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Acid-Resistant Concrete Coatings

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WORK reported in this paper was undertaken to find suitable coatings for use on concrete stave silos to resist the disintegrating action of acids generated in ensilage. Almost all the materials used in this study were furnished by nationally known manufacturers, and, for the most part, are regularly offered for sale. This paper attempts to give a comparative picture of the value of each of these materials under the action of weak acid, abrasion, and water absorption.

EXPERIMENTAL

Each coating was subjected to two different tests. First, an accelerated acid flow test[1] subjected the coating to acid action and abrasion. The test of Miller, Rogers, and Manson was altered by using a stronger (0.2 N) acetic acid, and the maximum period of the test was reduced to ten days.

The accelerated acid flow test gives a comparative picture of the acid-resisting qualities of each coating. The production of sand, gravel, and cement loosened from the coated bar by brushing was taken as evidence of disintegration. Although the loosened material obtained by the brushing was dried and weighed, the table gives only the number of days the coating withstood the test before erosion appeared.

This test also brings out several other important properties of a coating. It must have good coverage or the brushing will wear out thin parts of the coating and permit disintegration to start. The coating must also form a good bond with the concrete to prevent peeling or pitting, both of which permit disintegration to begin.

The second test involved drying a 2-in cube of concrete, entirely coated, in an electric oven at 75 to 85 C (degrees centigrade) for a period of 24 hr. This temperature was used because ensilage often approaches it. The cubes were then weighed, placed in beakers, and allowed to remain under tap water at room temperature for another 24 hr. The cubes were removed, weighed again, and the percentage of absorption was calculated from the two weights. This water absorption test, while contributing less to the estimation of the value of a coating than the acid flow test, is a good measure of porosity. It was hoped that this test would give a method of predicting whether a coating would permit ensilage to stick to the silo wall, but in field tests, which are described later, no general rule has been determined.

All the concrete bars and cubes used in this investigation were made by the "dry tamped" method. The proportions of the ingredients by weight when dry were: gravel, [illegible]; coarse sand, 2.42; fine sand, 1.00; cement, 1.52. Enough water was then added to give a water-cement ratio of 5.1 gal per sack of cement. These proportions make seven staves, 12½ in wide and weighing about 79 lb each, per sack of cement. The concrete was cured in a steam chamber at about 75 C for 24 hr and then given a 7-days curing in air at room temperature.

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[1] Miller, D. G., Rogers, C. F., and Manson, P. W. Laboratory tests of concrete and mortars exposed to weak acids. Agr. Engr. 20:11 (November 1939).

RESULTS

From the 91 different coatings tested, the table includes those found to resist the acid flow test for more than 10 days, and a few coatings now in general use, for comparison. I believe that, unless the coating allows the adhesion of ensilage, each day of the acid flow test will approximate one year of actual use in a silo. Whether or not ensilage will adhere can be determined only by actual use.

Some of the coatings tested were placed on silos last summer. These silos were inspected recently after one year of use and notes on the results of this inspection are included in the following table:

TABLE OF RESULTS

Coating number	Description and cost of coating	Description of coating after one year's use	Acid flow test. Time in days of first evidence of disintegration	Water absorption. Weight gained by 2-in coated cube in tap water for 24 hr, per cent
Uncoated concrete			1	6.2
WAXES	(All the waxes were applied by melting the wax, brushing it on the concrete, and driving it in with a burner, leaving only a thin film on the surface)			
1	Paraffin (melting point 49 C). Cost, 2-3 cents per lb	This coating peels and checks slightly on a silo. This could be overcome if a silo were gone over with a blow torch every year	6	4.5
2	Paraffin plus a micro-crystalline petroleum hydrocarbon wax (melting point of wax, 110-145 F). Equal parts. Cost of wax, 5½ cents per lb	The addition of the higher melting-point, less brittle wax to the paraffin improves the coating. Still good after one year	8	No test
3	Paraffin plus butyl methacrylate polymer (1:1) fused together. Cost of polymer, 75 cents per lb		Greater than 10	3.1
4	Paraffin plus stearin pitch (1:1). Cost of pitch, 4 cents per lb	Some peeling of the coating near top of silo	Greater than 10	0.21
5	Paraffin plus stearin pitch (3:1)		Greater than 10	2.7
ASPHALT COATINGS	(Two coats applied in all cases, with 24 hr between coats)			
6	Grade A liquid asphalt paint. Cost, 16 cents per gal	Ensilage sticks and takes off some of the coating	Greater than 10	3.2
7	Heavy-duty black asphalt coating. Cost, $2.10 per gal	Excellent	Greater than 10	5.7
RUBBER BASE PAINTS				
8	An acid-resisting paint with a rubber derivative as a base, and containing graphite. Two coats were applied with 4 hr between coats. Cost, $3.80 per gal	Excellent	Greater than 10	8.3
9	Latex water emulsion. Applied in same manner as No. 8		Greater than 10	3.7
10	A rubber-base paint. Two coats were applied with 24 hr between coats. First coat thinned with 15 per cent xylol. Cost, $2.50 per gal		Greater than 10	3.9

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RESIN VARNISHES				
11	50 g of cumarone resin, 15 cu cm of fish oil, and 40 g of xylol. Stirred until homogeneous. One coat	Previous experience has shown that this coating resists disintegration for 2-3 yr	3	3.1
12	Same as No. 11, except that 10 g of 125 centipoise chlorinated rubber was dissolved in the xylol before mixing with the resin and fish oil. One coat		Greater than 10	4.6
13	A phenol modified oxidizing type alkyd applied as a 50 per cent solution in mineral spirits plus No. 11 in equal parts. One coat. Cost of alkyd solution, 13½ cents per lb	Ensilage sticks at joints of staves	Greater than 10	4.7
14	One coat of a toluol solution of a polystyrene resin, sold as a primer. (Cost, 40 cents per gal) followed in 4 hr by a coat of a regular polystyrene resin varnish		Greater than 10	4.5
15	An inert base paint containing chlorinated rubber. Two coats applied with first coat thinned considerably with a special thinner. Cost $3.25 per gal; thinner, $.60 per gal	Good	Greater than 10	2.7
16	A vinylite lacquer. The first coat thinned with 15 per cent of a special thinner. The second unthinned coat was applied after 24 hr. Cost of lacquer, $3.10 per gal; thinner, $0.15 per gal		Greater than 10	0.31
17	50 g of a chlorinated diphenyl resin, 15 cu cm of linseed oil, 10 g of 125 centipoise chlorinated rubber dissolved in 40 g of toluene. One coat. Cost of resin, 27 cents per lb		Greater than 10	0.7
18	50 g of a terpene phenolic resin (melting point 275-285F), 15 cu cm of tung oil dissolved in 40 g of xylol. One coat. Cost of resin, 11½ cents per lb		Greater than 10	3.4
19	50 g of butyl methacrylate polymer, 15 cu cm of linseed oil dissolved in 40 g of xylol. One coat. Cost of resin, $0.75 per lb		Greater than 10	0.5
20	Oxidizing type alkyd resin — chlorinated rubber formula. 10 g of the resin were dissolved in 40 g of toluene and 0.5 g of [illegible] per cent cobalt naphthenate drier were added. Ten g of [illegible] centipoise chlorinated rubber were dissolved in another [illegible] portion of [illegible] and the two [illegible] were mixed. [illegible] coats applied. Cost of resin, 12½ cents per lb. Cost of rubber, 55 cents per lb	Excellent	Greater than 10	0.2
21	Oxidizing type alkyd (No. 20) [illegible] and applied in equal weight of No. 11. Cobalt and lead naphthenate driers added. One coat	Ensilage sticks around the joints between the staves	Greater than 10	4.7
MISCELLANEOUS				
22	A coal tar derivative coating. One (cold) coat applied. Cost, $0.75 per gal		Greater than 10	3.7
23	Stearin pitch. This coating was applied in the same manner as the waxes		Greater than 10	7.7
24	Equal parts of stearin pitch and stearic acid fused together and applied by the usual wax method		Greater than 10	3.5

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RESULTS OF OTHER TESTS

1 A series of coatings made up of one-half pound of a resin and two pounds of 125 centipoise chlorinated rubber dissolved in one gallon of xylol were placed on silos last summer but not tested in the laboratory. The resins used were cumarone, a liquid phenolformaldehyde, and vinsol. After one year's service these coatings appear to be in excellent condition.

2 Other waxes such as cetyl acetamide, carnauba, ceresine, and ozokerite did not give results as satisfactory as those for the waxes reported in the accompanying table. In the laboratory, beeswax and candelilla wax gave results similar to paraffin.

3 The drying oils — soy bean, linseed, cottonseed, tung, and perilla — gave little protection to the concrete. The addition of lead and cobalt naphthenate driers to the oils increased their resistance slightly. The oils, especially tung oil, did give extra resistance as primer coatings for a resin varnish.

4 The addition of flue dust, bentonite, infusorial earth, animal charcoal, sulfur, wood charcoal, and basic calcium lignin sulfonate to the cumar varnish (No. 11) did not increase the resistance.

5 Natural resins, such as amberol, paranol, and ester gum, made into a varnish with linseed oil and xylol were not as satisfactory as the average synthetic resin.

6 Stearin pitch was successfully dissolved in a number of coal tar solvents and drying oils, but these solutions failed as coatings, because they possessed a brittleness that made them flake off easily when the concrete was brushed.

CONCLUSIONS

1 The most important consideration with waxes is their ease of application. Failures among the waxes are mostly due to high melting points and difficulty in applying the wax before it solidifies. Rapid solidification leads to brittleness and peeling, permitting disintegration to start. Good results were obtained with a mixture of paraffin and a softer, less brittle wax such as the microcrystalline petroleum hydrocarbons.

2 Asphalt coatings in general are very resistant to weak acids, but they often cause ensilage to adhere.

3 Most rubber-base paints have high acid resistance. The difficulty encountered in their use is the maintenance of a good bond between coating and concrete.

4 A chemically resistant resin varnish containing chlorinated rubber usually gave good results. The resin penetrates the concrete and forms a good bond, while the chlorinated rubber at the same time gives toughness and extra resistance to the coating.

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