TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-87/19+369-1F		

4. Title and Subtitle	5. Report Date
EVALUATION OF TEXTURE REQUIREMENTS FOR PORTLAND CEMENT CONCRETE PAVEMENTS	September 1985
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Alvin H. Meyer	Research Report 369-1F
9. Performing Organization Name and Address	10. Work Unit No.
Center for Transportation Research The University of Texas at Austin Austin, Texas 78712-1075	11. Contract or Grant No. Research Study 3-8-84-369
	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address Texas State Department of Highways and Public Transportation; Transportation Planning Division P. O. Box 5051 Austin, Texas 78763	Final
	14. Sponsoring Agency Code

15. Supplementary Notes

Study conducted in cooperation with the U. S. Department of Transportation, Federal Highway Administration. Research Study Title: "Evaluation of Texture Requirements for Portland Cement Concrete Pavements"

16. Abstract

The Texas State Department of Highways and Public Transportation (SDHPT) 1982 Standard Specifications required a transverse tine texture that many contractors were having a difficult time producing. In some cases, in order to meet the specifications, the contractors were producing excessively deep textures which lacked durability.

This research reviewed current literature and conducted a telephone interview to determine the experience and current practice of other agencies. As a result of this research, the SDHPT Specifications Committee has proposed special provisions for Specification Item 360.

17. Key Words	18. Distribution Statement
texture requirements, transverse tine, portland cement concrete, pavements, literature, interviews, recommendations	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	36	

Form DOT F 1700.7 (8-69)

EVALUATION OF TEXTURE REQUIREMENTS FOR PORTLAND CEMENT CONCRETE PAVEMENTS

by

Alvin H. Meyer

Research Report 369-1F

Evaluation of Texture Requirements for
Portland Cement Concrete Pavements
Research Project 3-8-84-369

conducted for

Texas State Department of Highways
and Public Transportation

in cooperation with the
U. S. Department of Transportation
Federal Highway Administration

by the

Center for Transportation Research
Bureau of Engineering Research
The University of Texas at Austin

September 1985

The contents of this report reflect the views of the author, who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

There was no invention or discovery conceived or first actually reduced to practice in the course of or under this contract, including any art, method, process, machine, manufacture, design or composition of matter, or any new and useful improvement thereof, or any variety of plant which is or may be patentable under the patent laws of the United States of America or any foreign country.

PREFACE

This is the final report describing the work done on the project entitled "Evaluation of Texture Requirements for Portland Cement Concrete Pavements." This project is being conducted at the Center for Transportation Research, The University of Texas at Austin, as part of the Cooperative Highway Research Program sponsored by the State Department of Highways and Public Transportation (SDHPT) and the Federal Highway Administration.

The report presents the results of a survey conducted by a telephone interview method and three field trips to selected sites. Based on an analysis of the survey, observations were made which led to recommendations for an improved surface texture for portland cement concrete pavements.

The writer is particularly grateful to the SDHPT Specifications Committee for their support throughout the project.

A. H. Meyer

September 1985

LIST OF REPORTS

Report No. 369-1F, "Evaluation of Texture Requirements for Portland Cement Concrete Pavements," by Alvin H. Meyer, presents the results of a national survey conducted by a telephone interview and three field trips to selected sites. The recommendations of this report have led to a proposed change in surface texture specifications for concrete pavements.

ABSTRACT

The Texas State Department of Highways and Public Transportation (SDHPT) 1982 Standard Specifications required a transverse tine texture that many contractors were having a difficult time producing. In some cases, in order to meet the specifications, the contractors were producing excessively deep textures which lacked durability.

This research reviewed current literature and conducted a telephone interview to determine the experience and current practice of other agencies. As a result of this research, the SDHPT Specifications Committee has proposed special provisions for Specification Item 360.

SUMMARY

PROBLEM STATEMENT

The Texas State Department of Highways and Public Transportation (SDHPT) 1982 Standard Specifications require a transverse tine texture finish with an average texture depth (ATD) of at least 0.060 inch, with no single test below 0.050-inch. Many contractors cannot satisfy these requirements without producing excessively deep textures in some areas. These excessively deep textures appear to lack durability and wear down at an accelerated rate.

The problem is to determine what modifications to the standard specifications are necessary in order to produce a more durable finish with adequate texture to satisfy the requirements of the driving public.

RESEARCH

A literature search and telephone survey were conducted to determine the experience and current specifications of other agencies. As a result of the research, the following recommendations are made.

RECOMMENDATIONS

Based on the results of the survey and a search of the literature, the following recommendations are made:

(1) Use an astrograss drag longitudinally as the initial texture. Specify carpet and drag as per the Minnesota DOT.

(2) Use metal tines spaced nominally at one inch center to center. The metal tine is to be 0.032 inch thick by 0.083 inch wide by 6 inches long.

(3) Delete the Average Texture Depth specification and replace with a nominal transverse groove depth of 3/16 inch with a 1/8-inch minimum.

(4) Require drag, tine texture, and curing equipment to be separate machines.

(5) Institute a riding quality (smoothness) specification. As an interim value (until data can be generated and analyzed for Texas paving) use a maximum of 12 inches per mile as measured by the California profilograph. Bridges, pavement projects less than 1/2 mile in length, and the first 1/2 mile of a project should be deleted from the riding quality determination.

(6) Institute a maximum temperature requirement for paving concrete at the time of placement (This is the same as SDHPT Item 420.11).

IMPLEMENTATION

Based on this research, the Specifications Committee of the Texas State Department of Highways and Public Transportation has proposed special provisions for Specifications Item 360, Concrete Pavement.

IMPLEMENTATION STATEMENT

As a result of this study, the Specifications Committee for the Texas State Department of Highways and Public Transportation recommended a special provision to Specification Item 360, Concrete Pavement (Water Cement Ratio). The special provision is included as Appendix A.

Other recommendations for smoothness and temperature are being considered for future modifications.

TABLE OF CONTENTS

EVALUATION OF TEXTURE REQUIREMENTS FOR PORTLAND CEMENT CONCRETE PAVEMENTS

PROBLEM STATEMENT

The Texas State Department of Highways and Public Transportation (SDHPT) 1982 Standard Specifications require a transverse tine texture finish with an average texture depth (ATD) of at least 0.060 inch with no single test below 0.050 inch. Many contractors cannot satisfy these requirements without producing excessively deep textures in some areas. These excessively deep textures appear to lack durability and wear down at an accelerated rate.

The problem was to determine what modifications to the standard specifications are necessary in order to produce a more durable finish with adequate texture to satisfy the requirements of the driving public.

BACKGROUND AND SIGNIFICANCE

In the late 1960's and early 1970's the SDHPT funded several studies to evaluate wet weather accidents (Ref 1), tire pavement interaction (Ref 2), and texture requirements and construction (Ref 3), among others, to determine pavement surface texture requirements. Based on these and the research and experience of other agencies the current (1982) standard specification was adopted.

The deeper texture was specified based on the desire to maintain an ATD of at least 0.035 inch for the majority of the pavement life. The ATD of 0.035 inch was selected on the basis of wet weather accident studies. Wearability studies and the experience of others (NCHRP Circular 170, Ref 4) suggested a wear-down of about 35 percent in early life (up to five years) and then a relatively stable surface for an extended period. Thus, the minimum texture depth of 0.050 inch was specified.

The transverse direction for the tines texture was specified because transverse textures, regardless of texture depth, showed higher skid values under all conditions.

In a recently completed study (Ref 5), Hankins concluded the following:

(1) Some 20 to 25 percent of the newly constructed pavements failed to meet an average texture depth of 0.060 inch.

(2) About 86 to 88 percent of the newly constructed pavements failed to meet the minimum texture requirements of 0.050 inch.

(3) There appears to be a conflict between the texture and roughness requirements in the standard specifications.

(4) The variance between operators can be large, particularly on heavily textured pavements. Some 0.020 to 0.030 inch was common even though the average difference was 0.016 inch.

(5) There has been some surface damage caused by the breaking and raveling of the ridges formed by the tines.

(6) The majority of engineers contacted in the districts have experienced trouble in obtaining the required tines texture levels, were concerned with the damage and the possibility of a structural strength loss caused by tining, and did not believe the possible reduction in wet weather accidents achieved by the tines was worth the possible reduced loss in structural life caused by tining.

(7) Percent "wear-down" is inconsistent. Levels below 0.035 inch can be found before structural rehabilitation becomes necessary even though textures greater than 0.060 inch were constructed initially. However, surfaces can be found where there are relatively large texture values after several million traffic applications per lane. Surfaces with larger initial texture values generally retain larger values longer, but surface strength and proper mix design must are very important in maintaining texture under the abrasive action of traffic.

These conclusions suggest a need to modify the current SDHPT standard specification for textures.

OBJECTIVES

The objectives for this study were to:

(1) Determine the texture required for PCC pavement with respect to texture type.
(2) Determine how other agencies obtain the required texture in terms of design (ATD and cross-slope) construction methods, cost, inspection, performance, and remedial treatments.
(3) Determine if current research by other agencies is expected to produce changes in their texture requirement and the expected results of those changes.
(4) Based on the results of objectives one, two, and three, examine the SDHPT specification for PCC pavement texture and make recommendations fo necessary modifications.

RESEARCH

A questionnaire was prepared for use in telephone interviews for this project. After review by the SDHPT and the Federal Highway Administration (FHWA), the questionnaire was used to survey seventeen highway agencies outside of Texas. A copy of the questionnaire is shown in Appendix A. The seventeen states surveyed have 78 percent of the rigid pavement in the federal aid primary systems, and 79 percent of the total rigid pavement in the federal aid system. A summary of the results of the survey is shown in Table 1.

In addition to the survey responses, most of the states sent copies of their current texture requirements for PCC pavements.

TABLE 1. SUMMARY OF QUESTIONNAIRE

State	Texture	Depth (Inches)	Spacing (Inches)	Inspection	Curing Sf/gal	Durability
Arizona	Burlap Drag & Trans. Tines	.09 - .20	3/4 ± 1/4	Tread Gage	100	Good
California	Burlap Drag & Trans. Tines	3/16 ± 1/8	3/4	Skid	200	Good
Florida	Trans. Tines	.10 - .15	1/2	Sand Patch	200	Good
Georgia	Trans. Tines	ATD .035	1/2	Sand Patch	150	Good
Illinois	Astro Turf & Trans. Tines Burlap under 40 mph	1/8 to 3/16	1/2 - 3/4	Tread Gage	250 ea. 2 Passes	Good
Iowa	Burlap or Turf & Trans. Tines	1/8 to 3/16		Tread Gage	1 1/2 Times 2 Passes	Good
Indiana	Burlap Drag & Trans. Tines	.12 to .19	Random 1/2 to 1 1/8	Ruler	150	Good
Louisiana	Trans. Tines	1/8 to 3/16	1/2	Tread Gage	100	Good
Michigan	Burlap or Turf & Trans. Tines	1/8 to 1/4	1/4 to 1	Wire Probe	200 ea. 2 Passes	Good
Minnesota	Astro Grass & Trans. Tines	1/8 to 3/16	1 1/2	Tread Gage	150 Nozzles 2 Dir.	Good
Mississippi	Burlap & Trans. Tines	3/16 ± 1/16	1/2	Tread Gage	150	Good
Missouri	Burlap & Trans. Tines	1/8	1/2 clear	16 Penny Nail	150	Average
Nebraska	Burlap Drag & Trans. Tines	1/8	1/2	Visual	150	Good
New York	Burlap Drag & Trans. Tines	3/16 ± 1/16	3/4	None	Same	Good
Ohio	Burlap & Broom or Tines	.15	5/8	Sand Patch	150	Good
Pennsylvania	Trans. Tines	3/32 to 3/16	3/8 to 3/4	Tread Gage	150	Good
Wisconsin	Turf & Trans. Tines Turf only - Urban	1/8 to 3/16	1	Visual	Increase over Turf	Good

(continued)

TABLE 1. (CONTINUED)

State	Smoothness	Verification	Noise	Vehicle Handling	Tire Wear	Adequate Texture	Critical Factor	Studies
Arizona	7" per mile	Profilograph	None	None	None	Yes	Timing	None
California	7" per mile	Profilograph	None	None	None	Yes	Timing	None
Florida	1/8" in 10'	Straight Edge	None	None	None	Yes	Timing	None
Georgia	65" per mile	Mays Meter	Some	None	None	Yes	Consistency	None
Illinois	15" per mile	Profilograph	None	None	None	Yes	Timing	None
Iowa	15" per mile	Profilograph	Some	None	None	Yes	Consistency	None
Indiana		Profilograph	None	None	None	Yes	Timing Consistency	Yes
Louisiana	1/8" in 10'	Rolling Straight Edge	None	None	None	Yes	Consistency	None
Michigan		Optical Device	None	None	None	Yes	Timing	None
Minnesota	<69" bonus >85" penalty	BPR Roughometer	None	None	None	Yes	Good Mix/ Good Inspect.	Yes
Mississippi	1/8" in 10'	Will use Mays Meter	None	None	None	Yes		None
Missouri	1/8" in 10'		None	None	None	Yes	Timing	None
Nebraska	0-12 100% >12 penalty	Profilograph	None	None	None	Yes	Timing	None
New York	Yes bonus penalty		None	None	None	Yes	Timing Consistency	Yes
Ohio	New this year 12" per mile	Profilograph	None	None	None	Yes	Timing Education	Yes Skid
Pennsylvania	0-15 100% >15 penalty	Profilograph	None	None	None	Yes	Timing	None
Wisconsin	12" per mile	Profilograph	None	None	None	Yes	Timing	None

Additionally, several states sent reports of research that had led to changes in the surface texture specifications for the respective states. Excerpts from selected reports are contained in the following material.

MINNESOTA (Ref 6)

All textures included an astro-grass drag in the longitudinal direction followed by transverse tines.

Recommendations

1. The tonal characteristics of the 1-1/4-inch spaced tining tend to discourage the use of this texture on future paving projects.
2. The test surfaces appear to have stabilized and an annual test should not be required in the future. A check on the sections might be made again in three or four years.
3. When determining tire noise from a given PCC pavement texture wait one or two years after construction to measure vehicle pass-by noise levels.
4. Use a transverse tine spacing of 1-1/2 inch when texturing the surface of a Portland Cement Concrete Pavement.

Minnesota also reported in unpublished data having made several measurements on PCC surface textures. Some of Minnesota's data are shown in Table 2.

GEORGIA (Ref 7)

As a direct result of this study, Georgia's specifications for the final finish for concrete pavement have been changed by special provision. Specifications for future projects will require the surface finish to be produced by mechanical equipment for grooving plastic concrete utilizing rectangular shaped spring steel tines spaced at approximately 1/2 inch center

TABLE 2. CONCRETE PAVEMENT TEXTURE DEPTH COMPARISON

Project M K005(3) (Tidwell)
Control 8005-12-4
Concrete From Gifford-Hill - Irvington Plant
Design GH-7 C.A.F. .80 - F.A.F. .80 - C.F. 5.5 - W.F. 5.25
Astro-Turf Drag Finish, Placed 1-28-82

Test No. 1	Sta. 33 + 50	Eastbound Lane	
Sand Patch Dia.	5.5		
	6.0	5.75 Avg. =	0.57 Texture
	6.0		
	5.5		
Test No. 2	Sta. 25 + 00	Eastbound Lane	
Sand Patch Dia.	6.25		
	6.25	6.25 Avg. =	0.50 Texture
	6.25		
	6.25		
Test No. 3	Sta. 29 + 50	Eastbound Lane	
Sand Patch Dia.	5.25		
	5.5	5.5 Avg. =	0.63 Texture
	5.5		
	5.75		

Project M K053(1) (Bellaire)
Control 8053-12-5
Concrete From Gifford-Hill - Westpark Plant
Design GH-7 C.A.F. .80 - F.A.F. .80 - C.F. 5.5 - W.F. 5.25
Burlap Drag Finish, Placed 1-26-82

Test No. 1	Sta. 18 + 00	Eastbound Lane	
Sand Patch Dia.	6.8		
	7.5	7.1 Avg. =	0.38 Texture
	7		
	7.1		
Test No. 2	Sta. 22 + 00	Eastbound Lane	
Sand Patch Dia.	7.25		
	7.5	7.25 Avg. =	0.36 Texture
	7		
	7.25		
Test No. 3	Sta. 25 + 00	Eastbound Lane	
Sand Patch Dia.	7.5		
	7.0	7.2 Avg. =	0.37 Texture
	7.0		
	7.25		

to center. Specifications for mechanical equipment used will give some assurance that the desired product will be obtained. However, the additional requirement of a minimum sand patch texture depth of 0.03 inch will also be included.

It is apparent that the sand patch test alone does not accurately describe the surface produced by plastic grooving. Texture depth with approximate groove size and spacing will be specified. Other finishes with texture depths comparable to that of a plastic grooved finish will probably have much lower skid resistance than a plastic grooved surface. Deep channels provide for better water passage and adequate groove spacing contributes to durability.

LOUISIANA (Ref 8)

Based on this study, the following conclusions are offered:

(1) Generally, skid numbers for the broom and metal tine experimental textures were higher than those for the burlap drag texture. The latter technique was previously specified in the Louisiana Department of Transportation and Development Standard Specifications and used extensively throughout the state.

(2) Metal tines, applied transversely to the centerline of the concrete pavement, preceded by heavy burlap drag applied longitudinally, produced grooves 1/8 to 3/16 inch deep with the highest skid number, a low speed gradient, and a noise level comparable to that of the standard burlap drag. As a result of the favorable data gathered on this study, this texturing technique has been adopted by the Louisiana Department of Transportation and Development as standard on all concrete pavements and bridge decks.

(3) The extra heavy nylon broom was capable of producing a texture with high initial skid number, but the time of finishing was so critical that uniform texture could not be consistently obtained. The researchers anticipated that the broom finish would have a wear

rate greater than that of the tined finish; however, no significant difference has been noted.

(4) None of the experimental textures produced objectionable road noise or increased the noise level significantly over standard burlap drag; however, all sections had comparatively high noise levels.

(5) The review of the accident data during the test period proved no significant relationship existed between the cause of an accident and the type of the texturing.

(6) Texture depth values decreased slightly between 4-year and 5-year evaluation periods. Skid resistance values and noise levels were about the same for all sections for the final evaluation period.

(7) For the early ages of the study, the finish produced by metal tines and applied transversely had the highest skid numbers and best speed gradient. However, skid numbers on all the sections have generally leveled off to approximately the same values after a period of five years. Textures produced by metal tines showed a greater depth by the sand patch method than the textures made by brooms.

It was recommended that the texturing technique of a longitudinal burlap drag followed by metal tines applied transversely to the centerline of the concrete pavement, which has been implemented by the Department, be continued as standard on all new concrete pavements and bridge decks.

ILLINOIS (Ref 9)

Reference 9 reports that textures (transverse tine, transverse broom, artificial turf, transverse roller, artificial-turf/transverse-tine combination, longitudinal tine, and longitudinal broom) were formed in the plastic surface of a continuously reinforced concrete pavement. Construction observations indicated that separate machines for texturing and for applying curing compound are preferred since the timing of the two operations is sometimes incompatible. During texturing, care must be taken to avoid

overlapping transverse textures, edge damage, and surface deformation caused by the pressure of the device.

Friction tests indicated that grooved textures are superior to broom and artificial-turf textures, with the artificial-turf/transverse-tine combination being the best. A Macro-Texture Index, based on both treaded-tire and smooth-tire friction numbers, shows promise as a surrogate texture-depth indicator. The index can determine, with a high degree of certainty, whether a surface has a coarse, medium, or fine texture. Smoothness tests verified that surface texture can influence Roughness Index values, with transverse-grooved textures being rougher than longitudinal textures. Most motorists can easily detect when they are on the transverse-roller texture, because its wider and deeper 2-inch-spaced grooves result in a humming noise like that produced by rumble strips. The transverse roller texture was eliminated as a final finish candidate because of its noise. During winter storms, natural crosswind and vehicle-generated wind caused blowing snow to collect more on longitudinally-tined and artificial-turf textures than the others.

Illinois also reports (Ref 10) a relationship between SN and the relative risk of a surface's becoming the scene of repeated wet-pavement accidents can be derived using the ratio of the percent of accident sites in each SN cell to the corresponding percentage from the stratified sample.

While a surface having an SN above 50 may be, by chance, the scene of wet-pavement accidents, the risk of its being the scene of repeated wet-pavement accidents is quite small. This risk becomes measurable when the SN is between 45 and 50, and increases by 20 times when the SN equals 30, and exceeds 200 times when the SN is 18.

PCC Final Finish

Reference 10 also reports that the 1979 Illinois Standard Specifications for Road and Bridge Construction regarding the final finish applied to portland cement concrete were revised in 1983. Transverse tine spacing was increased to 3/4-inch centers.

Specifications required that a final finish be applied to the plastic PCC surface using an artificial-turf carpet followed by a mechanically operated metal comb. The carpet is dragged longitudinally. The tining device was operated to produce transverse grooves spaced at approximately 1/2-inch centers, 1/8 to 3/16 inch deep, and 0.100 to 0.125 inch wide. Grooves obtained using the 1/2-inch spacing were sometimes eliminated by mortar flow.

Research by others suggests that grooves produced by wider tine spacings are less susceptible to elimination by mortar flow, and there tends to be less disruption of the surface between the grooves. Both 1/2-inch and 3/4-inch spacings are commonly used in texturing a PCC surface. The recommendation to increase tine spacing from 1/2-inch to 3/4-inch was made to lessen the chances of producing undesirable texturing. The change became effective in the Standard Specifications for Road and Bridge Construction adopted October 1, 1983.

HOUSTON

During the course of the survey reported herein it was discovered that an astro-turf drag had been used for the surface texture of a pavement in SDHPT District 12. The particulars of that pavement are found in Table 3 and pictured in Fig 1.

OBSERVATIONS FROM SURVEY

From a review of the survey summary and the available literature, several observations were apparent.

(1) Most agencies precede the transverse tine texture with a longitudinal drag, either burlap or carpet, to produce a final texture with some macro-texture longitudinally and deep groove transversely.

TABLE 3. EVALUATION OF TEXTURE REQUIREMENTS FOR PORTLAND CEMENT CONCRETE PAVEMENTS

Minnesota IH-90

Astrograss drag with transverse tine texture

9 mile section

1977 Initial Friction Number SN_{40} = 55.4 average

1982 Latest Friction Number SN_{40} = 49.1 average

Experimental Sections IH-90

Astrograss with transverse tine texture:

Tine Spacing	Initial 1978 SN_{40}	Latest 1982 SN_{40}
1/2 in.	63.2	54.0
3/4 in.	60.6	54.3
1 in.	54.9	50.1
1-1/4 in.	56.4	52.0
1-1/2 in.	56.2	49.9

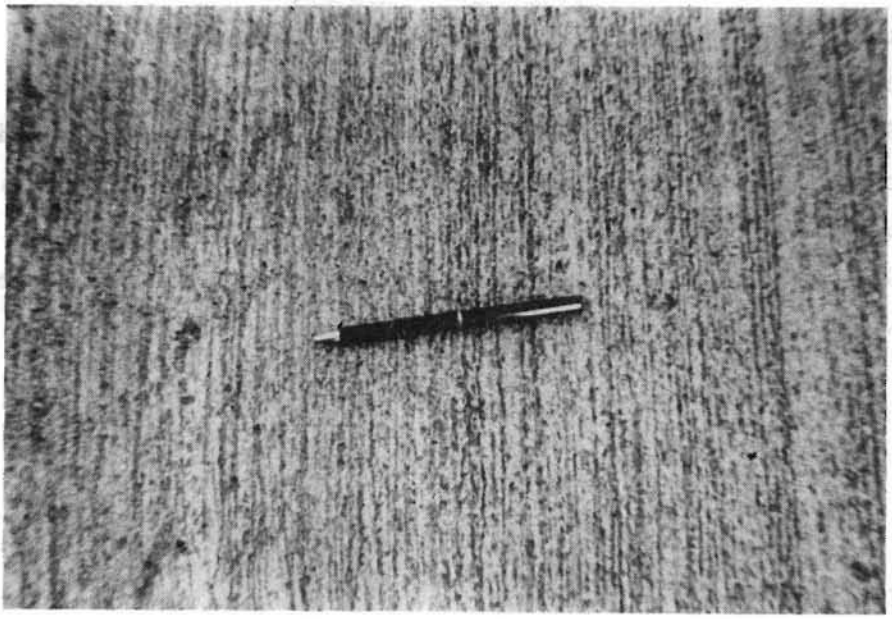

Fig 1. Surface texture produced by an astroturf drag used in District 12, Houston, Texas.

(2) The steel-tine-produced grooves were spaced greater than 1/2-inch center to center and were a minimum of 1/8-inch deep.
(3) The consistency of the mix and the timing of the tining operation are very important if the proper texture is to be obtained.
(4) Since the texturing and curing operations require significantly different timing, most agencies require separate machines for these operations.
(5) Most agencies have a smoothness requirement for PCC pavements, typically 7 to 12 inches per mile as measured by the California profilograph.
(6) Since many of the states surveyed have cooler construction periods than Texas, the temperature of the concrete at the time of placement may be important.
(7) Support from top administration along with education and training as to texture requirement is very important.

RECOMMENDATIONS

Based on the results of the survey and a search of the literature, the following recommendations are made:

(1) Use an astro-grass drag longitudinally as the initial texture. Specify carpet and drag as per Minnesota DOT.
(2) Use metal tines spaced nominally at one inch center to center. The metal tine is to be 0.032 inch thick by 0.083 inch wide by 6 inches long.
(3) Delete Average Texture Depth specification and replace with a nominal transverse groove depth of 3/16 inch with a 1/8-inch minimum.
(4) Require drag, tine texture, and curing equipment to be separate machines.
(5) Institute a riding quality (smoothness) specification. As an interim value (until data can be generated and analyzed for Texas

paving) use a maximum of 12 inches per mile as measured by the California profilograph. Bridges, pavement projects less than 1/2 mile in length, and the first 1/2 mile of a project should be deleted from the riding quality determination.

(6) Institute a maximum temperature requirement for paving concrete at the time of placement. This is the same as SDHPT Item 420.11.

These recommendations should produce a texture similar to that shown in Fig 2.

As a result of this study, recommendations 1, 2, 3, and 4 above have been implemented in a Special Provision to Item 360, Concrete Pavement (Water Cement Ratio). The special provision is contained in Appendix A. Recommendations 5 and 6 are being considered for future implementation.

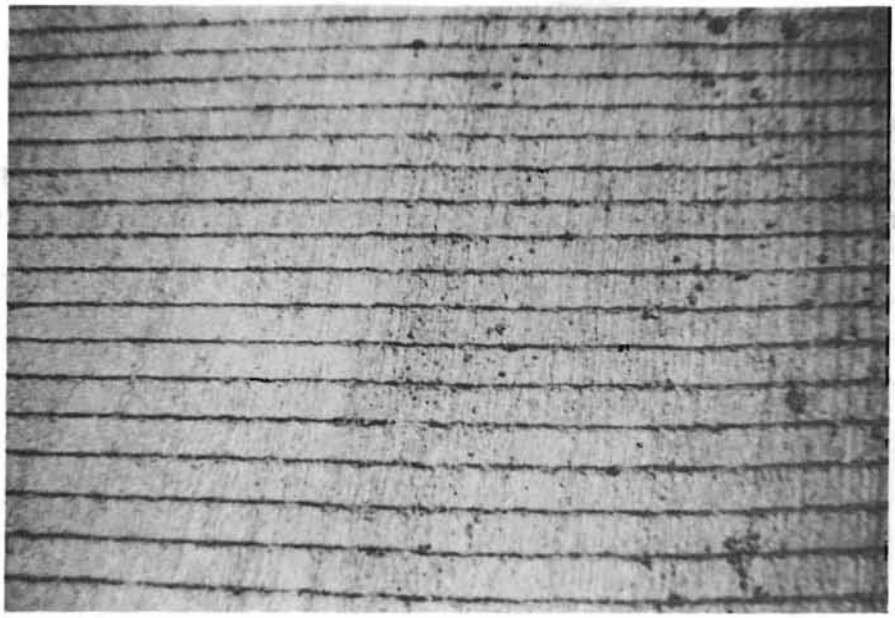

Fig 2. Texture produced by longitudinal carpet drag and transverse tines.

REFERENCES

1. Morgan, R. R., B. Ashkar, K. D. Hankins, P. R. Tutt, "The Degree of Influence of Certain Factors Pertaining to the Vehicle and the Pavement on Traffic Accidents Under Wet Conditions," Research Report No. 1-8-69-133-3F, Highway Design Division, Texas Dept. of Highways and Public Transportation, September 1970.
2. Olson, R. H., J. H. Johnson, B. M. Gallaway, "Final Report on Vehicle-Pavement Interaction Study," Research Report No. 2-8-69-138-7F, Texas Transportation Institute, Texas Department of Highways and Public Transportation, October 1974.
3. Ledbetter, W. B., A. H. Meyer, D. E. Ballard, "Evaluation of Full Scale Experimental Concrete Highway Finishes," Research Report No. 2-8-70-141-4F, Texas Transportation Institute, Texas Department of Highways and Public Transportation, September 1974.
4. Meyer, A. H., "Surface Wear of Portland Cement Concrete Pavements," Transportation Research Circular 170, National Research Council, Transportation Research Board, Washington, D.C., September 1975.
5. Hankins, K. D., "A Review of Tines Texturing of Portland Cement Concrete Paving," Research Report No. 1-10-77-187-10, Transportation Planning Division, Texas State Department of Highways and Public Transportation, June, 1984.
6. "Traffic Noise: A Comparison of Traffic Noise Generated by Tire/Pavement Interaction on Five Different Surface Textures Applied to a Portland Cement Concrete Pavement," Noise Analysis and Development Unit, Office of Environmental Services, Technical Services Div., Minnesota Department of Transportation (undated).
7. Thornton, J. B., "Determination of Desirable Finish for Concrete Pavement," GDOT Research Project No. 7110, Office of Materials and Tests, Georgia Department of Transportation, July 1974.

8. Law, Sheldon M. and Masood Rasoulian, "Texturing of Concrete Pavements," FHWA/LA-79/134, Louisiana Department of Transportation and Development, August 1979.

9. Dierstein, Philip G., "A Study of PCC Pavement Texturing Characteristics in Illinois," FHWA/IL/PR-095, Illinois Department of Transportation, February 1982.

10. Dierstein, P. G. and J. E. LaCroix, "A Summary of the Illinois Skid-Accident Reduction Program, March 1980 - March 1984," State of Illinois Department of Transportation, Bureau of Materials and Physical Research (undated).

APPENDIX A. SPECIAL PROVISION TO ITEM 360 CONCRETE PAVEMENT (WATER CEMENT RATIO)

SPECIAL PROVISION

TO

ITEM 360

CONCRETE PAVEMENT
(Water Cement Ratio)

For this project, Item 360, "Concrete Pavement (Water Cement Ratio)", of the Standard Specifications, is hereby amended with respect to the clauses cited below and no other clauses or requirements of this item are waived or changed hereby.

Article 360.3. Equipment, is supplemented by the following:

(12) Texturing Equipment. A carpet drag shall be mounted on a bridge and the dimensions of the drag shall be 6 feet by the width of the concrete being placed, so that a strip of carpet up to at least 4 feet wide is available to be in contact with the pavement surface while the drag is operated. The carpeting used shall be an artificial grass type having a molded polyethylene pile face with a blade length of 5/8 inch to one inch and total minimum weight of 70 ounces per square yard. The backing shall be of a strong, durable material not subject to rot, which shall be adequately bonded to the facing to withstand use as specified.

The transverse metal-tine device shall be mechanized and be equipped with 4-inch to 6-inch steel tines, spaced nominally at one inch, center to center, approximately 0.032 inch by 0.083 inch (cross section), arranged so as to obtain randomized grooves approximately 3/16 inch deep, minimum 1/8 inch. Other texturing equipment may be approved for use by the Engineer, provided an equivalent texture is obtained.

The texturing equipment shall be equipment which is operated independently from the preceding spreading-and-finishing equipment and from the following curing operation.

Article 360.8. Spreading and Finishing, Subarticle (1) Machine-Finishing. The eighth and ninth paragraphs are voided and replaced by the following:

Unless the pavement is to be overlaid under this contract, after completion of the straightedge operation, as soon as construction operations permit, the pavement surface shall be given a final finish texture. This final finish shall be obtained by drawing the specified carpet drag longitudinally along the pavement before the concrete has attained its initial set. The actual contact surface shall be regulated so that a coarse texture satisfactory to the Engineer is obtained.

In addition to and immediately following the carpet drag, the pavement surface shall be given a transverse metal-tine texture. The metal-tine device shall be operated so as to obtain randomized grooves approximately 3/16 inch deep, minimum 1/8 inch. Manual methods for achieving similar results may be used on ramps etc. Tining shall be omitted within two inches of transverse joints.

Unless otherwise shown on the plans, the above-specified metal-tine texturing will not be required on cross-overs, or on restricted-speed-limit areas (below 35 MPH).

Pavement which is to be overlaid under this contract will not require the carpet drag or tine texturing.

Emergency Procedures

The Contractor shall have available at all times hand rakes with tines and hand-operated carpet drags for the purpose of providing texture in the event of equipment breakdown.

Article 360.11. Deficient Pavement Thickness. The first paragraph is voided and replaced by the following:

The adjustment in unit prices provided for in this article will apply only when measurement for payment is by the square yard. The adjustment may be waived by a note on the plans where concrete-pavement work is narrow widening or small placements.

Article 360.13. Payment. The second paragraph is voided and replaced by the following:

Excavation required by this item in the preparation of the subgrade and for the completion of the shoulders and slopes will be measured and paid for in accordance with the provisions governing the Item "Roadway Excavation", the Item "Borrow", special specification Item "Excavation" and/or special specification Item "Embankment", with the provision that yardage will be measured and paid for once only, regardless of the manipulations involved; or where shown on plans, such work will be measured and paid for in accordance with the provisions governing the Item, "Blading". Measurement of subgrade excavation for payment will be limited to a total width of that of the pavement plus 1 foot on each side. Payment under excavation items will not be allowed within the areas designated for "Blading".