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CHARACTERIZATION OF SILICATE SEALERS ON CONCRETE

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ABSTRACT

Sealing concrete with soluble sodium silicate may improve surface properties such as hardness, permeability, chemical durability, and abrasion resistance. Previously, such treated surfaces had not been characterized sufficiently to provide a complete understanding of how silicate improves concrete properties. Therefore, it is the object of this work to contribute to the understanding of how the application of soluble silicate alters the surface of concrete by verifying its effects on absorption, abrasion resistance, chloride permeability, chloride penetration, and surface composition. © *1997 Elsevier Science Ltd*

Introduction

Soluble sodium silicates, also known as "waterglass," are utilized in several different aspects of the cement industry. For example, they act as set accelerators shotcreting applications; they can be incorporated into cementitious waste forms; and they serve as moisture reducers in the wet kiln process of clinker production. One of the foremost uses of soluble sodium silicate is as a concrete sealer. Unlike other sealants, which either repel water (e.g., silanes, silicones, stearates) or function as a physical barrier coating (e.g., epoxies, polyesters, vinyls), soluble silicate sinks into the concrete surface and, theoretically, reacts with portlandite to form C-S-H gel according to:

$$Na_2SiO_3 + y\ H_2O + xCa(OH)_2 \rightarrow xCaO{\cdot}SiO_2{\cdot}y\ H_2O + 2NaOH$$

As a result, the surface has enhanced properties such as decreased permeability, increased hardness, and overall increased durability. It was the object of this work to experimentally verify the microstructural and physical effects of the application of soluble sodium silicate to typical concrete surfaces.

Materials and Methods

Aqueous sodium silicates are used as sealers for concrete surfaces by themselves or in combination with other sealing systems to keep unwanted ingress of chemicals or water into the body of concrete objects. This study identified five standardized tests or characterization methods (see Table 1) that were used to quantify the effects of aqueous silicates when used

TABLE 1
Summary of Standardized Tests

Test	Property	Sample
-ASTM C 642	absorption	used with paver
-ASTM C 418	abrasion resistance	used with paver
AASHTO T-277-83	chloride permeability	used with lab concrete
-NCHRP 244	chloride penetration	used with lab concrete
Scanning Electron Microscopy	surface morphology characterization	used with lab concrete

on concrete. The study was further expanded to include a relatively low cost concrete paving block that was contrasted to good quality laboratory concrete.

Two different liquid sodium silicates were used in the experiments. Both had a SiO_2/Na_2O weight ratio of 3.22. One, called "N" silicate, had 37.6% solids, and the other "OW," 38.6% solids. The latter also contained an anionic surfactant. Various dilutions of each were applied to two different types of samples.

Commercial Paving Block

Each of these samples was soaked in a silicate solution for one hour. The silicate was diluted over a range of 1–4 parts silicate: 1 part water by weight. Absorption (ASTM C 642) and abrasion resistance (C 418) tests were performed on these samples.

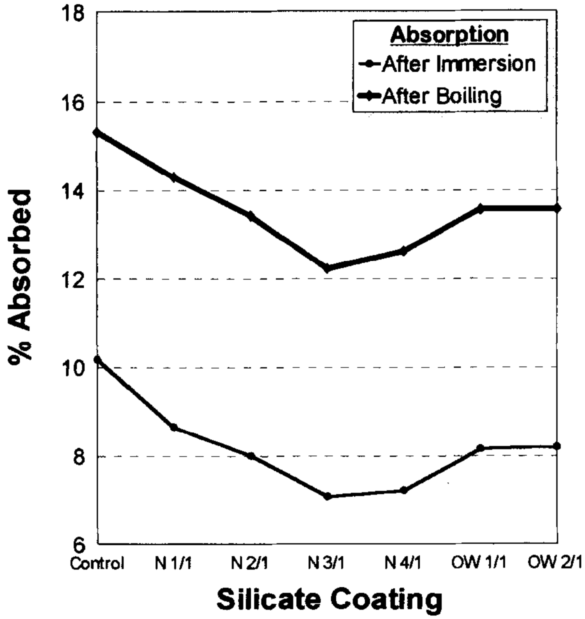

FIG. 1.
Percent absorbed vs. silicate treatment (ratio silicate to water).

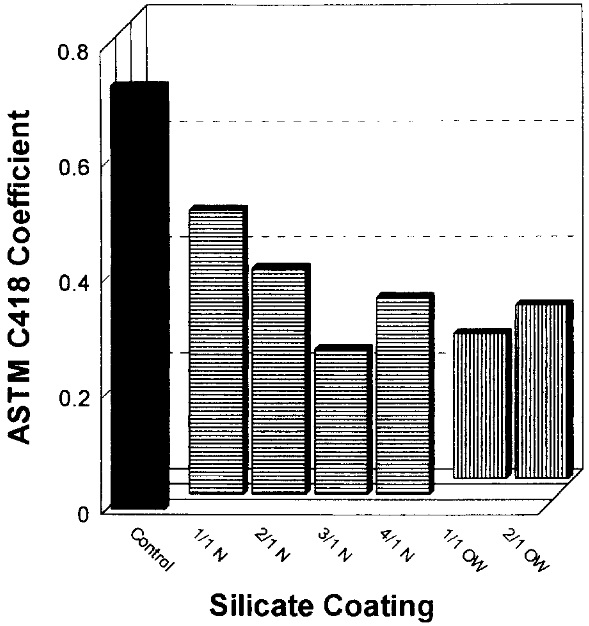

FIG. 2.
Abrasion coefficient vs. silicate coating(ratio silicate to water).

Laboratory Concrete

The second type of sample was a laboratory concrete with w/c = 0.48, 16.9% OPC, 40.2% coarse aggregate, 34.8% sand, and air entrainer. Silicate was applied with a brush, and after 20 minutes of drying, a second coating was applied. Because these samples had significantly higher density than the pavers, more dilute silicate solutions were used – either 1 part N: 3 parts water or 1 part OW: 3 parts water. These samples were analyzed for chloride permeability (AASHTO T-277-83) and chloride penetration (NCHRP 244), and they were also viewed in the scanning electron microscope (SEM).

Because the NCHRP 244 test may be unfamiliar, a brief description follows.

1) 4-inch cubes are cast, demolded after 1 day, and lightly sandblasted on the seventh day. Throughout these first 7 days and for the next 14 days, the cubes are cured in plastic bags at 23°C. The cubes are weighed every 7 days.
2) The cubes are then removed from the bags and stored in air at 23°C, 50%RH. Three samples are coated after 1 day of air drying, 3 more after 5 days, and 3 more after 21 days. After being coated, the samples are returned to the curing chamber to complete a total of 31 days curing in air. Five samples are not coated but serve as the controls. During this period the cubes are weighed periodically.
3) All of the coated samples plus three of the controls are immersed in a 15% NaCl solution for 21 days and weighed periodically.
4) Samples are removed from the solution and returned to the chamber at 23°C, 50%RH for 21 days. Again, they are weighed every few days throughout the 21-day period.
5) At the end, the samples are crushed and analyzed for Cl.

TABLE 2
Chloride Permeability Results

Treatment	Age of Coating	Charge Passed After 5 Hr. (Coulombs)	% of Control
Control	1 day	12599	—
1 N: 3 water	1 day	9979	79.2
1 OW: 1 water	1 day	10757	85.4
Control	28 day	13219	—
1 N: 3 water	28 day	8993	68.0
1 OW: 1 water	28 day	7238	54.8

Results

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Results of the absorption test are shown in Figure 1 as % absorbed vs. different dilutions of the silicate treatment. In every case, there was an improvement with the silicate coating. The most effective coating was 3 parts N: 1 part water which provided a 30% decrease in absorption vs. the control. Figure 2 depicts the abrasion coefficient vs. silicate coating concentration. The lower the coefficient, the higher the abrasion resistance. Again, there is improvement for the coated samples. In this case, there is a 67% decrease in the coefficient for the 3 parts N: 1 part water coating vs. the control. It is interesting to note that in both of these graphs, the optimum dilution is N 3:1. A more concentrated solution such as N 4:1 is not as effective, probably because it is not penetrating into the surface as well. The presence of the surfactant generally provides additional improvement and also shows the advantage of good penetration.

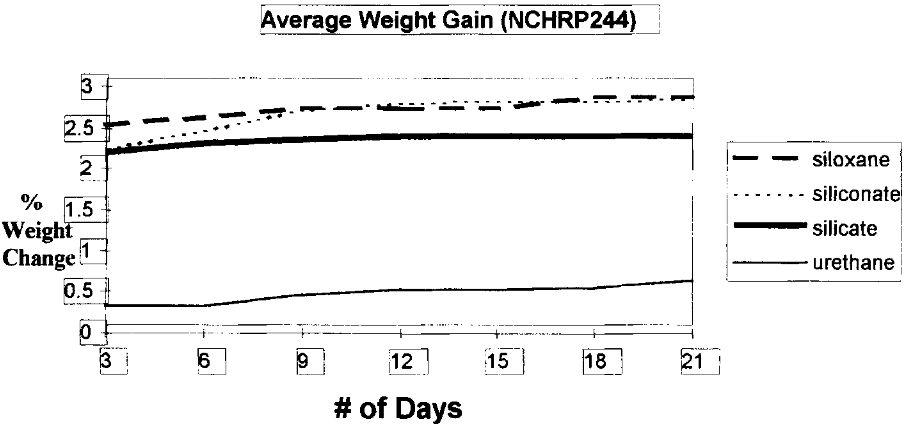

FIG. 3.
Average weight gain of treated concrete (NCHRP 244).

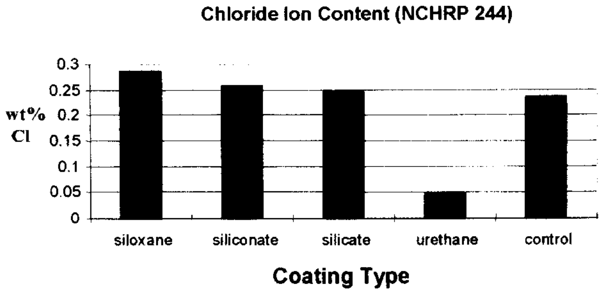

FIG. 4.
Average chloride content of treated concrete (NCHRP 244).

Laboratory Concrete

Chloride permeability was measured on 6-month-old laboratory specimens. The results are given in Table 2. The control samples for 1- and 28-day treatment ages are the same ages as the treated samples (values for 5-hour data are presented instead of normal 6-hour because the 28-day control sample began to overheat after 5 hours of the test). The treatment resulted in about a 20% improvement for the 1-day samples and 30–40% improvement for the 28-day-old samples.

For the NCHRP 244 chloride penetration test, the results showed that, in general, the weight gained during immersion in NaCl was less for treated samples than for the untreated samples, indicating that less chloride is penetrating into the coated cubes. This was further supported by analyzing for chloride in the bulk sample.

This test is very complex and it shows only marginal improvements in chloride penetration when the concrete is sealed with silicate. In the NCHRP 244 report, silicate (31.4% solids) was also tested. One coating was applied undiluted. Figure 3 shows the results from the immersion part of the 244 test (performed by Wiss, Janney, Elstner & Associates, Inc. (1)). This graph shows that silicate resists water absorption slightly better than siloxanes and siliconates but considerably less than urethanes. The chloride content of the concrete after exposure to NaCl is shown in Figure 4 for four different coatings and a control sample. Silicate actually had a higher chloride content than the control, but the standard deviation in

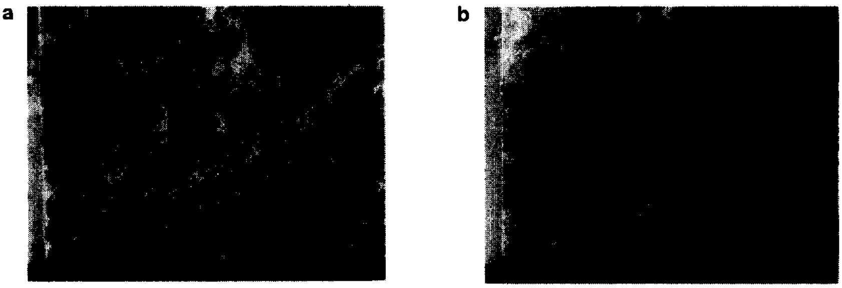

FIG. 5.
Coated (*a*) and uncoated (*b*) surfaces of concrete.

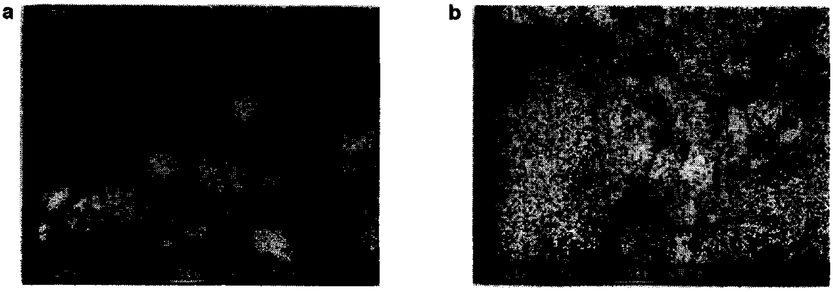

FIG. 6.
Si X-ray dot map of coated (*a*) and uncoated (*b*) surfaces.

the data suggests that the values are the same. In general, silicates seem to affect concrete's ability to prevent chloride penetration only slightly when tested using the NCRP procedure.

SEM micrographs of uncoated and coated (1 part N: 3 parts water) surfaces are presented in Figure 5. The stark contrast in surface texture is evident; the untreated sample appears rough and pitted, but the treated sample is smooth. The fine cracks in the silicate coating probably resulted from sample preparation. Si X-ray dot maps for each surface are shown in Figure 6. The brightness of the coated specimen indicates the abundance of Si on the surface. The patches of Si seen on the uncoated surface are attributable to quartz sand grains. Conversely, from the Ca dot map (Figure 7), the untreated sample appears very bright, whereas the treated sample is much darker as a result of the Ca being covered by the layer of silicate. Only an area in the upper left-hand corner and along the left edge of the figure shows much Ca because the coating had been chipped off. The implication of these results is that the coated surface will be less susceptible to deleterious reactions involving Ca, for example acid attack of portlandite.

Summary

Silicates are applied to concretes as aqueous solutions. Cady (2) reports that sodium silicate is the most commonly used silicate (72%) while the remainder is split somewhat evenly between potassium and fluosilicates. The work presented here and the work of others suggests that silicates will be moderately effective when used as sealers for concretes. The

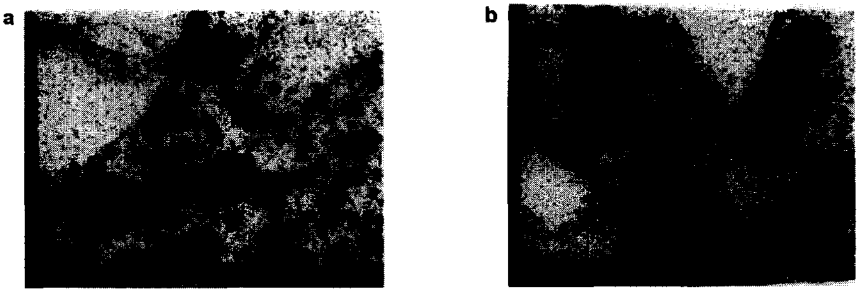

FIG. 7.
Ca X-ray dot map of uncoated (*a*) and coated (*b*) surfaces.

exact mechanisms by which the silicates act to improve the performance of concretes is unclear. McGettigan (3) states that the silicates are effective sealers as the result of SiO_2 precipitating in the pores. Others (4) report that the silicates react with excess calcium present in the near surface region of the concrete to form relatively insoluble calcium-silicate hydrates. A third theory is that the silicates form an expansive gel similar to that formed in alkali silicate reactions that fills the pores in the concrete by swelling. Whatever the precise mechanisms, the general consensus is that silicates act as the result of pore blocking. The observations made during the course of this study suggest that silicates perform as sealers as the result of a combination of mechanisms. The mechanisms dominating the performance of the sealer will most likely vary from application to application.

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