Preliminary Report on Skid Resistance of Linseed Oil-Coated Concrete

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•ANYONE who has read the American Society for Testing and Materials (ASTM) Special Technical Publication No. 366 (1) knows that there are many ways to measure skid resistance of road surfaces. Data are comparatively easy to collect, but their interpretation is sometimes difficult. During the past several years, we have collected data and gained some information and experience in coating concrete with linseed oil and in measuring skid resistance. A coating of linseed oil properly applied imparts resistance to freeze-thaw cycles and to salt for both air- and nonair-entrained concrete made with portland cement. Our studies on the skid resistance of the linseed oil-coated concrete are reported in this preliminary paper.

Initially, we undertook studies on our own parking lot with a static tester and, later, with a British portable (BP) tester (2). In 1966 and 1967, we arranged with Districts 3 and 4, Illinois Division of Highways, to carry out skid-resistance tests with the BP tester. Attempts to coordinate our testing with the BP tester, and testing with the Portland Cement Association (PCA) trailer on suitably oiled areas, were successful for only a limited period in 1967. Although these tests are preliminary in nature, we believe that a report of our findings will guide others working with linseed oil as a coating for concrete.

EXPERIMENTAL

Materials and Methods

Compounds used were the National Flaxseed Processor Association (NFPA) anti-spalling compound and a linseed oil emulsion developed at the Northern Laboratory (NU). The NFPA compound contains equal volumes of boiled linseed oil and mineral spirits (3). The NU emulsion compound is prepared from equal volumes of soil and water mixtures (4). The emulsion contains 50 volume percent of a mixture containing 97 percent of boiled linseed oil and 3 percent of saturated tallow alcohols and 50 volume percent of a water phase containing 0. 37 percent sodium hydroxide and 0. 03 percent dipicolinic acid and water 99. 6 percent (by weight). Characteristics of the NFPA solution and the NU emulsion are given in Table 1.

Application of Coating

The NFPA and NU compounds were applied by several procedures: paint brush for small areas, portable spray tank for somewhat larger areas, and spray bar rigs mounted behind trucks for bridges and roadways.

When a brush was used on squares on a closed section on an Interstate road, the compound was measured out for a given area and applied much in the same manner as painting. A 3-in. pig bristle brush of good quality was used. A DeVilbiss[1] MBC paint

[1]Mention of firm names or trade products is made for information only and does not constitute endorsement by the U. S. Department of Agriculture over other firms or similar products not mentioned.

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TABLE 1

CHARACTERISTICS OF LINSEED OIL "COMPOUNDS"*

Property	NFPA Solution	NU Emulsion
Pounds of oil per gallon	3.85	3.85
Density		
Grams per cc	0.854	0.958
Pounds per gallon	7.12	7.98
Viscosity (Brookfield at 25 C, 60 rpm)	9	11
pH	—	11.5

*NFPA = National Flaxseed Processors Association.
NU = Northern Regional Research Laboratory.

sprayer was used on our north parking lot and sidewalks. This portable sprayer operates satisfactorily with both NFPA and NU compounds at 35 to 40-psi air pressure. A measured amount of material was sprayed over a given area.

Bridges and roadways were coated with spray bar rigs mounted on small carriage wheels behind trucks. The rigs varied from location to location. Width of spraying bar varied from 6 ft to ones that covered one lane on an Interstate bridge including gutter and sidewalks. Compound was sucked by gear pump from a 55-gal drum mounted on the truck. Some rigs had wind shields on each side of bar, but others did not. The pumps usually supplied the material to the spray rig at about 40 psi.

The sand used in these tests was furnished by the State and passed their specifications for fine aggregate. The fly ash was furnished by the Chicago Fly Ash Company. Sand and fly ash were spread on test squares from different hand shakers specifically made for the purpose. Sand was spread on bridges by a workman standing on a truck and throwing the sand from a shovel in an arc.

Generally, the NFPA compound and our NU emulsion were applied to previously uncoated areas at the rate of 0.025 gal per sq yd and then at the rate of 0.015 gal per sq yd for a total oiling of 0.04 gal per sq yd or approximately 0.16 lb of oil per sq yd. Additional information on the procedures for oiling is given elsewhere (3-8).

Measurement of Friction

The coefficient of friction between rubber and concrete was determined in selected areas of the NU parking lot by drawing a box over the surface by means of weights and pulleys (static tester). The bottom of the box was covered with a piece of gasket rubber ¼ in. thick, 5¼ in. wide, and 8 in. long. Coefficients were measured at 16 different places in each area (four times at each of four weights). The weight of the box empty was 666 g; with added weights, it was 1,166, 1,666, and 2,166 g. Measurements were made before and after wetting the surfaces with a thin film of water.

Measurements were also made with a BP tester (2), developed by the British Road Research Laboratory. It is a pendulum instrument. All measurements were made with a British rubber pad. Each value reported in this paper represents an average of at least five determinations, sometimes 10 or more.

The PCA trailer was used in a few tests. This trailer, described in Dillard and Mahone's monograph (1), measures the drawbar pull with both wheels locked. During some tests on dry but coated concrete about 2 to 4 hr after oiling, it was necessary to adjust the brakes because the load at 40 mph was too great for the brakes to hold.

The values reported by all three methods are the coefficient of friction multiplied by 100.

DISCUSSION AND RESULTS

Previous reports (3-8) show that linseed oil in mineral spirits and linseed oil emulsions soak rapidly into concrete. How much oil concrete can absorb depends on a number of factors. Among these are roughness of the concrete and previous treatments of the surface. Smooth, highly troweled surfaces absorb much less than rough, broomed surfaces. Often previously oiled surfaces will absorb less than unoiled. Older concrete appears to absorb less oil than new concrete.

Since we knew that concrete improperly or freshly coated with linseed oil can be slippery, we determined the skid resistance of coated concrete that had weathered for a considerable period. Sections of our north parking area at NU were selected for these tests since coated and uncoated areas were available. Two to three years after

TABLE 2

SKID RESISTANCE OF COATED CONCRETE AFTER AGING VALUES AS COEFFICIENT OF FRICTION TIMES 100

NU Parking Lot	Static Tester		BP Tester[a]	
	Dry	Wet	Dry	Wet
Coating 1 NFPA compound[b]	111	95	100	80
Coating 1 NU emulsion	101	92	104	80
Coating 2 NFPA compound[c]	100	92	101	78
Coating 2 NU emulsion	97	90	98	72
Control—uncoated	96	91	108	80

[a]British portable tester.
[b]Coating 1: One coat of linseed oil compound or emulsion at the total oil rate of 0.16 lb per sq yd.
[c]Coating 2: Two coats of linseed oil compound or emulsion at a total oil rate of 0.16 lb per sq yd.

oiling the skid resistance of the coated and uncoated areas was approximately equal (Table 2).

Visual examination of the surfaces suggests that the differences in friction values within the same test procedure are probably caused by differences in the roughness of the concrete and not by any effect of the oil. This observation is true whether measured by the static or BP tester.

Standards of skid resistance for the BP tester are values suggested by the Road Research Laboratory (2). A summary of these standards is given in Table 3.

In another series of tests, four bridges on Illinois Interstate highways were evaluated. Two were tested 6 months and 2 years, respectively, after oiling. The other two bridges had been oiled three times at 2, 3, and 5 years before the test. Data given in Table 4 show that values from the BP tester were high when the bridge decking was dry. When it was wet, bridge 1 rated "good," bridge 2 rated well above "generally satisfactory," bridge 3 was just below "generally satisfactory," and bridge 4 values were slightly lower. No bridge was potentially slippery by the suggested standards. On bridges 3 and 4, we were able to obtain data with the BP tester and the PCA trailer. The values agree well with each other although the PCA trailer gave somewhat higher values in the tests.

These data indicate that properly applied linseed oil has no long-term effect on lowering the skid resistance of concrete below standards set by the Road Research Laboratory. All areas tested in this report would be classified as easy sites.

Initial Coatings on Roadways and Bridges

Three areas were coated and tested. None had received any previous oil coating. Two areas (bridge 5 and roadway) were open to construction traffic only, but the third

TABLE 3

SUGGESTED VALUES OF SKID RESISTANCE FOR USE WITH THE BRITISH PORTABLE TESTER

Category	Type of Site	Skid Resistance on Wet Surface	Standard of Skid Resistance Represented
A	Most difficult sites, such as: a. Roundabouts (cloverleaves) b. Bends with radius less than 500 ft on nonrestricted roads c. Gradients, 1 in 20 or steeper, of length greater than 100 yd d. Approach to traffic lights on derestricted roads	Above 65	"Good"—fulfilling the requirements even of fast traffic, and making it most unlikely that the road will be the scene of repeated skidding accidents
B*	General requirements, i.e., roads and conditions not covered by categories A and C	Above 55	"Generally satisfactory"—meeting all but the most difficult conditions encountered on roads
C*	Easy sites, e.g., straight roads with easy gradients and curves, and without junctions, and free from any features, such as mixed traffic, especially liable to create conditions of emergency	Above 45	"Satisfactory only in favorable circumstances"
D	All sites	Below 45	"Potentially slippery"

*On smooth-looking or fine-textured roads in these categories, vehicles having smooth tires may not find the skid resistance adequate. For such roads, accident studies should also be made to ensure that there are no indications of difficulties due to skidding under wet conditions. All tests were made in wheel trace areas.

TABLE 4

SKID RESISTANCE OF AGED AREAS—BRIDGES ON INTERSTATE

Bridge	BP Tester		PCA* Trailer	Remarks
	Dry	Wet	Wet	
1	95	72		6 months after oiling
2	104	62		2 years after oiling
3	111	54	61	Oiled 2, 3, and 5 years before test
4	114	51	56	Oiled 2, 3, and 5 years before test

*Portland Cement Association.

(bridge 6) was open to traffic. Some of the collected data are given in Table 5. If a limited area is coated with oil, traffic appears to transfer some oil not absorbed by the concrete to the road beyond.

All three areas were potentially slippery immediately after oiling. Where oil was absorbed slowly but the road was open to traffic, the concrete recovered to the initial dry skid resistance within 3 hr and to the initial wet values within 24 hr. At 3 hr the wet values were low but still acceptable by the criteria of the British Road Research Laboratory. Bridge 5 recovered to a "generally satisfactory" rating within 3 hr. With little traffic complete recovery required some time—between 3 days and 2 months, but no data are available within this period. Bridge 6 recovered to "satisfactory under favorable conditions" in 3 hr and to original wet skid resistance in 1 day. The roadway with no traffic recovered slower than the other two areas. It was coated at 40 F. Neither the roadway nor bridge 5 was open to traffic until after wet values for skid resistance had returned to initial values.

Reoiling of Concrete

Reoiling concrete can be done without substantially lowering skid resistance, except for a rather short period after the reoiling. This period varies (Table 6). Again, the amount of applied oil and the traffic conditions appear to be factors in the rate of recovery. The recovery to initial dry skid-resistance values occurred in less than 4 hr. The wet values obtained with the BP tester showed that all three areas recovered to initial values within 24 hr. Bridge 2 received less linseed oil than bridges 3 and 4 and recovered to higher BP test values quicker. Bridge 2 had sanded and unsanded areas. The unsanded areas recovered to initial values of wet skid resistance within 2.5 hr. All three bridges showed some transfer of oil by traffic to the road beyond. Wet test values with the PCA trailer for bridges 3 and 4 were low at 3 to 4 hr and did not return to initial values in 23 hr, although at this time they were approaching initial values. Additional wet tests with the PCA trailer were not feasible then because it was needed

TABLE 5

SKID RESISTANCE OF FRESHLY OILED CONCRETE—BP TESTER VALUES

Area	Before Oiling	Within 30 Min	After 3 Hr	After 3 Days	Subsequent Tests	
					Values	Days
Bridge 5[a]:						
Dry	97	42	102	99	96	60
Wet	76	—	58	60	79	60
Bridge 6[b]:						
Dry	103	38	114	114	117	7
Wet	62	—	46	60	62	7
Roadway[c]:						
Dry	97	35	77	100	—	—
Wet	76	—	52	63	78	19

[a]Bridge was not open to traffic immediately before or after oiling. New road. Two coats of compound at total rate of 0.04 gal per sq yd. Open to construction traffic. No data available between 3 and 60 days.

[b]Bridge was 13 years old. Bridge open to traffic. Oil absorbed slowly. Value at 1 day—wet skid resistance was 63. Two coats at the total rate of 0.04 gal per sq yd.

[c]Roadway was laid same year as oiling. Not open to traffic. Oil applied in two coats at a total rate of 0.04 gal per sq yd. Open to some construction traffic. No data available between 3 and 19 days.

TABLE 6

SKID RESISTANCE OF REOILED CONCRETE[a]

Area	Before Reoiling	Within 30 Min	After 3 to 4 Hr	After 22 to 24 Hr
Bridge 2:				
Dry (BP)	104	50	112	110
Wet (BP)	62	—	58	62[b]
Wet (BP)	58	(47 dry)	61	63[c]
Bridge 3:				
Dry (BP)	111	40	110	—
Dry (PCA)	—	40	68	—
Wet (BP)	54	—	49	55
Wet (PCA)	61	—	37	48
Bridge 4:				
Dry (BP)	114	31	99 (120 at 1.5 hr)	—
Dry (PCA)	—	35	57	—
Wet (BP)	51	—	44	55
Wet (PCA)	56	—	38	50

[a]All bridges were opened to traffic between tests. Linseed oil was applied in one coat at the rate of 0.027 gal per sq yd on bridge 2 and 0.03 gal per sq yd on bridges 3 and 4. Traffic on all bridges transferred some oil to road beyond bridge. Sand was used on parts of bridge 2. These bridges are the same ones reported in Table 4.
[b]Average of oil and sand.
[c]No sand applied.

elsewhere. The rate of change of the wet values between 4 and 24 hr was sufficient to predict that both bridges 3 and 4 would recover their original PCA values shortly.

Use of Abrasive Materials

Sand and other abrasive materials are sometimes used to reduce slipperiness of surfaces. Spreading an abrasive material serves two purposes: (a) it can absorb material on the road that may cause the slipperiness, and (b) it may increase the skid resistance of the surface. Tests were run on bridges that were open to traffic and on small squares closed to traffic (Table 7).

Results given in Table 7 do not show any particular merit in using sand to decrease the slipperiness of linseed oil-coated areas. Sand may assist in removing excess oil. Wet skid-resistance values for sanded areas 3 hr after application of the oil were lower than values for unsanded areas. At 24 hr and at 7 days, most of the sanded areas had recovered to the initial values. Almost all the sand was gone, and visual inspection showed that some oil was carried off or absorbed by the sand in the traffic areas, as well as the areas closed to traffic.

Fly ash in these limited tests does show an advantage at 3 and 24 hr after oiling compared to sand or oil alone. Recovery to original skid-resistance values was achieved. The fly ash darkens the concrete, and it might be objectionable for this reason.

Amount of Oil for Application

The amount of oil that should be applied to a specific area of concrete needs to be studied further. On concrete that has not been previously coated but has set for 28 to 30 days, 0.16 lb of oil per sq yd (0.04 gal of compound per sq yd in applications of 0.025 and 0.015 gal per sq yd) appears to be suitable. The finishing or other surface treatment can vary this amount. In an area finished with a trowel, the desirable

TABLE 7

USE OF ABRASIVE MATERIALS WITH LINSEED OIL—BP TESTER VALUES

Area[a]	Initial	Oil Only			Sanded			Fly Ash		
		3 Hr	24 Hr	7 Days	3 Hr	24 Hr	7 Days	3 Hr	24 Hr	7 Days
Bridge 2:										
Dry	104	112	110	108	112	111	109	—	—	—
Wet	62	61	63	63	57	61	61	—	—	—
Bridge 6:										
Dry	103	120	119	115	112	114	118	—	—	—
Wet	62	53	66	61	44	61	63	—	—	—
Roadway squares:										
Dry	85	92	108	103	81	100	96	74	90	101
Wet	64	56	49	55	63	52	57	65	61	62

[a]Bridges 2 and 6 were open to traffic. Roadway was not. Fly ash darkened the road area considerably. See Tables 5 and 6 for rates of oiling for bridges. Roadway was coated by brush at the total rate of 0.04 gal per sq yd of compound; square 3 X 3 ft were coated.

TABLE 8

EFFECT OF SURFACE TREATMENT ON SKID RESISTANCE VALUES—BP TESTER VALUES

Surface Treatment	Dry	Wet	Remarks
Trowel	76	60	Oil coated 2½ years before with 0.08 lb per sq yd
Broom:			
1	93	83	Oil cured 2½ years before
2	96	77	Oil cured 2½ years before
3	99	80	Wax resin cured 2½ years before
4	100	82	Uncoated
Burlap drag:			
1	108	80	NU parking lot, 3½ years old, uncoated
2	97	76	Interstate, uncoated

amount appears to be less than 0. 08 lb of oil per sq yd. Attempts to coat troweled areas at NU with this amount gave slippery spots. Most areas finished with a broom or bag appear to absorb 0. 16 lb per sq yd if given sufficient time. Troweled areas do not have as high skid resistance as broomed or burlap-dragged areas. The latter two appear to be about equal in skid resistance, as evidenced by data in Table 8.

Age of the concrete may also be a factor since studies showed that older concrete absorbs oil less rapidly than new concrete. For example, recovery from initial slipperiness was very rapid with our broom-finished NU sidewalks when they were new and initially coated with 0. 16 lb per sq yd. When these sidewalks were 2. 5 years old, previously uncoated areas were coated with the same amount and appeared slippery. They had not recovered their original skid resistance after 2 months; Table 9 gives BP tester values on the areas that received no previous treatment or were treated with wax resin. In the same table, note that the previously oil-cured sidewalks did recover to approximately the original high skid-resistance values when coated with 0. 10 lb per sq yd. Slightly more, or 0. 12 lb per sq yd, did not permit rapid recovery.

Rapid recovery was made with either reoiling or new oiling of old concrete where traffic transferred excess oil to the roadway beyond the area of application. Data in Table 10 for heavily traveled bridges 2, 3, and 6 show that 3 to 24 hr was sufficient for recovery to original wet values. Where traffic was light, more than 24 hr was required to attain skid-resistance values equal to the original values before oiling. Although the section of roadway had achieved BP tester values of 61 in 24 hr, which the Road Research Laboratory criteria consider "generally satisfactory," recovery to original skid-resistance values did not occur until sometime between 3 and 19 days.

Other factors may be involved in recovery of skid resistance, such as temperature of the concrete and air above it, wind velocities at and shortly after application of the oil, and dryness of the concrete. Some data related to the effect of temperature are given in Table 11. Note that the roadway had not recovered a dry skid resistance equal to the initial value within 3 hr, but it did recover original dry skid resistance in 19 hr. Procedures need to be developed for determining how much linseed oil should be applied under a given set of conditions, such as a specific concrete area, time permitted for absorption before the road is reopened to traffic when the road is dry, time permitted if the road becomes wet shortly after oiling, and how rapidly the oil is absorbed.

Precautionary safety measures should be taken when operations lead to conditions that are hazardous. The extent of these measures will depend on the conditions. Among

TABLE 9

EFFECT OF AMOUNT OF OIL ON SKID RESISTANCE VALUES—NU SIDEWALKS

Amount of Oil (lb/sq yd)	Wet BP Values		Previous Treatment
	Before Oiling	Two Months After Oiling	
0. 16	82	58	None
0. 16	80	57	Wax resin 2½ years before
0. 10	83	78	Oil cured 2½ years before
0. 12	77	58	Oil cured 2½ years before

TABLE 10

EFFECT OF THE AMOUNT OF OIL AND TRAFFIC CONDITIONS ON WET SKID RESISTANCE VALUES

Area	Amount of Oil (lb/sq yd)	Traffic Conditions	Before Oiling or Reoiling	Wet BP Tester Values, Time After Oiling		Subsequent Tests	
				3 Hr	24 Hr	Values	Days
Bridge 2	0.108 (reoiling)	Heavy (sand and no sand)	62	58	62	61	7
		Heavy (no sand)	58	61	63	63	7
Bridge 3	0.12 (previously oiled 3 times)	Heavy	54	49	55	—	—
Bridge 5	0.16 (new pavement, 6 months old)	Light	76	58	60 (3 days)	79	60
Bridge 6	0.16 (first oiling, old pavement)	Very heavy	62	46	63	62	7
Roadway	0.16 (new pavement, 2 months old)	Light	72	52	61	63	3
						79	19

TABLE 11

EFFECT OF TEMPERATURE ON RECOVERY OF DRY SKID RESISTANCE VALUES

Area	Original	After 30 Min	After 1 Hr	After 3 Hr	Temperature, F
Bridge 2	100	46	106	115	66
	105		100	112	
Bridge 5	97	42	—	102	100
Bridge 6	102	43	94	120	61
	103	36	54	116	
Roadway	97	35	—	77	40
				108 (19 hr)	

the more important factors are the amount of oil applied, the temperature of the road, the weather, the age, finish and previous coatings of the concrete, the extent of traffic and the nature of the road area. Highway officials should give consideration as to what the precautionary measures should be. Under ideal conditions, the concrete is slippery for a short period after application, usually less than an hour, and only slightly longer when the pavement is wet. When conditions are less than ideal, these periods of slipperiness as measured by the BP tester and the standards of the Road Research Laboratory are only slightly increased. The time to complete recovery of original skid resistance was extended for varying periods and depended on the conditions.

SUMMARY AND CONCLUSIONS

Linseed oil compounds can be applied to new, old, and previously oiled concrete, and a rapid recovery to original skid-resistance values can be achieved. In a number of tests, dry skid-resistance values were restored within 3 hr. At a low temperature of 40 F, recovery is delayed to sometime between 3 and 19 hr. Wet skid-resistance values on test bridges usually recovered to original values within 3 to 24 hr. Longer recovery times were encountered with wet skid resistances under certain conditions such as low temperatures and no traffic. Since it is possible for a variety of reasons to apply too much oil, highway officials need to consider precautionary measures to reduce hazards. If the road needs to be open to traffic as soon as possible, certain factors need to be considered before oiling: the amount of oil to be applied; extent and nature of area to be coated; temperature of the road; the event of rain; and the age, finish and previous coatings given to the concrete. Procedures that transfer oil from a coated area speed the return of skid-resistance values to original values. A test to determine capacity of concrete to absorb linseed oil compounds is needed.

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