 6. Spray bars and a finish board on the back of the concrete paver .................. C-4
Figure 7. Repairing pits by hand left by the concrete paver ....................................... C-5
Figure 8. Hand finishing the edge of the bridge deck .............................................. C-5
Figure 9. Final finish made with a Fresno float ....................................................... C-6
Figure 10. Surface texturing with a tine float .......................................................... C-6
Figure 11. Spraying white curing compound .......................................................... C-7
Figure 12. Curing a deck with a burlap blanket ...................................................... C-7
Figure 13. Wetting burlap and covering over with plastic for 72 hours ...................... C-8
Figure 14. Removing a curing blanket on the completed overlay ............................. C-8
Figure 1. Calibrating finish grade height.

Figure 2. Mixing grout for overlay bond strength.
Figure 3. Spreading silica fume concrete for the overlay.

Figure 4. Spreading silica fume concrete by hand.
Figure 5. Concrete paver spreading silica fume concrete.

Figure 6. Spray bars and finish board on the back of the concrete paver.
Figure 7. Repairing pits by hand left by the concrete paver.

Figure 8. Hand finishing the edge of the bridge deck.
Figure 9. Final finish made with a Fresno float.

Figure 10. Surface texturing with a tine float.
Figure 11. Spraying white curing compound.

Figure 12. Curing deck with burlap blanket.
Figure 13. Wetting burlap and covering overlay with plastic for 72 hours.

Figure 14. Removing curing blanket on the completed overlay.
APPENDIX D
Test Results

Field report (profilograph testing of silica fume overlay bridge)................................. D- 2
Skid data sheet.................................................................................................................... D- 3
Compressive strength test report (Terracon)..................................................................... D- 9
Virginia test method.......................................................................................................... D-21
Rapid determination of the chloride permeability of concrete (AASHTO T 277)........... D-24
Profilograph work has been completed on the Silica Fume overlay bridge and approaches. The table below shows the profilograph readings along with the numbers from the K.J. Law Profilometer.

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<th>LOCATION</th>
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The coefficient of variation for the profilometer in the above table is 7.63%. This figure is slightly higher than has been seen in roadway testing (an average of 6%). The interim report will be completed by the end of October and will contain the results of all the profilometer testing to date.

From the standpoint of profilograph smoothness, this is one of the smoothest bridges that the Research office knows about in the state. The maximum allowable roughness on the typical bridge in new construction is 40 in/mi. The average bridge is approximately 27 in/mi. Anything under 15 in/mi is awarded the highest pay factor (1.05). Taking these figures into consideration, the Silica Fume overlay seems to be a success. Additional factors like performance over time will need to be considered, but the start is very encouraging.
**SKID TEST DISCLAIMER**

This test is conducted solely for the purpose of generating input data for priority programming of maintenance and construction projects. Tests are performed by field personnel not trained nor expert in scientific testing procedure. While every effort is made to conduct tests accurately, tests are not subject to rigorous scientific control. The test results are calculated as the product of a mechanical test wherein a skid trailer tire interfaces with the road surface providing an approximate value which may be converted to a coefficient of friction for that portion of the road surface actually in contact with the tire of the test trailer. The calculated coefficient of friction has value only as to the surface actually tested and no attempt should be made to use this test as a means of evaluation of untested surface areas or for correlation of this test with tests of other tested surface areas.

**TEST IS PERFORMED SOLEY FOR THE PURPOSES INDICATED AND NO REPRESENTATIONS AS TO ITS ACCURACY, RELIABILITY, OR APPLICABILITY FOR OTHER PURPOSES ARE EXPRESSED OR IMPLIED.**

---

**SKID DATA SHEET**

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*Rev. October 1, 1990  Oklahoma Department of Transportation, Traffic Engineer Division  Form TE-2-468*
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SKID DATA SHEET

SITE: 035-10-36 Carter
LANE: SBOL
DRIVER: RMB
OPERATOR: JAL
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Compressive Strength Test Report

In general compliance with ASTM.

Terracon Project No. 03991159
Report No. 1

Client Wildcat Concrete Services, Inc.
PO BOX 750075
Topeka, KS 66675

Att: Mr. Raymond E. May

Field Mix Data
Sample Date: 08/06/99 Time: 12:30
Sampled by: Callaway
Placement Description: I-35 overlay
Sample Location: far right north bound lane, mile marker 47
Placement Method: direct discharge

Field Test Data
Test Result
Slump, in. 5.25
Air Content, % 4.0
Concrete Temperature, °F 82
Ambient Temperature, °F 74

Laboratory Test Data (ASTM C 39)
Nominal Specimen Size 6x12
Date submitted to laboratory 08/09/99
Specimen No. A B C D
Specimen Size, inches 6 6 6 6
Cross-Section Area, sq. inches 28.27 28.27 28.27 28.27
As Received Specimen Wt., lbs. 28.1 27.9 28.0 28.1
Tested By Burton Burton Speaks Speaks
Date Tested 08/13/99 08/13/99 09/03/99 09/03/99
Age at Test, days 7 7 28 28
Fracture Type c c d d
Total Load, lbs. 170000 180000 200000 190000
Compressive Strength, psi 6010 6440 7070 6720

Comments:

Distribution: Wildcat Concrete Services, Inc. (2)
ODOT (1) Ms. Kimberly Gordon

Notes:
Field mix and field test data provided by others
Reviewed by: Thomas Hawes
Construction Services Mgr.

Distribution: Wildcat Concrete Services, Inc. (2)
ODOT (1) Ms. Kimberly Gordon

Notes:
Field mix and field test data provided by others
Reviewed by: Thomas Hawes
Construction Services Mgr.
Compressive Strength Test Report

in general compliance with ASTM.

Terracon Project No. 01991159
Report No. 2

Client: Wildcat Concrete Services, Inc.
PO BOX 750075
Topeka, KS 66675

Project: Carter County Bridge Overlay
I-35 Bridges

Sampled by: Callaway
Sample Date: 08/06/99
Sampled by: Callaway
Time: 3:50
Sampled by: Callaway
Sample Location: on bridge, far right
Sampled by: Callaway
north bound lane
Sampled by: Callaway
Placement Method: direct discharge
Sampled by: Callaway
direct discharge, crane and bucket, pumpl

Field Test Data

Test
Slump, in.
Air Content, %
Concrete Temperature, °F
Ambient Temperature, °F
Plastic Unit Weight, pcf

Result
3.0
6.2
82
88

Laboratory Test Data (ASTM C 39)

Nominal Specimen Size
Specimen No.
Specimen Size, Inches
Cross-Section Area, sq. inches
As Received Specimen Wt., lbs.
Tasted By
Date Tested
Age at Test, days
Fracture Type
Min. Compressive Strength, psi
Total Load, lbs.
Compressive Strength, psi

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<td>09/03/99</td>
</tr>
<tr>
<td>Age at Test, days</td>
<td>7</td>
<td>7</td>
<td>28</td>
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</tr>
<tr>
<td>Fracture Type</td>
<td>c</td>
<td>c</td>
<td>a</td>
<td>a</td>
</tr>
<tr>
<td>Min. Compressive Strength, psi</td>
<td>210000</td>
<td>210000</td>
<td>210000</td>
<td>205000</td>
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<tr>
<td>Total Load, lbs.</td>
<td>6370</td>
<td>7960</td>
<td>7430</td>
<td>7250</td>
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<td>180000</td>
<td>225000</td>
<td>210000</td>
<td>205000</td>
</tr>
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</table>

Distribution: Wildcat Concrete Services, Inc. (2)
ODOT (1) Ms. Kimberly Gordon

Notes:
- Field mix and field test data provided by others
- Field test data by Terracon in general compliance
  with sampling ASTM C 172, Casting Specimens C 31,
  Slump C143, Air Content C 173 or C 231, Temperature
  C 1064, Unit Weight C 138

Reviewed by: Thomas Hawes
Construction Services Mgr.
Compressive Strength Test Report

in general compliance with ASTM.

Terracon Project No. 03991159
Report No. 3

Client Wildcat Concrete Services, Inc.
PO BOX 750075
Topeka, KS 66675

Attn: Mr. Raymond E. May

Sample Date: 08/10/99
Sampled by: Stevenson
Placement Description: northbound land east shoulder
Sample Location: 40' from south end
Placement Method: direct discharge

Field Test Data
Test | Specification | Result | Mix No. | Coarse aggregate size | Water added on site, gal. | Batch time, min.: |
--- | --- | --- | --- | --- | --- | --- |
Slump, in. | 5.5-7.5 | 3.5 | | | | |
Air Content, % | | 4.2 | | | |
Concrete Temperature, °F | 95 | 88 | | | |
Ambient Temperature, °F | 95 | 88 | | | |
Plastic Unit Weight,pcf | 173000 | 175000 | | | |

Laboratory Test Data (ASTM C 39)

<table>
<thead>
<tr>
<th>Nominal Specimen Size</th>
<th>6x12</th>
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<tbody>
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<td>Specimen Size, inches</td>
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</tr>
<tr>
<td>Cross-Section Area, sq. inches</td>
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<tr>
<td>As Received Specimen Wt., lbs.</td>
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<tr>
<td>Tested By</td>
<td>Burton</td>
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<td>Data Tested</td>
<td>08/17/99 08/17/99 09/07/99 09/07/99</td>
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<tr>
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Comments:

Distribution: Wildcat Concrete Services, Inc. (2)
ODOT (1) Ms. Kimberly Gordon

Reviewed by: Thomas Hawes
Construction Services Mgr.

Notes:
- Field mix and field test data provided by others
- Field test data by Terracon in general compliance with sampling ASTM C 172, Casting Specimens C 31, Slump C143, Air Content C 173 or C 231, Temperature C 1064, Unit Weight C 138

Reviewed by: Thomas Hawes
Construction Services Mgr.
Compressive Strength Test Report

In general compliance with ASTM.

Terracon Project No. 03991159
Report No. 4

Client: Wildcat Concrete Services, Inc.
PO BOX 750075
Topeka, KS 66675

Attn: Mr. Raymond E. May

Field Mix Data
Sample Date: 08/13/99 Time: 2:35
Sampled by: Callaway
Placement Description: south bound lane
Sample Location: truck #4, right before bridge
Placement Method: direct discharge

Field Test Data
<table>
<thead>
<tr>
<th>Test</th>
<th>Result</th>
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</thead>
<tbody>
<tr>
<td>Slump, in.</td>
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<tr>
<td>Air Content, %</td>
<td>8.9</td>
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<td>Concrete Temperature, °F</td>
<td>88</td>
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<td>Ambient Temperature, °F</td>
<td>79</td>
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<td>Plastic Unit Weight, psf</td>
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Laboratory Test Data (ASTM C 39)

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<tr>
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<th>Date submitted to laboratory</th>
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<tr>
<td>Specimen Size, inches</td>
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<tr>
<td>Cross-Section Area, sq. inches</td>
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</tr>
<tr>
<td>As Received Specimen Wt., lbs.</td>
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<td>Fracture Type</td>
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<td>c</td>
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<td></td>
</tr>
<tr>
<td>Compressive Strength, psi</td>
<td>5910</td>
<td>5380</td>
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</tbody>
</table>

Comments: ___________________________________________

Distribution: Wildcat Concrete Services, Inc. (2)
ODOT (1) Ms. Kimberly Gordon

Notes:
☐ Field mix and field test data provided by others
☐ Field test data by Terracon in general compliance with sampling ASTM C 172, Casting Specimens C 31, Slump C143, Air Content C 173 or C 231, Temperature C 1084, Unit Weight C 138

Reviewed by: Thomas Hawes
Construction Services Mgr.

Fracture Types

D-10
Compressive Strength Test Report

In general compliance with ASTM.

Terracon Project No. 03991159
Report No. 5

Client Wildcat Concrete Services, Inc.
PO BOX 753075
Topeka, KS 66675

Attn: Mr. Raymond E. May

Field Mix Data
Sample Date: 08/30/99 Time: 2:00AM
Sampled by: Broomfield
Placement Description: Bridge Deck Paving

Sample Location: South Bound right lane
Placement Method: Paving Machine

Field Test Data
Test Result Specification
Slump, in. 3.25
Air Content, % 9.4
Concrete Temperature, °F 86
Ambient Temperature, °F 78
Plastic Unit Weight, psf

Laboratory Test Data (ASTM C 39)
Nominal Specimen Size 6x12 Date submitted to laboratory 08/21/99
Specimen No. A B C
Specimen Size, inches 6 6 6
Cross-Section Area, sq. inches 28.27 28.27 28.27
As Received Specimen Wt., lbs. 28.4 28.4 28.4
Tested By Burton Tanner Tanner
Date Tested 08/27/99 09/17/99 09/17/99
Age at Test, days 7 28 28
Fracture Type b c c
Min. Compressive Strength, psi 220000 230000 227000
Total Load, lbs. 227000
Compressive Strength, psi 7780 8140 8030

Notes:
☐ Field mix and field test data provided by others
☐ Field test data by Terracon in general compliance
  with sampling ASTM C 172, Casting Specimens C 31,
  Slump C 143, Air Content C 173 or C 231, Temperature
  C 1064, Unit Weight C 120

Distribution: Wildcat Concrete Services, Inc. (2)
ODOT (1) Ms. Kimberly Gordon

Reviewed by: Thomas Hawes
Construction Services Mgr.

D-11
Compressive Strength Test Report

In general compliance with ASTM.

Terracon Project No. 03991159
Report No. 6

Client: Wildcat Concrete Services, Inc.
PO BOX 750075
Topeka, KS 66675

Attn: Mr. Raymond E. May

Field Mix Data
Sample Date: 08/20/99 Time: 3:00AM
Sampled by: Broomfield
Placement Description: Bridge Deck

Sample Location: Right south bound lane
Placement Method: Paving Machine

Field Test Data
Test Slump, in. 3.25
Air Content, % 5.6
Concrete Temperature, °F 84
Ambient Temperature, °F 81
Plastic Unit Weight, pcf

Laboratory Test Data (ASTM C 39)

Nominal Specimen Size 6x12
Specimen No. A B C
Specimen Size, inches 6 6 6
Cross-Section Area, sq. inches 28.27 28.27 28.27
As Received Specimen Wt., lbs. 27.9 27.9 27.9
Tested By Burton Tanner Tanner
Date Tested 08/27/99 09/17/99 09/17/99
Age at Test, days 7 28 28
Fracture Type b a b
Min. Compressive Strength, psi
Total Load, lbs. 240000 245000 232000
Compressive Strength, psi 8490 8670 8210

Notes:
- Field mix and field test data provided by others
- Field test data by Terracon in general compliance with testing ASTM C 112, Casting Specimens C 31, Slump C 143, Air Content C 173 or C 231, Temperature C 1064, Unit Weight C 128

Distribution: Wildcat Concrete Services, Inc. (2)
ODOT (1) Ms. Kimberly Gordon

Reviewed by: Thomas Hawes
Construction Services Mgr.
Compressive Strength Test Report

Terracon Project No. 03991159
Report No. 7

In general compliance with ASTM.

Client: Wildcat Concrete Services, Inc.
PO BOX 750075
Topeka, KS 66675

Project: Carter County Bridge Overlay
I-35 Bridges

Sample Date: 08/27/99 Time: 12:05
Design Strength at 28 days 5000 psi

Sampled by: Callaway
Material: concrete, gravel, mortar

Placement Description: north bound left lane
Material Supplier: Joe Brown

Sample Location: Truck #1
Concrete Temperature, °F 89

Placement Method: direct discharge
(6x12)

Field Test Data

<table>
<thead>
<tr>
<th>Test</th>
<th>Result</th>
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</thead>
<tbody>
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<td>Slump, in.</td>
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<tr>
<td>Concrete Temperature, °F</td>
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<td>Ambient Temperature, °F</td>
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<td>Plastic Unit Weight, pcf</td>
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Laboratory Test Data (ASTM C 39)

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</tr>
<tr>
<td>Cross-Section Area, sq. inches</td>
<td>28.27 28.27 28.27 28.27 28.27</td>
</tr>
<tr>
<td>As Received Specimen Wt., lbs.</td>
<td>28.6 28.7 28.6 28.7</td>
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<tr>
<td>Tested By</td>
<td>Speaks Speaks</td>
</tr>
<tr>
<td>Date Tested</td>
<td>09/03/99 09/09/99 09/24/99 09/24/99</td>
</tr>
<tr>
<td>Age at Test, days</td>
<td>7 7 28 28</td>
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<td>Fracture Type</td>
<td>b c</td>
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<td>Min. Compressive Strength, psi</td>
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<td>Total Load, lbs.</td>
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<td>Compressive Strength, psi</td>
<td>7850 7430</td>
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Notes:
- Field mix and field test data provided by others
- Field test data by Terracon in general compliance with sampling ASTM C 172. Casting Specimens C 31, Slump C143, Air Content C 173 or C 231, Temperature C 1054, Unit Weight C 138

Reviewed by: Thomas Hawes
Construction Services Mgr.

Distribution: Wildcat Concrete Services, Inc. (2)
ODOT (1) Ms. Kimberly Gordon

Fracture Types: a b c d e f u

D-13
Compressive Strength Test Report

In general compliance with ASTM.

Terracon Project No. 03991159
Report No. 8

Client: Wildcat Concrete Services, Inc.
PO BOX 750075
Topeka, KS 66675

Client: Wildcat Concrete Services, Inc.
PO BOX 750075
Topeka, KS 66675

Attn: Mr. Raymond E. May

Field Mix Data
Sample Date: 08/26/99 Time: AM
Sampled by: Sloan
Placement Description: approach to bridge
doek
Sample Location: north bound lane, left
of center
Placement Method: direct discharge

Field Test Data
Test Result
Slump, in. 1.25
Air Content, % 5.3
Concrete Temperature, °F 89
Ambient Temperature, °F 84
Plastic Unit Weight, pcf

Laboratory Test Data (ASTM C 39)
Nominal Specimen Size 6x12 Date submitted to laboratory 09/09/99
Specimen No. A B C
Specimen Size, inches 6 6 6
Cross-Section Area, sq. inches 28.27 28.27 28.27
As Received Specimen Wt., lbs. 28.4 28.4 28.4
Tested By Stinson Stinson Stinson
Date Tested 09/23/99 09/23/99 09/23/99
Age at Test, days 28 28 28
Fracture Type d d d
Min. Compressive Strength, psi 270000 265000 270000
Total Load, lbs. 9550 9370 9550
Compressive Strength, psi 9550 9370 9550

Notes:
Field mix and field data by: Terracon Services
with sampling ASTM C 171, Casting Specimens C 31,
Slump C143, Air Content C 123, Density Specimen
C 1094, Unit Weight C 1299.

Distribution: Wildcat Concrete Services, Inc. (2)
ODOT (1) Ms. Kimberly Gordon

Reviewed by: Thomas Rawes
Construction Services Mgr.

D-14
Compressive Strength Test Report

Terracon Project No. 03991159
Report No. 9

Client Wildcat Concrete Services, Inc. Project Carter County Bridge Overlay
PO BOX 750075 I-35 Bridges
Topeka, KS 66675 __________________________________________

Attn: Mr. Raymond E. May

Field Mix Data
Sample Date: 09/14/99 Time: 8:25 Sampled by: Callaway
Placement Description: Patching on Bridge
Sample Location: South Bound, Left
Placement Method: DIRECT DISCHARGE

Field Test Data
Test Slump, in. Air Content, % Concrete Temperature, °F Ambient Temperature, °F Plastic Unit Weight, pcf
Result 1.75 5.5 83 70

Laboratory Test Data (ASTM C 39)
Nominal Specimen Size 6x12
Specimen No. A B C D
Specimen Size, Inches 6 6 6 6
Cross-Section Area, sq. inches 28.27 28.27 28.27 28.27
As Received Specimen Wt., lbs. 28.1 28.0 28.1 28.0
Tested By Tanner Tanner
Date Tested 09/21/99 09/21/99 10/12/99 10/12/99
Age at Test, days 7 7 28 28
Fracture Type a c
Min. Compressive Strength, psi
Total Load, lbs. 182500 185000
Compressive Strength, psi 6460 6510

Notes:
☐ Field mix and field test data provided by others
☐ Field test data by Terracon in general compliance with testing ASTM C 172, Casting Specimens C 31, Slump C 143, Air Content C 173 or C 331, Temperature C 1994, Unit Weight C 138

Reviewed by: Thomas Hawes
Construction Services Mgr.

Distribution: Wildcat Concrete Services, Inc. (2)
ODOT (1) Ms. Kimberly Gordon

Fracture Types

D-15
## Compressive Strength Test Report

### Terracon Project No. 03991159

**Compressive Strength Test Report**

In general compliance with ASTM.

**Client** Wildcat Concrete Services, Inc.  
**Project** Carter County Bridge Overlay

**PO BOX 750075**  
**Topeka, KS 66675**  
**Client** Wildcat Concrete Services, Inc.  
**Project** Carter County Bridge Overlay

**Field Mix Data**

- **Sample Date:** 09/15/99  
- **Sampled by:** Callaway  
- **Placement Description:** Bridge Deck

**Placement Information**

- **Sample Location:** South Bound, Left Lane
- **Placement Method:** DIRECT DISCHARGE

**Field Test Data**

- **Slump, in.** 3  
- **Air Content, %** 6.9  
- **Concrete Temperature, °F** 87  
- **Ambient Temperature, °F** 79  
- **Plastic Unit Weight, pcf**  

**Laboratory Test Data (ASTM C 39)**

<table>
<thead>
<tr>
<th>Specimen No.</th>
<th>A</th>
<th>B</th>
<th>C</th>
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<td>Cross-Section Area, sq. inches</td>
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<td>As Received Specimen Wt., lbs</td>
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**Notes:**  
- Field mix and field test data provided by others.  
- Field test data by Terracon in general compliance with sampling ASTM C 172, Curing Specimens C 31, Slump C 143, Air Content C 173 or C 231, Temperature C 1064, Unit Weight C 138.

**Reviewed by:** Thomas Hawes  
**Construction Services Mgr.**

**Distribution:** Wildcat Concrete Services, Inc. (2)  
**ODOT (1) Ms. Kimberly Gordon**
Compressive Strength Test Report

Client: Wildcat Concrete Services, Inc.
PO BOX 750075
Topeka, KS 66675

Project: Carter County Bridge Overlay
I-35 Bridges

Sample Date: 09/21/99  Time: 5:45
Sample by: Callaway
Placement Description: Paving North of the Bridge

Sample Location: South Bound, I-35 Left Lane
Placement Method: DIRECT DISCHARGE

Field Test Data
Test | Result |
--- | --- |
Slump, in. | 3.5 |
Air Content, % | 9 |
Concrete Temperature, °F | 75 |
Ambient Temperature, °F | 54 |
Plastic Unit Weight, psf |

Laboratory Test Data (ASTM C 39)

<table>
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<th>Cross-Section Area, sq. inches</th>
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<th>Tested By</th>
<th>Date Tested</th>
<th>Age at Test, days</th>
<th>Fracture Type</th>
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</table>

Notes:
- Field mix and field test data provided by others
- Field test data by Terracon in general compliance with sampling ASTM C 172, Curing Specimens C 31, Slump C 143, Air Content C 173 or C 231, Temperature C 1064, Unit Weight C 108

Distribution: Wildcat Concrete Services, Inc. (2)
ODOT (1) Ms. Kimberly Gordon

Reviewed by: Thomas Hawes
Construction Services Mgr.
Compressive Strength Test Report

In general compliance with ASTM.

Terracon Project No. 03991159
Report No. 11

Client Wildcat Concrete Services, Inc.
PO BOX 750075
Topeka, KS 66675

Attn: Mr. Raymond E. May

Field Mix Data
Sample Date: 09/21/99
Sampled by: Callaway
Time: 5:45
Placement Description: Paving North of the Bridge
Sample Location: South Bound, I-35 Left Lane
Placement Method: DIRECT DISCHARGE

Field Test Data
Test Result
Slump, in. 3.5
Air Content, % 9
Concrete Temperature, °F 79
Ambient Temperature, °F 54
Plastic Unit Weight, pcf

Laboratory Test Data (ASTM C 39)
Nominal Specimen Size 6x12
Specimen No. A B C D
Specimen Size, inches 6 6 6 6
Cross-Section Area, sq. inches 28.27 28.27 28.27 28.27
As Received Specimen Wt., lbs. 27.1 27.1 27.2 27.2
Tested By Heasby Heasby Howell Howell
Date Tested 09/30/99 09/30/99 10/19/99 10/19/99
Age at Test, days 9 9 28 28
Fracture Type C C C C
Min. Compressive Strength, psi 155000 175000 220000 230000
Total Load, lbs. 5480 6190 7780 8140
Compressive Strength, psi

Distribution: Wildcat Concrete Services, Inc. (2)
ODOT (1) Ms. Kimberly Gordon

Notes:
□ Field mix and field test data provided by others
☐ Field test data by Terracon in general compliance with sampling ASTM C 172, Casting Specimens C 31, Slump C 143, Air Content C 173 or C 231, Temperature C 1064, Unit Weight C 138

Reviewed by: Thomas Hawes
Construction Services Mgr.
Compressive Strength Test Report

Terracon Project No. 00991159
Report No. 12

Client: Wildcat Concrete Services, Inc.
PO BOX 750075
Topeka, KS 66675

Attn: Mr. Raymond E. May

Field Mix Data
Sample Date: 09/21/99 Time: 9:10
Sampled by: Callaway
Placement Description: Paving, South Bound
Left Lane
Sample Location: South End of Bridge
Placement Method: DIRECT DISCHARGE
(direct discharge, crane and bucket, pump)

Field Test Data
Test | Result | Specification
--- | --- | ---
Slump, in. | 2.75 | |
Air Content, % | 6.2 | |
Concrete Temperature, °F | 79 | |
Ambient Temperature, °F | 57 | |
Plastic Unit Weight, pcf | | |

Laboratory Test Data (ASTM C 39)
Nominal Specimen Size 5x12 Date submitted to laboratory 09/25/99
Specimen No. | A | B | C | D
--- | --- | --- | --- | ---
Specimen Site, inches | 5 | 6 | 6 | 6
Cross-Section Area, sq. inches | 28.27 | 28.27 | 28.27 | 28.27
As Received Specimen Wt., lbs. | 28.1 | 28.1 | 28.0 | 28.1
Tested By | Hesby | Hesby | |
Data Tested | 09/30/99 09/30/99 10/19/99 10/19/99 |
Age at Test, days | 9 | 9 | 28 | 28
Fracture Type | c | c | | |
Min. Compressive Strength, psi | 197500 181500 | |
Total Load, lbs. | 6990 6420 | |
Compressive Strength, psi | | |

Notes:
- Field mix and field test data provided by others
- Field test data by Terracon in general compliance with sampling ASTM C 172, Casting Specimens C 31, Slump C 143, Air Content C 173 or C 231, Temperature C 1064, Unit Weight C 138

Reviewed by: Thomas Hawes
Construction Services Mgr.

Distribution:
Wildcat Concrete Services, Inc. (2)
ODOT (1) Ms. Kimberly Gordon

Fracture Types:
- a
- b
d
e
f

D-19
Compressive Strength Test Report

In general compliance with ASTM.

Terracon Project No. 03991159
Report No. 13

Client
Wildcat Concrete Services, Inc.
PO BOX 750075
Topeka, KS 66675

Attn: Mr. Raymond E. May

Field Mix Data
Sample Date: 09/21/99
Sampled by: Callaway
Placement Description: On Roadway Paving
South of the Bridge
Sample Location: South Bound I-35
Left lane
Placement Method: DIRECT DISCHARGE

Field Test Data
Test
Slump, in. 2.5
Air Content, % 4.7
Concrete Temperature, °F 82
Ambient Temperature, °F 62
Plastic Unit Weight, psf

Laboratory Test Data (ASTM C 39)
Specimen No. 6 x 12
Specimen Size, inches
Cross-Section Area, sq. inches
As Received Specimen Wt., lbs.
Tested By
Date Tested 09/30/99 09/30/99 10/19/99 10/19/99
Age at Test, days 9 9 28 28
Fracture Type C C
Min. Compressive Strength, psi
Total Load, lbs. 195000 203000
Compressive Strength, psi 6900 71.80

Distribution: Wildcat Concrete Services, Inc. (2)
ODOT (1) Ms. Kimberly Gordon

Notes:
☑ Field mix and field test data provided by others
☑ Field test data by Terracon in general compliance
  with sampling ASTM C 172, Casting Specimen C 31,
  Slump C 143, Air Content C 173 or C 231, Temperature
  C 1064, Unit Weight C 138

Reviewed by: Thomas Hawes
Construction Services Mgr.

Reviewed by: Thomas Hawes
Construction Services Mgr.
<table>
<thead>
<tr>
<th>Test Number</th>
<th>Location</th>
<th>Type of Failure</th>
<th>Tensile Load (lbs)</th>
<th>Result (psi)</th>
<th>Overlay Thickness</th>
</tr>
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<tbody>
<tr>
<td>1A</td>
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<td>1</td>
<td>200</td>
<td>80</td>
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Tests 1 thru 6 performed on 09/28 & 09/29/99
Test Area: 2.57 inches

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<th>Location</th>
<th>Type of Failure</th>
<th>Tensile Load (lbs)</th>
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<th>Overlay Thickness</th>
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CARTER COUNTY I-35 BRIDGES

ODOT PROJECT NUMBER TBOI-0035-1(110)044
STRUCTURES NBI 17229 & 17255

VIRGINIA TEST METHOD FOR OVERLAY ADHESION

<table>
<thead>
<tr>
<th>Test Number</th>
<th>Location</th>
<th>Type of Failure</th>
<th>Tensile Load (lbs)</th>
<th>Result (psi)</th>
<th>Overlay Thickness</th>
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Tests 7 thru 12 performed on 11/09/99
Rapid Determination of the Chloride Permeability of Concrete
AASHTO T 277

Job Name: Carter County Bridge
Job No.: 03991159
Date: 1/19/00

Date tested: 1-3-00 thru 1-17-00

Test Results

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>Maximum Current Recorded, Amps</th>
<th>Total Charge Passed, Coulombs</th>
<th>Chloride Permeability</th>
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<tbody>
<tr>
<td>1NL-A</td>
<td>0.017</td>
<td>385</td>
<td>Very Low</td>
</tr>
<tr>
<td>1NL-B</td>
<td>0.025</td>
<td>578</td>
<td>Very Low</td>
</tr>
<tr>
<td>2NL-A</td>
<td>0.02</td>
<td>438</td>
<td>Very Low</td>
</tr>
<tr>
<td>2NL-B</td>
<td>0.031</td>
<td>879</td>
<td>Very Low</td>
</tr>
<tr>
<td>3NL-A</td>
<td>0.017</td>
<td>585</td>
<td>Very Low</td>
</tr>
<tr>
<td>3NL-B</td>
<td>0.013</td>
<td>333</td>
<td>Very Low</td>
</tr>
<tr>
<td>S-1 NB</td>
<td>0.114</td>
<td>2379</td>
<td>Moderate</td>
</tr>
<tr>
<td>S-2 NB</td>
<td>0.014</td>
<td>333</td>
<td>Very Low</td>
</tr>
<tr>
<td>S-3 NB</td>
<td>0.011</td>
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</tr>
<tr>
<td>TSL-A</td>
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</tr>
<tr>
<td>TSL-B</td>
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<tr>
<td>2SL-A</td>
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<td>3SL-A</td>
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<td>3SL-B</td>
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</tr>
<tr>
<td>S-2 SB</td>
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<td>Very Low</td>
</tr>
<tr>
<td>S-3 SB</td>
<td>0.036</td>
<td>756</td>
<td>Very Low</td>
</tr>
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</table>

Type of sample: 3.75" diameter core
Location of test sample within sample: top 0.2" to 2.2"