Effect of Linseed Oil Coatings on Resistance of Concrete to Scaling

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•MANY STATE highway departments have been using surface coatings to protect concrete pavements from scaling and disintegration caused by the use of deicing chemicals. These coatings are often applied to concrete placed late in the fall to give it added protection and to compensate for the short aging period before the concrete is subjected to freezing. One of the materials often used for surface protective coatings is linseed oil.

The specifications governing the use of this material vary. Some States specify its use as an emulsion, whereas others require that it be diluted with mineral spirits when applied. One or two applications of the linseed oil may be required.

Tests were made in the laboratory of the U. S. Bureau of Public Roads to determine whether the use of the surface treatments of linseed oil are beneficial in preventing scaling of the concrete.

MIX DATA

Four different mixes were used in these tests: (a) non-air-entrained concrete with 2½-in. slump, (b) non-air-entrained concrete with 6-in. slump, (c) air-entrained concrete with 2½-in. slump, and (d) air-entrained concrete with 6-in. slump. The mix data are given in Table 1.

MATERIALS

All mixes used a type I portland cement with an equivalent alkali content of 0.6 percent, a siliceous sand with a fineness modulus of 2.75, and a crushed limestone uniformily graded from 1 in. to No. 4. When needed, a commercially available aqueous solution of neutralized Vinsol resin was used to entrain air. The linseed oils used met Federal specifications.

CURING

The test specimens were 16- by 24- by 4-in. slabs with a raised edge or dam around the perimeter of the top surface. The specimens were similar to those described in a recent report of the Bureau (1). The slabs were cast in watertight molds with metal bases. The top surfaces of the slabs were screeded with a wooden straightedge and about 3 hr after molding were given a light broomed finish, similar to that given a concrete pavement. All specimens were molded, finished and cured in as nearly the same manner as possible. All were cured in the molds with wet burlap for 2 days and ponded for 12 days. They were then dried in laboratory air at 70 to 80 F and 30 percent RH for 7 days before application of the surface treatments. After the surface treatments were applied, the slabs were kept in laboratory air for 7 to 14 days and then placed in the outdoor exposure area. When two applications of a surface treatment were used, they were applied 24 hr apart. All specimens were from 28 to 35 days old when they were stored in the exposure area; the first natural freeze occurred 3 days later.

Paper sponsored by Committee on Effect of Ice Control.

TABLE 1

MIX DATA[a]

Proportions by Dry Weight (lb)	Cement Content (sk/cu yd)	Water Content (gal/sk)	Slump (in.)	Air Content (%)	Plastic Concrete (lb/cu ft)
94 - 205 - 305	6.2	5.5	2.6	2.0	149.1
94 - 205 - 305	6.1	6.2	6.0	1.4	148.7
94 - 190 - 305	6.2	5.2	2.7	5.0	145.9
94 - 190 - 305	6.1	5.9	6.2	5.1	144.2

[a]Materials used: type I portland cement, crushed limestone 1 in. max, and siliceous sand (F. M. 2.75).

SURFACE TREATMENTS

Ten identical slabs were made for each of the four mixes. Two slabs for each mix were given the following surface treatments: (a) no surface treatment (control slabs), (b) two applications of boiled linseed oil, (c) two applications of raw linseed oil, (d) one application of boiled linseed oil, and (e) two applications of linseed oil emulsion. The first coating for both the boiled and raw linseed oil was applied as a mixture of equal parts by volume of linseed oil and mineral spirits at a rate of 1 gal/40 sq yd of surface. The second coat was applied as undiluted linseed oil at a rate of 1 gal/67 sq yd.

The linseed oil emulsion used consisted of 1 part boiled linseed oil, 1 part kerosene, 3 parts water plus a small amount of trisodium phosphate, and a small amount of non-detergent soap powder as an emulsifying agent. The emulsion was applied at a rate of 1 gal/10 sq yd of surface for each application.

Observations were made of the time necessary for the various coatings to be absorbed by the concrete. The boiled and raw linseed oils diluted with mineral spirits were absorbed in about 30 min, whereas the linseed oil emulsion was absorbed in about 100 min. The rate of absorption varied as the mix of concrete on which the material was applied.

The air-entrained concrete with high slump absorbed the coatings more rapidly than the other mixes. The non-air-entrained concrete with high slump absorbed them the next fastest, followed by the air-entrained low slump concrete, whereas the non-air-entrained low slump concrete took the longest to absorb the coatings. A second coat took longer to absorb into the concrete than the first coat. This information may be of value as a guide for the use of these materials in the field.

TESTING PROCEDURE

Each evening when freezing was expected, the top surface of each slab was covered with ¼ to ½ in. water. The next morning, flake calcium chloride was spread uniformily over the ice-incrusted surface at a rate of about 2.4 lb/sq yd of surface. This rate of application is greater than would be used in the field but is that used on other research projects. After the ice melted, the surface was washed and covered with fresh water.

The specimens were examined periodically and rated by visual observations according to the amount and depth of the scaling. The numerical ratings are as follows:

- 0 = no scale;
- 1 = scattered spots of very light scale;
- 2 = scattered spots of light scale with mortar surface above coarse aggregate removed;
- 3 = light scale over about one-half of the surface;
- 4 = light scale over most of the surface;
- 5 = light scale over most of the surface, with a few moderately deep spots where the mortar surface was below the upper surface of the coarse aggregate;
- 6 = scattered spots of moderately deep scale;
- 7 = moderately deep scale over one-half of the surface;
- 8 = moderately deep scaling over entire surface;
- 9 = moderately deep scaling and scattered spots of deep scale with the mortar surface well below the upper surface of the coarse aggregate; and
- 10 = deep scale over entire surface.

A rating of 5 or more would indicate significant or major scaling. The ratings given the slabs were based on the judgment of different observers at the various times that the observations were made, which accounts for occasional slight reversals.

These specimens were in the outdoor exposure area for two winters and had a total of 105 cycles of freezing and thawing (45 cycles the first winter and 60 cycles the second). Previous tests have shown that exposure for two winters is sufficient to indicate the resistance of concrete test specimens to scaling caused by the use of calcium chloride.

TEST RESULTS

The average ratings of the slabs after 10, 20, 30, 45, 60, 80, and 105 cycles of freezing and thawing are given in Table 2. Slabs of non-air-entrained concrete with low slump and no surface coatings had a rating of 10 after 30 cycles of freezing and thawing. The tests on these slabs were discontinued. None of the slabs which had the linseed oil surface coating showed any sign of scaling at that time. At 45 cycles, scaling had started on the slabs with one coat of boiled linseed oil and those with the two coats of the emulsion. At 105 cycles the slabs with 2 coats of the emulsion showed severe scaling over part of the surface, those with one coat of boiled linseed oil showed light scaling over the entire surface, those with two coatings of boiled or raw linseed oil showed very little scaling.

For the non-air-entrained concrete with high slump, the slabs with no surface treatment were completely scaled after only 20 cycles of freezing and thawing. For this same number of cycles, the slabs with one coat of boiled linseed oil and those with two coats of the emulsion had ratings of 4 and 2, respectively; those with two coatings of raw and boiled linseed oil showed no signs of scaling. After 45 cycles, deep scaling over the entire surface was found on the slabs with one coat of boiled linseed oil. Those with two coats of the emulsion had a rating of 9 after 60 cycles. After 105 cycles, the slabs with two coats of the boiled linseed oil had an average rating of 2 and those with two coats of raw linseed oil an average rating of 4. There was a marked difference in the amount of scaling between the two slabs given the two coats of the raw linseed oil. One slab had virtually no scaling, whereas the other was severely scaled over a portion of its surface. No reason can be given for the difference in performance of these supposedly identical slabs.

All slabs prepared with air-entrained concrete with low slump showed good resistance to scaling. After 105 cycles of freezing and thawing, the slabs with two coatings

TABLE 2

RATING OF SLABS[a]

Surface Coatings	Slump (in.)	Air Content (%)	Rating After Cycles Shown						
			10	20	30	45	60	80	105
(a) Non-Air-Entrained Concrete									
None	2.6	2.0	4	9	10	—	—	—	—
2 coats boiled linseed oil	2.6	2.0	0	0	0	0	0	0	1
2 coats raw linseed oil	2.6	2.0	0	0	0	0	1	1	1
1 coat boiled linseed oil	2.6	2.0	0	0	0	1	2	2	4
2 coats linseed oil emulsion	2.6	2.0	0	0	0	2	4	5	6
None	6.0	1.4	8	10	—	—	—	—	—
2 coats boiled linseed oil	6.0	1.4	0	0	1	1	1	1	2
2 coats raw linseed oil	6.0	1.4	0	0	1	1	3	4	4
1 coat boiled linseed oil	6.0	1.4	1	4	9	10	—	—	—
2 coats linseed oil emulsion	6.0	1.4	0	2	5	7	9	9	9
(b) Air-Entrained Concrete									
None	2.7	5.0	0	0	0	0	1	1	3
2 coats boiled linseed oil	2.7	5.0	0	0	0	0	0	0	1
2 coats raw linseed oil	2.7	5.0	0	0	0	0	0	0	1
1 coat boiled linseed oil	2.7	5.0	0	0	0	1	2	3	4
2 coats linseed oil emulsion	2.7	5.0	0	0	0	0	1	2	3
None	6.2	5.1	0	0	0	0	3	4	6
2 coats boiled linseed oil	6.2	5.1	0	0	0	0	0	0	2
2 coats raw linseed oil	6.2	5.1	0	0	0	1	3	3	4
1 coat boiled linseed oil	6.2	5.1	0	2	4	5	6	6	5
2 coats linseed oil emulsion	6.2	5.1	0	1	1	1	4	4	5

[a]Each value average for two test specimens.

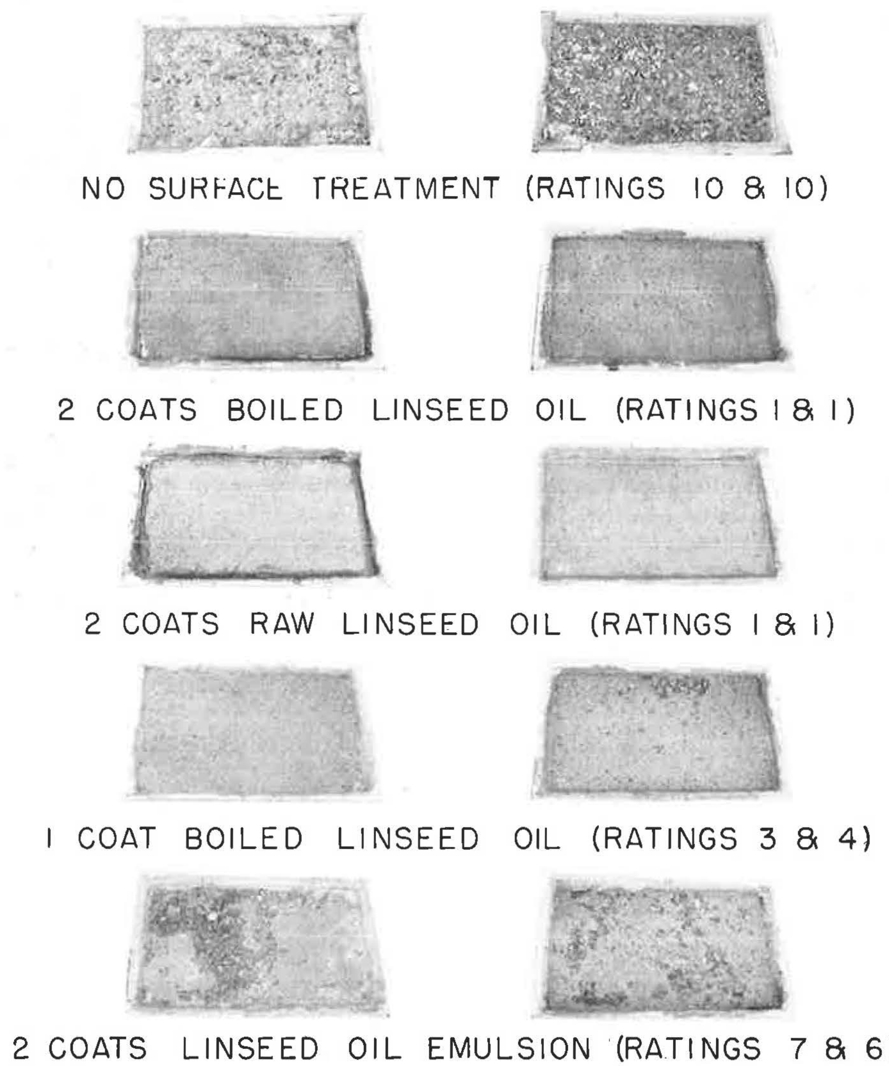

Figure 1. Effect of linseed oil surface treatments on scaling: 105 cycles, slump 2.6 in., air 2.0 percent.

Figure 2. Effect of linseed oil surface treatments on scaling: 105 cycles, slump 6.0 in., air 1.4 percent.

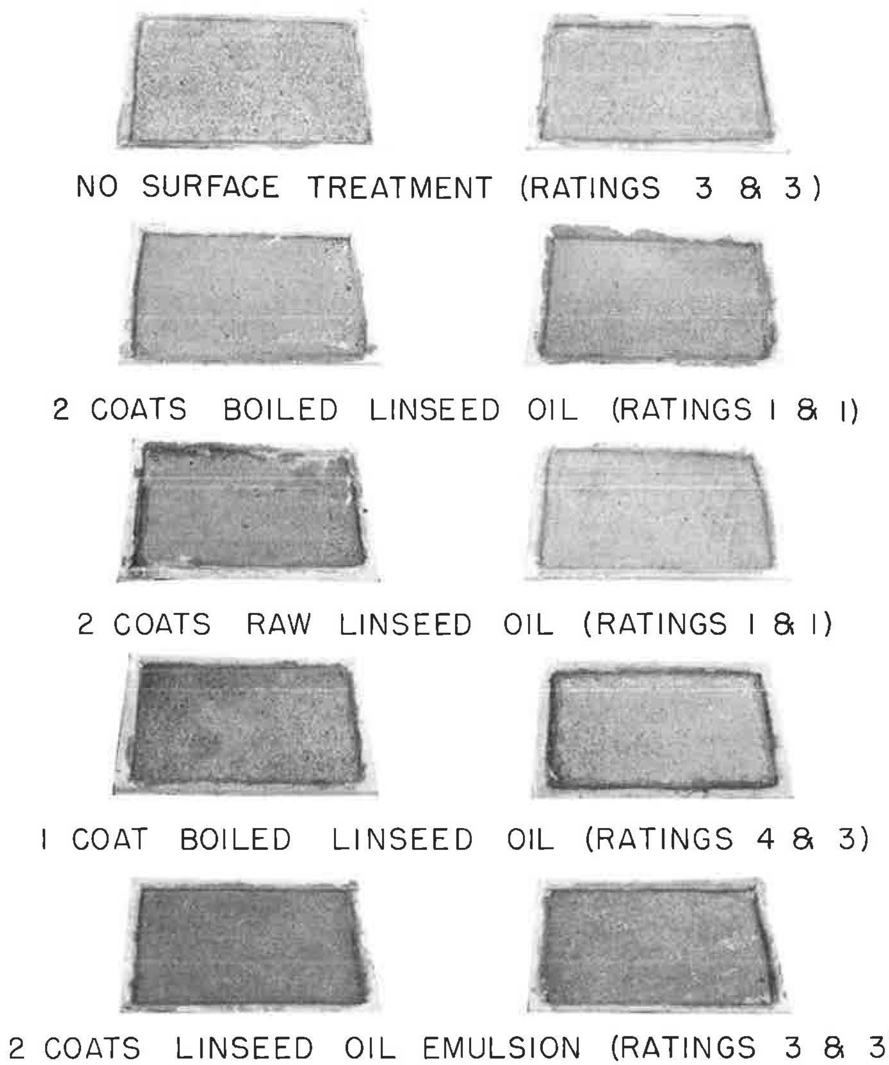

Figure 3. Effect of linseed oil surface treatments on scaling: 105 cycles, slump 2.7 in., air 5.0 percent.

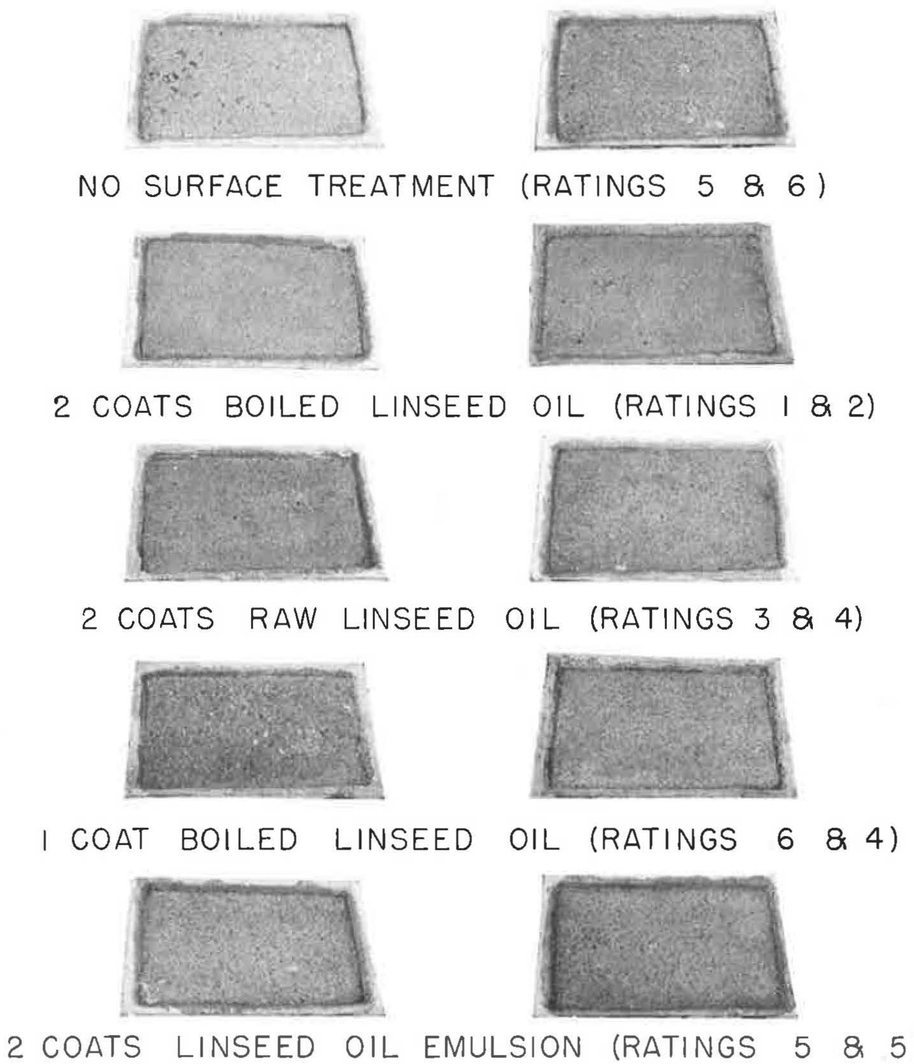

Figure 4. Effect of linseed oil surface treatments on scaling: 105 cycles, slump 6.2 in., air 5.1 percent.

of the boiled or raw linseed oils showed very little scaling and were rated as 1. The average rating for the other slabs was 3 or 4, including both the treated and the untreated or reference slabs.

The slabs prepared with air-entrained concrete and high slump showed good to fair resistance to scaling. The slabs with two coatings of the boiled linseed oil had the best resistance, having a rating of 2 after 105 cycles. Those with two coatings of the raw oil had a rating of 4 after 105 cycles. These was little difference in the average ratings of the other slabs; all were 5 or 6.

Photographs of all slabs after 105 cycles of freezing and thawing or when they were given a rating of 10 are shown in Figures 1 through 4. These figures also show the final rating of each slab. There was, in general, good uniformity between the two slabs from the same mix given the same surface treatment. Only in the one case, previously mentioned, was the difference in ratings between the two similar slabs greater than 2. In over half the cases, the ratings given were the same.

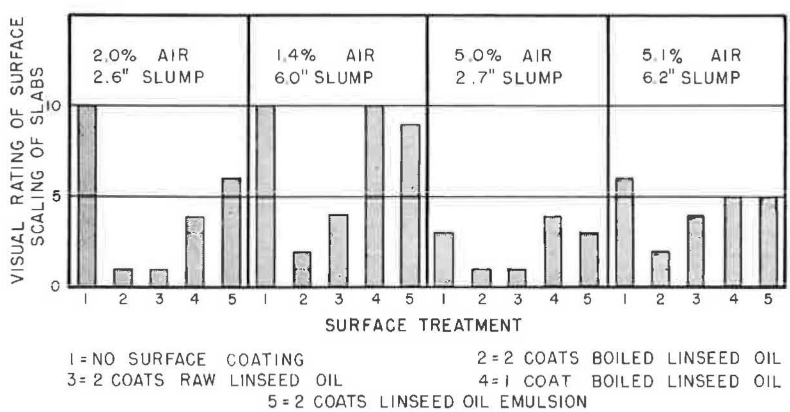

Figure 5. Effect of linseed oil surface coatings on scaling after 105 cycles of freezing and thawing with $CaCl_2$.

SUMMARY

A summary of the ratings of the slabs after 105 cycles of freezing and thawing is shown in Figure 5. For both the low and the high slump non-air-entrained concretes, all linseed oil surface treatments were beneficial in preventing or delaying scaling caused by the use of deicing chemicals. Applications of two coats of either the boiled or the raw linseed oil were the most beneficial surface treatments. With one exception, the slabs given two coats of boiled or raw linseed oil were the only non-air-entrained concrete specimens that did not show significant scaling after 105 cycles.

For the air-entrained concrete of low or high slump, the two-coat application of either boiled or raw linseed oil was the only surface treatment effective in preventing or delaying scaling. The other surface treatments were of little or no benefit. For the low slump air-entrained concrete, non of the slabs, including those with no surface treatment, showed significant scaling. All slabs prepared from the high slump air-entrained concrete except those given two coats of boiled or raw linseed oil showed significant scaling.

The slabs treated with two coats of boiled linseed oil were equally or more resistant to scaling than those treated with two coats of raw linseed oil.

Greater resistance to scaling was furnished by the low slump concrete than by the corresponding high slump concrete, and greater resistance was furnished by the air-entrained concrete than by the corresponding non-air-entrained concrete.

REFERENCE

1. Grieb, W. E., Werner, G., and Woolf, D. O., "Resistance of Concrete Surfaces to Scaling by De-Icing Agents." Public Roads, 32(3) (Aug. 1962).