Restoration of Frictional Characteristics on Older P.C.C. Pavement

Final Report

Iowa Highway Research Board Project HR-224

June 1986
Highway Division

Iowa Department of Transportation

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Final Report
for
Iowa Highway Research Board
Project HR-224

RESTORATION of FRICTIONAL CHARACTERISTICS on OLDER PORTLAND CEMENT CONCRETE PAVEMENT

by

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RESTORATION OF FRICTIONAL CHARACTERISTICS ON OLDER PCC PAVEMENT

INTRODUCTION

Safety is a very important aspect of the highway program. The Iowa DOT initiated an inventory of the friction values of all paved primary roadways in 1969. This inventory, with an ASTM E-274 test unit, has continued to the present time. The testing frequency varies based upon traffic volume and the previous friction value.

Historically, the state of Iowa constructed a substantial amount of pcc pavement during the 1928-30 period to "get Iowa out of the mud". Some of that pavement has never been resurfaced and has been subjected to more than 50 years of wear. The textured surface has been worn away and has subsequently polished. Even though some pavements from 15 to 50 years old continue to function structurally, because of the loss of friction, they do not provide the desired level of safety to the driver. As a temporary measure, "Slippery When Wet" signs have been posted on many older pcc roads due to friction numbers below the desirable level. These signs warn the motorist of the current conditions. An economical method of restoring the high quality frictional properties is needed.

OBJECTIVE

The objective of the research is to identify a cost effective method of restoring the frictional characteristics on older pcc pavement.

PAVEMENT GROOVING

Location

Except for a short 1500 experimental section of transverse grooving on I-80 in Iowa County, the only pavement grooving by the Iowa DOT of a surface that has not been entirely diamond ground was cut into I-29 on the north edge of Council Bluffs (Pottawattamie County). In recent years there has been a substantial amount of diamond grinding to correct the profile on new construction or projects to restore the profile of older pavement. Grooving is sometimes used to replace the transverse texture after diamond grinding.

A short section of longitudinal grooving was cut into pavement either side of the "G" Avenue overpass on I-29 (Station 161± to 143+25) in 1974 by Pavement Specialists of Dallas, Texas. A 1980 safety enhancement project (Pottawattamie I-29-3(30)55--01-78) for longitudinal grooving began at Station 143+25 (end of the 1974 grooving project) and extended northeasterly for 1.7 miles to Station 749+10. The research transverse pavement grooving, added to the 1980 project by extra work order, began at Station 749+10 in the NB roadway only and extended to 753+50. The traffic volume at this location has been approximately 10,000 VPD from 1980 through 1986.

Pavement Properties

This section of pcc pavement was constructed in 1968 as Pottawattamie project I-IG-29-3(9)57. The concrete was a Class V aggregate mix of the following proportions:

	Absolute Volume	Weight (lbs.) per cu. yd.
Cement	0.134965	714
Water	0.172994	291
Air	0.06	---
Class V Aggregate	0.600439	2650
Fine Limestone	0.031602	143

The Iowa DOT "Class V" aggregate is a Platte River sand-gravel originating from decomposed feldspathic rock meeting the following gradation:

Sieve Size	Percent Passing
1-1/2"	100
No. 4	80-92
No. 8	60-75
No. 30	25-35
No. 200	0-1.5

The Iowa DOT friction inventory prior to the grooving had yielded Friction Numbers below the desirable level. Traffic and studded tires had worn away the initial texture.

Construction

The longitudinal grooving covered by Pottawattamie project I-29-3(30)--01-78 began on July 16, 1980, and the project, including the extra work ordered transverse grooving, was completed on August 2, 1980. The grooving was completed under the 1977 Standard Specifications and Special Provisions for Pavement Grooving, June 17, 1980, SP-297 (Appendix A). The extra work of transverse groov-

ing was performed essentially as required by SP-297 except for the change in direction of cut.

The contractor, Construction Diamond Services, Inc. of Columbus, Ohio, used a five foot multiblade arbor mounted on the front of a "Cat" 944 end loader for the longitudinal grooving. A vacuum system was mounted on the rear for removal of the slurry resulting from the wet cut grooving operation. The groover was equipped with a depth control sensing device which adjusted the cutting head to uniformly obtain the minimum 1/8-inch-deep grooves.

A special grooving machine was brought to the project for the transverse grooving. The cutting arbor for this unit was mounted on an underslung carriage near the middle of a straight truck unit. The cutting head would traverse one lane, then be raised and moved ahead and properly positioned for the next pass.

Cost

The cost of the longitudinal grooving, including traffic control, was $1.30 per square yard. Originally the contractor had indicated that transverse grooving would be twice the cost for longitudinal grooving or $2.60 per square yard. The cost for transverse grooving was actually $0.50 per sq. ft. or $4.50 per square yard. Due to the very small quantity involved (10,000 sq. ft.) and the need of another special unit, the extra work order cost may not be indicative of that for competitive bidding on a large project.

Performance

The objective of the grooving was to improve the coefficient of friction so the major evaluation was testing with an ASTM E-274 friction tester. In addition to the friction, the depths of the grooves in the wheelpath have been measured periodically. Random measurements in the wheelpath over the length of each section have been obtained with a tire tread gage graduated in 1/32" increments. All individual measurements were recorded to the nearest whole 1/32" with the average shown to 0.1 of 1/32" (Table 1).

Table 1
Groove Depth Summary

Date	Groove Depth, 1/32 inch					
	Transverse			Longitudinal		
	Average	High	Low	Average	High	Low
10-07-81	7.9	9	7	6.6	10	3
10-18-82	6.5	8	5	5.0	7	3
11-14-83	6.5	8	5	4.5	6	3
09-25-84	6.0	7	5	4.8	6	3

The depth of the transverse grooving was much more uniform than the longitudinal grooving. Approximately 1/16" of the groove depth has been lost in three years. This still leaves 1/8" average depth on the longitudinal and 3/16" average depth on the transverse. There was greater change in groove depth in the first year and a much slower loss of groove depth in the last two years.

Friction Numbers were determined as outlined in ASTM E-274 with both an ASTM E 501 treaded tire and an ASTM E 524 smooth tire. A Friction Number (FN) survey is given in Table 2.

Table 2
FRICTION NUMBER SUMMARY

Date	Section Without Grooving		Section With 1974 Longitudinal Grooving		Section With Research Longitudinal Grooving in 1980		Section With Research Transverse Grooving in 1980	
	Treaded	No Tread	Treaded	No Tread	Treaded	No Tread	Treaded	No Tread
7-11-80	26*	12*			24*	14*	26*	14*
7-11-80			31	30				
9-17-80	30	13	29	27	32	32	36	37
5-7-81	30	12	30	26	33	29	37	34
6-7-82	34	15	34	30	38	33	44	35
6-14-83	35	12	30	30	35	33	38	36
6-12-84	28	15	35	37	35	35	40	40
9-25-85	32	15	33	32	35	31	39	37

*Prior to grooving

The average Friction Numbers with the treaded tire at 40 MPH prior to grooving ranged from 24 to 26. The smooth tire yielded an average FN ranging from 12 to 14 before grooving. Testing of the adjacent nongrooved section of I-29 since 1980 has yielded Friction Numbers of about 31 with the treaded tire and about 14 with the smooth tire.

Friction testing of the 1974 grooving with the treaded tire since 1980 has yielded a FN of about 32 or only slightly better than the ungrooved pavement. When tested with the smooth tire, the 1974 grooving shows a substantial benefit with a FN of about 30 compared to 14 on the ungrooved section.

The 1980 longitudinal grooving yielded Friction Numbers 4 points higher (35) with the treaded and 18 numbers higher (32) with the smooth tire than the ungrooved section.

The 1980 transverse grooving yielded the best Friction Numbers. The treaded tire FN is about 39, or 8 numbers higher than nongrooved and 4 numbers higher than longitudinal grooving. The smooth tire again yields a FN much higher on the transverse grooved than the ungrooved with 37 compared to 14.

Discussion

Even though the transverse grooving provides the best friction values, it may not be economically attractive due to the greater cost ($2.60 to $4.50 per square yard compared to $1.30 per square yard for longitudinal grooving). Another limiting feature of grooving is that there is no profile correction and quite often faulting makes profile correction desirable in rehabilitation projects.

SURFACE DRESSING

The intent of the research was to use a Gun-All machine to apply a latex modified pcc mortar surface dressing patterned after research by Purdue University(1). Laboratory testing demonstrated that a slump of eight inches was necessary to achieve good adhesion and bonding. The Gun-All machine will not function well with a concrete mix having a slump greater than three inches, so it could not be used. Initially very small experimental areas of latex modified pcc mortar surface dressing were applied.

Latex Modified Concrete Surface Dressing (LMCSD) on I-35

The first experimental LMCSD was mixed in the Materials Laboratory. The only aggregate for this mix was a manufactured quartzite sand from L. G. Everist of Dell Rapids, South Dakota. The gradation was:

Sieve Size	Percent Passing
3/8"	100
No. 4	99
No. 8	92
No. 16	73
No. 30	56
No. 50	23
No. 100	5.5
No. 200	1.8

From laboratory testing, the mix proportions developed for the small experimental applications were:

	Absolute Volume	Weight (lbs.) per cu. ft.
Cement	0.117385	23.00
Quartzite Sand	0.465351	76.66
Water	0.141827	8.85
Latex Bonding Agent	0.085567	5.90
Air	0.189870	----

On October 31, 1980, the LMCSD was applied to a 10' x 2' area on a drive just west of the Materials Laboratory at the Iowa DOT Ames Complex and on the NB passing lane of I-35 at Milepost 110.95 (A 3' x 2' area in the wheelpath). The area near the laboratory was cleaned with a 2000 psi water blaster just prior to application.

The material was spread approximately 1/8" thick with a stiff bristled push broom. No traffic was allowed on the areas near the laboratory for 20 hours and none on the I-35 application for four hours.

Latex Modified Concrete Surface Dressing on US 69

The LMCSD placed in the wheelpath of the passing lane on I-35 adhered well and was still in good condition in March 1984, 3½ years after application. Application equipment remained the major problem in placing the LMCSD. There was no commercially available equipment that had demonstrated satisfactory placement of the LMCSD. Hand spreading and brooming would be too labor intensive.

The Iowa DOT owned and operated a slurry machine for applying thin surface coatings of bituminous slurry seals. This was a similar operation and appeared to exhibit potential for spreading the LMCSD material.

Location

A two-lane, 24' wide section of US 69 just north of Ames between Milepost 119.25 and Milepost 119.43 was selected for the larger experimental application. This section carried a traffic volume of about 4000 VPD and yielded an average Friction Number of 30 when tested with an ASTM E-274 trailer.

Materials

The LMCSD was produced at the Manatt's Inc. Ready Mix plant adjacent to the project on the north edge of Ames. Two loads were batched into ready mix trucks for application to the southbound lane on May 1, 1984. The first was 5 cu. yd. and the second was 5 1/2 cu. yd.

The batch quantities for 1 cubic yard were:

Portland Cement	621 lbs.
Del Rapids Quartzite Sand	2070 lbs.
Water	196 lbs.
Proweld Bonding Agent	80 lbs.

A typical gradation of the sand from L. G. Everist of Del Rapids, South Dakota, was:

Sieve Size	Percent Passing
No. 4	100
No. 8	92
No. 10	83
No. 16	71
No. 30	53
No. 50	23
No. 200	1.5

Construction

Traffic control was provided by Iowa DOT maintenance personnel. The southbound lane was closed and flagmen controlled one lane traffic in the northbound lane.

Various methods of surface preparation were used.

Waterblast Cleaning (2000 psi)	Sta. 129 to 138
Rotary Brooming	Sta. 138 to 141
Rotary Brooming + Sandblast Cleaning	Sta. 141 to 141+10
Rotary Brooming	Sta. 141+10 to 143
Rotary Brooming + Compressed Air	Sta. 143 to 143+10
Rotary Brooming	Sta. 143+10 to 145

The first load of LMCSD was batched at 9:35 a.m. All materials except the bonding agent were batched and thoroughly mixed before adding the Proweld bonding agent at 9:40.

Application through the slurry box spreader began at approximately 10:00 a.m. with beautiful sunny weather. Initially the rubber screed on the rear of the box was wiping the surface nearly clean. The rubber screed was gradually raised in an effort to leave the desired 1/8" thickness. The joints were somewhat faulted and slightly raised due to joint heave. This tended to leave a thicker application near the joints. Addition of a 2' long single layer burlap drag behind the rubber screed yielded a surface that looked very good. The application of the first load of LMCSD material looked good and for the most part was approximately 1/8" except for the slightly thicker areas near the joints.

The second load of LMCSD material worked very poorly. There were a substantial number of balls of quartzite sand that kept raising the rubber screed. The thickness in some places reached 3 inches. An unsuccessful effort was made to remove the excess material with squeegees and brooms. The LMCSD was spread to Station 129 even with the severe problems. A truck with an underbody ice blade was brought in to remove the excess thickness of the second load.

The LMCSD was opened to normal traffic at 5:00 p.m. By the next morning, there was severe failure in the wheelpaths. The LMCSD was not strong enough or sufficiently cured in the thicker areas near

the joint. These areas abraded and dislodged down to the original concrete surface. The random holes in the LMCSD surface yielded an unacceptably rough ride.

A decision was made to remove the LMCSD from the southbound lane and abandon application of the northbound lane. A truck with a carbide tipped underbody ice blade was used for the removal. The LMCSD was hard and very well bonded and was extremely difficult to remove from the pavement.

Evaluation

The only evaluation of the US 69 LMCSD was visual reviews. There appeared to be no significant difference in the bonding on the different surface preparations. Even though some LMCSD remains in the wheelpath, most of the application has been worn away.

The I-35 LMCSD adhered well through 1984, but by June 1986, the traffic had worn away almost all material in the wheelpath.

Discussion

The failure of the US 69 LMCSD application does not exhaust all possibilities of modifications to make the system function. Basically, one serious limitation of the system is the absence of proven application equipment. A rotary broom as a final operation would reduce the potential of thick application.

The thin application of LMCSD on most pcc pavements may not fulfill all of the rehabilitation needs. On older pavements, there is quite often joint faulting or heaving that would require more than 1/8" to improve the longitudinal profile. Another possibility would be the use of a thicker application in conjunction with Type III High Early Cement.

HOT SAND ASPHALT RESURFACING

Location

The research application of thin, hot sand asphalt resurfacing was laid just east of the I-80, I-35 EB bridge over an abandoned railroad at the north edge of Des Moines. This is bridge No. 7732.1 R 080 located just east of the Merle Hay, IA 401 interchange.

Construction

A tack coat was first applied to this 175 feet of 24 feet wide pavement on September 22, 1980. The tack coat was not uniform and there were numerous areas of insufficient cover. The area was retacked and on September 29, 1980, the day the hot sand asphalt mix was laid. This resulted in a very thick shiny tack coat.

The intended asphalt content of the mix produced by Iowa Road Builders at the Des Moines plant was 7.5%. Test results of a sample of the mix are given in Appendix B. The mix was batched in two, eight ton loads for laying each of the two lanes. The temperatures of the loads were 285°F and 325°F. The first load covered 165 feet of a 12' lane plus about 1 foot of shoulder taper. This

was a rate of 67 lb. per square yard or an average thickness of 0.65 inch. The second load covered 185 feet approximately 12.5' wide. This is 62 lb. per square yard or an average thickness of 0.60 inch. The mix was compacted with a steel roller soon after completion of the laying of the asphaltic concrete.

Cost

The cost of the mix was $33 per ton. On other Iowa DOT projects, the cost (April 1981) of hot sand asphalt resurfacing was approximately as follows:

Hot Sand Asphalt	$ 15 per ton
Asphalt Cement	$225 per ton
Prime or Tack	$ 1 per gallon
Base Preparation	$400 per mile

From these prices, the cost per square yard is:

Hot Sand Asphalt @ 65 lbs/sq. yd.	=	$0.49 sq. yd.
Asphalt Cement @ 7.5%	=	0.55 sq. yd.
Prime or Tack @ 0.05 gal/sq. yd.	=	0.05 sq. yd.
Base Preparation @ $400/mile	=	0.03 sq. yd.
APPROXIMATE TOTAL COST	=	$1.12 per sq. yd.

Performance

Quite often, there have been problems of bonding thin layers of asphalt concrete to PC concrete. This application of hot sand as-

phalt averaged between 0.60 and 0.65 inches thick and bonded well. It also was not worn away by traffic in six years as happens with some thin asphalt concrete surface layers. It did provide a durable surface.

The Friction Numbers obtained with an ASTM E 274 test using an ASTM E 501 treaded tire were not as high as expected or desired. In 1982, the average Friction Number in the inside wheelpath of the driving lane was 28 and 41 in the passing lane. It had changed only slightly by 1985 with 29 in the driving lane and 41 in the passing lane. The 1986 values were 29 in the driving lane and 43 in the passing lane which would indicate that the Friction Numbers remain unchanged.

Discussion

Hot sand asphalt has been used with better results on I-80 in Dallas County. The Friction Number of the inside wheelpath of the driving lane at 40 mph had remained above 40 for 11 years after resurfacing. I-80 in Dallas County has an ADT of 13,000 compared to the 32,000 on I-80, 35 in Polk County east of the Merle Hay interchange. The difference in traffic does not explain the difference in Friction Numbers as they have remained relatively constant with respect to age on both of these sections.

A possible reason for the lower numbers on the research section would be an increased asphalt cement (AC) content due to the liberal application of prime or tack coat. Because of the thin layer

(0.60 inch) the liberal tack coat may have increased the AC content above the 7.5% added AC content. Another possible reason for the lower friction numbers could have been allowing traffic to use the resurfacing before it had cooled sufficiently. The resulting friction numbers have remained unchanged by traffic from 1982 through 1986.

CONCLUSIONS

This research on restoration of frictional characteristic supports the following conclusions:

1. Pavement grooving is an effective means of improving friction on older PCC pavement.
2. Transverse grooving provides better Friction Numbers than longitudinal grooving.
3. Improved application equipment is needed for use and proper evaluation of LMCSD.
4. It was not possible to determine the longevity of LMCSD from this research.
5. The thin layer of hot sand asphalt was durable, but resulting Friction Numbers were marginal.

ACKNOWLEDGEMENTS

Research project HR-224 was sponsored by the Iowa Highway Research Board and the Iowa Department of Transportation. Research funding from the Primary Road Research Fund in the amount of $8,000 was approved for this project.

The author wishes to extend his appreciation to the Council Bluffs Resident Construction Office personnel for their inspection and assistance on the grooving. Maintenance personnel also deserve recognition for their participation in the application of the surface dressing material and hot sand asphalt resurfacing.

REFERENCE

1. C. F. Scholar & R. R. Forrestel, Use of a Very Thin Overlay to Reestablish the Skid Resistance of a Concrete Pavement, TRR 752, pp 17-21, 1980.

SP-297

IOWA DEPARTMENT OF TRANSPORTATION
Ames, Iowa

Special Provisions
for

PAVEMENT GROOVING

June 17, 1980

THE STANDARD SPECIFICATIONS, SERIES OF 1977, ARE AMENDED BY THE FOLLOWING ADDITIONS. THESE ARE SPECIAL PROVISIONS AND SHALL PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

297.01 GENERAL. This work involves grooving the existing pavement surface, removal of the debris and control of dust created by the operation, and associated traffic control. All traffic lanes are to be grooved. Bridge floors are to be grooved unless otherwise designated on the plans. Ramps are to be grooved only when specifically designated on the plans. The pavement surface will be described on the plans.

297.02 GROOVING SPECIFICATIONS. Each 12-foot traffic lane shall have 10 feet of its width longitudinally grooved, leaving the outside 12 inches and the inside 12 inches ungrooved. The grooving in each lane shall be continuous over the length designated by the engineer. The grooving pattern shall be nominal 0.095-inch-width by minimum 1/8-inch-depth grooves spaced on 3/4-inch centers. An external slurry pickup device shall be used, or the pavement surface shall be flushed clean with water at the end of each day's work.

Grooving is expected to cover 100 percent of the width designated, and to the minimum depth specified. Exceptions will be made for manholes, bridge joints and similar obstructions. The grooving operation shall be especially controlled on bridge floors and in areas of traffic signal detectors so that the minimum depth is not exceeded.

297.03 TRAFFIC CONTROL. This work is to be done while the road is open to public traffic. Traffic control shall be in accord with the plans and 1107.09.

297.04 LIMITATIONS. All work shall be done during daylight hours, unless otherwise specifically authorized by the engineer. Only one traffic lane may be closed at a time, and ramp traffic shall be maintained at all times using flagmen as necessary. All traffic lanes are to be open to traffic at night and during other nonworking periods, and all equipment is to be removed from the travel lanes and shoulder during nonworking periods. Equipment storage within the right-of-way is to be as far from travel lanes as is practical. Before a lane closure is opened to traffic, the debris is to be picked up or the surface flushed. Each day's operation shall be planned for full-width grooving of the traffic lane, with each pass to be brought up to approximately the same location. No work will be permitted on Sundays or holidays.

The contractor shall conduct his operation in such a manner that debris does not create a safety hazard to traffic in the adjacent lane and that dust does not create a safety hazard or a public nuisance.

297.05 METHOD OF MEASUREMENT. The engineer will compute the area of grooving satisfactorily completed, from the length and the nominal width of grooving. The nominal width of a 12-foot traffic lane is 10 feet.

297.06 BASIS OF PAYMENT. Payment will be made at the contract unit price for the number of square yards of pavement grooving completed. This payment will be full compensation for grooving, removal of debris, and traffic control.

IOWA DEPARTMENT OF TRANSPORTATION
OFFICE OF MATERIALS
AMES LABORATORY
TEST REPORT - BITUMINOUS MATERIALS

MATERIAL A. C. ASPH. SAND SURF. 3/8"@7.5% LAB NO ABC0-339
INTENDED USE
PROJECT NO I-IR-80-5(95)149--14-77 COUNTY POLK
CONTRACTOR IOWA ROAD BUILDERS
PRODUCER IOWA ROAD BUILDERS CONTRACT NO C-17582
PLANT DES MOINES, IOWA
UNIT OF MATERIAL AC-20. 16 TONS. DES. 1579
SENDERS NO HM-1-X
SAMPLED BY V.MARKS
DATE SAMPLED 9/29/80 DATE RECD 9/29/80 DATE REPORTED 10/13/80

SIEVE ANALYSIS PERCENT PASSING

SIEVE	GM.RET	% RET	% PSG
1-1/2	0.0	0.00	0.00
1.05	0.0	0.00	0.00
3/4	0.0	0.00	0.00
1/2	0.0	0.00	0.00
3/8	0.0	0.00	100.00
4	69.0	4.63	95.37
8	224.0	15.03	80.34
16	247.0	16.57	63.77
30	333.0	22.35	41.42
50	419.0	28.13	13.29
100	137.0	9.20	4.09
200	12.0	0.80	3.29
WASH	46.0	3.29	0.00
PAN	3.0	0.00	0.00

DRY WT. 1491.500
SUM OF RETAINED WTS. 1490.000

% AGGREGATE BY EXTRACTION	93.200
% BITUMEN BY EXTRACTION	6.800
SPECIFIC GRAVITY	2.170
MARSHALL STABILITY	543.000
MARSHALL FLOW 0.01 IN.	8.000

1" SPEC. 75 BLOW ONE SIDE SP. GR.	2.20
RICE SPECIFIC GRAVITY	2.395

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R. HUMPHREY
V. MARKS
DICK BRACKETT
I-IR-80-5(95)149--14-77, POLK

BY BERNARD C. BROWN
TESTING ENGINEER