Some Tests of Studded Tires in Illinois

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•EXTENSIVE testing in Europe and in this country has shown that pneumatic tires equipped with tungsten carbide studs embedded in the treads produce traction on icy and hard-packed snow surfaces that is much superior to the traction produced by standard tires.

Studded tires have been widely accepted in Europe where they were introduced a few years ago, and similar acceptance can probably be anticipated in this country now that principal tire manufacturers are introducing the tires here.

It is generally acknowledged that studded tires have an abrasive effect on pavement surfaces; however, there is considerable difference of opinion and little factual information on the severity of the abrasive action likely to take place.

Laws enacted many years ago in a number of states, including Illinois, apparently make the use of studded tires illegal. These laws, although not intentionally directed against the use of studded tires at the time of enactment, were put into effect to protect pavement surfaces against excessive wear.

Because of the proven safety features of studded tires on ice and packed snow, consideration must be given to permitting their use. However, the benefits to be derived from the use of studded tires must be weighed against the expense that may be incurred if they cause excessive damage to pavement surfaces. Other possible disadvantages must also be examined in their appraisal.

Unlike tire chains, studded tires are likely to be used continuously during the entire winter season, on dry pavement as well as on ice and packed snow. Therefore, damage to dry pavement surfaces through repetitive passages of tires equipped with metal studs becomes an important factor.

To obtain some general information on the likely effects of studded tires on dry pavement surfaces, a short pilot study using vehicles equipped with these tires was conducted during the winter and spring of 1965 on the grounds of the Physical Research Laboratory of the Bureau of Research and Development, located 5 mi northwest of Ottawa, Ill. At the site, three different types of pavement surfaces were available for testing with no inconvenience to the traveling public. The major objective of this study was to develop information on the abrasive effects of studded tires on typical Illinois pavement surfaces.

A supplementary study of the traction of studded tires on dry concrete was also made when it appeared during the abrasion tests that the studded tires were not performing as well as standard tires on dry surfaces.

Automobile tires equipped with tungsten carbide studs embedded in the treads were tested under constant speed (25 mph) and under a series of starts and stops on portland cement concrete, bituminous concrete, and a bituminous surface treatment (Illinois subclass A-3). A test was also made with regular tires on the portland cement concrete. All of the pavements were constructed in 1958. The bituminous-treated surface has carried local traffic since that time, but neither the portland cement concrete nor the bituminous concrete surfaces had carried traffic previously. In some of the tests, a steel beam equipped with Ames dials was used to measure changes in the pavement surface. Photographs and plaster-of-paris casts were made for visual evidence of damage to the pavement surfaces caused by the studded winter tires.

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Figure 1. Loop 1 of AASHO Road Test, where studded tire test was conducted.

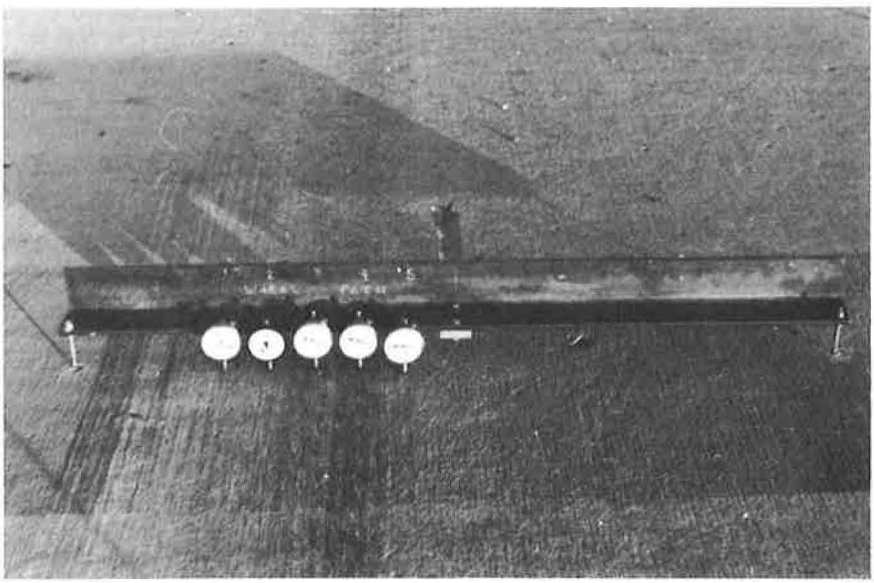

Figure 2. Beam used to measure pavement surface depression in wheelpath at each test site.

In view of the pilot nature of the study, and a desire to obtain general information quickly, most of the results obtained were necessarily qualitative, with quantitative measurements being at a minimum. The device developed for measuring the depths to which surface abrasion extended under application of the studded tires was not perfected until late in the test program.

Within the foregoing limitations, the study showed that wide use of tires having tungsten carbide studs embedded in the treads can be expected to cause abrasion in the

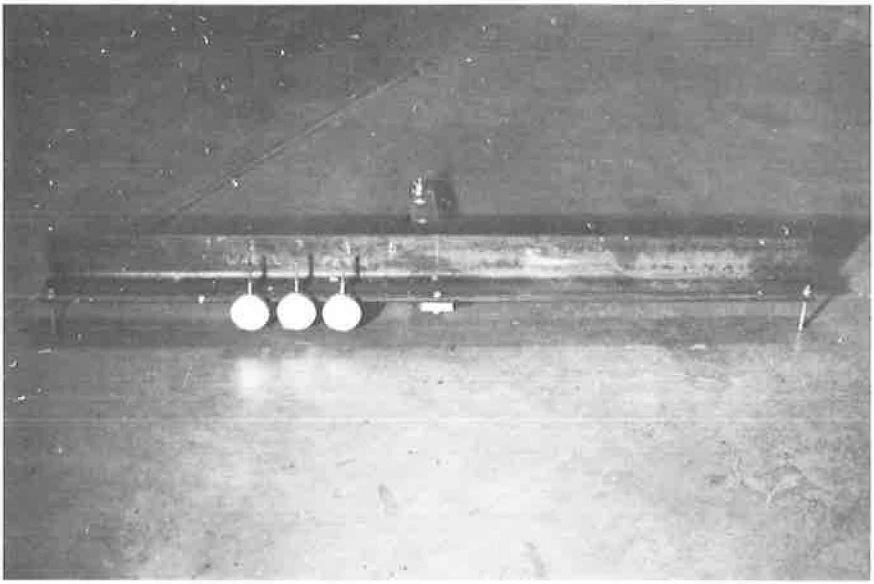

Figure 3. Beam with new dials used in special tests

wheelpaths of highway pavement surfaces. This abrasion undoubtedly would be most severe at intersections and at other locations where vehicles might be expected to make frequent starts and stops or sharp turns.

These statements are based on visual evidence of surface abrasion caused by studded tires on three principal types of pavement surfaces, and on measurements of depth of abrasion made on a dry portland cement concrete pavement. Measurements made on the portland cement concrete pavement with the steel beam equipped with Ames dials indicated that the pavement surface was abraded to a depth of almost $\frac{1}{16}$ in. in 50 start and stop applications (25 rapid starts followed by 25 emergency stops).

Evidence also indicated that, on dry pavements, vehicles equipped with studded tires require greater distances for stopping than vehicles equipped with regular (standard non-snow tread) tires.

EXPERIMENTAL PROCEDURE

Initially, seven test sections were marked with paint on the pavement surfaces of the east half of loop 1, the one remaining loop of the AASHO Road Test facility (Fig. 1). Of these, three were on a portland cement concrete surface andfour were on a bituminous-concrete surface. One section on each type of pavement was designated for start tests, one for stop tests, and one for constant speed (25-mph) driving. The fourth section on the bituminous-concrete surface was located on the turnaround at the east end of the loop, and was used for observing the effect of the studded tires while turning. Starts and stops were both the normal (with no spinning or sliding of the wheels) and the emergency type (with wheels spinning to start and sliding to stop). Normal start and stop tests preceded the emergency start tests and stop tests on a given test section.

Each test section was subjected to 250 passes of a vehicle equipped with studded tires. An eighth test section on the bituminous surface-treated pavement of the adjacent township road was subjected to a limited number of start and stop tests. Twenty-five emergency starts followed by 25 emergency stops were applied to this section.

A steel beam on which Ames dials were mounted (Fig. 2) was set on gage plugs cemented into the pavement with the dials in the wheelpath at each test site. The beam and dials were used to measure changes in the pavement surface. Measurements were made before the tests were started and after successive sets of applications at each test section. Unfortunately, the device did not function satisfactorily until near the end of the test series.

Photographs were taken of the test sections before the test and after each set of applications. Plaster-of-paris casts were made in the wheelpaths of the sections designated for start and stop tests at the beginning, after 200 applications, and after completion of all test runs.

At the conclusion of the main test series, three special tests on portland cement concrete surface were added, using a new arrangement of Ames dials and a modified measurement procedure that showed promise of giving more reliable measurements of abrasion depth (Fig. 3). Photographs and plaster-of-paris casts were also made of some of the special sections. A special test consisted of 25 rapid starts followed by 25 emergency stops across the test section. Measurements were made before and after each set of applications. At least ten minutes was allowed for the beam to become stabilized at equilibrium with the air temperature before taking initial readings. Measurements made in this way were reproducible.

The special tests were conducted on both a dry and an icy portland cement concrete surface with studded tires, and on a dry portland cement concrete surface with standard tires.

Two Allstate and four Goodyear studded snow tires, together with several standard tires, were used in the tests. The two Allstate tires had 52 tungsten carbide studs per tire equally spaced around the circumference in four rows, two rows along each edge of the tread. Studs were set approximately flush with the tread surface, ranging from slightly below the surface to about $^1/_{32}$ in. above it. These two tires were mounted on the rear wheels of a 1961 Plymouth sedan. The Goodyear studded tires contained from 103 to 108 tungsten carbide studs per tire, also arranged in two rows along each edge of the tread. The studs on these tires protruded on the average about $^3/_{32}$ in. above the surface of the tread. The Goodyear tires were mounted on all four wheels of a 1962 Chevrolet station wagon (Fig. 4).

The Chevrolet was used in the first series of tests that included regular driving and starts and stops. For the subsequent special rapid-start and emergency-stop tests, the Plymouth was used for the starts, and the Chevrolet for the stops. Only the Chevrolet was used in the stopping distance tests.

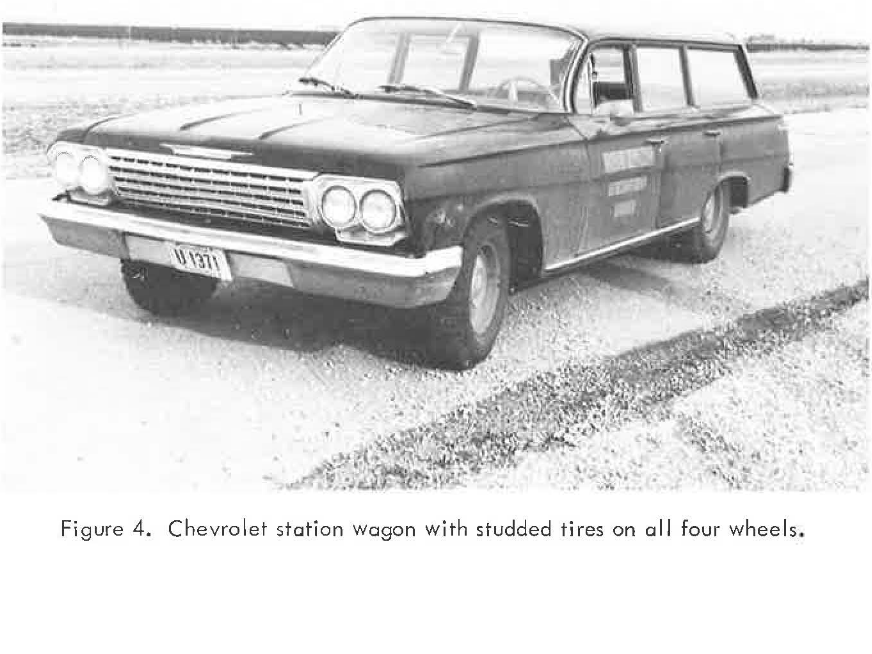

Figure 4. Chevrolet station wagon with studded tires on all four wheels.

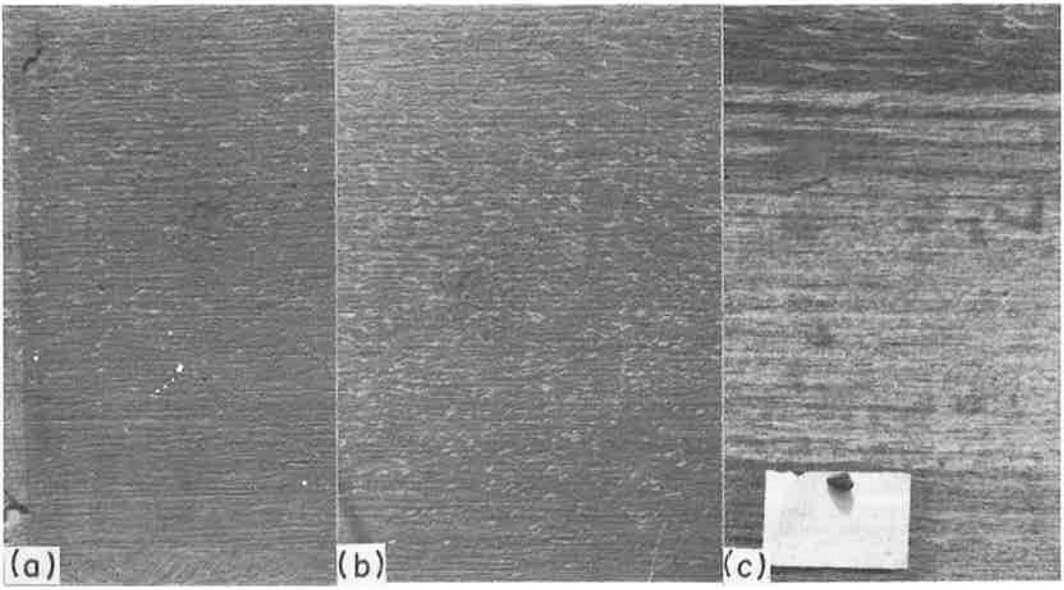

Figure 5. Portland cement concrete pavement surface after (a) 25 normal starts, (b) 125 normal starts, and (c) 175 normal starts plus 75 rapid starts.

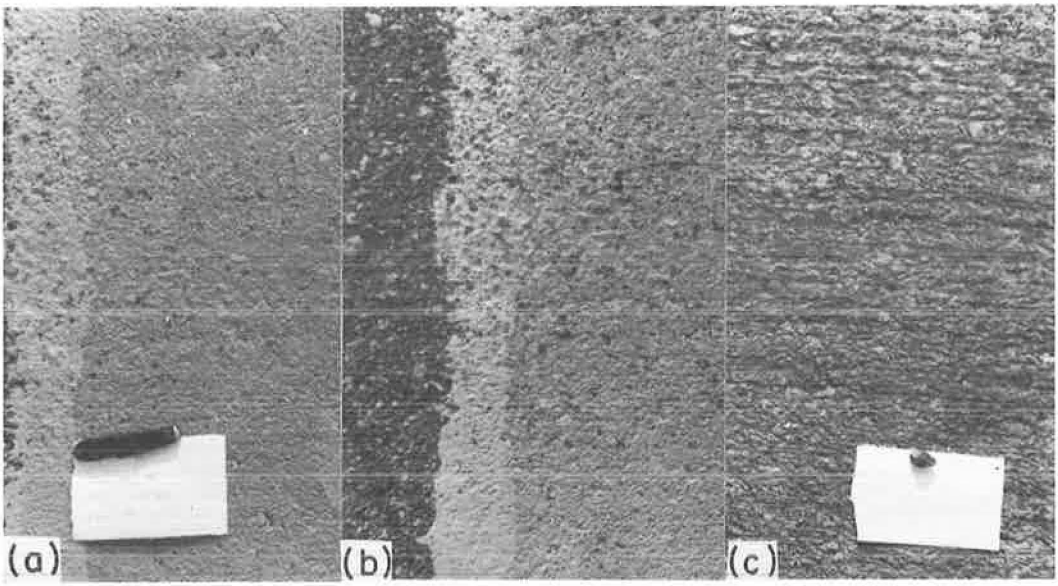

Figure 6. Bituminous-concrete pavement surface after (a) 25 normal starts, (b) 125 normal starts, and (c) 175 normal starts plus 75 rapid starts.

TEST RESULTS

Starting Tests

The starting tests included a series of normal and rapid starts over a test section of portland cement concrete pavement and a test section of bituminous-concrete pavement.

A complete series of tests over a section included 175 normal starts (starting without spinning rear wheels) followed by 100 rapid starts (starting under full power with spinning rear wheels).

Figure 5 shows the portland cement concrete pavement surface after 25 normal starts, after 125 normal starts, and after 175 normal starts followed by 75 rapid starts. The bright scratches crossing the burlap drag marks in the view taken after 25 applications are striations in the pavement surface made by the tire studs. After 125 applications of normal starts the stud marks were more numerous and the burlap drag marks were beginning to disappear. The abrasion of the pavement surface was much greater under rapid-start testing. Abrasion by the studded tires after 250 applications (175 normal starts plus 75 rapid starts) extended completely through the original surface in the center of the wheelpath, and a new surface was exposed (Fig. 5).

The condition of the bituminous-concrete surface at various stages during the starting tests is shown in Figure 6. The dark line to the left in Figures 6a and 6b indicates the limits of the painted area in the test sections. The effects of studded tires in starting on the bituminous-concrete surface were about the same as those on the portland cement concrete surface. The dark specks in Figures 6a and 6b are gouges in the pavement surface made by the metal studs. Figure 6c shows the surface after 250 applications (175 normal starts followed by 75 rapid starts). The paint was completely removed and the pavement surface markedly abraded.

Stopping Tests

A series of 175 normal stops followed by 75 emergency stops was run on both the portland cement concrete surface and the bituminous-concrete surface. A normal stop consists of stopping the test vehicle without sliding the tires; emergency stops were made with the wheels locked.

The progression of damage to the surface of the portland cement concrete pavement with succeeding applications of stops is shown in Figure 7. The light-colored marks in Figures 7a and 7b were made by the studs when brakes were applied without locking the wheels. Inadvertently, brakes tended to lock and some sliding of the tires occurred during the normal stops. Figure 7c was taken after application of 175 normal stops

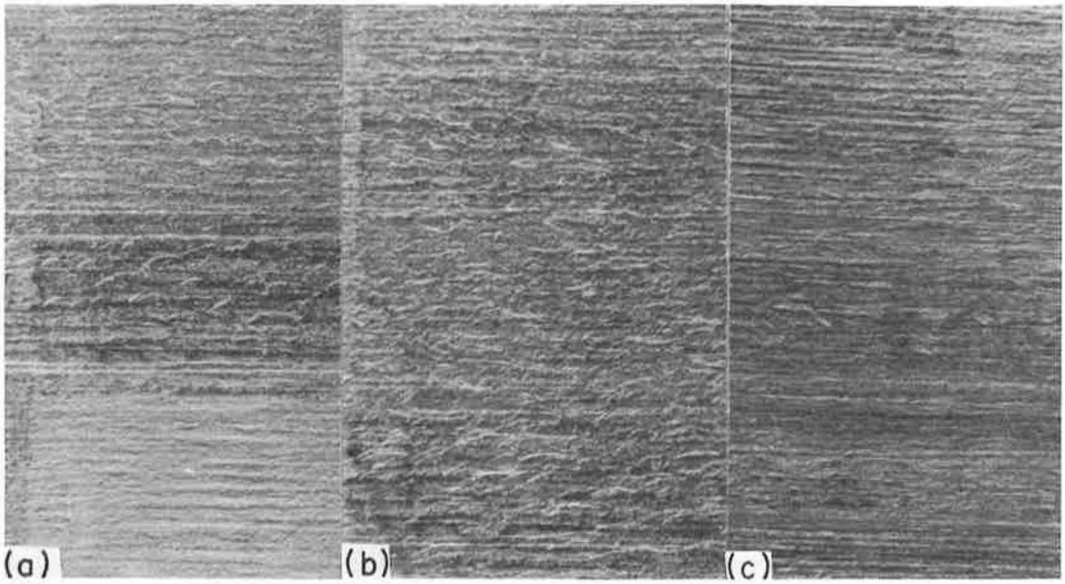

Figure 7. Portland cement concrete pavement surface after (a) 25 normal stops, (b) 125 normal stops, and (c) 175 normal stops plus 75 emergency stops.

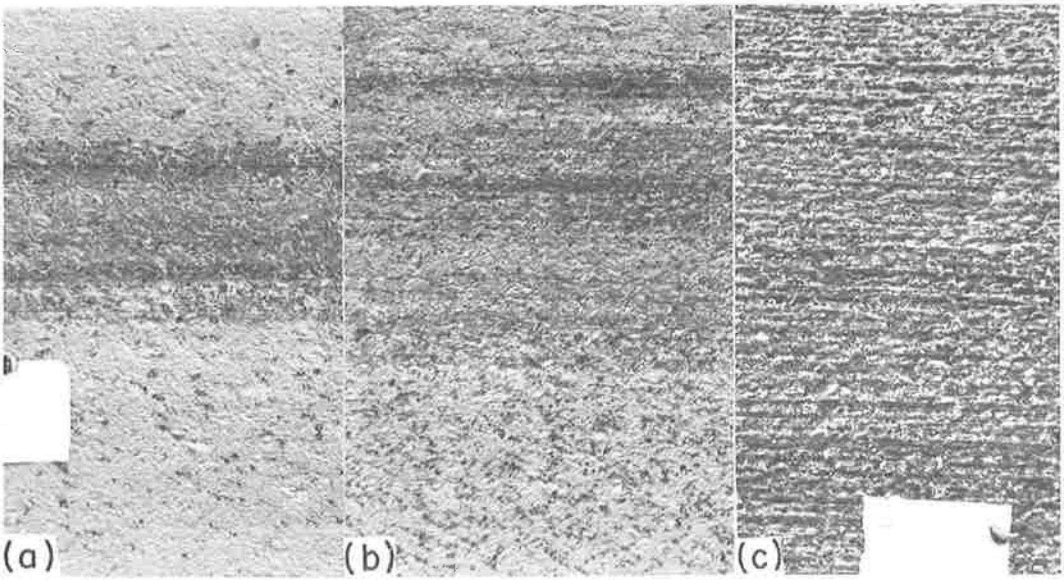

Figure 8. Bituminous-concrete pavement surface after (a) 25 normal stops, (b) 125 normal stops, and (c) 175 normal stops plus 75 emergency stops.

Figure 9. Bituminous-concrete surface after application of 175 normal stops followed by 25 emergency stops.

followed by 75 emergency stops. By this time, abrasion of the pavement surface had reached the point that the burlap drag marks had been completely obliterated in the center of the wheelpath.

Similar results were obtained during the stopping tests on the bituminous-concrete surface (Fig. 8). As with the stopping tests on the portland cement concrete surface, emergency stops with the wheels locked caused the greatest amount of abrasion of the pavement surface (Figs. 8a and 8b).

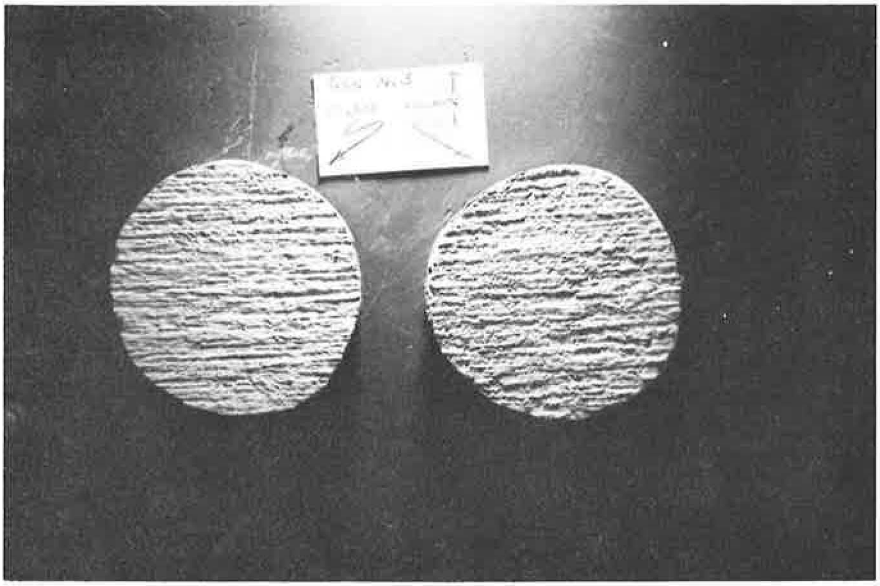

Figure 10. Plaster-of-paris casts of surface of portland cement concrete pavement before testing (left) and after 200 stop applications (right).

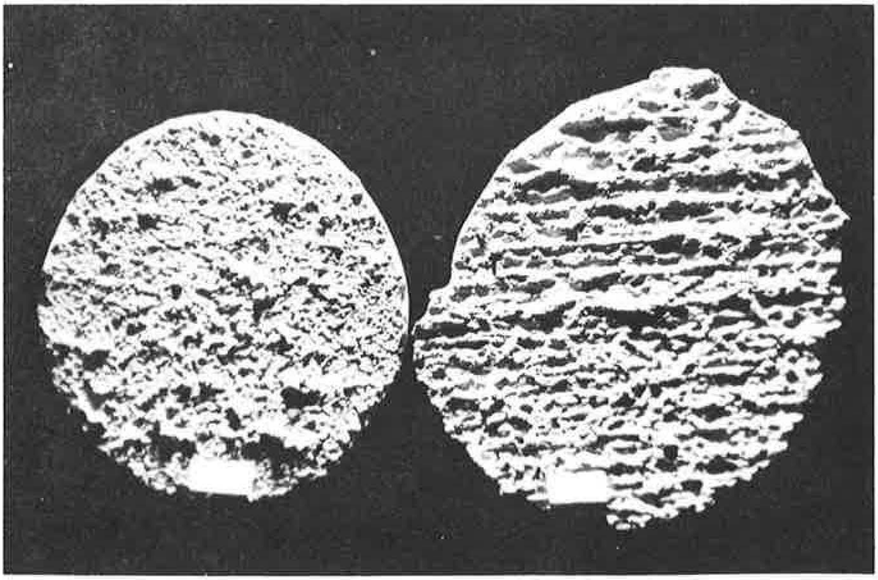

Figure 11. Plaster-of-paris casts of the surface of bituminous-concrete pavement before testing (left) and after 200 stop applications (right).

On the stopping test section of the bituminous-concrete pavement the paint mark was completely obliterated in the wheelpaths and abrasion of the surface was evident after 175 normal stops followed by 25 emergency stops (Fig. 9).

Comparisons of plaster-of-paris casts of the pavement surface made before testing and after the application of 175 normal stops followed by 25 emergency stops are shown in Figures 10 and 11.

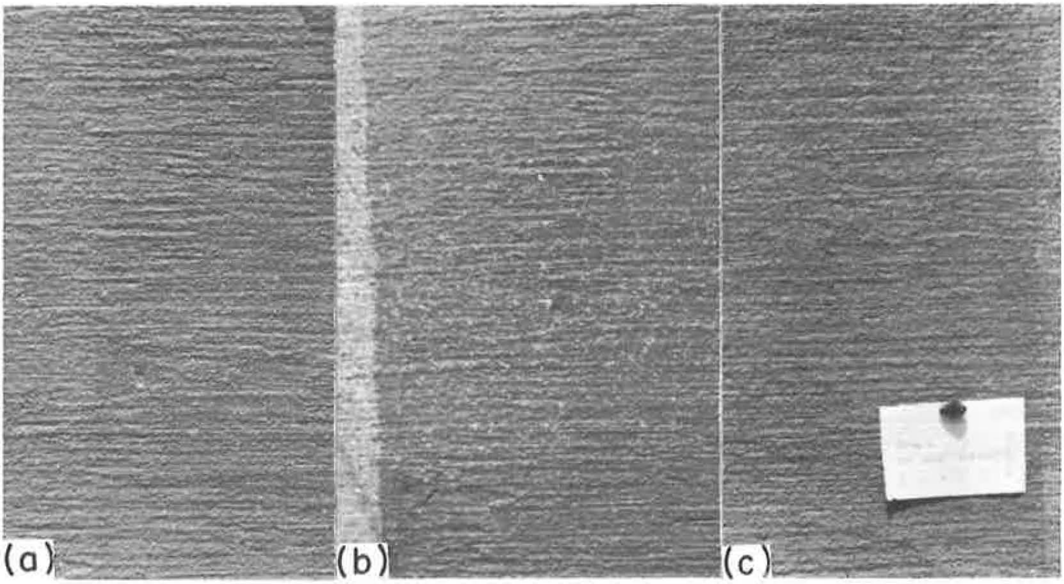

Figure 12. Portland cement concrete surface after constant-speed testing: (a) 25 applications, (b) 125 applications, and (c) 250 applications.

Constant-Speed Tests

One test section of portland cement concrete pavement and one of bituminous-concrete pavement were used for testing studded tires with the vehicle operating at a constant 25-mph speed; 250 applications of the vehicle were made on each section (Figs. 12 and 13). Abrasion in this series of tests was indicated only as small pock marks, which appear as white dots (Fig. 12) and as black specks (Fig. 13). Abrasion of the pavement surfaces during constant-speed testing was very minor, although the marks in the wheelpaths were clearly visible at the end of testing.

Turning Tests on Bituminous-Concrete Surface

The abrasive effects of turning on a bituminous concrete surface appeared to be intermediate between those occurring under constant-speed driving and those occurring under starting and stopping. Turning produced stud marks or striations in the pavement surface that were almost normal to the direction of travel because of the twisting effect as the vehicle turned. Figure 14 shows the bituminous-concrete surface after 25, 125, and 250 applications. The test pavement has a 20-ft radius along the inside edge, which is similar to the turning radius at many intersections.

Material loosened by the abrasive action of the studs was clearly visible on the pavement surface.

Starting and Stopping Tests on Subclass A-3 Surface Treatment

A series of 25 rapid starts followed by 25 emergency stops was applied to the subclass A-3 bituminous-treated surface of the township road that parallels loop 1. The studded tires caused deep abrasion of the A-3 treatment (Figs. 15 and 16). Figure 15 shows the pavement surface after completion of the testing; Figure 16 shows the plaster-of-paris casts made before and after testing, with the severity of grooving indicated by the left-hand cast.

Special Tests

An effort was made to develop instrumentation for obtaining quantitative measurements of the depths of surfacing removed by the studded tires. After the tests were

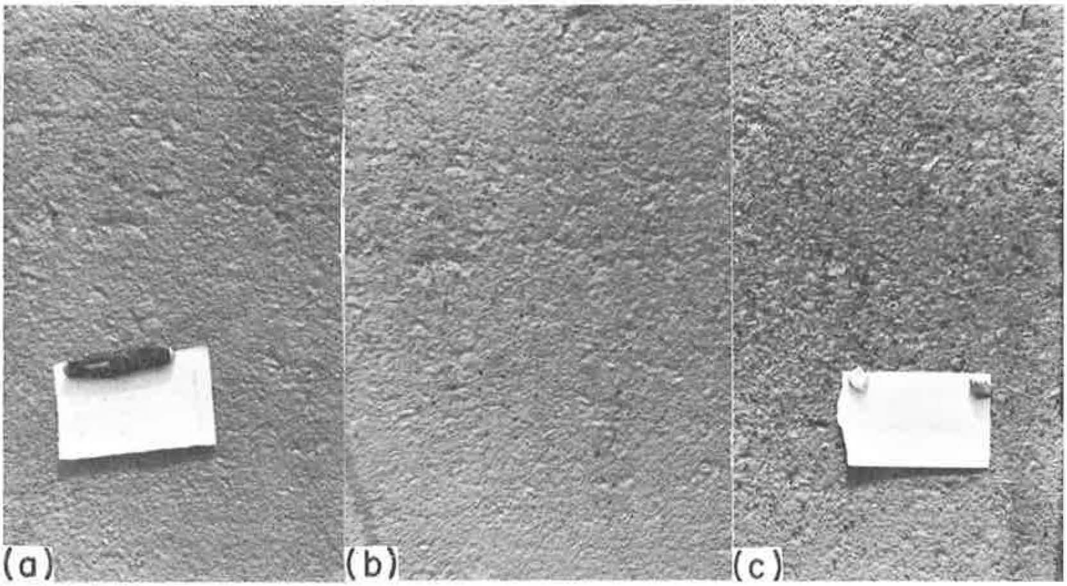

Figure 13. Bituminous concrete surface after constant-speed testing: (a) 25 applications, (b) 125 applications, and (c) 250 applications.

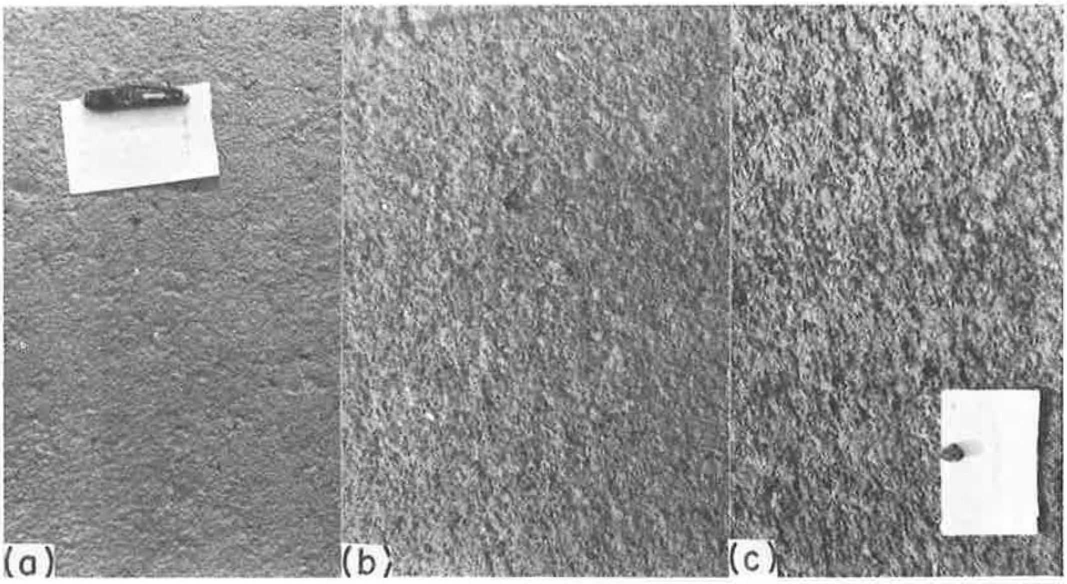

Figure 14. Turning tests on bituminous concrete surfaces after (a) 25 applications, (c) 125 applications, and (c) 250 applications.

begun, it was found that the instrumentation was not yielding reliable results. Because of the pilot nature of the tests, the need to complete them quickly, and the uncertainty concerning the length of time required to develop satisfactory instrumentation, the originally planned series of tests was completed without the instrumentation.

Following completion of the original series of tests, the instrument developed for measuring depth of surface abrasion under studded tires was modified in an attempt to improve its reliability. When it appeared that some success had been attained, a

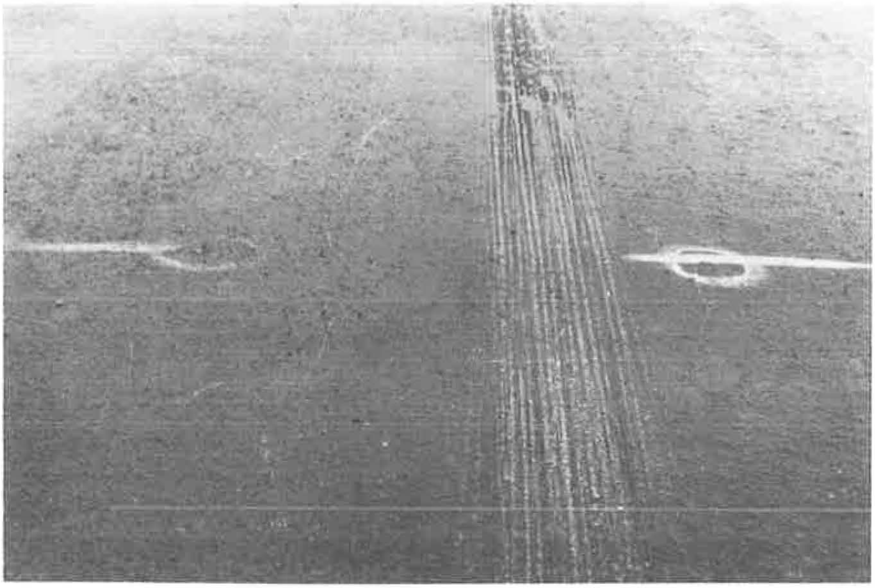

Figure 15. Subclass A-3 surface treatment after completion of testing.

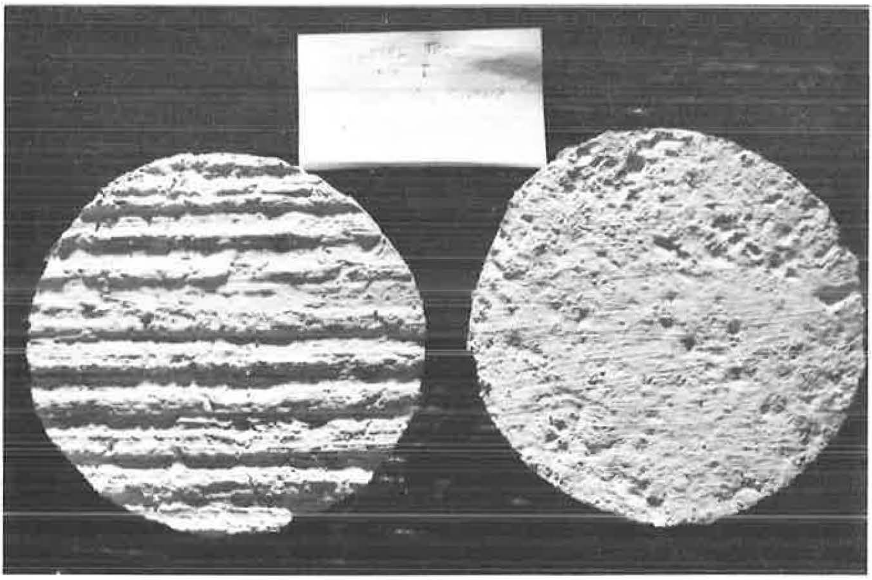

Figure 16. Plaster-of-paris casts of A-3 surface treatment before testing (right) and after completion of testing (left).

second series of field tests of studded tires was undertaken. Because the additional information to be gained through the use of the modified instrumentation did not appear sufficiently important to warrant a complete repetition of the original tests, the test schedule was modified.

The modified instrument consisted of fewer Ames dials mounted on a short portion of the original beam.

TABLE 1

AVERAGE DEPRESSION OF WHEELPATH DURING 50 APPLICATIONS OF RAPID STARTS AND EMERGENCY STOPS[a]

Treatment	Avg. Wheelpath Depression (in.)		
	Dry PCC[b]	Icy PCC[b]	Dry PCC[c]
25 rapid starts	0.040	0.017	0.004
25 rapid starts and 25 emergency stops	0.043	0.019	0.004

[a]Dial readings taken in triplicate and averaged for wheelpath depression for each test.
[b]Tested with studded tires.
[c]Tested with regular tires.

The special tests included 25 rapid starts followed by 25 emergency stops on each of three test sections: (a) a section of dry portland cement concrete tested with studded tires; (b) a section of ice-covered portland cement concrete tested with studded tires; and (c) a section of dry portland cement concrete tested with regular tires. Results are given in Table 1.

Dial readings indicated that surface abrasion took place in all three special tests. The amount of abrasion from regular tires was appreciably less than that produced by the studded tires. The effect of studded tires on the icy surface was less than on the dry surface.

Dry Portland Cement Concrete Surface, Studded Tires.—Abrasion of the pavement in this special test (Figs. 17 and 18) appeared similar to that resulting from the original starting and stopping tests.

Icy Portland Cement Concrete Surface, Studded Tires.—Water was poured over the surface of the pavement and allowed to freeze solid (Figs. 19 and 20). For the initial beam measurements the ice was chipped away under each dial. After three applications of rapid starts, two sets of grooves had been cut through the ice into the pavement surface by the studs (Fig. 19). The same type of grooving was evident at all test sections where serious damage occurred as a result of spinning the wheels during rapid starts. During this test, the initial grooves appeared quickly and the studs tended to slip into the grooves on successive passes, widening the grooves and rounding off the ridges between the grooves. Grooving did not appear to be increased in intensity as a result of the ice on the surface. After 25 applications of rapid starts, all of the ice had been removed from the wheelpaths and pronounced grooves had been made in the pavement surface (Fig. 20). Chips on the surface are ice fragments chipped out of the wheelpath.

Dry Portland Cement Concrete Surface, Regular Tires.—This study was conducted as a control test using regular tires. On completion of testing, there was no evidence of the test except for the black rubber marks caused by spinning and sliding the tires (Fig. 21).

Traction Tests

This test series was to obtain information on the relative stopping distances required by vehicles mounted on studded snow tires and on standard tires. A general impression that the studded tires required greater stopping distances during the abrasion tests indicated the desirability of this supplementary study.

The Chevrolet station wagon was used in all the stopping-distance tests, and the same driver was used throughout the series. The same studded Goodyear tires were also used.

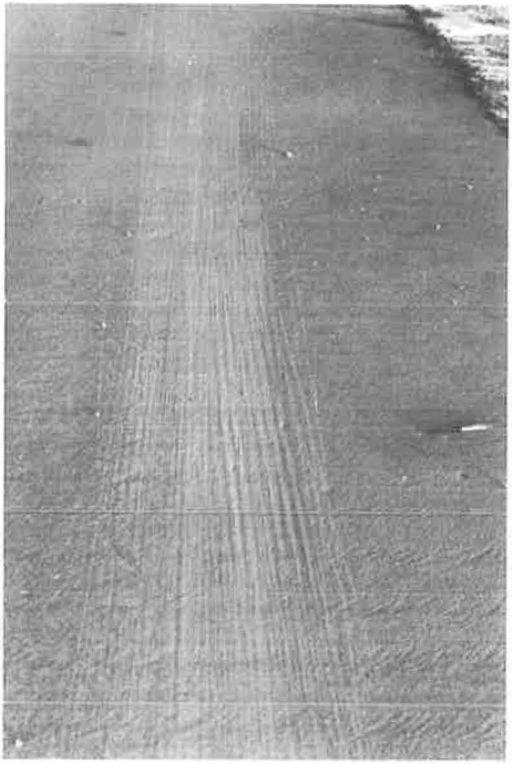

Figure 17. Special test no. 1 on portland cement concrete; pavement surface after completion of tests.

Figure 18. Special test no. 1; pavement surface after completion of tests.

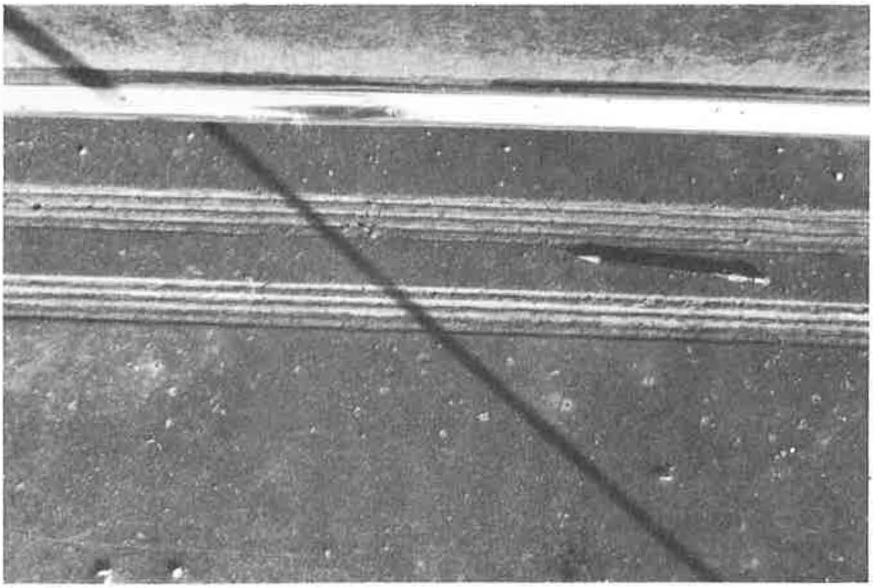

Figure 19. Special test no. 2; icy portland cement concrete surface after three applications of rapid starts.

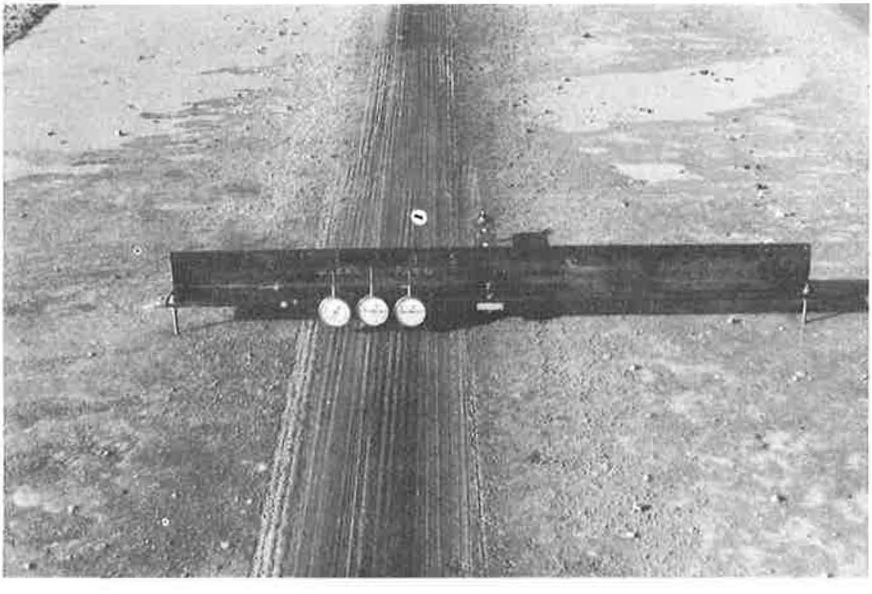

Figure 20. Special test no. 2, surface after completion of tests.

A toy pistol firing a dart with a rubber suction cup triggered by a solenoid activated by the brake was used to mark the pavement at the start of braking action. The dart cup was dabbed with wet paint to mark the pavement surface. Stopping distances were measured from the paint mark to the gun muzzle on the rear bumper of the stopped vehicle.

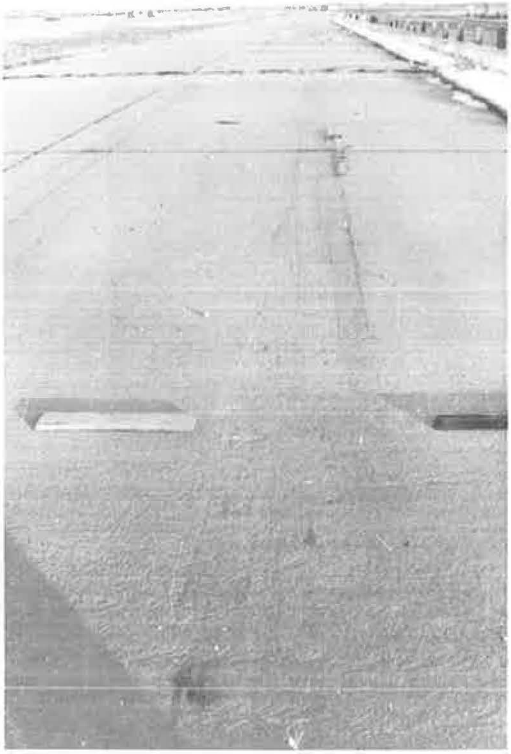

Figure 21. Special test no. 3 on dry portland cement concrete pavement with regular tires, after completion of test.

TABLE 2

COMPARISON OF STOPPING DISTANCES FOR REGULAR AND STUDDED TIRES

Tire Combination	Required Distance (ft)		
	At 10 MPH	At 20 MPH	At 30 MPH
Four regular tires	5.9 (1.00)[a]	18.1 (1.00)[a]	44.6 (1.00)[a]
Two studded tires on rear	5.4 (0.92)[a]	19.5 (1.08)[a]	48.7 (1.09)[a]
Four studded tires	6.3 (1.07)[a]	22.2 (1.23)[a]	52.2 (1.17)[a]

[a]Ratios of indicated stopping distance to stopping distance for regular tires.

All of the stopping-distance tests were made on a dry portland cement concrete surface. Stops were made from speeds of 10, 20, and 30 mph. The tests were not extended to higher speeds because of the danger of the vehicle becoming unmanageable on the two-lane pavement of the test site. Three tire systems were used in the tests: (a) four studded tires; (b) two studded tires in the rear and standard tires in front; and (c) four standard tires. The test for each tire system and speed combination was repeated five times, a total of 45 test runs.

Results of the stopping-distance tests on dry concrete pavement are given in Table 2. For rear-mounted studded tires (regular tires in front), stopping distances ranged up to 9 percent greater than for regular tires; and for studded tires on all four wheels, stopping distances ranged up to 23 percent greater than for regular tires.

DISCUSSION

The surfaces of all three types of pavement were abraded by the studded winter tires for all conditions of testing. The starting and stopping tests produced the most serious abrasion, especially the rapid starts and emergency stops. The abrasion caused by the turning tests rated second, and the least amount occurred in the constant-speed tests.

During the rapid-start and emergency-stop tests, the tungsten carbide studs tended to cut four grooves in the pavement surface. These grooves corresponded to the four rows of studs in the tires. The studs tended to slip into the grooves on successive applications, and produced relatively deep grooves in the pavement early in the test. Successive applications tended to widen the grooves and eliminate ridges between the grooves.

Previous tests by other agencies have demonstrated that studded winter tires perform better on icy and hard-packed snow surfaces than either regular tires or standard snow tires. However, during these tests the regular tires exhibited more traction than the studded tires on dry pavement surfaces. Spinning the rear wheels during rapid start tests was more easily accomplished with studded tires than with regular tires. Stopping-distance tests on dry concrete pavement showed that up to 23 percent more stopping distance is required for a passenger car mounted on four studded tires than for a car with four regular tires. More spinning and sliding during starts and stops in emergency conditions with studded tires would tend to increase the damage done to pavements and at the same time decrease driver safety and vehicle control.

Available information on studded winter tires indicates that the tires are designed so that the rate of wear of the rubber tread and of the tungsten carbide studs would be the same. Under the conditions of these tests, however, the tire treads wore at a faster rate than the tungsten carbide studs. Measurements of the protrusion of the studs from the surface of the tread taken before and after the tests indicated that the average protrusion had increased by $^{3}/_{64}$ in. for both brands of tires. The average protrusion of the studs from the tread surface for the Goodyear tires was $^{3}/_{32}$ in. before testing and $^{9}/_{64}$ in. at the completion of testing. For the Allstate tires, the studs were flush with the tread surface before testing and protruded $^{3}/_{64}$ in. from the tread after testing. One of the Goodyear tires showing protrusion of the studs at the completion of the tests is shown in Figure 22.

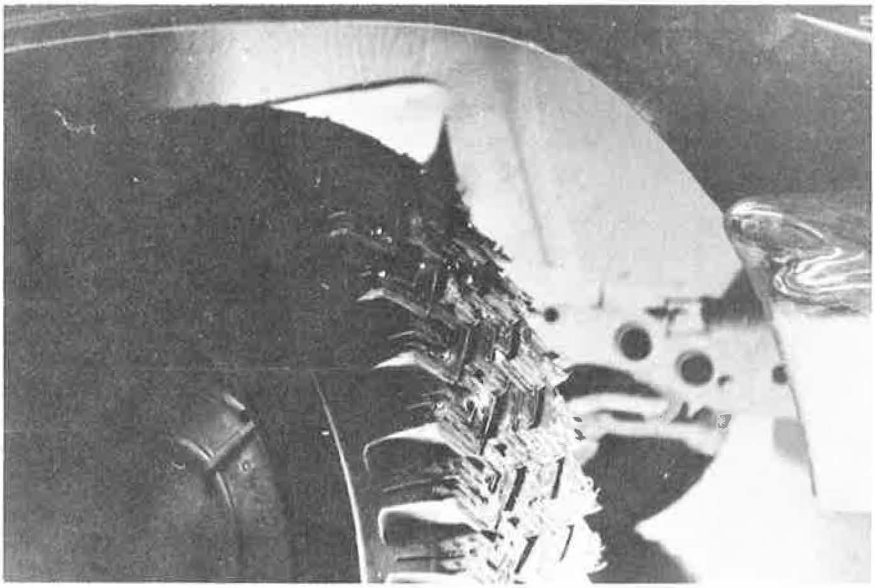

Figure 22. Goodyear tire showing protrusion of tungsten carbide studs at completion of testing.

Reports on tests of studded winter tires by other agencies have indicated loss of some of the studs during testing, and several agencies have expressed concern over the possible hazard of expulsion of studs at high speeds. During the tests at Ottawa, which involved fewer than 200 veh-mi of travel, four studs were lost from one tire and one stud was lost from each of two other tires.

SUMMARY

Advantages of Studded Tires

Tungsten-carbide studded tires permit better stopping and starting traction on ice and hard-packed snow than either regular tires or snow tires, but they do not provide as much traction as chains. The effectiveness of studded tires in improving traction on ice and hard-packed snow has been demonstrated adequately by numerous agencies both in this country and abroad. There is little question but that they are safer than either regular tires or snow tires on ice and hard-packed snow.

Disadvantages of Studded Tires

1. Studded tires have an abrasive effect on pavement surfaces. Unlike tire chains, studded tires can be expected to receive continuous use during the entire winter season as do ordinary snow tires. In a substantial part of the country, they can be expected to receive far more use on bare pavements than on ice- or snow-covered pavements. Studded tires are generally acknowledged to have an abrasive influence on pavement surfaces; the severity of the abrasive action is controversial. The results of exploratory tests involving up to 250 passages of typical studded winter tires mounted on passenger cars traveling on dry portland cement concrete, bituminous concrete, and bituminous surface treatment showed visible evidences of slight abrasion in normal driving and pronounced abrasion under emergency stop and start conditions. Abrasion depths up to $\frac{1}{16}$ in. were measured after 25 emergency stops followed by 25 quick starts on a concrete pavement. All pavements tested showed evidences of abrasion with the bituminous surface treatment showing the most pronounced abrasion. Tests were started with new tires in which the studs were flush with the tread surface or only slightly protruding. Measurements of stud protrusion before and after the tests showed an average increase in stud protrusion of $\frac{3}{64}$ in. caused by greater wear of the rubber. It can be surmised that even greater abrasion would have been recorded in the tests if the tires had been similarly worn before testing began. The test results suggest that abrasion caused by studded tires at locations of frequent stops and starts, or where frequent turning movements occur, would probably lead in some circumstances of heavy traffic to a need for special surface repairs.

2. Studded tires may be less safe on dry pavements than regular tires. Exploratory tests showed that on dry pavement up to 23 percent more stopping distance is needed for a vehicle mounted on four studded tires than for a vehicle with regular tires. Nine percent more stopping distance was needed when only rear-mounted studded tires were used.

3. Loss of studs from studded tires traveling at high speeds is a potential hazard. Various agencies have reported the loss of studs from tires in travel. During the Illinois tests, which involved fewer than 200 veh-mi of travel, four studs were lost from one tire, and one stud from each of two other tires.