# Penetrating Sealers for Concrete: Survey of Highway Agencies

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A survey on the use of penetrating sealers for portland cement concrete was conducted by distributing questionnaires to all U.S. and several Canadian highway agencies. Information was obtained on applications of penetrating sealers, extent of use, qualification of sealers and test procedures used, and problems of application and performance. Although the survey results indicated much interest by highway agencies in using penetrating sealers, applications are limited. Linseed oil is widely used in many localities. Results also indicated that test procedures used to qualify sealers vary widely among agencies, with some agencies relying on data supplied by vendors or on results of testing carried out by other organizations. There is currently little activity related to in-place field testing of penetrating sealers.

It is generally accepted that the ingress of sufficient amounts of moisture and chloride salts into portland cement concrete structures leads to corrosion of reinforcing steel and eventual degradation of the reinforced concrete. This problem has led to the development of various approaches to reduce or eliminate the ingress of chlorides and moisture into concrete. These include the use of waterproofing membranes, rigid cementitious overlays, polymer overlays, and various coatings and sealants (*1–3*). Membranes and overlays, although effective in many cases, are engineered systems that require considerable construction detailing and relatively high labor installation costs. Many of the available coatings may not be applicable to wearing surfaces. Although linseed oil-based materials have been used to seal concrete surfaces, their use has diminished recently because of their effects on surface color and reflectance of concrete and the need for frequent reapplication. The introduction of new types of sealers, commonly referred to as "penetrating sealers," has generated considerable interest as a relatively inexpensive and easy means of prolonging the life of reinforced concrete structures (*4,5*). The survey described in this paper aimed at developing current (1989) information on the use and application of penetrating sealers by highway agencies in the United States and Canada.

## OBJECTIVES AND SCOPE

The survey described in this paper had the following objectives: (a) update information on extent of use of penetrating sealers, (b) delineate the major application areas for sealers, (c) obtain information on testing procedures used by highway agencies in qualifying penetrating sealers, and (d) note problems commonly occurring in application and performance of sealers. A questionnaire was the primary source of this information. In addition, reports submitted by the agencies surveyed, data from published literature, and follow-up calls were used to develop further information.

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## QUESTIONNAIRE AND RESPONSES

A questionnaire about the use of penetrating sealers for concrete was sent to all U.S. and 11 Canadian highway agencies. The questionnaire was primarily composed of simple yes or no and multiple category questions. In a few cases, those surveyed were asked to supply copies of documentation, such as specifications, test procedures, and lists of products and approved vendors. In addition, respondents were given the opportunity to discuss any problems they had experienced with either the application or performance of penetrating sealers.

Responses were received from all agencies surveyed. Of the respondents, four U.S. and two Canadian agencies had not used penetrating sealers. Surveys from these agencies were not included in tabulations. The data base, therefore, consists of 46 U.S. and 9 Canadian highway agencies.

Responses to questions about use, applications, and qualifications of penetrating sealers are summarized in Table 1. Responses to questions concerning test procedures and problems are summarized in Table 2. Although U.S. and Canadian responses are presented as separate tables, statistics were developed on the responses of the 55 agencies combined.

## DISCUSSION OF RESULTS

### Extent of Use

The current use of penetrating sealers and linseed oil is summarized in Table 3. The categories listed (extensive, moderate, limited, and experimental) did not represent specific numbers or percentages of structures in any state or province, but simply represented the perceived use of such materials by the respondent's agency. The number of agencies claiming extensive use of linseed oil is greater than the number claiming extensive use of penetrating sealers. Most agencies are using penetrating sealers on a limited or experimental basis. Four agencies have recently discontinued use of linseed oil and two have discontinued use of penetrating sealers. Two of the agencies that discontinued use of linseed oil had used it extensively in the past. One of the agencies that discontinued use of penetrating sealers had used it extensively in the past, and

TABLE 1 SUMMARY OF RESPONSES—USE, APPLICATIONS, AND QUALIFICATIONS

| STATE | EXTENT OF USE | APPLICATIONS | QUALIFICATION | PRODUCT LIST |
|---|---|---|---|---|
| AL | Lim.-L.O. | Decks | Prescription | NO |
| AR | Mod.-L.O./Exp. | Decks | Prescription | NO |
| CA | Ext.-L.O./Lim. | Decks,beams,piers,caps,appurtenances, barriers | Internal testing, vendor data | YES |
| CO | Lim. | Decks,sidewalks | Prescription | NO |
| CT | Mod. | Decks,appurtenances,barriers | Vendor data | YES |
| DE | Lim. | Decks,piers,caps,barriers,appurtenances | Vendor data | NO |
| FL | Lim. | Decks,beams,piers,caps,appurtenances | Internal testing ,vendor data | YES |
| GA | Ext.-L.O. | Decks | Prescription | YES |
| I D | Lim.-L.O. | Decks | Internal/external testing | NO |
| I L | Mod-L.O./Lim. | Decks,piers,caps,barriers appurtenances,pavements | Vendor data | YES |
| IN | Exp. | Decks | Internal testing | YES |
| I A | Mod. | Piers,caps,curbs,gutters | Internal testing | YES |
| KS | Ext. | Decks, appurtenances | Internal testing | YES |
| KY | Lim. | Decks | Vendor data | YES |
| LA | Exp. | Decks | Experimental only | NO |
| ME | Ext.-L.O./Lim. | Decks,piers,caps,barriers,appurtenances | Vendor and other data | NO |
| MD | Lim.-L.O. | Decks | Internal testing | NO |
| MA | Mod. | Appurtenances,barriers | Internal testing | YES |
| M I | Ext.-L.O./Lim. | Decks(L.O.),Piers | Internal/external testing | YES |
| MN | Exp. | Decks,barriers | Experimental only | YES |
| MO | Ext.-L.O. | Decks,barriers,appurtenances | Internal testing | NO |
| MT | Mod.-L.O. | Decks,beams,appurtenances | Internal/external testing | NO |
| NE | Mod. | Decks | Internal testing,prescription | YES |
| NV | Exp. | Decks | Experimental only | NO |
| NH | Ext. | Beams,piers,caps,walls,appurtenances, barriers | External testing, vendor data | YES |
| NJ | Exp. | Decks | Internal testing,prescription | YES |
| NM | Ext. | Decks,beams,caps,appurtenances | Internal testing,vendor data | YES |
| NY | Mod. | Decks,piers,caps,appurtenances,barriers | Internal testing | YES |
| NC | Ext.-L.O./Lim. | Decks,appurtenances | Certification | NO |
| ND | Ext.-L.O./Lim. | Decks | Internal testing | YES |
| OH | Mod. | Beams,appurtenances | Vendor data | YES |
| OK | Ext. | Decks,piers,appurtenances | Internal testing | YES |
| OR | Lim. | Beams,piers,caps,appurtenances | External testing,vendor data | YES |
| PA | Lim. | Decks,piers,caps,barriers | Internal testing | YES |
| R I | Lim. | Appurtenances | Internal testing | YES |
| SC | Mod.-L.O. | Decks | Prescription | NO |
| SD | Ext.-L.O. | Decks | Internal testing,prescription | YES |
| TN | Lim. | Decks | Internal testing | NO |
| TX | Ext.-L.O. | Decks | Prescription | NO |
| UT | Exp. | Decks,piers,barriers,appurtenances | Experimental only | YES |
| VT | Ext.-L.O./Exp. | Piers,caps,barriers,appurtenances | Internal testing | NO |
| VA | Lim. | Decks,appurtenances,pavement | Internal testing | YES |
| WA | Exp. | Decks,beams,piers,caps | External testing | NO |
| WV | Ext. | Decks,beams,appurtenances | Vendor data | YES |
| W I | Ext. | Decks | Internal testing | YES |
| WY | Mod./Lim. | Pavement/decks | Internal testing,vendor data prescription | YES |

| PROVINCE | EXTENT OF USE | APPLICATIONS | QUALIFICATION | PRODUCT LIST |
|---|---|---|---|---|
| AB | Ext. | Decks,beams,piers,appurtenances | External testing,vendor data | YES |
| BC | Ext. | Decks, appurtenances | Internal testing, vendor data | YES |
| MB | Lim. | Decks, curbs | Vendor data,prescriptipn | NO |
| NB | Lim. | Decks, appurtenances | Internal/external testing | NO |
| NS | Lim. | Decks,barriers | Internal testing | NO |
| ON | Lim. | Beams,barriers | Internal testing | YES |
| QE | LIm. | Piers,barriers,appurtenances | Internal testing | YES |
| SK | Lim. | Decks,barriers,appurtenances | AB DOT data | YES |
| YT | Lim. | Decks,appurtenances | By recommendation | NO |

Note-Use categories abbreviated as follows:

Ext.-Extensive use.
Mod.-Moderate use.
Lim.-Limited use.
Exp.-Experimental use only.
L.O.-Use category refers to linseed oil only (i.e. Mod.-L.O.)

TABLE 2 SUMMARY OF RESPONSES—TEST PROCEDURES AND PROBLEMS

| STATE | TEST PROCEDURES USED | PROBLEMS | | FIELD TESTS |
|---|---|---|---|---|
| | | APPLICATION | PERFORMANCE | |
| AL | not tested routinely | NO | NO | NO |
| AR | AASHTO M233-L.O. | NO | NO | NO |
| CA | NCHRP 244,absorption | YES | n/a | NO |
| CO | not tested routinely | YES | YES | NO |
| CT | rely on vendor test data | NO | NO | NO |
| DE | rely on vendor test data | NO | NO | NO |
| FL | Impressed current | YES | NO | YES-Chloride sampling |
| GA | ASTM D260-L.O. | n/a | Questionable | NO |
| ID | NCHRP 244,pen.depth, vapor perm,skid no. | n/a | n/a | NO |
| IL | NCHRP 244, ASTM C 672 | NO | NO | NO |
| IN | Field evaluation | NO | YES | YES-long term sampling |
| IA | AASHTO T259 | NO | NO | NO |
| KS | ASTM C 642, AASHTO T259 | YES | YES | YES-Chloride sampling |
| KY | rely on vendor test data | n/a | n/a | NO |
| LA | not tested routinely | NO | YES | YES-Chloride sampling |
| ME | rely on vendor and other DOT data | NO | NO | NO |
| MD | only use L.O. | YES | n/a | NO |
| MA | similar to NCHRP 244 | NO | NO | YES-visual inspection |
| MI | AASHTO T 259 | NO | NO | NO |
| MN | Field evaluations | YES | YES | YES-Chloride sampling |
| MO | ASTM C 672,C 642,AASHTO T 259 | NO | NO | NO |
| MT | L.O. recently eliminated from specs. | n/a | n/a | NO |
| NE | AASHTO T 259 | YES | NO | YES-Chloride sampling |
| NV | not tested routinely | NO | Unknown | YES-Chloride sampling |
| NH | NCHRP 244 | NO | NO | NO |
| NJ | Saline absorption | NO | NO | YES-visual scale ratings |
| NM | ASTM C642, AASHTO T 259 | NO | NO | NO |
| | OK DOTpen. depth,vapor perm | | | |
| NY | similar to NCHRP 244 | NO | NO | NO |
| NC | not tested routinely | YES | YES | NO |
| ND | ASTM C642, AASHTO T 259 | NO | NO | NO |
| | OK DOT pen. depth,vapor perm | | | |
| OH | rely on vendor test data | NO | NO | NO |
| OK | ASTM C642, AASHTO T 259 | NO | NO | YES-water flood and |
| | pen. depth,vapor perm | | | observe |
| OR | NCHRP 244,ALB&FL tests | NO | NO | NO |
| PA | AASHTO T 259 | n/a | n/a | NO |
| RI | Chloride intrusion | NO | Unknown | NO |
| SC | not tested routinely | n/a | Questionable | NO |
| SD | used as curing compounds only | YES | n/a | NO |
| TN | AASHTO T 259 | n/a | n/a | NO |
| TX | not tested routinely | NO | NO | NO |
| UT | Freeze-thaw test | Unknown | Unknown | NO |
| VT | AASHTO T259(modified),absorption | NO | YES | YES-Chloride sampling |
| VA | ASTM C 666, AASHTO T 277 | YES | YES | YES-field cores |
| WA | NCHRP 244 | NO | YES | NO |
| WV | rely on vendor test data | NO | NO | NO |
| WI | AASHTO T 32, T 259, FL test | NO | n/a | YES-field cores |
| WY | ASTM C 642, OK DOT vapor prem, | NO | YES | YES |
| | pen. depth | | | |

Note: L.O.- Linseed oil.

| STATE | TEST PROCEDURES USED | PROBLEMS | | FIELD TESTS |
|---|---|---|---|---|
| | | APPLICATION | PERFORMANCE | |
| AB | Water absorption | NO | NO | NO |
| BC | AB and OK DOT test procedures | YES | n/a | NO |
| MB | rely on vendor test data | NO | NO | NO |
| NB | n/a | NO | YES | YES-water flood |
| NS | n/a | NO | YES | NO |
| ON | Water/saline absorption,ASTM C672 | NO | YES | NO |
| | AASHTO T277 | | | |
| QE | similar to NCHRP 244 | YES | n/a | NO |
| SK | rely on AB DOT test data | NO | NO | NO |
| YT | not tested routinely | unknown | unknown | NO |

TABLE 3 EXTENT OF USE OF PENETRATING SEALERS AND LINSEED OIL

| Extent of Use | Number of Agencies | |
|---|---|---|
| | Penetrating Sealers | Linseed Oil |
| Extensive | 7 | 9 |
| Moderate | 7 | 4 |
| Limited | 23 | 3 |
| Experimental | 9 | 0 |

discontinued use because of the sealer's apparent inability to reduce chloride ion infiltration into bridge decks.

### Application Areas

As presented in Figure 1, the most widely used application of penetrating sealers is on concrete bridge decks.

This is an extremely interesting and significant statistic. Perhaps the most influential report on the performance of penetrating sealers, NCHRP Report 244 (*7*), states in its foreword, "The research concentrated on the protection of structural elements *other* than the top surface of the bridge deck." Indeed, the need for efficient and cost-effective means to protect non-wearing surfaces and substructural elements of bridges was the main impetus for funding the project under which NCHRP Report 244 was written. It was acknowledged that systems that provide adequate wearing surfaces (such as membranes and rigid overlays) were already available for protection of bridge decks, but could not be practically applied to substructures. However, it appears that aggressive marketing of penetrating sealers has lead to their increased use on wearing surfaces, although NCHRP Report 244 did not include abrasion subsequent to sealing in its test program, a procedure that is of vital importance in testing any materials for use on highway wearing surfaces.

About 30 percent of the respondents are using penetrating sealers in substructural elements such as piers, pier caps, and support beams. Again, this is probably because deck deterioration is still the primary problem in most areas, although occurrences of salt-induced damage to support and substructures has increased in recent years (*8,9*). About the same percentage of respondents apply penetrating sealers to median barriers in which deterioration problems have been noticed (*10*). Finally, 28 agencies reported use of penetrating sealers on appurtenance elements, which include parapets, abutments, railings, and sidewalks.

### Qualification of Sealers

Highway agencies have traditionally relied on tests carried out within their own laboratories to qualify various products for use on their work. Recently, however, there has been a move toward accepting products on the basis of tests performed by or for manufacturers that demonstrate the product's compliance with ASTM, AASHTO, or specific agency specifications.

Data developed during the survey support these trends (Figure 2). Although most agencies still rely on internal testing to qualify sealers, many agencies use data submitted by vendors, prescribe sealers on the basis of prior testing experience, or utilize external testing agencies. The use of vendor data can be considered an indirect use of external testing agencies, because vendors often have their products tested by independent laboratories, and include these data in technical documentation submitted to highway agencies. Many agencies rely on a combination of various methods for qualification, often using internal or external testing, supplemented by vendor data, as one example. Finally, the category of "other" includes

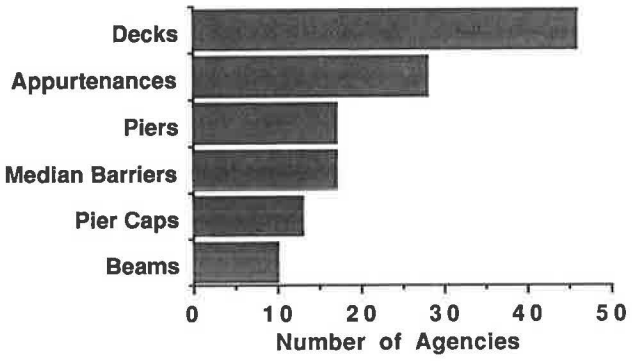


FIGURE 1 Application areas for penetrating sealers.

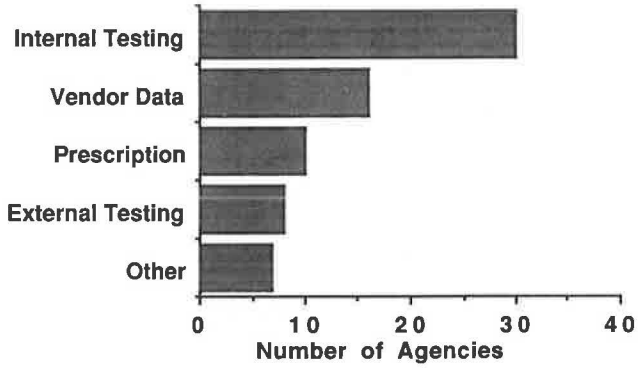


FIGURE 2 Procedures used to qualify penetrating sealers.

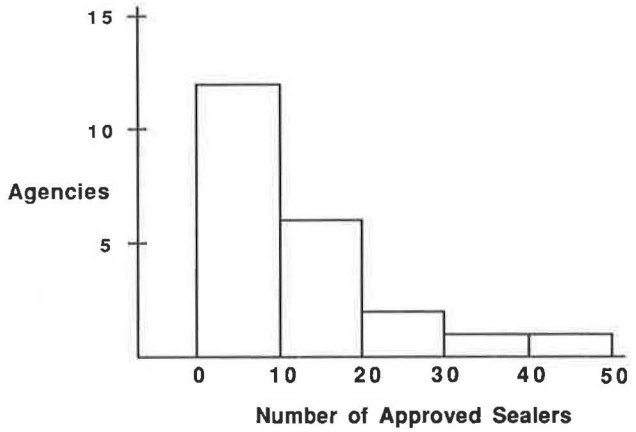


**FIGURE 3 Number of penetrating sealers on approved product lists.**

those agencies in which sealers were only used experimentally, in which lots of sealer were certified before use (linseed oil only), or in which data from other agencies were utilized.

### Lists of Approved Products

Agencies were asked to list all approved penetrating sealers, including trade names and manufacturers. A few agencies had approved many products—Florida, Iowa, Ohio, and Pennsylvania each approved more than 20 products. Other agencies carried only a handful of sealers on their approved lists. A histogram summarizing these data is given in Figure 3.

Categorization of these data by generic type of sealer is difficult because the information was not available in many cases, and indeed, the quantity of such products on the market makes product categorization by sealer type a formidable task. However, familiarity with many of the products indicates that sealers with silane and siloxane bases predominated. Sealers with epoxy bases and other formulations are the next most common.

### Test Procedures

Many agencies use more than one test procedure for their evaluations (Table 2). Additionally, a number of agencies rely on data submitted by vendors, and do not carry out their own tests.

A tabulation of test procedures in use by agencies, in decreasing order of usage, is given in Table 4. The most widely used procedure is AASHTO T 259, "Resistance of Concrete to Chloride Ion Penetration," which is commonly referred to as "90-day ponding." The second most widely used test is Series II of NCHRP Report 244 (7). This is not a standarized test method, but rather the report of a laboratory investigation. As such, considerable latitude in testing and interpretation of results is possible. ASTM C 642 "Standard Test method for Specific Gravity, Absorption, and Voids in Hardened Concrete" is the next most widely used method, along with other non-standard absorption methods. A number of techniques have been developed by the Oklahoma Department of Transportation, and are used by a number of other agencies. These techniques include tests for average penetration depth of sealers and vapor permeability. Finally, tests for deicer scaling resistance (ASTM C 672), freeze-thaw resistance (ASTM C 666), rapid chloride permeability (AASHTO T 277), and skid number are used by a small number of agencies.

Because of the wide variety of test procedures employed, it is extremely difficult to compare the performance of par-

TABLE 4 TEST PROCEDURES USED IN EVALUATION OF PENETRATING SEALERS

| Test Procedure | Number of Agencies |
|---|---|
| AASHTO T 259 | 13 |
| NCHRP 244[a] | 9 |
| ASTM C 642 | 6 |
| Absorption (not ASTM C 642) | 6 |
| Rely on Vendor Data | 6 |
| Penetration depth[b] | 5 |
| Vapor Permeability[b] | 5 |
| Other Tests | 5 |
| ASTM C 672 | 3 |
| AASHTO T 277 | 2 |
| Freeze-Thaw Testing | 2 |
| Skid Resistance Testing | 1 |

a) Most agencies utilize Series II testing as described in NCHRP Report 244 (7).
b) Test procedures developed by Oklahoma DOT.

ticular sealers with one another in examining results generated by different agencies. In addition, it is difficult to assign any degree of confidence to the data generated using varying methods, precision data resulting from standardized interlaboratory comparison tests are available for only one class of methods (freeze-thaw testing) and freeze-thaw methods are only used by two agencies in evaluating sealers. The precision of the two most widely used techniques, AASHTO T 259 and NCHRP Report 244, has not been determined.

### Problem Areas

Agencies were asked to supply information developed in both the application and performance of penetrating sealers. Twelve agencies noted problems in applications, while 13 agencies noted problems in performance. Two agencies expressed the opinion that the performance of penetrating sealers was "questionable."

Various problems were reported by the respondents on the application of penetrating sealers. These problems included drifting and evaporation in hot and windy conditions, difficulty in obtaining specified coverage on newly placed concrete, slippery surfaces when linseed oil or other more viscous sealers were used, runoff during application, discoloration of concrete, flammability, non-uniform application, and little or no apparent penetration.

There were also certain areas in which respondents indicated performance of penetrating sealers to be less than desired. Several respondents indicated that many penetrating sealers were ineffective (or at least not as effective as claimed) in reducing infiltration of chloride ions into concrete. This was often manifested as a loss of effectiveness with time, and was especially bothersome on wearing surfaces in which effectiveness was expected to be about 3 years at most. Other performance problems included reduction of skid resistance (for those sealers that left a surface residue), failure to improve freeze-thaw and scaling resistance in non-air-entrained concretes, and failure to halt corrosion of reinforcing steel (as measured by half-cell potential surveys).

### Field Test Procedures

Field testing of penetrating sealers has primarily consisted of periodic sampling of concrete for chloride ion penetration, using either core or drill samples. Although this does yield information on long-term effectiveness, the tests are destructive, time-consuming, and the number of samples that can reasonably be obtained from a given structure is limited. A second technique, used by at least two agencies, is to flood the treated sections with water and observe absorption of water into the concrete. If the water remains on the surface or "beads up," the sealer is judged to be effective; if it is rapidly absorbed into the concrete, the sealer is judged to be ineffective. Because this test is qualitative, it has significant subjective aspects. More rapid, quantitative field techniques are needed to assess the effectiveness of penetrating sealers.

## CONCLUSIONS

There is keen interest in using penetrating sealers by most highway agencies in North America. The trend is moving away from such traditional products as linseed oil toward higher quality (and more expensive) materials such as silanes and siloxanes. Current use is limited, although several agencies are applying sealers to a significant number of structures. Qualification and test procedures for sealers vary from agency to agency, and more standardized acceptance methods are needed. There are problems in both application and performance of sealers, which must be resolved before highway agencies can be assured long-term performance.

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