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Appraisal Of Alternative Methods For Restoration Pavement Surface Texture

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16. ABSTRACT

This report covers the methods that have been used to provide surface texture for worn pavements in California. Worn grooved PCC pavements appear to have the greatest need for new methods since longitudinal grooving continues as a cost effective treatment for worn PCC pavements.

For economic reasons, regrooving in the wheel paths of worn grooved pavements should be tried. If regrooving is unacceptable, it appears that diamond blade grinding is an effective texture treatment in addition to providing a desirable plane for any subsequent grooving.

Open graded asphalt concrete overlays on PCC pavements have been used successfully on lightly traveled roads and are now being evaluated on roads with heavy traffic.

Cold planing PCC pavements is not acceptable in California because of the excessive spalling at cracks, but it may be an acceptable treatment for AC pavements.

Continued evaluations of all methods are necessary because it may take ten or more years to determine the effectiveness of a surface treatment.

17. KEYWORDS

Highway maintenance, pavement surface texture, open graded mixes, grinding, grooving, rehabilitation

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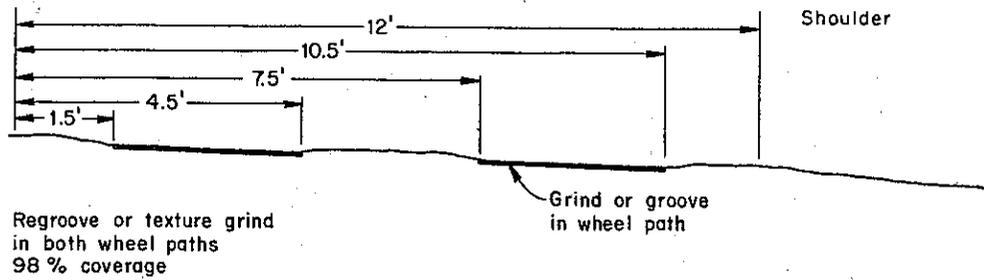
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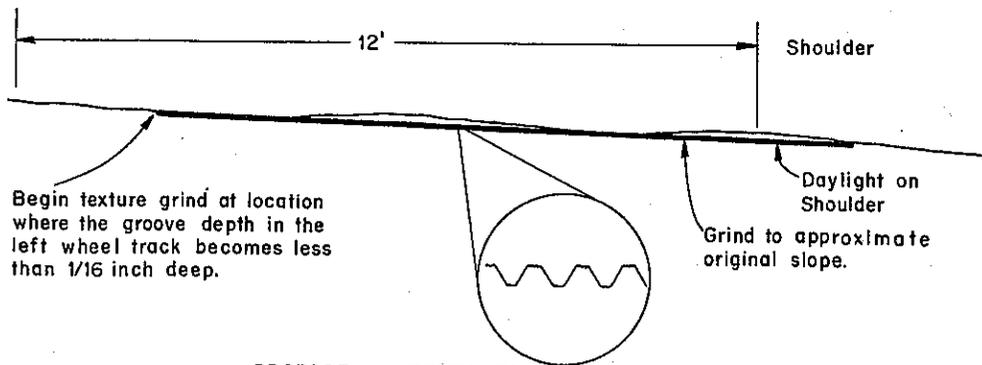
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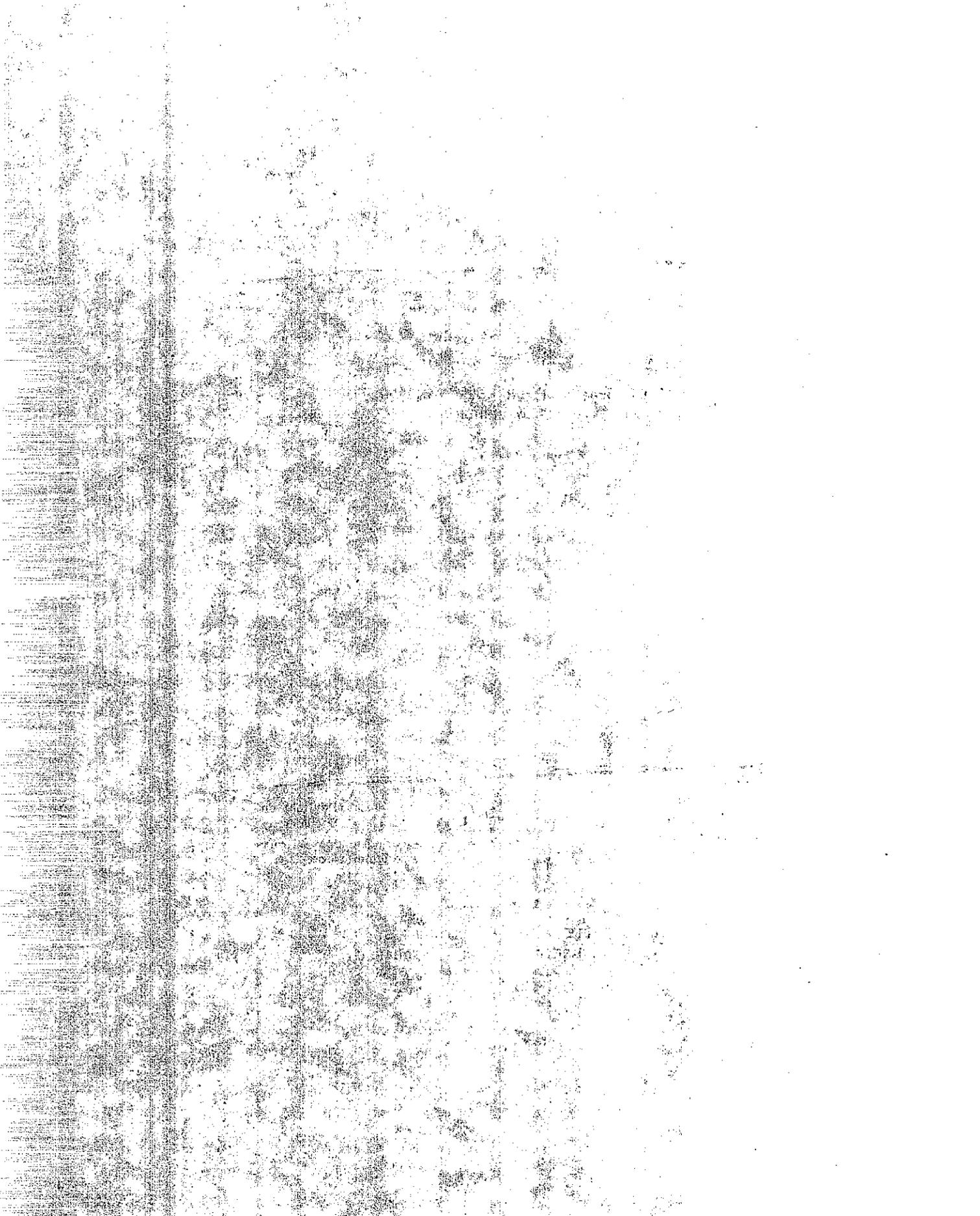
PROPOSED PATTERN FOR REGROOVING OR
RETEXTURING BY GRINDING

Figure 11



PROPOSED PATTERN FOR RETEXTURING BY
GRINDING IF FUTURE REGROOVING IS PROBABLE

Figure 12





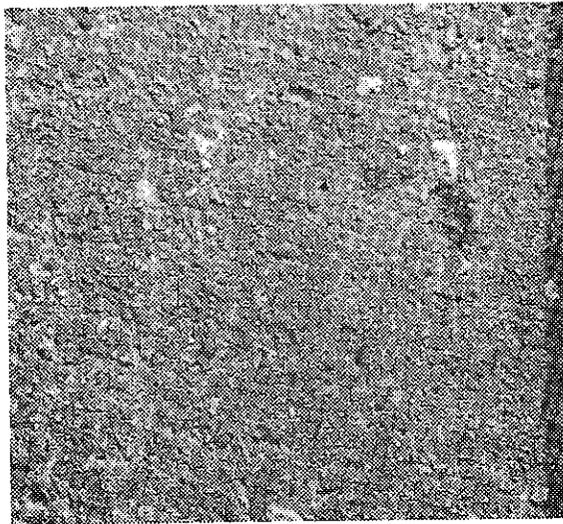
Example of spalled joints after cold planing
a PCC roadway.

Figure 10



This open graded asphalt concrete surfacing has raveled in several locations. The primary reason for the failure appears to be placement at marginally low temperatures. Also, a light and erratic tack coat probably contributed to the loss. Several failures have been patched with a DGAC mix.

Figure 9



PCC surface adjacent to OGAC overlay.



Minimal ravelling at the end of the overlay.

Figure 8



Reflection cracks will spall if not sealed.

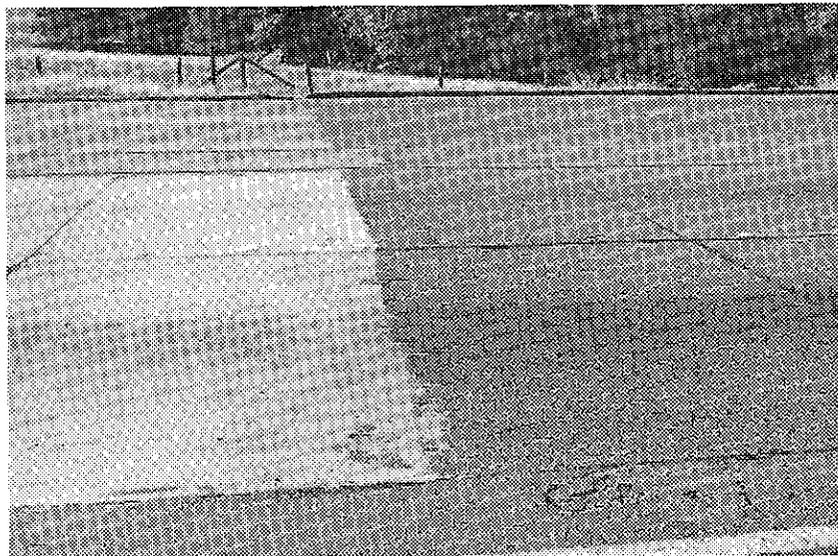


End of overlay northbound exhibits the only bond problem on the project.

Figure 7

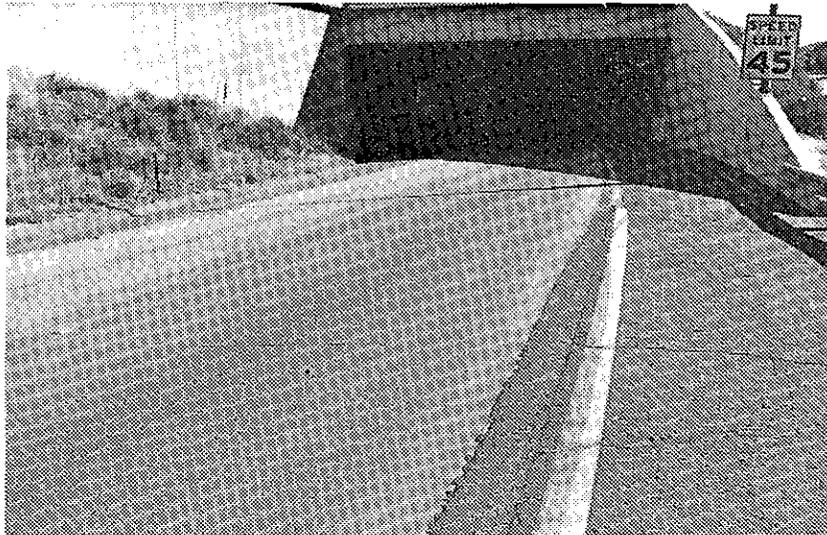


OGAC placed over PCC to delineate a turn lane.



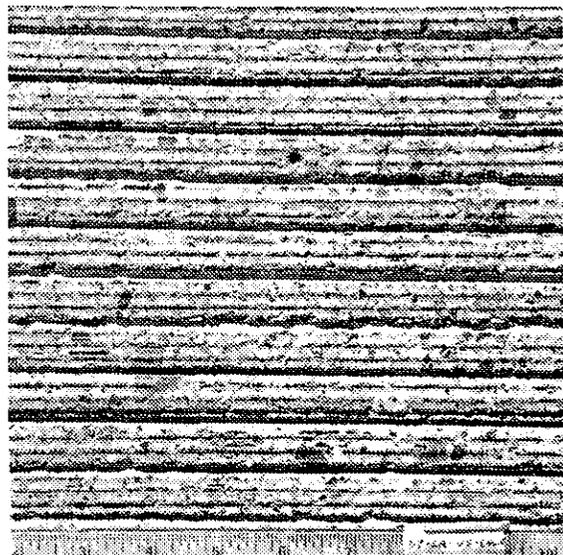
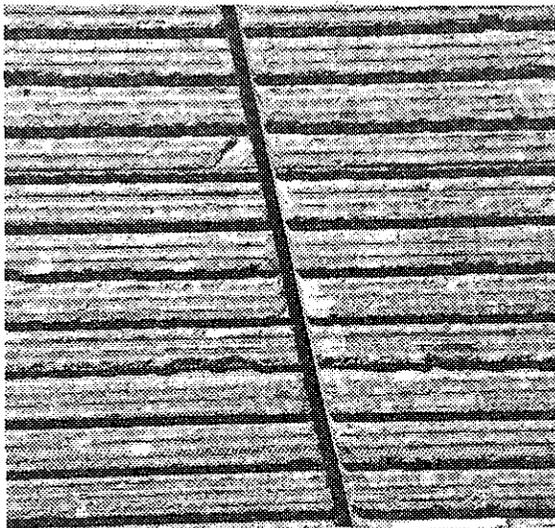
Transition indicates a very good bond to the PCC.

Figure 6



Additional texture was provided to this grooved PCC roadway by grinding.

Figure 4



Example of texture by lightly grinding (texture-grind) a grooved PCC pavement

Figure 5

FREQUENCY OF REAR END TYPE
WET PAVEMENT ACCIDENTS PER MILE

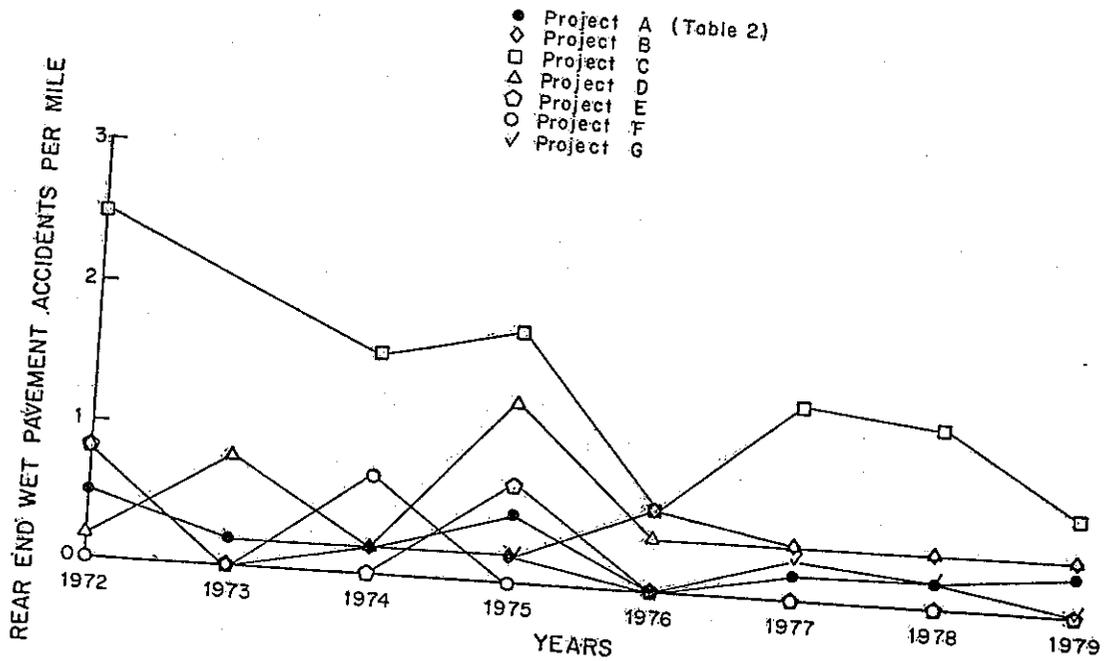


FIGURE 3

TABLE 2

Frequency of Rear End Type
Wet Pavement Accidents Per Mile

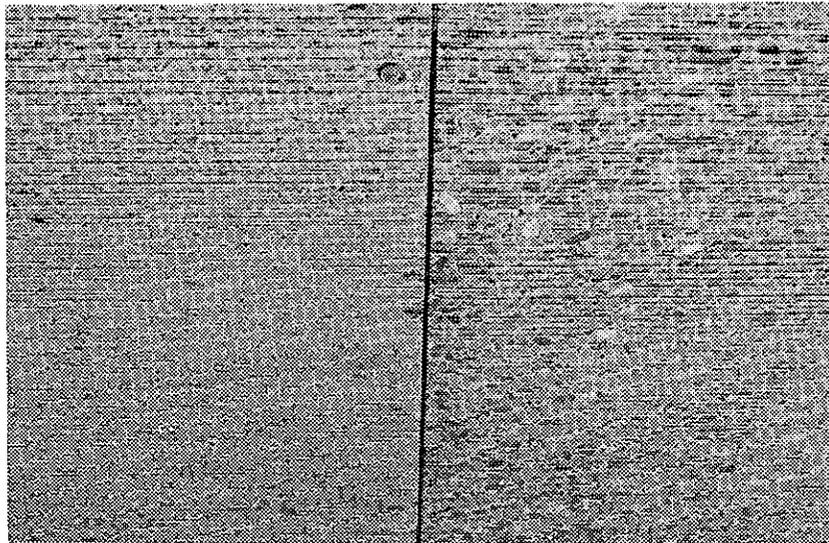
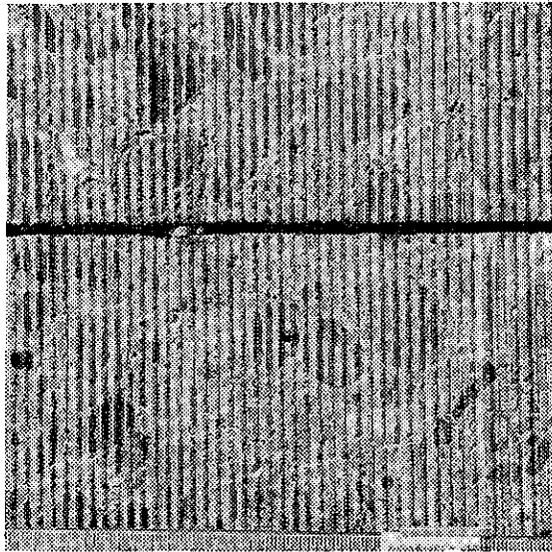
Location	Date Ground	Year								
		1972	1973	1974	1975	1976	1977	1978	1979	
04-SCL-17 (A) 18.4/24.4	3/71	0.5	0.2	0.2	0.5	0	0.2	0.2	0.4	0.4
04-ALA-17 (B) 10.4/15.5	12/72	0.8	0	0.2	0.2	0.6	0.4	0.4	1.3	0.7
04-ALA-17 (C) 15.5/21.0	1/69	2.5	-	1.6	1.8	0.5	1.4	0.4	0.4	0.4
04-CC-80 (D) 0.0/5.2 W	8/72	0.2	0.8	0.2	1.3	0.4	0.4	0.2	1.0	0.6
04-CC-80 (E) 0.0/5.2 E	8/72	0.8	1.0	0.2	0.4	0.2	0	0	0	0
08-SBD-10 (F) 21.0/23.1	3/70	0	0	0.7	0	0	0	0	0	0
08-SBD-10 18.0/21.0 W	5/67	-	-	0	0	0	0	0	0	0
08-SBD-10 18.0/21.0 E	5/67	-	-	0	0	0	0	0	0	0
08-SBD-10 (G) 11.2/18.0	1/66	-	-	-	0.2	0	0.3	0.2	0.2	0

TABLE 1

Location	Date		Lane	SN ₄₀ Value		SN ₄₀ Dif.	Age of Ground Pgmt. Years		EAL (million)	
	Ground	Test		Standard Texture*	Ground Texture		1976	Total		
04-SCL-17 18.4/24.4	3/71	1/76	S 2/2	26 (1)**	29 (20)	+3	4.83	2.068	10.0	
		12/78		30 (2)	27 (17)		7.75			
04-ALA-17 10.4/15.5	12/72	4/76	N 3/3	36 (3)	40 (17)	+4	3.33	1.118	3.7	
		1/79		34 (5)	31 (7)		6.08			
04-ALA-17 15.5/21.0	1/69	4/76	N 3/3	36 (3)	37 (18)	+1	7.25	1.566	11.4	
		1/79		34 (5)	31 (13)		10.0			
04-CC-80 0.0/5.2	8/72	5/76	W 3/3	35 (4)	37 (16)	+2	3.75	1.151	4.3	
		1/79		34 (4)	33 (13)		6.42			
"	"	5/76	E 3/3	29 (5)	30 (13)	+1	3.75	1.151	4.3	
		1/79		30 (5)	33 (12)		6.42			
08-SBD-10 21.0/23.1	3/70	10/76	W 4/4	37 (6)	34 (4)	-3	6.58	1.572	10.3	
		4/78		37 (5)	35 (3)		8.08			
08-SBD-10 18.0/21.0	5/67	10/76	W 4/4	35 (4)	33 (2)	-2	9.42	1.503	14.2	
		4/78		38 (2)	34 (3)		10.92			
"	"	10/76	E 4/4	34 (2)	33 (2)	-1	9.42	1.503	14.2	
		4/78		41 (3)	37 (1)		10.92			
08-SBD-10 11.2/18.0	1/66	10/76	W 4/4	32 (3)	32 (9)	0	10.75	1.262	13.6	
		4/78		39 (5)	36 (5)		12.25			

*Standard texture is the finish provided initially during construction. These projects had a burlap drag finish.

**The number in parenthesis is the number of test values represented in the average.



Grinding to improve rideability leaves a satisfactory texture providing the wheel path on the leave side of the joint is also textured by the grinding (deeper cut for surface texture).

Figure 1

APPENDIX

Figures and Tables

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5. Page, B. G., "New and Innovative Methods and Materials for Pavement Skid Resistance," California Department of Transportation, Office of Transportation Laboratory, Report No. FHWA-RD-78-145, July 1977.
6. Neal, B. F. and Woodstrom, J. H., "Evaluation of Cold Planers for Grinding PCC Pavements," California Department of Transportation, Office of Transportation Laboratory, Report No. FHWA-CA-TL-78-15, September 1978.

necessary. To achieve this it is proposed that the grinding should start in the left wheel track at a location that will texture the worn wheel track but minimize the ledge or lateral step off resulting from the grinding. The surface to the right of the left wheel track should be ground at the same slope as the original pavement and the grinding should extend to approximately one foot on the shoulder. Then if additional texture becomes necessary to reduce wet pavement accidents the ground area can be grooved.

The cost of these improvements will vary depending on the size of the project and the location. In addition, aggregate hardness will influence the cost of a grooving, grinding or cold planer project. Approximate costs (1978) per square yard are:

Grooving	PCC	\$1.00
Texture grinding	PCC	2.50
"	AC	3.00
Cold planer	PCC	2.20
"	AC	.70
0.06 ft OGAC		1.00*

*It is preferable to overlay all adjacent lanes, so this will increase the effective cost of an overlay on multilane roadways needing improvement in one lane.

treatments of restoring worn, grooved surfaces but the potential for problems seems high at this time. Because the absence of grooves is primarily in the wheel path, regrooving might be done only in the wheel path. A proposed pattern is shown in Figure 11.

Several attempts were made to program a regrooving job for this research project but they were unsuccessful mainly because of funding priorities in the Districts. A primary concern about regrooving is that wider or variable width grooves may result and vehicle riding/steering sensitivity may become a problem. There have been some complaints, particularly from motorcycle riders about the effects of the standard safety grooves on rideability. Signs have been installed to inform cyclists of pavement grooves ahead. Signing appears to be a workable solution on first-grooved pavements but additional adverse riding effects are unacceptable and regrooving may not be appropriate. For this reason, care should be exercised in locating a proposed test section for the first regrooving project. A sign informing the motorist of grooved pavement should be installed if none exists at the test area.

If regrooving is determined to be unsatisfactory, then a texture created by grinding in each wheel path is proposed for consideration. This texture grinding should be performed with great care. Excessive grinding in the wheel paths will provide channels to collect water and this must not be allowed. There may be some locations where a very high friction demand is expected and texture by grinding may be considered marginal. For such locations it seems prudent to grind as much of the lane as practical to remove existing grooves and prepare the surface for grooving should it be

-Grind that portion of the lane from the left wheel path having shallow grooves across the lane to the shoulder area. This would provide surface texture, accommodate surface runoff, and provide a reference plane if standard grooving becomes necessary.

One approach that appears to have merit for AC pavements is the cold planer such as the CMI Rotomill, the Barber Green RX75 or the Cutler Eager Beaver. Cold planing provides a satisfactory surface for AC pavements but the experience with the wear and the noise characteristics is limited. Currently, most AC cold planer projects involve overlays so it will be necessary to establish test sections to obtain wear data under a variety of conditions before adopting this treatment for AC pavements.

Experience in California has demonstrated that cold planing portland cement concrete pavements results in considerable spalling at the transverse joints.** Figure 10 illustrates this spalling problem. Spalling appeared to be reduced by temporarily sealing the joints before milling but subsequent investigations indicate that spalling at these joints occurs under continued traffic exposure. The spalling is considered excessive and unacceptable(6).

A treatment that should be considered is to regroove a worn grooved pavement. Regrooving is less costly than other known

**This treatment was reported to have been done successfully in some eastern states.

In addition to optimum temperature requirements, it is generally believed that a heavy tack coat (0.15 gal/sq yd or 0.68 litre/m² residual asphalt content) is necessary to achieve a satisfactory bond to the old pavement.

A before/after accident study reveals that the open graded asphalt concrete surfacing shows a 70% reduction in wet pavement accidents(4). This is essentially the same reduction that was achieved by grooving. Therefore, it is concluded that the open graded surfacing is an effective skid resistance treatment.

Chip Seal

A chip seal is another type of treatment that is sometimes used to improve the skid resistance of a worn or polished PCC or AC pavement surface. Roadways having high traffic volumes require a strong binding agent. Several epoxy and polyester resins have been used with success(5). The cost of these chip seals has been considerably higher than the other treatments. Except under special circumstances, the use of these relatively high-cost chip seals cannot be justified.

New Approaches

Surface treatments that should be tried on a limited basis and evaluated for economy and performance are:

- Cold planer to texture AC pavements
- Regroove worn grooved pavements in the wheel paths only
- Texture-grind the worn grooved pavements in the wheel paths

traffic whenever economically feasible. One installation of OGAC over PCC on 03-Sac-80 has performed satisfactorily for over one year. This roadway has an AADT of 105,000 consisting of 4.6 percent trucks for an annual EAL of 732,000. Follow-up investigations will determine if an OGAC overlay (on PCC pavement) is acceptable under heavy traffic.

Temperature specifications for OGAC are very important for this type of overlay. Batch temperatures above 275°F (135°C) or placement temperatures above 250°F (127°C) result in a thin asphalt film thickness that does not provide enough bond strength. Also, the asphalt oxidizes more readily. Placing and compaction temperatures less than 200°F (93°C) or ambient temperatures less than 60°F (16°C) for pavements and 70°F (21°C) for bridge decks also results in lower bond strength and less interlock than desired. Raveling will usually occur when placed under these out-of-specification conditions. Once the surface aggregate is disturbed, the loss in the wheel track generally continues down to the original surface. Figure 9 is a picture of such a failure. This roadway, 03-Sac-05, has an AADT of 49,000 vehicles. The existing truck traffic provides an annual EAL of 927,000.

An OGAC overlay was placed on an adjacent structure at optimum temperatures and the performance has been satisfactory for more than one year. This project resulted in specification changes that increase the minimum ambient temperature for placement from 60°F (16°C) to 70°C (21°C) for bridge decks and prohibit the dumping of OGAC in a windrow and then placing the material in the asphalt paver with loading equipment. It is noteworthy that both changes relate to the spreading and compacting temperature.

Variations in the surface profile, especially after several years of heavy truck traffic cause the greatest quality control problem with grinding or grooving texture treatments. The depressions make it difficult to obtain uniform depth of grooves or texture across the lane and faulted joints require special attention and effort. Grinding appears to be an appropriate treatment to remove the profile variations and provide good surface texture. It also prepares the surface for longitudinal grooving if further treatment is necessary to reduce wet pavement accident frequencies.

Open Graded Asphalt Concrete Overlay

Another treatment that was included in our survey is open graded asphalt concrete (OGAC). A 0.06 foot OGAC thickness was placed over a PCC roadway on 05-SLO-01 for delineation purposes in June, 1973. This four lane highway has an average annual daily traffic count of approximately 15,000 vehicles (1976). Trucks make up three percent of this traffic providing a Traffic Index of 8.5, and a one year equivalent axle load (18 kips) of approximately 30,000. This is considered moderate-to-light truck traffic.

The inevitable reflection cracks over the joints of the PCC slabs have been treated with crack sealant. The overall appearance of this project is very good after 5-1/2 years of service. Figures 6, 7 and 8 depict the 5-1/2 year old surfacing. Although some reports indicate that bonding thin AC layers to PCC may be a problem, it appears that OGAC can be an acceptable improvement of worn PCC as well as worn AC surfaces. It is unclear whether the surface improvement by OGAC should be limited to roadways with moderate truck traffic or if it is acceptable for all roadways regardless of

Grinding and Grooving

There is one dramatic illustration where grinding has improved texture of a heavily traveled roadway that had previously been grooved. This roadway is a truck bypass that carries approximately 2.7 million EAL annually (AADTT=12,600). The pavement was grooved after a major accident occurred in a tunnel. After the grooving operation, it was decided that a light grinding* of the surface was justified to provide additional texture. After two years, it appears that the texture is resisting the polishing action of the heavy traffic. Pictures of the texture and the geometrics are shown in Figures 4 and 5.

When compared to overlays or seals, one of the primary advantages of texture grinding or grooving as an improvement is that results are not subject to construction temperature variations for most climatic conditions. Therefore, the quality of the treatment should be more uniform. It should also be easier to schedule a work program when temperature considerations are not necessary. Another advantage is that the lateral step off that results from longitudinal grinding may be less than 0.01 foot and no more than 0.015 foot which should not be objectionable to the motorists when changing lanes. Therefore, in most cases only the lane or lanes needing improvement must be treated. This eliminates the need and cost of resurfacing all lanes, some of which may not need it.

*referred to as texture grinding

accidents to total accidents and the percent of time that a pavement is wet. For example, on the average, Santa Clara County has wet pavements 4 percent of the time and 14 percent of the accidents are wet pavement accidents. The average wet pavement accident rate for the test section in Santa Clara County since the pavement grinding is 10 percent. The average wet pavement time for the corresponding period is 3.6 percent which yields an adjusted wet pavement accident rate of 11 percent ($\frac{4.0}{3.6} \times 10 = 11.1$). Therefore, unless a specific site within this test section exhibits a concentration of wet pavement accidents, this section of pavement would be considered to be "low priority" for safety fund expenditures. Based on this criteria, all of the surfaces presented here are satisfactory and an effective texture extends beyond the ten million EAL suggested earlier.

Several years of wet pavement accident statistics are shown in Table 2 and Figure 3 for the areas that were ground in the outer lanes. Although several of these ground locations are not in areas that have the higher friction demand such as curves or weaving sections the general trend of wet pavement accidents indicate that grinding provides an acceptable texture. Rear end type accidents were selected in preference to total wet pavement accidents because sideswipe and other classifications are less likely to relate to one lane and therefore might bias the data. If the ground texture becomes polished and ineffective it is probable that the wet pavement accident frequency and especially the rear end accident frequency would increase.

2. Comparable test sections could not be found for this study. Either geometrics or traffic conditions varied sufficiently to preclude sufficient area for data collection. Therefore, a comparison between skid numbers obtained on ground and standard textures in the outer lanes was used to obtain some measure of the lasting quality of a ground PCC surface. This data is presented in Table 1. Skid numbers were obtained on ground pavement surfaces and on "standard" surfaces (burlap or broomed) adjacent to the ground pavement in 1976 and again in 1978 or 1979. The difference between the skid numbers on the ground texture and those on the standard texture are tabulated for each test year.

The total number of equivalent 18,000 pound axle loads (EAL) that have traveled the roadway since the grinding operation are shown in the table. These values are compared to the respective differences in skid number in Figure 2.

If the assumption is made that the effectiveness of the grinding is lost when the skid number of the ground area reaches that of the standard texture, then the average texture life of a ground PCC surface is approximately ten million EAL or about six or seven years for these heavily traveled roads. It is probable that, as in grooving, texture-grinding provides some benefit to the motorist (lateral stability) that is not reflected in the longitudinal skid test measurements and therefore a longer effective service life may be obtained.

Currently the criteria used in California to justify skid resistance improvements are the ratio of wet pavement

pavements by eliminating the step off thereby improving riding quality. This procedure has been especially practical where additional outer lanes were constructed to widen the roadway. Since the new outer lanes would carry much of the truck traffic, the service life of the recently ground lane appears to match the expected service life of the new lanes(3). (In this reference, service life refers to slab cracking or further faulting but it appears to apply to texture as well.) Although this grinding was performed primarily to improve pavement characteristics other than skid resistance, these projects provided some beneficial information. They were investigated to determine if grinding should be considered as a viable treatment to restore skid resistance. The evaluation was made by comparing the ground texture to the finished surface that has been exposed to traffic since construction.*

Attempts to use accident frequencies to compare the long term effectiveness of texture by grinding to the standard texture were unsuccessful because:

1. Prior to 1971, accident records were not coded to show the lane location of a collision or skid related accident. Counting accidents that occurred in all four lanes when only one lane is ground would be misleading.

*Most of the PCC surfaces were initially textured with a burlap drag, some with a broom, or both. Either longitudinal burlap drag or broom finish textures will be referred to as "standard texture" in this report.

are specified in areas where considerable wear has occurred. The groove depths on bridge decks are not less than 1/8 inch (3.2 mm) nor more than 3/16 inch (4.8 mm). Grooves over inductive loop detectors are cut not less than 1/16 inch (1.6 mm) nor more than 1/8 inch (3.2 mm) deep.

Longitudinal grooving has been used statewide because of its effectiveness and relatively low cost.

Grinding

One important requirement when grinding is to create sufficient surface texture to provide satisfactory skid resistance. A coefficient of friction of not less than 0.30 as determined by Test Method No. Calif. 342 is specified for ground surfaces in Section 42 of the California Standard Specifications. To achieve a desired texture, grinding contractors place thin spacers between the cutting blades to obtain approximately five blades to the inch. This leaves some spalled or broken concrete surface between the blades and increases the skid resistance. Examples of a "ground" texture are shown in Figure 1. It should be noted that grinding to create texture only would expose less aggregate than the grinding for rideability but the surface roughness or skid resistance would be basically the same.

Pavement grinding has been performed on several California highways to improve rideability. Grinding has been an acceptable abrasive means to reduce excessive roughness or bumps on newly constructed pavements in California since 1958. On a much smaller scale, grinding has been used since 1965 to extend the useful life of old faulted PCC

DISCUSSION

To achieve the objectives of this project it was necessary to follow two avenues. One was to examine existing treatments or improvements to pavement surfaces and relate their application to this project. The other was to explore any new ideas or approaches that appeared promising by establishing test sections on new contracts providing for such improvements. The number and type of treatments available for evaluation were fewer than anticipated.

Existing Treatments

Surface "treatments" that were considered to be feasible for restoring texture and skid resistance of worn or polished PCC pavements or grooved PCC pavements are:

- Groove PCC pavements with diamond blades
- Grind PCC pavements with diamond blades
- Grind and groove PCC pavements
- Open graded asphalt concrete overlay
- Chip seals

Grooving

The effectiveness of reducing wet pavement accidents by longitudinal grooving PCC pavements in California was mentioned in the Introduction. As specified in Section 42 of the California Standard Specifications, the grooving blades are 0.095 inch (2.4 mm) wide ± 0.005 inch (0.1 mm) and are spaced 3/4 inch (19.0 mm) on centers. Typical groove depths for pavements are not less than 1/8 inch (3.2 mm) or more than 1/4 inch (6.4 mm) deep. However, groove depths not less than 3/16 inch (4.8 mm) nor more than 5/16 inch (7.6 mm)

IMPLEMENTATION

Since the retexturing methods recommended have not been tried and evaluated, they should be considered to be a part of additional research and therefore, installed as test sections or very small contracts. Documentation of "before" and "after" wet pavement accidents, construction procedures and problems, rideability and noise parameters should be required for the recommended surface improvement procedures. The Transportation Laboratory will coordinate and work with the Office of Construction to evaluate new equipment and to develop new procedures to improve the texture of worn and polished highways.

PCC Pavements

1. Establish test sections of old, worn grooved pavement and regroove only the wheel tracks to determine the feasibility of this treatment.
2. As an alternate to regrooving, texture the worn, grooved pavement in the wheel tracks only by grinding, to determine the feasibility of this treatment.
3. If it is suspected that wheel track grinding alone may not provide adequate texture for a location, the lane should be ground from the left wheel track onto the right shoulder at the existing cross slope (see Figure 12) so that pavement grooving can be performed as needed in the future.

AC Pavements

1. Provide various textures with a cold planer to determine the skid resistance and lasting quality of this treatment.
2. Apply a chip seal or open graded asphalt concrete, as required by existing conditions.

In those areas where open graded AC is not used for one reason or another (e.g., where chains are required), a well designed dense graded AC surface could be used.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions from the acquired data are as follows:

1. Grooving is the preferred treatment for improving the surface texture of a polished portland cement concrete pavement.
2. Based upon the results of nine sections of faulted portland cement concrete pavement that were ground to improve rideability, it appears that a satisfactory texture can be obtained by surface grinding alone. Using skid resistance as a basis for the evaluation, a ground pavement texture has an effective life of approximately ten million EAL.
3. In some cases thin, open graded asphalt concrete overlays have been successfully applied to portland cement concrete pavements. A heavier than normal tack coat application rate, particularly with hot applied AR 4000 paving grade asphalt, appears to increase the bond between the PCC pavement and the thin AC overlay.
4. Cold planing appears to be a satisfactory treatment to retexture asphalt concrete pavements but the durability of the treatment needs to be investigated.
5. Cold planing is not acceptable treatment for PCC pavement because of excessive spalling at the transverse joints and at any existing cracks.

The following recommendations are suggested to establish a program to improve worn grooved highways.

Appropriate methods considered for restoring skid resistance to worn or polished pavement surfaces were:

Regrooving

Grinding

Grinding and grooving

Cold planing (milling)

Thin blanket of asphalt concrete

It is expected that these methods of texture improvement will be superseded by improved methods in the future.

INTRODUCTION

For more than fifteen years it has been the practice in California to reduce wet pavement accident frequencies on portland cement concrete pavements by sawing longitudinal grooves in the pavement surface. This program has been very successful. The early grooving projects(1) exhibited an 85% reduction in wet pavement accidents, and a later study(2) attributes a 69% reduction in wet pavement accidents to grooving. It is reasonable to expect a somewhat greater improvement from the early projects which probably had a greater need of surface improvement, but significant improvements were also achieved in later projects.

Grooving specifications include limits on the depth and spacing of grooves to prevent spalling between deep sawcuts. Although this permits a common basis for contract bidding purposes, it sometimes results in minimal groove depth in the wheel paths where the vehicle tires have worn depressions in the pavement surface. Subsequent wear by traffic over several years results in even shallower groove depths. Also, the control of groove depth on some of the earlier projects was somewhat ineffective and the acceptable groove depths were sometimes marginal. It was recognized that eventually some secondary improvement in texture would become necessary where shallow grooves existed. As a result, this research project was initiated to determine the best method or methods to improve skid resistance characteristics of worn, grooved PCC pavements or polished PCC and AC pavements.

TABLE OF CONTENTS

	<u>Page</u>
INTRODUCTION	1
CONCLUSIONS AND RECOMMENDATIONS	3
IMPLEMENTATION	5
DISCUSSION	6
REFERENCES	18
APPENDIX (Figures and Tables)	19

CONVERSION FACTORS

English to Metric System (SI) of Measurement

<u>Quantity</u>	<u>English unit</u>	<u>Multiply by</u>	<u>To get metric equivalent</u>
Length	inches (in) or (")	25.40 .02540	millimetres (mm) metres (m)
	feet (ft) or (')	.3048	metres (m)
	miles (mi)	1.609	kilometres (km)
Area	square inches (in ²)	6.432 x 10 ⁻⁴	square metres (m ²)
	square feet (ft ²)	.09290	square metres (m ²)
	acres	.4047	hectares (ha)
Volume	gallons (gal)	3.785	litres (l)
	cubic feet (ft ³)	.02832	cubic metres (m ³)
	cubic yards (yd ³)	.7646	cubic metres (m ³)
Volume/Time (Flow)	cubic feet per second (ft ³ /s)	28.317	litres per second (l/s)
	gallons per minute (gal/min)	.06309	litres per second (l/s)
Mass	pounds (lb)	.4536	kilograms (kg)
Velocity	miles per hour (mph)	.4470	metres per second (m/s)
	feet per second (fps)	.3048	metres per second (m/s)
Acceleration	feet per second squared (ft/s ²)	.3048	metres per second squared (m/s ²)
	acceleration due to force of gravity (G)	9.807	metres per second squared (m/s ²)
Weight Density	pounds per cubic (lb/ft ³)	16.02	kilograms per cubic metre (kg/m ³)
Force	pounds (lbs)	4.448	newtons (N)
	kips (1000 lbs)	4.448	newtons (N)
Thermal Energy	British thermal unit (BTU)	1055	joules (J)
Mechanical Energy	foot-pounds (ft-lb)	1.356	joules (J)
	foot-kips (ft-k)	1.356	joules (J)
Bending Moment or Torque	inch-pounds (ft-lbs)	.1130	newton-metres (Nm)
	foot-pounds (ft-lbs)	1.356	newton-metres (Nm)
Pressure	pounds per square inch (psi)	6895	pascals (Pa)
	pounds per square foot (psf)	47.88	pascals (Pa)
Stress Intensity	kips per square inch square root inch (ksi \sqrt{in})	1.0988	mega pascals \sqrt{metre} (MPa \sqrt{m})
	pounds per square inch square root inch (psi \sqrt{in})	1.0988	kilo pascals \sqrt{metre} (KPa \sqrt{m})
Plane Angle	degrees (°)	0.0175	radians (rad)
Temperature	degrees fahrenheit (F)	$\frac{t_F - 32}{1.8} = t_C$	degrees celsius (°C)

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION
DIVISION OF CONSTRUCTION
OFFICE OF TRANSPORTATION LABORATORY

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APPRAISAL OF ALTERNATIVE METHODS FOR
RESTORATION OF PAVEMENT SURFACE TEXTURE

Study Made by Roadbed and Concrete Branch
Under the Supervision of D. L. Spellman, P.E.
Principal Investigator J. A. Matthews, P.E.
Co-Investigator B. G. Page, P.E.
Report Prepared by B. G. Page, P.E.

APPROVED BY



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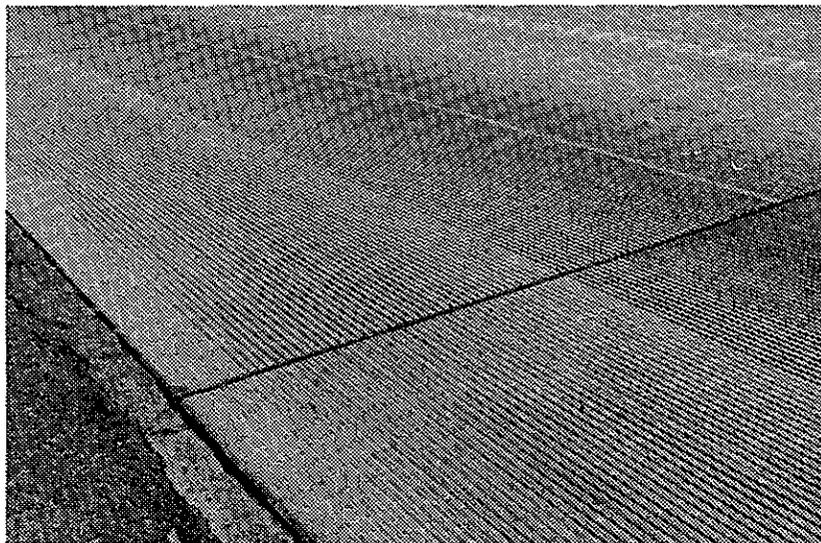
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15. SUPPLEMENTARY NOTES This study was conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.					
16. ABSTRACT This report covers the methods that have been used to provide surface texture for worn pavements in California. Worn grooved PCC pavements appear to have the greatest need for new methods since longitudinal grooving continues as a cost effective treatment for worn PCC pavements. For economic reasons, regrooving in the wheel paths of worn grooved pavements should be tried. If regrooving is unacceptable, it appears that diamond blade grinding is an effective texture treatment in addition to providing a desirable plane for any subsequent grooving. Open graded asphalt concrete overlays on PCC pavements have been used successfully on lightly traveled roads and are now being evaluated on roads with heavy traffic. Cold planing PCC pavements is not acceptable in California because of the excessive spalling at cracks, but it may be an acceptable treatment for AC pavements. Continued evaluations of all methods are necessary because it may take ten or more years to determine the effectiveness of a surface treatment.					
17. KEY WORDS Highway maintenance, pavement surface texture, open graded mixes, grinding, grooving, rehabilitation			18. DISTRIBUTION STATEMENT No restrictions. This document is available to the public through the National Technical Information Service, Springfield VA 22161		
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**FINAL REPORT
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