State of Illinois
DEPARTMENT OF PUBLIC WORKS AND BUILDINGS
Division of Highways
Bureau of Research and Development

SOME TESTS OF STUDDED TIRES IN ILLINOIS

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EFFECT OF STUDDED TIRES ON PAVEMENT SURFACES

INTRODUCTION

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

The studded tires have received wide user acceptance in Europe where they were introduced a few years ago, and similar acceptance probably can be anticipated in this country now that principal tire manufacturers are introducing the tires here.

It is generally acknowledged that studded tires will exercise an abrasive influence over pavement surfaces; however, there is a 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 the studded tires illegal. These laws, although not intentionally directed against the use of studded tires at the time of enactment, were placed in 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 should 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 the tires equipped with steel 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 on the grounds of the Physical Research Laboratory of the Bureau of Research and Development located five miles northwest of Ottawa, Illinois. 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 some 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 also was made when it appeared during the abrasion tests that the studded tires were not performing as well as regular tires on dry surfaces.

Automobile tires equipped with tungsten carbide studs molded 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 Subclass A-3, bituminous treated surfaces. A test also was run on portland cement concrete surface with regular tires. 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.

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

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

The above statements are based on the visual evidences 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 a steel beam equipped with Ames dials indicated that the pavement surface was abraded to a depth of almost 1/16 inch in 50 start and stop applications (25 rapid starts followed by 25 emergency stops).

Evidence also was found to indicate that vehicles equipped with studded tires require greater distances for stopping than do vehicles equipped with regular tires on dry pavements.

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 (Figure 1).

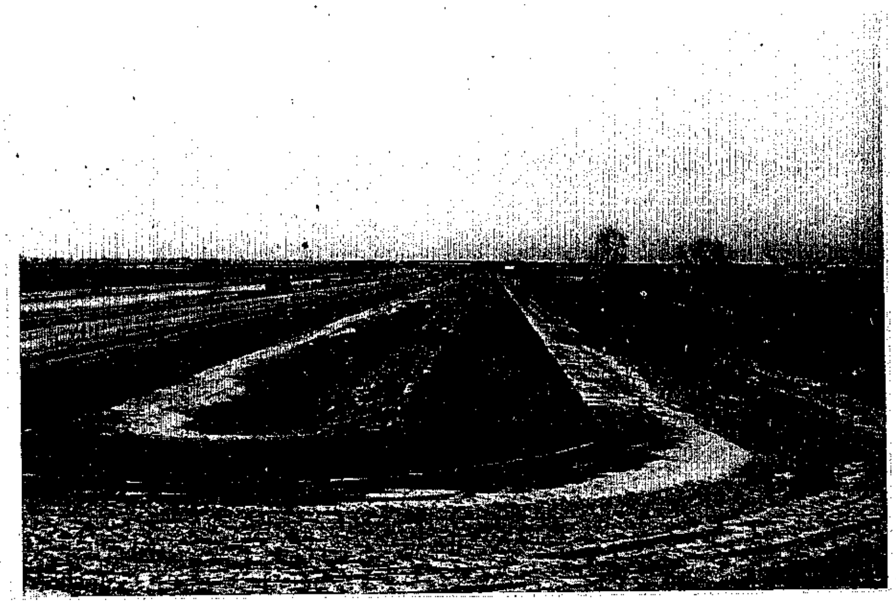


Figure 1. Loop 1 of the AASHO Road Test where studded tire test was conducted.

Of these, three were on a portland cement concrete surface and four 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 designated for observing the effect of the studded tires while turning on bituminous concrete pavement. Starts and stops were both normal, with no spinning or sliding of the wheels, and of an emergency type with wheels spinning to start and sliding to stop. Normal start tests and stop tests preceded the emergency start tests and stop tests on a given test section. A total of 275 applications of a vehicle equipped with studded winter tires were applied to each of these sections. An application is considered to be one pass of a vehicle across a test section.

An eighth test section on the A-3 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 (Figure 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. Errors in dial readings were found to be produced principally by warping of the test beam due to temperature fluctuations and by dial malfunction.

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.

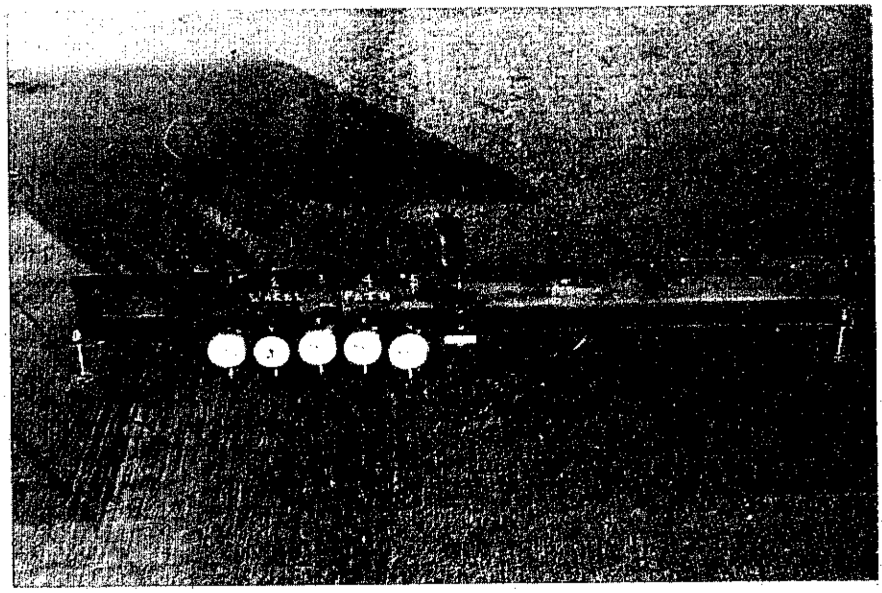


Figure 2. The beam used to measure pavement surface depression in the wheelpath at each test site.

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. Photographs and plaster of paris casts also were made of some of the special sections. A special test consisted of 25 emergency starts followed by 25 emergency stops across the test section. Measurements were made before and after each set of applications. At least ten minutes were allowed for the beam to become stabilized at equilibrium with the air temperature before taking initial readings. Measurements made in this way were found to be reproducible.

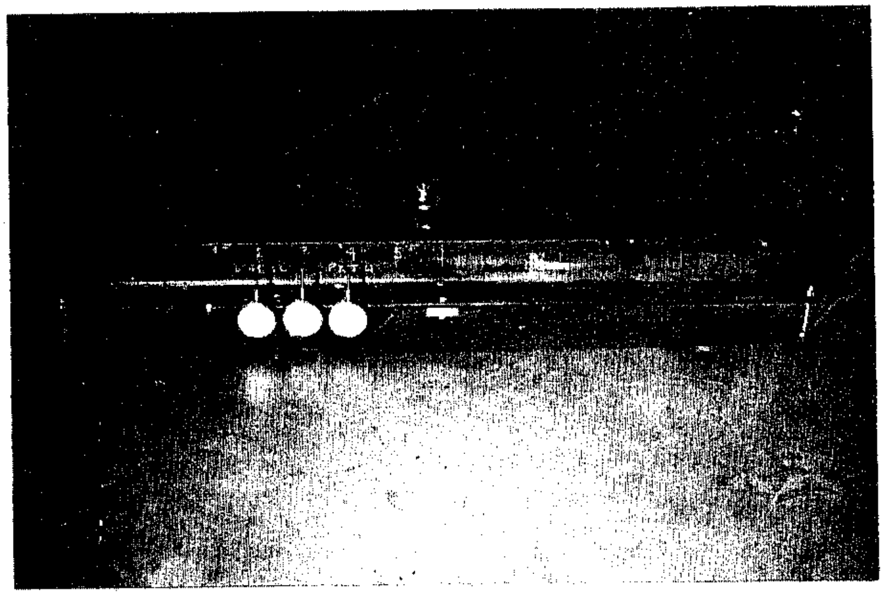


Figure 3. The beam with new dials used in the special tests.

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

Two Allstate tires from Sears Roebuck Company and four tires from Goodyear Tire and Rubber Company with tungsten carbide studs and snow grip tread were available for use 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 tread surface to about 1/32" above. These two tires were mounted on the rear wheels of a 1961 Plymouth sedan. The Goodyear 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" above the surface of the tread. The Goodyear tires were mounted on all four wheels of a 1962 Chevrolet station wagon (figure 4).

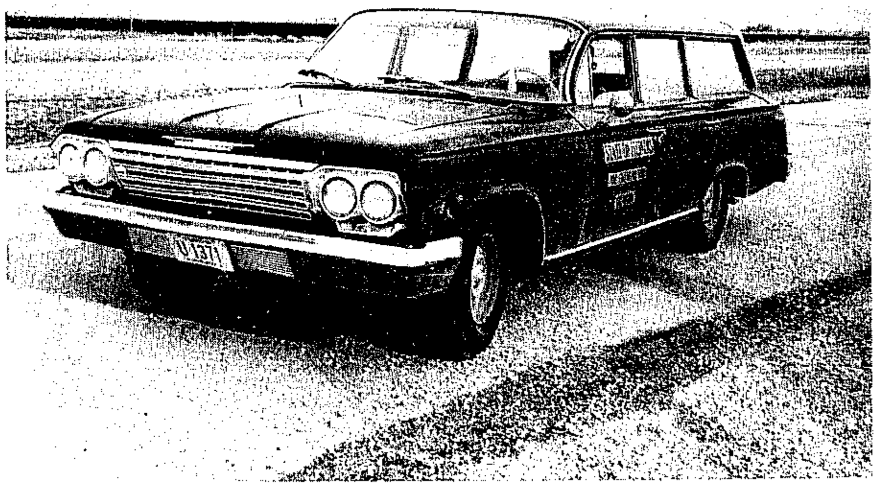


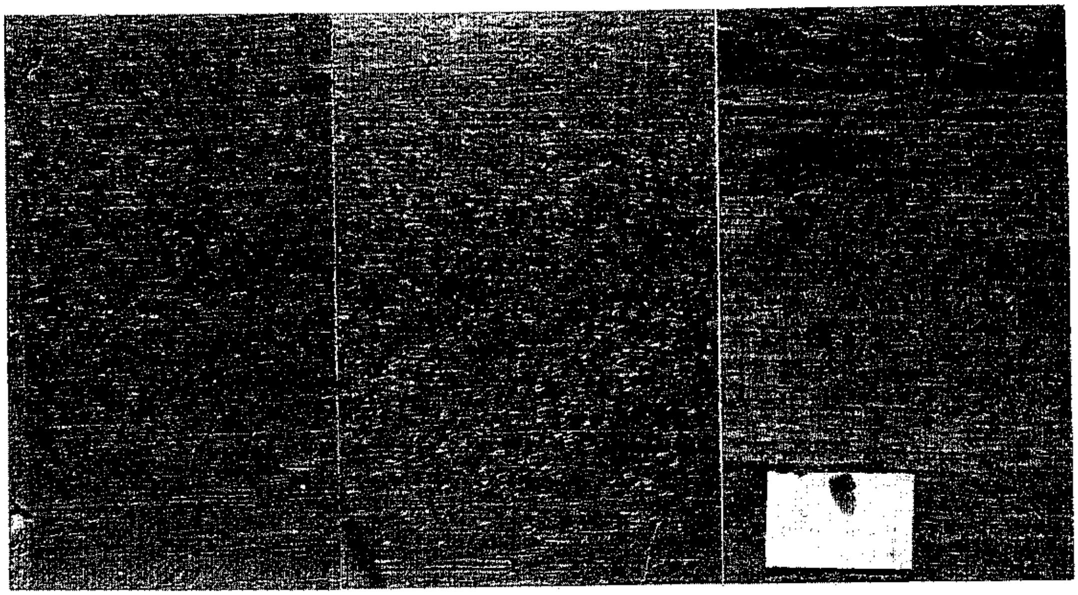
Figure 4. Studded tires by Goodyear were placed on all four wheels of a 1962 model Chevrolet station wagon.

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).

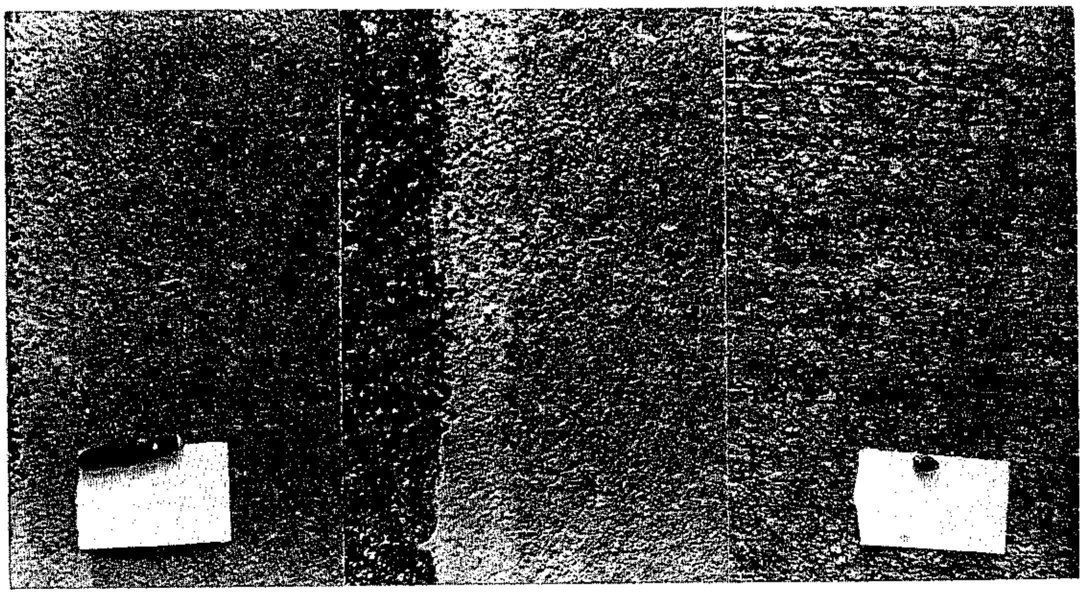
The condition of the portland cement concrete pavement surface at various stages during the starting tests is shown in Figure 5. The figure includes photographs of the pavement surface after 25 normal starts, after 125 normal starts, and after 175 normal starts followed by 75 rapid starts. The bright 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 the rapid-start testing. As can be seen in Figure 5, abrasion by the studded tires after 250 applications (175 normal starts plus 75 rapid starts) had extended completely through the original surface in the center of the wheelpath and a new surface had been exposed.



(1) After 25 normal starts
(2) After 125 normal starts
(3) After 175 normal starts
plus 75 rapid starts

Figure 5. Views of portland cement concrete pavement surface after successive numbers of starts.

The condition of the bituminous concrete surface at various stages during the starting tests is shown in the photographs of Figure 6. The dark line to the left in frames (1) and (2) 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 on the portland cement concrete surface. The dark specks in frames (1) and (2) are gouges in the pavement surface made by the steel studs. Frame (3) is a view of the surface after 250 applications (175 normal starts followed by 75 rapid starts). As is shown, the paint was completely removed and the pavement surface markedly abraded.



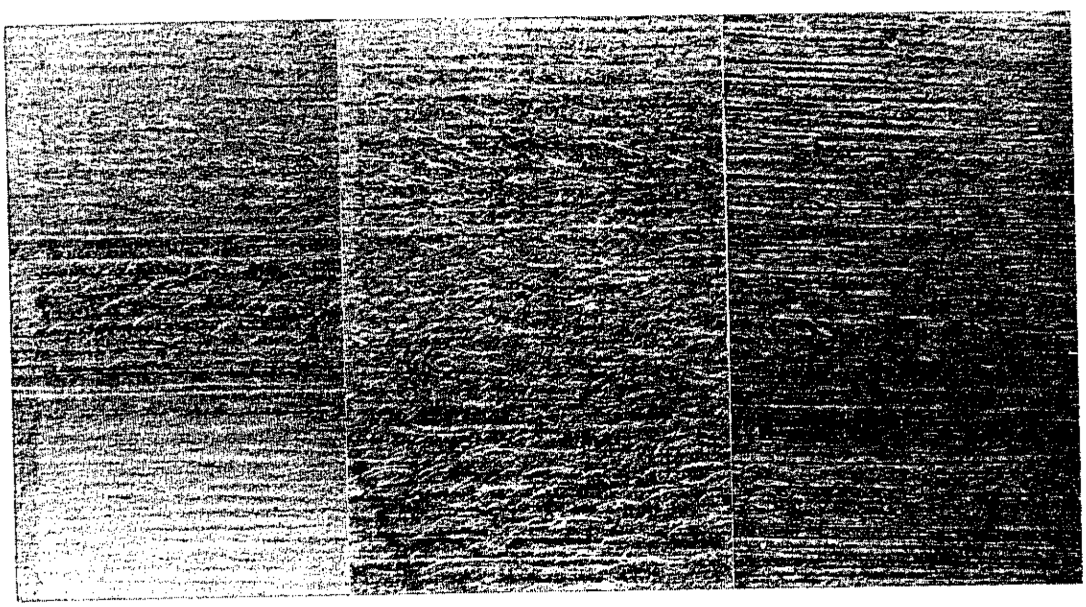
(1) After 25 normal starts
(2) After 125 normal starts
(3) After 175 normal starts plus 75 rapid starts

Figure 6. View of bituminous concrete pavement surface after successive numbers of starts.

Stopping Tests

A series of 175 normal stops followed by 100 emergency stops were run on each of the two types of pavement surfaces - portland cement concrete and bituminous concrete. A normal stop infers stopping the test vehicle without sliding the tires; emergency stops were made with the wheels locked.

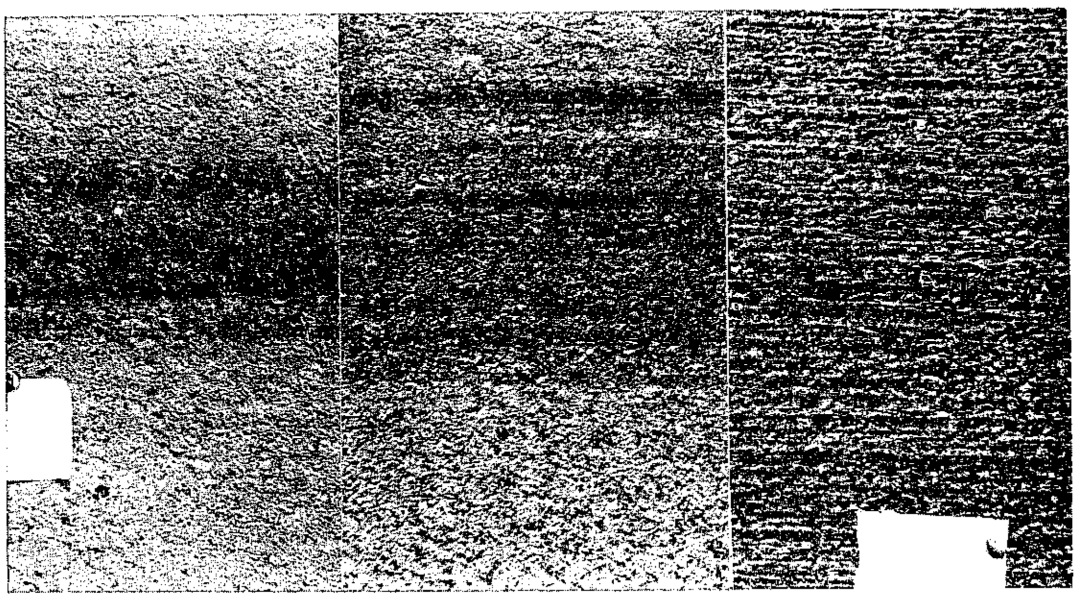
The progression of damage to the surface of the portland cement concrete pavement with succeeding numbers of applications of stops is illustrated in Figure 7. The light-colored curved marks shown in frames (1) and (2) were made by the studs when brakes were applied without locking the wheels. Inadvertently, brakes would tend to lock and some sliding of the tires was produced in the normal stops. The view of the pavement surface in (3) was taken after the application of 175 normal stops followed by 75 applications of emergency stops. By this time, abrasion of the pavement surface had proceeded to the point that the burlap drag marks had been completely obliterated in the center of the wheelpath.



(1) After 25 normal stops
(2) After 125 normal stops
(3) After 175 normal stops plus 75 emergency stops

Figure 7. Views of portland cement concrete pavement surface after successive numbers of stops.

Similar results were obtained during the stopping tests on the bituminous concrete surface, as shown in Figure 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. This is evident in the pronounced change in surface appearance shown in frames (2) and (3) of Figure 8.



(1) After 25 normal stops
(2) After 125 normal stops
(3) After 175 normal stops

Figure 8. Views of bituminous concrete pavement surface after successive numbers of stops

An overall view of the stopping test section on bituminous concrete pavement taken after the application of 175 normal stops followed by 25 emergency stops is shown in Figure 9. As can be seen, the paint mark has been completely obliterated in the wheelpaths, and abrasion of the surface is evident.

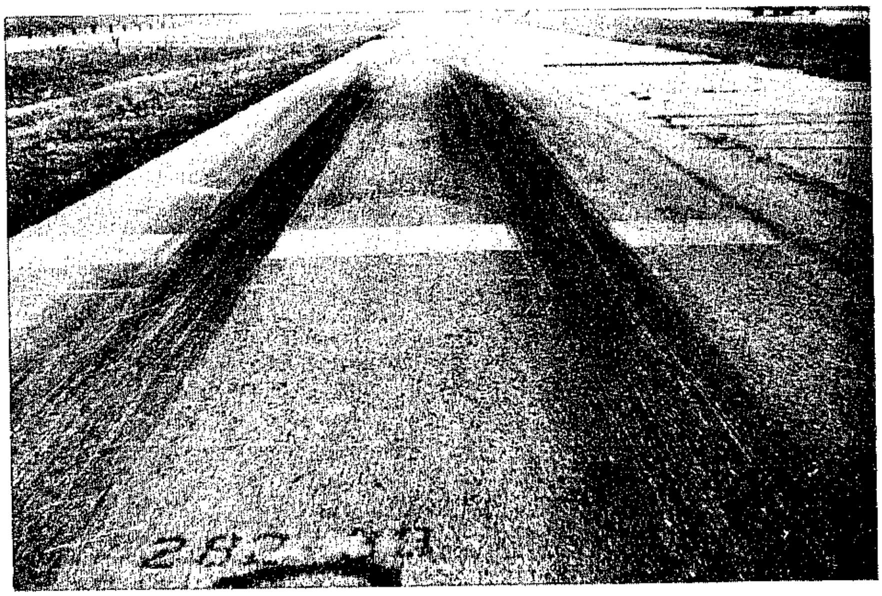


Figure 9. View of bituminous concrete surface taken after the application of 175 normal stops followed by 25 emergency stops.

Comparisons of the 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 provided in Figure 10 for portland cement concrete pavement and in Figure 11 for bituminous concrete pavement. The casts on the left of the figures are the ones made before testing.

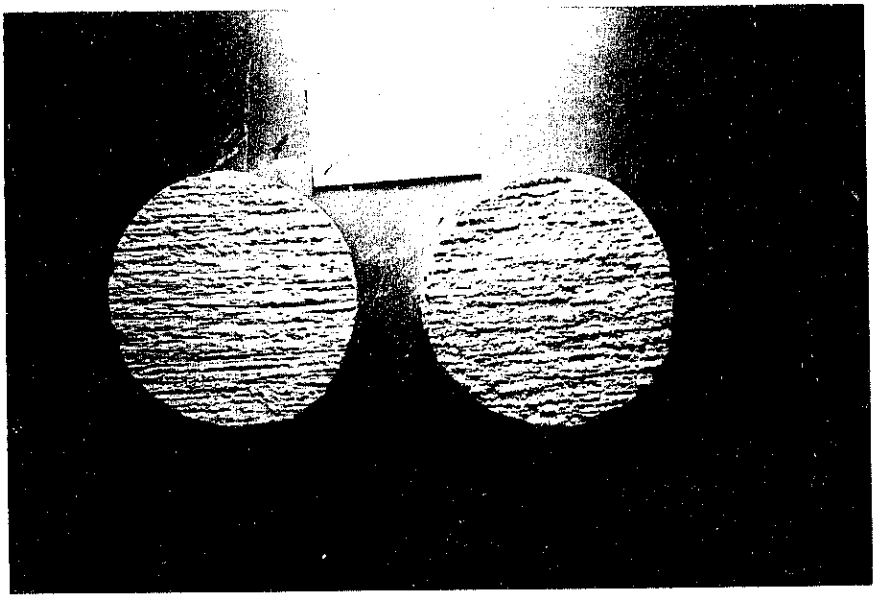


Figure 10. Comparison of plaster of paris casts of the surface of portland cement concrete pavement before testing (left) and after 200 stop applications (right).

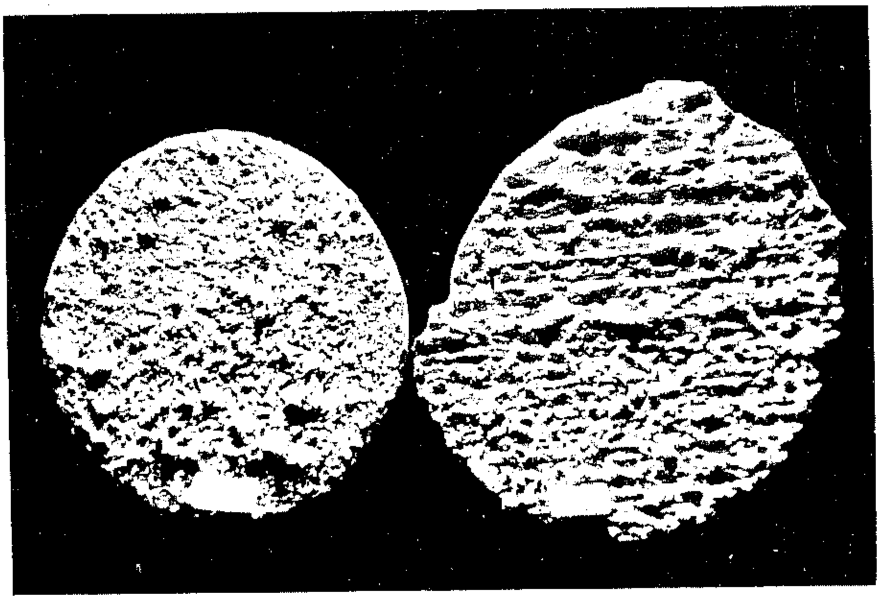
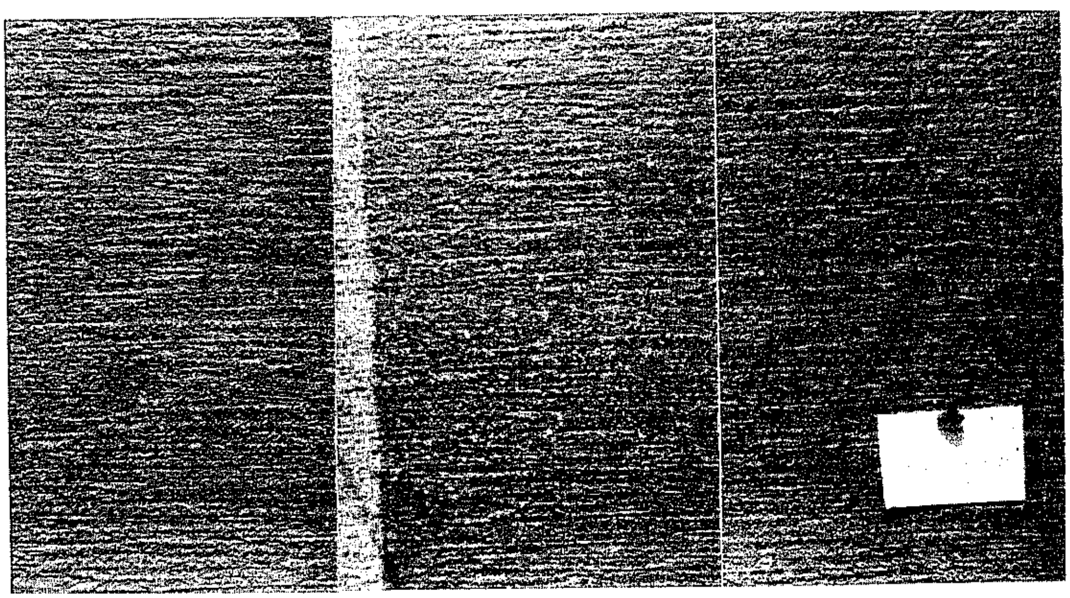


Figure 11. Comparison of plaster of paris casts of the surface of bituminous concrete pavement before testing (left) and after 200 stop applications (right).

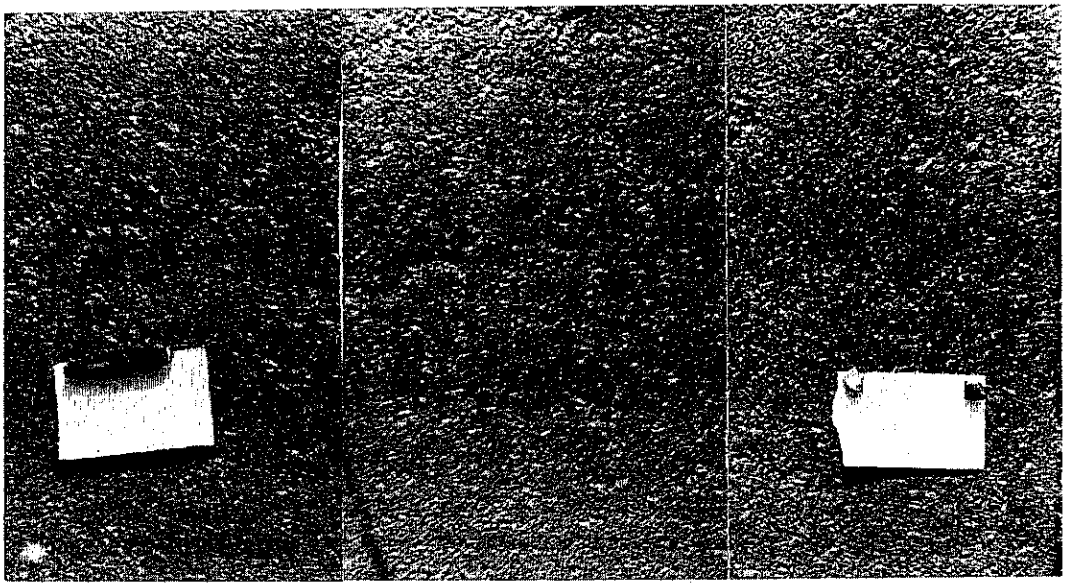
Constant Speed Tests

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. A total of 275 applications of the test vehicles were made on each of the two sections. The results are shown in Figures 12 and 13. Abrasion in this series of tests was indicated only as small pock marks. These marks show as white dots in Figure 12 and as black specks in Figure 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.



(1) After 25 applications
(2) After 125 applications
(3) After 250 applications

Figure 12. Views of portland cement concrete surface after successive applications of constant speed testing.



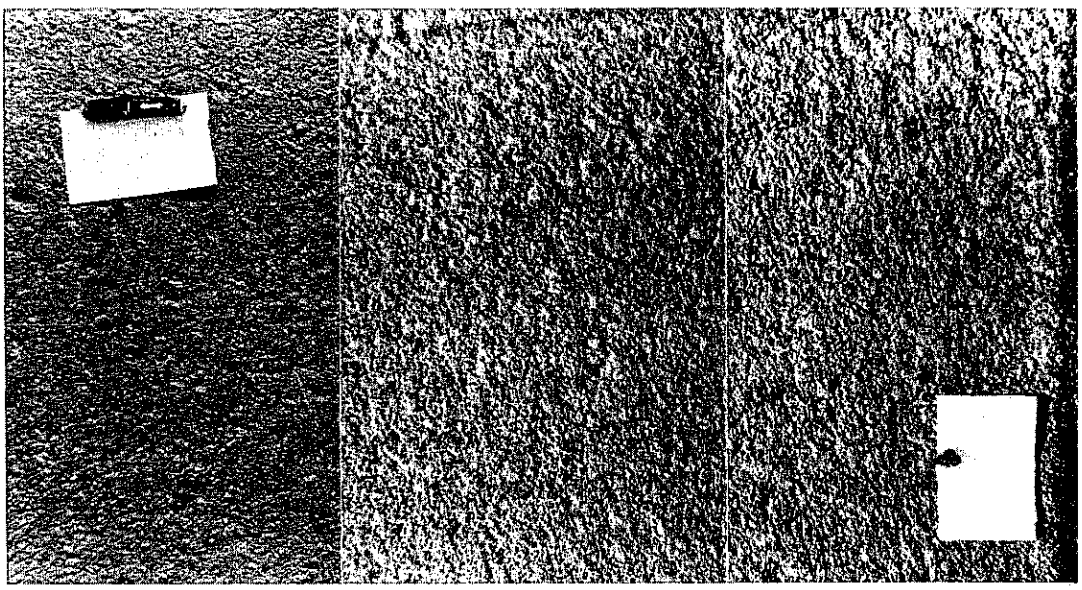
(1) After 25 applications
(2) After 125 applications
(3) After 250 applications

Figure 13. Views of bituminous concrete surface after successive applications of constant speed 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. In Figure 14 is shown the bituminous concrete surface after 25, 125, and 250 applications. The test pavement has a radius of 20 feet 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.



(1) After 25 applications
(2) After 125 applications
(3) After 250 applications

Figure 14. Turning tests on bituminous concrete surface.

Starting and Stopping Tests on Subclass A-3 Surface Treatment

A series of 25 rapid starts followed by 25 emergency stops were 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 Evidence of this is shown in Figures 15 and 16. Figure 15 includes a view of the pavement surface after completion of the testing. A photograph of the plaster of paris casts made before and after testing is shown in Figure 16. The severity of grooving is apparent from the cast shown in the left-hand side of the picture.

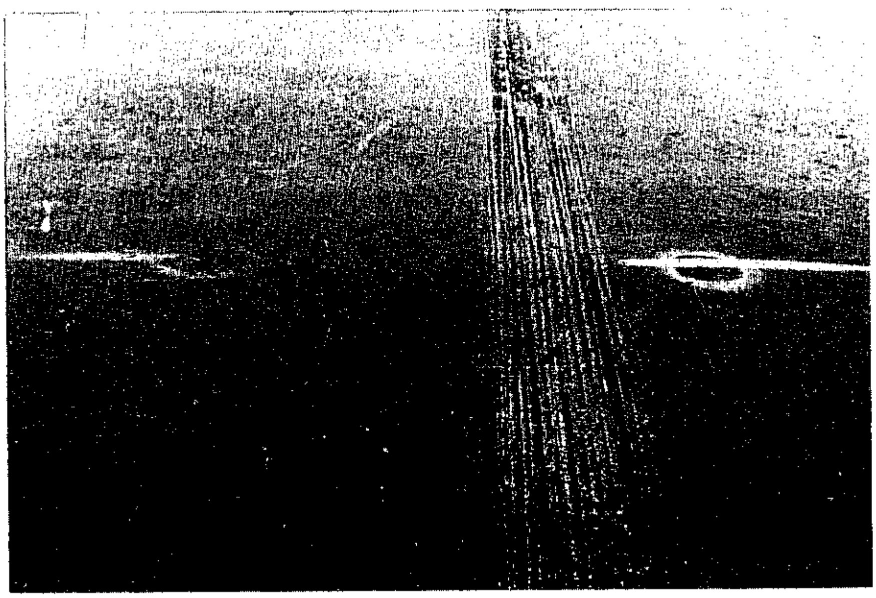


Figure 15. View of Subclass A-3 surface treatment after completion of testing.

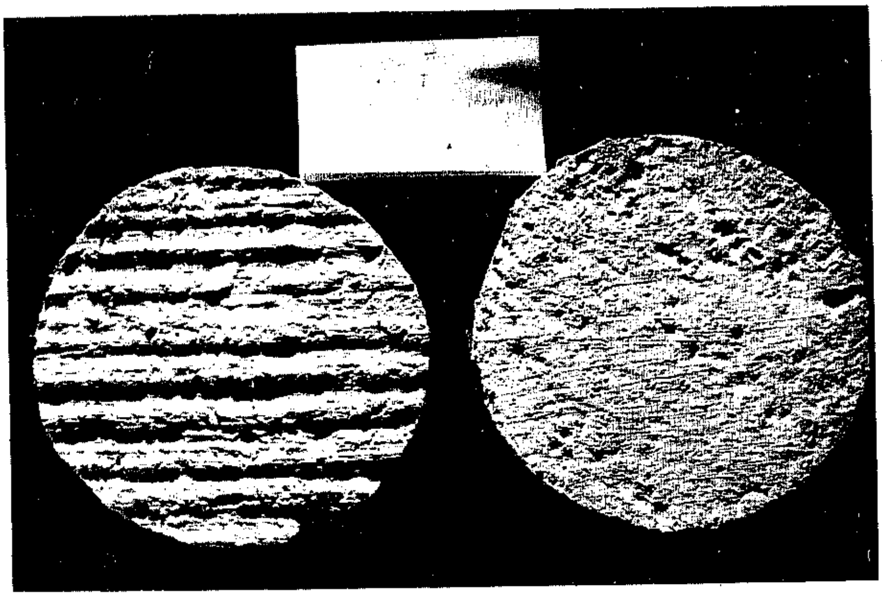


Figure 16. Plaster of paris casts of A-3 surface treatment before testing (right) and after completion of testing (left).

Special Tests

As indicated previously, an effort was made to develop some instrumentation for obtaining quantitative measurements of the depths of surfacing removed by the studded tires. After the tests had gotten under way, it was found that the instrumentation was not yielding reliable results. In recognition of the pilot nature of the tests and the need to complete them quickly, and the uncertainty as to the length of time that would be required to develop satisfactory instrumentation, it was decided that the originally planned series of tests should be completed without the instrumentation.

Following completion of the original series of tests, the instrument that was developed for measuring depth of surface abrasion under the studded tires was modified in an attempt to improve its reliability. When it appeared that some success had been attained, a second series of field tests of the studded tires was undertaken. The additional information to be gained through the use of the modified instrumentation did not appear to be of sufficient importance to warrant a complete repetition of the original tests, so the test schedule was modified accordingly.

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

The "Special Tests" included 25 rapid starts followed by 25 emergency stops on each of three test sections: (1) a section of dry portland cement concrete tested with studded tires, (2) a section of ice-covered portland cement concrete tested with studded tires; and (3) a section of dry portland cement concrete tested with regular tires. Results of the measurements of depth of surface abrasion occurring in the tests are listed in Table 1.

Table 1. Average depression of wheelpath during a total of 50 applications of rapid starts and emergency stops.

Treatment	Average Wheelpath Depression(inches) Dry PCC	Icy PCC	Dry PCC Regular Tires
25 rapid starts	0.040	0.017	0.004
25 rapid starts and 25 emergency stops	0.043	0.019	0.004

Note: Dial readings were taken in triplicate and averaged for the wheelpath depression for each test.

Dial readings indicated that surface abrasion took place in all three special tests. The amount of abrasion with regular tires was appreciably less than that obtained with 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" appeared similar to the results from the original starting and stopping tests. Figures 17 and 18 show an overall view and a close-up of the pavement surface at the end of testing.

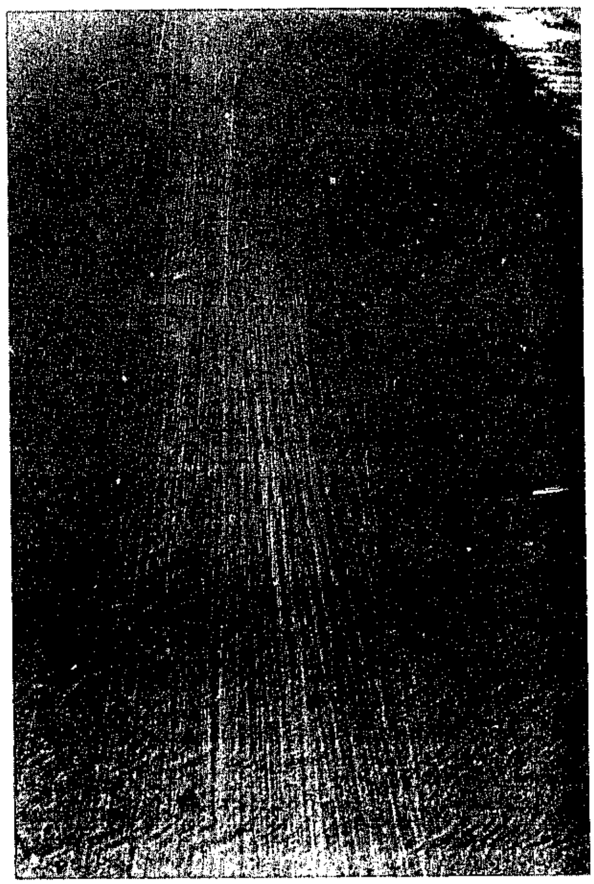


Figure 17. Special Test No. 1 on portland cement concrete - view of pavement surface after completion of tests.

Figure 18. Special Test No. 1 - Close-up of pavement surface after completion of tests.

Icy Portland Cement Concrete Surface, Studded Tires.--Water was poured over the surface of the pavement and allowed to freeze solid. Views of the test surface are shown in Figures 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 (Figure 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.

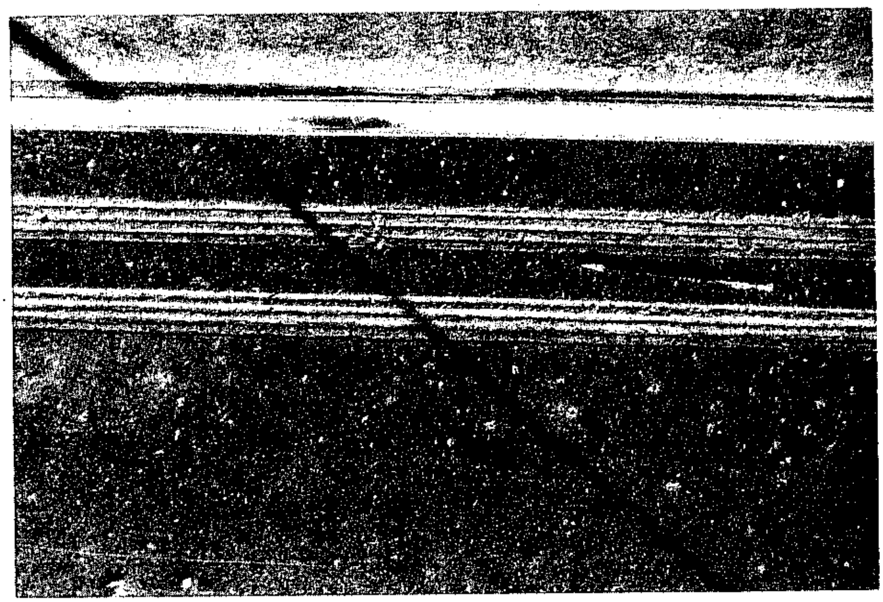


Figure 19. Special Test No. 2 - Icy portland cement concrete surface after three applications of rapid starts.

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. The condition of the pavement surface at the end of the test is shown in Figure 20. Chips on the surface are ice fragments chipped out of the wheelpath.

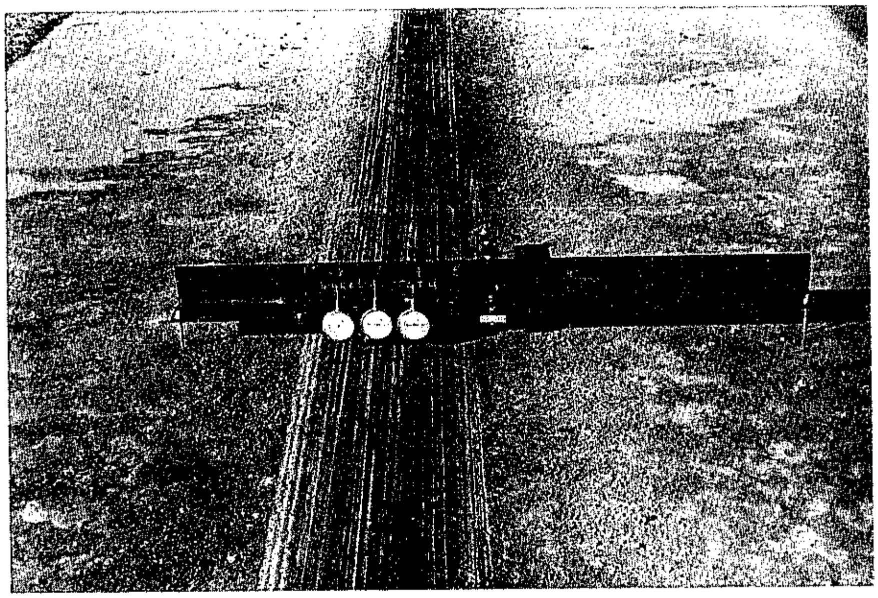


Figure 20. Special Test No. 2 - View of surface after completion of tests.

Dry Portland Cement Concrete Surface, Regular Tires.--This study was conducted as a control test using regular tires and included 25 applications of rapid starts followed by 25 applications of emergency stops. Figure 21 is a view of the pavement surface at completion of testing. Except for the black rubber marks caused by spinning and sliding the tires, no evidence of the test is visible.

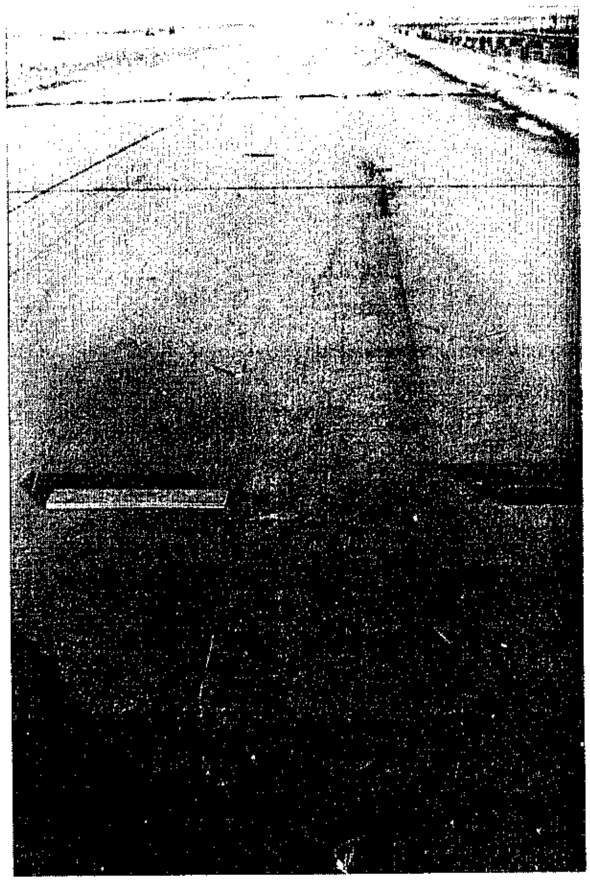


Figure 21. Special Test No. 3 on dry portland cement concrete pavement with regular tires. View after completion of test.

Traction Tests

This test series was undertaken to obtain some information on the relative stopping distances required by vehicles mounted on studded tires and on regular tires. A general impression that studded tires were requiring 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 studded Goodyear tires from the initial study were used, together with regular tires of standard make.

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.

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 miles per hour. Three tire systems were used: (1) four studded tires; (2) two studded tires in the rear and regular tires in front; and (3) four regular tires. The test for each tire system and speed combination was repeated five times, for a total of 45 individual test runs.

Results of the stopping-distance tests on dry concrete pavement are summarized in Table 2. It will be noted that, for rear-mounted studded tires (regular tires in front), stopping distances ranged up to 9 per cent greater than for regular tires; and that for studded tires on all four wheels, stopping distances ranged up to 23 per cent greater than for regular tires.

Table 2. Comparison of Stopping Distances for Regular and Studded Tires

Tire Combination	Required Stopping Distance (Feet) At 10 mph	At 20 mph	At 30 mph
Four Regular Tires	5.9 (1.00)*	18.1 (1.00)	44.6 (1.00)
Two Studded Tires on Rear	5.4 (0.92)	19.5 (1.08)	48.7 (1.09)
Four Studded Tires	6.3 (1.07)	22.2 (1.23)	52.2 (1.17)

*Parenthetical expressions are ratios of indicated stopping distance to stopping distance for regular tires.

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 inch for both the Goodyear and the Allstate tires. The average protrusion of the studs from the tread surface for the Goodyear tires was 3/32 inch before testing and 9/64 inch at the completion of testing. For the Allstate tires, the studs were flush with the tread surface before testing and protruded 3/64 inch from the tread after testing. A view of one of the Goodyear tires showing protrusion of the studs at the completion of the tests is shown in Figure 22.

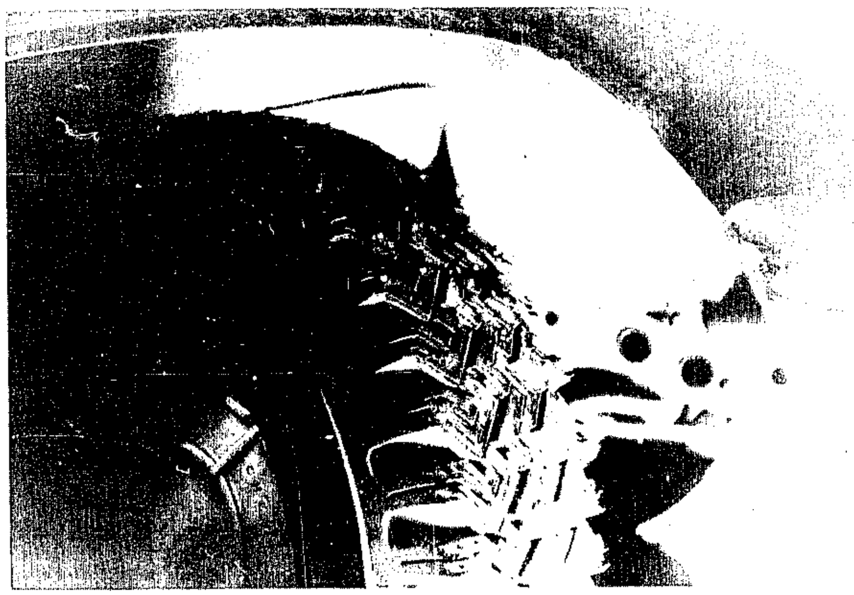


Figure 22. View of Goodyear tire showing protrusion of tungsten carbide studs at completion of testing.

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

SUMMARY AND RECOMMENDATION

Advantages of Studded Tires

(1) Tungsten-carbide studded tires afford better stopping and starting traction on ice and hard-packed snow than do either regular tires or snow tires; but not 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 Illinois, they can be expected to receive far more use on bare pavements than on ice or hard-packed snow covered pavements. It is generally acknowledged that studded tires have an abrasive influence on pavement surfaces; the severity of the abrasive action is controversial.

The results of exploratory tests by the Division of Highways that involved up to 275 passages of typical studded winter tires mounted on passenger cars traveling on dry portland cement concrete, bituminous concrete, and Subclass A-3 bituminous surfaces showed visible evidences of slight abrasion in normal driving and pronounced abrasion under emergency stop and start conditions. Abrasion depths up to 1/16 inch were measured after 25 emergency stops followed by 25 quick starts on a concrete pavement. All pavements tested showed evidences of abrasion; with the A-3 surface showing the most pronounced abrasion.

All tests were conducted with passenger cars. It can be deduced that abrasion caused by studded tires on trucks of greater weight would be even more serious.

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 3/64 inch 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 are interpreted to suggest that abrasion caused by studded tires at locations of frequent stops and starts, or where frequent turning movements occur, probably would lead in some circumstances of heavy traffic to the need for special maintenance.

(2) Studded tires appear to be less safe on dry pavements than regular tires.

Exploratory tests by the Division of Highways showed up to 23 per cent more stopping distance needed on dry pavements for a vehicle mounted on four studded tires as compared with regular tires. Nine per cent 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 less than 200 vehicle-miles of travel, four studs were lost from one tire, and one stud each from two other tires.