New York State's Experience in Use of Silicones

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The study of silicone treatment of concrete has been carried on by the New York State Department of Public Works since 1953. After determining that there might be merits in its use, a decision had to be made as to the type of silicone to use. For various reasons, the water soluble silicone was selected.

Then followed months of testing with various types of concrete mixes. This was necessary as the use of silicones prior to this time had been limited primarily to building materials. Testing methods were developed that would approximate field conditions applicable to bridge construction. Particular attention was given to rate of absorption of water, freezing and thawing, resistance to action of sodium chloride and light reflectance.

In 1954, field test experiments were made on 13 panels of the New York State Thruway. Silicone treatment of varying concentrations from one-half of 1 percent to 5 percent were placed on five panels. Six panels had no treatment and were used for control, and two panels were treated with a petroleum distillate.

A retreatment of the panels with a 2 percent silicone was made in November of 1956. The rate of application varied with the percentage of concentration in the original treatment, indicating a defense in depth after two years use.

The fascia and pier facings in the approaching lane of one structure over the New York State Thruway were treated for study of light reflectance on silicone treated concrete.

In June 1955 an interim specification was drawn for the use of water soluble silicone on all exposed concrete in new structures. This specification is now incorporated in the latest edition of the Public Works Specifications adopted January 2, 1957.

There are ten structures that have been completed utilizing water soluble silicone which have been opened to traffic for at least one winter season. Inspection of these structures in October of 1957 shows no deterioration or spalling of the concrete.

● THE SURFACE treatment of concrete by highway departments in an attempt to give it a protecting covering against the elements and thereby increase its durability is not new. Upon introduction to silicones in 1953, the New York State Department of Public Works became interested in the unusual possibility exhibited by this comparatively new product.

New York State's geographical location is such that there are widespread areas of the highway system that can expect to be subjected to as many as 75 freeze-thaw cycles, 80 wet-dry cycles together with 35 salt applications per year. This in the light of their effects upon concrete together with an expanded highway and bridge construction program pointed up the fact that building must be in a manner that would minimize future maintenance. These were the basic reasons why E. W. Wendell, then Deputy Chief Engineer (Bridges, Grade Separations and Structures) since retired, caused a study of silicone treatment for concrete to be inaugurated.

The first phase in this study was to evaluate the two types of silicones that were available, namely the water soluble and the solvent type. Consideration was given to the penetration, hazard and economy of each type.

Conditions involved in that initial study and the conclusions were as follows:

Penetration. Application of the silicone solution under construction conditions and schedules would most likely have to be made on moist concrete or at best surface dry concrete. It was felt that under these conditions the water soluble silicone solution would penetrate to a greater depth than the solvent type silicone solution. This is greatly due to the difference in the method of curing of the silicone materials. The water soluble silicone solution could penetrate a moist surface without resulting in a chemical reaction, whereas the solvent type silicone solution would tend to cure upon contact with the moist surface without penetrating.

Hazard. Recognizing the lack of controls on large highway and bridge construction projects the hazards involved in the use of the water soluble silicone which is very caustic and the solvent type silicone which is toxic, due to the large volume of solvent mist, had to be carefully studied. Water soluble silicone solution with a pH factor of 13 was considered to be less hazardous than the solvent type silicone solution containing Toluol with a flash point of 40 F or Xylol with a flash point of 75 F.

Economy. Recommendation of the manufacturers indicated that a two percent water soluble silicone solution would offer the same repellency as a five percent solvent type silicone solution and result in a considerable saving in the cost of the silicone solids. Furthermore, water being a prerequisite of a construction project, its availability and low or negligible cost in contrast to the cost of material, packaging and shipping charges of solvents indicated that the water soluble silicone would be the most economical.

Based on the advantages that accrue to the water base material after giving due consideration to all these factors; namely, penetration, hazard and economy, the water soluble silicone was selected for testing.

Since prior to this time the use of silicones in construction had been limited primarily to building materials, testing procedures would have to be developed that would approximate field conditions applicable to bridge construction.

The Silicone Products Department of the General Electric Company located at Waterford, N. Y., which is only 10 miles north of Albany, cooperated by making their laboratory and personnel available to the Department for any testing desired.

The first investigation was to attempt to determine the amount of penetration that could be expected with the water soluble silicone solution. Sample blocks 6- by $3\frac{1}{2}$- by $1\frac{1}{2}$-in. deep were made of both mortar and concrete. These blocks were immersed in a two percent water soluble silicone solution for six seconds, removed and let cure. The blocks were then broken and immersed in water, removed and the depth of the edges exhibiting evidence of no wetting were measured. The apparent penetration of the water soluble silicone solution into the mortar block averaged approximately $\frac{1}{4}$ in., while in the concrete block the measured penetration averaged approximately 1/8 in. The apparent difference in the depth of penetration is attributed to the fact that the coarse aggregate in the concrete blocks was topped by only 1/8 in. of cement matrix (Fig. 1).

A testing program using air-entrained concrete and non-air-entrained concrete was then set up. Sample blocks 6- by $3\frac{1}{2}$- by $1\frac{1}{2}$-in. deep would be molded so that a $\frac{1}{4}$-in. depression would be obtained in the top of the block, to permit the freezing of a layer of water. Untreated and treated blocks would be given identical tests. The two types of concrete sample blocks would be set up in three series; namely, untreated, oil treated in conformance with New York State Department of Public Works specifications and two percent water soluble silicone treated. The treated blocks were sprayed to simulate a field application.

Figure 1. Depth of penetration of silicone in mortar block on right and concrete block on left.

The General Electric Company constructed a rapid cycle freeze-thaw apparatus (6 cycles of freeze-thaw per day) and the conditions of the test were controlled as specified in ASTM Method C-291 with some exceptions. (One cycle out of six, the center of the block temperature did not reach 0 F and there was a 55-min delay before the frozen sample entered the 50 F water-thaw tank.) Both the treated and untreated blocks were mounted side by side on the endless belt of the apparatus and subjected to identical test conditions.

Typical data obtained from this test showed that non-air-entrained concrete blocks with no surface treatment or when treated with oil failed completely in from 35 to 40 cycles, whereas when treated with two percent silicone solution the blocks showed no failure and only slight surface scaling in 75 to 90 cycles (Fig. 2).

Air-entrained concrete blocks with no surface treatment or when treated with oil showed no failure and only moderate surface scaling after 90 cycles, whereas the silicone treated blocks showed no failure and practically no surface scaling after 90 cycles.

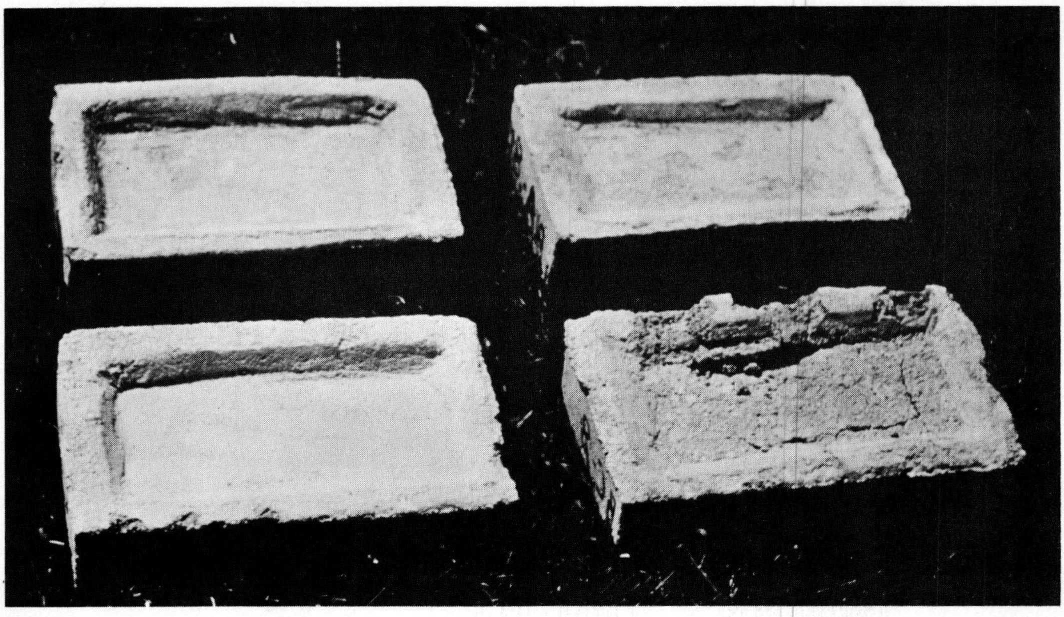

Figure 2. Effect of 35 cycles of freeze-thaw: upper blocks of air-entrained concrete, lower blocks of non-air-entrained concrete, blocks on left—silicone treated, blocks on right—untreated.

To simulate field conditions, rock salt was applied to frozen blocks of air-entrained concrete. Considerable surface scaling was noted on the untreated and oil treated blocks after 10 cycles, whereas there was no indication of any surface scaling of the silicone treated blocks after 20 cycles.

The results of these laboratory tests clearly indicated that portland cement concrete treated with silicone could be expected to exhibit superior durability.

Tests were then run on rate of water absorption of treated and untreated blocks. Blocks were selected which had been exposed to 25 freeze-thaw cycles, dried thoroughly, weighed, then placed in a tray having $\frac{1}{4}$ in. of water where they remained for 24 hr. The blocks were then wiped off and weighed again. The average absorption of untreated blocks was in excess of eight percent, whereas the average absorption of silicone treated blocks was less than $1\frac{1}{2}$ percent.

This indication that silicone treated concrete tended to repel the invasion of water prompted a request to the General Electric Company engineers to run tests on light reflectance of treated and untreated concrete. This was in recognition of the responsibility for providing the traveling public with the safest highway possible.

This resulted in laboratory measurements of light reflectance as well as some field measurements to determine what values of light reflectance existed.

Measurements were made on laboratory prepared concrete samples with laboratory test equipment and the results obtained indicated that the light reflectance of untreated concrete surfaces dropped from 35 percent

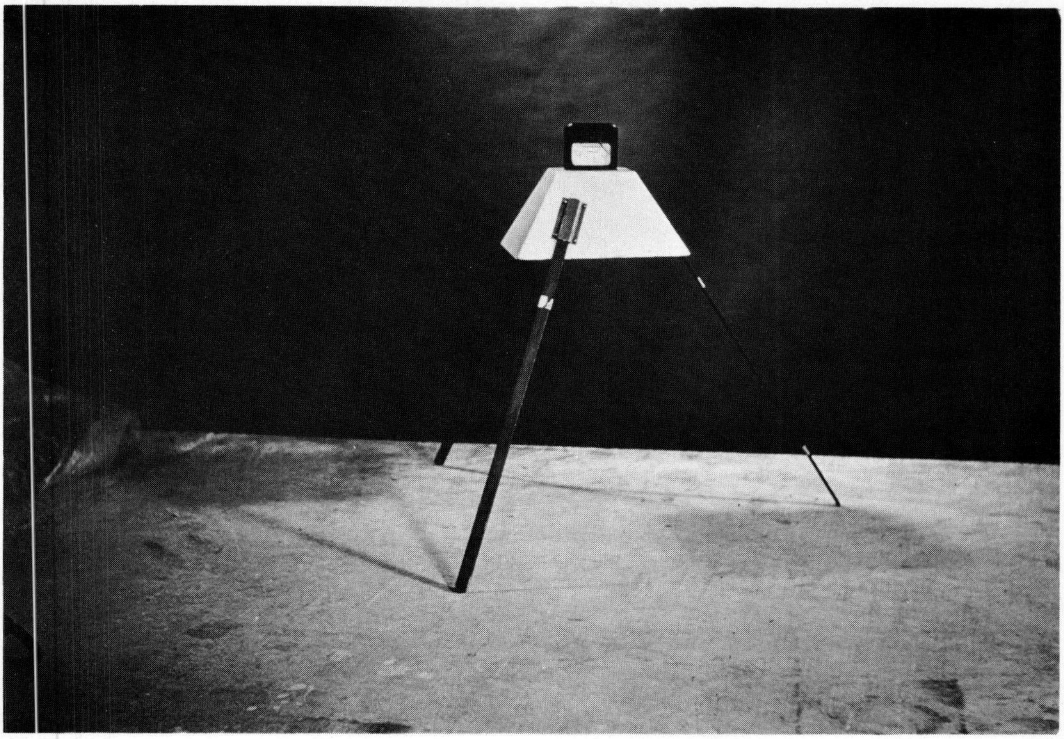

Figure 3. Apparatus for measuring light reflectance.

to 50 percent when they became wet, whereas the light reflectance of silicone treated concrete surfaces did not change appreciably when they became wet.

Readings were then made on untreated and treated outdoor concrete test panels, using a special reflectance standard and a foot candle meter as specified by the ASA Practice for Street and Highway Lighting.

Measurements were made using the method described on page 27 of Appendix C of the ASA Practice for Street and Highway Lighting, 1953. The 0- to 100-ft candlemeter, with a reduced aperture, was mounted on a tripod box (Fig. 3) and readings were taken over the various test areas. The reference standard (Reflectance Factor of 75 percent) was placed over the test areas and readings were recorded with the standard in place and with the concrete dry and wet (Figs. 4 and 5).

The 75 percent standard was used to calculate the reflectance levels of the various test areas and the average of the test results showed that the light reflectance value of the untreated panels was reduced 50 percent when wet, whereas the light reflectance value of the silicone treated panels was reduced only 13 percent when wet (Fig. 6).

In June 1955 the Deputy Chief Engineer (Bridges, Grade Separations and Structures), ordered an interim specification drawn for the use of water soluble silicone on all exposed concrete in new structures based upon the results obtained from the test program. This specification called for the dilute solution to contain two percent silicone and to be mixed by

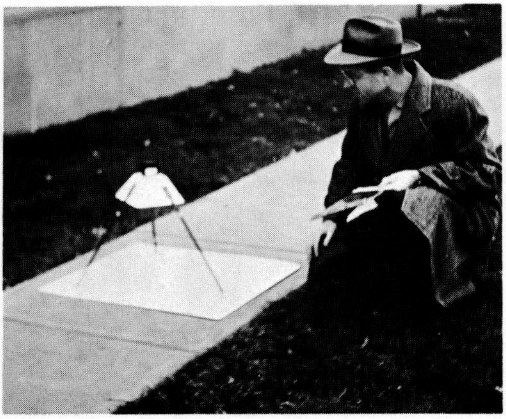

Figure 4. Measuring light reflectance—reference standard in place.

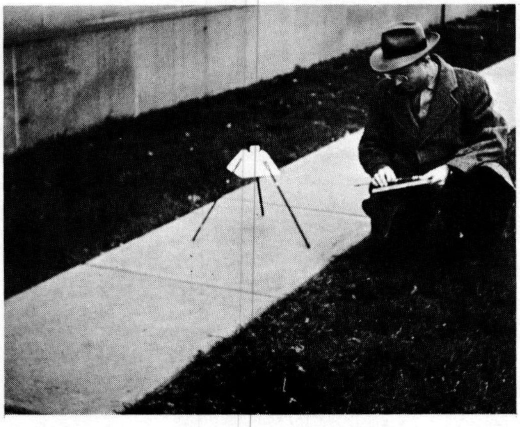

Figure 5. Measuring light reflectance—wet and dry treated and untreated concrete panels.

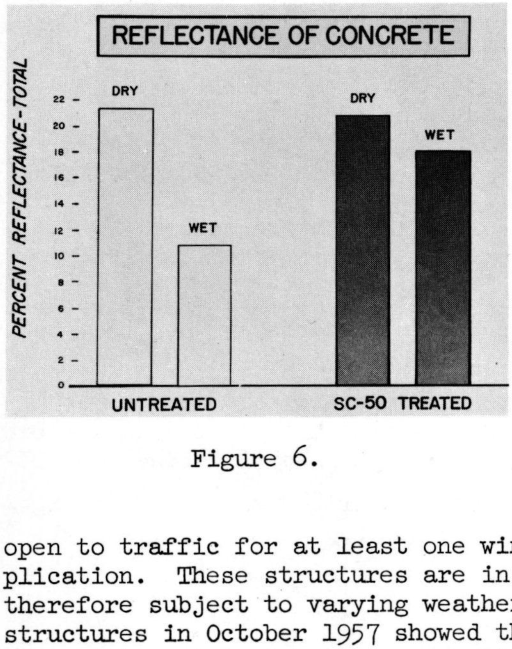

Figure 6.

weight 10 parts of silicone concentrate and 90 parts of water. In the revised specification the proportions are equated to gallons for ease of mixing in the field. To better insure field application and tp provide inspectors an opportunity to be sure that the silicone treatment had been accomplished, a fugitive dye (Phenolphthalein) was added to the silicone concentrate. The rate of application of the dilute solution is indicated as 12 square yards per gallon.

Since the interim specification for water soluble silicone was introduced in June 1955, there have been ten structures, completed and open to traffic for at least one winter season which had the silicone application. These structures are in various parts of the state and are therefore subject to varying weather conditions. Inspection of these structures in October 1957 showed the concrete to be in excellent condition with no deterioration or spalling evident except in one instance which makes for an interesting observation. It was noted on one structure that all the concrete with the exception of a section of the curb facing some 20 feet long was in perfect condition. The curb facing in this 20-ft section showed deterioration approximately 2 in. above the wearing course. Upon investigation it was learned that the bridge engineer responsible for the construction of this structure had been visited by a salesman who gave him a 5-gal sample of a product purported to be superior to the material called for in the specifications. The engineer allowed the application of this material in the area involved with the attendant result.

A field test program was instituted on a section of the New York State Thruway in the vicinity of Albany consisting of thirteen 100-ft slabs of the driving lane. The silicone concentration from one-half percent to five percent were applied to five slabs. One slab was treated with one-half-percent silicone solution, one slab a five-percent silicone solution and the other three slabs a two-percent silicone solution. The silicone was applied at the rate of 100 sq ft per gal. Six slabs received no treatment, two slabs were treated with colorless petroleum distillate oil compound.

This test was inaugurated on May 11, 1954 and it is believed to be the first such demonstration on new highway construction in the United States.

This section of the Thruway was opened to traffic in October of 1954. On November 16, 1956 a reapplication of a two-percent water-soluble silicone solution on the panels originally treated with silicone was made (Fig. 7). The rate of application on retreatment of the slabs having the original treatment of five-percent and two-percent silicone solution was 153 sq ft per gal or approximatelt one and one-half times the original rate of application.

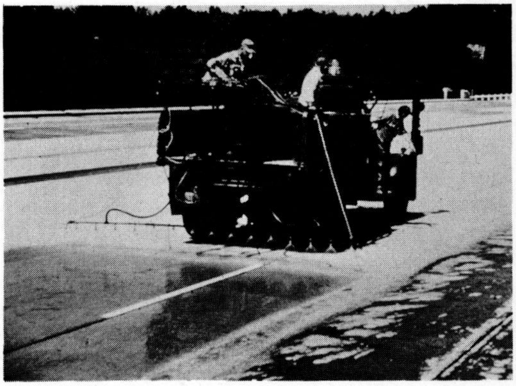

Figure 7. Equipment for spraying silicone solution on traveled way.

This would appear to indicate that the original silicone treatment had established a defense in depth. There is also an indication that the five percent silicone solution had provided no more protection than the two percent silicone solution. The rate of application on retreatment of the slabs having original treatment of $\frac{1}{2}$ percent silicone solution was 100 sq ft per gal which was identical to the initial rate of application indicating that this concentration of silicone is not suitable for long service. The color of the silicone treated slabs in this test area when wet is much lighter than the untreated or oil treated slabs.

On November 16, 1956 the fascia and pier facing in the approaching lane of the Schenectady Interchange bridge over the Thruway were treated with a two-percent water-soluble silicone solution for a study in contrast of treated and untreated concrete during periods of wetting (Figs. 8 and 9). Figures 10 and 11 are pictures taken of this structure on November 28, 1957 after two days of rain. They clearly indicate that this kind of silicone application on structures of this type contribute greatly to the safety of the highway. Figure 12 illustrates the difficulty encountered in applying water-soluble silicone to the bridge pylon which has received a carborundum rubbed finish.

Products are discovered, developed, modified and improved as rapidly as research, time and money make it possible. Therefore, it is advisable that product users be kept informed of any developments by industry so that as materials or conditions change, the process of evaluation may be kept continuous.

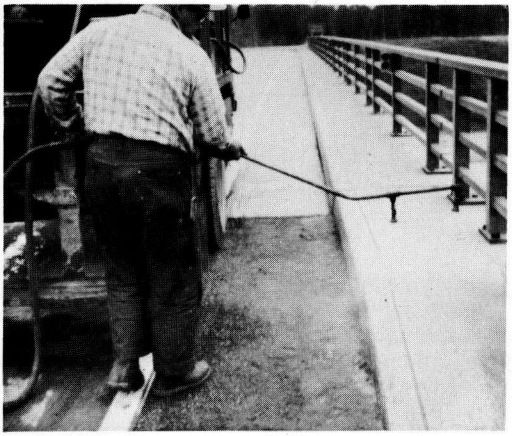

Figure 8. Equipment for spraying silicone solution on small areas and vertical surfaces.

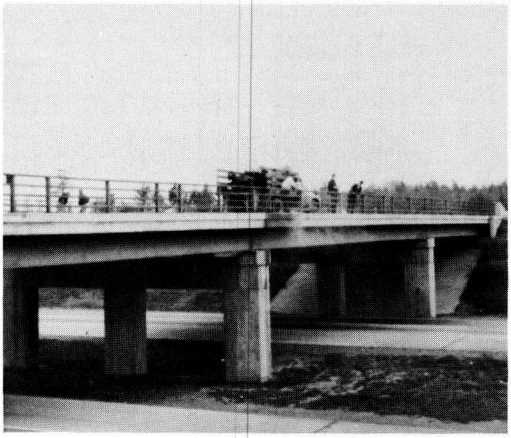

Figure 9. Treating fascia and pier facings of Schenectady Interchange bridge, November 16, 1956.

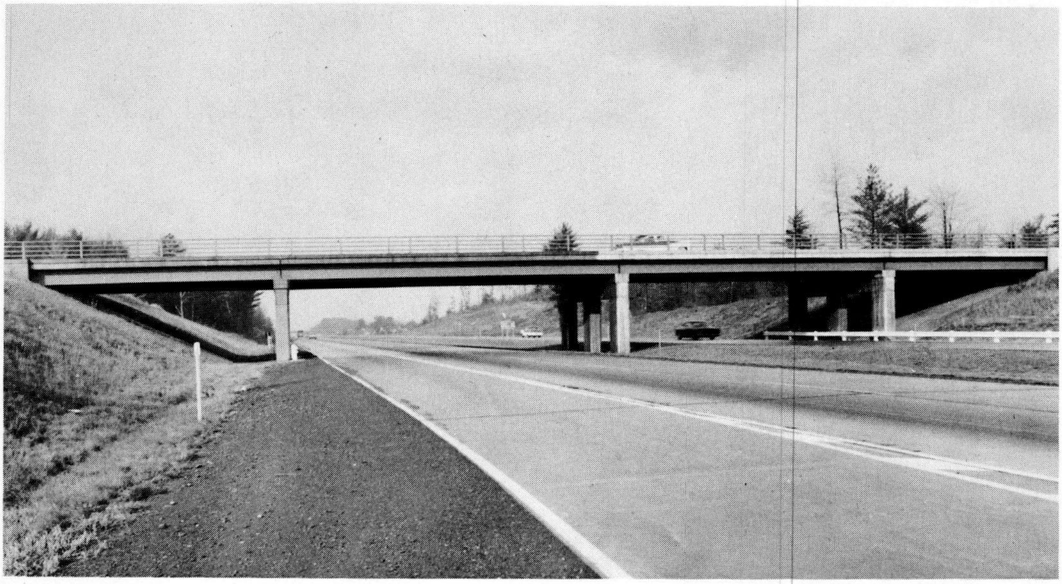

Figure 10. Fascia and pier facings to the right treated with silicone appears much lighter than the rest of the structural concrete (November 28, 1957).

There have been developments in the field of silicone chemistry since the first evaluation in 1953 and 1954. The solvent type silicone in particular shows the result of research in that higher polymer silicones are available today. There is an indication that a two percent solvent type silicone would offer the same repellency as the original five percent solvent type silicone. It would then appear that the cost of the silicone solids for either the water soluble or solvent type would be the same. Also the use of mineral spirits, with a flash point of from 110 F as sol-

Figure 11. Close-up of pier facing and fascia (November 28, 1957).

Figure 12. Carborundum rubbed pylon exhibits very little benefit from treatment.

vents has removed the objectionable hazard that applied to the original solvent type silicone studied.

In July 1957, a test program was entered into with the Silicone Division of the Union Carbide Corporation in Tonawanda, New York, in order to evaluate solvent type silicones. The concrete used in this program conforms with the New York State Department of Public Works Specifications for structural concrete. Tests are being conducted on four types of concrete; namely, non-air-entrained, non-air entrained plus Plastiment, air-entrained and air-entrained plus Plastiment. This program has not been completed to date but the results that have been obtained are very encouraging.

In October 1957, a problem was confronted where all the prestressed units of several structures had been cured, contrary to specifications, with a wax-resin type curing compound. This, of course, made the application of the specified water soluble silicone impossible. It was necessary then to write an amending specification in which it was required that the surface treated with the curing compound be abraded with power driven wire brushes, blown clean and a two percent solvent type silicone be applied.

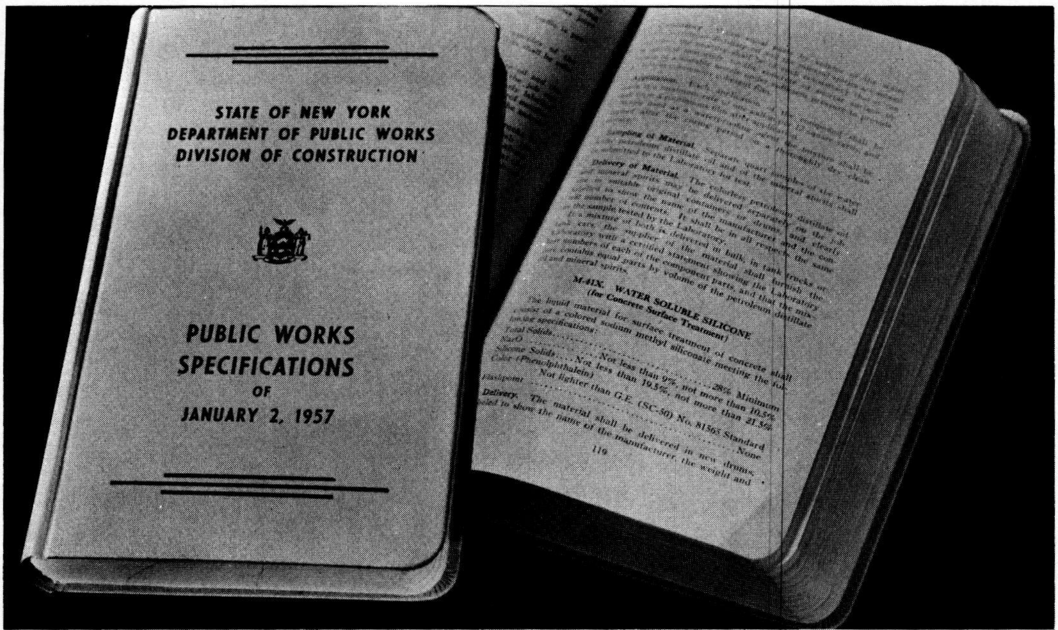

Figure 13. Material specification as included in the construction specifications of the New York State Department of Public Works.

On November 11, 1957 the first such treatment was applied. The rate of application was approximately 100 sq ft per gal. The temperature at the time of application was 18 F.

It is the opinion that the durability of concrete can be greatly increased if given a surface treatment of silicone. Tests and experience clearly prove that any concrete treated with silicone will give better performance in that it will absorb less moisture, demonstrate greater light reflectance, repel intrusion of deleterious salt solutions and demonstrate a greater resistance to freeze-thaw action.

For the reasons enumerated the Water Soluble Silicone specification has been incorporated in the Construction Specifications that were approved January 2, 1957 (Fig. 13).

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