EFFECT OF STUDDED TIRES ON VARIOUS PAVEMENTS AND SURFACES

Milan Krukar and John C. Cook, Washington State University

This paper presents results obtained from testing at the G. A. Riedesel Pavement Testing Facility at Washington State University during the period from February 11 to May 4, 1972. The purpose of this project was fourfold: to determine pavement wear caused by studded tires, to evaluate the resistance of different pavement materials and textures used in the states of Washington and Idaho to wear caused by tire studs, to test pavement materials and overlays to reduce tire stud damage, and to study the effect of studded truck tires on pavements. The findings indicate that some pavement materials are more resistant to the effect of studded tires than are others. Different types of studs reduced wear of various pavement materials. All types of studded tires tested caused some pavement wear, and this affected the skid resistance values.

•THIS study of the effect of studded tires was divided into three phases. During phase 1, various pavement materials and surface textures were evaluated in 1971-72. Phase 2 consisted of evaluating various pavement overlays during 1972-73. In phase 3, the results were evaluated and compared with actual highway conditions. This paper is concerned only with phase 1.

DESCRIPTION OF TEST

Ring 5 consisted of three concentric tracks on which 16 tires traveled in eight wheelpaths. The tracks were divided into six sections 43 ft in length and were then further subdivided. The center track had 12 different portland cement concrete surface textures, and the inside and outside tracks were constructed of asphalt concrete and some steel fibrous and polymer concrete sections. A total of 46 sections were tested; there were 20, 12, and 14 sections in the outside, center, and inside rings respectively as shown in Figure 1.

The G. A. Riedesel pavement testing apparatus, which consists of three arms each with dual tires supporting a water tank, was modified so that two sets of passenger tires could be mounted inside the truck duals on the inside track. Two passenger tires were hung on each of the two arms so as to travel on the outside ring in four separate wheelpaths. A total of 16 tires were mounted on the apparatus; each passenger tire carried a 1,000-lb load at 28-psi inflation, and each truck tire carried a 4,000-lb load at 80-psi inflation.

Three of six truck tires, size 11 × 22.5, were studded with 240 type 3 studs. These were the driving tires in wheelpath 6. The outside truck tires, in wheelpath 5, were unstudded and freewheeling. The 10 passenger-car tires were all G78 × 14 with winter snow tread; four were unstudded (wheelpath 8) and four had 112 type 1 studs (wheelpath 7). On the outside track, four passenger-car tires were used on four different wheelpaths. The unstudded, the type 1, the type 2, and the type 3 studded tires were in wheelpaths 1, 2, 3, and 4 respectively.

Types of tire studs are identified by number in the following manner: Type 1 has a controlled protrusion, type 2 has a composite core with small tungsten carbide chips in a soft binding matrix, and type 3 has the conventional solid tungsten carbide pin encased in a steel jacket. There is also the unstudded passenger tire.

Transverse profile measurements were made with the WSU profilometer, the camera box shadow-wire technique, and a straightedge. Temperature measurements of the pavements were taken with iron-constantan thermocouples and were automatically recorded. Skid resistance measurements were made with the California skid tester. Stud protrusion and tread depth measurements were taken at regular intervals.

SUMMARY OF RESULTS

Following is a summary of the study results.

1. Results of tests and comparisons of materials among the three tracks should be made with care and judgment. There were enough differences in the tests that, in some cases, direct comparisons cannot be made. The center track had truck tires, whereas the inside and outside tracks had passenger tires. Each of the tracks had different amounts of wheel passes. Wheelpaths 1 through 4 of the outside track had 542,357 passenger-tire wheel passes; wheelpaths 5 and 6 had 1,627,071 truck-tire wheel passes on the center track. Wheelpath 6 had 1,396,935 studded truck-tire passes and 230,136 unstudded truck-tire passes; wheelpaths 7 and 8 had 1,627,071 passenger-tire passes. Also, the effect of speed with the inside wheels traveling at slightly lower speeds than the outside wheels could have affected the rate of wear.
2. All studded tires caused measurable wear on all surfaces of the test track. Comparative wear ratios, which were calculated only for the outside track (Table 1), show that the type 2 stud caused less wear than either the type 1 or type 3 stud in that order. Pavement surface wear caused by unstudded tires was essentially unmeasurable. It is interesting to note that, even though the type 1 stud did not reach the desired pin protrusion because of the low test speeds, pavement wear was still considerably reduced.
3. The portland cement concrete pavements showed more resistance to studded-tire wear than did the asphalt concrete pavements (Table 1 and Fig. 2). The skid resistance values were considerably lower for the portland cement concrete pavements than for the asphalt concrete pavements (Table 2).
4. Of the asphalt concrete pavements, the class B asphalt concrete sections (100 percent passing the ⅝-in. sieve) showed the most initial resistance to wear by studded tires, followed by the class G (100 percent passing the ½-in. sieve), and then the class E asphalt concrete (100 percent passing the 1¼-in. sieve). The class E asphalt concrete with respect to maximum rut depth and area removed at the end of test was slightly superior to the class G asphalt concrete (Fig. 1).
5. Tests were made on the steel fibrous concrete overlays (Wirand concrete) to study different types of mix designs with respect to their wear resistance to studded tires. The Wirand concrete with ⅜-in. aggregate (section 0-2aC) proved to be the most resistant to wear from studs and to be equal to the ¼-in. polymer concrete overlay in section 0-2bB and regular portland cement concrete. All the steel fibrous concrete sections showed superior skid resistance values as wear progressed (Table 2). Under WSU test conditions, the steel fibers in the studded-tire wheelpaths had a tendency to become dislodged and spread over the track and protrude somewhat out of the pavement.
6. The gilsonite product rejuvenating treatment on two of the asphalt pavements showed little or no improvement over the regular asphalt concrete sections (Table 1). An initial reduction in skid resistance was observed. Final skid resistance was comparable to other types of asphalts (Table 2).
7. The surface materials tested showing the greatest resistance to studded-tire wear were the different types of polymer overlay: the polymer cement and polymer flyash concretes (Table 1 and Fig. 1). These materials showed good resistance to all tire studs. However, their skid resistance values decreased drastically with wear (Table 2).
8. Different surface textures, formed while the portland cement concrete was plastic, showed no great advantage for wear resistance. The reason is that the textures probably consisted of sand-cement mortar that was deficient in coarser aggregate and thus had relatively little strength to resist the tire studs.

Figure 1. Plan view of testing apparatus and pavement sections.

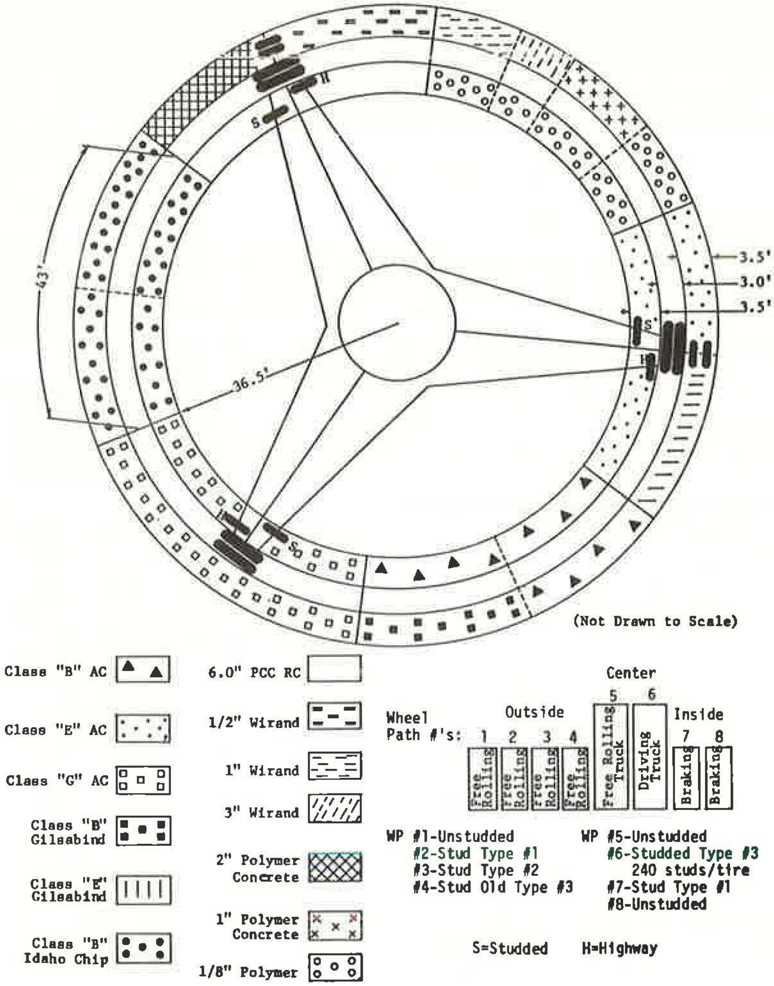


Table 1. Comparative pavement wear (passenger-car tires and outside track only).

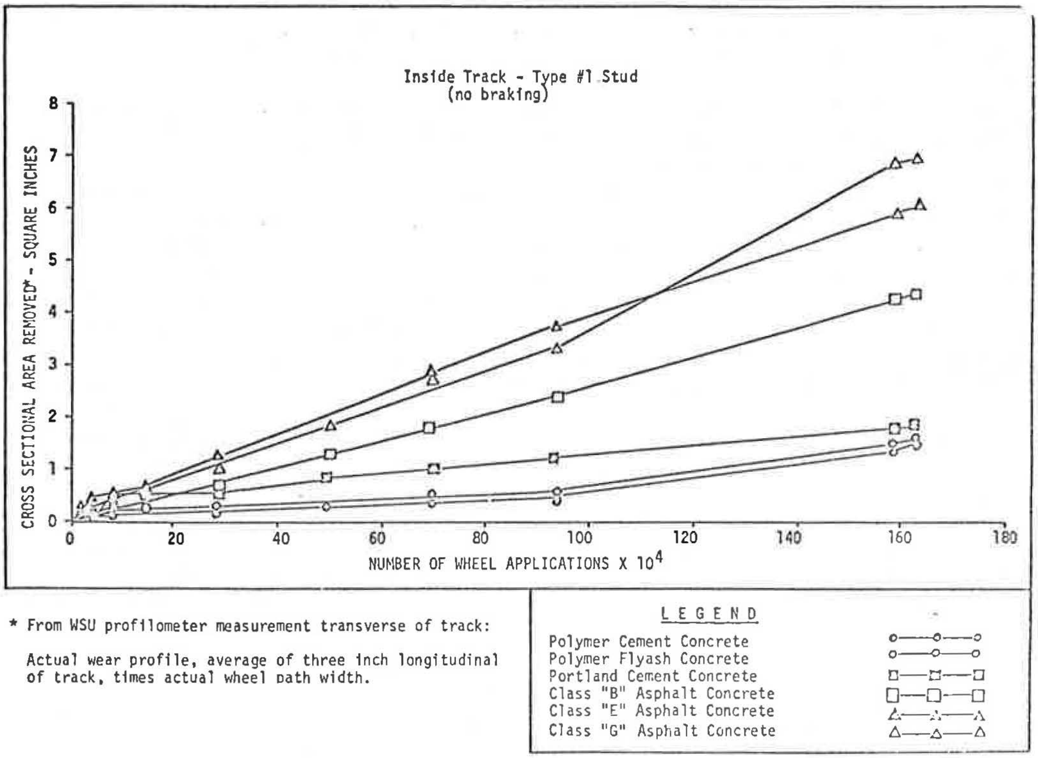
Sec-tion	Pavement	Wheelpath 1, No Studs		Wheelpath 2, Type 1 Stud		Wheelpath 3, Type 2 Stud		Wheelpath 4, Type 3 Stud	
		Percentage of Wear[a]	Wear Ratio[b]	Percentage of Wear	Wear Ratio	Percentage of Wear	Wear Ratio	Percentage of Wear	Wear Ratio
0-1bA	½-in. Wirand concrete	6.1	16.4	83.6	1.2	47.8	2.1	100	1
0-1bB	½-in. Wirand concrete	0.7	142.9	78.3	1.3	34.8	2.9	100	1
0-1bC	½-in. Wirand concrete	2.4	41.7	117.6	0.8	41.2	2.4	100	1
0-1bD	½-in. Wirand concrete	11.0	9.1	95.2	1.0	47.6	2.1	100	1
0-2aA	1-in. Wirand concrete	3.0	33.3	109.0	0.9	40.9	2.4	100	1
0-2aB	1-in. Wirand concrete	3.1	32.4	75.0	1.3	33.3	3.0	100	1
0-2aC	3-in. Wirand concrete	1.7	60.0	122.2	0.8	77.8	1.3	100	1
0-2bA	1-in. polymer concrete[c]	0.75	133.3	183.3	0.6	80.0	1.2	100	1
0-2bB	¼-in. polymer concrete	0.83	120.5	75.0	1.3	108.3	0.9	100	1
0-3a	Class E asphalt concrete	10.4	9.7	82.1	1.2	50.0	2.0	100	1
0-3b	Class E asphalt concrete, Gilsabind	2.1	47.1	71.9	1.4	46.9	2.1	100	1
0-4a	Class B asphalt concrete	4.5	22.3	96.6	1.0	41.4	2.4	100	1
0-4b	Class B asphalt concrete, Gilsabind	4.7	21.4	96.7	1.0	43.3	2.3	100	1
0-5a	Class G asphalt concrete	6.7	15.0	73.3	1.4	46.7	2.1	100	1
0-5b	Class G asphalt concrete	2.4	40.8	76.3	1.3	39.5	2.5	100	1
0-6a	Idaho chip seal	—	—	—	—	—	—	100	1
0-6b	Idaho chip seal	19.5	5.1	30.0	3.3	55.0	1.8	100	1

[a] Percentage of wear = type Y stud average wear/type 3 stud average wear x 100 percent.

[b] Wear ratio = 100/percentage of wear.

[c] Some of the wear was due to poor bond.

Figure 2. Comparison of area removed with type of material.



* From WSU profilometer measurement transverse of track:

Actual wear profile, average of three inch longitudinal of track, times actual wheel path width.

Table 2. Comparison of percentage of reduction in skid resistance values.

Section	Pavement	All Passes[a]	Unstudded Wheelpaths 1 and 8	Percentage of Reduction	Wheelpath 1, Studs 2 and 7	Percentage of Reduction	Wheelpath 2, Stud 3	Percentage of Reduction	Wheelpath 3, Stud 4	Percentage of Reduction
I-1a	Portland cement concrete	47	34	28	27	43	—	—	—	—
I-1b	Portland cement concrete	47	38	19	27	43	—	—	—	—
0-1bA	½-in. Wirand concrete	45	21	53	37	18	31	31	28	38
0-1bB	½-in. Wirand concrete	43	17	60	38	12	27	37	30	30
0-1bC	½-in. Wirand concrete	43	14	67	30	30	24	44	23	47
0-1bD	½-in. Wirand concrete	45	18	60	28	38	30	33	33	27
0-2aA	1-in. Wirand concrete	44	22	50	31	30	25	43	33	25
0-2aB	1-in. Wirand concrete	46	23	50	34	26	30	35	30	35
0-2aC	3-in. Wirand concrete	46	25	46	30	35	25	46	27	41
I-2aA	⅛-in. polymer cement	41	30	27	16	61	—	—	—	—
I-2aB	⅛-in. polymer flyash	25	22	12	14	44	—	—	—	—
I-2bA	⅛-in. polymer flyash	23	29	+26	13	43	—	—	—	—
I-2bB	⅛-in. polymer cement	25	26	4	14	44	—	—	—	—
0-2bA	1-in. polymer concrete	40	24	40	18	55	24	40	16	60
0-2bB	¼-in. polymer concrete	38	27	29	17	55	16	58	18	53
I-3a	Class E asphalt concrete	36	31	14	25	31	—	—	—	—
I-3b	Class E asphalt concrete	43	37	14	27	37	—	—	—	—
0-3a	Class E asphalt concrete	42	26	38	32	24	28	33	31	26
0-3b	Class E asphalt concrete, Gilsabind	35	23	34	35	0	24	31	33	6
I-4a	Class B asphalt concrete	39	32	18	25	36	—	—	—	—
I-4b	Class B asphalt concrete	45	31	31	25	44	—	—	—	—
0-4a	Class B asphalt concrete	40	24	40	28	30	22	45	29	28
0-4b	Class B asphalt concrete, Gilsabind	26	30	+15	39	+50	30	+15	26	0
I-5a	Class G asphalt concrete	34	30	12	32	6	—	—	—	—
I-5b	Class G asphalt concrete	44	37	16	26	41	—	—	—	—
0-5a	Class G asphalt concrete	40	31	23	40	0	32	20	43	+8
0-5b	Class G asphalt concrete	38	30	21	36	5	33	13	33	13

[a] Taken from the entire section.

[b] Minus values except where noted.

9. The initial rate of wear was in most cases higher than the medium, final, and average rates for almost all test pavements. This indicates that there would be high initial wear that would decrease as stud protrusions and tires wear down. In the real world, one might expect high wear rates at the beginning of winter when tires and studs are new.

10. Skid resistance values dropped with wear caused by the studded tires (Table 2). The portland cement concrete value reduction was particularly noticeable and showed a polishing effect in the worn wheelpaths.

11. The effect of studded truck tires was a high initial wear rate that slowed noticeably. This was due to the fact that, as the studded driving truck tires wore a groove, the weight of the truss shifted to the freewheeling truck tires. Hence, the wear rates are not indicative of those found elsewhere for studded truck tires.

12. The wear rates and some results compared favorably with those obtained at the American Oil Company tests, but they seem to be low for those obtained from field highway data. This may be because of the conditions of tests.

13. Comparison of wheelpath measurements with different methods and procedures shows that the results were quite comparable.

14. Poor construction weather affected some results—especially the 2.0-in. thick polymer concrete, where epoxy replaced the cement in a regular portland concrete mix. Low temperatures resulted in poor bonding of the aggregate, which quickly came loose with wheel passes. Therefore, the data on this material are excluded from this report.

15. The Idaho chip seal sections were also placed under extremely poor weather conditions with the result that the chips did not adhere to the rubberized asphalt. In areas where the chips were retained, the pavement showed good resistance to tire studs. However, data are sparse and included whenever they were available (Table 1).

ACKNOWLEDGMENTS

This project was initiated by the Transportation Systems Section of the College of Engineering Research Division, Washington State University, and is financed by the Washington Department of Highways, Idaho Department of Highways, and Federal Highway Administration.

REFERENCES

1. Krukar, M., and Cook, J. C. The Effect of Studded Tires on Different Pavement and Surface Textures. Transportation Systems Section Publication H-36, Washington State Univ., July 1972.
2. Krukar, M., and Cook, J. C. Studded Tire Pavement Wear Reduction and Repair. Transportation Systems Section Publication H-39, Washington State Univ., Dec. 30, 1972.