PAVEMENT FRICTION NEEDS

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At 61 sites, skid trailer and stopping-distance tests were performed to establish a correlation between Virginia's skid trailer and the stopping-distance car. The regression analyses performed indicate that the trailer and the car are equivalent at a skid number of 30; however, as the pavement friction increases, the trailer gives progressively higher numbers than the car. We determined the relationship between accumulated traffic volumes and friction levels by conducting tests at 46 sites. It was found that (a) bituminous mixes manufactured from polish-resistant materials still had high skid resistance after 30 million vehicle passes, (b) portland cement concrete surfaces manufactured from silica sands had lost much of their skid resistance after 25 million passes, and (c) bituminous mixes manufactured from limestone approached a slippery condition after fewer than 2 million vehicle passes. We studied 521 sections, totaling 312.8 miles, on Virginia's Interstate System to determine the relationship between the percentage of wet pavement accidents and the predicted stopping-distance skid numbers. The sites were separated into four categories: open roadway, non-open roadway, open interchanges, and non-open interchanges. It was found that the minimum predicted stopping-distance skid number for the traffic and passing lanes of Interstate roadways with mean traffic speeds of 65 and 70 mph should be 42 and 48 respectively.

•THE PURPOSE of the investigation reported here was to provide the state of Virginia with information for determining the wet friction levels needed for various traffic conditions on its Interstate System (1). All pavement friction data for the analyses were obtained with the Virginia Highway Research Council's skid-test trailer (2).

Machine correlation and regression analyses were performed on the data obtained with the Council's skid trailer and stop meter stopping-distance car so that data collected by the skid trailer (reported as SN) could be used to predict the stopping-distance skid numbers that would have been obtained had the stopping-distance car (reported as PSDN) been used.

An analysis of the traffic volume-PSDN relationship was made for data obtained on roads constructed of three paving materials: portland cement concrete manufactured from silica sand, polish-susceptible bituminous mixes, and polish-resistant bituminous mixes.

In the compilation of the information for determining the wet friction values needed for various traffic conditions, prime consideration was given to ascertaining the relationship between the percentage of wet accidents and the PSDN. To the extent possible, the geometric configurations of the roadways were considered. Only data for the Interstate System were analyzed. The compiled wet-pavement accident data were not limited to skidding accident statistics, inasmuch as inadequate friction could promote accidents not involving skidding, e.g., breakway and non-locked-wheel deceleration accidents. In addition, it is sometimes impossible to determine from the accident reports whether skidding was a major contributing factor.

The greatest limitation of the study was the inability to collect rapidly, and in a usable form, the amount of roadway geometric and pavement surface descriptive data

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necessary to determine the wet friction levels needed for various traffic conditions. Of all the data needed, the skid data might be the easiest to collect; the difficulty is locating and reducing the supporting data into a form compatible with the skid data. In addition to the difficulty cited, the following problems are noted:

1. On roads carrying over 1,000 vehicles per day, Virginia generally does not permit the use of polish-susceptible aggregates. Thus the lower range of skid numbers is not included in this study. Although this is an admirable situation for a highway department to be in, it does reduce the effectiveness of this type of research.
2. As a general rule, Virginia does not have any really harsh textures on its high traffic volume roads. In the past, portland cement concrete roads have been finished with one coverage of a burlap drag, and the high traffic bituminous roads have all been hot plant mixes laid with a regular paving machine. In addition, the gradation has been such that for even the coarsest of the surface mixtures the finished surface has been rather smooth. Some intermediate mixes were included in the study. These mixes are coarser than surface mixes but not so coarse as base mixes, and they are usually used in a leveling course between the base and the surface course. However, they are found only on low traffic volume roads.

MACHINE CORRELATION AND REGRESSION ANALYSES

In the opinion of the authors, skid data are more meaningful if analyzed and reported as predicted stopping-distance skid numbers. For this reason, several regression analyses were performed with the trailer skid number as the independent variable and the car stop meter skid number as the dependent variable. (The data were obtained from correlation tests made at six times between April 1968 and May 1970.) Later these equations will be used to determine predicted car skid numbers. Each data point used in the various analyses is an average value of five tests for both the car and the trailer.

Tests with the skid trailer were conducted at various speeds at the 62 sites, and the stopping-distance car was used to obtain tests at 40 mph and in some cases at other speeds at 61 sites. The data are given in Table 1.

As mentioned the data were collected and regression analyses made in six different groups. Even though the results did change from group to group, there did not appear to be any orderly change with regard to time. Regression analyses from each group for the trailer at 40 mph and the car at 40 mph are shown in Figure 1 and given in Table 2. Because no noticeable effect of time could be established, the 40-mph analysis for all 62 sites was used for predicting the stopping-distance skid numbers. The curve for this analysis is shown in Figure 2.

It should be noted that the Virginia trailer and the car are equivalent at an SN of 30; however, contrary to what was expected, the trailer gives progressively higher numbers than the car as the pavement friction increases. It will be shown later that the correlation between many other trailers and the stopping-distance car is about 1:1.

RELATIONSHIP BETWEEN TRAFFIC VOLUME AND PSDN

Table 3 gives the relationship of accumulated traffic volume to stopping-distance number (both actual and predicted) at 40 mph for Virginia S-4 and S-5 mixes (Appendix) composed of nonpolishing aggregate, portland cement concrete composed of nonpolishing aggregate, and I-2 and I-3 mixes composed of 100 percent limestone.

For the determination of accumulated traffic volume by lane, a computer program was written in which the lane volume breakdown was based on information contained in the Highway Capacity Manual (3). In this program, trucks were considered to be 2.5 automobiles. The results of this analysis are shown in Figure 3. For the I-2 and I-3 mixes the accumulated volume is plotted versus actual SDNs (at 40 mph) rather than PSDNs.

As can be seen from Figure 3, the limestone mixes drop drastically and reach stopping-distance skid numbers in the low forties, with an accumulated volume of only 1.6 million. The S-4 and S-5 mixes still retain PSDNs in the mid to high forties and seem to level off after 25 to 30 million vehicle passes. The portland cement concrete mixes also level off but decrease more rapidly and reach values in the mid to low forties at 20 to 25 million vehicle passes.

Table 1. Skid numbers obtained with stopping-distance car and with skid trailer.

Site	Mix Type	Car Distances (ft) by Speed (mph) 20	30	40	50	Trailer Distances (ft) by Speed (mph) 20	30	40	50
1	I-2			46		67	62	56	50
2	I-3			42		66	58	54	51
3	I-2			46		68	62	52	50
4	I-3	40	42	36	32	50	48	41	36
5	I-3	48	46	46	44	66	60	51	46
6	I-2	54	54	55	53	78	68	60	57
7	Weblite		61	65	65		88	84	81
8	Weblite		64	61	61		84	73	72
9	Weblite		54	52	48		59	52	48
10	Weblite		52	45	44		69	60	55
11	Weblite		56	52	45		75	70	57
12	Weblite		57	54	51		78	66	66
13	I-2		42	42			54	52	
14	I-3		39	41			57	53	
15	I-2		47	46	45		58	54	48
16	Sprinkle								
	Weblite		62	58			82	70	
17	I-2								
	Sprinkle								
	Granite		52	51			72	60	
18	Sprinkle								
	Weblite		63	58			78	60	
19	Sprinkle								
	No. 8 slag		64	63			83	79	
20	Sprinkle								
	Slag sand		64	64			89	83	
21	Sprinkle								
	Fine weblite		63	64			89	78	
22	Sprinkle								
	No. 8 crushed								
	gravel		63	62			82	67	
23	I-3		47	44			56	50	
24	I-2		51	48			63	58	
25	I-3		34	34			44	36	
26	Weblite		56	52	40		75	70	48

Site	Mix Type	Car Distances (ft) by Speed (mph) 30	40	50	Trailer Distances (ft) by Speed (mph) 20	30	40	50	60
27	Weblite	64	59	58		88	80	78	
28	Weblite	59	55	52		80	73	68	
29	Weblite	51	45	40		67	57	48	
30	Weblite	69	67	66		96	93	92	
31	Concrete		59		80		64		52
32	Concrete		63		98		80		60
33	Concrete		54		82		66		54
34	Concrete		61		96		76		56
35	S-4		56		91		73		60
36	S-4		60		98		82		68
37	S-4		53		77		65		52
38	S-4		61		94		78		62
39	S-5		60		89		74		55
40	S-5		64		95		78		62
41	Concrete		40		71		58		49
42	Concrete		46		79		65		53
43	Concrete		51		85		71		60
44	S-4		55		85		71		62
45	S-4		57		86		76		65
46	Concrete		44		71		58		49
47	Concrete		52		79		65		53
48	Concrete		57		83		68		59
49	Concrete		48		71		60		50
50	Concrete		54		77		64		51
51	Concrete		55		82		66		55
52	S-4					70	64		
53	Concrete		53		82		68		60
54	Concrete		57		88		75		64
55	Concrete		48		74		61		49
56	Concrete		54		88		68		56
57	Concrete		41		64		49		41
58	Concrete		44		70		47		40
59	Concrete		48		76		61		52
60	Concrete		52		85		64		54
61	Concrete		40		67		48		37
62	Concrete		51		85		62		47

Figure 1. Stopping-distance car versus trailer regression curves.

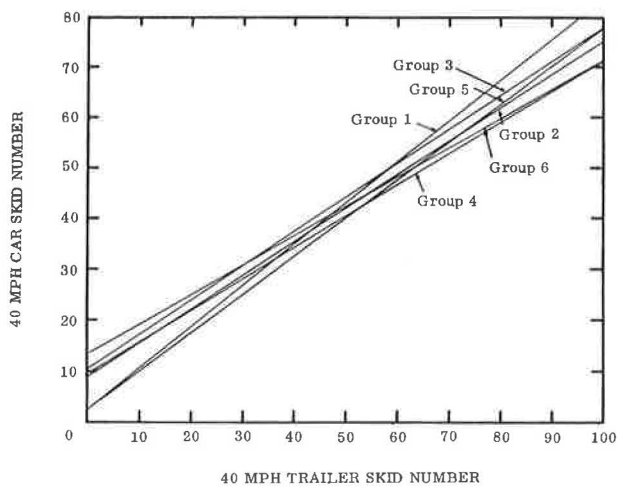


Table 2. Regression analyses by groups.

Group	Sites	Time Tested	Equation[a]	Sample Size	Correlation Coefficient	Standard Error
1	1 to 6	April to May 1968	$y = 0.81x + 2.7$	12	0.83	3.51
2	7 to 15	Aug. to Sept. 1968	$y = 0.66x + 9.1$	12	0.91	3.64
3	16 to 25	Sept. 1968	$y = 0.67x + 10.7$	16	0.94	3.57
4	26 to 30	May 1969	$y = 0.62x + 9.6$	5	0.99	0.52
5	31 to 51	March 1970	$y = 0.75x + 2.9$	25	0.85	3.29
6	52 to 62	April to May 1970	$y = 0.58x + 13.4$	15	0.96	1.55
1 to 4	1 to 30		$y = 0.63x + 11.6$	45	0.92	3.56
1 to 6	1 to 62		$y = 0.63x + 11.2$	112	0.92	3.01

[a] y is stopping distance number.

Figure 2. Regression curve for stopping-distance car versus trailer at 40 mph.

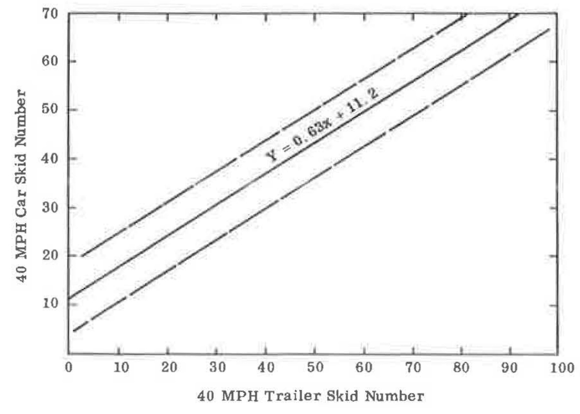
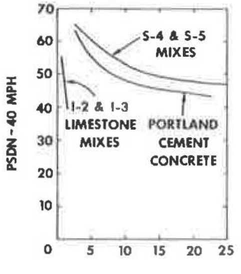


Table 3. Traffic volume versus stopping-distance number (at 40 mph).

	Portland Cement Concrete		S-4 and S-5 Mixes		I-2 and I-3 Mixes			Portland Cement Concrete		S-4 and S-5 Mixes	
Site	Accumulated Traffic (millions)	PSDN	Accumulated Traffic (millions)	PSDN	Accumulated Traffic (millions)	SDN	Site	Accumulated Traffic (millions)	PSDN	Accumulated Traffic (millions)	PSDN
1	10.9	52	12.7	50	1.12	46	26	8.6	48	0.6	65
2	2.2	61	2.5	57	1.57	42	27	21.9	42	2.6	61
3	12.4	48	13.9	49	0.74	46	28	8.6	50	0.5	64
4	2.5	63	2.9	57	0.86	46	29			3.4	65
5	14.7	48	14.0	50	0.59	55	30			0.7	68
6	2.9	65	3.0	57	1.12	42	31			0.8	65
7	15.5	48	28.4	46	1.57	41	32			0.3	65
8	3.1	63	12.4	52	0.74	46	33			2.6	65
9	24.6	45	6.2	63	0.86	44	34			0.6	67
10	9.0	50	1.2	67	0.59	48	35			2.6	65
11	24.3	42	5.2	65			36			0.6	70
12	8.8	45	0.9	67			37			1.8	66
13	24.5	43	30.2	47			38			0.4	67
14	8.9	47	14.5	52			39			1.8	65
15	24.1	43	28.4	46			40			0.4	68
16	8.6	50	12.4	51			41			1.8	65
17	21.4	44	3.2	59			42			0.4	67
18	8.1	53	0.6	63			43			2.2	65
19	21.8	42	3.1	59			44			0.5	72
20	8.5	50	0.6	62			45			2.8	65
21	21.8	42	3.2	59			46			0.6	70
22	8.5	49	0.6	65			47			2.8	65
23	21.9	44	5.2	60			48			0.6	69
24	8.6	49	0.6	63			49			3.4	65
25	21.9	42	3.3	59			50			6.7	70

Figure 3. Traffic volume versus PSDN.



RELATIONSHIP BETWEEN PERCENTAGE OF WET-PAVEMENT ACCIDENTS AND FRICTION

We studied 521 sections on Virginia's Interstate System, totaling 312.8 miles, to determine the relationship between the percentage of wet-pavement accidents and PSDNs. The sites were separated into 4 categories: open roadway (level and tangent areas not at interchanges), non-open roadway (vertical or horizontal curves or both not at interchanges), open interchanges (level and tangent areas at interchanges), and non-open interchanges (vertical or horizontal curves or both at interchanges). Initially, consideration was given to using more categories broken down in more detail, but because of the difficulty in classifying sites it was decided to use the broad ones outlined here. Classifying a site as open or non-open was very difficult. Geometric data were not readily available, so the authors drove over each site and classified it according to their combined judgment. Sight distance was considered of prime importance. Therefore, areas with gentle horizontal or vertical curves that afforded good sight distance were classified as open roadway.

Sites not at interchange areas generally were $\frac{1}{2}$ mile in length. Sites at interchange areas were usually longer, generally about 1 mile, and were determined by starting $\frac{1}{10}$ mile before the exit ramp and ending $\frac{1}{10}$ mile beyond the entrance ramp.

The percentage of wet-pavement accidents (the ratio of wet-pavement accidents to total accidents) was selected as the factor for analysis for two reasons. First, it was the only meaningful wet-accident figure easily obtainable, inasmuch as wet-accident rates were almost impossible to compute. Second, it was hoped that by selecting this factor the effect of traffic volume would be reduced. It is pointed out that one basic assumption was made in this analysis; namely, the amount of time the pavement was wet was considered to be essentially equal for all sections tested.

The possible effects of traffic volume were also taken into account by subdividing each classification into four lane-traffic volume groups: 0 to 3,999 average vehicles daily (AVD) per lane, 4,000 to 7,999 AVD per lane, 8,000 to 11,999 AVD per lane, and 12,000 to 15,999 AVD per lane.

Because there is no way of ensuring in which lane a car was driving at the initial stage of the wet accident, a weighted PSDN was obtained for each site. Trailer skid tests were taken at 40 mph in each lane (generally a site consisted of two passing and two traffic lanes), and averages were obtained for the traffic and passing lanes. A weighted trailer skid number was then usually obtained by summing 80 percent of the average skid number for the traffic lane and 20 percent of the average number for the passing lane. These factors were used because the normal traffic for the sites was 80 percent in the traffic lanes and 20 percent in the passing lanes. Other weighted factors based on traffic volume and number of lanes were used when appropriate. The general 40-mph regression equation discussed earlier was then used to predict the weighted 40-mph stopping-distance skid number for the site. Finally, because the passing lane is likely to demand more friction than the traffic lane due to passing maneuvers and to higher average speed, the relationships of percentage of wet accidents on all lanes and friction on the traffic lane only and the passing lane only were studied. It might also be economically feasible to maintain a higher friction value on passing lanes than on traffic lanes.

After weighted PSDNs were obtained for each site, the 1969 accident data were used to determine the percentage of wet accidents for each site. These data are given in Table 4. Figure 4 shows the data in a more summarized form, where percentage of wet accidents for the skid number groups 40 to 44, 45 to 49, 50 to 54, and 55 and above are plotted versus the average group skid number. It is pointed out that for sites at interchanges the accident data included only those accidents occurring on the main road.

Notice in Table 5 that, in effect, only three of the AVD groups were applicable for each classification because very few data fell in the highest group. Also, the ranges in skid data were not the same between traffic volume groups and skid number groups, obviously because the higher volume sites usually had more accumulated traffic and therefore lower skid numbers.

Two things are evident from the data given in Table 5 and shown in Figure 4. First, in most cases there was a definite negative slope, i.e., the percentage of wet accidents,

Table 4. Skid number versus percentage of wet accidents.

	0 to 3,999 AVD					4,000 to 7,999 AVD					8,000 to 11,999 AVD					12,000 to 15,999 AVD				
	Section		Accidents			Section		Accidents			Section		Accidents			Section		Accidents		
				Wet					Wet					Wet					Wet	
Weighted SN	No.	Miles	Total	No.	Percent	No.	Miles	Total	No.	Percent	No.	Miles	Total	No.	Percent	No.	Miles	Total	No.	Percent
Open Roadway																				
41											4	2.4	29	9	31					
42						5	2.6	39	20	51	5	2.5	9	0	0	4	1.9	8	1	12
43						16	8.5	48	14	29										
44	2	1.0	3	1	33	13	6.4	41	8	20	1	0.7	13	2	15	2	0.8	16	0	0
45						12	7.9	49	6	14	3	1.5	9	1	11					
46	4	2.0	4	1	25	20	11.1	102	10	10	3	1.3	8	0	0					
47	2	1.0	9	3	33	21	10.9	75	8	11	9	1.9	35	11	32					
48	3	1.3	5	1	20	11	5.4	40	4	10	8	3.8	44	6	13					
49	2	1.1	2	0	0	6	3.2	13	1	8										
50	11	6.0	15	3	20	4	1.8	6	2	33										
51	8	4.3	10	0	0															
52	6	3.0	4	1	25	5	3.7	42	9	21	9	2.0	35	3	8					
53	12	5.8	30	6	20															
57	27	15.0	19	0	0															
62	36	18.5	34	5	15															
63	35	20.4	36	2	6															
Non-Open Roadway																				
40											3	1.5	18	8	44					
41											12	6.6	96	42	44					
42						4	2.1	42	14	33										
43	1	0.4	2	0	0	1	0.5	1	0	0										
44						9	5.2	82	22	27	4	2.0	25	8	33	3	2.0	21	3	14
45						3	1.6	25	5	20	5	3.1	27	3	11					
46	1	0.5	1	0	0	7	3.8	67	19	28	6	3.5	56	9	16					
47	3	1.6	7	3	43	8	7.9	45	13	29	6	1.2	45	10	22					
48						4	2.3	10	4	40	2	1.3	18	0	0					
49						1	0.7	3	0	0										
50	4	2.2	14	3	21	2	1.2	4	0	0	3	1.5	26	3	12					
52	1	0.5	4	2	50															
53	2	1.1	7	2	29															
57	3	2.1	6	0	0															
62	3	2.0	3	1	33															
63	11	5.1	7	2	29															
Open Interchanges																				
41											2	1.1	47	21	45					
42						1	0.8	10	1	10	1	1.0	7	3	43					
43						3	2.3	22	2	9										
44											1	0.5	2	1	50					
45						2	1.3	17	1	6										
46						4	3.2	38	5	13										
47	1	0.6	9	1	11	6	4.9	51	8	16	2	1.6	32	5	16					
48	1	0.5	2	0	0	3	1.9	23	2	9										
49	2	1.5	16	5	31	1	0.4	3	1	33										
50	5	3.4	26	6	23	1	0.8	2	0	0	1	0.8	19	2	11					
51	2	1.3	19	5	26															
52	2	1.0	7	3	43	2	0.9	5	2	40	1	0.7	18	5	28					
57	6	4.0	7	0	0															
62	5	2.8	9	2	22															
63	6	4.6	15	6	40															
Non-Open Interchanges																				
41											1	0.7	11	6	54					
42																2	0.7	18	1	5
43						4	3.9	137	63	46										
44						5	6.1	158	47	30	1	1.1	28	7	25	1	0.8	20	6	30
45	1	0.7	12	6	50	2	1.6	19	4	21										
46						3	2.0	27	3	11	3	2.4	47	11	23	1	0.8	21	1	5
47						3	3.0	12	0	0	4	3.6	109	34	31					
48	2	1.6	29	9	31	3	2.4	28	8	29	1	1.0	9	3	33					
49	1	0.6	4	1	25	1	0.5	3	1	33	1	6.8	189	52	28					
51	1	1.0	3	0	0	1	0.8	12	2	17										
52	2	1.8	11	1	9						1	0.5	9	0	0					
57	5	3.3	15	6	40															
62	3	2.5	13	2	15															

Figure 4. Skid number versus percentage of wet accidents.

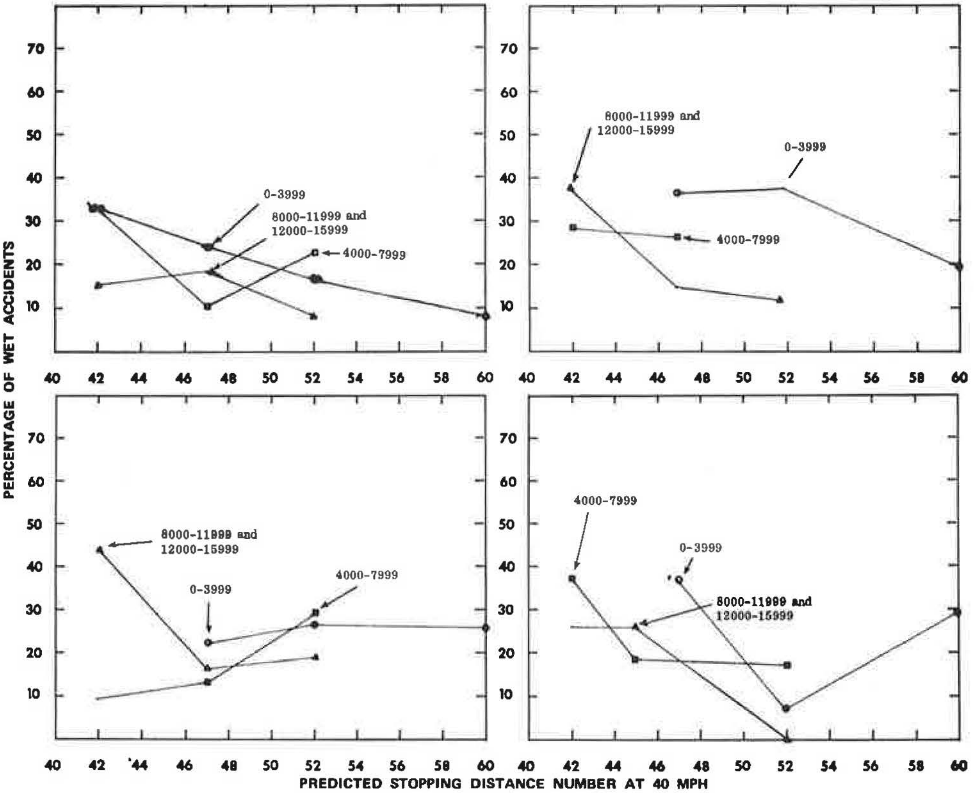


Table 5. Summary of skid number versus percentage of wet accidents.

	Open Roadway					Non-Open Roadway					Open Interchanges					Non-Open Interchanges				
			Accidents					Accidents					Accidents					Accidents		
	Section			Wet		Section			Wet		Section			Wet		Section			Wet	
Weighted SN	No.	Miles	Total	No.	Per-cent	No.	Miles	Total	No.	Per-cent	No.	Miles	Total	No.	Per-cent	No.	Miles	Total	No.	Per-cent
40						3	1.5	18	8	44										
41	4	2.4	29	9	31	12	6.6	96	42	44	2	1.1	47	21	45	1	0.7	11	6	54
42	14	7.0	56	21	38	4	2.1	42	14	33	2	1.8	17	4	24	2	0.7	18	1	5
43	16	8.5	48	14	29	2	0.9	1	0	0	3	2.3	22	2	9	4	3.9	137	63	46
44	18	8.9	73	27	37	16	9.4	128	33	26	1	0.5	2	1	50	7	8.0	206	60	29
45	15	9.9	58	7	12	8	4.7	52	8	15	2	1.3	17	1	6	3	2.3	31	10	32
46	27	14.4	114	11	10	14	7.8	124	28	23	4	3.2	38	5	13	7	5.2	95	15	16
47	27	13.3	114	22	18	13	10.7	97	26	27	9	7.1	92	14	15	7	6.6	121	34	28
48	22	8.5	89	11	12	6	3.6	18	4	22	4	2.4	25	2	8	6	5.0	66	20	30
49	8	4.3	15	1	7	1	0.7	3	0	0	3	1.9	19	6	32	3	7.9	196	54	28
50	15	7.8	21	5	24	9	4.9	44	6	14	7	5.0	47	8	17					
51	8	4.3	10	0	0	1	0.5	4	2	50	2	1.3	19	5	26	2	1.8	15	2	13
52	15	8.7	81	13	16	2	1.1	7	2	29	5	2.6	30	10	33	3	2.3	20	1	5
53	12	5.8	30	6	20															
57	27	15.0	19	0	0	3	2.1	6	0	0	6	4.0	7	0	0	5	3.3	15	6	40
62	36	18.5	34	5	15	3	2.0	3	1	33	5	2.8	9	2	22	3	2.5	13	2	15
63	35	20.4	36	2	6	11	5.1	7	2	29	6	4.6	15	6	40					

decreased as the PSDN increased. Second, if volume were a factor, it appears that on the average the percentage of wet accidents was lower with increased volumes. In many cases the data are erratic, probably because of the small number of accidents the percentages were based on. The authors feel that certainly at least 50, and preferably 100 or more, total accidents per skid number group (e.g., 40 to 44) would be necessary to provide fairly accurate results. It is obvious in Table 5 that many skid number groups have less than 50 total accidents. However, the consistency of the negative slope and the smaller percentage of wet accidents with the higher volume for each of the classifications indicate that these are defensible results.

The decrease in percentage of wet accidents with an increase in the PSDN was, of course, expected. However, the lower percentage of wet accidents associated with the higher volumes of traffic was not expected. This finding perhaps can be explained by the fact that the roads with the lowest traffic volumes had less traffic than they were designed for; thus drivers could make errors without becoming involved in accidents. This, of course, would hold the total number of accidents to a minimum, which in turn might make the wet to dry ratio high, even with a few wet accidents.

The data in each AVD group for each site category were combined so that a better estimate could be made of the shape and location of the percentage of wet accidents versus PSDN curve (Table 5 and Fig. 5). The curves shown in Figure 5 were developed by starting at the lowest PSDN for each category and adding PSDNs until at least 50 total accidents were available. This percentage of wet accidents was then plotted versus the average PSDN of the group from which the percentage was computed. It was felt that the possible effect of volume on percentage of wet accidents shown previously should not prevent the combining of data in the manner described, inasmuch as the vast majority of data fell in the two middle volume groups.

The following conclusions can be drawn from data in Figure 5:

1. There is very little difference in the shapes and locations of the four curves. There does, however, seem to be some tendency for the curves to move up and to the right with the complexity of the roadway situation; i.e., the percentage of wet accidents is usually at least slightly lower at any given PSDN for the open roadway condition than for the other conditions. The order of complexity in this case would be open roadway, non-open roadway and open interchange about equal, and then non-open interchange.
2. The breaking point for all four curves, i.e., the point with the greatest change in slope, appears to be at about a PSDN of 45. Again the curve seems to increase slightly with the complexity as mentioned in number 1. This point at which the greatest change in slope occurs should be selected as a guideline for a minimum PSDN.

Obviously, these results are averages, and to apply them to a particular existing roadway situation as a general remedy for areas having a high percentage of wet accidents would not always be appropriate without considering factors such as the total wet-accident history. However, it is felt that the results could be used in the development of general design guidelines for the PSDNs needed on new construction. Also, they could be incorporated in a general policy regarding resurfacing or other corrective action when a site has a PSDN lower than the guideline and a history of a high percentage of wet accidents, particularly if it is an accident-prone location in terms of the total number of accidents or the accident rate.

When these findings are used as guidelines, it should be remembered that the PSDNs shown are weighted. Actually, in a guideline for design or maintenance of a skid-resistant pavement, actual traffic lane and passing lane skid numbers would be of prime importance. Therefore, Figure 6 shows the actual wet accident-skid number curves for the traffic and passing lanes for all locations where there were only two lanes in one direction. The breaking point is a PSDN of 48 for the traffic lane and a PSDN of 42 for the passing lane. Because the passing lane would experience more acceleration during passing maneuvers, it is logical that the friction demand would be higher.

It is obvious that additional work is needed with more definitive geometric data describing each site. It is felt by the authors that one possible reason that the curves did not differ more was the very general way in which the site categories were derived.

Figure 5. Summary of skid numbers versus percentage of wet accidents for all four site categories.

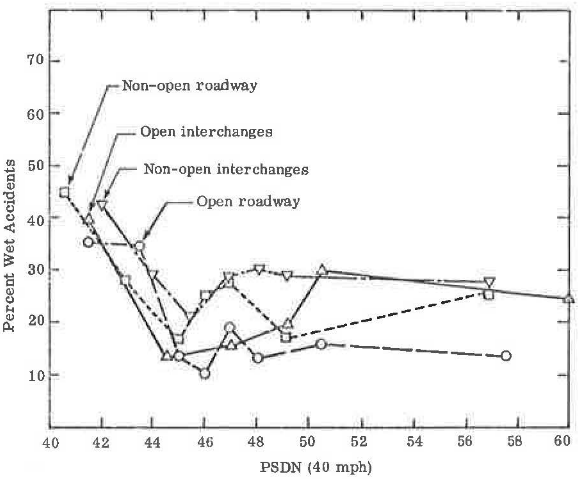


Figure 6. Traffic lane and passing lane PSDNs versus percentage of wet accidents.

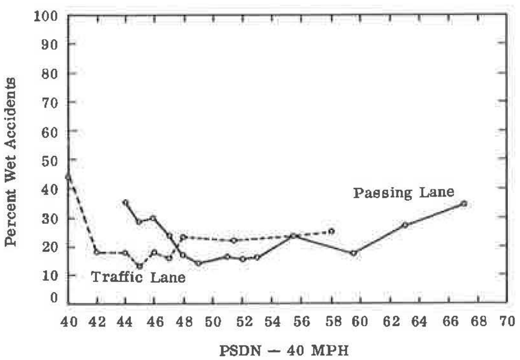
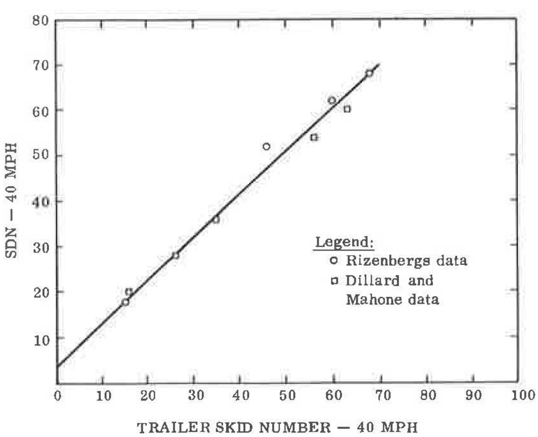


Figure 7. Relationship between stopping-distance skid number and trailer skid number.



A comparison of the 42 PSDN (40 mph) found in this study with the recommended minimum interim stopping-distance skid number requirements reported by Kummer and Meyer (4, Table 19) seems to indicate a discrepancy. However, it should be noted that the 42 PSDN applies to the Virginia Interstate System, which is designed for a 70-mph traffic speed. Also, unpublished data available from other researchers at the Virginia Highway Research Council indicate average speeds on many of the sites included in the study to be between 65 and 70 mph. Therefore, based on the mean traffic speed, the stopping-distance number proposed by Kummer and Meyer would be about 55 to 57 or 13 to 15 numbers higher than the number established in this study.

The authors feel that part of this apparent discrepancy is due to the relationship between the trailer and stopping-distance methods used by Kummer and Meyer to obtain the stopping-distance numbers. The relationship they used was based on research results obtained in a study by Dillard and Allen (5) in 1958, and none of the trailers used in that study is still in service.

Correlation studies undertaken since 1965 indicate a somewhat different relationship. Data taken from a report by Dillard and Mahone (6, Fig. 17) and from a report by Rizenbergs (7, Fig. 8) are shown in Figure 7. These data indicate an approximate 1:1 relationship.

Based on Kummer and Meyer's recommended skid trailer values and the correlation shown in Figure 7, the minimum stopping-distance number required for a mean speed of 70 mph would be 47 instead of 57. This, of course, would bring the findings of this study into closer agreement with those of Kummer and Meyer, particularly with regard to the passing lane, which as shown in Figure 6 is 48, as well as with the recent guidelines set forth by the U.S. Department of Transportation (8).

This value of 42 is also in disagreement with the findings of McCullough and Hankins (9), which indicate an SN of 40 (at 20 mph) and an SN of 30 (at 50 mph) to be desirable. The SN (40 mph) by extrapolation would be about 35, which is much lower than the 42 indicated earlier as desirable. Of course, there is no way of knowing how the skid trailer used by McCullough and Hankins might relate to those used in the Tappahannock (6) and Florida (7) correlation studies. This uncertainty is one reason that the authors feel it is very important to develop regression equations for individual skid trailer skid numbers versus stopping-distance skid numbers, particularly because data from the Florida correlation study indicate that the variability between skid numbers obtained by several stopping-distance cars was much less than that obtained by the trailers.

CONCLUSIONS

1. The regression analyses performed on the stopping-distance car data and the trailer data indicate a relationship of 1:1 at an SN of 30; however, as the pavement friction increases, the trailer gives progressively higher numbers than the car. The Tappahannock and Florida correlation studies indicate that there is an approximate 1:1 relationship between the SN for many skid trailers and the SDN for the extent of the correlation curve.

2. The accumulated traffic-PSDN relationships indicate that nonpolishing S-4 and S-5 mixes retain an average PSDN of 48 after 25 to 30 million vehicle passes. Nonpolishing portland cement concrete mixes lose resistance more rapidly than do nonpolishing S-4 and S-5 mixes, and on the average portland cement concrete mixes have a PSDN of about 44 after 20 to 25 million vehicle passes. The PSDNs for I-2 and I-3 limestone mixes decrease more rapidly than those for the S-4, S-5, and portland cement mixes and reach an average of 42 after 1.6 million vehicle passes.

3. Based on the analysis of percentage of wet accidents versus PSDN, it appears that a minimum traffic lane PSDN of 42 and a passing lane PSDN of 48 are desirable for Interstate roads with a mean traffic speed of about 65 to 70 mph. It can be demonstrated that the passing lane values are in agreement with those recommended by Kummer and Meyer, assuming that a different relationship exists between skid trailers and the stopping-distance method that they used.

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APPENDIX

BITUMINOUS CONCRETE MIXTURES

Type	Percentage by Weight Passing Square Mesh Sieves*										Percent Bituminous Materials	Mix Temperature (At Plant)
	1½	1	¾	½	⅜	No. 4	No. 8	No. 30	No. 50	No. 200		
S-1						100	95-100	50-95	25-65	0-8	8.5-10.5	225-300°F
S-2					100	95-100	60-85	20-40	10-30	2-10	9.5-12.0	225-300°F
S-3					100	90-100	70-95	25-55	15-35	2-12	6.5-10.5	200-240°F
S-4				100	90-100		60-80	25-45	10-30	2-10	5.5- 9.5	225-300°F
S-5 / I-3				100	80-100		35-55	15-30	7-22	2-10	5.0- 8.5	225-300°F
I-1		100	90-100		85-100	75-100	60-95	25-60	12-35	2-12	5.0- 7.5	225-300°F
I-2		100	95-100		60-80	40-60	25-45		5-14	1-7	4.5- 8.0	225-300°F

*In inches except where otherwise indicated. Numbered Sieves are those of the U. S. Standard Sieve Series.