PILOT FIELD STUDY OF CONCRETE PAVEMENT TEXTURING METHODS

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The effect of different texturing methods on texture depth, initial skid resistance, texture uniformity, and texture durability was studied through a designed field experiment installed at five different locations. The textures studied included those produced by three conventional methods (burlap drag, natural-bristle broom, and wire broom) and one unconventional method (fluted magnesium float). The latter method produced uniform, parallel, ⅛-in. deep, semicircular ribs on ⅜-in. centers. All textures were placed perpendicular to the centerline of the pavement. Textures produced by the fluted float were found to be deeper and to provide greater skid resistance than textures produced by the burlap drag or the natural-bristle broom. They were equivalent in these respects to those produced by the wire broom but were found to be more uniform and to wear at a slower rate. It was concluded that more consideration should be given to the merits of such geometrically definable textures and that the relationships among texture geometry, skid resistance, and abrasion resistance should be the subjects of more research.

•THE skid resistance of a concrete pavement—defined for this discussion as tire-pavement friction in the locked-wheel mode (1, pp. 11-13)—results from a combination of intrinsic and extrinsic factors. Of principal importance among the former is the texture of the pavement surface itself, which results from the distribution of asperities of various sizes and shapes over the surface. It has been accepted that pavement designed for high-speed travel should have a texture composed of both fine and coarse asperities because both contribute—although differently—to tire-pavement friction. [A comprehensive discussion of the mechanism of this friction is given elsewhere (1).]

Coarse asperities, which are responsible for what has been called macrotexture or macroroughness, can be controlled by the engineer because they are primarily a function of the method used to texture the pavement surface. In addition to contributing directly to tire-pavement friction, coarse asperities (macrotexture) provide channels for the drainage of water trapped between a pavement and a moving tire. Hydrostatic pressure and skid resistance are dependent on the extent to which water is prevented from draining during the tire-pavement contact period. If hydrostatic pressure develops to the extent that the tire is supported entirely by water film, hydroplaning (the complete loss of interfacial friction) results.

Because of the increasing volumes of high-speed traffic and the growth of interest in the skid resistance of pavements, there has been a tendency to use texturing methods that create deep textures. Not only do these textures have great inherent resistance to skidding, but also they drain well.

The purpose of this paper is to describe the partial results of a pilot field study of four different concrete pavement texturing methods. Data are presented regarding the

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initial texture and skid resistance of the experimental pavements, and the relative durability of the textures themselves are tentatively evaluated.

STUDY SCOPE AND PROCEDURES

During the 1969 construction season, a designed experiment was built in new pavements at five different sites in New York State. Two specific objectives of the experiment were to determine the initial depth and skid resistance of textures produced by different texturing methods under conditions of field control and to evaluate the relative durability of the textures under the abrasive action of traffic. A third objective was to determine whether a measure of texture depth could be correlated with locked-wheel skid resistance for a variety of texturing methods combined.

The four texturing methods employed were as follows:

1. Burlap drag—typical of that commonly used in the United States and in New York State prior to 1969;
2. Natural-bristle broom—typical of that used in New York State since 1969 and gaining popularity throughout the United States;
3. Wire broom—widely used in England and elsewhere in the British Commonwealth; and
4. Fluted magnesium float—a device that produces a uniform surface of parallel, semicircular ribs on $^3/_8$-in. centers with $^1/_8$-in. penetration.

The first three are conventional methods and were selected to represent the range of current practice in the United States and abroad. The fourth is an unconventional method; i.e., to the authors' knowledge, it had been used only experimentally on two bridge decks in New York State. The details of each method are given in the Appendix, and profiles of representative textures are shown in Figure 1.

Each of the four methods was used on two 120-ft long test sections (A and B) that were placed in the driving lane of pavements at five different sites. The sites selected included a variety of concrete materials and traffic characteristics. All experimental textures were manually placed perpendicular to the pavement centerline at all sites by the same personnel. Details of the sites are given in Table 1, and the data collected at the time of placement are given in Table 2.

Texture depth and skid resistance in the wheelpaths were measured immediately after construction and periodically since then. Texture depths were measured by the sand-patch method (2) after the residual curing compound was removed. Skid tests were performed at speeds of 40 and 55 mph with a locked-wheel trailer in accordance with ASTM Designation E 274-65T. Trailer tires conformed to ASTM Designation E 249-66.

TEST RESULTS

The experiment involving initial textures was designed for a two-factor, four-level (texturing methods) by five-level (sites) analysis of variance with single replication (3). Independent analyses were made for initial texture depth and initial skid resistance at speeds of 40 and 55 mph. In each case, the method of texturing was found to produce a significant effect. Similarly, mean texture depth and skid resistance at speeds of 40 and 55 mph were found to differ significantly from site to site for the same texturing method. No significant interaction was found between methods and sites. Analysis for the components of variance (Table 3) indicated that 68 to 79 percent of the total variance encountered in texture depth and skid resistance was associated with site-to-site and method-to-method effects combined. The results of all initial measurements on the experimental textures are given in Tables 4 and 5.

Subsequent measures of texture depth have shown that the experimental textures wear at a rate dependent primarily on the level of traffic, the initial texture depth, and the method of texturing employed (Table 6).

Variations in the level of texture depth and skid resistance that occurred from site to site for the same texturing method have not yet been fully studied and thus are not included here. Their importance, however, should not be minimized.

Figure 1. Transverse profiles of study textures.

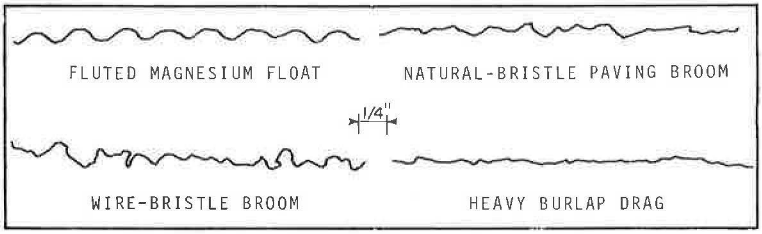


Table 1. Study sites.

Site	Driving Lane AADT: Total	Driving Lane AADT: Trucks (percent)	Speed Limit (mph)	Estimated Studded Tire Use[a] (percent)	Remarks
1	1,410	1.0	50	30	Most vehicles gradually accelerating or decelerating
2	1,200	5.0	55	40	Pavement snow-packed up to 3½ months each year
3	1,710	4.0	60	40	Most vehicles gradually accelerating
4	5,160	1.0	65	35	–
5	1,870	10.0	60	30	–

[a]Legal between October 15 and May 1.

Table 2. Weather conditions and concrete properties at time of test section placement.

Site	Test Section	Date Placed (1969)	Weather: Temperature (F)	Weather: Relative Humidity (percent)	Weather: Clouds (percent)	Weather: Wind Velocity (mph)	Concrete: Mean Slump (in.)	Concrete: Mean Air Content (percent)	Concrete: Proctor Penetration[a]
1	A	8/14	86	47	0	0-5	2.5	5.7	500 psi at 2½ hr
	B	9/24	67	32	50	0-5	2.4	5.4	–
2	A	7/31	75	70	0[b]	0-5	1.5	4.3	500 psi at 3½ hr
	B	8/1	78	64	0[b]	0-5	1.5	5.2	500 psi at 3 hr
3	A	8/11	82	50	50	16-25	1.8	6.3	500 psi at 3 hr
	B	8/12	78	45	0	16-25	1.5	5.9	460 psi at 2¾ hr
4	A	9/25	55	67	100	0-5	2.5	6.0	160 psi at 6½ hr
	B	9/29	50	52	50	0-5	2.5	6.0	–
5	A	10/30	46	36	0	0-5	2.3	5.3	–
	B	10/30	46	37	0	0-5	2.4	7.7	–

[a]ASTM Designation C 403-65T.
[b]Haze.

Table 3. Percentage of contribution of components to total observed variance.

Source of Variance	Texture Depth	Skid Number at 40 mph	Skid Number at 55 mph
Texturing methods	54.2	21.7	40.1
Sites	24.3	55.9	28.0
Site-method interactions	10.2	5.6	8.1
Sampling error	11.2	8.3	13.7
Testing error	0.1	8.5	10.1
Total	100.0	100.0	100.0

Table 4. Summary of initial texture depths.

Site	Test Section	Initial Texture Depth (in. x 10^3): Burlap Drag	Bristle Broom	Wire Broom	Fluted Float	Within-Site Avg
1	A	13.3	26.3	53.3	30.3	
		22.2	28.0	44.3	57.3	
		38.7	31.5	57.3	48.3	
	B	17.0	46.7	53.5	27.3	
		27.0	29.0	40.3	37.8	
		31.3	31.2	22.3	35.7	
	Avg	24.9	32.1	45.2	39.5	35.4
2	A	18.3	23.8	40.0	44.7	
		17.3	26.8	22.3	48.8	
		19.5	27.7	36.5	50.1	
	B	15.0	23.2	49.7	48.0	
		14.3	24.5	30.2	49.2	
		14.8	20.0	17.8	50.5	
	Avg	16.5	24.3	32.8	48.6	30.5
3	A	12.2	24.3	37.5	34.3	
		12.6	18.5	46.7	34.2	
		14.0	13.7	38.5	34.8	
	B	11.7	27.2	31.5	44.0	
		15.8	21.3	24.2	26.5	
		8.0	15.2	39.7	49.3	
	Avg	12.4	20.0	36.4	37.2	26.5
4	A	12.3	48.0	20.0	45.5	
		15.5	26.3	38.8	53.7	
		11.2	38.7	36.8	38.7	
	B	16.5	30.2	34.3	47.5	
		17.7	41.8	21.7	41.0	
		14.3	24.5	35.0	44.8	
	Avg	14.6	34.9	31.1	45.2	31.5
5	A	25.7	46.5	80.5	53.3	
		25.7	46.8	83.3	51.5	
		37.0	46.3	61.3	68.5	
	B	19.5	49.8	58.7	44.3	
		20.8	39.0	48.3	47.5	
		29.8	45.0	58.0	48.2	
	Avg	26.4	45.6	65.0	52.2	47.3
Within-texture avg		19.0	31.4	42.1	44.5	

Note: Each value is the average of six tests (two tests each by three technicians). Tests were performed at three different wheelpath locations for each test section and method combination.

Effects of Texturing Method

Figure 2 shows the effect of texturing method (based on average values for all five sites) on both initial mean texture depth and mean skid resistance at speeds of 40 and 55 mph. The fluted float and wire broom methods produced the deepest textures and the highest skid resistances. The results of statistical significance tests between pairs of these data are given in Table 7. The fluted float and wire broom methods produced virtually the same results.

Texture Depth Versus Initial Skid Resistance

The entrapment of water between a sliding tire and a wetted pavement surface is responsible for the development of hydrostatic pressure. Pavement-tire friction decreases as hydrostatic pressure increases. The low skid numbers attained at the testing speed of 55 mph (Fig. 2) reflect this principle. Similarly, the greater sensitivity of skid resistance to characteristics of the macrotexture at higher testing speeds is shown by the greater slope of the relationship at a speed of 55 mph (Fig. 2).

The primary pavement characteristic related to drainage is the mean hydraulic radius, i.e., the ratio of the cross-sectional area of the average drainage channel to its wetted perimeter (4). Because the wetted perimeter is so difficult to measure, Gillespie (5) worked with the drainage area alone and was able to show that it correlated with the skid characteristics of six actual pavements. Goodman (6) reasoned, therefore, that a measure of mean texture depth based on drainage area is equivalent to measuring the drainage area itself and cited "mean texture depth" derived from the sand-patch test as an example.

It is not surprising, therefore, to find the good correlations between texture depth and skid resistance shown in Figure 2. This is particularly true for the three conventional texturing methods, which all produce irregular patterns that vary primarily in depth. The fact that the texture produced by the fluted float method fits this same relationship suggests that its depth and drainage area are related to one another in the same way as in the textures produced by the other three methods. This suggestion is supported by the data shown in Figure 3. This figure shows the relationships between texture depth and drainage area and texture depth and skid resistance for one of the experimental sections. Drainage areas were measured from microprofiles by using a planimeter—a method similar to that used by Gillespie (5).

The relationship between skid resistance and texture depth in pavements, as measured by the the sand-patch test, has been demonstrated elsewhere (7, 8). This is the first time, however, to the authors' knowledge that the relationship has been shown to hold for a variety of textures produced in concrete by different methods. This tends to reinforce the significance of texture depth as a determinant of skid resistance.

Texture Depth Versus Coefficient-Speed Gradient

A paramater equally important as texture depth to skid resistance (as measured at a particular testing speed) is the rate at which skid resistance changes with testing speed—the so-called coefficient-speed gradient (9). The decrease in this gradient can be inferred from the convergence of the 40- and 55-mph lines with increasing texture depth as shown in Figures 2 and 4. The data shown in Figure 4 are based on average values of mean texture depth and coefficient-speed gradient for the 20-texture method and site combinations. The relationship is curvilinear—asymptotic on one end to a texture depth of 8 to 9 in. $\times 10^{-3}$ (representing no texture at all) and approaching zero gradient on the other as texture depth increases. This relationship has been demonstrated elsewhere (5, 10).

Uniformity of Texture Depth

Standard deviations of texture depth corresponding to each of the texturing methods are shown in Figure 5. Each standard deviation was computed from 30 values that represent mean texture depths measured at three points in the wheelpath of each of the 10 experimental sections. Figure 5 shows that, for the conventional texturing methods,

Table 5. Summary of initial skid numbers.

Site	Test Section	Initial Skid Number at 40 mph*: Burlap Drag	Bristle Broom	Wire Broom	Fluted Float	Within-Site Avg	Initial Skid Number at 55 mph*: Burlap Drag	Bristle Broom	Wire Broom	Fluted Float	Within-Site Avg
1	A	63	64	63	61		43	55	55	61	
		55	63	60	63		37	55	52	61	
	B	55	63	58	66		52	60	57	54	
		49	60	60	64		52	60	54	52	
	Avg	55.5	62.5	60.3	63.5	60.4	46.0	57.5	54.5	57.0	53.8
2	A	59	55	66	70		38	44	52	61	
		49	49	59	66		38	40	56	57	
	B	49	50	62	62		39	38	61	63	
		52	59	66	66		29	31	56	57	
	Avg	52.3	53.3	63.3	66.0	58.7	36.0	38.3	56.0	59.5	47.5
3	A	58	72	72	72		43	58	70	69	
		63	70	72	72		42	57	70	66	
	B	61	66	67	72		52	55	64	63	
		64	72	70	72		49	51	61	61	
	Avg	61.5	70.0	70.3	72.0	68.4	46.5	55.3	66.3	64.8	58.2
4	A	38	46	51	51		26	41	44	46	
		38	46	53	51		24	41	42	46	
	B	41	58	55	40		31	50	48	47	
		37	63	58	48		31	52	50	47	
	Avg	38.5	53.3	54.3	49.5	48.9	28.0	46.0	46.0	46.5	41.6
5	A	49	54	61	61		46	49	60	58	
		48	55	58	58		46	51	60	58	
	B	52	52	57	51		42	48	55	46	
		51	49	60	51		42	45	48	43	
	Avg	50.0	52.5	59.0	55.3	54.2	44.0	48.3	55.8	51.3	49.8
Within-method avg		51.6	58.3	61.4	61.3		40.1	49.1	55.8	55.8	

*Each value (except averages) represents one skid test.

Figure 2. Effect of texturing method on initial texture depth and skid resistance.

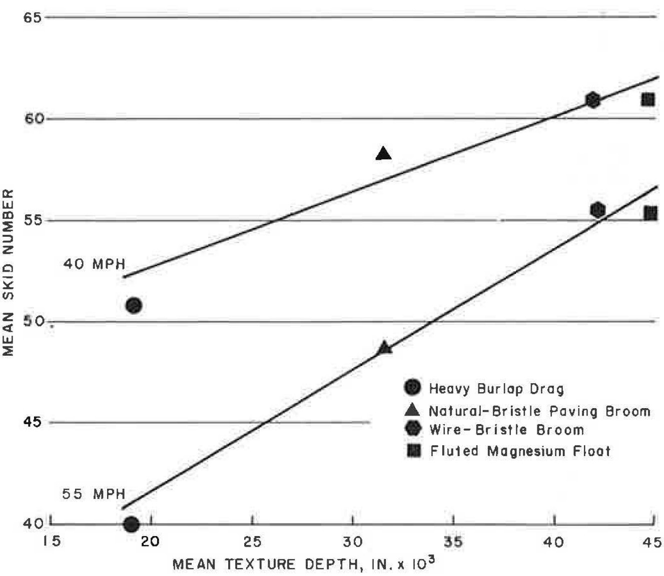


Table 6. Mean texture depth wear rates.

Site	Mean Texture Depth (in. x 10^3): Burlap Drag	Bristle Broom	Wire Broom	Fluted Float
1 (opened 7-70)				
Initial	24.9	32.1	45.2	39.5
9-70; 0.414 VP	20.9	25.7	37.0	37.4
4-71; 1.862 VP	8.5	10.0	16.5	15.0
8-71; 4.376 VP	8.0	9.2	15.0	17.0
2 (opened 10-69)	16.5	24.3	32.8	48.6
Initial	11.6	18.4	24.5	43.7
5-70; 2.880 VP	9.8	16.0	21.7	40.4
8-70; 4.323 VP	8.8	15.5	22.0	40.9
9-70; 4.320 VP	9.0	14.4	22.5	39.2
4-71; 6.840 VP				
3 (opened 12-70)				
Initial	12.4	20.0	36.4	37.2
5-71; 2.565 VP	8.0	9.7	19.3	17.4
8-71; 4.104 VP	8.0	9.2	18.7	15.4
4 (opened 8-70)				
Initial	14.6	34.9	31.1	45.2
9-70; 1.888 VP	9.8	22.7	21.7	38.6
5-71; 13.215 VP	8.0	10.5	11.5	10.0
8-71; 22.654 VP	8.0	8.2	8.9	8.5
5 (opened 12-70)				
Initial	26.4	45.6	65.0	52.2
3-71; 1.503 VP	15.4	19.7	31.5	27.0
8-71; 3.506 VP	8.3	15.8	27.0	24.2

Note: VP = estimated cumulative number of vehicle passes x 10^5; mean texture depth measured by using the sand patch method.

Table 7. Results of tests for significance of differences among texturing methods.

Texturing Methods Compared	Texture Depth	Skid Resistance: At 40 mph	At 55 mph
Burlap drag			
Bristle broom	Significant	Significant	Significant
Wire broom	Significant	Significant	Significant
Fluted float	Significant	Significant	Significant
Bristle broom			
Wire broom	Significant	Not significant	Significant
Fluted float	Significant	Not significant	Significant
Wire broom			
Fluted float	Not significant	Not significant	Not significant

Note: Test conducted by using the student t-test at the 0.90 confidence level.

Figure 3. Relationships between texture depth and drainage area and texture depth and skid resistance, site 4, section B.

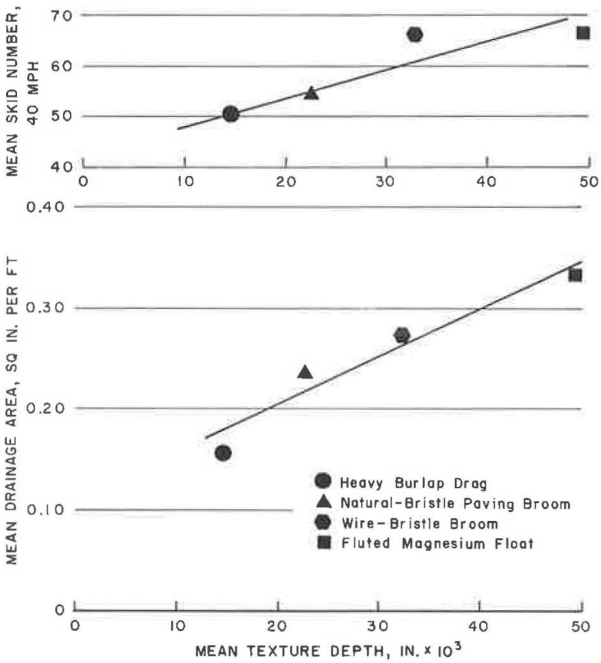
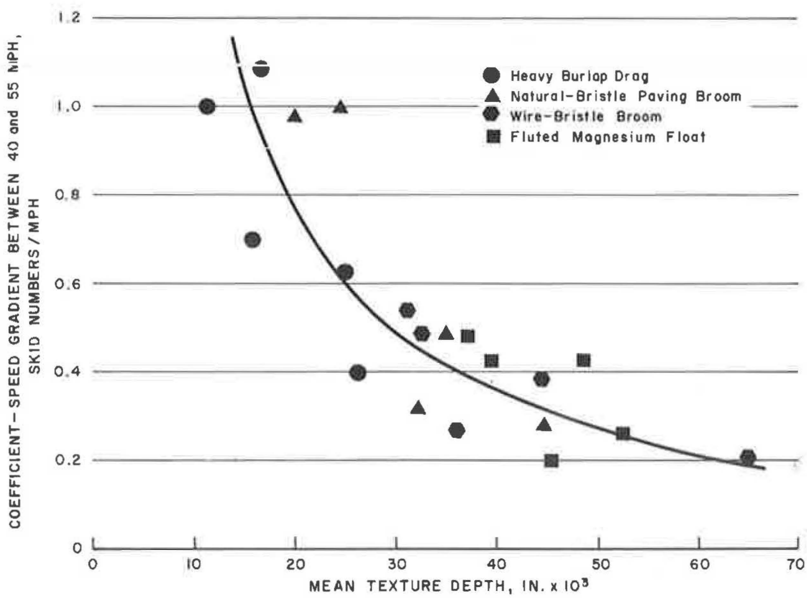


Figure 4. Effect of texture depth on coefficient-speed gradient.



uniformity decreases with increasing mean texture depth. However, the texture produced by the fluted float method is one of the deepest, and its uniformity is relatively high. Apparently, this is because the fluted float (when manually operated) is less sensitive to variation in the stiffness of surface mortar at the time of texturing than are the other methods.

Durability of Texture and Skid Resistance

Because of the abrasion that results from increased traffic volume and speed, winter maintenance, and the use of tungsten carbide studs by a large portion of the driving public in New York State, even the deepest textures have little chance of surviving for more than a few years. At the most heavily traveled experimental location (site 4), for instance, all of the textures had been worn to mean depths of from 0.008 to 0.009 in. after the first year of service. This is equivalent to the complete removal of all macrotexture and corresponds to reductions in skid number of between 31 and 40 at a speed of 40 mph and 22 and 32 at a speed of 55 mph. From this experience, it could be argued that many high-volume, high-speed concrete highways may require maintenance to restore skid resistance long before they require it to level wheelpath ruts.

The range of decay in texture depth encountered in this study is shown in Figure 6. Sites 2 and 4 respectively show the least and the greatest wear after 1 year of service. Site 2 has the lowest driving-lane AADT and is snow-packed for 3½ months each year; thus, it does not receive nearly the volume of studded-tire traffic one would otherwise expect. Site 4 is a heavily traveled commuter route that is located outside of Rochester. It has the highest driving-lane AADT of the five sites.

The data shown in Figure 6 lead to the conclusion that the amount of pavement texture remaining at any particular time will depend primarily on the volume of traffic that has passed over it and on the texture's initial depth. Methods that produce deep textures, such as the wire-bristle broom and the fluted float, have an advantage in this respect.

If the texture wear data from site 2 are projected at the same decay rate and the traffic volume figures are corrected to account for the period of snowpack, the following generalization could be proposed:

> Under conditions where 35 to 40 percent of vehicle operators use studded tires for periods up to 6½ months of the year, a texture with an initial mean depth of 0.045 to 0.050 in. would be expected to last for 6 years or more if the AADT over the textured surface does not exceed 850. On the other hand, if the AADT over the surface exceeds 5,000, the texture would probably disappear in less than 1 year.

No consideration has been given in this discussion to the effect of the quality of the mortar in which the textures were actually placed on the rates of wear experienced. Although the importance of this factor is recognized, the authors believe that the durability of texture on a high-speed, high-volume highway such as that at site 4 depends primarily on total traffic volume.

The levels of skid resistance corresponding to texture depths at site 4 after 1 year of traffic have been noted. Figure 7 shows average depths and skid resistances, both initially (before opening to traffic) and in the summer of 1971, for textures at all experimental sites. As expected, the reduction in texture depth has been accompanied by a decay in skid resistance, and the textures have maintained the same order with respect to one another in both depth and skid resistance.

Texture Wear Rates

In an effort to look more closely at the effect that texturing methods have on the rate of texture wear, we computed average wear rates for the textures produced by each method after an average of only 200,000 vehicle passes. The results (Fig. 8) represent wear characteristics during the early service life of the textures. Two points are worth noting:

Figure 5. Effect of texturing method on uniformity of texture depth.

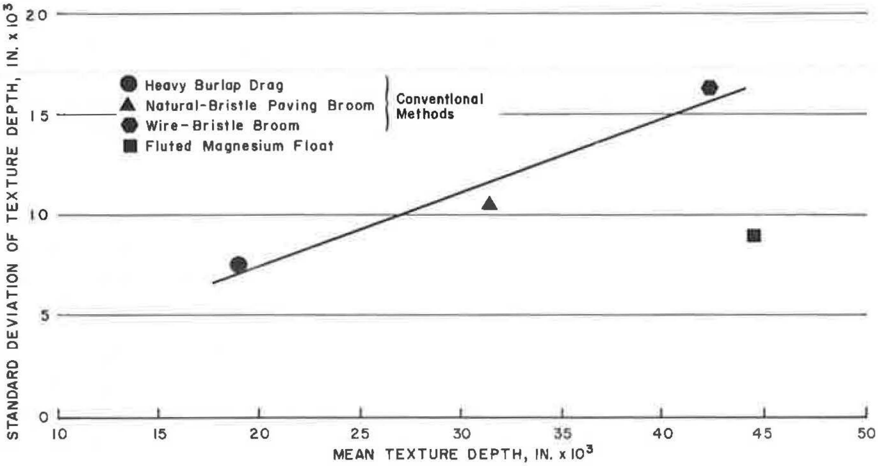


Figure 6. Decay of texture depth.

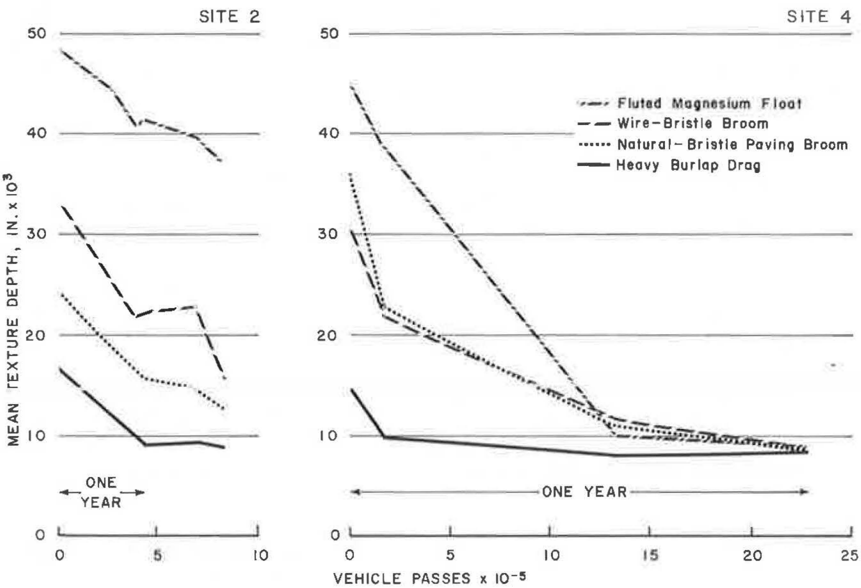


Figure 7. Changes in texture depth and skid resistance.

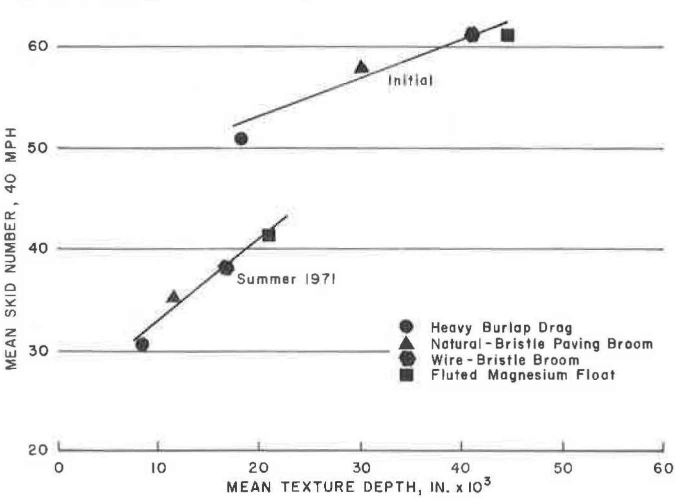


Figure 8. Early rates of texture wear.

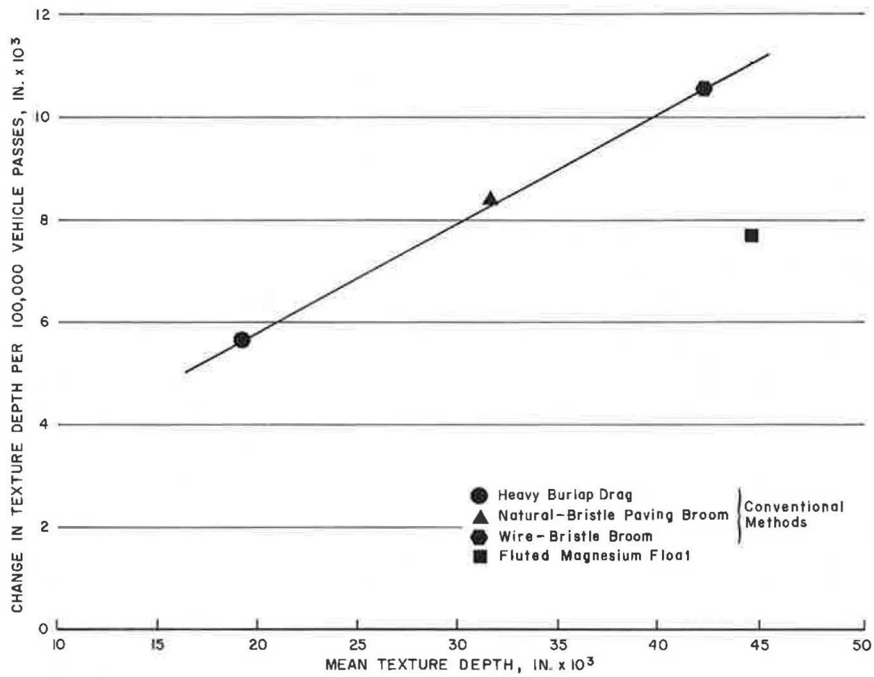


Figure 9. Hypothetical texture wear curve.

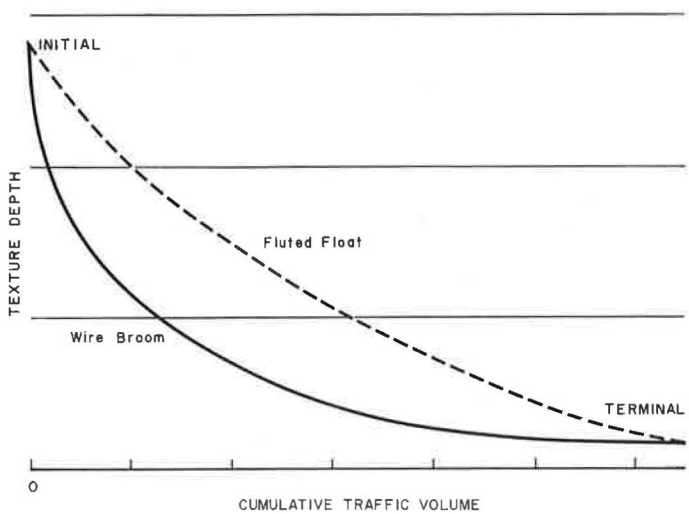


Table 8. Vehicle noise generated on study textures.

Texturing Method	Mean Texture Depth (in. x 10^3)	Sound Pressure Level[a] (dB)	
		At 50 mph	At 60 mph
Bristle broom	39	96.0	97.5
Wire broom	48	96.0	98.0
Fluted float	48	90.5	96.0

Note: Sound measured by using a sound level meter (Realistic Model No. 33-1028, operated in the "fast" response setting) with the 0 to 180 deg axis of the microphone perpendicular to the pavement edge.

[a]Reference 0.0002 μ bar.

1. As with uniformity, the early rate of wear appears to be a function of initial texture depth, at least for textures produced by the conventional methods; i.e., deeper textures wear faster. There may be two reasons for this. First, the deeper textures have higher "peaks" and "ridges," which are inherently more vulnerable to abrasion than are shallow textures because they carry higher unit loads than the pavement surface as a whole. Second, the rougher the texture is, the more vulnerable it may be to improper curing and abrasion. This would occur because of (a) the increased surface area and, therefore, thinner films for the same rate of membrane curing compound application; (b) the probable tendency for curing compounds to run off the "peaks" and collect in the "valleys"; and (c) the inaccessibility of certain surfaces to sprayed curing compounds.
2. In contrast to textures produced by the conventional methods, the relatively deep texture produced by the fluted float has an unexpectedly low rate of wear. This is probably because of the inherent abrasive resistance of its relatively smooth surface and the fact that it does not embody many of the features of more irregular surfaces that may inhibit proper curing.

It appears that the typical wear curve for any texture is one of decreasing negative slope (Fig. 6). Initially, the texture probably wears rapidly as the tips of the vulnerable peaks are abraded. With the passage of traffic, however, wear (decrease in texture depth) occurs at a progressively lower rate that corresponds to the increasingly larger surface available to carry tire loads. Textures produced by the fluted float method appear to have an advantage in this respect as well. Not only should the textures produced by the fluted float last longer because they are initially deeper than the textures produced by the other methods, but also they should wear at a more uniform rate and thus provide a greater average texture depth during their service life. The latter point is illustrated by Figure 9, which is a hypothetical wear curve for two textures having the same initial texture depth and life expectancy but different geometric configurations.

Sound Generation

Sound pressure level measurements were made of the passage of a 1968 Ford Fairlane passenger car, at cruising speed and with regular-tread tires, over three of the experimental textures at one of the sites. These measurements, summarized in Table 8, were made from a point 2 ft above ground and 2 ft outside the edge of pavement. No measures of spectral content of the sound were made. It appears from these limited observations that an increase in texture depth, within the range observed, is not associated with a significant increase in sound, as measured by sound pressure level. Also, for equivalent texture depths, the texture produced by the fluted float method may generate less sound than those produced by more conventional methods. No differences in sound pressure level were detectable from inside the automobile.

CONCLUSIONS

From the foregoing, the following specific conclusions can be drawn:

1. Textures produced by the different methods investigated varied significantly in both mean texture depth and initial skid resistance at speeds of 40 to 55 mph. Textures produced by the wire broom and fluted magnesium float methods were generally equivalent in mean texture depth and initial skid resistance and were superior to those produced by the natural-bristle broom and burlap drag methods.
2. Textures produced by the same method varied significantly from site to site in both mean texture depth and initial skid resistance.
3. Mean texture depth, as measured by the sand-patch method, correlated to a high degree with mean skid resistance for the variety of texturing methods studied both before and after exposure to traffic.
4. A high degree of correlation was also found between mean texture depth and the coefficient-speed gradient at speeds of 40 and 55 mph.
5. For the conventional texturing methods, uniformity of initial texture depth was found to vary inversely with mean texture depth. In contrast, the comparatively deep

texture produced by the fluted float method was nearly as uniform as that produced by the burlap drag method (the shallowest texture).

6. The amount of pavement texture remaining at any particular time varied considerably from site to site, depending primarily on cumulative traffic volume, initial texture depth, and wearing characteristics of the particular texture. With the 30 to 40 percent studded snow-tire use estimated for the experimental sites, the deepest textures were observed to last for less than 1 year under the heaviest traffic encountered and projected to last for 6 years under the lightest traffic.

7. The rate at which the textures produced at the same site by different methods were worn depended on initial texture depth and texturing method. Wear rate increased with increasing texture depth for the conventional texturing methods. In contrast, the texture produced by the unconventional fluted float method, which was one of the deepest, wore at a relatively moderate rate.

8. For equivalent texture depths, the texture produced by the fluted float method generated no more sound than did those produced by conventional methods.

SUMMARY

As a result of this work, fundamental and practical information has been obtained regarding the characteristics and performance of textures produced in concrete pavements by different methods. Because texture depth appears to be a reliable determinant of skid resistance, particularly at high speeds, it appears that the deeper the texture is, the safer the riding surface is. This, of course, must be consistent with considerations of tire wear, noise generation, and riding quality. Noise generation and riding quality do not seem to be problems within the range of texture depths now under consideration.

There appear to be some disadvantages in using deep textures, at least those produced by methods that might be considered conventional. It may be more difficult, for instance, to control the uniformity of deep textures. Of greater significance, though, is the tendency of deep textures to wear more rapidly during their early service life, which would rapidly nullify their initial advantage.

One possible route to producing an optimum texture is to design its geometry as other components of the highway are designed. Some possibilities are suggested by the performance of the texture produced by the fluted float method. This method not only provided deep textures with high skid resistance and low coefficient-speed gradients, but it also produced textures that were more uniform and that appeared to wear at a lower rate. The texture produced by this method rides well and may generate less noise than textures of equal mean depth that are placed by other methods. Further study of the parameters of texture geometry and how they relate to the characteristics of texture performance is suggested.

If, as is widely accepted, studded tires are responsible for accelerated pavement wear, many of the considerations discussed here are probably largely academic, at least in those regions of the country where studded tires have attained a substantial degree of public acceptance. The most compelling argument against the use of studded tires may not be rutting, hydroplaning, or the ultimate repair bill, but the drastic reduction of skid resistance that may be occurring on many new, high-speed, high-volume concrete highways as the result of accelerated wear of textures.

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APPENDIX

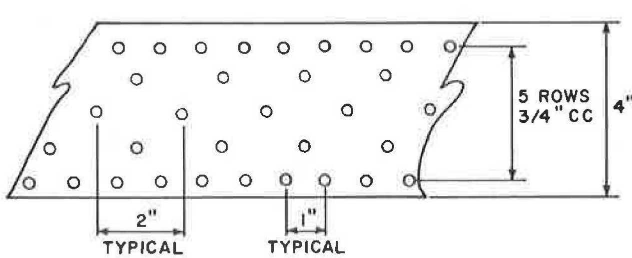
DETAILS OF EXPERIMENTAL TEXTURING DEVICES

Burlap Drag

The burlap drag consists of four layers of 10.4-oz burlap that are 5 ft long and 4 ft wide. The device is used in a damp state.

Natural-Bristle Broom

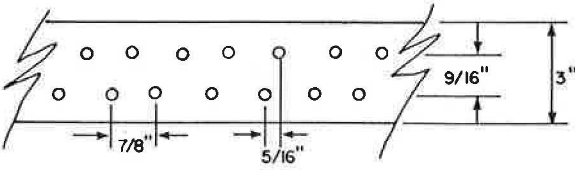
The natural-bristle broom has a 3.7-lb broom head consisting of a 16-in. long by 4-in. wide by 2-in. deep wooden block with 6-in. long, 100-bristle tufts in five rows on $^3/_4$-in. centers; individual bristles are $^1/_{32}$ to $^1/_8$ in. wide and approximately $^1/_{32}$ in. thick.



Wire-Bristle Broom

The wire-bristle broom has a 4.5-lb broom head consisting of a 28-in. long by 3-in. wide by 2-in. deep wooden block with 5-in. long, 10-bristle tufts in two rows on $^7/_8$-in.

centers; individual bristles consist of $^{1}/_{16}$- by $^{1}/_{100}$-in. steel tapes.



Fluted Magnesium Float

The fluted magnesium float has a 10.4-lb float head 40 in. long and $7^{1}/_{2}$ in. wide, which is fluted to produce a nominal pattern.