Pavement Overlays Using Polyester Resin and Asphalt Laminates

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●SELECTED PLASTICS have found wide use in industry because of their high tensile, flexural, and adhesive strength. These qualities, along with resistance to fuel, water, oil, detergents, and oxidation make some of them especially attractive to the highway engineer for pavement coatings.

The major limitations on current overlay systems are high initial cost and the need for precise control and timing during construction. It is now possible to apply resins with controlled setting rates over asphalt concrete (AC) or portland cement concrete (PCC) surfaces (1). With this type of system a substantial improvement in skid resistance, solvent resistance, and durability can be realized compared with conventional coatings and overlays. This paper describes a new overlay method that has these advantages. It is based on ordinary seal coat application methods which simplify construction problems. In addition to asphalt, polyester resin and selected aggregates are used to obtain the desirable qualities needed in the pavement overlay. This new overlay has been demonstrated to be effective by means of several large-scale field tests. The new method is the subject of pending patent application.

DEVELOPMENT OF A LAMINATED SYSTEM

Early experiments by the California Research Corporation used a polyester resin to bond quartz chips directly to a PCC pavement. The resin was sprayed by hand (2) on the surface of a wharf prepared by steam cleaning and a dilute acid etch. After nearly three years of heavily loaded vehicle traffic combined with sea spray, the surface is still intact, although the points of the quartz chips have been dulled. Figure 1 shows one of these surfaces. The cost of this type of coating can be justified where critical conditions exist.

A group of similar experiments was made on an AC main access road in the Richmond Refinery of the Standard Oil Company of California. In this case, these resin surfaces caused the existing AC to crack severely around each experimental section (Fig. 2).

To prevent these cracks around the next test pads, $^3/_8$-in. chips were first bonded by asphalt to the existing AC pavement. The purpose of the asphalt layer was to serve as a slip plane to relieve curing and thermal stresses between the existing pavement and subsequent layers of resin. Moreover, because asphalt is used for the initial bond, resin requirements are less than one-half those of the earlier systems. Precleaning is eliminated for the same reason. In this experiment, a cationic asphalt emulsion was used without precleaning other than sweeping the pavement. Chips were spread into the freshly applied emulsion; and after the emulsion had thoroughly dehydrated, the chips were sprayed with polyester resin. Another layer of $^1/_4$-in. chips was then applied, followed by another application of resin, and finally by a layer of sand. There is no sign of cracking in the overlay or in the adjacent AC. It is in excellent condition after nine months of heavy truck traffic. Figure 3 shows this coating, and Figure 4 illustrates a section of typical overlays using this system.

CONSTRUCTION OF LAMINATED OVERLAYS

All of these laminated overlays are constructed in a similar way. The first layer resembles a conventional seal coat with suitable chips or stones being imbedded in an appropriate amount of asphalt. The asphalt rate and aggregate size and type are

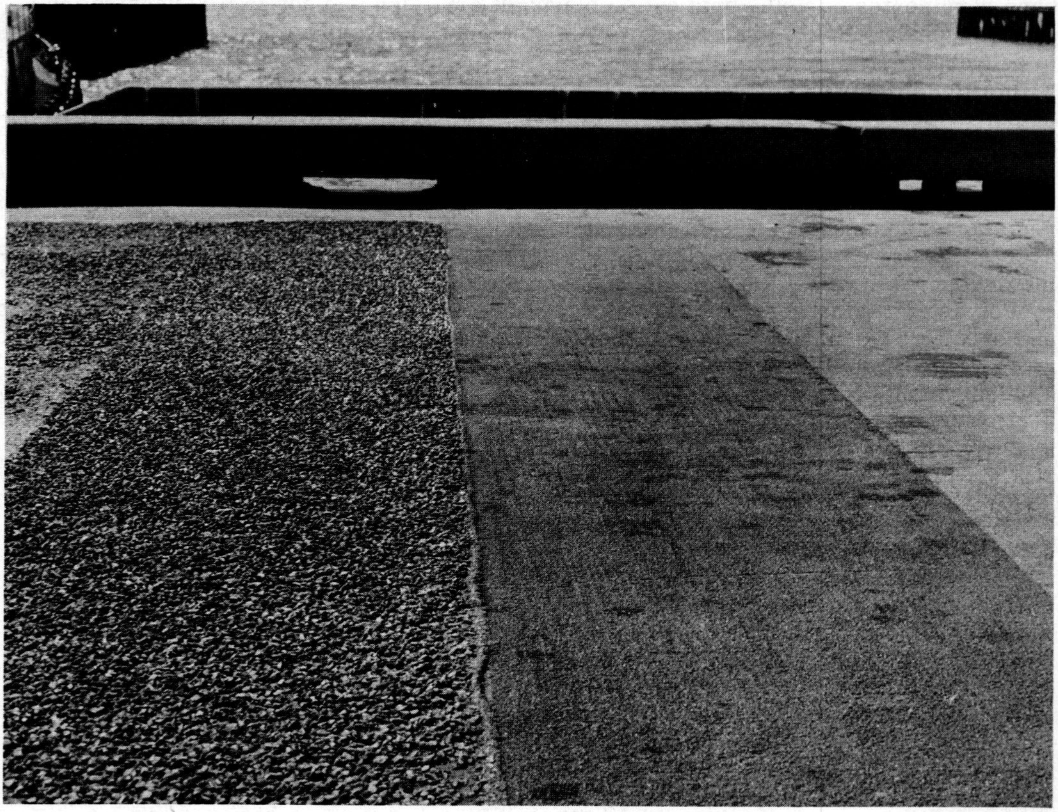

Figure 1. Condition after $2\frac{1}{2}$ yr service of large and small aggregate seal coats bonded directly to PCC with polyester resin.

selected for the particular result desired. Pneumatic-tired rolling is preferred because it gives good stone imbedment without grinding and breaking the chips. A sand "choke" follows, which provides a support to help keep the larger stones from whipping out if traffic is permitted before the resin is applied. Prior to the resin spray application, excess sand is removed by light mechanical sweeping. The sand choke, together with the chips, acts as a matrix which is bonded together by the resin. The sand further serves to absorb the resin before it reaches the underlying asphalt. This is necessary because polymerization of the resin is inhibited by contact with asphalt. A final sanding produces the desired surface texture. Multiple coats may be obtained by further application of resin and sand. Curing time can be adjusted readily from a few minutes to several hours, and thus no difficulty is encountered in opening the newly overlaid pavement to traffic. A final heavy sweeping is generally desirable to remove excess sand.

SELECTION OF MATERIALS AND APPLICATION RATES

The polyester resin and asphalt laminated systems can be easily adapted to give many different kinds of coatings. If an especially coarse-textured, high noise-level surface is needed to serve as an audible traffic warning, the initial layer is a 1-in. aggregate held in place by approximately 0.3 gal per sq yd of asphalt. Figure 5 is a close-up of a "rumble" surface. Unlike ordinary seal coats, the amount of asphalt used is not critical so long as it is sufficient to hold the stones in place until the resin is applied and is not so large that the stones are submerged in asphalt. Also, unlike ordinary seal coats, the type of asphalt used is, from limited data, not critical. Overlays have been service-tested using both cationic asphalt emulsion and hot 85/100 penetration paving asphalt. Both work well; however, the emulsion is preferred if it can be allowed to dehydrate.

If a thin, lightweight (¼-in.) overlay is required, the initial seal is made with ⅜-in. chips, or pea gravel, held by approximately 0.15 gal per sq yd of asphalt. Typical application rates, based on the Corporation's experience, are given in Table 1.

Because high durability is desired for these special overlays, care should be taken in aggregate selection. If antiskid properties are necessary, stones with high polishing resistance, or special antiskid materials, should be used. Clean, dry, "one-sized" aggregates are preferred. Grain size distributions of aggregates used in these experiments are given in Table 2.

Polyester resins were selected because of their great strength, chemical resistance, and excellent bonding qualities. These resins have low toxicity, cure well in the temperature range of 40-150 F, and have a viscosity convenient for spraying and mixing at ambient temperatures (3).

CONSTRUCTION EQUIPMENT

Procedures for making the initial seal coat with asphalt follow conventional practices and use readily available equipment. Asphalt emulsions or hot asphalt are spread by spraying with an ordinary distributor. Coarse chips may be spread by tailgating from

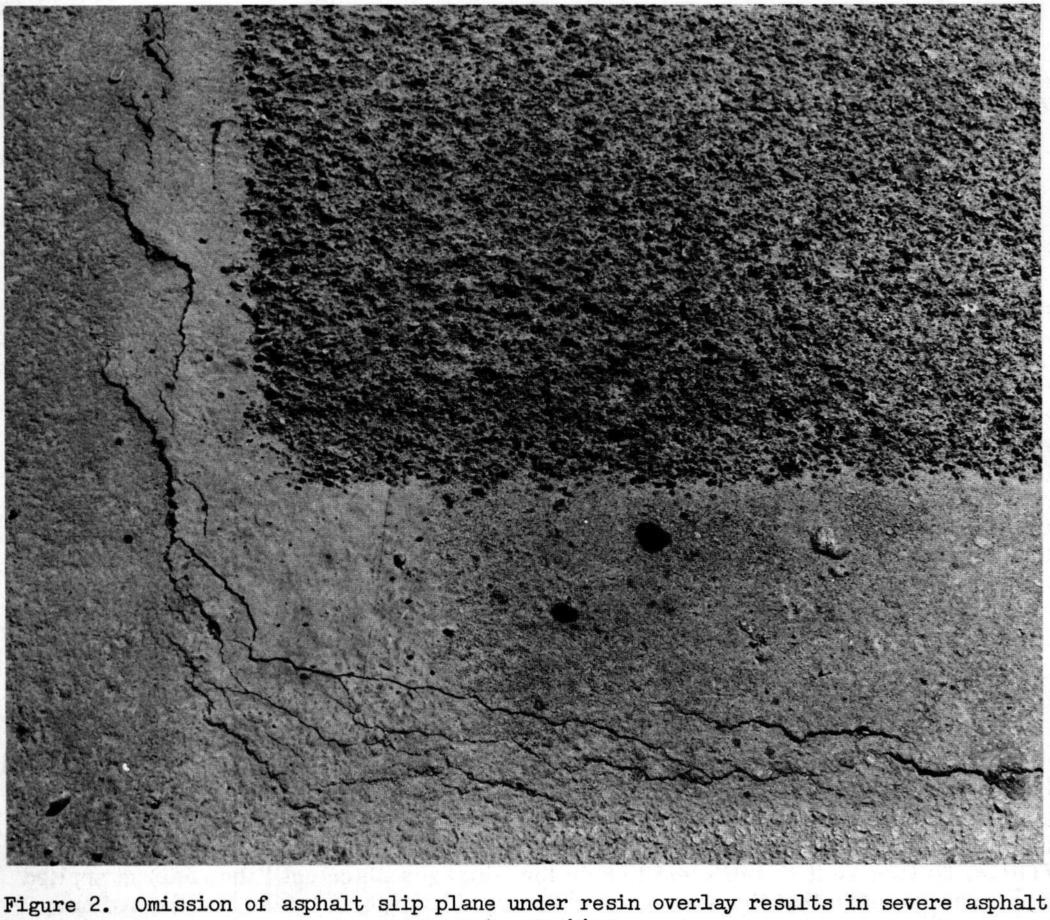

Figure 2. Omission of asphalt slip plane under resin overlay results in severe asphalt concrete cracking.

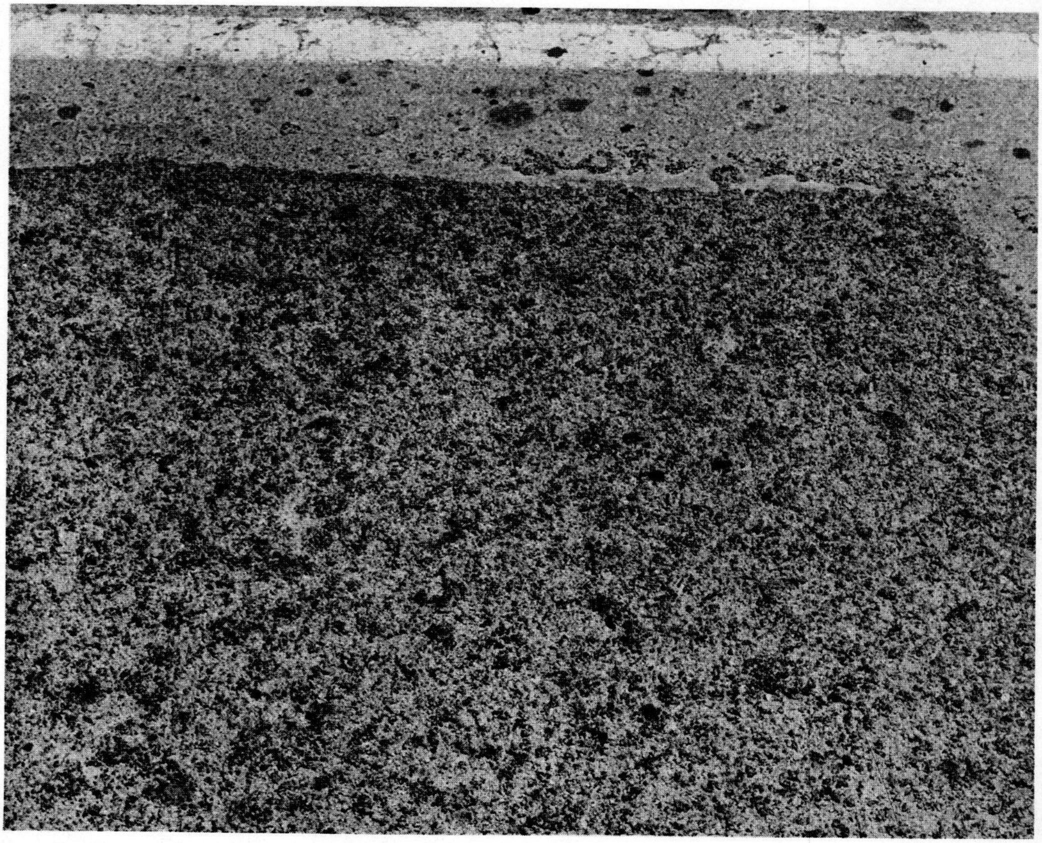

Figure 3. Properly used asphalt slip plane under polyester overlay. No sign of cracks in asphalt concrete after 9 mo. service.

a truck or, preferably, with a commercial self-propelled chip spreader. Sand application may be ty tailgating as well.

To obtain accurate and close control of aggregate spreading rates needed for experimental purposes, the small belt spreader shown in Figure 6 was constructed. It consists of a wheel-mounted, 10-ft wide hopper feeding a moving continuous belt. Belt and forward speeds are controlled by separate variable-speed electric drives.

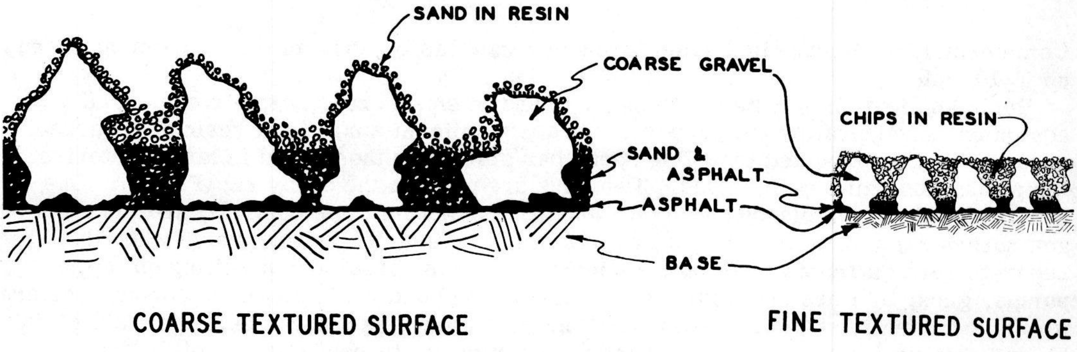

Figure 4. Sectional diagram of laminated overlays.

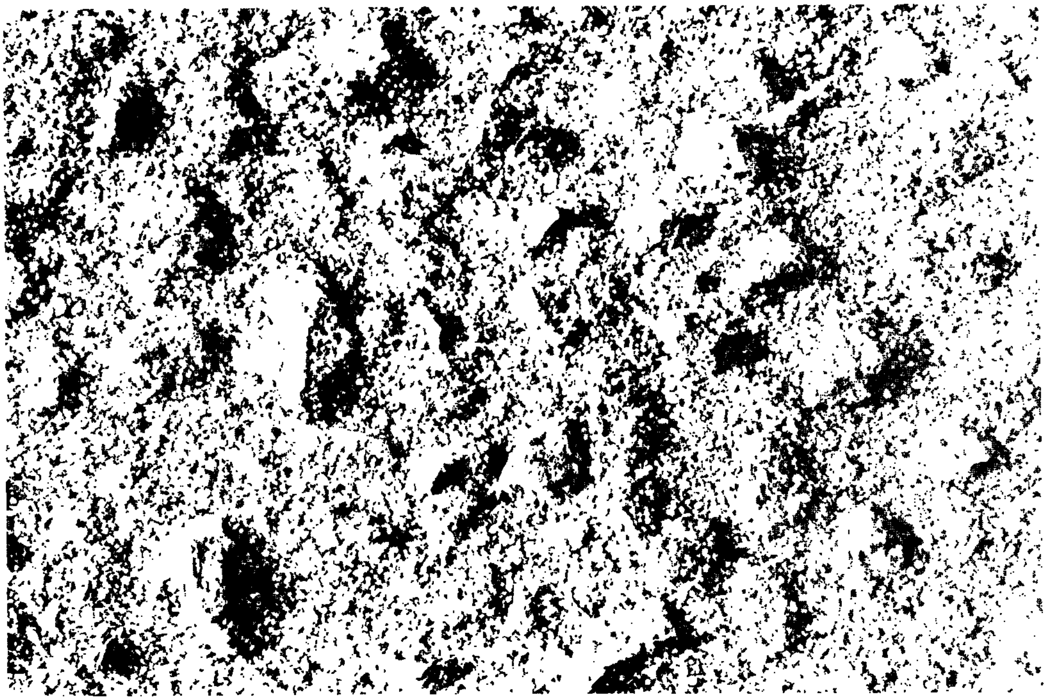

Figure 5. Rumble strip surface texture using 1-in. chips.

TABLE 1

MATERIAL REQUIREMENTS FOR POLYESTER RESIN AND ASPHALT LAMINATES

Overlay Types	Overlay Uses	Avg Asphalt Spray Rate (gal/sq yd)	Coarse Aggregate Type	Coarse Aggregate Rate (lb/sq yd)	Polyester Resin Spray Rate (gal/sq yd)	Fine Agg for Choke and Final Cover Type	Fine Agg for Choke and Final Cover Rate (lb/sq yd)
Thin antiskid	Curves, intersections, slippery surfaces	0.15	3/8 x No. 4 chips	15	0.1	No. 8 grits	10
Thin overlay	Solvent resistance, prevent raveling	0.15	"Pea gravel"	15	0.1[a]	No. 8 sand	8
Armor coat	Heavy traffic areas	0.25	3/4- by 1/2-in chips	20	0.2[a]	No. 8 grits or sand	10
Rumble strip	Safety warning	0.30	1- by 3/4-in chips	30[b]	0.2	No. 8 sand	10

[a]Several courses of resin and fine aggregate may be applied
[b]Use sparingly to obtain coarse texture

Commercial, self-propelled chip spreaders can easily perform this function at speeds up to 10 mph.

Resin application may be performed by hand in small areas, using commercial equipment developed for the purpose. To apply uniform amounts of resin over large areas, a trailer-mounted traveling spray bar similar to those used in large factories for production painting was used. Two guns are used on the spray rig (Fig. 7). One gun sprays the resin blended with accelerator (for setting time control), and the other gun sprays resin blended with catalyst. In this fashion, the setting starts when the separate spray streams meet on the pavement. Thus, problems of setting up in the pumps, guns, or lines are minimized. The catalyst and resin mixture (without accelerator) is sufficiently stable for use within one or two days, and the accelerator and resin blend is stable for weeks. Ample time for equipment cleanout is available. The

TABLE 2

GRAIN SIZE DISTRIBUTION DATA FOR OVERLAY AGGREGATE

ASTM Sieve Designation	Square Opening (mm)	Cumulative Percent Passing by Weight					
		3/8-in. Chips	"Pea Gravel"	3/4-in. Chips	1-in. Chips	No. 8 Grits	No. 8 Sand
1¼	31.7	-	-	-	-	-	-
1 in.	25.4	-	-	-	100	-	-
3/4 in.	19.1	-	-	100	92	-	-
1/2 in.	12.7	-	-	37	31	-	-
3/8 in.	9.52	100	100	24	5.6	-	-
No. 4	4.760	56	91	3.0	0.2	-	-
No. 6	3.327	28	1.0	1.3	-	100	-
No. 8	2.380	8.0	0	0	-	81	100
No. 10	2.000	4.0	-	-	-	39	93
No. 16	1.190	0	-	-	-	0	24
No. 20	0.840	-	-	-	-	-	1.0
No. 30	0.590	-	-	-	-	-	-

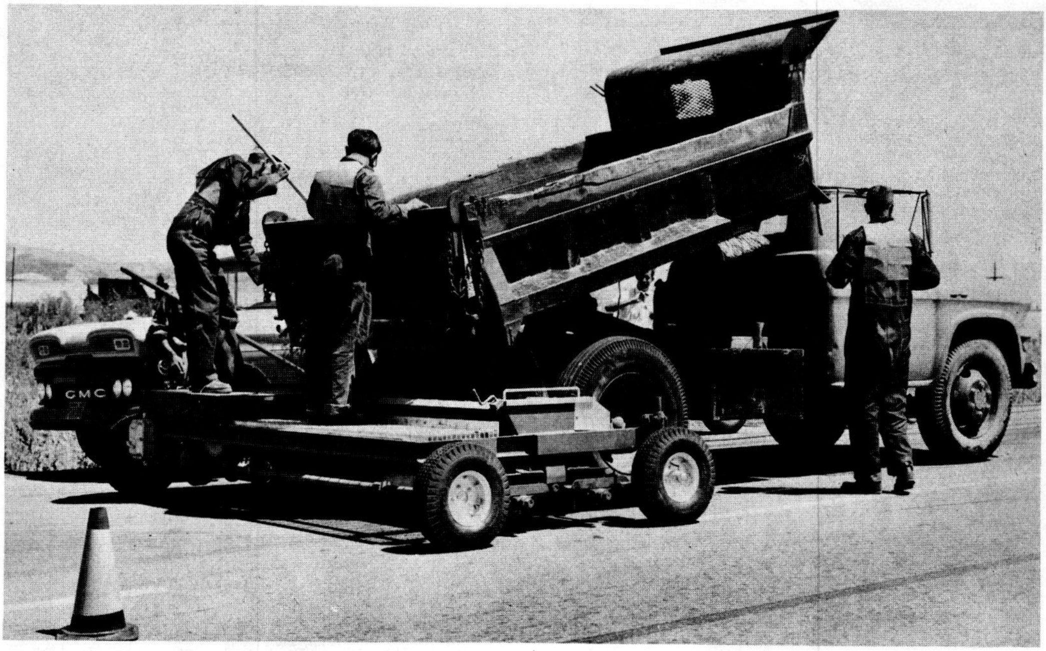

Figure 6. Loading chip spreader with aggregate.

separate guns are supplied with resin under pressure from two air-operated pumps. Pumps and resin containers are placed in the spray rig (Fig. 8). Application rates are controlled by pump pressure and forward speed of the rig.

To obtain the close control of spray rates desired for their experiments, forward movement of the spray rig is adjustable by a variable-speed electric drive from 0-20 ft a minute. Transverse speed of the moving guns is also adjustable, but 240 ft a minute has proved to be a practical rate. Automatic gun shutoff is easily adjusted to control spray widths from 2-10 ft. Application rates are independent of the spray width because the spray gun movement is always the full width of the spray bar.

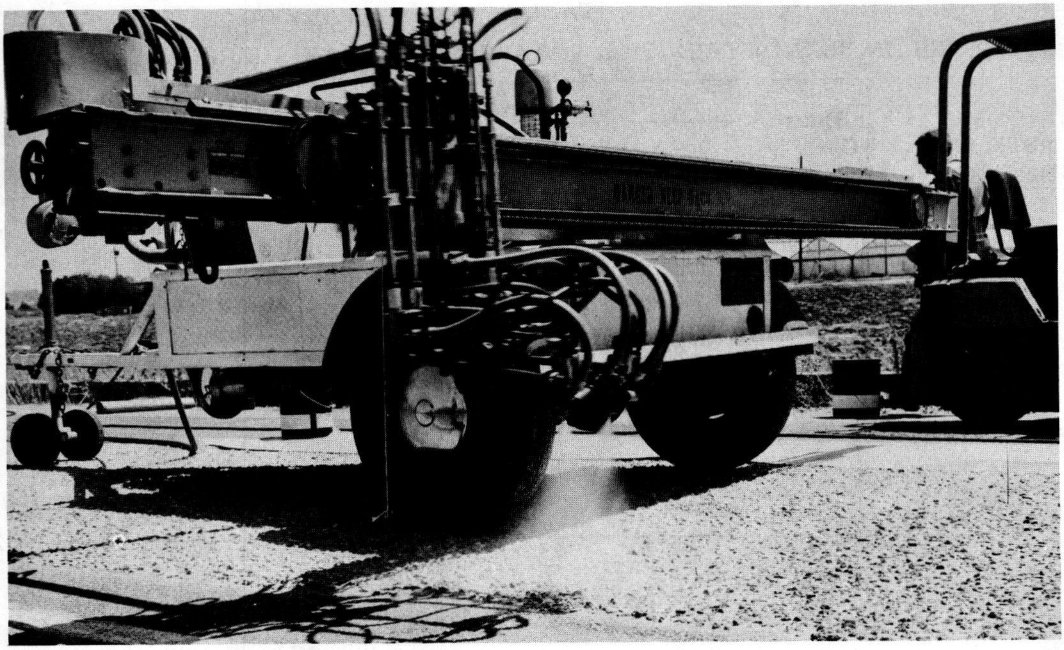

Figure 7. Resin spray rig in operation on rumble strip.

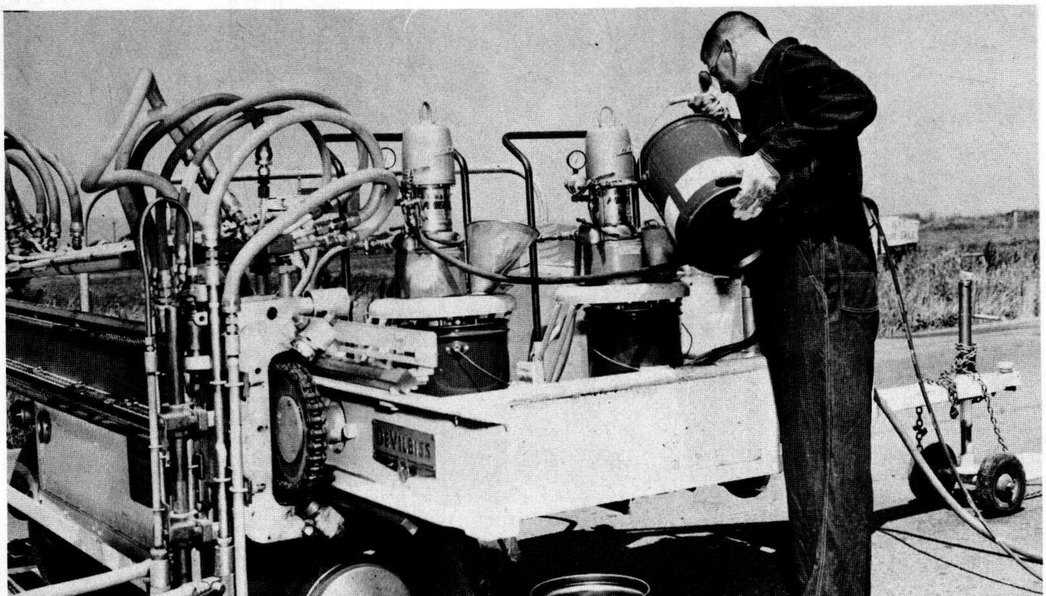

Figure 8. Filling spray rig resin containers.

This method, using traveling spray guns, is preferred to a gang of multiple spray heads because of ease of calibration and control for experimental work. Where very large areas are to be coated rapidly, twin spray bars with multiple heads may be used.

Mixing the resin with catalyst and accelerator was done at the work site just prior to spraying. For large applications, automatic proportioning and blending equipment may be used. Recently, spray guns have been developed which meter catalyst into the resin while spraying. These should be especially useful on large projects, because premixing resin and catalyst is eliminated. Experimental procedure has been to carry a barrel of resin and a laboratory mixer in the back of a pickup truck preceding the spray rig down the road. This truck also tows an air compressor and a gasoline-driven electric generator (Fig. 9).

RUMBLE STRIP CONSTRUCTION

The first public demonstration of the durability of this new system was made on a public highway in Contra Costa County, California. The purpose was to install a traffic safety improvement called "rumble strips," designed by the County Public Works Department. The basic objective is to alert drivers, thus slowing down fast-moving cars approaching dangerous intersections or other hazards. This is accomplished by placing 25-ft long pads of rough-textured aggregate at 50- to 100-ft intervals on the appropriate lane. Previous experience with conventional rumble strips in Cook County, Illinois (4), as well as elsewhere in Contra Costa County, showed that asphalt binders do not retain sparsely placed, large-size aggregate for prolonged periods under heavy traffic unless it is fully choked with smaller-size aggregate or is a part of a multiple seal coat. This is an especially serious problem because the initial hazard may be increased rather than diminished by loose stones and slippery surfaces.

This first installation was made during July 1960 on Third Street near Paar Boulevard outside of Richmond, California. A major portion of the finished job is shown in Figure 10. The materials and quantities used are given in Table 1, except that the asphalt rate was 0.4 gallon per square yard. Aggregate gradings are shown in Table 2. Six pads were constructed on AC, two pads on the PCC bridge deck, and an antiskid pad at the

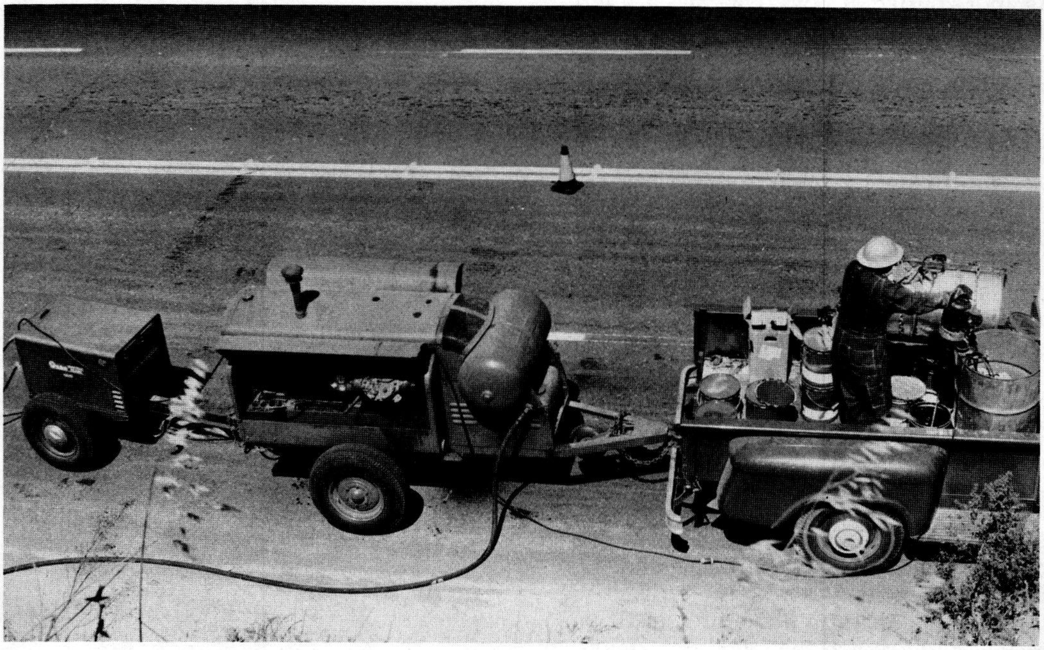

Figure 9. Truck for resin blending tows air compressor and generator.

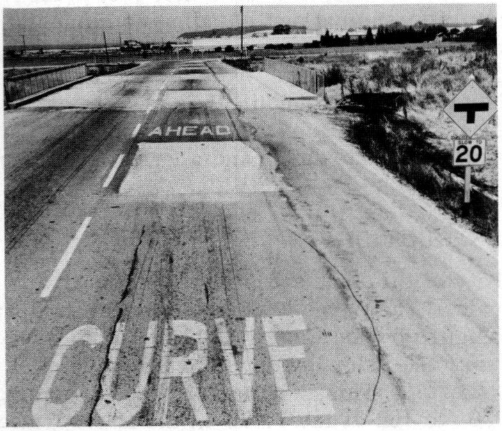

Figure 10. Several completed rumble strips north of Richmond, California.

intersection using the same general procedure. The materials recommended in Table 1 for antiskid pads were used. The asphalt rate was 0.25 gal per sq yd, and the resin rate was 0.20 gal per sq yd.

A second group of rumble strips (Fig. 11) was opened to traffic in August 1960 in the northbound lanes of San Pablo Avenue (business, US 40), approaching a stop sign south of Rodeo, California. In addition, an antiskid pad was installed on the last 90 ft before the stop sign. The 12 strips were designed as an experiment to study the following variables: type and amount of polyester resins, amount of asphalt, size and shape of aggregate, and the use of fine fillers in the resin. Some sections were purposely underdesigned to determine optimum conditions.

The several kinds of polyester resins were included in this field test to establish the optimum resin properties for the overlay system. The characteristics of the resins used are given in Table 3. Resins A and B are high impact types and C and D, rigid types. In the Rodeo field test, all four resins were applied at rates from 0.15 to 0.3 gal per sq yd. Resin A was applied at rates as high as 0.5 gal per sq yd. In some of the experiments these resins were extended with as much as 60 percent limestone dust filler (-325 mesh).

Most of the large chips used were the 1- by ¾-in. size described in Table 2. However, some experiments included a ¾- by ½-in. crushed granite or a 1- by ¾-in. uncrushed gravel. In these particular experimental sections the initial asphalt bond between the AC base and the large chips was made using hot 85-100 penetration grade asphalt applied at both 0.25 and 0.4 gal per sq yd. Also included for control purposes in this series of experiments was a section made without any resin.

PERFORMANCE OF RUMBLE STRIPS

The Richmond rumble strips are subjected to a traffic count of 900 vehicles a day (5). With the minor exceptions noted in the following paragraph, all of the strips are in excellent condition after five months' service and show no loss of stones.

There is a slight indication of asphalt bleeding through the porous resin-sand matrix on the PCC bridge deck. Apparently less asphalt may be used to bond chips to PCC. There is no evidence of this in the sections on the AC. There is no evidence of AC cracking adjacent to the coatings except in a few places where the resin was accidentally applied directly to the AC. The slip plane of asphalt between the base and the overlay appears to prevent cracking. Two cracks appeared

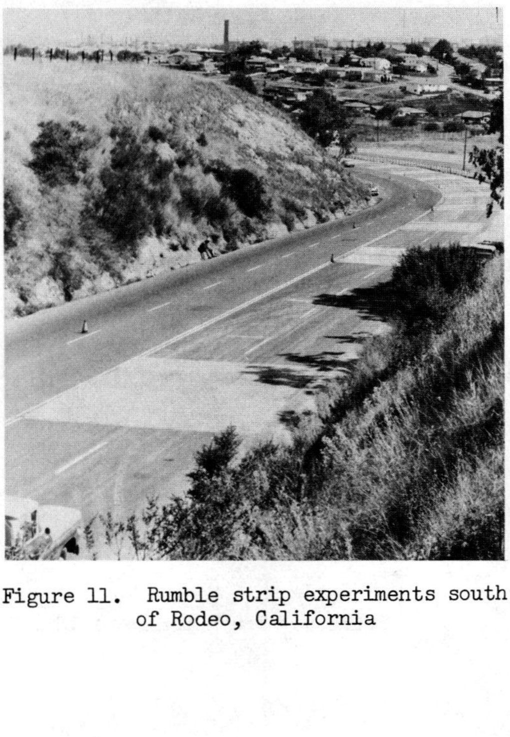

Figure 11. Rumble strip experiments south of Rodeo, California

TABLE 3

PROPERTIES OF POLYESTER RESINS USED
(Clear Casting Types Containing Styrene)

Properties	Resin A	Resin B	Resin C	Resin D
Barcol hardness	33-36	17	40-45	30-35
Flexural strength, psi	18,000	11,800	15-20,000	13-17,000
Flexural modulus, psi	4.8×10^5	2.9×10^5	5.4×10^5	6.2×10^5
Impact strength, ft-lb/in.	6-8	3-4	2.5-3	2.6
Heat distortion temperature, deg F	174	127	240-250	198
% styrene in resin	40	40	40	33

across the center of the antiskid sections. These appeared before the resin had completely cured and before traffic was allowed on the sections. This cracking appears to have occurred because an excess of resin was used which resulted in an abnormal amount of shrinkage during curing.

High noise level rumbles are obtained with the 1- by ¾-in. granite chips. At 50 mph on the uncoated pavement in a car with windows closed, the background noise level by the driver's ear was 94 decibels. As the car crossed each strip, the noise level increased to an average of 104 decibels for a fraction of a second. The significant increase in noise level, together with slight vibrations through the steering wheel, is repeated each time the driver crosses a rumble strip before the intersection. A heavily laden truck was observed to lock its wheels over this section to avoid an accident. Except for streaks of rubber, no damage was evident.

The Rodeo rumble strips are subjected to approximately 1,000 vehicle passages per day (5). After five months' traffic, periodic inspections of the nearly 200 separate tests resulted in the following conclusions:

1. In the few sections where no resin was applied, stones were lost from both the high- and low-rate asphalt application areas. Many of the stones were lost in the first two weeks. In all of the resin-coated test strips, no loss of stones was evident.
2. No cracking of the AC base is evident around the edge of the pads.
3. No cracking in the overlay was evident where moderate resin application rates were used. However, cracks appeared where large and excessive amounts of resin were used, that is, greater than 0.3 gal per sq yd.
4. Where these large amounts of resin were used, cracking was more extensive when filler content was high, presumably because the higher viscosity of the filled resin prevented adequate penetration into the sand matrix.
5. No cracks were seen in filled resin strips where spray rates were moderate, that is, 0.3 gal per sq yd or less.
6. Where sand and resin application rates were highest, rumble was low because of the relatively smooth surface.
7. At this time there do not appear to be any differences in the behavior of the four resins used. This comparison includes all resins both unfilled and filled at equal levels. At a later time, significant differences may appear.

Ratings of these test sections will be continued for several years. Present application recommendations (Table 1) emphasize durability of the overlay. However, as shown by preliminary results, substantially lower resin quantities, as well as the use of extenders, may be permissible without appreciable sacrifice in durability.

OTHER USES FOR RESIN AND ASPHALT LAMINATED OVERLAYS

As mentioned in earlier paragraphs, this new system is easily adapted to various purposes. For example, although no precise measurements of skid resistance have been made at the present installations, it is evident that there is a substantial increase in friction of the antiskid pad compared to the original pavement. Retention of high antiskid properties depends on proper aggregate selection (6). In addition, the sawtooth nature of the surface provides deep channels for water drainage and should reduce the amount of wiping action required of tire treads for high friction in wet weather.

Suitable coatings can be provided where thin, low-weight overlays are required because of dead weight or grade change limitations. Thus, commercial floors, bridge decks, and wharf decks may be benefited by the proper laminated overlay.

Although not net field tested, preliminary work shows that coatings highly impervious to solvents can also be made. Using a chemically inert resin, no damage either to the overlay or to the surface below will occur as the result of fuel spills or special washing procedures. The resin is thermosetting, and no damage by jet blasts is expected because of the exceptional strength of the system and the heat resistance of the resin.

The high tensile strength of these overlays may be of value in the structural design of flexible pavements. By bonding a resin system to both the upper and lower surfaces of an AC layer, a composite action may be obtained which greatly increases the modulus of elasticity of the surface layer. The principle would be similar to the action occurring in a wooden beam having steel flanges. The exceptional strength of laminated aircraft wing structures also depends on the same principle. Preliminary tests show this concept to be sound.

Application to emergency or military problems in stabilizing loose sands should not be overlooked. Polyester resin viscosities are low, and positive setting is rapidly attained at ambient temperatures above 40 F. Therefore, simple penetration treatments are possible.

CONCLUSIONS

Laminated resin and asphalt overlays have demonstrated their use as durable coatings under heavy vehicles and where special surface textures are required. Either large or small particles can be held firmly in place against intense traffic abuse. Rumble strip durability shows significant improvement over past practice using asphalt alone.

Conventional construction procedures and equipment are used for the most part to construct the new system; therefore, special training is not required. Although a spray rig is needed, the components are all commercially available. In addition, simpler methods for resin application are available if there is not the need for the experimental flexibility designed into the equipment as described in this paper.

All of the equipment used is portable, independent of large central plants, and may be used in remote areas. Because of this and the absence of need for pretreatment of existing surfaces, installation costs are minimum. While the initial cost of resins is high compared with those of cement and asphalt, resins have desirable properties that neither of these other materials possess. Thus, annual cost of the laminated overlay system may prove substantially lower than that of other alternatives. A number of additional uses for the resin and asphalt-laminated overlay are suggested as a result of the present installations in California.

ACKNOWLEDGMENTS

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