EVALUATION OF A POST-HYDRATION CONCRETE HARDENER

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TABLE OF CONTENTS

INTRODUCTION

Occasionally, structural concrete fails to reach its design strength due to various reasons, including improper curing, higher than specified water to cement ratio, high air content, or lower cement content. On one recent Federal Highway Administration (FHWA) project, a topical application (SURTREAT TPS-II), purported to strengthen concrete, was applied to improve the strength of the concrete. Non-destructive surface measurements indicated an increase in strength after treatment.

The SURTREAT product used at Frenchman Lake Road Bridges, TPS-II, now called GPHP, is a water-soluble silicate blend. These types of products interact with hydrating portland cement and increase the calcium silicate hydrate (CSH) at the expense of calcium oxide. Although these types of products are sometimes heavily marketed, treatment with these products is of questionable effectiveness[1].

The FHWA's experience with these products is limited. More information was needed on the effectiveness of these products to strengthen and improve the quality of the concrete. There is evidence that these types of products improve the surface strength of concrete, but very little is known about strength or other improvements with depth in the concrete.

This application was evaluated to determine the effectiveness of the treatment. For this investigation, concrete cores obtained from treated and untreated concrete at Frenchman Lake Road Bridge were evaluated using several petrographic techniques and some physical properties tests. Funding for this study was provided by FHWA and the Bureau of Reclamation's Science and Technology program. FHWA provided the majority of the funding.

CONCLUSIONS

1. The treated concrete surfaces contain slightly more calcium carbonate and slightly less calcium hydroxide (Portlandite) than untreated concrete, as indicated by x-ray diffraction analysis. The greater amount of calcium carbonate may be a result of carbonation or treatment with SURTREAT. No increase in CSH was detected.

2. The hardened cement paste from the treated surfaces areas exhibits a lighter gray color when specimens are saturated surface dry. On this basis, the depth of penetration appears to average about ¼ inches.

3. The treatment appears not to have decreased paste voids.

4. Improvements in concrete quality as a result of the treatment were not observed.

5. Improvement in compressive strength resulting from treatment of the concrete was not evident.

6. Improvement in density of the concrete resulting from treatment of the concrete was not evident.

[1] Nixon, Randy and Dr. Richard Drisko, "The Fundamentals of Cleaning and Coating Concrete", The Society for Protective Coatings (SSPS), 2001, Chap. 8, pg. 165

7. Water absorption of treated concrete, observed during measurements made for specific gravity determinations, seemed to be high.

8. More thorough investigations into the effectiveness of these products seem warranted. These types of products are heavily marketed from time to time, and some manufacturer's claims are hard to substantiate. If these products do, in fact, improve concrete quality, more knowledge about when and where they are appropriate for use would benefit potential users.

PROCEDURE

A two-phase testing program was recently completed, coordinated by the Federal Highway Administration (FHWA), and performed by the Bureau of Reclamation (BOR) at their Research Laboratories located in Building 56 at the Denver Federal Center. Phase I was Evaluating Post-Hydration Concrete Hardening Admixtures, and Phase II of the program consisted of Assessing Set Retarding Admixtures. This report contains results of testing for Phase 1 of the program.

Phase 1 consisted of evaluating the properties of concrete treated with SURTREAT TPS-II, which was applied to about 1000 ft^2 of the concrete in the Abutment 1 Breastwall and Abutment 2 Cap at Plumas National Forest, Frenchman Lake Road Bridge, California. The compound was applied to the concrete on May 23 through May 25, 2000 in an attempt to increase the strength of the concrete. Prior to the application of SURTREAT compound, the Abutment 2 cap was treated with a curing compound.

A project report from SURTREAT describing the process for treating the concrete and the mix design of the concrete is attached in Appendix A. Apparently, concrete was placed in the structures around the end of April. Problems with the concrete were noted shortly after placement. Appendix B contains information about concrete compressive strengths and concrete placement information that alerted FHWA that they might have a problem with concrete strengths at the bridge. The concrete was treated near the end of May, and the concrete quality was evaluated by SURTREAT personnel using a rebound hammer near the middle of September.

Cores from the treated and untreated concrete were obtained near the end of June, 2002, and shipped to Denver. For comparison purposes, the untreated samples of concrete came from concrete that was reported not to have experienced strength gain problems. Cores arrived in BOR's laboratory in early July, and were logged (Appendix C) and tested.

Several testing programs were considered to evaluate the full impact of SURETREAT on concrete. Among those were:

$ Compressive strength tests, with elastic properties

$ Change in freezing and thawing durability with depth

$ Change in chloride ion penetration with depth

$ Petrographic and thin section examinations at different depths, including thin sections, X-ray diffraction analysis and scanning electron microscope examination as needed to investigate the effects of SURTREAT.

$ If a companion core can be obtained from the same concrete that was not treated, then a petrographic comparison will be made between treated and untreated concrete.

We also originally planned to test SURTREAT and 2 or 3 other similar products on laboratory prepared specimens to more fully test the products in a controlled situation. However, due to time and budget constraints, and the apparent reluctance of the suppliers we contacted of these products to submit samples, no laboratory prepared concrete specimens were evaluated.

In addition, there were insufficient core for freezing and thawing and chloride ion permeability testing, so that testing was not performed. Instead, additional petrographic studies were performed.

A number of physical properties tests and petrographic examinations were performed on submitted samples of concrete from Frenchman Lake Road Bridge. The petrographic examinations comprised the bulk of the work efforts for this program.

PHYSICAL PROPERTIES TESTS

The attached core log notebook (Appendix C) fully describes the recovered concrete cores.

During logging, and specimen examination and selection, cores were stored in BOR's core layout room (50% relative humidity, 73 deg. F. temperature) under moist towels, which were covered with plastic sheeting. Once specimens were selected for testing, they were sawcut from the cores, and moved to BOR's fog room (100 % relative humidity, 73 deg. F).

Cores were all about 2 ¾-inches diameter and about 6-inches long. The concrete core contained numerous voids, more than we would expect to see.

Table 1 shows results from specific gravity, compressive strength, and elastic properties tests performed on specimens obtained from the concrete cores. Appendix D contains plots of stress vs. strain for the tested specimens.

Specific gravity of the concrete was determined after the specimens were removed from the 100 percent humidity room. Due to the porous nature of the concrete, the specimens were placed in water buckets for about 3 weeks before measurements were made for determining the specific gravity to ensure that the concrete was fully saturated. The control specimens absorbed about 3 percent water, while the treated specimens gained over about 4 percent water, compared to the original dry weight. Lime was added to the water, to prevent leaching of calcium hydroxide. Mass measurements were taken over a period of several days, until mass gain from water absorption stopped.

For testing, all cores, (except B9-71, Abut1, sample 6) were cut to length so that the length to diameter ratio was 2:1. Specimen B9-71, Abut1, sample 6 had a length to diameter ratio of 1.68, and test results were adjusted according to ASTM C-42 "Obtaining and Testing Drilled Cores and Sawed Beams of Concrete". Compressive strength testing was performed according to ASTM C-39 "Compressive Strength of Cylindrical Concrete Specimens". The ends of the compressive strength specimens were capped with a sulfur compound to achieve end tolerances according to USBR 4617, "Capping Cylindrical Concrete Specimens". Testing to determine elastic properties was done according to USBR 4469 "Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression". Data for elastic properties calculations were gathered automatically using electrical resistance strain gauges glued to appropriate locations of the concrete tests specimens.

Table 1. – Physical Properties Test Results

Core ID	Specific Gravity	Compressive Strength (lb/in^2)	Modulus of Elasticity ($x10^6 lb/in^2$)	Poisson's Ratio
Control 2	2.16	3750	2.72	.22
Control 3	2.17	3400	2.46	.21
B9-71, Abut1,Sample 6	2.28	3600	2.28	.21
#2, Unknown location	2.28	3200	2.72	.22
B9-72, Abut2, Sample 7	2.25	3110	2.34	.14
B9-71, Abut1, Sample 4	2.28	2910	2.02	.12

Specific gravity values are lower than expected for concrete of this type and age. However, these values are in agreement with the number of voids observed in the core, indicating relatively high porosity of the concrete, when compared to normal concrete.

Compressive strengths reported here are about the same to somewhat higher than results reported in the FHWA document (Appendix B). Since the concrete was placed about 2 years before we obtained the samples, some strength gain would be normal and expected. The consequences of drilling the concrete may mask some of the strength gain, since some believe that drilling causes some damage to the concrete cores.

Documentation of rebound testing of the treated concrete is provided in Appendix A. Results reported there are substantially higher than test results reported in Table 1. That is not unusual or surprising, since rebound hammer test results should not be used to measure actual strength of concrete. Rebound hammer test results are suitable for locating areas of different concrete strength from one area to another.

Modulus of Elasticity values and Poisson's Ratio values for 2 specimens were lower than expected for quality concrete and reflect the low quality of the concrete tested here.

Rebound hammer testing of the concrete cores was performed according to ASTM C-805 "Rebound Number of Hardened Concrete". Although the procedure calls for doing the tests on 6-inch minimum diameter specimens, we performed the tests in an attempt to determine differences in concrete quality from top to bottom of the concrete cores. However, after numerous attempts on two core samples, the process was halted. It was very difficult getting readings, due to the porosity and softness of the core, and in many cases, the hammer was damaging the concrete and breaking off pieces of the core. Damaged ends were removed before compressive strength testing was conducted.

PETROGRAPHIC EXAMINATION

Several samples were examined petrographically. Examinations were performed to determine the effects of the treatment, and if possible, the depths of treatment. Complete details of the examination are in Appendix E.

The examination consisted of megascopic and microscopic evaluations, including scanning electron microscope, as well as X-ray diffraction analysis and a few qualitative physical and chemical techniques. The purpose of the examinations was to try and detect differences between treated and untreated concrete.

Visually, the examined core specimens exhibit only slightly lighter gray paste in the top about ¼ inch. This becomes apparent only after immersing the specimens in water and then allowing them to dry to saturated surface-dry condition.

X-ray diffraction (XRD) analysis was conducted on four of the selected core specimens, with one sample prepared from the top about ¼ inch, and one from well below that area. The hardened paste was separated from aggregate as much as practicable for the analysis. In each case, there was a slight enrichment of calcium carbonate ($CaCO_3$), and a corresponding decrease in Portlandite ($Ca(OH)_2$) in the top (treated) portions.

Paste from treated and untreated areas appears similar in all other respects; no trend or difference in void density, configuration, or distribution within a specimen was observed. Nor could any morphological or textural feature(s) be detected by petrographic or scanning electron microscope (SEM) that could be ascribed to the treatment. No significant difference in elemental composition could be detected using energy dispersive spectroscopy (EDS).

The surfaces treated with SURTREAT were somewhat rough and weathered. Tests for water absorption on these surfaces indicate they are slightly and moderately absorptive but occasionally highly absorptive. The outer surface of the control specimen is only slightly absorptive.

The treated concrete surfaces contain slightly more calcium silicate hydrates and slightly less calcium hydroxide (Portlandite) than untreated concrete, as indicated by X-ray diffraction analysis. The hardened cement paste from these areas also exhibits a lighter gray color when specimens are saturated surface dry. On this basis, the depth of penetration appears to average about ¼ inch. The treatment appears not to have affected detectable paste voids.