Skid Number and Speed Gradients on Highway Surfaces

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In the project from which this paper was derived, three major factors that influence the skid number (SN) and speed gradient (G) were studied: tire tread depth, water film, and pavement surface texture (1). However, only the effect of pavement surface is discussed here; the measurement of texture is not considered. The 31 sites that were included in the study are given in Table 1.

In the study, tread depths of 0.87 cm, 0.71 cm, 0.56 cm, 0.40 cm, 0.24 cm, and bald (11/32 in, 9/32 in, 7/32 in, 5/32 in, 3/32 in, and bald) and water film thicknesses of 0.04, 0.05, 0.08, and 0.10 cm (0.015, 0.020, 0.030, and 0.040 in) were tested at speeds of 48.3, 64.4, 80.5, 96.6, and 112.6 km/h (30, 40, 50, 60, and 70 mph). For each combination of test conditions, 5 skid resistance measurements were made at each site for each speed, which totaled more than 13 000 tests. The data reported here have been combined and averaged from all tread depths, excluding bald, and all water film thicknesses for each test speed. Detailed descriptions of the testing method and the procedures used in combining the data can be found elsewhere (1). However, I feel that the data show the same general trends that would be expected with treaded tires and the normal water output required by ASTM E 274-70 (2).

RESULTS

In the analysis of the test data, the pavements generally fit into three groups: steep gradients—0.50 G or greater, intermediate gradients—0.28 to 0.40 G, and flat gradients—0.20 G or less. The curves for the three groups are shown in Figure 1.

Five of the 31 sites provided G values of 0.50 or greater. They consisted of smooth concrete, a sand asphalt, and a well-worn S-5 bituminous concrete. Table 2 gives the average SNs for the various test speeds, the average G for each of these sites, and the total accumulated traffic.

Twenty of the 31 sites fit in the intermediate speed gradient group. Table 3 gives the summary data for these sites. The sites consisted of various aged S-5 bituminous concrete surfaces; a special urban bituminous mix (3); a surface treatment; and several types of portland cement concrete textures including single burlap-dragged, longitudinally tined, grooved, and bush-hammered textures (4).

Table 4 gives the summary data for the sites in the flat gradient group. These sites consisted of bituminous concrete surfaces, open-graded (popcorn mix) bituminous surfaces, and surface treatments.

Basically, the textures for the pavements represented by the three curves in Figure 1 are

1. Steep gradient, which is for surfaces with smooth macrotexture but gritty or smooth microtexture.
2. Intermediate gradient, which is for all of those surfaces with a good combined microtexture and macrotexture. In addition, some well-worn surfaces that would originally have been found in the steep gradient group fell into this group when they lost their microtexture. Also included are some well-worn surfaces that originally would have been in the flat gradient group. These two exceptions can usually be identified by a lower than expected SN_{40} value combined with knowledge concerning the accumulated traffic passes and the material from which the surface was fabricated.
3. Flat gradient, which is for surfaces with excellent microtexture and macrotexture.

The estimated slopes for the curves are as follows for various speed ranges (1 km/h = 0.621 mph):

Group	48 to 80 km/h	64 to 96 km/h	80 to 112 km/h	48 to 112 km/h
Steep	0.73	0.61	0.47	0.60
Intermediate	0.42	0.33	0.25	0.33
Flat	0.23	0.17	0.08	0.15

It should be noted that the gradient decreased as the test speed increased and that the gradient between 64.4 and 96.6 km/h (40 and 60 mph) was quite similar to the gradient between 48.3 and 112.6 km/h (60 and 70 mph). On

Publication of this paper sponsored by Committee on Surface Properties-Vehicle Interaction.

Table 1. Site information.

Site Number	Type of Surface	Year Placed	Lane	Accumulated Traffic (vehicles)
1	Portland cement concrete	1970	EBTL	4 028 870
2	Portland cement concrete	1970	WBPL	1 007 218
3	S-5 bituminous concrete[a]	1970	EBTL	4 028 870
4	S-5 bituminous concrete[a]	1970	WBPL	1 007 218
5	S-1 sand asphalt[a]	1968	N&SBTL	3 149 950
6	Portland cement concrete	1959	SBTL	17 212 962
7	Portland cement concrete	1959	SBPL	4 303 240
8	Mechanically chipped concrete	1974	SBTL	0
9	Mechanically chipped concrete	1974	SBPL	0
10	S-5 bituminous concrete[a]	1969	EBTL	4 411 755
11	S-5 bituminous concrete[a]	1969	WBTL	4 411 755
12	S-5 bituminous concrete[a]	1969	EBPL	1 102 939
13	S-5 bituminous concrete[a]	1969	WBPL	1 102 939
14	Bituminous urban mix[a]	1971	SBTL	3 255 800
15	Bituminous urban mix[a]	1971	SBPL	3 255 800
16	Popcorn bituminous mix	1973	NBTL	2 285 630
17	Popcorn bituminous mix	1973	SBPL	571 408
18	S-5 bituminous concrete[a]	1968	NBTL	9 187 050
19	S-5 bituminous concrete[a]	1968	SBPL	2 296 762
20	Portland cement concrete	1973	EBTL	2 106 780
21	Portland cement concrete	1973	EBTL	526 695
22	Portland cement concrete	1968	EBTL	13 430 175
23	Portland cement concrete	1968	EBPL	7 815 106
24	Grooved portland cement concrete	1968	EBTL	13 430 175
25	Grooved portland cement concrete	1968	EBPL	7 815 106
26	Surface treatment	1969	NBPL	534 542
27	Surface treatment	1969	SBTL	2 138 170
28	Surface treatment	1970	NBPL	449 680
29	Surface treatment	1970	SBTL	1 798 720
30	S-5 bituminous concrete[a]	1965	WBPL	2 342 388
31	S-5 bituminous concrete[a]	1965	EBTL	9 369 550

Note: EB = eastbound; WB = westbound; NB = northbound; SB = southbound; TL = through lane; and PL = passing lane.

[a]Specifications can be found in Road and Bridge Specifications (5).

the other hand, the gradient between 48.3 and 80.5 km/h (30 and 50 mph) bears little resemblance to that between 80.5 and 112.6 km/h (50 and 70 mph). Therefore, great care should be taken in selecting test speeds to establish gradients.

There is no question that the average G value decreased with increased macrotexture. Exceptions to this were the grooved concrete pavements on which the grooves or macrotexture provided ample water escape routes but no microharshness; therefore, the gradient was rather steep. This finding indicates that, in addition to a provision for the escape of water, a pronounced

Figure 1. Speed gradients for three groups of pavements.

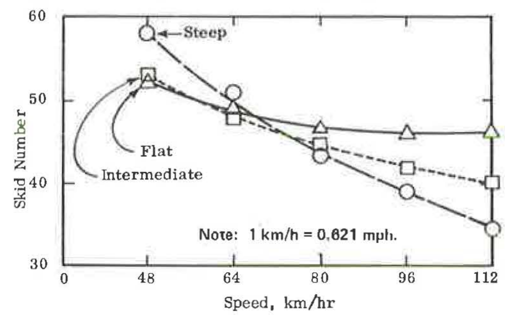

Table 2. Summary data for steep gradient group.

Site Number	Skid Number 48 km/h	64 km/h	80 km/h	96 km/h	112 km/h	Slope (SN/km/h)	Accumulated Traffic (millions of vehicle passes)
1	58	50	43	39	35	0.58	4.0
2	67	60	52	47	41	0.65	1.0
5	62	54	46	39	33	0.73	3.1
23	57	52	45	42	37	0.50	7.8
31	47	40	32	28	25	0.55	9.4
Average	58	51	43	39	34	0.60	

Note: 1 km/h = 0.621 mph.

Table 3. Summary data for intermediate gradient group.

Site Number	Skid Number 32 km/h	48 km/h	64 km/h	80 km/h	96 km/h	112 km/h	Slope (SN/km/h)	Accumulated Traffic (millions of vehicle passes)
3	–	54	45	45	51	39	0.38	4
4	–	56	53	49	47	44	0.28	1
6	–	37	32	29	25	23	0.35	17
7	–	47	42	37	33	31	0.40	4
8	–	42	37	33	31	30	0.30	0
9	–	50	45	41	37	36	0.35	0
10	–	53	49	45	42	40	0.33	4.3
11	–	52	49	45	44	42	0.25	4.3
14[a]	61	56	46	50	48	–	0.33	3.25
15[a]	65	59	55	51	49	–	0.40	3.25
18	–	53	50	46	42	39	0.35	9
19	–	56	53	50	46	44	0.30	2.5
20	–	60	58	56	53	48	0.30	2
21	–	72	66	63	59	57	0.38	2.5
22	–	50	44	39	36	38	0.30	13.5
24	–	49	48	43	41	39	0.25	13.5
25	–	56	52	49	45	40	0.40	7.7
27	–	42	38	35	33	31	0.28	2
29	–	45	41	37	36	34	0.28	1.75
30	–	55	48	47	41	41	0.35	2.3
Average		53	48	44	42	40	0.33	

Note: 1 km/h = 0.621 mph.

[a]Only 0.05-cm (0.020-in) film of water tested with speeds 32.2 to 96.6 km/h (20 to 60 mph).

Table 4. Summary data for flat gradient group.

Site Number	Skid Number 48 km/h	64 km/h	80 km/h	96 km/h	112 km/h	Slope (SN/km/h)	Accumulated Traffic (millions of vehicle passes)
12	53	50	48	46	46	0.18	1
13	53	50	47	46	48	0.18	1
16	50	50	48	47	45	0.13	2.3
17	50	47	46	46	46	0.10	0.5
26	51	48	46	42	43	0.23	0.5
28	53	49	48	47	46	0.18	0.5
Average	52	49	47	46	46	0.15	

Note: 1 km/h = 0.621 mph.

microtexture is needed to provide a flat gradient. By the same token, if an open-graded bituminous mix is manufactured with aggregate that is highly polish susceptible, it probably will develop a rather steep gradient in addition to becoming slippery.

The data, then, point to the following: High G values are common to pavements that do not have a relatively high degree of macrotexture. Although this fact merely substantiates previous research on the subject, if the surface has a sharp microtexture, as is the case for all locations except site 31 in the steep gradient group, its skid resistance can be excellent at all legal speeds with legal tread tires.

The highest skid numbers recorded in the study were at low speeds in the steep gradient group, which means that a low macrotexture and a high microtexture provide the best skid-resistance surface at low speeds [64.4 km/h (40 mph) and lower]. Cities and counties should take this into account when they are paving streets with low speed limits. On the other hand, the open-graded mixes, which provide flat gradients, provide a very desirable surface for high-speed traffic. Grooving does not improve the skid resistance or the G value for treaded tires. Thus, because grooving does not decrease the G value, I suggest that the mere provision for water escape does not guarantee that the pavement surface will have a flat gradient.

REFERENCES

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