EVALUATION OF LINSEED OIL AS A CONCRETE SEALANT

by

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ABSTRACT

Sealants are normally used on concrete surfaces to prevent penetration of free water and salt solution which could lead to significant deterioration, especially in locations with extreme temperature swings and repeated freezing and thawing cycles. This paper presents an extensive experimental program undertaken at The University of Manitoba to evaluate linseed oil as a concrete sealant and to provide data which could be used to examine the effectiveness of the linseed oil/mineral spirits (1:1) solution as a sealant in comparison to other commercially available sealants under the same field and laboratory conditions. The six different sealants that were investigated include boiled linseed oil/mineral spirits (1:1) solution, silane sealant, siloxane sealant and three different mixtures of boiled linseed oil/mineral spirits (1:1) and silane.

The field investigation included application of the various sealants to the concrete pavement of three locations, a city street, highway and airport taxiway, located in Winnipeg, Manitoba. During the course of the field investigation, representative core samples were extracted in order to determine the effectiveness of the various sealants in terms of screening chlorides in conjunction with a visual evaluation to evaluate the effectiveness after exposure to winter conditions.

The laboratory investigation phase of the study included salt water absorption, vapour transmission, chloride penetration, surface-scaling resistance, rapid freeze-thaw, abrasion and moisture content tests.

The results obtained after the first two years indicate that the performance of linseed oil/mineral spirits (1:1) as a concrete sealant is comparable, and in some cases superior to that of siloxane sealant, and much superior to that of the silane sealant. This is provided that linseed oil/mineral spirits is given adequate drying time after application.
INTRODUCTION

In regions where there are extreme temperature fluctuations, repeated freeze-thaw cycles transform free water in concrete into ice which causes volume change and induces large internal stresses. This physical change leads to significant cracking and eventually deterioration of the concrete. There is also a possibility of a chemical reaction. When salt is applied to roads to control ice, a solution is formed which can penetrate into the concrete and corrode the reinforcing steel. Both types of damage are dependent on penetration of water and the degree of saturation of salt in solution. Sealants are applied to concrete to effectively retard the water or salt solution from penetrating the concrete.

In the early 1960's, linseed oil and other sealants were commonly used as antiscaling compounds as well as chloride screens for concrete pavements. During this period, a number of studies were undertaken to evaluate the effectiveness of concrete sealants in enhancing the durability of concrete (1-7). Boiled linseed oil in mineral spirits was found to be effective in delaying the onset of scaling in concrete. Periodic surface retreatment was found also to be necessary for long term protection of the concrete.

The use of concrete sealants decreased with the introduction of air entrainment as the most effective means of producing durable and frost-resistant concrete. However, concrete that is adequately air entrained for frost resistance, is nevertheless often damaged by repeated application of deicing salts. Concrete finishing procedures may also drive water to the surface making the concrete susceptible to frost damage. Thus there is a definite need to provide added protection to air entrained concrete. Sealing of concrete surfaces also reduces chloride intrusion and prevents corrosion of steel reinforcement.

EXPERIMENTAL PROGRAM

The primary objective of the experimental investigation, undertaken at The University of Manitoba, is to evaluate linseed oil as a concrete sealant and to provide data which could be used to compare its effectiveness to other commercially available sealants. The study consists of field and laboratory investigations. The six different concrete sealants which were used are:

(i) commercially available boiled linseed oil/mineral spirits (LN);
(ii) commercially available silane product (S);
(iii) commercially available siloxane product (SX);
(iv) a mixture consisting of equal parts of boiled linseed oil/mineral spirits and a silane product (LS);
(v) a mixture consisting of three parts boiled linseed oil/mineral spirits and two parts silane product (L3S2);
(vi) a mixture consisting of two parts boiled linseed oil/mineral spirits and three parts silane product (L2S3).
In the field investigation, the sealants were applied to sections of three selected concrete pavement locations including a city street, provincial highway and airport taxiway. The pavements were examined for surface scaling after one winter season, 1989-1990. Concrete cores were extracted from coated and uncoated areas of the pavements. These cores were used to determine the effectiveness of the sealants as chloride screens and the absorption characteristics of the concrete pavements after one winter season. Additional cores will be taken in May of 1991.

The laboratory investigations included standard methods, using concrete specimens, to evaluate performance and the behaviour of each sealant under various testing conditions. These included salt water absorption, vapour transmission, chloride penetration, surface-scaling resistance, rapid freeze-thaw, and abrasion tests.

**FIELD INVESTIGATION**

The age of the concrete of the city street and the provincial highway was 7 days, whereas the concrete at the airport was 7 years old at time of sealant application. At each site, seven sections were used for the six different types of sealants considered in this investigation. The seventh section was left uncoated for comparison. All the sealants were applied at a rate of 3.07 L/m² as shown, at the city street location, in Figure 1. Prior to the application of the sealants, two 150 mm (6 in.) diameter concrete cores were extracted from each test site to determine the air void characteristics using ASTM C457, Standard Practice for Microscopical Determination of Air-Void Content and the Parameters of the Air-Void System in Hardened Concrete.

Seven days after application of the sealants, 57 mm (2.25 in.) diameter cores were extracted from the concrete pavements. Two cores, representing each type of sealant, were extracted from the concrete pavement at each of the three field locations. In the laboratory, one core was used to determine sealant penetration depth while the other was used to evaluate the effectiveness of each sealed surface for screening chlorides.

In the spring of 1990, additional 57 mm diameter cores were extracted from the concrete pavements from each coated and uncoated section of the three sites. One core was used to determine the absorption characteristics of the sealed concrete pavements, and the second core was used to determine the chloride content. This procedure will be repeated in May of 1991.

**LABORATORY INVESTIGATION**

All specimens were cured for 14 days at 23°C and 100% relative humidity (RH) and were kept in plastic bags to simulate field conditions. The specimens were moved to a humidity controlled room, where they were kept at 23°C and 50% RH to dry before application of the sealants. The application rate was the same as that was used in the field.
Salt Water Absorption Test: The specimens used in this test were 76 mm (3 in.) cubes which were lightly sandblasted prior to coating. The drying time considered in this investigation before application of the sealants was 1, 14, or 28 days. The two drying times considered after application of the sealants were 7 and 45 days. However the 45 day drying time was used only for specimens which were dried 14 days before coating. Details of the test followed the procedure proposed in Reference (8); however, the specimens were immersed in a 15% sodium chloride solution and weighed at selected time intervals over a period of 90 days.

Prior to the absorption of the coated specimens in the salt water solution, specimens representing each of the types of sealants were used to determine the moisture content of each specimen using a simple desiccating apparatus.

Vapour Transmission Test: At the completion of the absorption test, the specimens were air dried at 23°C and 50% relative humidity. Weight measurements were taken at selected time intervals for a minimum period of 90 days. The weight loss of the specimens was used to determine the vapour transmission characteristics of the sealants. Test procedure is described in detail in Reference (8).

Salt Water Ponding Test: A 4% sodium chloride solution was ponded on 305x305x76 mm (12x12x3 in.) slab specimens which were cured for 14 days, dried for 7 days before application of the sealers and allowed to dry for another 7 days. The slabs were stored for a period of 90 days at room temperature and subjected to 4% sodium chloride solution ponded on the top surface at a depth of about 13 mm (0.5 in.). Cores, 25 mm (1 in.) in diameter were extracted from each specimen and analyzed for chloride content.

Rapid Freeze-Thaw Test: ASTM C666 Procedure A, Resistance of Concrete to Rapid Freezing and Thawing in water was used to perform this test. At selected time intervals, weight and frequency of vibration were measured for each specimen. The weight measurement was used to determine material loss, while the frequency measurement was used to determine the change in stiffness (dynamic modulus of elasticity) of the tested specimens.

Scaling Resistance Test: Slab specimens, with dimensions of 254x254x75 mm. (10x10x3 in.) were used. The slabs were air dried at 23°C and 50% relative humidity for 14 days before application of the sealants and 7, 14 and 45 days after application of the sealants. ASTM C672-84, Scaling Resistance of Concrete Surfaces Exposed to Deicing Chemicals was used for this test. Specimens were subjected to cycles of freezing overnight (16 hours) and thawed during the day (8 hours) at 23°C and 100% relative humidity. After every five cycles, the scaling due to freeze-thaw damage was collected from each specimen, washed, dried and weighed. After completion of 60 freeze-thaw cycles, samples were analyzed for chloride content.

Abrasion Test: In order to evaluate the effectiveness of sealed concrete after a certain amount of abrasion, the top 0.5 millimetres is removed from one surface of the coated specimens, and tested for ponding and absorption. A precision grinding machine was used and the surface was cleaned using pressurized air. This test is currently in progress and therefore, the test results are not presented in this paper.
TEST RESULTS OF THE FIELD INVESTIGATION

No noticeable damage was observed at the three sites after one year of exposure to winter conditions. Test results of the cores extracted from the field were used to evaluate the performance and behaviour of the different sealants as follows:

Penetration Depth of Sealants: The measured penetration depth of the sealants at the three test sites, based on cores which were extracted after 7 days, is shown in Figure 2. The penetration depth at the airport was unmeasurable, which is most likely due to the fact that the concrete was seven years old and of low porosity. The lower penetration depth of the silane for the highway concrete compared to that of the city street could be attributed to the windy condition under which the sealants were applied at the highway which could cause evaporation of the sealants. This also leads to the conclusion that field conditions at the time of application and age of concrete can influence the penetration depth of a sealant.

Reduction in Absorption: The measured reduction in absorption, based on cores which were extracted after one winter season, versus sealant penetration depth is shown in Figure 3 for the three test sites. The results indicate that, in general, the effectiveness of all three sealants increased with increasing sealant penetration depth. The measured results indicate that linseed oil and siloxane sealants are more effective than the silane sealant for the same levels of sealant penetration depth. The results also suggest that all sealants appear to be more effective for young concrete, as in the case for the city street and highway pavement, than for old concrete, as in the case for the airport site.

Chloride Intrusion: The measured chloride contents of the specimens coated with different sealants in comparison to uncoated specimens at the city street and highway test sites are given in Figure 4, which indicates that linseed oil is the most effective, compared to the other sealants, in reducing chloride penetration for both tested sites. The airport site was not subjected to deicing salts; therefore extracted cores were not analyzed for chloride content.

Based on the measured performance of all sealants tested under field conditions, it can be concluded that linseed oil is the more effective sealant in comparison to all other sealants including combinations of linseed oil and silane.
TEST RESULTS OF THE LABORATORY INVESTIGATION

Results of the various tests conducted in the laboratory, including tests which are in progress, will be briefly presented and discussed.

Reduction in Absorption: The measured reduction in absorption, in comparison to the uncoated specimens, for linseed oil, silane and siloxane for specimens dried for 28 days prior to coating, is shown in Figure 5. The results indicate that initially, for a period of 36 days, both silane and siloxane were more effective than the linseed oil. After this initial period, the effectiveness of the silane drops very rapidly and both the siloxane and linseed oil remain as the most effective sealants up to the measured period of 90 days.

The absorption rate could be influenced by the moisture content of the specimens before immersing into the salt solution. The influence of the moisture content of the specimens prior to soaking was considered in evaluating its effect on the reduction in the absorption due to coating of the specimens by the various sealants.

The measured moisture content for specimens dried 1, 14, and 28 days before coating and 7 days after coating are presented in Table 1 for the different sealants. Obviously, the results indicate, in general, that the drying time prior to coating reduces the moisture content. However, the measured moisture content of the specimens coated by linseed oil and dried for one day, showed significant moisture content prior to soaking in comparison to the other sealants. The measured moisture content and the absorption values were used to determine the real salt water content for the specimens coated with linseed oil, as shown in Figure 6. It can be seen that the real salt water content in the specimens is virtually the same for all three cases of drying time prior to soaking. This leads to the conclusion that the amount of actual salt water content during soaking is independent of the time prior to application of the linseed oil.

Reduction in Salt Water Content: Durability of concrete is significantly affected by the degree of salt water saturation. The effectiveness of different sealants in terms of their ability to reduce penetration of salt water solution was evaluated. The measured moisture content of the specimens prior to soaking and the absorption of the coated and uncoated specimens was used to determine the reduction in real water content in comparison to uncoated specimens, as shown in Figure 7. In this Figure, specimens were dried for 14 days prior to coating and 7 days after application of the linseed oil. The behaviour is similar to the behaviour observed in Figure 5 where both the siloxane and the linseed oil performed better than the silane after an initial period of 20 days in this case.

To study the effect of the drying time after coating, a set of specimens, dried for 14 days before the application of the various sealants, were allowed to dry for 45 days before soaking in the salt solution. The measured reduction in salt water content, shown in Figure 8, also indicates that linseed oil is comparable to the siloxane and both are significantly more effective in comparison to the silane sealant.
The influence of the drying time on the effectiveness of the linseed oil is shown in Figure 9. It is evident that the drying time of 45 days after application of the sealant significantly enhances the effectiveness of the linseed oil in reducing the salt water content.

**Vapour Transmission:** The ability of a sealant to allow water vapour to escape from the concrete upon drying is also an important phenomenon that influences the effectiveness of any sealant.

The weight gain due to soaking of the specimens in salt solution for 90 days and the weight loss due to drying for 90 days, for the various sealants including the uncoated specimen, is shown in Figure 10.

The net vapour transmission for coated and uncoated specimens during drying time is shown in Figure 11. The results indicate that the silane coated specimen is virtually the same as that of the uncoated specimen. Although siloxane and linseed oil coated specimens appear to exhibit similar performance, it should be noted that the real salt water content in the linseed oil coated specimen before drying is much higher than that of the siloxane coated specimen.

**Salt Water Ponding Test:** Test results of cores extracted from ponding test slab specimens were used to determine the reduction in chloride intrusion of the specimens coated with various sealants relative to the uncoated specimens are shown in Figure 12. The results clearly show that the linseed oil and siloxane sealants are more effective than the silane sealant in reducing chloride intrusion.

**Freeze-Thaw Durability:** Reduction in the measured stiffness of coated and uncoated specimens is shown in Figure 13. The results indicate that the reduction in the stiffness of siloxane and silane sealed specimens is larger than the linseed oil and uncoated specimens. Similar behaviour is also shown in Figure 14 for the weight loss of the specimen as a function of the number of freeze-thaw cycles.

It should be noted that these specimens were totally coated on the six surfaces with the sealants. The degree of damage reflects the ability of each sealant to hinder water transfer through the coated surface. Subjecting the specimens to rapid freeze-thaw caused serious damage to the specimens coated with siloxane, despite the fact that all other tests show siloxane as the superior sealant. Therefore, it is the opinion of the authors that this type of test is not suitable to evaluate the effectiveness of sealed concrete specimens.

**Scaling Resistance Test:** Measured loss in weight for specimens subjected to ponding and freeze-thaw cycles is given in Figure 15. The results indicate that both siloxane and linseed oil are significantly effective in comparison to silane which has moderate effect up to 20 cycles. It was observed that, after 20 cycles, the concrete treated by silane deteriorates rapidly while linseed oil was more effective than siloxane in reducing scaling due to freeze-thaw up to the measured 45 cycles.
Samples taken from these specimens were analyzed for chloride content. The results, illustrated in Figure 16, show that linseed oil is the most effective sealant at screening chlorides. A photograph of the concrete surface after 60 freeze-thaw cycles of four specimens coated with siloxane (SX), linseed oil (LN), silane (S) and uncoated (UN), is shown in Figure 17. Comparison of the four specimens clearly indicates that the specimen coated with linseed oil shows the least amount of deterioration.

**SUMMARY and CONCLUSION**

An experimental program was undertaken at the University of Manitoba to examine the effectiveness of linseed oil as a sealant for concrete. The investigation consisted of field testing and laboratory investigations to examine the performance of linseed oil as compared to several other commercially available sealants.

The field investigation included coating of concrete pavement of a city street, provincial highway and airport taxiway. The performance was evaluated based on visual inspection, chloride intrusion and reduction of absorption.

The laboratory investigation consisted of various tests including absorption test, vapour transmission, salt water ponding, rapid freeze-thaw and scaling resistance test.

Based on the test results measured for two years, the following conclusions can be drawn:

1. The effectiveness of a sealant is a function of its penetration depth and could be influenced by field conditions at time of application, age and porosity of concrete.
2. Linseed oil and siloxane sealants are more effective in reducing chloride intrusion than the silane sealant for both field and laboratory investigations.
3. When linseed oil is allowed to adequately dry, its ability to reduce salt water content in specimens is comparable to siloxane and better than silane.
4. Linseed oil is the most effective or is as effective as siloxane in reducing scaling due to freeze-thaw testing.
5. Linseed oil/mineral spirits (1:1) was found to be more effective than linseed oil mixed with different proportions of silane.

The research is still in progress and cores will be extracted from the three test sites in June 1991, to examine the effect of two winter seasons.
ACKNOWLEDGEMENTS

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Table 1: Moisture contents for specimens dried 7 days after coating.

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<thead>
<tr>
<th>SEALANT</th>
<th>MOISTURE CONTENT (%)</th>
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<tbody>
<tr>
<td></td>
<td>DRYING TIME BEFORE COATING</td>
</tr>
<tr>
<td></td>
<td>1 DAY</td>
</tr>
<tr>
<td>LINSEED OIL (1:1)</td>
<td>3.88</td>
</tr>
<tr>
<td>SILANE</td>
<td>2.85</td>
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<tr>
<td>SILOXANE</td>
<td>3.10</td>
</tr>
<tr>
<td>UNCOATED</td>
<td>2.57</td>
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Figure 1: Sealer application at city street location.
Figure 2: Sealant penetration depths at test sites.

Figure 3: Reduction in absorption versus sealant penetration depth for field concrete cores.
Figure 4: Relative chloride contents for concrete cores from city and highway pavements after 1989/1990 winter season.

Figure 5: Reduction in absorption for laboratory test specimens. Specimens air dried for 28 days prior to coating, 7 days after coating.
Figure 6: Real salt water content for linseed oil coated specimens. Specimens air dried for 1, 14, 28 days prior to coating, 7 days after coating.

Figure 7: Reduction in real water content for laboratory test specimens. Specimens air dried for 14 days prior to coating, 7 days after coating.
Figure 8: Reduction in real salt water content for laboratory test specimens 14 days dry prior to coating, 45 days after coating.

Figure 9: Reduction in real salt water content for linseed oil coated specimens. Specimens air dried for 14 days prior to coating.
Figure 10: Weight gain and loss for laboratory test specimens. Specimens air dried for 14 days prior to coating, 7 days after coating.

Figure 11: Vapour transmission for the laboratory test specimens. Specimens air dried for 14 days prior to coating, 7 days after coating.
Figure 14: Weight loss versus number of rapid freeze-thaw cycles for laboratory test specimens.

Figure 15: Weight loss versus number of freeze-thaw cycles in the surface scaling resistance test.
Figure 12: Reduction in chloride intrusion after 90 days ponding for laboratory test specimens.

Figure 13: Relative stiffness versus number of rapid freeze-thaw cycles for laboratory test specimens.
Figure 16: Chloride content for the specimens used in scaling resistance test after 60 freeze-thaw cycles.

Figure 17: Test specimens used in scaling resistance test after 60 freeze-thaw cycles. SX - siloxane coated, LN - linseed oil coated, SL - silane coated, UN - uncoated.