Protection of Concrete from Deleterious Effects of Ice Removal Chemicals

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• A MAJOR maintenance problem facing highway departments in the snow and ice belts of the northern hemisphere is keeping roads and streets in condition for the safe movement of traffic throughout the year. The significance of this maintenance problem becomes more apparent, in this era of rising prices, when highway departments have to stretch maintenance budgets to satisfy the demands of the motoring public.

Prior to World War II, plowing, sanding, or cindering was considered adequate for ice and snow control. Since then, the public has pressured highway departments for roads clear of ice and snow. The most widespread means employed is the use of chemicals, principally sodium chloride and calcium chloride. However, the use of chlorides has created a serious problem of scaling or spalling of portland cement concrete because of their deleterious effects.

Numerous methods have been used to protect portland cement concrete against the actions of these chemicals. Often the line of investigation was determined by evaluation of products with which the individual investigator was already familiar. This investigation is no exception. This report describes some experiences using a coal tar compound to protect portland cement concrete from the harmful effects of chlorides.

The problem of maintaining concrete highways and structures against the harmful effects of ice control and other chemicals is not new. Forty years ago Lord (1) investigated the practicability of protecting concrete with tar against alkali waters. His investigations showed that portland cement concrete of good quality could be protected against alkali attack by coating with water gas tar and coal tar. In all of his investigations the protection to portland cement concrete was increased when the concrete was coated with water gas tar followed by a coat of coal tar.

LABORATORY INVESTIGATION

After World War II, when the problem of salt action on cement concrete was becoming evident, an investigation was started to determine the effectiveness of various tar compounds to protect portland cement concrete. The fact that coal tar in conjunction with water gas tar was more effective than water gas tar alone suggested the investigation of various coal tar compounds combining the penetrating properties of water gas tar with the protective properties of coal tar.

In 1957 a blend having the typical test properties given in Table 1 was developed and test-marketed for protecting concrete. The product is marketed under the name "Concrete Sealer." The protective characteristics of this coal tar blend were evaluated in the laboratory using the following procedures on prepared specimens of air-entrained and non-air-entrained PC concrete.

Effects of Calcium Chloride Solutions

Tests on Air-Entrained Concrete.—In the investigation on the effects of $CaCl_2$ solution, PC concrete slabs (24 × 12 × 2 in.) made with air-entrained portland cement were purchased from a local construction company and stored for six months before using.

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TABLE 1

TYPICAL TEST PROPERTIES OF CONCRETE SEALER

Determination	Value
Specific gravity at 25/25 C	1.122
Water (% by vol.)	1.8
Specific viscosity, Engler, 50 cc at 40 C	2.4
CS_2 insoluble (% by wt.)	3.13
ASTM D-20 distillation	
(% by wt.) to 170 C	0.9
200 C	2.6
235 C	16.9
270 C	38.6
300 C	50.1
Softening point of residue above 300 C (R & B °C)	39.0
Specific gravity at 15.5/15.5 C, distillate to 300 C	1.027
Sulfonation index, total distillate (% by wt.) to 300 C	0.1

From information furnished by the supplier, the slabs consisted of one part type 1-A portland cement, two parts sand, and three parts pea gravel and had a minimum strength of 4,000 psi.

Surface Penetration by 20% $CaCl_2$ Solution.—For the surface penetration test a slab was prepared in the following manner:

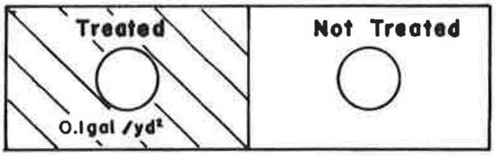
The surface on one-half of the slab was coated with 0.1 gal per sq yd of sealer and allowed to cure for 24 hr, whereas the surface on the remaining half was left uncoated.

On each half a cylinder made from a quart can coated with coal tar pitch was sealed to the surface and filled to a depth of 4½ in. with a 20% $CaCl_2$ solution then allowed to stand at room temperature (Fig. 1).

Every two days solution was added to the can on the untreated section to bring the level to 4½ in. The level of the solution in the cylinder on the coated section remained constant and the treated portion of the slab remained dry. After two weeks, the concrete on the surface and edges of the untreated section started to disintegrate. After 15 months, when the test was discontinued, the treated section was still intact, whereas the untreated section showed measurable disintegration.

Immersion in 20% $CaCl_2$ Solution.—For the immersion test a concrete slab was prepared in the following manner:

The slab was cut in half. One half was completely coated with 0.1 gal per sq yd of sealer and allowed to air cure in the laboratory for 24 hr. At the end of 24 hr both halves were immersed in shallow (3 in. deep) pans in a 20% $CaCl_2$ solution (Fig. 2). The solution covered the slabs to a depth of ½ in. The pans were



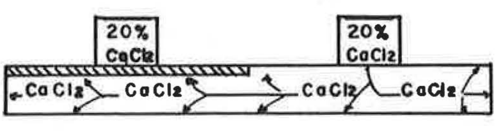


Figure 1. Surface penetration 20% $CaCl_2$ solution into treated and non-treated air-entrained concrete.

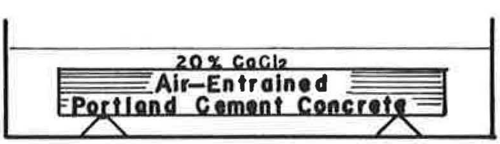


Figure 2. Immersion in 20% $CaCl_2$.

left uncovered in the laboratory at room temperature and the solution was allowed to evaporate and crystallize. Every 14 days tap water was added to bring the solutions back to the original depth. At the end of 14 days the uncoated section had started to disintegrate; after 140 days it had almost completely disintegrated. After 280 days, when the test was discontinued, the coated section was still intact with no signs of distress.

Tests on Non-Air-Entrained Concrete. —In the investigation on the effects of dilute solutions of NaCl and $CaCl_2$, under freezing-and-thawing conditions, concrete mortar blocks were prepared following the procedure described in ASTM Test Method D 1191-52-T. After curing, the blocks were stored for six months before using.

Freezing and Thawing in 3% Solutions of NaCl and $CaCl_2$. —Some of the blocks were treated by immersing in sealer for a few minutes at room temperature, then allowed to air cure 24 hr at room temperature. The treated and untreated blocks were placed in porcelain pans and immersed in 3% solutions of NaCl and $CaCl_2$. The pans were placed in a cold box at -20 F for 16 hr, removed, and the solutions allowed to thaw for 2 hr. The samples were then removed from the solutions and allowed to air-dry at room temperature for 6 hr. This procedure was repeated for 15 cycles.

At the end of 5, 10 and 15 cycles of freezing and thawing, the blocks were examined for signs of spalling. After 5 cycles, the untreated blocks showed signs of spalling. After 15 cycles the surface of the untreated blocks was completely pitted, whereas the treated blocks remained intact with no signs of distress.

FIELD APPLICATIONS

The sealer has been used experimentally by several State highway departments and toll road authorities. It has been marketed commercially in New York, Connecticut, Pennsylvania, Ohio, and the District of Columbia.

Primarily it has been used to protect new portland cement concrete. However, it has also been used to treat new or spalled portland cement concrete prior to surfacing with a hot plant mix or surface treatment.

New York

In 1957 the Town of Greece, N. Y., reported a serious maintenance problem. New PC concrete depressed curbing deteriorated during the first winter under the action of rock salt used for ice control. Different kinds of sealers and protective coatings had been tried, with generally unsatisfactory results. The newly developed sealer was offered, and used to treat 8 miles of new PC concrete depressed curbing and 1 mile of PC sidewalks. After six years the concrete is still sound, with no signs of spalling or scaling due to the action of salt. The untreated portland cement concrete curbing failed after one winter due to the deleterious effects of salt.

Connecticut

In December 1957 Connecticut treated several PC concrete bridge decks that were poured after October 1, 1957, on the Connecticut Turnpike, east of the Branford Toll Station. These decks have been subjected to ice removal chemicals through six winters, with no signs of scaling or spalling on the treated sections.

Pennsylvania

In late November 1959, a week before being opened to traffic, an area of approximately 12,000 sq yd on the Oil City Bypass on Pa. 62 was treated with 0.10 gal per sq yd. The application was made during 40 F weather. Right after application, rain started and continued for several days. This was the first time that the sealer was subjected to rain before curing occurred. Apparently the rain did not interfere with the protective properties of the sealer. The treated pavement has gone through three winters, with no evidence of scaling. Inspection in September 1962 showed no evidence of scaling, whereas an adjacent untreated pavement exhibited several small areas (5 to 10 sq yd each) that were scaling.

On December 11, 1959, new PC concrete totaling approximately 35,000 sq yd—on the interchange of US 20 with the Erie Thruway and on Pa. 89 at Northeast, Pa.—was treated with 0.10 gal per sq yd of sealer. Shortly after application of the sealer started, a freezing rain mixed with snow and sleet began, then later changed to snow. The project engineer decided to complete the treatment, because the forecast was for snow and he wanted the new pavement to have some protection before using salt. These treatments have been subjected to three winters with no evidence of spalling or scaling.

In October 1960, two weeks prior to opening Interstate 90 to traffic, about 55,000 sq yd of new PC concrete pavement were treated with 0.07 to 0.08 gal per sq yd of sealer. After two winters there is no evidence of spalling or scaling on the treated areas. However, a number of bridge decks on Interstate 90 that were not treated have spalled considerably from the effects of ice control chemicals. Several of these bridge decks have been repaired at a cost of approximately $3 per square yard.

In November 1960, just prior to opening to traffic, approximately 18,000 sq yd of new PC concrete on a section of US 119, known as Homer City Bypass, were treated with 0.072 gal per sq yd of sealer. This section of highway borders on a spray pond used for water aeration and much of the time the pavement is damp. Whenever the temperature drops below freezing, the pavement is salted twice a day. This treated pavement has been through two winters with no signs of scaling. On the areas not treated, the concrete is spalling and scaling.

In December 1961, 7,000 sq yd on a new concrete bridge deck at Tionesta, Pa., were treated with 0.053 gal per sq yd of sealer. This bridge was subjected to frequent treatments of salt and sand during the 1961-62 winter, with no harmful effects to the concrete.

OTHER FIELD APPLICATIONS

The sealer has also been used to treat spalled concrete before resurfacing with hot plant mix or surface treatment and to treat new PC concrete pavement prior to surfacing with hot plant mix.

In 1958 an opportunity arose to use the sealer on several short sections on the New York Thruway near Utica that had disintegrated to the point that they were unsafe and required extensive rehabilitation to restore the riding surface and prevent further damage to the concrete. These damaged sections were treated with 0.20 gal per sq yd of sealer, then surfaced with a treatment of RT-10 and N. Y. No. 1 (½ in.–¼ in.) chips or N. Y. 1-A (¼ in.–⅛ in.) chips. After three years, the treatment was still intact, with no indication of further disintegration of the damaged concrete.

In 1959 the Ohio Turnpike reported a serious maintenance problem at Exit 11. As cars decelerated then stopped at the toll gate extra amounts of salt solution dripped off the cars, causing spalling. To prevent further deterioration of the pavement, and to prevent further action of ice removal chemicals, the area was treated with 0.1 gal per sq yd of sealer, then covered with a hot plant mix (to restore the smooth riding surface). After three winters there are no signs of further deterioration.

During 1961 and 1962 several new PC bridge decks and overpasses in Washington, D. C., were treated with two applications of 0.1 gal per sq yd of sealer, followed by an application of coal tar pitch emulsion, prior to surfacing with hot plant mix. It is still too early to determine the long-time effectiveness of these treatments.

GENERAL COMMENTS

When to Apply Sealer

Field and laboratory tests were conducted to determine the best time to apply the sealer to portland cement concrete. Observations showed that the sealer applied to new clean portland cement concrete penetrated and dried within 24 hr after application. In the field, this indicated that the best time to treat is before the pavement is opened to traffic. Highway traffic tends to fill the pores in PC concrete pavement with dirt, rubber, oil and grease. However, the sealer can be applied to concrete pavement after opening to traffic. In one instance, 12 miles of PC concrete pavement 3 to 5 years old were treated with the sealer material, which usually penetrated and dried within 24 hr.

Method of Application

The sealer can be applied through standard bituminous distributors, by tack coat (spray) equipment, by sprinkling cans, or by brush. It is a thin material with a viscosity of 5 to 30 centipoises at 100 F. When applied through a bituminous distributor, the distributor tank, lines, and spray bars should be cleaned before adding the sealer, which will cut and loosen any bituminous residue, thus giving an unsightly appearance to the pavement. In addition, the spray bar should be covered with a hood to prevent the fog spray from being carried by the wind. This is especially important in built-up areas. The usual rate of application varies from 0. 04 to 0. 10 gal per sq yd. General practice has been to apply (at 125 to 150 F) about 0. 05 gal per sq yd of sealer when no pretests have been performed to determine optimum application rates. Preferably, pretests should be made on the pavement or structure that is to be treated.

Color Characteristics

The initial color of portland cement concrete pavement treated with the sealer varies from light brown to deep black. This is a temporary condition; after several months, traffic wears off the surface color and within 12 to 18 months the color of the pavement is only slightly darker than that of untreated concrete.

CONCLUSIONS

Experience during the past five years in the laboratory and field show that Concrete Sealer, a coke oven coal tar material, definitely retards or prevents damage from ice removal chemicals to portland cement concrete used in highway and bridge deck construction. For best results it should be applied to new PC concrete pavements before opening to traffic. It has also been used to treat partially deteriorated pavement prior to resurfacing. It is advisable that it be used at intersections, bridge decks, interchanges, overpasses, steep grades, etc., where frequent use of ice control chemicals is expected.

REFERENCES

1. Lord, E. C. E., ______. Pub. Roads, Vol. 5, No. 3 (May 1924); Vol. 6, No. 11 (Jan. 1927); Vol. 8, No. 6 (Aug. 1927); Vol. 12, No. 4 (June 1931); Vol. 23, No. 11 (Jan., Feb., Mar. 1944).