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RESEARCH UPDATE

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REPAIR OF SUBSTRUCTURE CONCRETE USING SHOTCRETE

Reference

Work Plan 87-C&R-24

Background

Inspired by reports that concrete forming and placement costs for bridge substructure rehabilitation could be reduced with pneumatically applied concrete, research was initiated to evaluate the performance of shotcrete.

Subsequently, it was found that Vermont was not alone in its desire to learn more about the durability and integrity of shotcrete used for bridge repairs. Following a series of discussions involving the Agency, private industry and the division office of the Federal Highway Administration, a wet mix shotcreting demonstration was set up for the Northeastern States Materials Engineers Association meeting on October 21, 1987.

The site chosen for the application was Bridge No. 61S over Vt. Rte. 2A on Interstate 89 at the Williston Interchange. Gilbertson Shotcrete Specialties, a division of Master Builders, Inc. agreed to furnish the labor, equipment and materials for the demonstration at no cost to the State.

A 4' by 12' section of the bottom of the northerly pier cap on Bridge 61S was prepared by District No. 5 maintenance forces. Preparation included the removal of unsound and delaminated concrete with a 15# chipping hammer in an area extending 4' from the easterly nose of the pier cap to the mid-point between the two columns, see Figure 1. As much of the bottom of the cap was severely delaminated, large segments up to 2 square feet in area, fell to the ground with little or no chipping effort. A saw cut was made at the mid-point to prevent concrete removal beyond the scope of the project. Concrete was chipped out 9" to 15" up each vertical face of the cap for the same 12' length as the bottom. The depth of removal was a minimum of 1" beyond the primary reinforcing steel into sound concrete. Ninety five percent of the exposed reinforcing steel was visibly corroded and the horizontal portion of the stirrups were rusted through, see Figure 2. At the completion of the removal operation the entire area was sand blasted to remove any remaining contaminants and rust from the reinforcing steel.

Materials

At the recommendation of Raymond Towne of Gilbertson Shotcrete Specialties, their prepackaged cement based mortar, GS-Shotpatch 10, was used for the repair. Gilbertson's product literature indicates that "GS-Shotpatch 10 is a ready-to-use, multi component, cement based mortar specially designed for durable repairs or overlays using either the wet or dry mix shotcrete application system." Thirty cubic feet of this material was delivered to the project site in 55 pound bags. One bag yields approximately 0.43 $ft.^3$.

Poor weather conditions created placement difficulties which resulted in a materials shortage. To complete the application, two cubic yards of ready-mixed mortar were delivered by the S. T. Griswold Co., Inc. of Williston, Vermont, the following day. The mix contained 970 lb. per cubic yard of Type I, Glens Falls cement and approximately 2700 lb. per cubic yard (SSD) of Griswold's concrete sand. An air entraining admixture and enough water to yield a 0.38 water/cement ratio was added at the batch plant.

In conjunction with the GS-Shotpatch 10 mortar and the ready-mixed mortar, Gilbertson's HPS Shotcrete Accelerator was incorporated into the mix at the nozzle. HPS Shotcrete Accelerating Admixture reportedly improves surface bond, decreases rebound and improves early strengths. It was used at a dosage rate of 3% by weight of cement.

Application

The shotcrete application was performed by United Gunite of Irvington, New Jersey. They used a Kaiser brand mixer and screw pump to deliver the concrete through a hose to the nozzle. At the nozzle, compressed air was injected into the material flow along with the set accelerating admixture.

Although the positive displacement pump was capable of discharging 7 $yd.^3/hr.$ the rate of application was between 1/4 $yd.^3/hr.$ and 1 $yd.^3/hr.$. The GS-Shotpatch 10 was placed in the mixing hopper, see Figure 3, along with approximately 0.7 gallons of water per 55 lb. bag. Each batch was thoroughly mixed before being dumped into the pump. When the ready-mixed mortar was applied, the mix was discharged from the truck directly into the mixing hopper and then into the pump.

The GS-Shotpatch 10 mortar was pneumatically applied to the pier cap on the afternoon of October 21, 1987. As temperatures were in the $40^{\circ}F$ to $45^{\circ}F$ range, the nozzleman had some difficulty with bond when material depths became too great, see Figure 4. When the supply of GS-Shotpatch 10 was depleted, the shotcreting operation was discontinued until the following day. The repair was completed with the ready-mixed mortar which was delivered in two - one cubic yard loads.

Following the completion of the troweling operation, the entire surface was covered with a liquid membrane curing compound, see Figure 5, and insulating blankets to protect the shotcrete from excessive evaporation and freezing temperatures. The overnight low temperatures on the 22nd and 23rd of October were 28°F and 26°F respectively.

Test Results

All specimens were cast in a vertical position using Gilbertson Shotcrete Specialty's GS-Shotpatch 10. Fabrication was completed with the same equipment and procedures used on the substructure repair, see Figure 6.

Given in Table 1 are results of testing for compressive strength, resistance to chloride ion penetration and freeze-thaw durability.

Ten 4" diameter cores were extracted from two 18" by 18" unreinforced test panels measuring 6" in thickness. The cores were tested for compressive strength (AASHTO T24-86) at 7, 14, 28, 56 and 90 days following standard moist curing.

Compressive strength of the cores were 10 to 25 percent higher than typical values of 6" x 12" cylinders representing Class AA, Portland Cement Concrete currently used for structural repairs.

After 14 days of moist curing and 28 days air drying, the two specimens to be used for determining resistance to chloride ion penetration were tested for base level chloride ion content. Upon completion of 100 days of continuous ponding with a 3% NaCl solution, the specimens were resampled for total chloride ion content at depths of 0.25" to 1" and 1" to 2", in accordance with AASHTO T260-84.

The two specimens used to determine freeze-thaw durability were cycled from 40°F to 0°F and back to 40°F in a 3% NaCl solution 300 times following an initial 14 day moist curing period. The 3" x 3" x 16" samples were tested for weight loss and fundamental transverse frequency at 50 cycle intervals (AASHTO T161-86).

Results of both chloride ion penetration testing and freeze thaw evaluations compared favorably with previous studies conducted with Class AA concrete*. Freeze-thaw durability and permeability of the GS-Shotpatch 10 mortar was essentially equivalent to the Class AA concrete.

*Research Update Number 89-1

Field Performance

A field inspection of the project conducted on April 23, 1990 revealed a series of hairline cracks spaced at 10 to 15 inches along the vertical faces of the pier cap. Cracking extended down one face of the patched area across the bottom of the cap and up the other face. The cracks were interconnected in a random pattern on the bottom. The exact cause and depth of the cracks is unknown. In general, the finer the aggregate in the mixture, the more likely shrinkage cracking will occur. As the outer portion of the repair contained no material coarser than the 3/8" sieve size, this is one possible explanation for the cracking.

Soundings taken on the entire repair area indicated one delaminated section measuring 20" by 23" located 40" from the east face of the westerly column. The remainder of the shotcrete appeared very solid and quite well bonded despite the extremely poor condition of the adjacent concrete and the undesirable weather during application.

Recommendations

The use of pneumatically applied concrete should be permitted on a full scale rehabilitation project where the application and performance can be closely monitored. The shotcrete contractor should be prequalified and use of an accelerating admixture considered mandatory. Although no application was made with silica fume, this admixture should be given serious consideration when shotcrete is specified.

Until the Agency has gained experience with the dry mix process, the recommendations herein apply only to the wet mix process.

TABLE 1

GS-SHOTPATCH 10 (SHOTCRETE) MORTAR

Compressive Strength, Freeze-Thaw Durability
and Chloride Ion Concentration Test Results

Sample ID	GS10-A	GS10-B	Class AA
Compressive Strength, psi			
7 days	5670	5170	4310
14 days	6310	5830	5150
28 days	6510	6460	5960
56 days	6050	6970	----
90 days	7410	7010	----
Resistance to Freezing and Thawing			
Weight Loss, %			
@ 300 cycles	5.2	5.2	3.8
Durability Factor			
@ 300 cycles	113.5	114.1	103.4
Chloride Ion Penetration, PPM(lb./cy) of Concrete			
Base Level	132(0.5)	136(0.5)	47(0.2)
100 day Ponding			
1/4" to 1" depth	692(2.8)	556(2.2)	918(3.7)
1" to 2" depth	172(0.7)	148(0.6)	110(0.4)

FIGURE 1

Preparation of Existing Concrete Substructure

FIGURE 2

Prepared Surface

FIGURE 3

Mixing/Pumping Operation

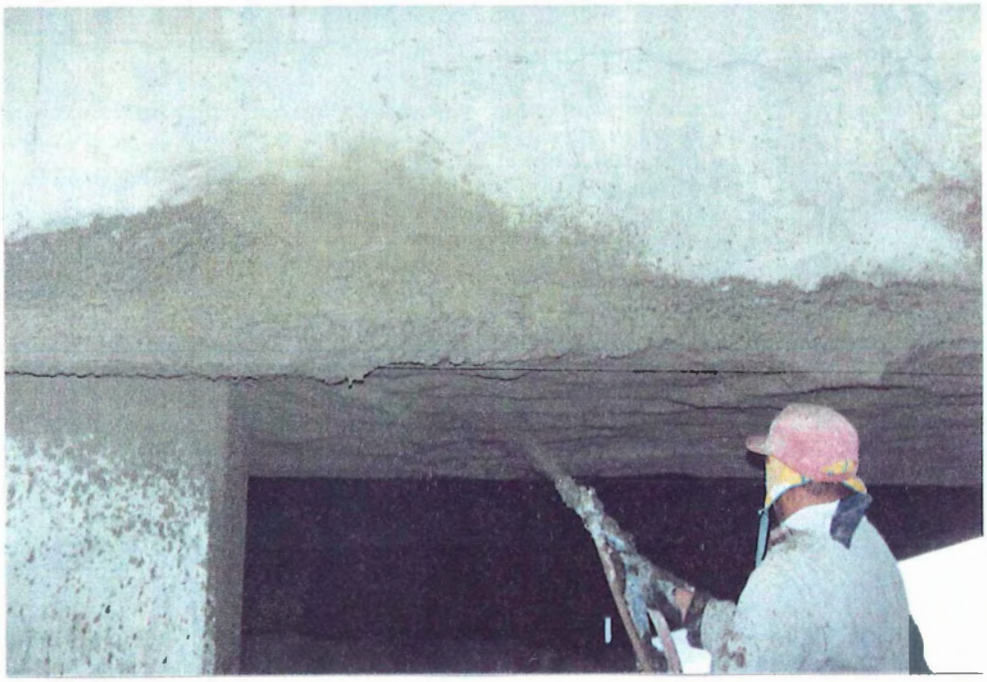

FIGURE 4

Shotcrete Application

FIGURE 5

Completed Repair

FIGURE 6

Test Specimen Fabrication