Use of a Very Thin Overlay to Reestablish the Skid Resistance of a Concrete Pavement

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An experimental project conducted on an old concrete pavement to evaluate two methods of reestablishing pavement skid resistance is described. Both methods involve using very thin overlays to enhance skid resistance rather than improving the structural capacity of the pavement. Good skid resistance was ensured by selecting aggregates that had proved to give superior skid performance when subjected to polishing action. Adhesion of the very thin overlay to the existing pavement surface was enhanced by the use of admixtures. Both latex and acrylic emulsions were found to be effective. Placement methods were by screeding on a 0.6-cm (0.25-in) thickness or by brooming on a 0.3-cm (0.125-in) thickness. The brooming method was successful, but the screeding was not because the material lost adhesion in many areas. Placement details and skid-test data are presented. The excellent results, in regard to both skid resistance and adhesion, warrant further applications of the technique in order to evaluate its performance under conditions of heavier traffic.

The surface of many kilometers of structurally sound concrete pavement has become worn from traffic, and this has resulted in a reduction in pavement skid resistance. This paper describes an experimental project conducted to reestablish pavement skid resistance by using a relatively economical, very thin portland cement mortar overlay (1). The structural capacity of the pavement section is neither reduced nor increased. Several techniques were evaluated in a field installation; one technique was exceptionally successful.

In the context of this investigation, a very thin overlay was defined as having a depth of 0.9 cm (0.375 in) or less. The goals were to evaluate application techniques and the adhesion of the resulting very thin overlay to the original pavement.

Good long-term skid resistance was ensured by using selected aggregate for the overlay mixture. In Indiana, two materials that exhibit outstanding resistance to polishing and also give a good macrotexture are blast-furnace slag and crushed lightweight aggregate (expanded shale) (2). Natural sand was used in some early test strips to evaluate the application techniques.

Adhesion was enhanced by using either liquid latex or acrylic emulsion in the overlay mixtures. These materials proved to be effective, and, because of the shallow depth of the most successful technique, their cost is reasonable for these applications.

SITE DESCRIPTION

The site of the field test installation was on a straight section of an old 5.5-m (18-ft) wide concrete pavement (formerly US-52) that is currently part of the Tippecanoe County, Indiana, highway system (see Figure 1). The average daily traffic is approximately 200 vehicles. The pavement is badly cracked and faulted, and there is old joint sealer adjacent to many cracks and joints. Some areas of bituminous patching exist (see Figure 2). The pavement is not in structurally sound condition. It was selected because it was convenient and available long enough to allow evaluation by a skid trailer and had some traffic and exposure to winter snow-removal operations.

FIELD TEST STRIPS

The layout of the 14 test strips is shown in Figure 3. Two application techniques, screeding and brooming, were used with different mortar mixes. This resulted

Figure 1. View of test site showing test strips in place on left side of pavement.

Figure 2. Bituminous patch on existing pavement before overlay.

Figure 3. Layout of test strips.

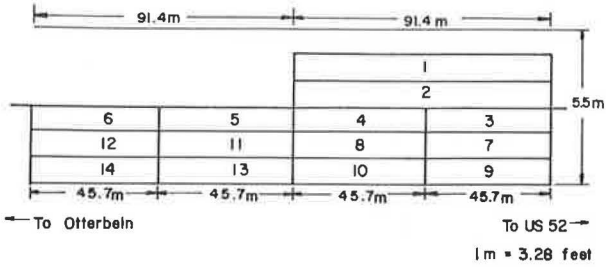


Table 1. Mix designs for test strips.

Strip	Aggregate	Absorption (%)	m[a]	Aggregate[b] (kg)	Latex[c] Percent	Latex[c] Amount (kg)	Antifoam B[d]	Rhoplex[e] Amount (kg)	Rhoplex[e] Percent	Dow Antifoam
1	Natural sand	2.5	2.75	79.43	-	-	-	-	-	-
2	Natural sand	2.5	2.5	72.63	-	-	-	-	-	-
3	Slag	4	2.5	69.29	10.66	40	0.43	-	-	-
4	Slag	4	2.75	76.20	10.66	40	0.43	-	-	-
5	Lightweight	15	1.5	45.97	12.00	45	0.48	-	-	-
6	Lightweight	15	2.0	61.29	12.00	45	0.48	-	-	-
7	Lightweight	15	1.0	30.65	12.00	45	0.48	-	-	-
8	Lightweight	15	1.5	43.97	12.00	45	0.48	-	-	-
9	Slag	4	2.25	62.36	10.66	40	0.43	-	-	-
10	Slag	4	2.0	55.43	-	-	-	32	8.50	0.43
11	Slag	4	2.5	69.29	10.66	40	0.43	-	-	-
12	Slag	4	2.0	55.43	12.00	45	0.48	-	-	-
13	Slag	4	2.5	69.29	10.66	40	0.43	-	-	-
14	Lightweight	15	1.5	43.97	-	-	-	32	8.50	0.43

Note: 1 kg = 2.2 lb; 1 m³ = 264 gal.

[a] Sand-cement ratio, by weight.
[b] Aggregate weight = (weight of cement x m) + (weight of cement x m x absorption).
[c] Liquid latex, by weight of cement.
[d] Antifoam B is 1.82 percent of latex, by weight.
[e] Liquid Rhoplex, by weight of cement.
[f] Antifoam B is 2.29 percent of Rhoplex MC-76, by weight.
[g] Total amount of water added = (water from latex + acrylic) + extra water.

Figure 4. Texture of screeded overlay.

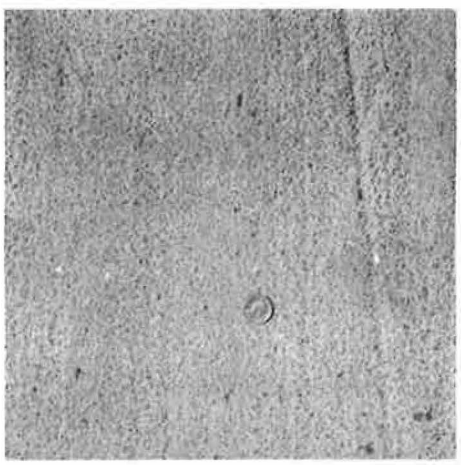


Figure 5. Brooming mortar onto old pavement surface.

in 12 overlay test strips (strips 1 and 2 were placed in October 1977 as part of the preliminary evaluation and are not considered in this paper except to say that they did not adhere well; the remaining 12 strips were placed in May 1978).

Strip 1 and strips 3-6 were all placed by screeding at an overlay depth of 0.9 cm (0.375 in) (strip 2 was broomed and had the same depth). Strips 7-14 were applied by brooming, and the overlay depth was 0.3 cm (0.125 in).

VERY THIN OVERLAY MIXTURES

A type 1 portland cement was used. Aggregates were either blast-furnace slag or lightweight (expanded shale) of sand size in which approximately 22 percent was retained on the 2.36-mm (No. 8) sieve and 11 percent on the 0.3-mm (No. 50) sieve.

The two admixtures used to enhance adhesion were Dow Latex 464, a Saran-base latex emulsion with 50 percent solids that is produced by Dow Chemical Company, and Rhoplex MC-76, an acrylic emulsion with 46-48 percent solids that is produced by Rohm and Haas Company. An appropriate antifoamer, recommended by the manufacturer, was used with both admixtures. Calcium chloride was used as an accelerator on five of the test strips.

Mixing and placement were done on site under a variety of temperatures [10°C-35°C (50°F-95°F)] and wind conditions. The water-cement ratio was varied for each mix to obtain the desired consistency. The target was a water-cement ratio of 0.45, but actual values varied from 0.42 to 0.57.

Details of each mix are given in Table 1. The variations that occurred did not have a detectable influence on either the adhesion or the skid resistance of the test strips.

APPLICATION TECHNIQUES

The overlay for each test strip was applied by hand after mixing in a small portable mortar mixer. The methods were relatively primitive because of the hand labor required. The two techniques evaluated were screeding and brooming. Both are capable of being mechanized on a larger application. Two strips were applied to dry pavement, which required more mix water for the needed consistency. All others were applied to moist pavement. Because dry pavement quickly absorbs water and liquid admixtures, stronger adhesion may result, but no difference is yet apparent.

Although the existing pavement surface was not in good condition, it was free of oil. All overlays were applied to the existing pavement without treating the

$CaCl_2$	Aggregate Moisture Content (%)	Actual Water Added (kg)	Total Water per Batch* (kg)	Actual Water-Cement Ratio	Batch Volume (m^3)
-	8.3	-	-	-	-
-	9.0	-	-	-	-
-	7.0	1.6	6.92	0.44	0.051
0.80	8.1	1.1	6.46	0.47	0.055
0.80	20.0	0.0	6.00	0.57	0.055
0.80	12.9	2.5	8.49	0.52	0.064
-	6.0	3.6	9.63	0.43	0.050
-	5.8	4.1	10.08	0.47	0.051
0.80	7.0	2.3	7.60	0.45	0.049
-	6.0	3.6	8.14	0.43	0.045
-	5.2	4.5	9.87	0.51	0.053
-	5.2	2.3	3.26	0.42	0.046
-	5.2	4.5	9.87	0.51	0.053
0.80	9.5	3.6	8.14	0.46	0.049

surface or repairing the joints. Needless to say, cracks reflected through, and the overlay did not adhere to the bituminous patches.

Screeding

The screeding procedure was used on strips 1, 3, 4, 5, and 6. After the pavement was swept, the screeding technique involved the following steps:

1. The 0.9x3.5-cm (0.375x1.375-in) doorstop molding was placed on the pavement to form a 0.9-m (3-ft) wide strip.
2. The mortar was dumped in several piles within the strip from a buggy.
3. As the mortar was spread to its approximate depth, it was brushed into the wetted pavement with a stiff broom in an attempt to improve bonding.
4. The mortar was screeded by using an aluminum channel.
5. While a batch was being periodically screeded, stops were made to patch any irregularities in the fresh overlay. This was usually done with a trowel but, if the problem area was large, the overlay was rescreeded.
6. After a batch was placed, a curing compound was sprayed on the strip if necessary. A curing compound was used only on days when a high rate of water evaporation could occur—i.e., on sunny days or warm, windy days. If curing compound was used, it was sprayed approximately 1 h after placement of the batch. When the compound was not used, it was felt that the skin formed by the latex was enough to prevent excess evaporation.
7. The forms were removed any time after the screeding was finished and before the mortar set.

The largest drawback of the screeding operation was the slow rate of overlay placement. Since the screeding was done by hand, it proved to be very laborious, and it was difficult to complete a strip in one day. Both problems could be partly alleviated by installing a vibrator on the channel. This would cause the mortar to flow into place and reduce the amount of physical work while increasing production.

A very serious problem with this technique is that of finishing. This was caused by the latex, not the application procedure. Seconds after a batch is exposed to the air, the latex forms a thin film all over the surface. This film is easily broken by vigorously working the mortar, as in brooming or screeding. When tining was attempted, however, this surface did not break and the mortar tended to tear. Since this made tining impractical, it was discontinued. The texture produced by the screeding (see Figure 4) was thought to have adequate skid-resistance qualities and was used as the final texture.

Another problem with the screeding technique was that of spreading the mortar to approximately the required depth. If this was not done properly, large amounts of mortar would build up in front of the channel and make screeding by hand virtually impossible.

The principal advantage of screeding lies in the anticipated life of the overlay. Because of its thickness, the overlay should last for many years under normal traffic conditions.

Brooming

The brooming technique was used on strip 2 and strips 7-14. After the pavement was swept clean, the brooming method involved the following steps:

1. Form molding was placed on one side of the strip 0.9 m (3 ft) from the edge of the adjacent strip (the forms were used only to mark the proper strip width).
2. The mortar was dumped in several piles within the strip from a buggy.
3. As the mortar was spread out over the strip to its approximate depth, it was scrubbed into the pavement surface with a stiff broom.
4. After the mortar was spread, a stiff broom was dragged longitudinally over it (see Figure 5) so that excess mortar was pulled forward, and the amount of pressure applied on the broom depended on the depth of the mortar and the harshness of the material (for a given area covered by one broom width, one to four passes were normally made to obtain the desired thickness).
5. The overlay was then patted with a second broom to force any loose aggregate into the overlay.
6. Curing membrane was applied after placement by use of a hand sprayer.
7. The forms were removed at a convenient time after the brooming of a batch was finished but before the mortar set.
8. After the mortar set, water was sprinkled onto the overlay two to four times for each fresh strip to keep the strip from drying.

The use of the brooming technique has three major advantages:

1. To complete a strip took a crew of five about 1.5 h, or 7.5 person-h. This would allow a crew with the proper experience and equipment to overlay a large area each working day.
2. Because of the overlay thickness, 0.3 cm (0.125 in), the yield per batch is very high.
3. No finishing was required because the brooming produces a naturally harsh surface (see Figure 6).

The primary problems in brooming were obtaining a uniform thickness and curing. When the broom was dragged forward to remove all excess mortar, the depth obtained fluctuated depending on the harshness of the material and the pressure applied on the broom. Because the overlay is so thin, these fluctuations are very difficult to see and are not detectable when one drives over the overlay. The real problem with the thinness of the broomed overlay lies in the fact that the service life of the overlay is significantly reduced.

On hot, sunny days, the overlays tended to dry very quickly if they were not cured with curing compound shortly after being placed. On the hottest days, even prompt curing was not enough to prevent detrimental water evaporation. Under these circumstances, water

Figure 6. Texture of broomed overlay.

had to be sprinkled over the overlay to prevent excessive evaporation.

Brooming is definitely the more efficient technique to use: It was four times faster to place a strip by brooming than by screeding. On the other hand, the screeded overlays are presumed to have a much longer life than the broomed overlays, not only because of thickness but also because it is anticipated that the individual aggregate particles will become dislodged from the broomed overlays. In the screeding technique, each aggregate particle is forced into the mortar by the action of the channel. In the brooming method, however, the particles tend to sit on top of the mortar so that more of each particle is exposed and the particles are more susceptible to being broken away from the mortar.

Generally, the brooming technique would be easier to use in the field because of its fast application rate. Once a local area of low skid resistance (a curve or intersection) was discovered and improvement was determined to be necessary, the area could feasibly be repaired between the morning and afternoon peak traffic hours, which would minimize traffic delays and inconvenience to drivers.

RESULTS OF FIELD EVALUATIONS

All field test strips functioned well for several months. Then, the strips placed by screeding were found to be adhering poorly to the original pavement. All delaminated material was removed before the onset of winter weather.

In contrast, the broomed overlay adhered extremely well. This has continued to be true into the second winter. Three salt applications were made by highway commission personnel. It is this method of application along with the admixtured mortar that has been successful and warrants further consideration.

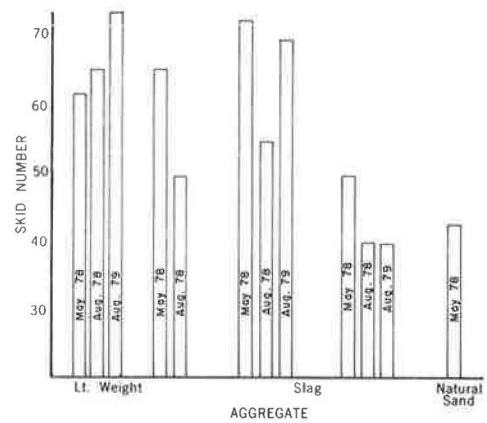
The primary reason for the success of the broomed application method is believed to be its thinness. In general, it is no more than 0.3 cm (0.125 in) thick, except for the larger aggregate particles that protrude above the nominal thickness. This thin section is fragile and many cracks can occur—for a variety of thermal, shrinkage, or flexural reasons—without destroying the adhesion of the very thin overlay to the underlying surface.

Table 2. Skid numbers determined from skid-trailer measurements at 66 km/h (40 miles/h).

Test Overlay Number	Skid Number			Standard Deviation[a]		
	5/31/78	8/31/78	8/11/79	5/31/78	8/31/78	8/11/79
1[b]	40.6			-		
2[b]	43.2			2.66		
3	38.2	34.2		2.57	2.27	
4	34.2	32.9		3.78	0.83	
5	39.4	39.2		3.46	1.10	
6	40.8	44.4		-	1.50	
7	72.8	66.6		2.06	6.65	
8	61.8	65.0	73.4	1.32	-	2.67
9	50.9	42.7	50.0	2.10	1.44	2.95
10	49.1	39.8	39.8	1.66	-	3.14
11	72.6	54.8	69.3	2.27	4.17	3.11
12	59.0	55.2		1.71		
13	62.8	49.4	62.4	3.40	7.74	2.81
14	65.2	49.5		1.96	-	-

[a]Based on three measurements.
[b]Preliminary evaluation data recorded one week after completion of overlay 2.

Figure 7. Skid-trailer measurements.



Local traffic was allowed to start passing over the thin overlays on the evening after the overlay placement. Sometimes this was only 4 h later. Obviously, a low strength exists in the overlay materials, but there is no apparent damage in the test strips, which are under the outer wheel path of the traffic.

Skid Resistance

Skid-trailer tests were conducted on each section by the Indiana State Highway Commission. The results are given in Table 2 and illustrated in Figure 7. Initially, the broomed sections had extremely high skid numbers because of the coarse texture and sharp character of the aggregate, which sometimes protruded from the surface. Traffic was sufficient to reduce that extreme, by breaking off protruding particles, to levels that are consistent with those of a new concrete pavement. Both slag and lightweight aggregate are producing good results, as are both the latex and acrylic admixtures.

FINDINGS AND RECOMMENDATIONS

A very thin, 0.3-cm (0.125-in) mortar containing selected aggregate for skid resistance and admixtures for good adhesion gave excellent results when it was applied by brooming onto an old existing concrete pavement. The results are explained as follows:

1. The brooming technique gives a high production rate and could be used with mechanical equipment to place a small amount of material per unit of pavement area. A reasonable yield would be 273 m^2 of very thin overlay per cubic meter of mortar (250 yd^2/yd^3).
2. Adhesion has been excellent. The only delamination occurred over bituminous patches and broke away, but the layer is so thin that it breaks up without damage to traffic and without causing objectionable roughness.
3. Skid resistance equal to or better than the original good skid resistance of the pavement was established.

It is recommended that this technique be further evaluated on concrete pavement surfaces that have less than desirable skid resistance. Any application should, in our opinion, ensure the following:

1. Mortar should contain polish-resisting aggregate.
2. Admixtures for adhesion, such as latex or acrylic emulsions, should be included in the mortar.
3. Pavement surfaces should be reasonably free of oil and loose dirt. High-pressure application of water may be sufficient to remove road oil, or sand blasting may be required.
4. Vigorous brooming is required to ensure adhesion.
5. The thickness of the mortar should be kept to a minimum. It is recommended that mortar depth not exceed 0.4 cm (0.187 in). This is not intended to include protruding aggregate particles.
6. Early traffic applications should be at speeds that are either uniform or less than 66 km/h (40 miles/h) to reduce the problem of shear forces on the young overlay.

The Indiana State Highway Commission is developing plans for applying a very thin broomed overlay to a section of state highway in the summer of 1980.

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Applicability of Radar Subsurface Profiling in Estimating Sidewalk Undermining

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The results of an evaluation of the applicability of the geophysical technique of radar subsurface profiling to estimating the extent of sidewalk undermining are reported. It was found that there is a distinct difference between the observed radar-echo patterns from a nonundermined sidewalk and those from an undermined sidewalk. Therefore, it is feasible to determine from a radar scan the length of sidewalk that is undermined. It is also feasible to determine the approximate depth of voids beneath an undermined sidewalk, although this may sometimes be difficult to achieve.

Severe undermining of sidewalks as a result of the erodibility of certain soils is a widespread problem in Fairfax County, Virginia (1). As Figures 1 and 2 show, undermining removes the support from under the sidewalks and results in faulting of the joints, thus creating hazards for pedestrians and peripheral problems in drainage and siltation. The maintenance costs associated with the problem of undermining amount to several million dollars per year. Maintenance personnel believe that as much as $50 million would currently be needed to correct the sidewalk problems that exist throughout Fairfax County.

Most major sidewalk maintenance is contracted, and it is desirable to require reliable estimates of materials and work quantities before the contract is drawn. However, the nature of sidewalk undermining is such that only in the most extreme cases is it possible to accurately estimate repair quantities before beginning the work. The result is that quantities typically run over the limit provided for in the contract. Then, in order to complete the necessary work in a given area, a new contract must be let at additional administrative costs and often at prices less favorable than those in the original contract.

Clearly, a reliable method of estimating the quantity of work required in the repair of an undermined sidewalk would be of great benefit to field engineers charged with the responsibility for maintaining sidewalks. The research reported in this paper was per-