PCC Pavement Texturing in Illinois

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PCC PAVEMENT TEXTURING IN ILLINOIS

By

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Interim Report
IHR-408
PCC Pavement Texturing

A Research Study Conducted by
Illinois Department of Transportation
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Federal Highway Administration

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16. Abstract

Seven textures were formed in the plastic surface of a CRC pavement during construction. They were formed using transverse tines, transverse broom, artificial turf, transverse roller, artificial turf-transverse tine combination, longitudinal broom, and longitudinal tines. Construction observations indicated that the use of one machine for both texturing and applying curing membrane is unsatisfactory since the timing of the two operations is incompatible. Care must be taken in texturing to avoid overlapping of transverse textures, edge damage, and damage due to stopping with the texturing device on the pavement.

Preliminary tests, before the pavement was open to traffic, indicated that the artificial turf-transverse tine combination had the highest friction numbers at the three test speeds and one of the lower speed gradients. The transverse-roller surface was completely inadequate from a frictional standpoint. Texture-depth measurements indicated the superiority of the artificial turf, transverse tine and the turf-tine combination. The noise tests showed that the turf-tine combination had the lowest noise level inside the vehicle but that none of the textures except the transverse roller (like rumble strip) should be ruled out for noise without further study. Roadometer tests gave Roughness Index values in inches/mile, ranging from 72 for the longitudinal broom to 91 for the turf-tine combination.

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INTRODUCTION

With the advent of high-speed, high-volume roadways it has become increasingly apparent that the frictional demands upon the tire-pavement interface have greatly increased. This is especially true under wet-weather conditions when the reduction in friction can be sufficient to cause a disproportionate number of wet-weather accidents at given locations. The highway engineer has come to know that by providing adequate micro- and macro-texture to the pavement, wet-weather friction and drainage can be assured. A number of states have experimented with various means of texturing PCC pavement in its worn state and in creating texture during construction. This project deals with texturing CRC pavement in its plastic state during construction. Seven of the most promising textures applied by this and other states were constructed contiguously on I-72, east of Springfield.

STUDY DETAILS

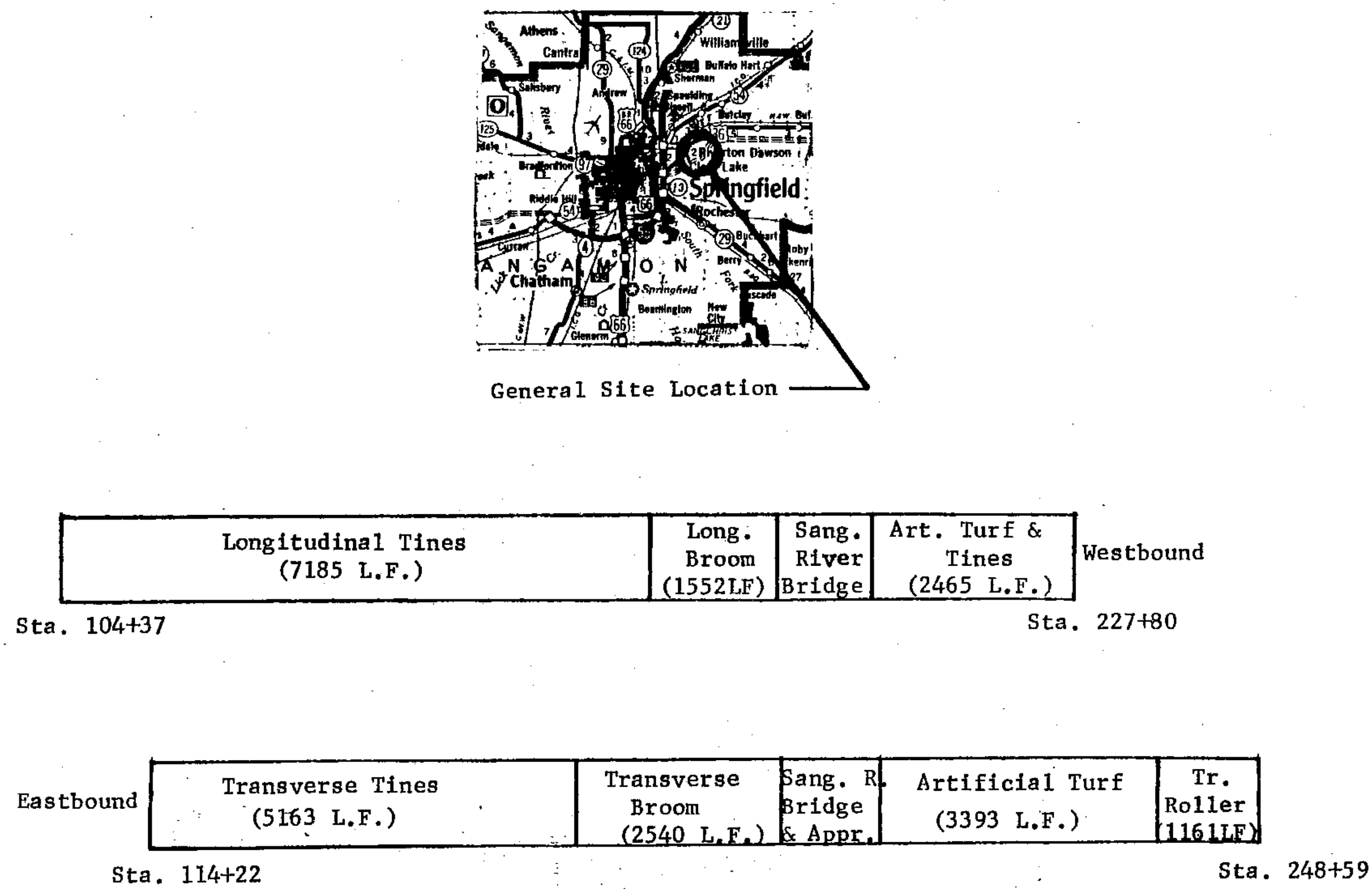
The construction of the seven textured surfaces was part of Project I-72-1(41)0, Section 84-10-C1, 1 SG, 1B-1), Sangamon County. The total project extends from Station 295+80 on the east to Station 22+90 on the west, with experimental texturing located within the total project as shown in Fig. 1, Layout of Experimental Textures. All special sections were constructed between two interchanges so that all have the same Average Daily Traffic (ADT) in each direction.

The initial test program included the measurement of friction number and speed gradient, texture depth, internal and external vehicle noise level, and pavement smoothness. In addition, silicone-rubber molds were cast on each of the textures. These tests were made in October and are to be followed with friction tests three times a year and a complete series of tests at 18 and 36 months after the initial series.

CONSTRUCTION OBSERVATIONS

The contractor delivered concrete from a central batch plant to the paving train in 9 yd^3 (6.9 m^3) Maxon side-dump trucks. The paving train consisted of four major pieces of equipment. Two Maxon concrete spreaders in tandem placed the steel while putting down the first and second lifts of concrete. This was followed by the CMI paving machine and hand-finishing with straightedges and long-handled floats. The CMI texturing/curing machine followed behind the hand-finishers, alternately texturing and backing up to apply the curing compound.

While bad weather precluded paving on four days, only one special texture had any rain fall upon it. A slight rain of short duration fell on transversely tined texture late in the day. Paving was stopped and the last 450 ft (137 m) was covered with plastic. No damage to the texture was discernible. A minor problem had to do with the proper mounting and leveling of the tines, brooms, and roller when changing from one texture to another. No time was allowed for the changeover before paving started so that there was excessive time between paving and texturing at the beginning of each day. Another problem resulted from the difficulty of positioning the texturing/curing machine longitudinally, which often led to overlap of the transverse textures between passes across the pavement. The major problem on all textured surface concerned the use of the combination texturing/curing machine. The operator alternated between texturing and applying the curing compound; texturing, falling back to cure, catching up on texturing, etc. For this reason he was not always texturing at the optimum time,



Note: 1 lineal foot (L.F.) = 0.305 meters

Figure 1. Layout of Experimental Textures

i.e., as the water sheen was disappearing. Each pass at texturing thus included concrete that was too dry, optimum, and too wet.

A more detailed description of the construction procedures, conditions and problems for the individual textures follows. As can be seen from Fig. 1 these are described as they appear from west to east in the eastbound direction and then east to west in the westbound direction, even though they were not constructed in this order or direction.

Transverse Tines

This section of the project was between eastbound Stations 114+22 and 165+85 (5163 lineal ft - 1574 m) and was paved on August 13, 1976. The weather ranged from clear early in the morning with a slight ground fog, to cloudy in the afternoon, to a light shower at 6:00 P.M. Temperatures ranged from a low of 66°F (18.9°C) to a high of 88°F (31.1°C). The tines were 1/16 in. x 6 in. (2 mm x 152 mm) and were mounted on 1/2-in. (13-mm) centers. The 8-ft-long (2.4-m) tine bar was mounted on the traverse mechanism centered under the texturing/curing machine as shown in Fig. 2. There was no difficulty in mounting the tine bar but there was nothing but the weight of the bar to apply pressure to the tines. For this reason the tines were digging in improperly, and shallow, uneven grooves resulted. Four springs were obtained and mounted at each end on both sides between the free-swinging bar and the adjacent structure. After the springs were added, grooves were obtained. Texturing was begun 1 hour and 20 minutes after the start-up of the paving train. An example of the texture obtained is shown in Fig. 3. Note the overlap of grooves between passes and the slight edge damage at the beginning of the traverse. While the machine operator was repeatedly cautioned not to overlap grooves, the difficulty in stopping and positioning the machine along the pavement resulted in frequent occurrences of this. While it was difficult to measure groove depth in the plastic concrete, the minimum depth of 1/8 in. (3.2 mm) was met or exceeded after the springs were added. Paving was stopped at 6:00 P.M. when a slight rain fell. The last 450 ft (137 m) of pavement was covered with plastic sheet after texturing, with little or no damage to the surface texture. Due to the flipping action at the end of each pass, there was no mortar buildup on the tines. There was no perceptible wear of the steel tines during the day.

Transverse Broom

This section of the project was between eastbound Stations 165+85 and 191+25 (2540 lineal ft) (774 m) and was paved on August 10, 1976. The weather was clear, with temperatures ranging from 83° (28.3°C) to 87°F (30.6°C). The broom was approximately 8 ft (2.4 m) long and was mounted under the texturing/curing machine in the same manner as the transverse tines as shown in Fig. 4. Even though there was no problem with mounting or leveling the broom, the time lag between paving start-up and texturing was 1 hour and 20 minutes. The mounting arrangement of the broom is shown in Fig. 5. Note in this photo that the overlap of texturing, mentioned previously, is occurring. Fig. 6 shows the texture obtained using the broom, while Fig. 7 shows some edge damage from the broom. As with other transverse texturing devices, there was no problem with grout buildup due to the flipping action at the end of each traverse. There was no perceptible wear of the broom during the day.

Artificial Turf

The special section constructed using artificial turf texturing was between eastbound Stations 203+05 and 236+98 (3393 lineal ft) (1034 m). This part of the project was done with Monsanto Astro-Turf 3 ft (.91 m) x full pavement width less 2 in. (51 mm) per side. This texture (longitudinal drag was substituted for the

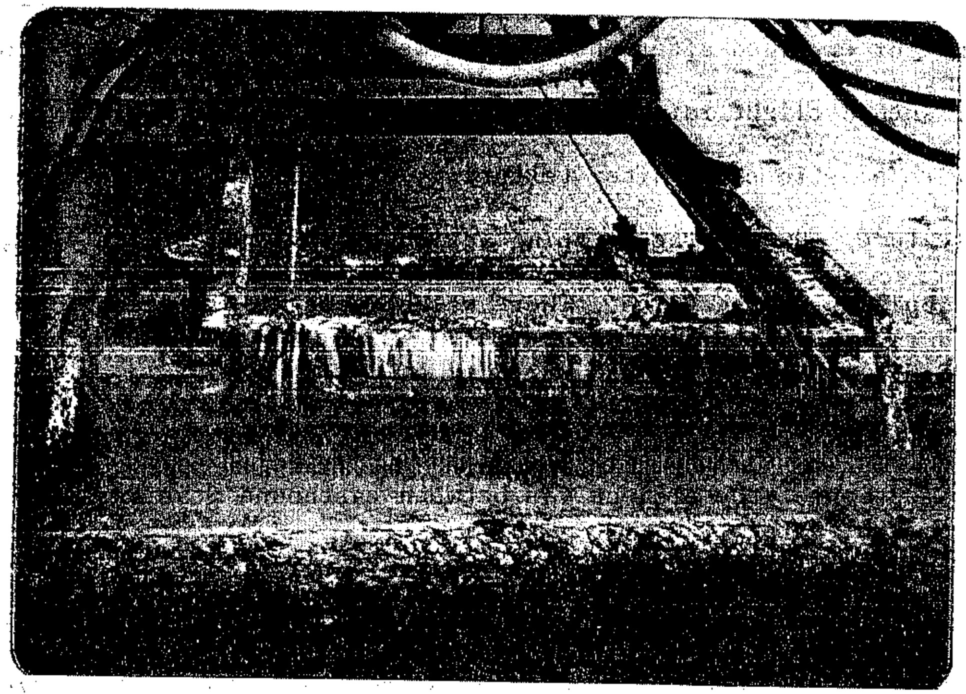


Figure 2. Transverse Tine Mounting Arrangement

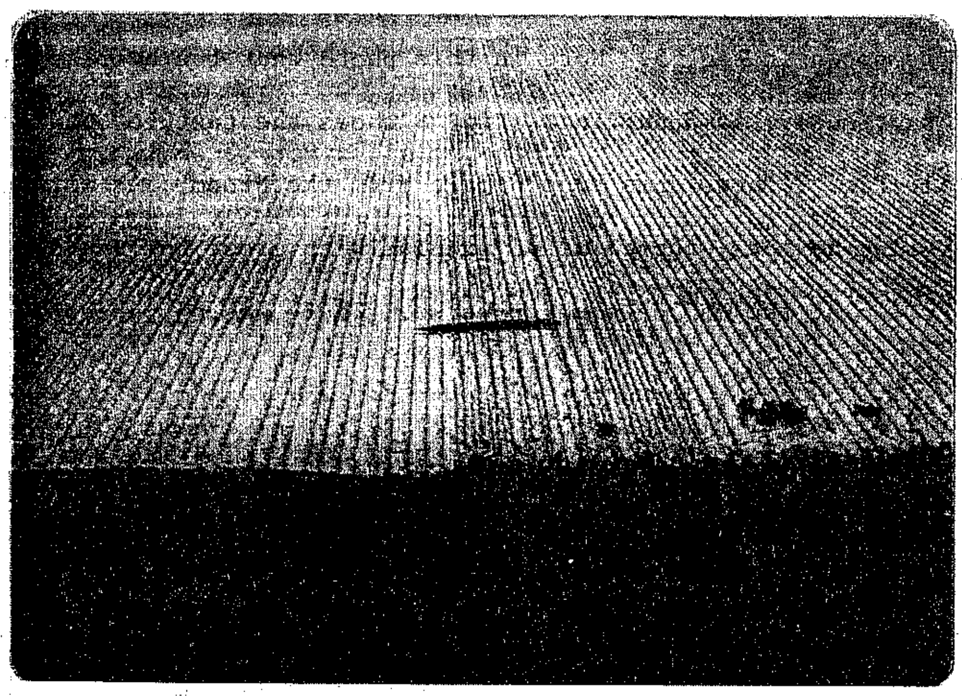


Figure 3. Transverse Tine Texture

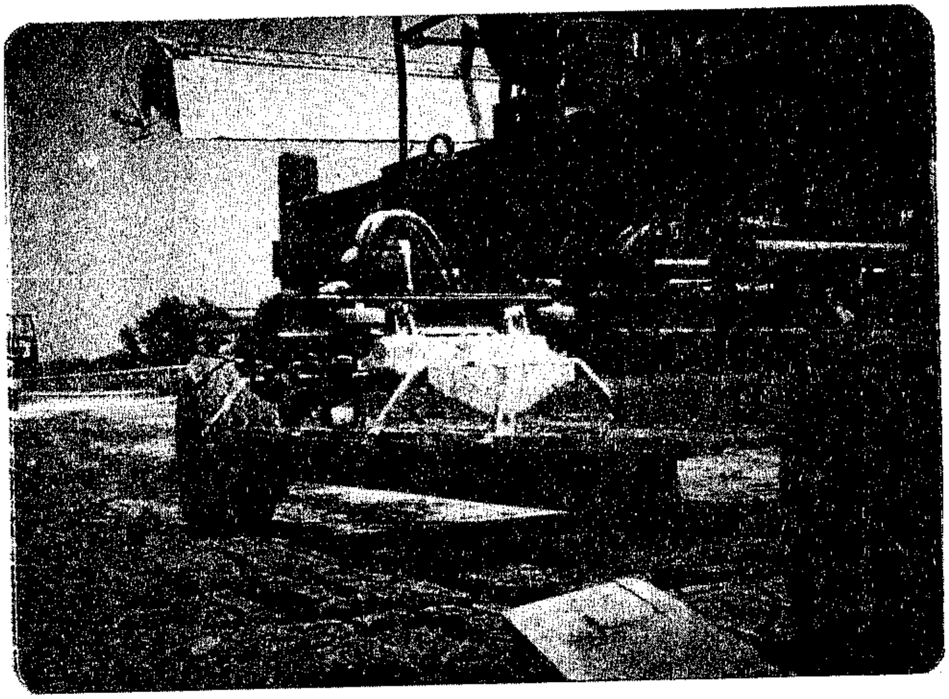


Figure 4. Transverse Broom Mounting Arrangement

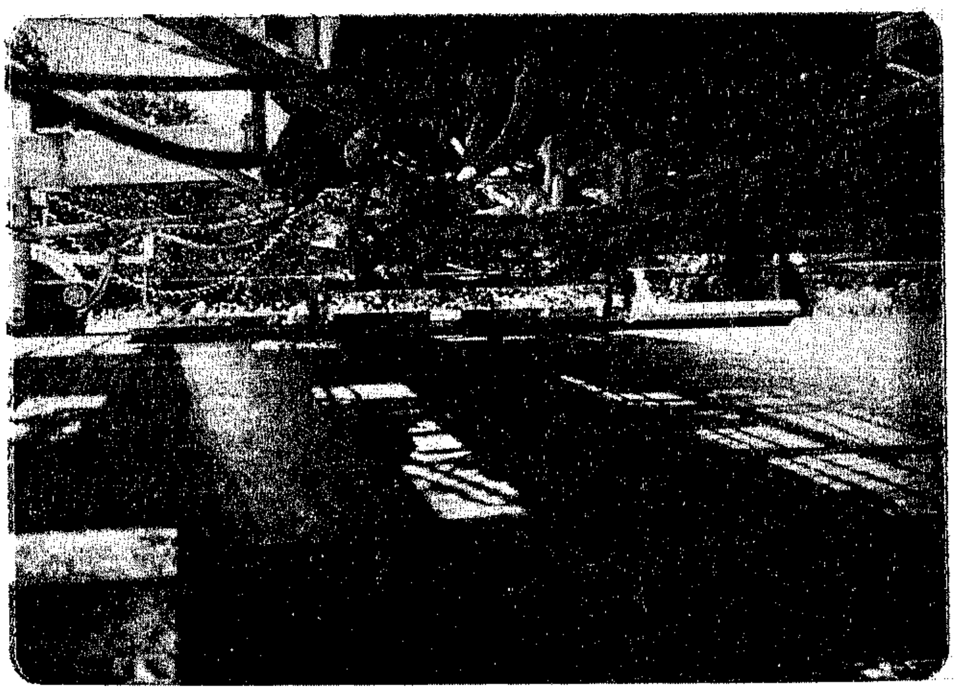


Figure 5. Transverse Broom in Operation

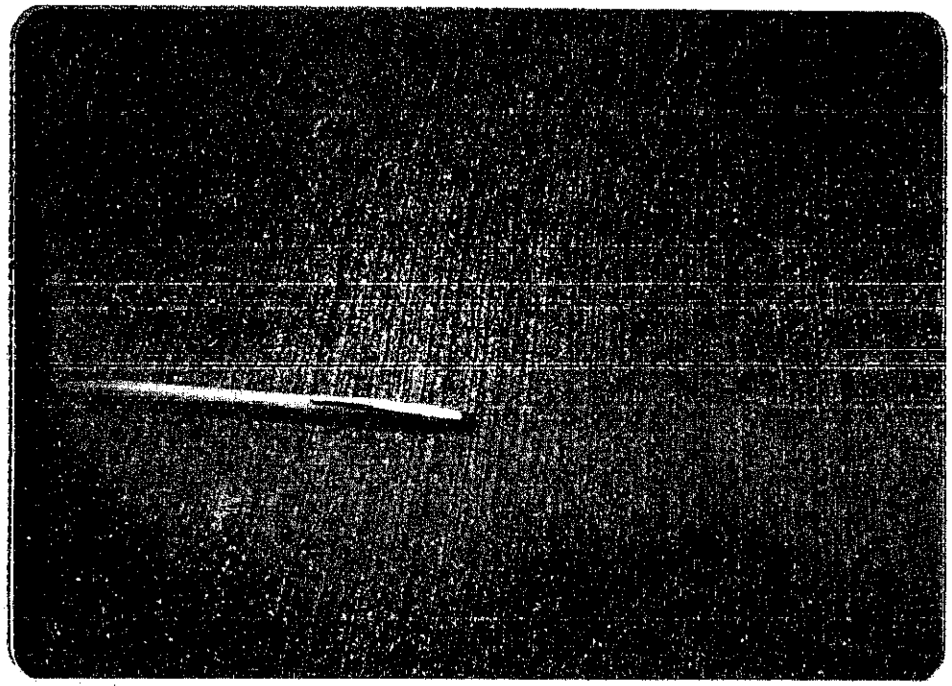


Figure 6. Transverse Broom Texture

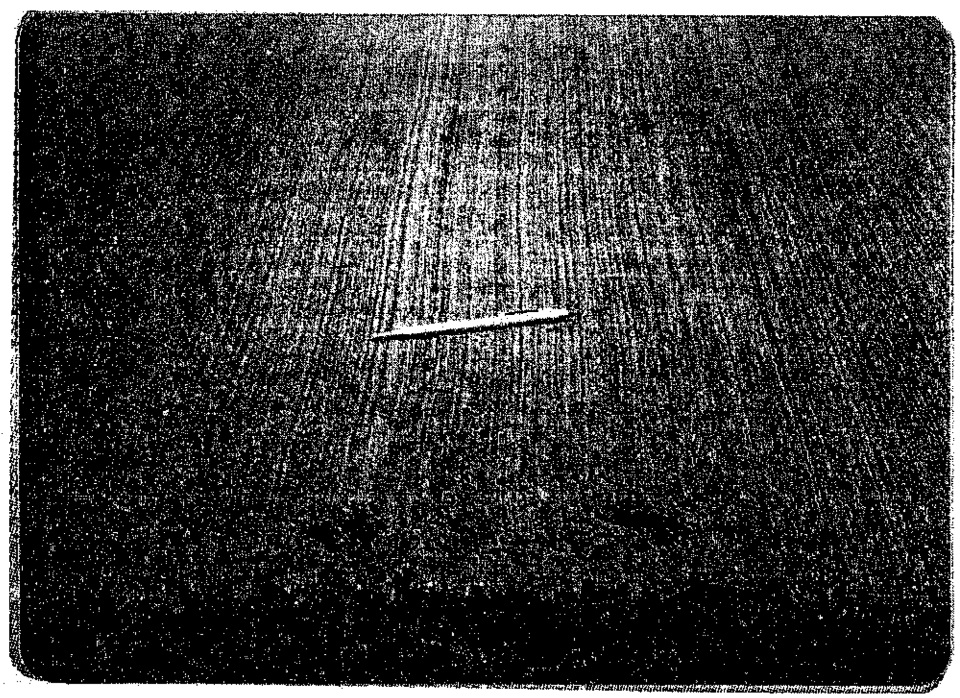


Figure 7. Transverse Broom Texture with Edge Damage

transverse roller after roller texturing proved unsatisfactory on August 23, and turf texturing was continued on August 24, 1976. The weather for these two days was clear to partly cloudy, with temperature during paving ranging from 82°F (27.8°C) to 86°F (30.0°C). In addition to this 3393-ft (1034-m) section, the pavement at each end of the experimental sections was textured with artificial turf drag. The artificial turf was mounted on a frame across the front of the texturing/curing machine, with a board attached as shown in Fig. 8 to provide the weight needed for adequate texture. Fig. 9 shows the texture obtained at near optimum. Each time the machine was backed up for curing, the grout was shaken or knocked off of the artificial turf and it was tied up clear of the pavement. No appreciable wear of the turf was found during the texturing of this section.

Transverse Roller

This portion of the project lies between eastbound Stations 236+98 and 248+59 (1161 lineal ft - 354 m). The weather was clear, with temperatures during texturing ranging between 71°F (21.7°C) and 82°F (27.8°C). The roller was 10 ft (3.05 m) long with 3/8-in. (9.5-mm) raised lands (1/8 in. at crest (3.2 mm) and 1/4 in. at root (6.4 mm) on 2-in. centers. The roller is shown mounted on the traverse mechanism of the texturing/curing machine in Fig. 10. A great deal of trouble was encountered in mounting and leveling the roller. First, the edge sensors had to be moved to clear the longer roller. Trouble was also had in getting the roller level with the pavement as seen in Fig. 10. Roller texturing was finally attempted about two hours after the start of paving. By this time the concrete was too dry, and very shallow texturing was obtained as seen in Fig. 11. Keeping the roller parallel with the pavement for the entire traverse was still a problem. The roller is free-wheeling and relies on its own weight for texturing force. At no time did good grooving result using this method.

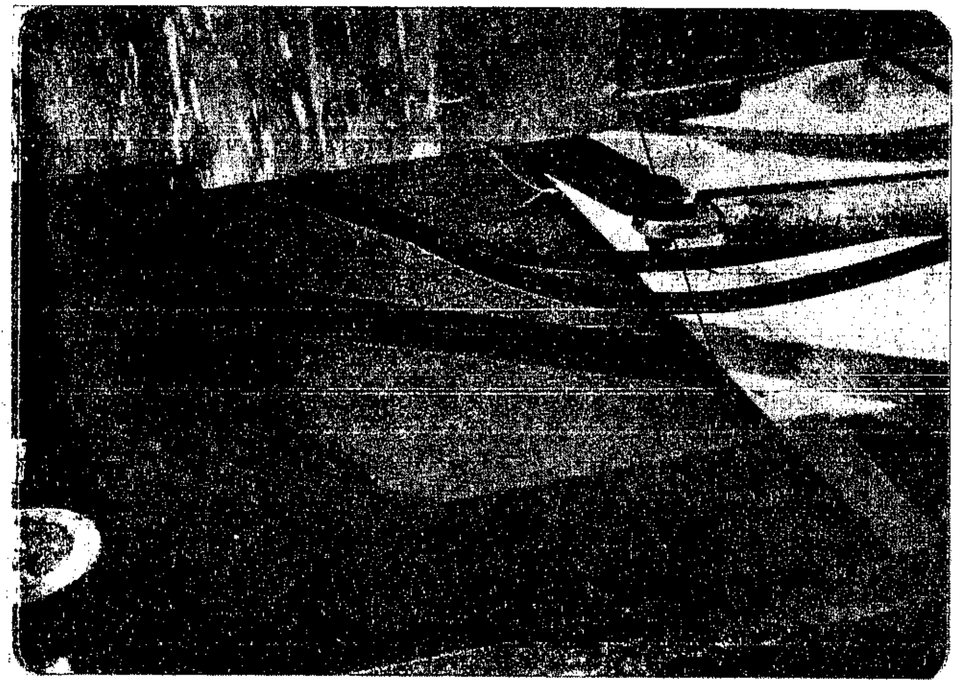


Figure 8. Artificial Turf Mounting Arrangement

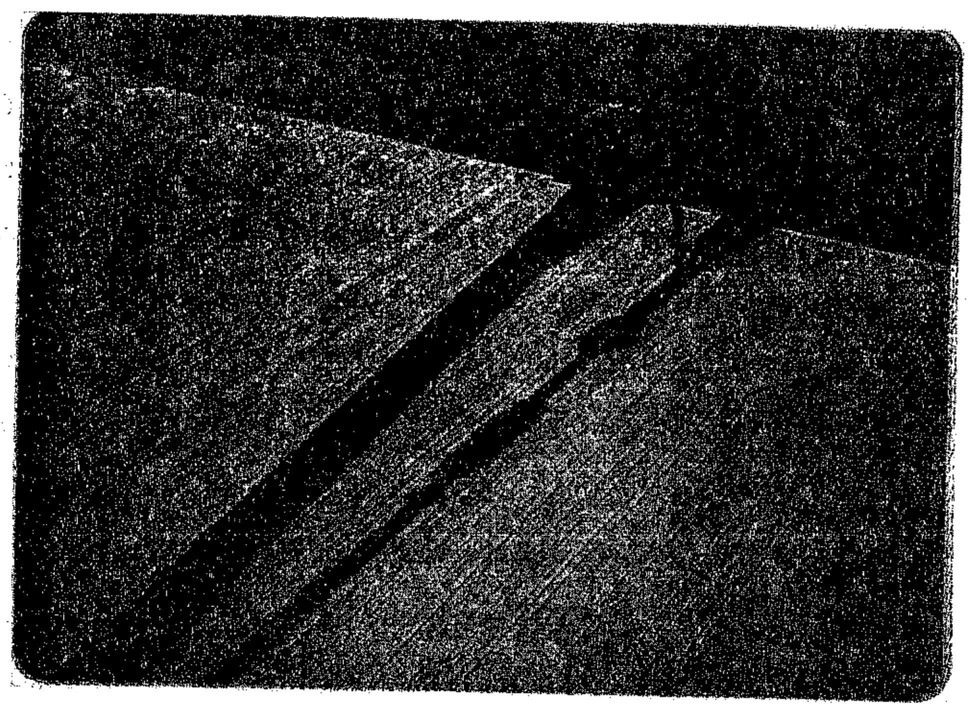


Figure 9. Artificial Turf Texture

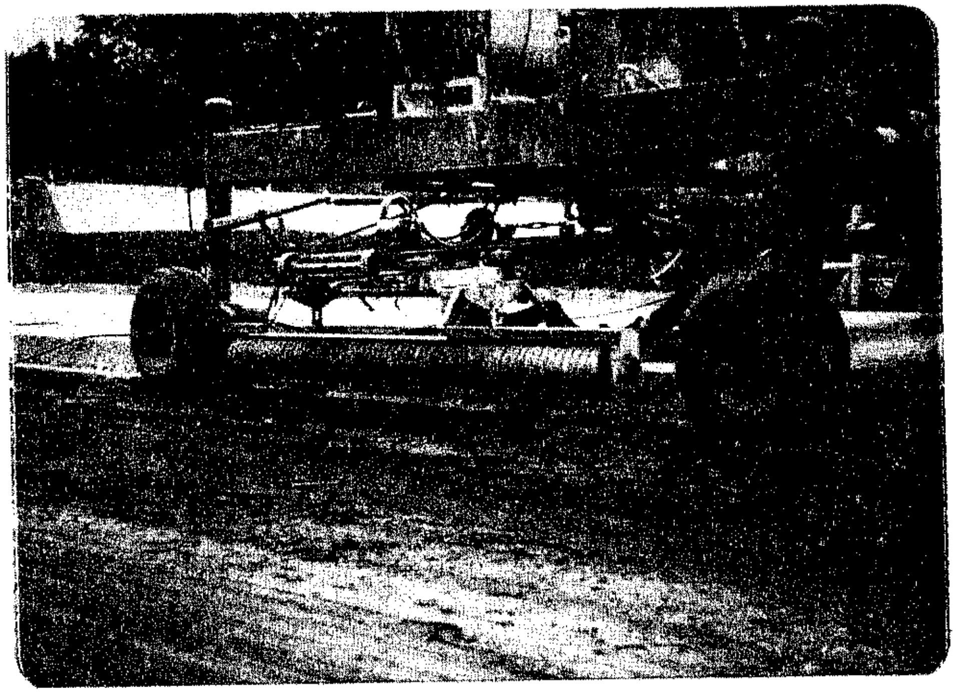


Figure 10. Transverse Roller Mounting Arrangement

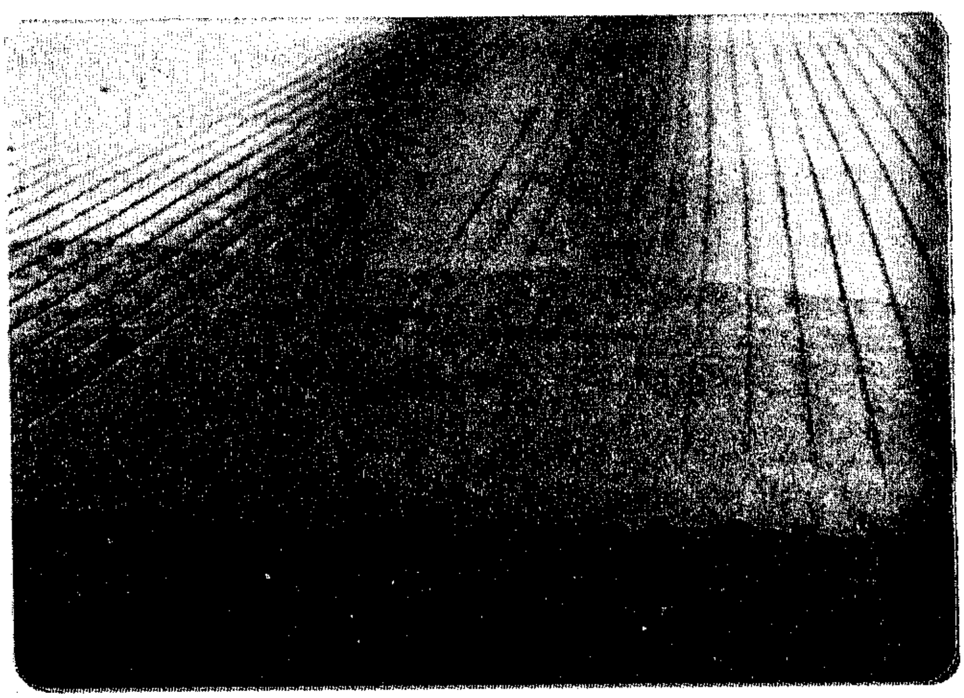


Figure 11. Teansverse Roller Texture - Too Dry

The grooves were either too shallow when the concrete was too dry or torn and messy when the concrete was too wet, and mortar was being picked up by and adhering to the roller (Fig. 12). Frequent wiping of the roller seemed to do little good. These difficulties might be overcome with a power-rotated roller and the application of an anti-sticking coating to the roller. Further, the weight of the roller caused edge damage to the pavement at both the beginning and end of each pass. The roller had to be supported by hand at each of these points to reduce this damage to the edges. The texture obtained with the roller was so poor that its use was discontinued after 1161 lineal ft (354 m), and artificial turf drag was substituted for the balance of this day's paving.

Artificial Turf and Transverse Tines

This part of the project lies between Stations 203+15 and 227+80 in the westbound lanes (2465 lineal ft - 751 m) and was paved on August 20, 1976. This texture was substituted for the balance of this day's paving after starting with the longitudinal broom on the west side of the bridge (Stations 176+22 to 191+74). After moving the paving train across the Sangamon River Bridge, it was decided that more could be gained from the study by switching from the relatively unpromising longitudinal broom texture to the more-promising artificial turf drag/transverse-tine texture. This texture was not included in the original work plan but appeared to offer great promise after viewing results of the textures obtained from the isolated use of each method. The weather during this texturing operation was clear, with temperatures ranging between 86°F (30.0°C) and 73°F (22.8°C). The texturing was done with the artificial turf mounted on the front frame and the tines mounted on the traverse mechanism of the texturing/curing machine in the same manner as when each was used alone. Fig. 13 shows the artificial turf texture and the combination turf and tine texture. Fig. 14 shows the texture at

Figure 12. Transverse Roller Texture - Too Wet

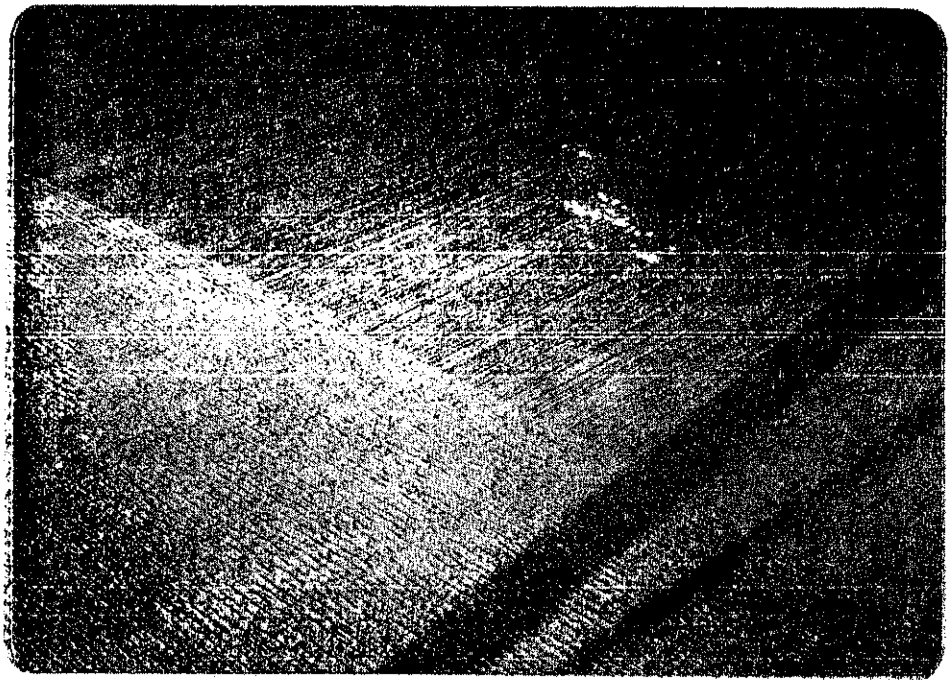


Figure 13. Artificial Turf and Transverse Tine Texture

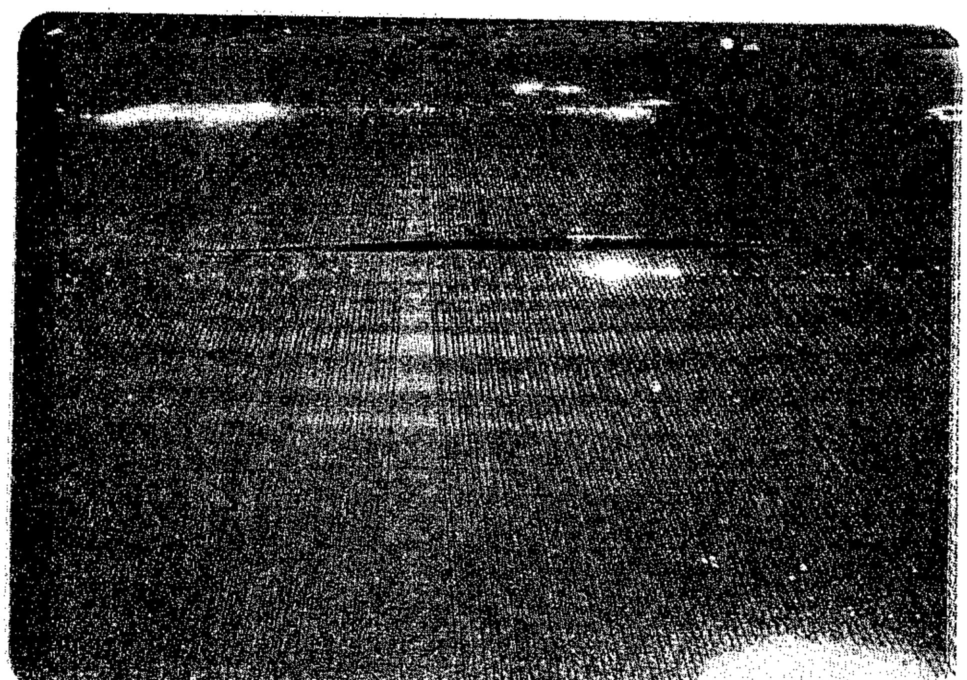


Figure 14. Turf and Tine Texture - Near Optimum

near optimum timing, with a gap between passes and the exposed longitudinal joint tape. Fig. 15 depicts the type of texture obtained when the concrete is too wet and plastic. As with the individual use of these devices, no problem of wear or grout buildup was encountered.

Longitudinal Broom

This textured surface lies between Stations 176+22 and 191+74 (1552 lineal ft - 473 m) in the westbound lanes. This surface was paved on August 20, 1976, west of the Sangamon River Bridge and was discontinued and replaced by the artificial turf/tine texture after crossing the bridge, as previously described. The weather was clear, with temperatures ranging from 77°F (25.0°C) to 85°F (29.4°C) during this part of the day's paving. The broom was the same type as used for the transverse broom texture. It was full pavement width and was mounted under the texturing/curing machine as shown in Fig. 16. Examples of the application and type of texture achieved are shown in Figs. 17 and 18. The delay between start-up of paving and texturing was 50 minutes. Grout was knocked off when the broom was raised for the curing cycle. No problem was encountered with grout buildup or broom wear.

Longitudinal Tines

The longitudinal tine surface was paved on August 19, 1976, and lies between Stations 104+37 and 176+22 (7185 lineal ft - 2190 m) in the westbound lanes. The weather was clear, with temperatures during the paving ranging between 59°F (15.0°C) and 85°F (29.4°C). The tine bar was full pavement width with 1/6-in. (2-mm) x 6-in. (152-mm) tines on 1/2-in. (13-mm) centers. It was mounted in the same manner as the longitudinal broom but tines near the edge of the pavement were bent upward to prevent edge damage (see Fig. 19). Little trouble was encountered in mounting the tines, but there was difficulty in adjusting their height to

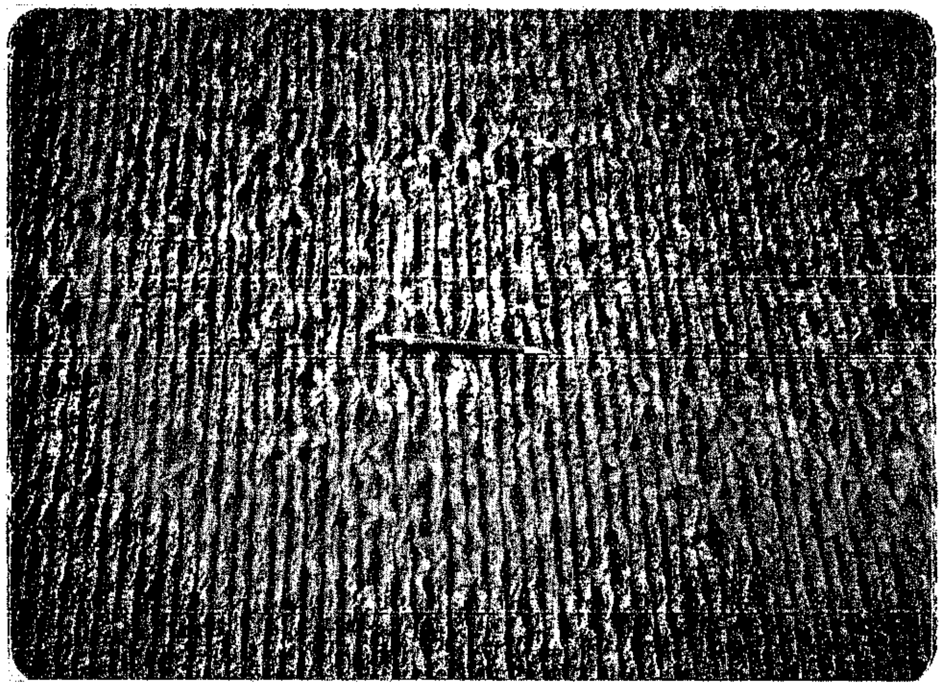


Figure 15. Turf and Tine Texture - Concrete Too Wet

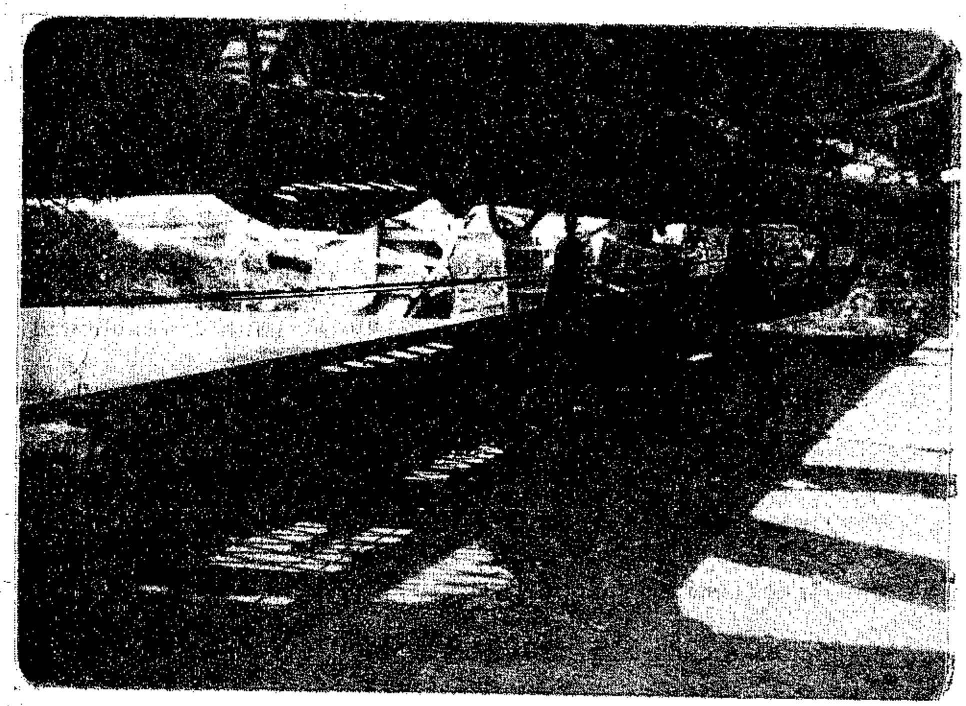


Figure 16. Longitudinal Broom Mounting Arrangement.

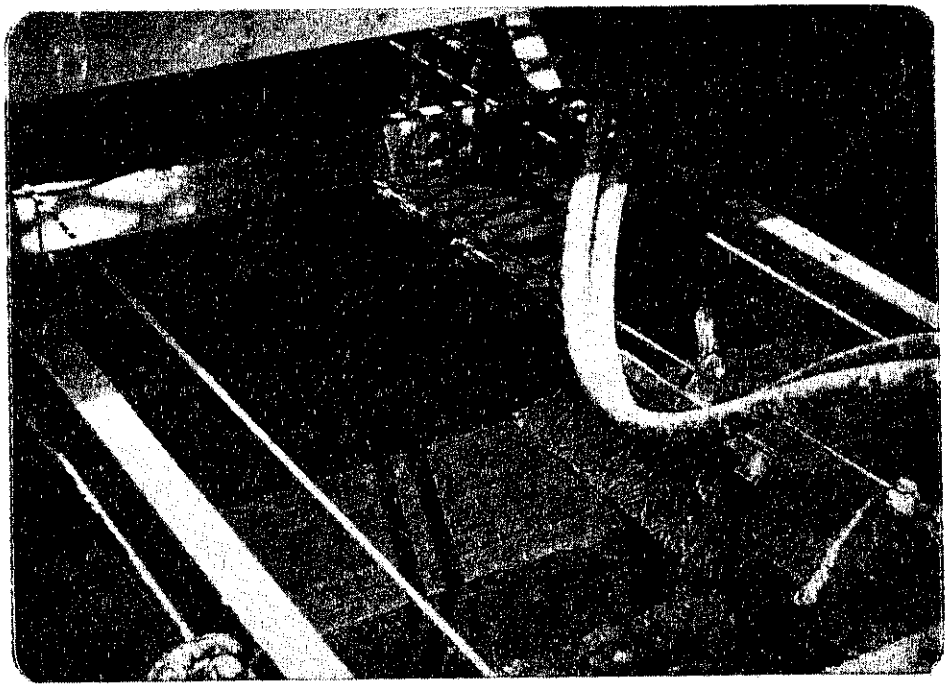


Figure 17. Longitudinal Broom in Operation

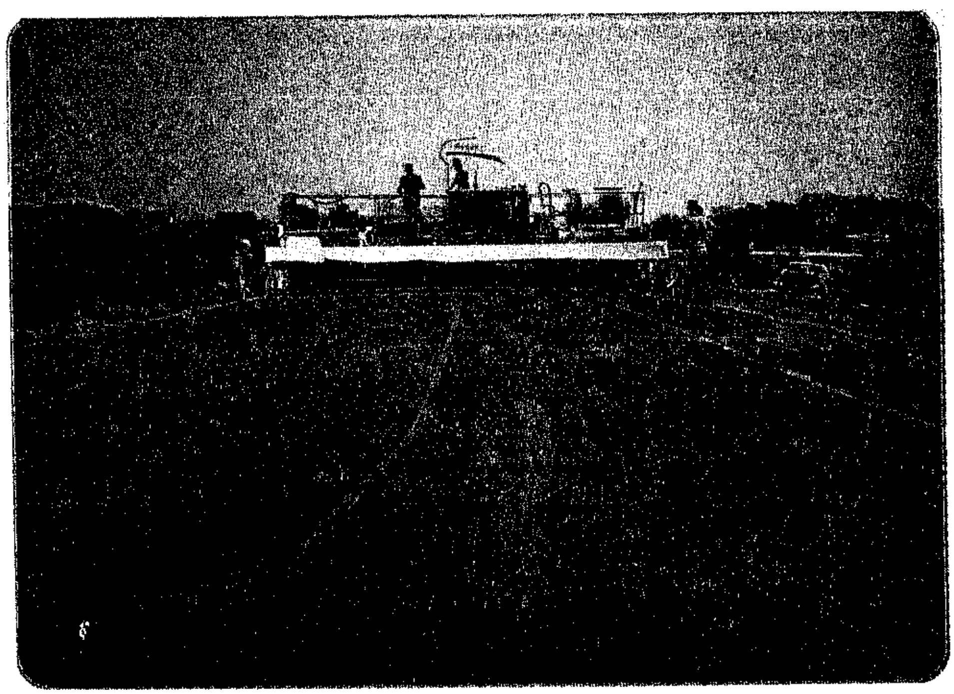


Figure 18. Longitudinal Broom Texture.

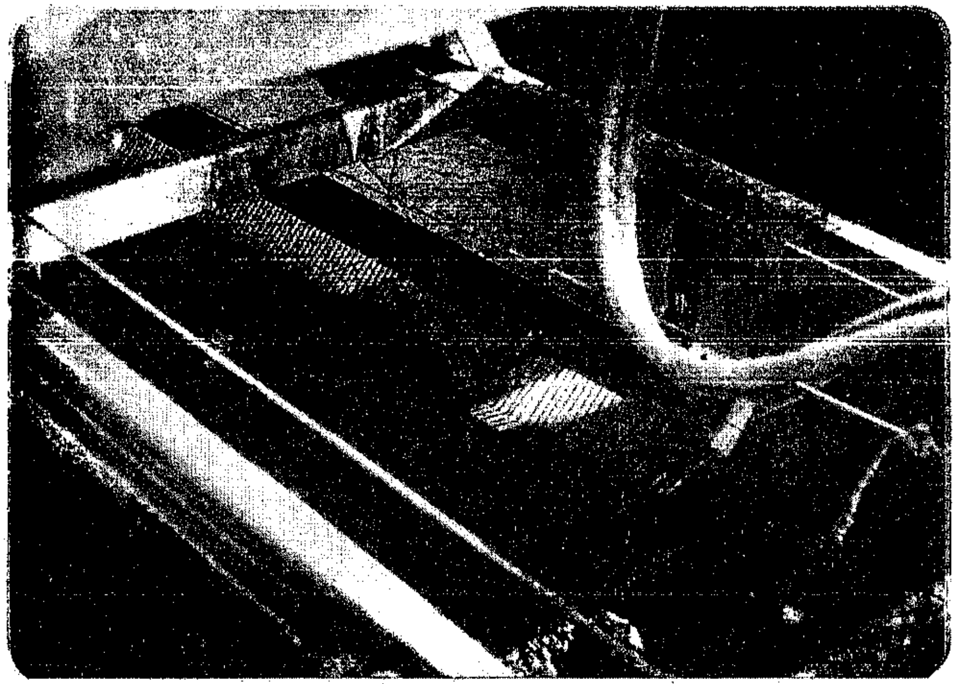


Figure 19. Longitudinal Tine Mounting Arrangement

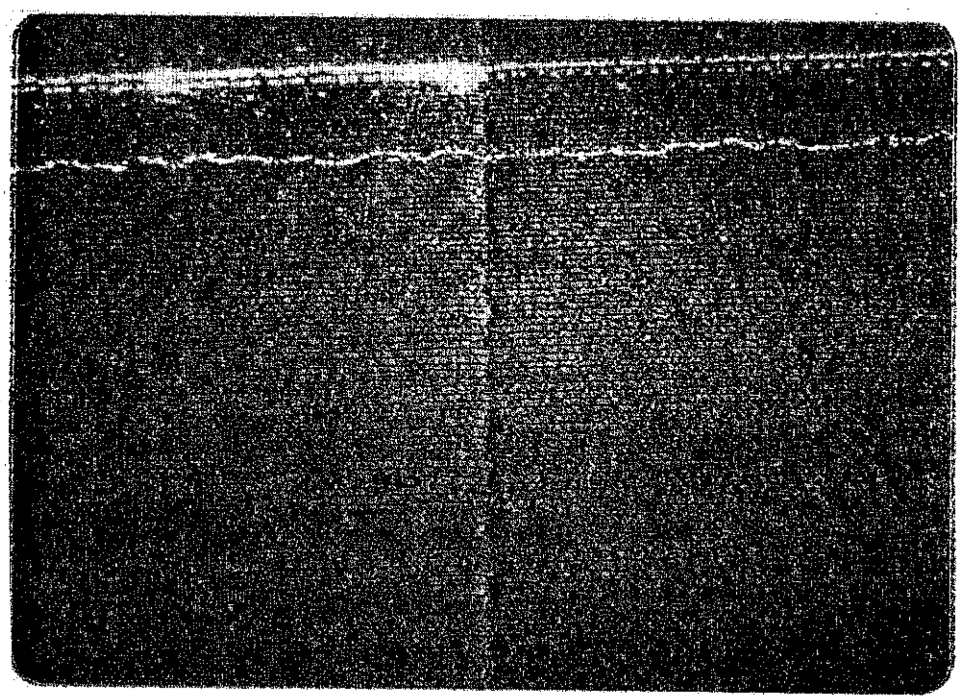


Figure 20. Longitudinal Tine Texture - Damage from Stopping Machine

obtain the proper texture. Texturing began approximately 1 hour and 15 minutes after paving start. A problem showed up very quickly when the texturing/curing machine was stopped without raising the tines. As can be seen in Fig. 20, the tines settled into the plastic concrete, leaving a wave across the width of the pavement. The operator was cautioned and care was taken to elevate the tines before stopping as well as when backing up. No further trouble was encountered with this problem and, as accurately as could be determined, satisfactory groove depth was being obtained (Fig. 21). The same problem of the proper timing of the texturing operation was present as existed throughout the project. No problem of mortar buildup on the tines nor tine wear was encountered during the day.

FIELD TESTS

The initial test program was carried out before the pavement was opened to traffic during the week of October 4 through October 8, 1976. Friction number, noise level, and smoothness tests were made as well as texture casts and depth measurements on each of the project surfaces. The weather during the test period was fair, except for a light rain on Tuesday morning. The maximum temperatures were 85°F (29.4°C), 70°F (21.1°C), 57°F (13.9°C), for the five days. No tests were made during the rain, and at times the sand-patch tests (depth measurements) were delayed by high winds. The test conditions, procedures, and results are discussed in detail in the individual test descriptions that follow.

Friction Tests

On October 5, 1976, when the friction tests were made, the weather was overcast, with an occasional mist during the morning. However, during the tests the pavement was dry except for the water put down by the system. This system used the standard ASTM two-wheel friction test trailer. From 8 to 11 lockups were

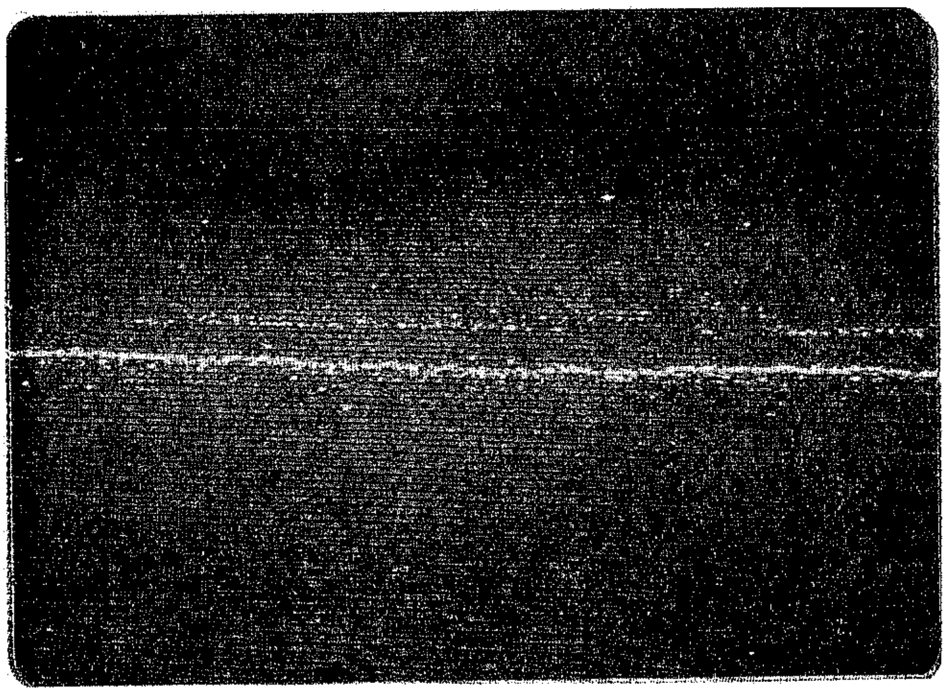


Figure 21. Longitudinal Tine Texture - Near Optimum

TABLE 1. FRICTION NUMBER AT 30, 40, and 50 MPH

Texture	$\overline{FN}_{30}$	Range	$\overline{FN}_{40}$	Range	$\overline{FN}_{50}$	Range
Artificial Turf & Trans. Tine	81(10)	69-87	71(11)	62-77	62(10)	53-74
Trans. Tine	79(10)	72-86	65(10)	59-73	56(8)	52-61
Trans. Broom	69(10)	60-74	61(10)	56-66	50(8)	45-55
Artificial Turf	68(10)	61-78	55(10)	42-65	42(10)	38-48
Long. Tine	66(9)	60-72	53(10)	46-60	45(10)	39-57
Long. Broom	65(9)	52-76	52(9)	43-65	37(8)	35-41
Trans. Roller	43(10)	40-45	32(9)	30-35	26(9)	23-30

Note: (x) Denotes number of tests.

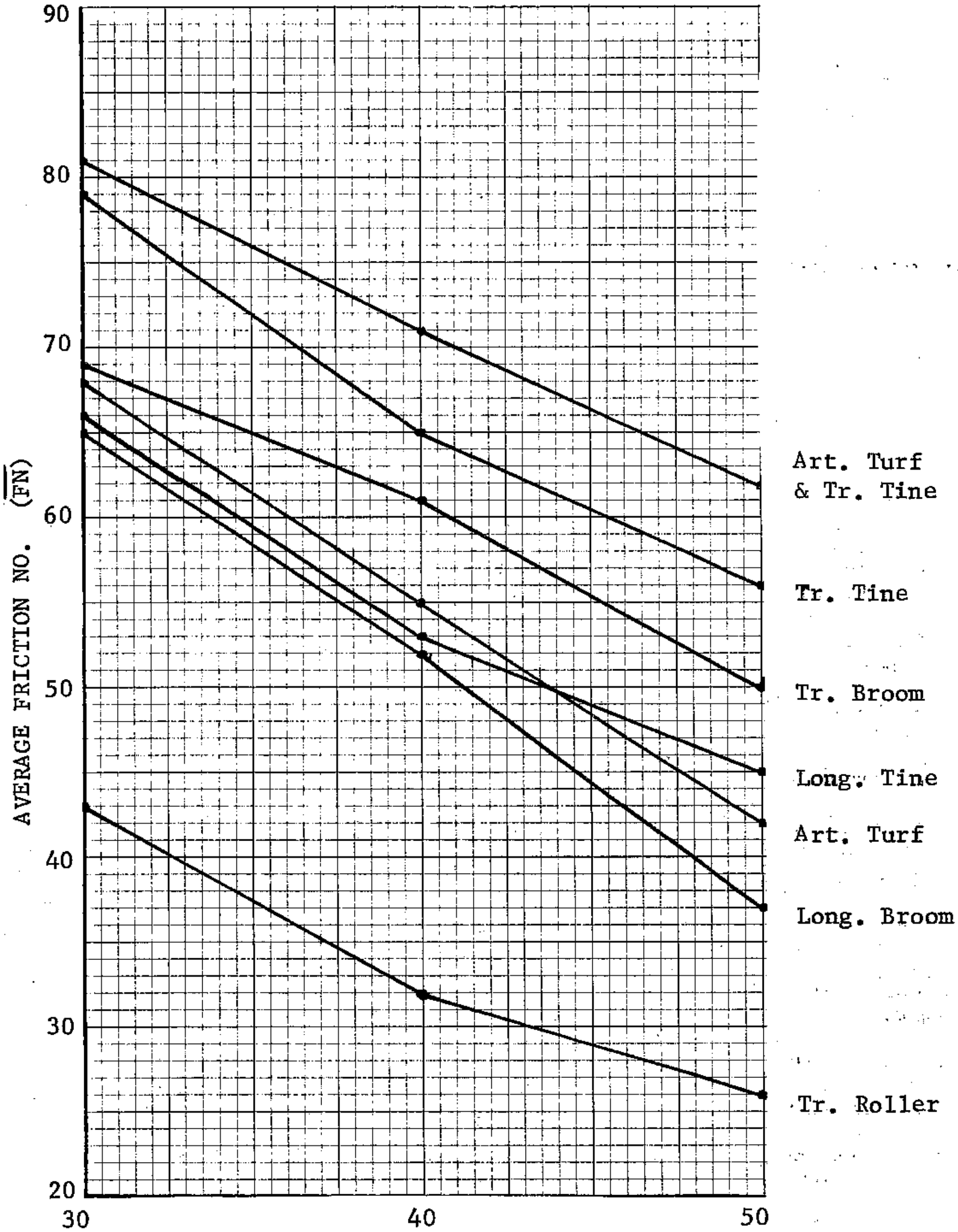
1.0 mph = 1.609 Km/hr

TABLE 2. FRICTION NUMBER-SPEED GRADIENT

Texture listed from high to low friction number

Texture	30 - 40 mph	40 - 50 mph	Rank
Artificial Turf and Transverse Tine	1.0	0.9	3
Transverse Tine	1.4	0.9	4
Transverse Broom	0.8	1.0	5
Artificial Turf	1.3	1.3	6
Longitudinal Tine	1.3	0.8	2
Longitudinal Broom	1.3	1.5	7
Transverse Roller	1.1	0.6	1

Note: 1.0 mph = 1.609 Km/hr



Note: 1.0 mph = 1.609 Km/hr

FIGURE 22. FRICTION NUMBER-SPEED GRADIENT

made in the left wheelpath of the traffic lane at 30 mph (49.3 Km/hr), 40 mph (64.4 Km/hr), and 50 mph (80.5 Km/hr). The results of these tests are given in Tables 1 and 2 and shown graphically in Fig. 22.

The order of friction number descends in going down the column of the tables. The combination of artificial turf and transverse tines provided the highest initial friction numbers. The longitudinal finishes (artificial turf alone, tine, and broom) are approximately equal at this time, but due to its deeper texture it is expected that the longitudinally tined surface will maintain its friction number better than the other two. The frictional properties provided by the transverse roller texture were the poorest and the friction numbers were lower than those obtained by any of the other texturing methods.

Both the tables and the graph show that the present speed gradients (before traffic) are higher than expected for all textures. Both the transverse and longitudinal broom gradients were steeper between 40 mph and 50 mph (64.4 and 80.5 Km/hr) than between 30 mph and 40 mph (48.3 to 64.4 Km/hr), whereas the gradients for other textures were either the same or flatter between 40 mph and 50 mph (64.4 and 80.5 Km/hr) range. This suggests that the broom textures provide less macro-texture or drainage than the other textures. In the past, new PCC pavement with burlap drag (the standard construction) has produced an FN_{40} of about 50, which ranks it above the transverse roller and just below the artificial turf, longitudinal tine, and longitudinal broom textures.

Texture-Depth Measurements

Average texture measurements were made at 10 locations on each texture using the sand-patch and the silicone-putty techniques. Since each of these methods results in an average depth over a given area, they both may give like numbers for unlike textures; that is, the same average depth is possible for a widely spaced, deeply grooved surface as for a closely spaced, shallow texture. Therefore, the value of these measurements lies more in construction quality control than in the comparison of the various textures. Further, since the two methods used do not give like measured depths, only a relative or qualitative ranking can be determined between textures. The Portland Cement Association and the American Concrete Paving Association have used values of a minimum average depth of 0.03 in. (0.76 mm), with a minimum reading of 0.02 in. (0.51 mm) as determined from the sand-patch method. (1)

The data given in Table 3 were obtained during the week of October 4, 1976, in the right wheelpath of the traffic lane (before traffic). These data indicate that the average depth obtained from the sand-patch method is appreciably less than that obtained from the silicone-putty method. Although a wide disparity exists between the two methods, the ranking of the texture depths is almost the same for both methods. By applying the 0.03-in. minimum sand-patch criteria, it is seen that the artificial turf and the combination of artificial turf and transverse tines are the only textures that exceed this value, with the transverse tines used alone having an average depth just below this minimum value.

In addition to the above measurements, silicone-rubber casts were made of each texture. From these negative castings, positive casts were made, and photographs of these are shown in Figs. 23 and 24. This type of molding technique produces a replica of the surface with little of the micro-texture but a good reproduction of the macro-texture.

TABLE 3. RESULTS OF TEXTURE DEPTH MEASUREMENTS

(Texture listed from high to low friction number)

Texture	Sand Patch Method			Silicone Putty Method		
	Average	Std. Dev.	Rank	Average	Std. Dev.	Rank
Artificial Turf & Trans. Tine	.039	.011	2	.063	.013	2
Trans. Tine	.029	.009	3	.064	.020	1
Trans. Broom	.016	.003	6	.045	.007	6
Artificial Turf (control)	.048	.012	1	.050	.008	3
Long. Tine	.022	.007	4	.047	.011	4
Long. Broom	.015	.004	7	.042	.008	7
Trans. Roller	.018	.004	5	.046	.009	5

Texture Depth given in inches.
Note: 1.0 inch = 2.54 cm

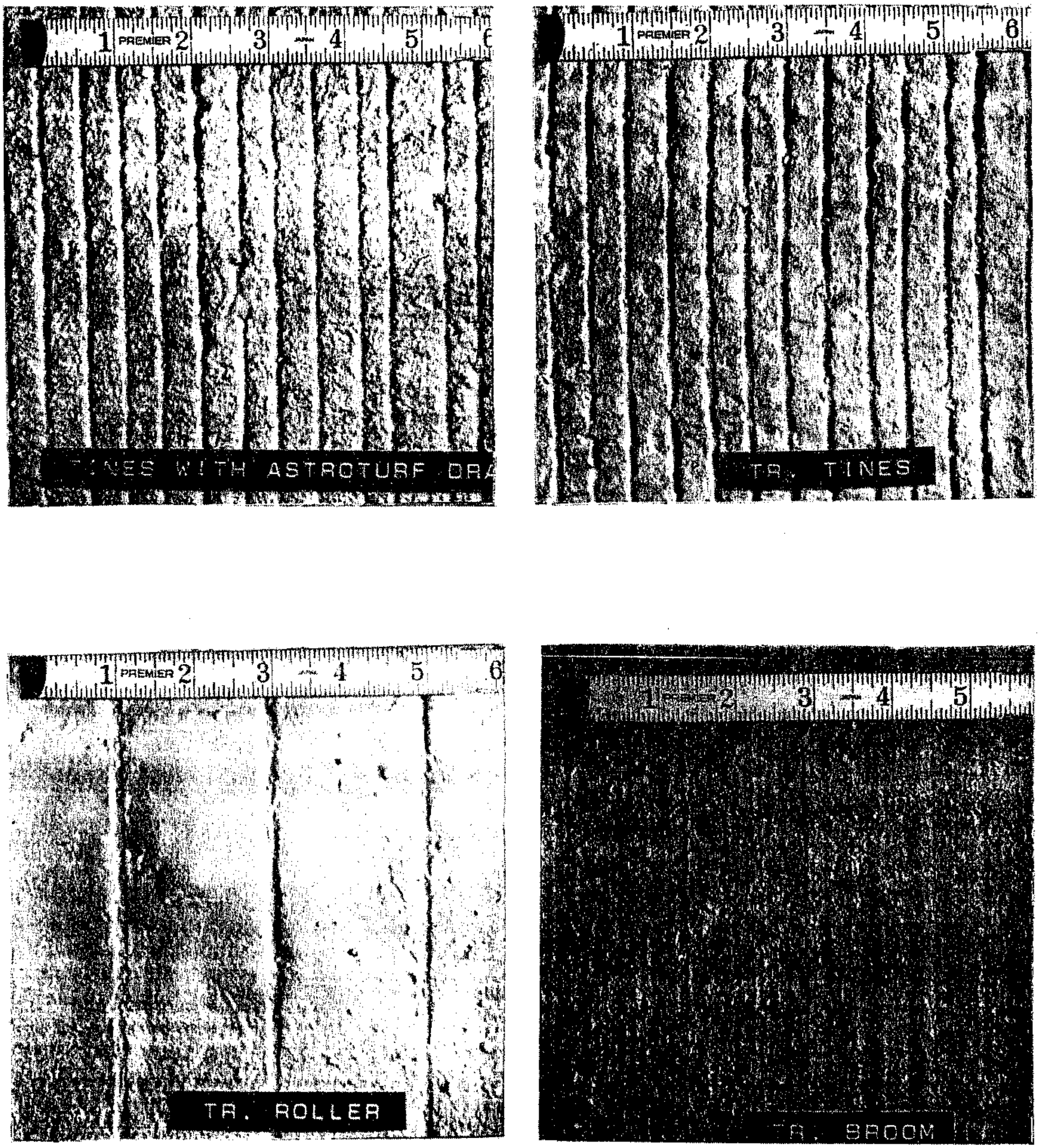


Figure 23. Transverse Textured Surface Castings

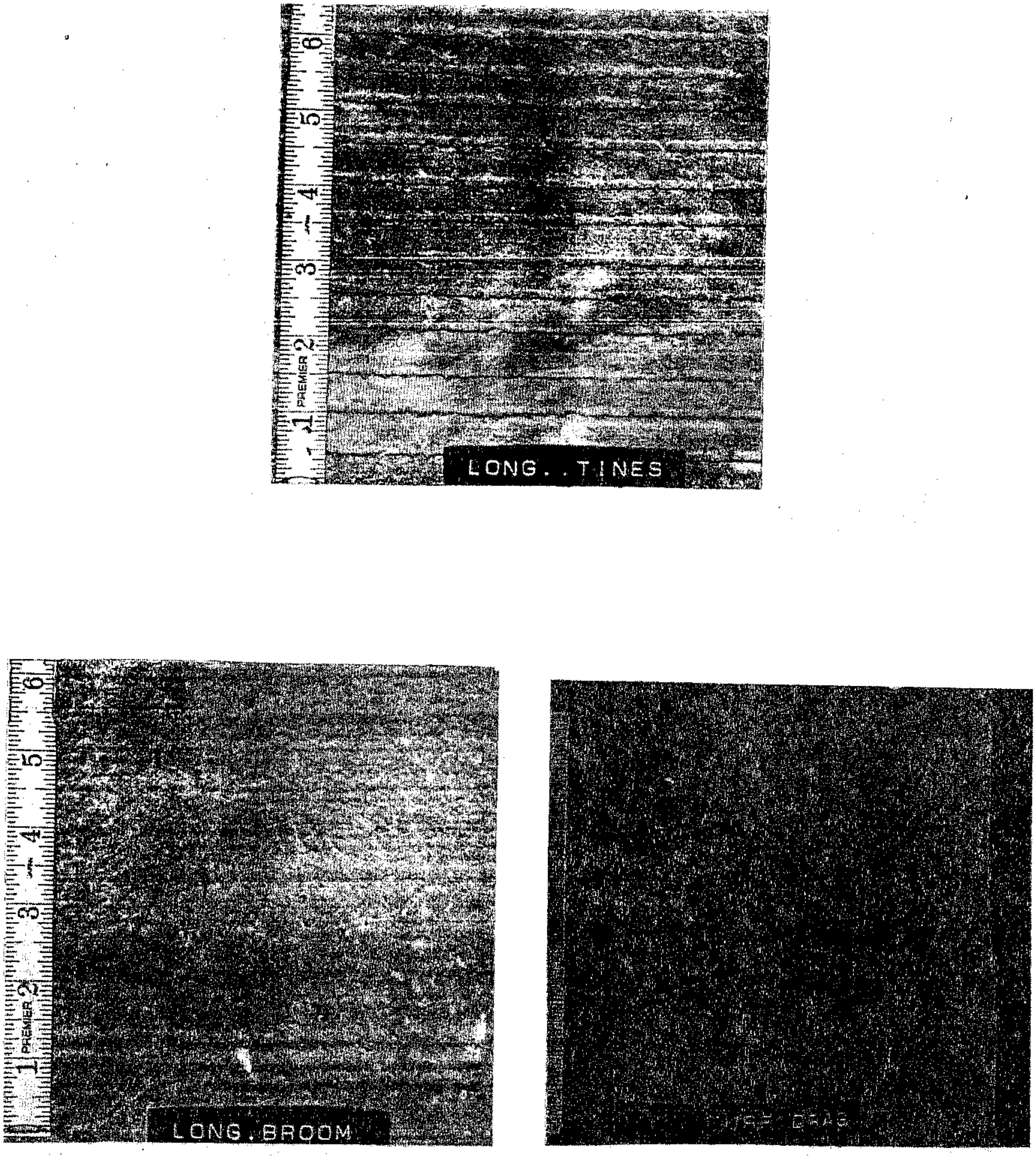


Figure 24. Longitudinal Textured Surface Castings

Noise-Level Tests

Noise-level measurements were made on October 7 and 8, 1976, to ascertain the degree of impact that texture had on noise generated at the tire-pavement interface. These tests were made at 55 mph (88.5 Km/hr) with a 1973 Dodge Polara station wagon, both under power and coasting (engine off, in neutral). The wagon had Uniroyal Fas Trak belted tires having approximately 6,000 mi (9700 Km) of wear.

Two B and K Sound Level Meters, Model 2205, were used to determine the noise levels inside the vehicle beside the driver's right ear and outside the vehicle 50 ft (15.2 m) from the centerline of the traffic lane. Readings were taken on the "A" scale using the slow mode. The "A" scale is filtered such that the response of the meter most nearly matches the nonlinear characteristics of the human ear. The outside readings were made with the meters located midway along each test section. The results of these tests are shown in Table 4. Tests were aborted and data were not included when the ambient noise level was less than 10dBA below the vehicle noise, since at this level the ambient noise added to the vehicle noise would result in an insignificant change in total noise level.

The tests made with the engine running mask the actual noise generated at tire-pavement interface. These noise levels are, as expected, higher than noise levels measured with the engine off by up to 3dBA. The levels measured while coasting contain both the tire-pavement-noise component and the wind-noise component. By using the same vehicle and speed for all tests, the wind-noise component should be about the same for all textures. Further, it has been determined subjectively that a 3dBA change in sound level is barely discernible to the ear; this change constitutes a doubling of sound level. (2)

TABLE 4. MEAN NOISE LEVEL (dBA)

(Texture listed from high to low friction number)

Texture	Inside Vehicle		Outside Vehicle	
	Powered	Coasting	Powered	Coasting
Artificial Turf & Trans. Tine	68	66	70	69
Trans. Tine	72	70	72	70
Trans. Broom	71	68	71	70
Artificial Turf (control)	68	67	67	66
Long. Tine	70	68	72	72
Long. Broom	67	67	67	66
Trans. Roller	72	69	72	71

A 10dBA change generally is perceived by humans as a sound twice as loud, while in fact it is 10 times the reference sound pressure level. Therefore, the range of sound levels between inside and outside at 50 ft (15.2 m) and the range between powered operation and coasting of the vehicle are at worst just discernible for any given texture. Among textures the range, both inside and outside the vehicle, was between 4 and 6dBA. As determined inside the vehicle, the order of rank from high to low for texture sound level was transverse tine, transverse roller, transverse broom, longitudinal tine, artificial turf, longitudinal broom, and artificial turf-transverse tine.

While these rankings indicate a difference in the noise produced by the different textures, it is apparent that the difference is insufficient to rule out the use of any texture for further study. The one texture that seemed obviously noisier inside the car to the personnel making the tests was the transverse roller texture. This undoubtedly is due to the wide, uniform spacing of the grooves, which resulted in the production of a predominant narrow-band frequency of sound (a humming noise). The other textures did not seem to be much different from one to the next. Since those textures with less depth will wear off quicker, it is probable that future noise measurements will result in a different ranking between textures.

Smoothness Tests

On October 5, 1976, the seven textured surfaces were tested for Roughness Index (RI). These tests were made using the Bureau of Materials and Physical Research Roadometer operated at 20 mph (32.2 Km/hr). Each wheelpath in both lanes was run and averaged. The average RI values determined for the seven textures are as follows:

Art. Turf Trans. Tines	Trans. Tine	Trans. Broom	Art. Turf	Long. Tine	Long. Broom	Trans. Roller
91	82	77	80	77	72	84

From these data it can be seen that the RI of the experimental pavement sections ranged from 72 for the longitudinal broom texture to 91 for the artificial turf/tine combination. The adjective ratings of riding quality corresponding to these RI values are "very smooth" (RI = 75 or less), and "slightly rough" (RI = 91 to 125). (3)

Previous work (4) has indicated that the riding quality of a pavement as measured by the roadometer is influenced by surface texture as well as by longitudinal and transverse undulations in the pavement surface. The above values further support this indication. The longitudinal broom-textured section had the lowest RI, or best riding quality, and was ranked poorest relative to texture-depth measurement. The artificial turf/tine combination-textured section had the highest RI, or poorest riding quality, and ranked second relative to texture-depth measurements. This section also had the highest friction value. In addition, it is interesting to note that for both the tine and broom texturing, the direction of texturing appeared to have some effect on the riding quality. Texturing in the longitudinal direction resulted in lower friction numbers, somewhat lower texture-depth measurements, and somewhat lower RI's, or better riding quality.

While the data on Roughness Index of the pavement section are not sufficient to isolate the effect of the different texturing methods on pavement riding quality, none of the RI values obtained are considered unacceptable for new pavement construction, or are such as to eliminate from further consideration any of the texturing methods.

WINTER-WEATHER OBSERVATIONS

Observations made by the Bureau of Maintenance and District 6 Maintenance personnel during snowstorms led to the suspicion that some of the textured surfaces may be trapping snow more than others, causing a slippery condition during these storms. It was further suspected that some of the textures were causing excessive wear of snowplow blades. These winter observations were made on I-72 between Springfield and the Macon County line (about 19 mi - 31 Km), of which approximately 4.3 mi (6.9 Km) is constructed with the IHR-408 experimental textures. The balance of this pavement is finished with artificial turf or burlap drag.

On January 13, 1977, an inspection was made of both EB and WB lanes of I-72 between Springfield and Buffalo (about 10 mi - 16 Km), shortly after a heavy snow. These observations were made by Mr. Jim Santarelli, Bureau of Maintenance and Mr. John Saner, Bureau of Materials and Physical Research. Snowfall had just stopped, but a south wind of 15-20 mph (24-32 Km/hr) was blowing the snow across the pavement.

A noticeable difference was observed in the greater amount of snow collecting on the artificial turf drag and the longitudinal tine pavement than the double burlap drag or the transverse textures. This had to do not only with the natural wind direction, but also with the action of vehicle-generated wind currents. It was also difficult to determine the effect of roadside landscape features on the wind patterns and, hence, the resultant snow accumulation. In conclusion, it seemed that the natural crosswind and the vehicle-generated wind had much less effect in blowing the snow off the longitudinal tine and artificial turf textures than the others.

CONCLUSIONS

The conclusions drawn here are, of course, based on only the construction phase and first series of tests, and therefore are tentative. It is possible that the tests to be carried out over the three-year period, after the pavement is open to traffic, will alter some of these conclusions.

Construction

1. The use of a single machine for both curing and texturing is not recommended, since the timing of the two operations is incompatible.
2. Care must be taken by the texturing machine operator not to overlap transverse textures. This creates a weak surface, susceptible to rapid wear.
3. Care must be taken to raise any longitudinal texturing device when the machine is stopped to prevent deformation of the surface by the pressure of the device.
4. Care must be exercised to avoid pavement-edge damage from whatever texturing device is being used.

Field Tests

1. Friction testing shows that the FN at all speeds (30, 40 and 50 mph) is highest for the combination of artificial turf drag and transverse tines. With the exception of the transverse roller, the transverse textures were higher than longitudinal ones. The transverse roller texture FN's were appreciably lower than all others, and further consideration of this method of texturing is not warranted. The speed gradients (FN/mph) before traffic were higher than expected for all textures. The high speed gradients (40 to 50 mph (64.4 to 80.5 Km/hr) indicate that textures with the higher macro-texture have lower speed

gradients. While the continuing test program will show the effects of traffic and weathering, it is felt that all gradients will change and that high macro-texture surfaces will have lower future gradients more in the expected range.

2. The texture-depth measurements made by the two methods gave the same order of rank except for the change between the two from first to third for artificial turf and the transverse tine textures. The artificial turf and transverse tine combination was second in each case, which might make the accuracy of the two methods suspect. The two broom surfaces and the transverse roller texture had the least average texture. Since each of the test methods results in an average depth over an area, they both may give like numbers for unlike textures; that is, the same average depth is possible for a widely spaced, shallow texture. Therefore, the value of these measurements lies more in the construction quality control of one type of texture than in the comparison of different types of texture.

3. The range of noise levels measured inside and outside the test vehicle as well as the difference between powered and coasting were, at greatest, just discernible for any given texture. Among textures, the range both inside and outside was between 4 and 6dBA, a noticeable difference. As determined inside the vehicle, the order of rank from high to low for noise level was transverse tine, transverse roller, transverse broom, longitudinal tine, artificial turf, longitudinal broom, and artificial turf-transverse tine. The difference in measured noise was insufficient to rule out the use of any of the textures but, subjectively, the transverse roller texture seemed much noisier. This

is undoubtedly due to the wide, uniform groove spacing resulting in a narrow-band frequency of sound (a humming noise). To observers, the other textures did not seem to be much different from one to the next. Future tests will determine the extent to which texture wear will change the noise levels and rankings of the textures.

4. The Roadometer tests indicate that the textures vary from an RI of 72 for the longitudinal broom surface to 91 for the artificial turf-tine combination. However, the total range of RI's is no greater than would be found on a similar length of standard pavement. For this reason, it cannot be stated with certainty that the different textures affect the smoothness of the pavement.

IMPLEMENTATION

At the inception of and preliminary planning for this study, it was anticipated that the various experimental texturing methods would be constructed. Next, construction data, along with data on the as-constructed condition of the experimental texturings relative to frictional characteristics, texture depth, noise, and smoothness, would be collected and analyzed. After this, recommendations would be formulated and implemented to revise the specifications to replace the double-burlap method of texturing with the method or methods which appeared to be the most satisfactory. Final recommendations for the best method of texturing would be forthcoming from the study following a three-year evaluation of performance of the experimental texturings.

The construction project was delayed, however, and construction of the experimental texturing was performed in the summer of 1976, one year later than originally anticipated. Because of this, the Division agreed early in 1976 to immediately revise its specifications to a more positive method of texturing new

PCC pavement before the preliminary results from the study were available. Based on limited experience in Illinois with both longitudinal texturing by the artificial turf drag and transverse tining, combined with reported experience of others, a decision was made to replace the double-burlap drag method of texturing with one requiring longitudinal texturing with artificial turf drag immediately followed by transverse texturing by tining. A special provision to cover this change was prepared and became effective March 1, 1976 (revised February 1, 1977) to be applicable to all rural high-speed PCC pavements. The preliminary results from this study covering the as-constructed condition of the experimental texturings support the choice of the method that was made in the spring of 1976.

REFERENCES

1. Guideline for Texturing of Portland Cement Concrete Highway Pavements, American Concrete Paving Association, Technical Bulletin No. 19, March 1975.

2. Wisleder, Dean, Traffic Noise and Vibration Manual, Illinois Department of Transportation, 1977.

3. An Analysis of 1972 Roadometer Tests on New Pavement Surfaces in Illinois, (IHR-504), Physical Research Report No. 46.

4. Factors Influencing the Riding Quality of New Pavement Surfaces in Illinois, (IHR-74), Physical Research Report No. 64.