TEXTURING OF CONCRETE PAVEMENTS

Final Report

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FACTORS FOR CONVERSION OF U.S. UNITS TO METRIC UNITS (S.I.)

To convert U.S. Units to Metric Units (S.I.), the following conversion factors should be noted:

Multiply U.S. Units	By	To Obtain Metric Units
Inches (in.)	2.5400	Centimeters (cm.)
Feet (ft.)	0.3048	Meters (m.)
Miles per hour (m.p.h.)	1.609	Kilometers per hour (k.m.h.)
Pounds (lbs.)	0.4536	Kilograms (kg.)
Gallons (gal.)	3.785	Liters (l.)

ABSTRACT

During the month of June, 1973, the plastic concrete surface of a section of Interstate 10 in the Baton Rouge area was textured using several different texturing techniques, such as burlap drag, brooms and metal tines. The purpose of this experimental research project was to learn which would perform the best in regard to skid resistance, nonhydroplaning properties, durability noise levels and uniformity. This report covers the final evaluation of the textured sections after five years of service.

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 a uniform texture could not consistently be 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.

IMPLEMENTATION

As a result of favorable data gathered on this study, it is 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.

INTRODUCTION

Prior to this research study, the Louisiana Department of Transportation and Development Standard Specifications required that the final finish for plastic concrete pavements be produced by a longitudinal burlap drag and that the resulting finish be reasonably free of grooves greater than 1/16 inch in depth. It became apparent from skid data obtained that this technique, when used to finish modern slip form pavements, would not result in a long-lasting skid resistant surface. A very stiff mix is required for slip form paving, and the simple burlap drag did not produce the surface macrotexture needed for skid resistance durability under increasing traffic volumes.

It was necessary for new texturing methods to be found that would provide an initial high skid resistant textured surface for plastic slip form paving as well as one that would last for a long period of time. The Georgia Department of Transportation and the Texas Transportation Institute were contacted for texturing information, since they had constructed experimental sections using the mechanical tining technique. Input from these agencies has been most valuable in the development of this study, as several of their texturing methods were used on this study's test sections, which are located on Interstate 10 in Baton Rouge, Louisiana.

PURPOSE

The purpose of this research study was to evaluate selected concrete textures for uniformity, nonhydroplaning properties, skid resistance, noise levels and durability.

SCOPE

The scope of this report included the description of the construction of test sections and the results of the evaluation period after the project was opened to traffic. The evaluation period of the study consisted of a sixty-month interval, after opening the sections to traffic, divided into five twelve-month periods in the project. Each test section was evaluated using the following techniques:

A. Visual Observation
B. Skid Resistance Measurements
C. Sand Patch Measurements for Determining the Texture Depths
D. Noise Level Measurements
E. Accident Data Analysis

METHOD OF PROCEDURE

A portion of State Project No. 450-10-19, Federal Aid Project No. I-10-3(51)160, was selected as the site of the test installations. The test site was located immediately south of Baton Rouge, Louisiana on Interstate 10 between the College Drive and Siegen Lane intersections westbound. The project as contracted to the T. L. James Construction Company was to construct the selected surface finishes on a 10-inch, jointed, unreinforced concrete pavement. Eight different surface textures were constructed using a CMI Autograde Texturing Finisher machine. Figures 1a, 1b and 1c on pages 7,8 and 9 map the location of each test section listed in Table 1 on page 11.

It was originally proposed that surface finishes using a burlap drag with tag ends and burlap with 60p trailing nails also be included in the study. However, attempts to use these methods did not prove successful; therefore, they were dropped from the study as being inconsistent in their ability to provide a sufficient texture depth with the stiff concrete mix which was used. Aggregate and concrete mix data are shown in Tables 2 and 3 found on pages 27 and 28 of Appendix A.

The experimental textured sections were completed in June, 1973, and construction traffic used the roadway until May, 1974, when the highway was officially opened to the public.

The roadway finish was tested immediately after construction and at 3, 6, 9. 12, 24, 36, and 60-month periods after the highway was opened to the public. The following procedures were used as a basis for testing the performance of each experimental section.

I. Visual observation included the use of photo-documentation. Original photographs were used as a reference for later comparisons. This procedure is not a test and is not definitive; therefore, it was not intended to cast judgment upon a particular section. However, it provided an accurate historical record of the construction and observation technique, as well as an accurate log of aesthetic conditions at the time of inspection.

II. Skid testing provided the most useful data for performance evaluation. All skid resistance measurements were made using a skid testing trailer conforming to ASTM E-274-70, at controlled speed and at designated time periods. During the time of evaluation, tests for skid resistance were made at the speeds of 20 m.p.h., 30 m.p.h., 40 m.p.h., 50 m.p.h., and 60 m.p.h. A skid number is the coefficient of friction x 100. The speed gradient is the slope of the line plotted with skid numbers versus designated speeds.

III. The sand patch method was used to aid in the determination of texture depths. Refer to Appendix B for the complete procedure for performing this test. The sand patch method has been primarly used to determine the texture depths of pavements that were constructed using a single burlap dragged, broomed, or belted finish. Its use in determining the actual depth of a tined textured finish is questionable since most grooves produced by a tine inherently have a lip of concrete mortar on each side. Also, should different personnel perform these tests, variability in results is almost always present. Therefore, the sand patch method was used in this study more as a guide and a relative comparison between sections and should not be taken as actual depths of grooves.

When obtaining the depth of a groove produced by a tine at a particular location, a tire tread depth wear gauge may be used. Refer to Appendix B for the procedure for using this method. Since concrete finishing techniques do not provide a perfectly uniform depth across or along a roadway, several readings must be taken and averaged. The gauge is a very useful tool when constructing a finish, as it allows immediate adjustment in depth should the specification tolerances be exceeded.

IV. Noise level measurements were taken to determine the sonic characteristics produced by traffic riding on the textured sections. A test vehicle was driven over each of the test sections at predetermined speeds. Noise levels were to be measured for both the exterior and interior of the vehicle. All measurements were made with a General Radio Type 1551-C Sound Level Meter operated on the A scale. The output of the meter was permanently recorded on a General Radio 1521-B Graphic Level Recorder. Interior noise level readings were not taken later in the study.

Exterior Noise Levels

The sound level meter was set up 25 feet from the center of the lane of travel of the test vehicle. The meter was placed on a tripod approximately 3 1/2 feet above the pavement surface with the microphone perpendicular to the vehicle travel path. Care was taken to locate the microphone, vehicle and observers far enough from the sound level meter to minimize reflected sound waves.

Noise level measurements were conducted for test vehicle speeds of 40 m.p.h. and 60 m.p.h. A minimum of two test runs at each speed was conducted. Additional runs were made if it was judged that other noise sources interfered with the test or of the results of the two runs differed by one or more decibels. The sound level meter was recalibrated each time the meter was moved to a new test section.

The vehicle was driven at a constant cruising speed (no acceleration or deceleration) with the motor engaged. Preliminary runs had indicated that there was little noise level difference between the motor-engaged and motor-disengaged conditions.

Interior Noise Levels

The sound level meter was set up at approximately driver's ear height between the driver and passenger sides of the front seat of the test vehicle. Sound level measurements were made continuously while travelling each test section. Vehicle speeds of 40 m.p.h. and 60 m.p.h. were used for this purpose. The graphic level recording was analyzed by carefully selecting an average maximum decibel reading over the length of the test section measurement. Data obtained from this study did not show objectionable interior noise.

V. Accident data was compiled from State Police records supplied to the Traffic and Planning Section of the Department. These accident reports were referenced to mileposts in tenths of miles. The data was analyzed for accident trends.

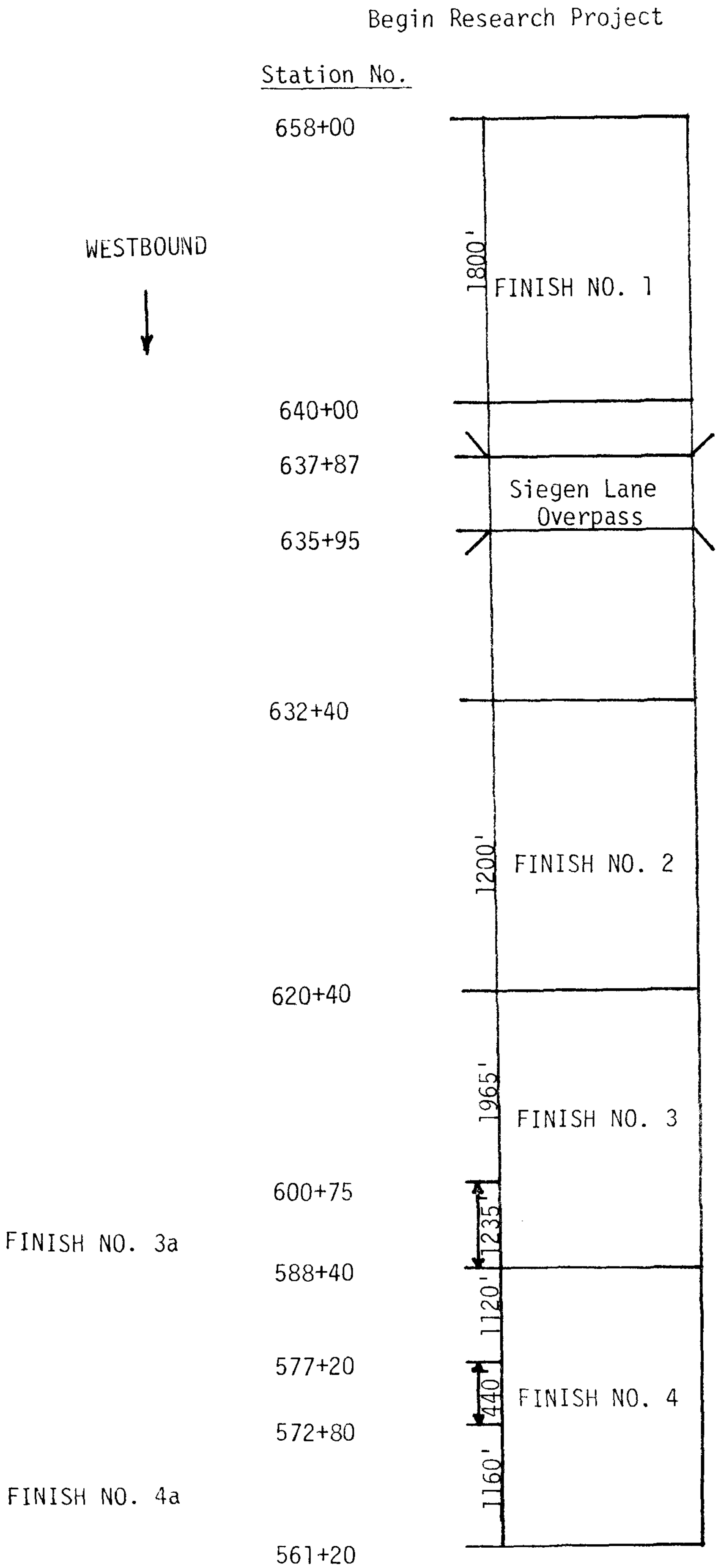
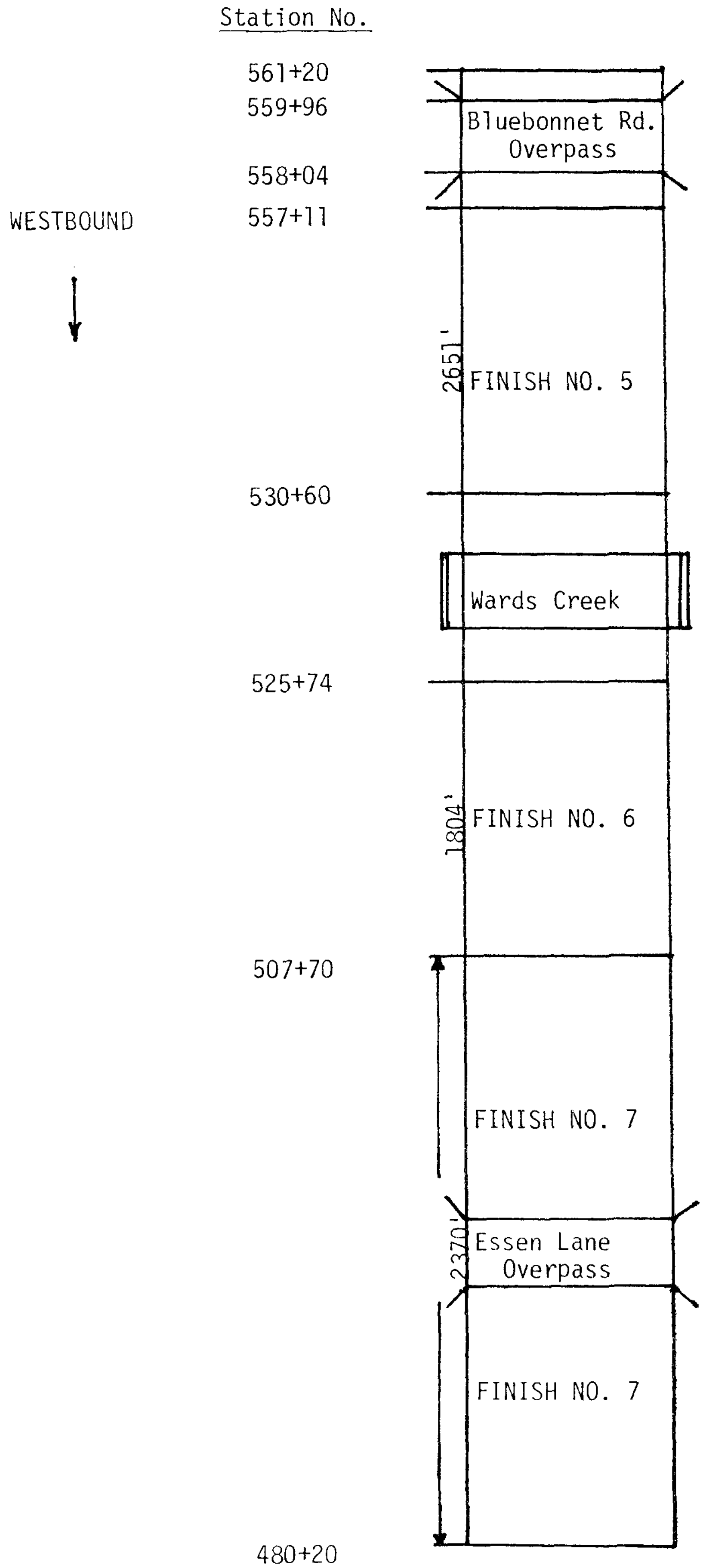


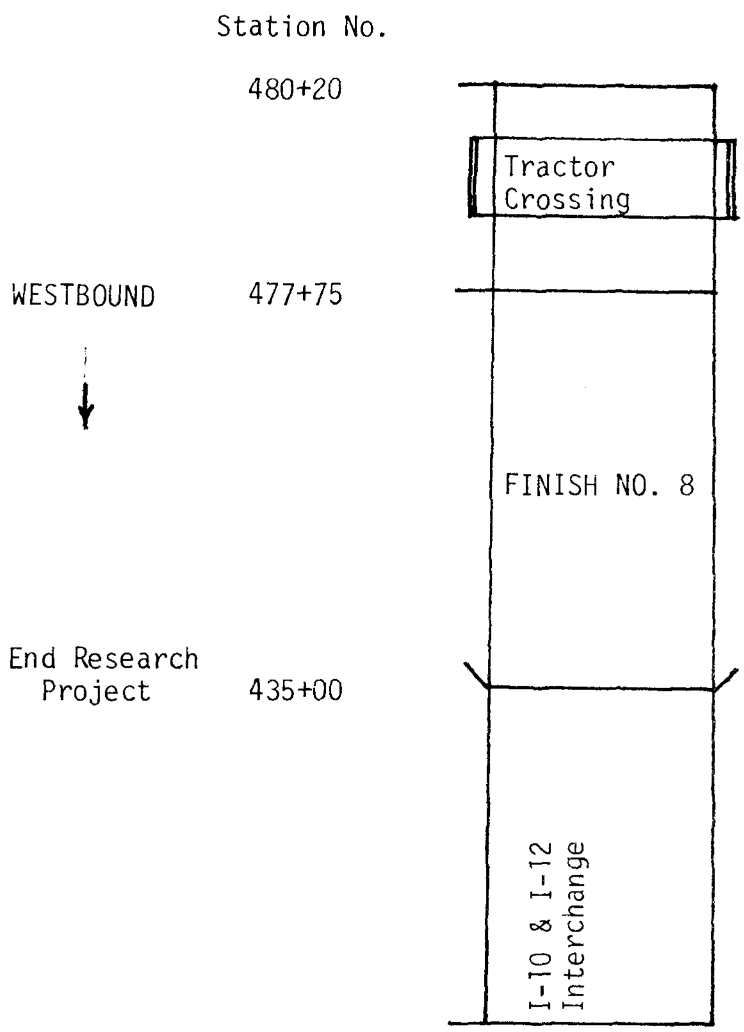
FIGURE 1a

LOCATION OF TEST SECTION



LOCATION OF TEST SECTIONS

FIGURE 1b



LOCATION OF TEST SECTIONS

FIGURE 1c

GENERAL DISCUSSION

Types of Surface Texture

Eight different types of surface texture, as shown in Table 1 on the following page, were constructed and evaluated. They were normal burlap drag (control section), transverse texturing with soft bristle broom, transverse texturing with heavy polyplastic broom, transverse texturing with extra heavy nylon broom, transverse texturing with metal tines, longitudinal grooving with extra metal tines preceded by heavy burlap drag, transverse grooving with extra metal tines preceded by heavy burlap drag, longitudinal texturing with extra heavy nylon broom. Two areas within the experimental broom sections which were rained on had to be resurfaced with a neat cement grout and retextured. One area was retextured transversely with a heavy polyplastic broom and the other transversely with an extra heavy nylon broom. These two areas were evaluated with the eight test sections. Figure 2 on page 12 shows a slip form paver that was used on the project. Figures 3 through 8 on pages 13 to 15 show some of the various textures and texturing techniques on as-built test sections.

TABLE 1

STATIONING AND TYPES OF FINISHES

Texture No.	Station to Station		Type of Finish
1	658+00	640+00	Burlap Drag, Longitudinal (Control Section)
2	632+40	620+40	Mechanical Broom, Soft Bristles, Transverse
3	620+40	600+75	Mechanical Broom, Heavy Polyplastic Bristles, Transverse
3a	600+75	588+40	Mechanical Broom, Heavy Polyplastic Bristles, Transverse - Retextured
4	588+40 572+80	577+20 561+20	Mechanical Broom, Extra Heavy Nylon Bristles, Transverse
4a	577+20	572+80	Mechanical Broom, Extra Heavy Nylon Bristles, Transverse - Retextured
5	557+11	530+60	Metal Tines (1/2" center, 4" long), Transverse
6	525+74	507+70	Metal Tines (1/2" center, 4" long), Longitudinal, Preceded by Burlap Drag
7	507+70	480+20	Mechanical Broom, Extra Heavy Nylon Bristles, Longitudinal
8	477+75	435+00	Metal Tines (1/2" center, 4" long), Transverse, Preceded by Burlap Drag

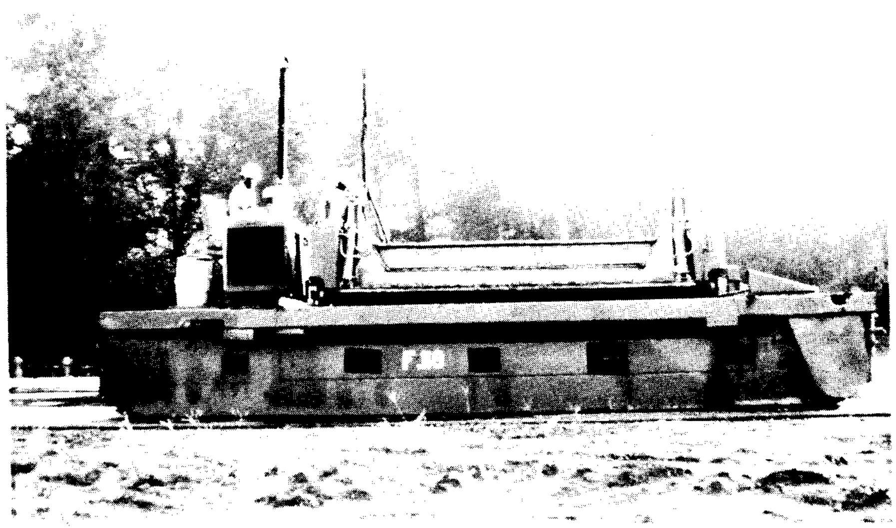


FIGURE 2

Rex Slip - Form Paver Used to Construct I-10 Highway near Baton Rouge, La.

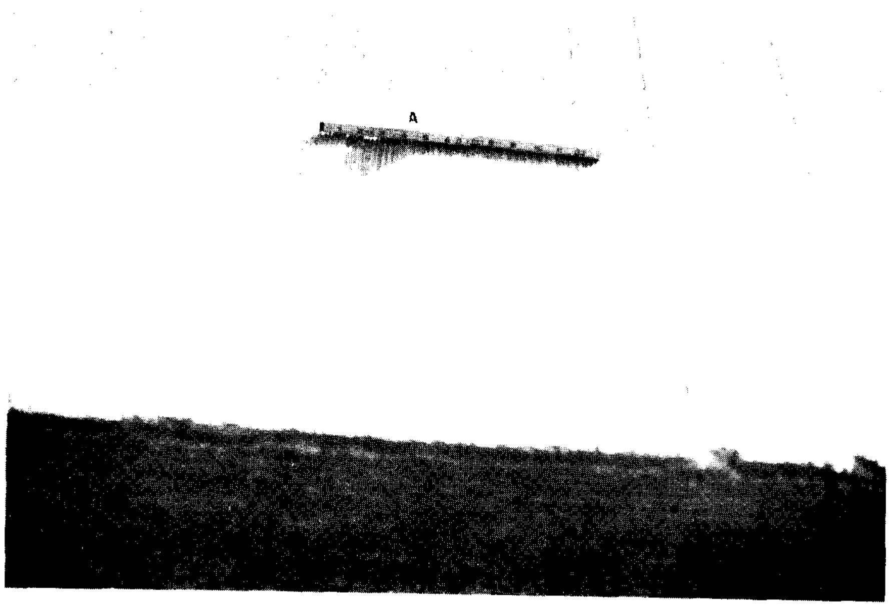


FIGURE 3

Mechanical Broom, Heavy Polyplastic, Transverse Texture

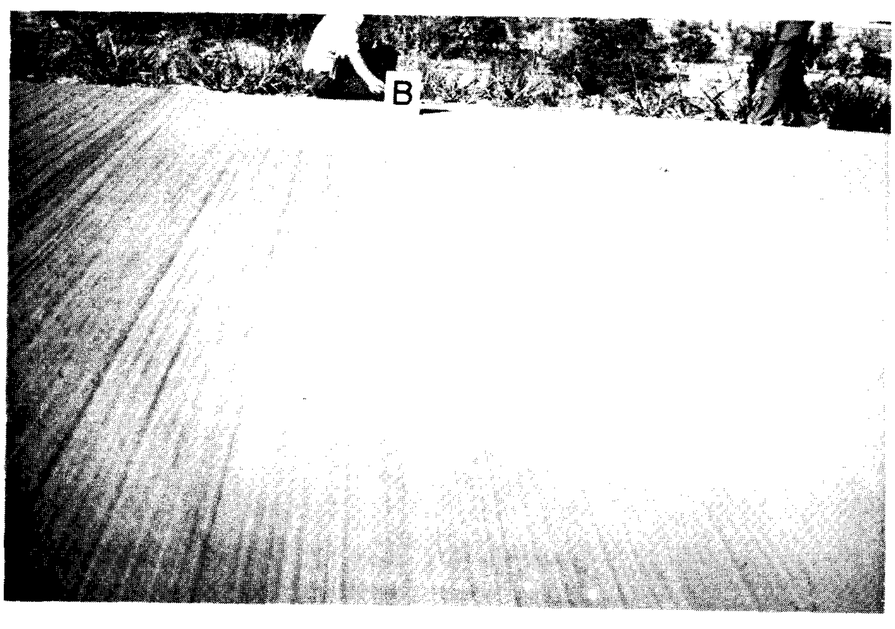


FIGURE 4

Mechanical Broom, Extra Heavy Nylon, Transverse Texture

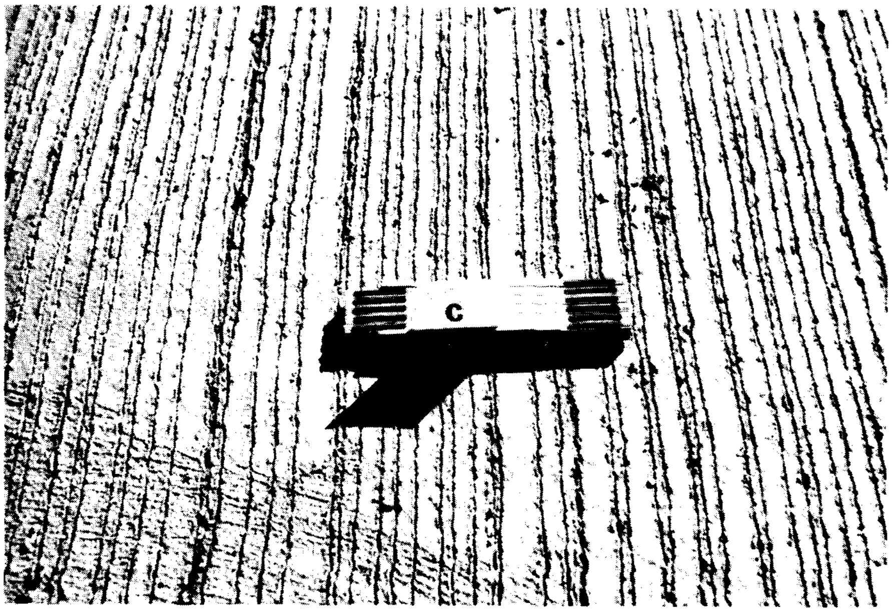


FIGURE 5

Mechanical (Metal) Tines, Transverse Texture

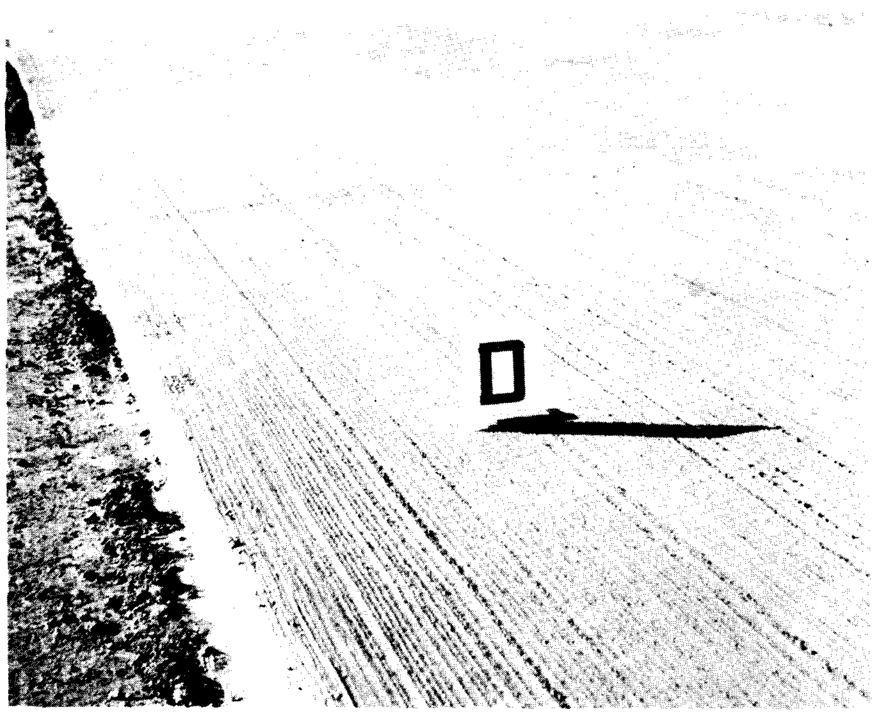


FIGURE 6

Mechanical (Metal) Tines, Longitudinal Texture, Preceded by Burlap Drag

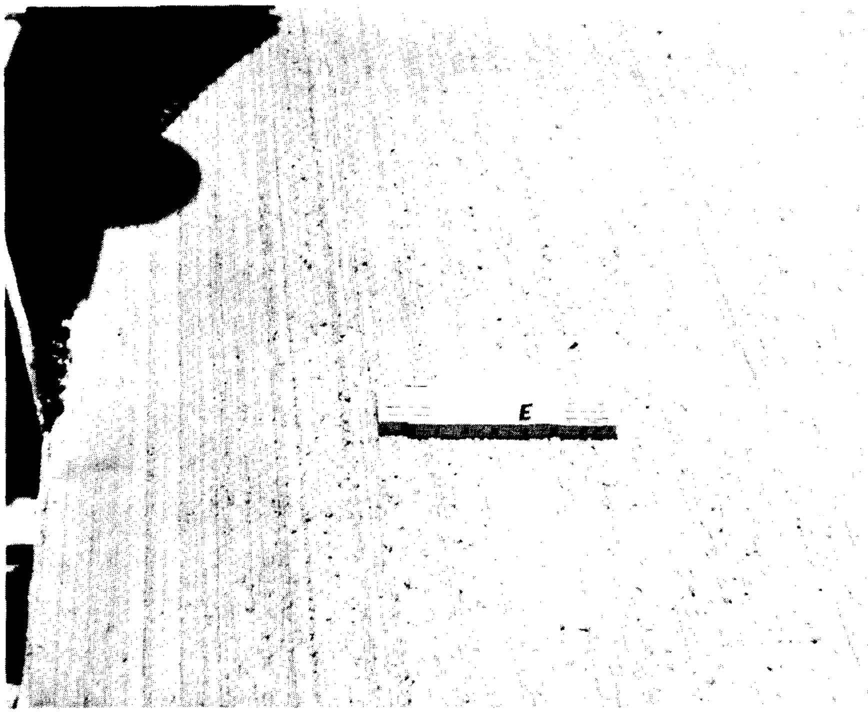


FIGURE 7

Mechanical Broom, Extra Heavy Nylon,
Longitudinal Texture

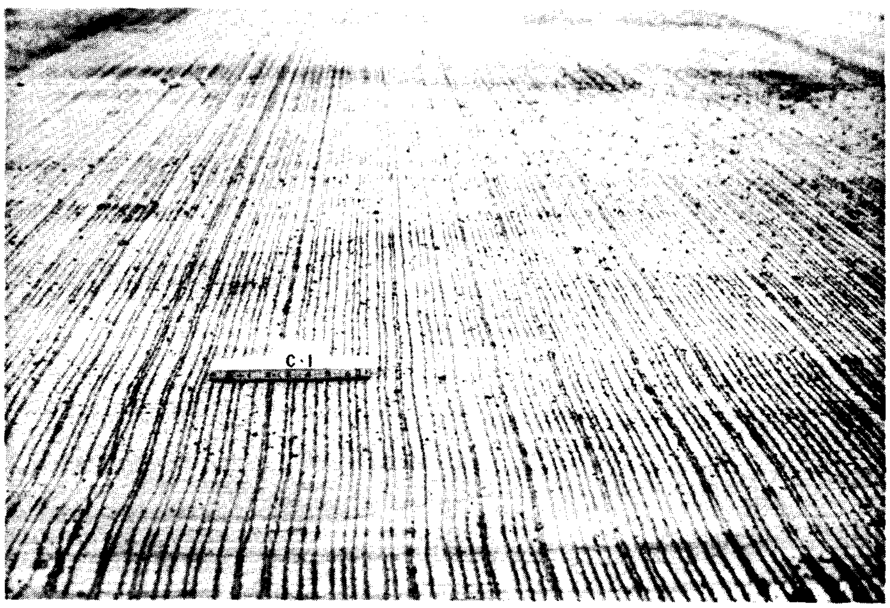


FIGURE 8

Mechanical (Metal) Tines, Transverse
Texture, Preceded by Burlap Drag

DESCRIPTION AND DISCUSSION OF SURFACE FINISHES

Finish No. 1
Burlap Drag Textured Finish

Two wide pieces of burlap cloth 24 feet in width and weighing 10 ounces per square yard were sewed together in a way that one was placed on the top of the other. Each burlap cloth was unraveled at one end approximately 6 inches, leaving trailing ends longitudinal to the pavement. When the cloth was mounted onto the front of the texturing machine, 3 to 4 feet of the burlap cloth was in horizontal contact with the pavement. Figure 9 on page 29 shows the standard burlap drag.

Immediately after transverse contraction joints were placed, the burlap cloth was dragged once longitudinally. The burlap drag was repeated until all the surface irregularities and excessive bleed water were eliminated and a gritty and uniform texture was obtained. The burlap was wetted each morning and was kept moist throughout the day. This was done to give the burlap cloth the extra weight needed to texture low slump concrete. The burlap mats that could not be cleaned with the water from a hose were discarded and replaced at the end of each day's pour.

Finish No. 2
Transverse Texturing with Soft Bristle Broom

A texturing broom (CMI No. 1-9180, Harper No. 7160) was attached to the texturing machine and was applied transversely over the surface of the concrete. The broom was made of three lines of 4-inch Palmyra fiber, spaced 11 rows per foot. Two 5-foot brooms were connected end to end to produce an overall length of 10 feet.

Soft bristle broom texturing produced on overly wet concrete had a tendency to flow back after the broom had made its pass. The broom being passed on relatively dry concrete caused small balls of dry concrete to be rolled up. From a short distance these small balls looked like popped corn because of their porous nature. This condition was referred to as "popcorning" by the researchers. The "popcorn" was not integral with the surface texture and was quickly brushed off by light traffic or a broom.

Finish No. 3

Transverse Texturing With Heavy Polyplastic Broom

This broom finish was produced by attaching the CMI heavy texturing broom (CMI No. 1-9181, Harper No. 9360) to the texturing machine and passing once over the surface transversely. The broom was made of two lines of 4-inch polypropylene black straight plastic fiber spaced 11 rows per foot (see Figure 10 on page 29). Two 5-foot brooms were connected end to end to produce an overall length of 10 feet. For this kind of texturing the time of finishing was critical, very often the grout was balled up to produce "popcorning" on the surface. The texture produced by this broom was better than that produced by soft bristle brooms. Figure 3 on page 13 shows a typical transverse finish with heavy polyplastic broom.

Finish No. 3a

Retextured Transverse Finish With Heavy Polyplastic Broom

An unexpected heavy rain washed away most of the texture at the end of Finish No. 3 located between Station 588+40 and Station No. 600+75. A neat cement grout was placed onto the surface after the rain stopped. The new surface was retextured by the same method as Finish No. 3. It was decided by the researchers that this section would be documented and listed separately in an effort to determine the longevity of this refinishing technique that is often used by contractors in this area. The five year evaluation of this retextured section showed that the skid numbers were lower than the original section (Finish No. 3). The final texture depth of this section, measured by the sand patch method, is about the same as Finish No. 3.

Finish No. 4

Transverse Texturing with Extra Heavy Nylon Broom

This broom finish was produced by attaching the CMI extra heavy nylon broom (CMI No. 1-9220) to the texturing machine and passing once over the surface of the concrete. The broom was made of two rows of very coarse, 1/8-inch diameter, nylon fibers in a cluster approximately 3/4-inch in diameter (see Figure 11 on page 30). Two 5-foot brooms were connected end to end to produce a 10-foot broom for transverse texturing. This broom was capable of producing a very rough and uniform texture. The time of finishing was also critical for this broom. It is so critical that a few minutes would make a great difference in the final finished product. In order to eliminate "popcorning" and a poor surface texture with low texture depth, texturing was done immediately before the disappearance of water sheen from the surface of the pavement. A superior texture was produced by this broom when compared to those produced by soft bristle and heavy polyplastic brooms.

Finish No. 4a

Retextured Transverse Finish with Extra Heavy Nylon Broom

Again a rain occurred during finishing and washed away most of the texture in the middle of Finish No. 4 between Station 577+20 and 572+80. After the rain stopped, a neat cement grout was placed on the damaged surface and it was retextured using the same method as Finish No. 4. The final evaluation of this area showed a sand patch depth of 0.023 inch, which is slightly deeper than the average final depth of the section that was not rained on and did not require. retexturing.

Finish No. 5

Transverse Texturing with Metal Tines

This finish was produced by attaching the CMI's metal tines (CMI No. 1-9203) to the texturing machine and passing once or twice over the surface of the concrete. The combs were made of a single row of flat wire teeth, inserted into holes in a 2-inch by 2-inch wooden head and secured on each side of the teeth with 1-inch square wood baffle strips. The metal tines were 0.032 inch by 0.083 wire on 1/2-inch centers, 4 inches long, with a 5-foot overall length of comb. Two 5-foot combs were connected end to end to produce a 10-foot comb for transverse texturing.

The time of finishing for this method is very critical. Should the metal tines be applied to the surface too early, the aggregate would be dragged up leaving a very undesirable finish: if applied too late, the surface would not be textured sufficiently for good skid results. Only with experience can one determine when to apply the tines. Figure 5 on page 14 shows a typical transverse finish with metal tines.

Finish No. 6

Longitudinal Texturing with Metal Tines Preceded by Burlap Drag

The CMI metal tines (CMI No. 1-9203) were attached to the texturing machine and were passed once over the surface of the concrete preceded by a burlap drag. The overall length of the tining comb was 24 feet. Figure 6 on page 14 shows a typical finish. The excess water present on the surface of the pavement was eliminated by the burlap drag which was connected to the front of the finishing machine. With no excess water on the surface, the curing compound was applied at the same time as grooving of concrete. This system worked well, as no delays were encountered and the operation was able to keep up with the paving train.

Finish No. 7

Longitudinal Texturing with Extra Heavy Nylon Broom

A CMI extra heavy nylon broom (CMI No. 1-9220) was attached to the texturing machine and was passed over the surface of the concrete to produce this finish. The overall length of the broom was 24 feet. This broom was capable of producing a very rough and uniform texture.

The time of finishing was critical. The texturing was applied immediately before the disappearance of the water sheen from the surface to avoid popcorning and a poor texture. Figure 12 on page 30 shows the "popcorning" effect. A superior texture was produced by using this broom when compared to the texture produced by using soft bristle and heavy polyplastic brooms. Figure 7 on page 15 shows a typical longitudinal finish with extra heavy nylon broom.

Finish No. 8

Transverse Texturing with Metal Tines Preceded by Burlap Drag

This finish was produced by attaching the CMI metal tines (CMI No. 1-9203) to the texturing machine and passing once over the surface of the concrete, preceded by a burlap drag. Two 5-foot combs were connected end to end to produce a 10-foot comb.

The burlap drag (which was draped from the front of the finishing machine) was applied first to rid the surface of excess water. The texturing machine used in this operation could also be used as a curing machine. However, since transverse tining was performed when the machine was stationary, the curing operation had to be performed as a separate function. After a section of highway had been tined, the machine would back up to the previously completed section and then proceed forward spraying curing compound up to the point at which the tining had stopped. This procedure was repeated for the length of the section. This at best was a difficult situation requiring too much coordination between texturing operation and the curing operation. It is highly recommended that a separate curing machine be used when texturing is accomplished by transverse tining.

DISCUSSION OF SKID RESISTANCE MEASUREMENTS

The final data obtained from the tested area is shown in Table 4 in Appendix A. The skid resistance measurements were taken at 20 m.p.h., 30 m.p.h., 40 m.p.h., 50 m.p.h. and 60 m.p.h.; the speed gradient and the average sand patch depth are also listed in the tables. The evaluation of final data showed the skid numbers and texture depth have decreased slightly for all the test sections. The smallest decrease in skid numbers was noted in Finish No. 3a which was the portion of Finish No. 3 that was retextured after a heavy rain washed away its original texture. The final skid numbers on all experimental textures ranged from 28 to 51 at 30 m.p.h., 28 to 45 at 40 m.p.h. and 22 to 42 at 50 m.p.h. All other finishes had about the same SN values except for Finish No. 3a. It seems that finishes produced by metal tines show high skid resistance at the early ages but tend to even out with the skid numbers relating to other textures at the later ages. In Table 4 on page 31 of Appendix A, the initial, one-year, two-year, three-year, and the five-year skid results are listed.

DISCUSSION OF NOISE LEVELS

The exterior noise levels on all sections at the 5 year evaluation period were approximately equal. This could be the result of the pavements age and wear. All the noise level values were generally high at both speeds (40 and 60 m.p.h.) as compared to normal roadway pavement construction. The noise data tables for initial, six-month, two-year, three-year and five-year periods are also shown in Table 5 on page 34.

DISCUSSION OF ACCIDENT DATA

The reviewing of accident data as shown in Table 6 on page 37 shows no significant relationship existed between the pavement texture and the cause of accidents. The test sections appear to be too short in length to really isolate, locate and identify possible causes of accidents due to texture, plus give any significant number of accidents.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions have been made throughout this project:

1. Generally skid numbers for all experimental textures were higher than the burlap drag texture which had been previously required in the Louisiana Department of Transportation and Development Specifications and used extensively throughout the State.

2. Metal tines, applied transversely to the centerline of the concrete pavement, preceded by a heavy burlap drag applied longitudinally, produced grooves 1/8 to 3/16 inch deep with the highest skid number, a low speed gradient and noise levels comparable to those of the standard burlap drag. This texturing technique has been adopted by the Louisiana Department of Transportation and Development as standard and is presently being applied to all new concrete pavements and bridge decks.

3. The extra heavy nylon broom was capable of producing a texture with a high initial skid number, but the time of finishing was so critical that a uniform texture could not consistently be obtained. (It was anticipated that the broom finish would wear more rapidly than the tine finish; however, no significant difference was noted).

4. The experimental textures did not produce objectionable road noise or increased the noise level significantly over the standard burlap drag finish; however, noise levels were high for all sections.

5. The review of accident data, gathered during the five years of the test period, proved no significant relationship existed between the cause of accidents and the pavement textures.

6. Texture depth values, skid resistance values, and noise level values remained fairly constant from the beginning of the evaluation period until the two year evaluation period. Skid resistance values dropped at the three-year evaluation period and decreased slightly at the five-year evaluation period. Texture depth were also decreased at the five year evaluation period. Noise levels were high for all sections as compared to pavements with standard burlap drag.

7. For the early ages of the study, the finish produced by metal tines and applied transversly 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. The final evaluation proved tnat textures produced by metal tines showed a deeper depth by 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 tne Department, be continued as standard on all new concrete pavements and bridge decks.

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APPENDIX A

AGGREGATE DATA, CONCRETE MIX DATA, PICTURES AND TEST RESULTS

TABLE 2

AGGREGATE DATA

T. L. James Stockpile 6/22/73

Fine Aggregate

Screen	Wt. Retained Pounds	Percent Retained	Accum. % Coarser	Accum. % Passing
3/8"	0	0	0	100
#4	11.1	2.1	2.1	97.0
#16	99.3	18.9	21.0	79.0
#30	102.4	19.5	40.5	——
#40	119.6	22.7	63.2	——
#50	106.7	20.3	83.5	16.5
#100	79.6	15.1	98.5	1.4
Pass #100				
Totals	526.3	100		
Wt. Before Sieving	526.3			

Specific Gravity = 2.62

Coarse Aggregate

Screen	Wt. Retained Pounds	Percent Retained	Accum. % Coarser	Accum. % Passing
2 1/2"				
2"				
1 1/2"	0	0	0	100
1"	1.26	4.3	4.3	95.7
3/4"	3.89	13.2	17.5	82.5
1/2"	12.91	41.4	58.9	41.1
#4	11.71	39.7	98.6	1.4
Pass #4	0.41	1.4		
Totals	29.46	100		
Wt. Before Sieving	29.46			

Specific Gravity = 2.53

TABLE 3

CONCRETE MIX DATA

Cement	Portland Cement Type I (5.8 bags/cubic yard)
Entrained Air	4% by volume
Slump	1/2 inch to 2 inches
Water, max. allowable	5.5 gal/bag of cement

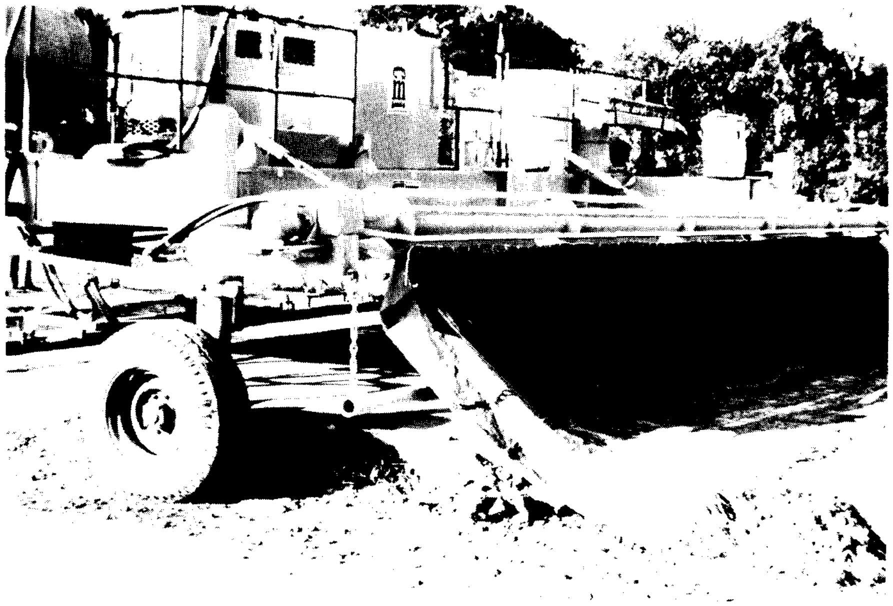

FIGURE 9

Standard Burlap Drag
In Back of Float

FIGURE 10

Heavy Polyplastic Broom on
Transverse Texturing

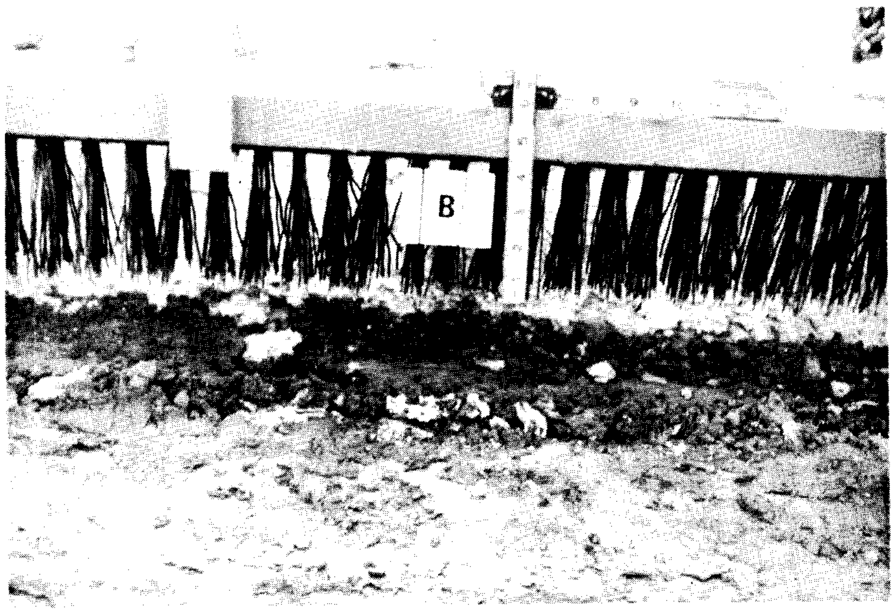

FIGURE 11

Extra Heavy Nylon Broom on Transverse Texturing

FIGURE 12

"Popcorning" on Longitudinal Texturing with Extra Heavy Nylon Broom

TABLE 4

SKID TEST AND TEXTURE DEPTH RESULTS

Finish No. 1 Normal Burlap Drag Texturing (Reference)

	SN_{20}	SN_{30}	SN_{40}	SN_{50}	SN_{60}	Speed Gradient	Texture Depth, Inches
Initial	60		45		38	0.55	0.024
1 Year	62		55	54	52	0.26	0.019
2 Year			56	52	52	0.28	0.019
3 Year		49	44	41		0.40	0.017
4 Year							0.017
5 Year		46.9	44.9	38.4		0.41	0.016

Finish No. 2 Transverse Texturing With Soft Bristle Broom

	SN_{20}	SN_{30}	SN_{40}	SN_{50}	SN_{60}	Speed Gradient	Texture Depth, Inches
Initial	65		50		45	0.50	0.029
1 Year	69		58	57	56	0.35	0.019
2 Year			57	53	54	0.23	0.018
3 Year		46	46	36		0.70	0.017
4 Year							0.015
5 Year		43.6	40.6	36		0.32	0.015

Finish No. 3 Transverse Texturing With Heavy Polyplastic Broom

	SN_{20}	SN_{30}	SN_{40}	SN_{50}	SN_{60}	Speed Gradient	Texture Depth, Inches
Initial	70		66		52	0.50	0.039
1 Year	68		56	54	52	0.38	0.020
2 Year			60	55	53	0.40	0.019
3 Year		50	44	42		0.40	0.018
4 Year							0.015
5 Year		49.8	43.6	40.4		0.46	0.015

Finish No. 3a Retextured Transverse Finish With Heavy Polyplastic Broom

	SN_{20}	SN_{30}	SN_{40}	SN_{50}	SN_{60}	Speed Gradient	Texture Depth, Inches
Initial	56		44		42		0.028
1 Year	65		39	41	42	0.55	0.023
2 Year			34	31	33	0.13	0.022
3 Year		34	34	27		0.45	0.020
4 Year							0.018
5 Year		28.8	28.2	22.2		0.30	0.016

TABLE 4 (CONTINUED)

Finish No. 4 Transverse Texturing with Extra Heavy Nylon Broom

	SN_{20}	SN_{30}	SN_{40}	SN_{50}	SN_{60}	Speed Gradient	Texture Depth, Inches
Initial	73		66		50	0.59	0.056
1 Year	69		57	57	53	0.35	0.032
2 Year			57	54	52	0.30	0.028
3 Year		47	41	42		0.25	0.025
4 Year							0.021
5 Year		51.4	45.5	39.1		0.55	0.018

Finish No. 4a Retextured Transverse Finish With Extra Heavy Nylon Broom

	SN_{20}	SN_{30}	SN_{40}	SN_{50}	SN_{60}	Speed Gradient	Texture Depth, Inches
Initial	73		71		47	0.63	0.078
1 Year	70		57	60	55	0.35	0.046
2 Year			59	55	55	0.25	0.038
3 Year		54	49	50		0.30	0.035
4 Year							0.035
5 Year		46.2	41.5	39.2		0.35	0.023

Finish No. 5 Transverse Grooving With Metal Tines

	SN_{20}	SN_{30}	SN_{40}	SN_{50}	SN_{60}	Speed Gradient	Texture Depth, Inches
Initial	70		61		53	0.43	0.033
1 Year	72		57	53	53	0.50	0.029
2 Year			55	54	53	0.10	0.025
3 Year		49	45	44		0.40	0.025
4 Year							0.020
5 Year		47.3	43.7	38.1		0.40	0.018

Finish No. 6 Longitudinal Grooving With Metal Tines Preceded By Burlap Drag

	SN_{20}	SN_{30}	SN_{40}	SN_{50}	SN_{60}	Speed Gradient	Texture Depth, Inches
Initial	74		58		47	0.70	0.034
1 Year	71		56	52	52	0.47	0.024
2 Year			57	53	51	0.35	0.022
3 Year		49	45	44		0.25	0.021
4 Year							0.018
5 Year		48.9	44.2	38.7		0.55	0.017

TABLE 4 (CONTINUED)

Finish No. 7 Longitudinal Texturing With Extra Heavy Nylon Broom

	SN_{20}	SN_{30}	SN_{40}	SN_{50}	SN_{60}	Speed Gradient	Texture Depth, Inches
Initial	67		58		49	0.45	0.052
1 Year	70		60	57	54	0.41	0.034
2 Year			60	54	49	0.58	0.027
3 Year		48	46	43		0.25	0.024
4 Year							0.020
5 Year		47.7	43.3	42.4		0.21	0.017

Finish No. 8 Transverse Grooving With Metal Tines Preceded By Burlap Drag

	SN_{20}	SN_{30}	SN_{40}	SN_{50}	SN_{60}	Speed Gradient	Texture Depth, Inches
Initial	69		67		54	0.40	0.039
1 Year	71		59	58	54	0.43	0.032
2 Year			57	56	52	0.23	0.028
3 Year		53	48	48		0.35	0.027
4 Year							0.025
5 Year		46.8	45.5	39.3		0.40	0.020

TABLE 5

EXTERIOR NOISE DATA (dBA)

Finish No. 1   Burlap Drag, Longitudinal (Control Section)

Testing Period	40 m.p.h.	60 m.p.h.
Initial	74	79
6 Months	72	79
2 Year	74	80
3 Year	80	84
4 Year	74	80
5 Year	79	88

Finish No. 2   Mechanical Broom, Soft Bristle Brush, Transverse

Testing Period	40 m.p.h.	60 m.p.h.
Initial	76	82
6 Months	76	83
2 Year	77	82
3 Year	81	87
4 Year	79	82
5 Year	79	87

Finish No. 3   Mechanical Broom, Heavy Polyplastic, Transverse

Testing Period	40 m.p.h.	60 m.p.h.
Initial	76	83
6 Months	77	83
2 Year	78	83
3 Year	86	89
4 Year	78	83
5 Year	81	88

Finish No. 4   Mechanical Broom, Extra Heavy Nylon, Transverse

Testing Period	40 m.p.h.	60 m.p.h.
Initial	75	83
6 Months	78	83
2 Year	76	82
3 Year	83	88
4 Year	79	83
5 Year	80	82

TABLE 5 (CONTINUED)

Finish No. 4a   Mechanical Broom, Extra Heavy Nylon, Transverse Retextured

Testing Period	40 m.p.h.	60 m.p.h.
Initial	79	86
6 Months	78	85
2 Year	81	88
3 Year	84	90
4 Year	83	86
5 Year	82	85

Finish No. 5   Metal Tines, Transverse

Testing Period	40 m.p.h.	60 m.p.h.
Initial	73	80
6 Months	75	81
2 Year	76	80
3 Year	78	84
4 Year	80	80
5 Year	79	81

Finish No. 6   Metal Tines, Longitudinal, Preceded by Burlap Drag

Testing Period	40 m.p.h.	60 m.p.h.
Initial	72	79
6 Months	75	82
2 Year	74	80
3 Year	79	81
4 Year	75	83
5 Year	78	81

Finish No. 7   Mechanical Broom, Extra Heavy Nylon, Longitudinal

Testing Period	40 m.p.h.	60 m.p.h.
Initial	75	81
6 Months	74	80
2 Year	75	81
3 Year	81	83
4 Year	75	80
5 Year	77	82

TABLE 5 (CONTINUED)

Finish No. 8 Metal Tines, Transverse Preceded by Burlap Drag

Testing Period	40 m.p.h.	60 m.p.h.
Initial	74	80
6 Months	75	81
2 Year	75	80
3 Year	82	84
4 Year	79	82
5 Year	80	82

TABLE 6
Accident Data

Finish No.	Description	Total Acc. Ocurred					No. of Acc. not Related to Surface Texturing				
		74	75	76	77	78	74	75	76	77	78
1	Burlap Drag, Longitudinal (Control Section)	0	2	2	3	1	0	0	2	3	1
2	Mechanical Broom, Soft Bristle Brush, Transverse	0	0	0	0	2	0	0	0	0	2
3	Mechanical Broom, Heavy Polyplastic Transverse	0	0	0	0	2	0	0	0	0	2
3a	Mechanical Broom, Heavy Polyplastic Transverse (Retextured)	0	2	1	2	2	0	2	1	2	2
4	Mechanical Broom, Extra Heavy Nylon, Transverse	0	0	0	1	1	0	0	0	1	1
4a	Mechanical Broom, Extra Heavy (Retextured)	0	0	0	0	0	0	0	0	0	0
5	Metal Tines (1/2" Center, 4" long), Transverse	1	3	1	1	0	1	3	1	1	0
6	Metal Tines (1/2" center, 4" long), Longitudinal Peeceded by Burlap Drag	0	0	0	1	0	0	0	0	1	0
7	Mechanical Broom, Extra Heavy Nylon, Longitudinal	2	4	2	1	2	2	4	2	1	2
8	Metal Tines (1/2" Center, 4" long), Transverse, Preceded by Burlap Drag	1	3	4	3	2	1	3	4	3	2
	TOTAL	4	14	10	12	12	4	14	10	12	12

APPENDIX B

TEST PROCEDURES

Method of Test for

MEASURING TEXTURE DEPTH OF PORTLAND CEMENT CONCRETE WITH METAL TINE FINISH

LDH Designation: TR 229-73

Scope

1. This method describes the procedure for measuring texture depth of fresh or hardened concrete finished with a metal tine.

Apparatus

2. (a) A tire tread depth measuring gauge with 1/32 of an inch (1 mm) graduations similar to the one shown in Figure 1.

(b) Wire brush

(c) Steel straightedge approximately 1/4 x 1 x 12 inches (6 x 25 x 305 mm).

Procedure

3. The depth of texture shall be measured from the original concrete surface. Any projections above the original surface shall be removed by wire brushing or with the steel straightedge prior to taking a measurement on hardened concrete. If measurements are being made on fresh concrete, the depth gauge shall be pressed down until substantially at the level of the original concrete surface.

With the depth gauge guides in contact with the original concrete surface, the plunger is depressed until contact is made with the bottom of the groove in the concrete. The gauge is then removed

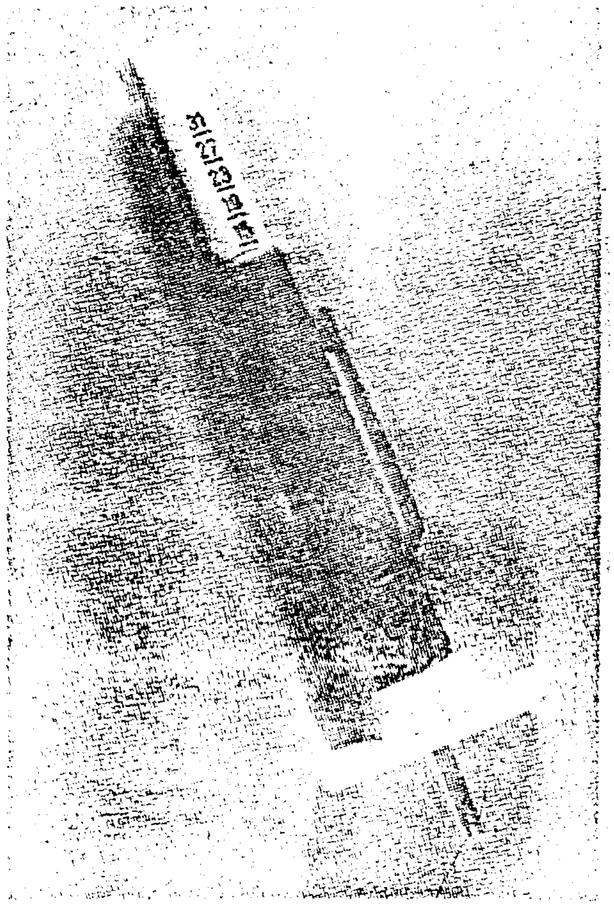

Figure 1

Depth Measuring Gauge

from the surface with care being taken to prevent the plunger from being disturbed. The texture depth is then read to the nearest 1/32 of an inch (1 mm) on the calibrated plunger. The plunger is then rezeroed and another depth measurement taken. This procedure is repeated until the necessary measurements are completed.

A sufficient number of random measurements shall be made throughout each day's operation to insure that the required texture depth is obtained.

Report

4. The depth of texture measured at a minimum of two locations per lot (or day's production if less than a lot) shall be recorded for each day's operation. At each of the locations, five measurements shall be taken transversely across the roadway. The individual readings and the average shall be recorded for each location.

Method of Test for

MEASUREMENT OF TEXTURE DEPTH BY SAND-PATCH

LDH Designation: TR 617-74

Scope

1. This method describes a procedure for determining the average texture depth of a selected portion of a pavement surface.

Apparatus

2. The apparatus shall consist of the following:

(a) Sand spreading tool consisting of a 2 ½ in. (63.5 mm) diameter flat wooden disc with a 1/16 in. (1.59 mm) thick hard rubber disc of the same diameter attached to one face and a short dowel serving as a handle attached to the other face.

(b) Metal cylinder with a volume of approximately 1.5 in.^{3} (24.6 cm^3).

(c) Natural silica sand from Ottawa, Illinois, graded to pass a No. 50 (.300 mm) sieve and retained on a No. 100 (.150 mm) sieve.

(d) Balance sensitive to .01 g.

(e) Ruler, 12 in. (305 mm) long, with markings in divisions of every 0.1 in. (2 mm).

(f) Wire brush and soft hand brush.

Procedure

3. (a) Normally a volume of 1.50 in.^{3} (24.6 cm^3) of sand is used in performing this test. This volume can be obtained by a cylinder 0.75 in. (19 mm) in inside diameter and 3.40 in. (86.4 mm) in height.

(b) If a volume other than 1.50 in.^{3}(24.6 cm^3) is desired, prepare a conversion table in which texture depths, T, can be determined for sand-patch diameters, D, ranging from 4 to 12 inches (100 to 306 mm) in increments of 0.1 in. (2 mm).

(1) Calculate the exact volume, V, of the metal cylinder prepared for this purpose.

(2) To prepare the conversion table, use the equation $T = \frac{4V}{\pi D^2}$

(c) Determine the weight of sand needed to fill the metal cylinder.

(1) Fill the cylinder to the top with dry sand and gently tap the base of the cylinder three times on a rigid surface. Add more sand to fill the cylinder again to the top and level the top with a straightedge.

(2) Determine the weight of sand in the cylinder. This weight of sand should be placed in suitable containers (35 mm film cans) and used for every sand-patch test. (The weight has been determined to be 38.83 grams for every 1.50in.^{3}[24.6cm^3].) If a balance is not available, the required amount of sand can be measured for each test by filling the metal cylinder according to the method described in Section 3c (1).

(d) The pavement surface selected for test must be dry. If the pavement has not been subjected to traffic, scrub the test surface with a wire brush to remove any loosely bonded particles or curing compounds that will be worn away by a small amount of traffic. Otherwise, the pavement surface should be swept with a soft hand brush.

(e) Pour the measured sand on the test surface and spread it with the rubber disc spreading tool into a circular patch with the surface depressions filled to the level of the peaks. The sand spreading tool should be kept flat on the surface and moved in a circular motion. Avoid losing any sand, especially during windy conditions. Sand used for one test should not be reused for another test.

(f) Measure the diameter of the sand-patch at five or more equally spaced locations and record to the nearest 0.1 in. (2 mm).

(g) For very smooth pavement surfaces where patch diameters are greater than 12 in. (305 mm), the diameter shall be listed as 12 in. (305 mm) plus and texture depth less than 0.013 in. (0.33 mm).

Calculation of Texture Depth

4. Compute the average diameter of the sand-patch and determine the texture depth by using the formula $T = \frac{4V}{\pi D^2}$, where:

V = Volume (in.^{3} or mm^3)
D = Sand patch diameter (in. or mm)
T = Texture depth (in. or mm)

Texture depths for a volume of 1.50 in.^{3}(24.6 cm^3) and diameters ranging from 4 to 12 inches (100 to 306 mm) in increments of 0.1 in. (2 mm) are given, in inches in Table I and in millimeters in Table II.

Reference

This test method is a modification of Test Method Tex-436-A, "Measurement of Texture Depth by the Sand-Patch Method," Texas Highway Department.

TABLE I

Texture Depth, in. (1.50 in.^{3} volume)

D = Sand-patch diameter, in.
T = Texture depth, in.

D	T	D	T	D	T
4.0	0.119	6.7	0.043	9.4	0.022
4.1	0.113	6.8	0.041	9.5	0.021
4.2	0.108	6.9	0.040	9.6	0.021
4.3	0.103	7.0	0.039	9.7	0.020
4.4	0.098	7.1	0.038	9.8	0.020
4.5	0.094	7.2	0.037	9.9	0.019
4.6	0.090	7.3	0.036	10.0	0.019
4.7	0.086	7.4	0.035	10.1	0.019
4.8	0.083	7.5	0.034	10.2	0.018
4.9	0.080	7.6	0.033	10.3	0.018
5.0	0.077	7.7	0.032	10.4	0.018
5.1	0.074	7.8	0.031	10.5	0.017
5.2	0.071	7.9	0.031	10.6	0.017
5.3	0.068	8.0	0.030	10.7	0.017
5.4	0.065	8.1	0.029	10.8	0.016
5.5	0.063	8.2	0.028	10.9	0.016
5.6	0.061	8.3	0.028	11.0	0.016
5.7	0.059	8.4	0.027	11.1	0.016
5.8	0.057	8.5	0.026	11.2	0.015
5.9	0.055	8.6	0.026	11.3	0.015
6.0	0.053	8.7	0.025	11.4	0.015
6.1	0.051	8.8	0.025	11.5	0.014
6.2	0.050	8.9	0.024	11.6	0.014
6.3	0.048	9.0	0.024	11.7	0.014
6.4	0.047	9.1	0.023	11.8	0.014
6.5	0.045	9.2	0.023	11.9	0.013
6.6	0.044	9.3	0.022	12.0	0.013

TABLE II

Texture Depth, mm (24.6 cm^3 volume)

D = Sand-patch diameter, mm
T = Texture depth, mm

D	T	D	T	D	T	D	T
100	3.13	152	1.35	204	0.75	256	0.48
102	3.01	154	1.32	206	0.74	258	0.47
104	2.89	156	1.29	208	0.72	260	0.46
106	2.79	158	1.25	210	0.71	262	0.46
108	2.68	160	1.22	212	0.70	264	0.45
110	2.59	162	1.19	214	0.68	266	0.44
112	2.49	164	1.16	216	0.67	268	0.44
114	2.41	166	1.14	218	0.66	270	0.43
116	2.33	168	1.11	220	0.65	272	0.42
118	2.25	170	1.08	222	0.64	274	0.42
120	2.17	172	1.06	224	0.62	276	0.41
122	2.10	174	1.03	226	0.61	278	0.40
124	2.04	176	1.01	228	0.60	280	0.40
126	1.97	178	0.99	230	0.59	282	0.39
128	1.91	180	0.97	232	0.58	284	0.39
130	1.85	182	0.94	234	0.57	286	0.38
132	1.80	184	0.92	236	0.56	288	0.38
134	1.74	186	0.90	238	0.55	290	0.37
136	1.69	188	0.89	240	0.54	292	0.37
138	1.64	190	0.87	242	0.53	294	0.36
140	1.60	192	0.85	244	0.53	296	0.36
142	1.55	194	0.83	246	0.52	298	0.35
144	1.51	196	0.81	248	0.51	300	0.35
146	1.47	198	0.80	250	0.50	302	0.34
148	1.43	200	0.78	252	0.49	304	0.34
150	1.39	202	0.77	254	0.49	306	0.33