Effects of Studded Tires on Pavement Wear and Traffic Safety

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INTRODUCTION

The question of whether the use of metal studs in automobile tires should be permitted as an aid to winter driving has been a highly controversial issue in Minnesota for a number of years. The state legislature in biennial sessions had legalized their use on Minnesota roads and streets for six successive winters from October 1965 through May 1971. But during its last session, in 1971, the legislature did not renew the permissive legislation, thus reverting to the previous old law under which studs were prohibited. However, at the same time a new statute was enacted which granted to nonresidents of Minnesota the privilege of driving in the state with studs up to 30 days in a calendar year.

The 1969 legislature had directed the Minnesota Commissioner of Highways to conduct a study of pavement wear and traffic safety as affected by studded tires and to report to the 1971 legislature to assist it in making a determination as to its source of action on future legislation. The Minnesota Highway Department undertook extensive research both with its own personnel and through contract agreements with outside agencies, and the results were reported to the legislature in May 1971.

Preliminary descriptions of these research efforts were reported at the Purdue Road School in 1970. Additional results of research studies are reported below.

PAVEMENT WEAR ASPECTS

Field Pavement Wear Observations

To illustrate how highway surface wear had continued to progress through the six winters, a series of figures will show the condition of two high-traffic pavements after about five or six winters of studded tire traffic.

Figure 1. This is a Portland cement concrete pavement with gravel aggregate after five winters of studded tire traffic—approximately 10,450 ADT per lane—estimated 1.7 million total studded tire passes.

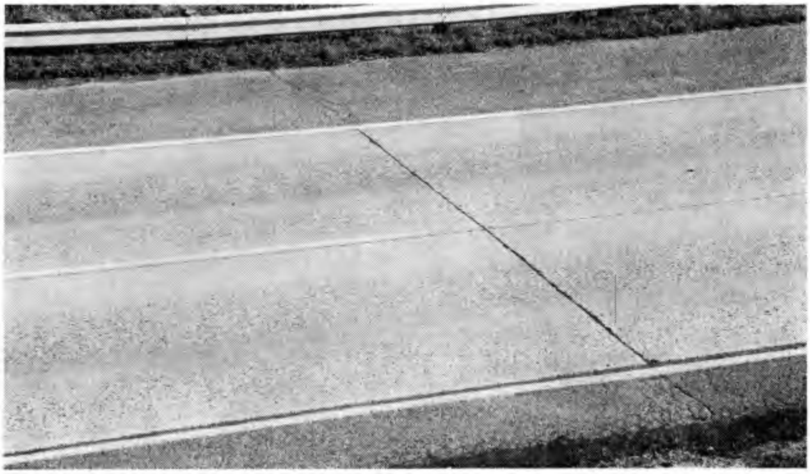
Figure 2. A close-up of the pavement at a measurement point on the same highway as in Figure 1 shows the depth of wear (0.32″) beneath the straightedge.

Figure 3. The same concrete pavement as previously shown but after six winters and an estimated 2.3 million total studded tire passes. The nearly full-width wear beneath the 10-ft straightedge illustrates how the wear pattern has gradually widened because of lateral shift of traffic to avoid driving in the roughened wheel paths. Mid-point of the lane now shows wear.

Figure 4. Another transverse profile of wheel path wear in an interstate concrete pavement containing limestone aggregate. Four tenth-inch wear depth in wheel paths beneath 10-ft straightedge after 4½ winters of studded tire traffic—approximately 17,500 ADT per lane—estimated 1.9 million total studded tire passes.

Figure 5. An asphaltic concrete pavement; gravel aggregate after six winters of studded tire traffic—approximately 9,800 ADT per lane—estimated 1.0 million total studded tire passes.

Figure 6. Close-up of the same pavement as shown in previous Figure. Depth of water 0.41 in. beneath the straightedge. Surface wear effect on texture is much the same as for Portland cement concrete.



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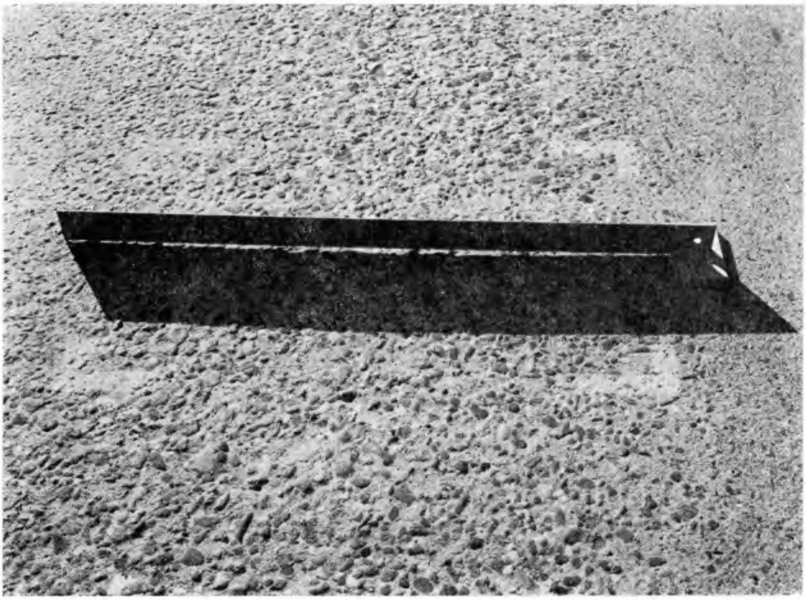

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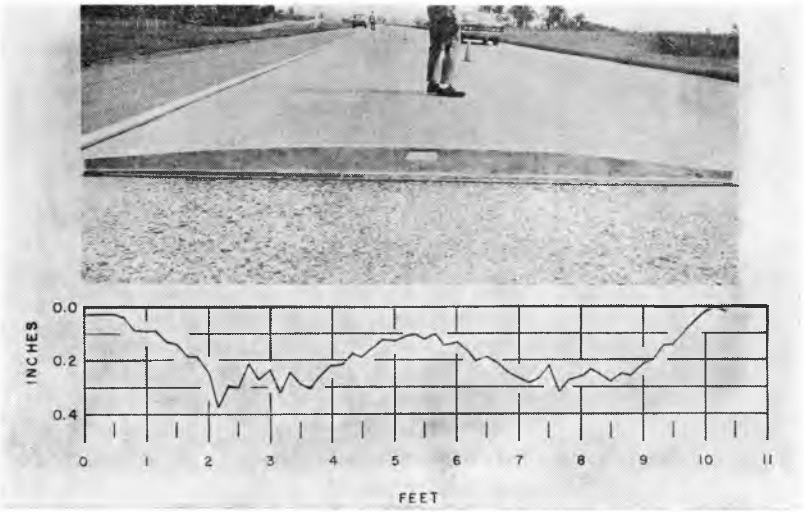

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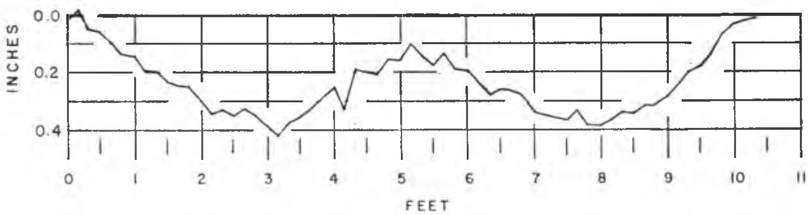
Figure 7. Safety grooving in Portland cement concrete—no studded tire traffic. Grooves ⅛ in. x ⅛ in. and ¾ in. apart.

Figure 8. Safety grooving in Portland cement concrete—two winters of studded tire traffic—grooves completely worn through.

Figure 9. In this figure are shown a series of projected composite average wear rate curves developed for each of several different generalized pavement types. The curves illustrate that the rate of wear is definitely influenced by the pavement composition.



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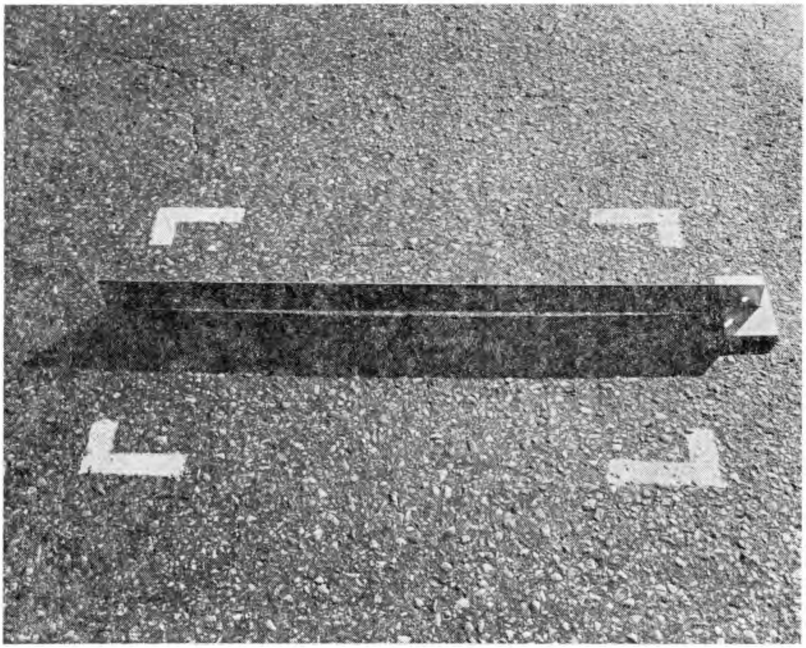

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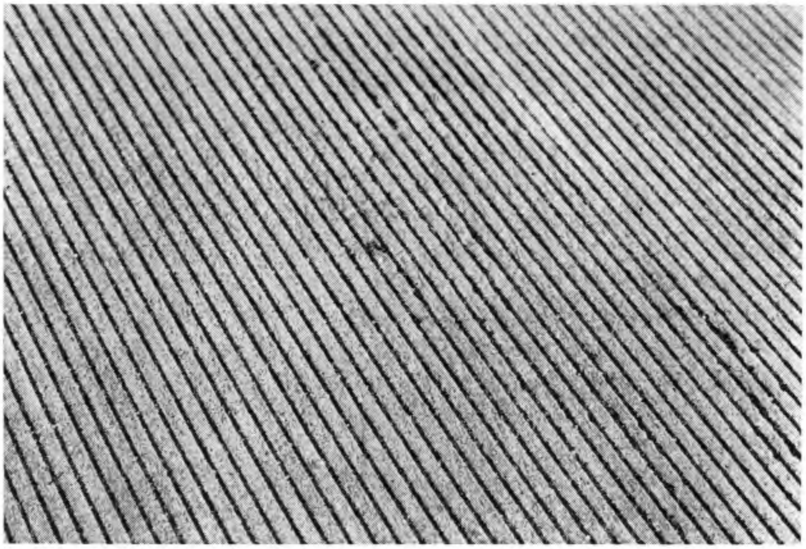
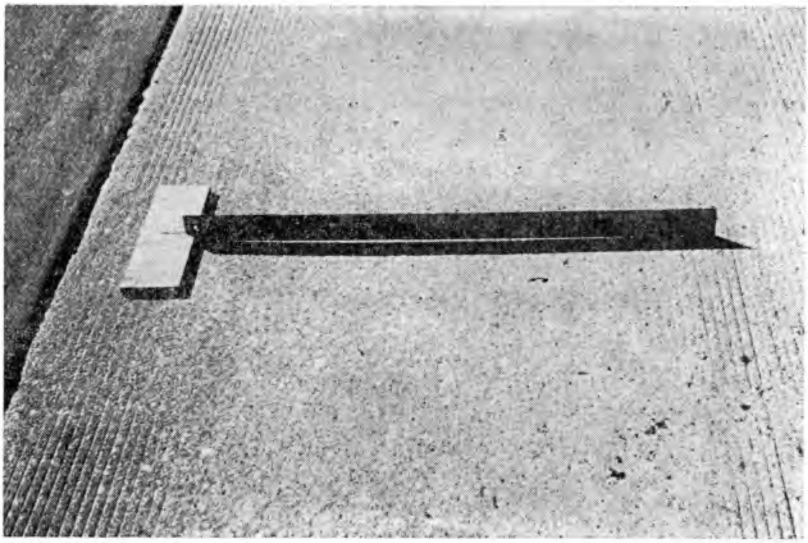


Figure 7. Safety grooving in Portland cement concrete—no studded tire traffic. Grooves $\frac{1}{8}$ in. x $\frac{1}{8}$ in. and $\frac{3}{4}$ in. apart.



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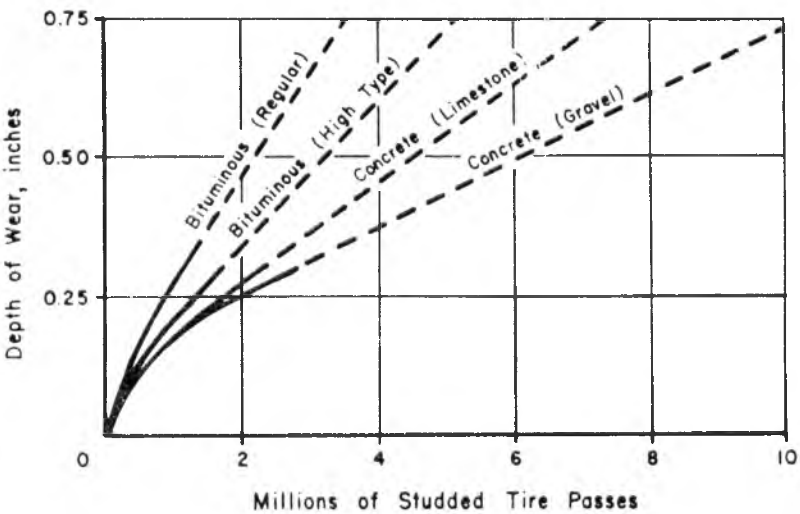

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Table 1—As a basis for estimating what the additional cost might be for future repair of studded tire damage to road surfaces, a judgment was made that the maximum depth of wheel path ruts that could be safely tolerated by traffic would be ¾in. For bridges the maximum depth considered allowable was set at ½ in. because of the possible detrimental effect that decrease of effective concrete thickness and corrosion of reinforcing steel might have upon the structural strength of the decks.

From the pavement-wear-rate curves a determination was made of the number of studded tire passes that will produce the critical rut depth for each pavement type as shown in this table:

TABLE 1.
STUDDED TIRE PASSES TO WEAR ¾ INCH

Pavement Type	*Millions*
Concrete—igneous gravel	10.1
Concrete—limestone	7.4
Bituminous concrete	5.1
Bituminous—intermediate	3.8

Computations were made to determine when each segment of state trunk highway and each bridge structure would have to be resurfaced if studded tires were continued in use. Resurfacing costs were based on using a bituminous overlay with a 1½-in. wearing course over sufficient leveling course to fill the ruts on roadways. Bridge deck repair would generally require other techniques such as an inlay rather than overlay, together with removal of damaged concrete and replacement with concrete patches.

In addition to rehabilitating existing worn pavements in the future, it is likely that, if studs were to continue, new pavement construction would probably utilize more costly materials to achieve greater wear-resistance. Taking into account the findings of the American Oil Company study, the increase in construction costs, as it would apply to the projected highway construction program, was also calculated.

The combined additional costs thus attributable to studded tires were estimated at $2.8 million by 1973 when, it was expected, a start on resurfacing would have to be made. By 1979 the yearly added cost would be expected to reach $13.3 million. Through 1980 the cumulative total was estimated at $55.2 million. These costs do not include normal maintenance repairs associated with structural deterioration such as normally caused by vehicle loads or climatic effects; they are only the added costs induced solely by studded tire effects.

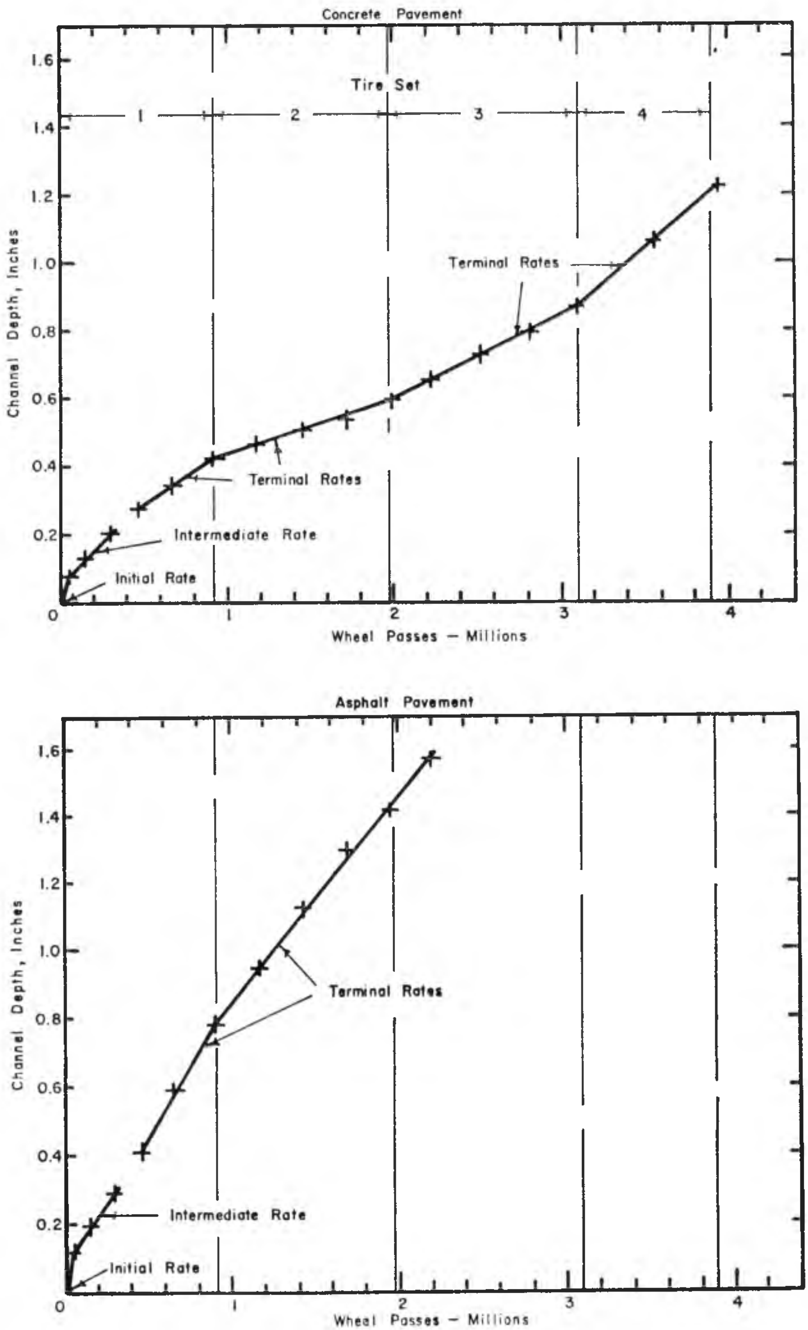


Figure 10. Typical wear rates at test track.

Laboratory Pavement Wear Study

Figure 10. In the American Oil Company laboratory study, a series of conventional pavement mixtures, both bituminous and Portland cement concrete, and a number of special pavement mixtures were subjected to the abrasive action of rotating, loaded, automobile wheels to determine the damage caused individually by studded tires, salt and abrasive sand. A total of 48 test slabs were included, 23 being bituminous, 24 Portland cement concrete, and one an epoxy resin-sand mixture.

As each test run progressed, periodic precise wear depth measurements were taken transversely across the wheel paths. Plots were made of the wear depth versus number of wheel passes, as shown in Figure 10. The upper curve is for a typical Portland cement concrete test pavement, and the lower curve for an asphalt test pavement. Differences in wear rates are obvious.

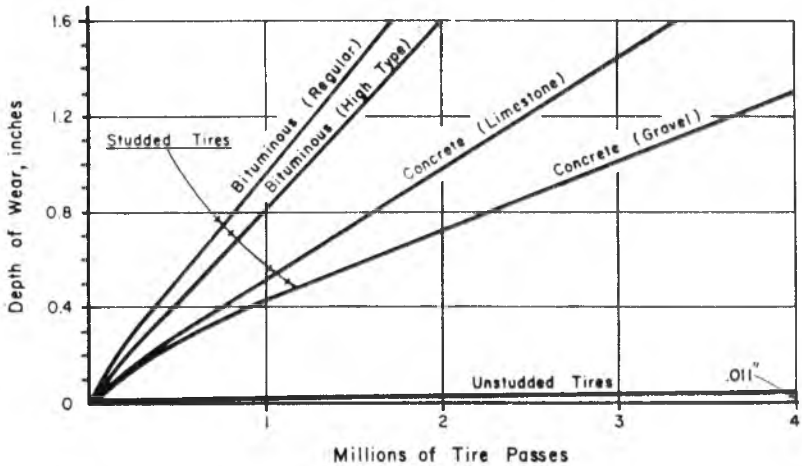
The wear rates indicated that the upper 0.1 inch of pavement wore most rapidly, being composed chiefly of Portland cement mortar or fine sand-asphalt mixture. This is referred to as the "initial" wear rate. The wear rate for the second zone, from about 0.1-in. to 0.2-in. depth, was somewhat slower, and is referred to as the "intermediate" rate. Beneath a depth of about 0.2 in., the wear rates, called "terminal", diminished perceptibly, apparently because of the presence of the coarse aggregate particles.

Analysis of the data for different sets of test tires revealed that the amount of stud protrusion varied from one set to another and rate of pavement wear increased with increase in stud protrusion. To obtain consistent data all wear rates were adjusted to a common base of 0.040-in. protrusion, which was selected because it represents the approximate average for the entire laboratory study.

Figure 11. The curves shown in Figure 11 represent the average laboratory wear rates produced by studded tires, with sand and salt applied, for four different generalized categories of pavement surfaces. The wear data have been adjusted also to the common base of 0.040-in. stud protrusion.

For unstudded tires the pavement wear, shown by the curve barely visible at the bottom of the chart, was hardly measurable, despite the simultaneous surface applications of sand and salt.

For the normal bituminous wearing courses the average terminal wear rates ranged between 0.75 and 0.95 in. per million studded tire passes. For conventional concrete pavements the corresponding wear rates ranged from 0.30 to 0.47 in. per million studded tire passes. The



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influence of different mix compositions, such as the kind of coarse aggregate, was reflected in different wear rates, as was also previously shown for real road surface wear rates. Concrete made with good quality gravel aggregate composed predominantly of hard igneous pebbles experienced the lowest wear rate among the commonly used paving mixtures. Concrete produced with a limestone coarse aggregate suffered a faster wear rate. Conventional bituminous mixtures, of both the higher type asphaltic concrete and of an intermediate or "regular" type, each in turn showed progressively more rapid wear.

Figure 12. This figure shows sections removed from two representative pavement test slabs after termination of their laboratory test runs. Unstudded tires had operated over the left-hand side of each slab; studded tires over the right side.

For unstudded tires with sand and salt applied, the average of the wear depths on all conventional test pavements was only 0.011 in. for more than four million tire passes, on an average rate of 0.0027 in. per million passes. This was less than one percent of the wear rate caused by studded tires on even the best concrete pavements. Thus the studded tires caused at least 100 times more abrasion damage than the wear increase produced by sand and salt with unstudded tires. Salt alone with unstudded tires produced no measurable pavement wear. The wear from sand and salt was scarcely measurable for unstudded tires after four million passes. The evidence seems inescapable that

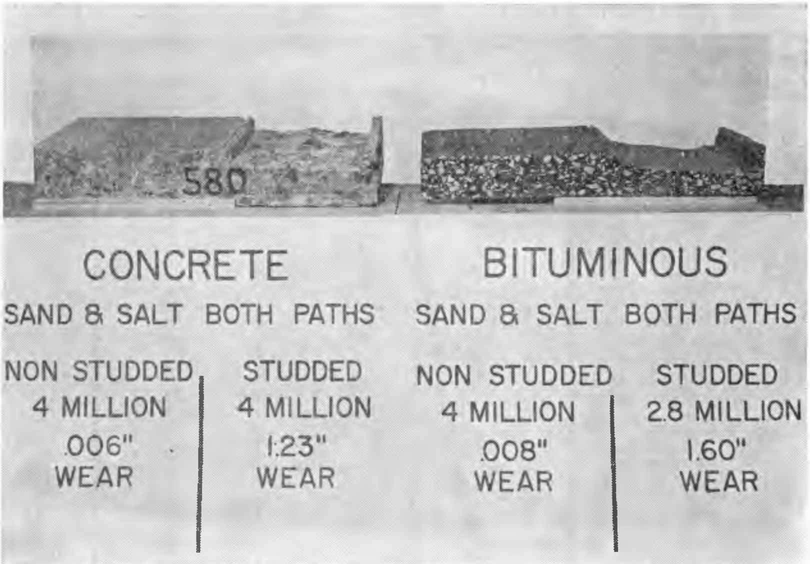

Figure 12. Laboratory wear on concrete and bituminous pavements.

the studded tires are by far the prime cause of pavement abrasion. It is clear also that sand and salt applied on good quality, air-entrained concrete or on asphalt pavements have little or no measurable wear effect when studded tires are not involved. When studs are involved, sand and salt do contribute measurably to the rate of wear.

In the special mixtures tested to evaluate whether greater wear resistance could be developed, wear reductions from 10 percent to as much as 50 percent, in one case, were achieved by use of trap rock or granite aggregates, by increasing the binder content, or, as in bituminous mixtures, by addition of rubber and asbestos together with the better aggregate. However, the increase in cost of materials would generally correspond about proportionately with the wear reduction achieved. A liquid surface hardener for concrete was ineffective. The most resistant surfacing was the epoxy resin-sand mixture, but the resultant surface would be too smooth and slippery for highways while the cost would be three to four times that of conventional concrete. Based on these results, it appears that no cost advantage would be gained by efforts to modify the paving mixture composition. There could, however, be some potential advantage in using better though more costly mixtures, particularly on roads that would be subjected to high studded tire traffic, thereby reducing the frequency of repair and attendant inconvenience to traffic.

Figure 13. The relationship between laboratory pavement wear and actual highway wear is shown by this graph which has been corrected for the adjusted test track wear rates based on 0.040-in. stud protru-

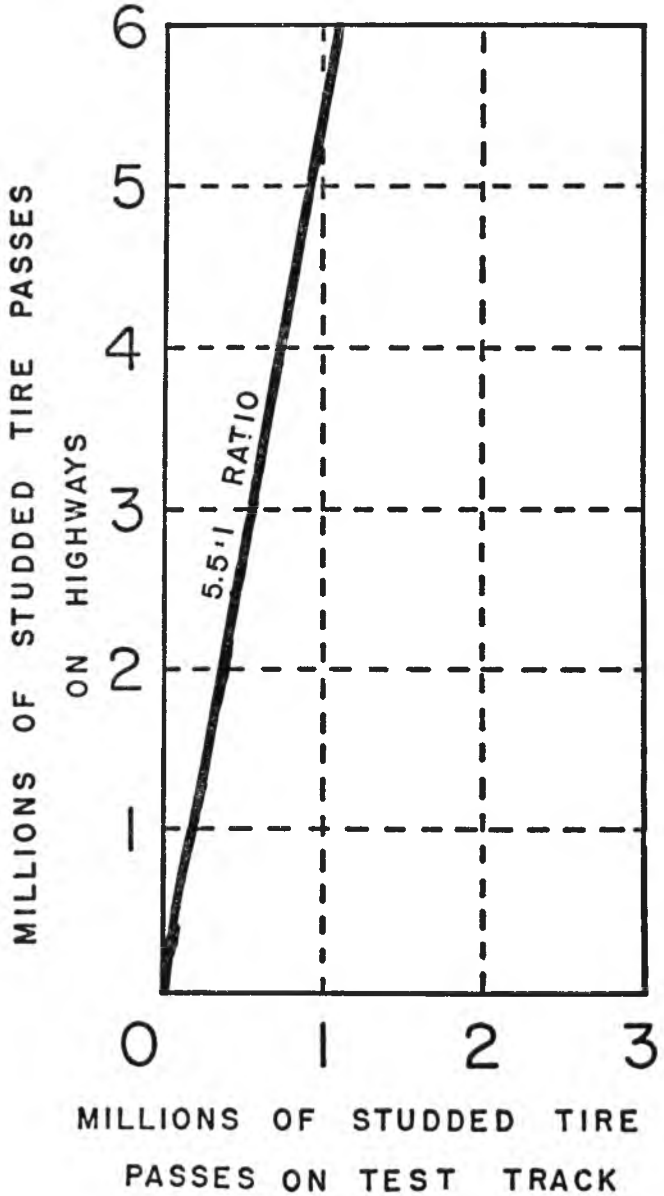

Figure 13. The relationship between laboratory pavement wear and actual highway wear.

sion. The slope of the curve is about 5.5:1, indicating that, on the average, the same wear depth produced by one million studded tire passes on the test track would be produced by 5.5 million passes on a highway surface of the same type. It was found that this ratio, 5.5:1, was substantially valid for all of the conventional pavement types.

TRAFFIC SAFETY ASPECTS

The third phase of the 1969 legislative directive to the commissioner of highways required that he, "Evaluate the effects, if any, that discontinuing the use of studded tires will have on highway safety."

Studded tires affect the performance of a vehicle in some degree as long as they are on the vehicle, and this can be on any pavement surface, even though it may not be icy and slippery. Furthermore, the physical effects that have been produced by studs on pavement surfaces can influence vehicle behavior the year around in some ways that are detrimental to safe travel. Therefore, any evaluation of studded tires should encompass all vehicle travel the year around, rather than only under winter conditions. Limitations on the performance of studded tires must also be recognized as well as the adverse driving effects they have created.

Road Condition Influence on Accidents

Figure 14. As seen in this figure, the total annual number of reported traffic accidents in Minnesota increased almost steadily from about 60,000 in 1958 to more than 100,000 in 1969 and 1970, except for declines in two years—1963 and 1970. In the latter case, the decline followed a national trend for that year. Not shown in the graph is the total of accidents in 1971, which has only recently been reported as about 104,000, thus reversing the decline seen in 1970. Interestingly, the annual increase in total accidents had continued to progress at a fairly uniform rate even after 1964, the year when studded tires first appeared in Minnesota.

As shown also in this graph, between the upper two curves, the proportion of all reported accidents that occurred on snowy and icy roads over the 13-year period averaged about 22 percent, ranging between 16 and 29 percent.

While the figures for total accidents and fatal accidents that have occurred in the winter 1971-72 are not yet available, the elimination of studs has not produced any obvious trend in the unadjusted data collected to date on fatalities or total accidents.

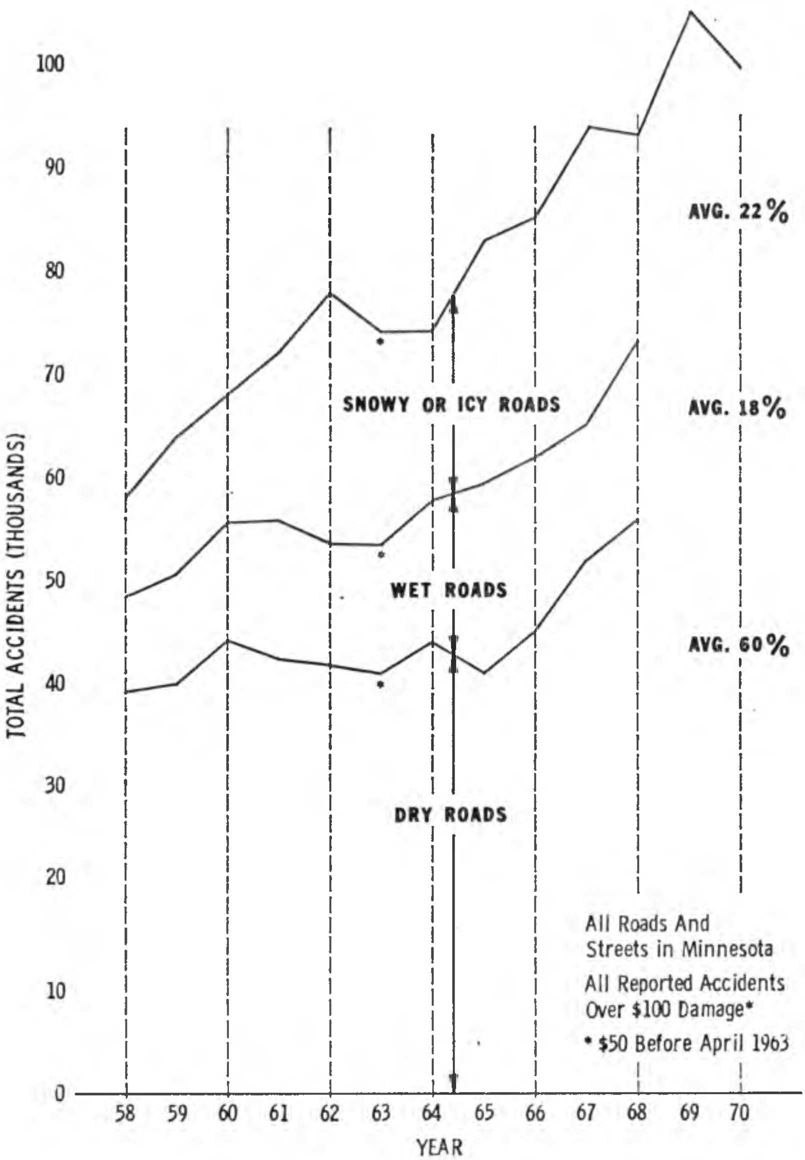

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Table 2 shows a tabulation of the proportions of time in the winter of 1969-70 that different surface cover conditions prevailed on various types of roads and streets. These data are based on about 18,000 observations made on representative thoroughfares in the Minneapolis-St. Paul urban area and surrounding rural areas.

TABLE 2.
WINTER ROAD COVER CONDITIONS—
PERCENT OF TIME (1969-70)

Road Type	*Bare*	*Icy*	*Snow*
Freeways	96%	2%	2%
State highways	90	4	6
County roads	74	11	15
Township roads	47	29	24

On freeways in the metropolitan area where studded tires could potentially be of some help, icy conditions existed only two percent of the winter time. State highways were bare for 90 percent of the time in winter, while even on county roads the surface was bare three-fourths of the time.

Similar observations in the metropolitan area for the winter 1970-71 yielded quite comparable findings.

For the winter 1971-72, observations have been made statewide. Incomplete results indicate that, on the average, state highways including freeways were bare 88 percent of the time, and icy only 3.4 percent of the time. The remaining eight percent of the time these roads were snowy or slush-covered and judged to be such that studs were considered not helpful.

County and township roads were bare 74 and 52 percent of the time, and icy 11 percent and 32 percent of the time, respectively. Urban streets were bare from 46 to 68 percent, and icy from 15 to 30 percent of the time.

Since the volume of traffic on the different types of roads varies widely, computations were made, as shown in Table 3, to show the proportion of winter travel for each of the general road cover conditions during the winter of 1969-70.

From this table it is seen that, on the average, in that winter about 25 percent of the winter travel was on snowy and icy roads. Since the winter travel during the 6½ month studded tire season

TABLE 3.
PROPORTION OF WINTER TRAVEL (1969-70)

	Road Cover			
Road Type	*All*	*Bare*	*Icy*	*Snowy*
Freeways	11%	10.6%	0.2%	0.2%
State highways	37	33	2	2
Local roads, streets	52	31	11	10
Total	100	75	13	12

(October 15-May 1) amounted to 48 percent of the total annual travel, only about six to seven percent for all the annual travel was on icy surfaces where studded tires could be of potential aid. Conversely, for 93 to 94 percent of the yearly travel, studded tires would have provided no benefit.

Studded Tire Influence on Vehicle Performance

The advantages of studded tires have generally been ascribed to their ability to improve upon the stopping, cornering, and traction performance of a vehicle when operating on a smooth ice surface. It has been commonly considered that their greatest advantage is the ability to reduce the stopping distance on ice and that this is the most important element of vehicle safety. The extent of this stopping capability has been amply demonstrated by numerous driving tests such as those conducted and reported by the National Safety Council Committee on Winter Driving Hazards, the Canada Safety Council, and the Ontario Highway Department. This feature will not be elaborated on at this time.

Control of a vehicle on ice when traveling in a straight line may be enhanced somewhat by use of studded tires on the rear wheels. But cornering and maneuvering, such as in making lane changes, are not improved by use of studded tires unless all four wheels are so equipped. The ability to maintain control of the vehicle's direction of travel under all conditions without losing control is now indicated to be even more important to safe operation on the road than is the stopping capability. The Cornell Aeronautical Laboratory safety study, to be discussed later, indicates that the vehicle preimpact behavior most frequently noted in connection with the accidents in that study was loss of directional control—not a lack of stopping capability.

Improvement of starting traction on icy surfaces through use of studded tires has also been rated highly as a benefit by many motorists. However, this is more often a matter of convenience rather than of safety, though some safety advantage may be ascribed to improved traction under certain conditions, such as when crossing a busy street intersection on glare ice or when climbing an icy hill and it becomes necessary to back down because of slippage.

Adverse Effects of Studded Tires

Aside from the diminished stopping ability of studded tires on bare pavements, there are other detrimental effects produced by studs that have year-round influence upon traffic safety. These effects are the direct consequences of the physical damage they cause to the pavement surfaces. Most of these effects have not been evaluated quantitatively by research data but are based on observations and driving experience. Included among such effects are the following:

1. Formation of shallow ruts or troughs in the pavement wheel paths that interrupt normal transverse run-off of water, cause more splash and spray onto adjacent vehicles and reduce driver visibility. Water accumulation may also contribute to occurrence of hydroplaning.
2. Destruction of longitudinal pavement grooving that had been provided as a safety measure, particularly on curves where skidding was a problem.
3. Accelerated loss of paint stripes used to delineate pavement lanes.
4. Roughening of the pavement surface in the wheel ruts causing vibration of vehicles accompanied by pronounced noise increase both inside and outside the vehicle.
5. Adverse effects on vehicle handling, especially when performing lane-changing and passing maneuvers.
6. Lateral displacement of vehicles, tending to shift from the normal center-of-the-lane courses and to crowd toward vehicles in an adjacent lane in the effort to avoid driving on the abraded rough-textured wheel path.

Cornell Aeronautical Laboratory Study of Studded Tire Safety

The Minnesota Highway Department initiated the study of Cornell Aeronautical Laboratory, Inc. (CAL) to ascertain if studded tires do, in fact, provide any greater safety in real world mixed traffic on the highways and streets under all conditions.

The general approach of the study was to compare the performance of autos with studded tires to that of autos with other tire types in terms of three potential effects of studded tires, namely: (1) reduced likelihood of being involved in an accident due to sliding, (2) improved preimpact control, and (3) reduced accident severity. Data for the study were collected through questionnaires sent to Minnesota registered automobile owners and through accident reports submitted by highway patrol officers and police of 11 municipalities.

Collection of data for the study was carried out between February and May 1, 1970 and from October 15, 1970 to January 4, 1971, the termination date for the study. This provided a total observation period of 5½ months. All questionnaires and accident reports were gathered by the Highway Department and forwarded to Cornell for coding, processing, analysis and report preparation. A large volume of data was gathered and numerous analyses made seeking significant relationships.

About 84,000 questionnaires were mailed, with a return of 47 percent. Of these, the sample coded and used in the study consisted of 17,040 returns. The main functions of the questionnaire were to determine the proportion of vehicles equipped with each type of tire and to measure the amount of their exposure to various road cover conditions. Responses from the questionnaire, as reported by Cornell, revealed the following for the total study period:

1. Thirty-six percent of the autos were equipped with studded tires, but only about one percent had them on all four wheels.
2. Thirty-eight percent of the driving during the study period was with studded tires, about 23 percent with snow tires, and about 39 percent with regular tires.
3. Six percent of all driving in Minnesota during the 6½ month studded tire period was on roads reported as completely covered with ice, snow, slush or frost. Another six percent was on roads mostly covered, and 18 percent on roads with scattered cover. The remaining 70 percent of travel was on roads essentially bare. This figure corresponds reasonably well with the 75 percent estimated independently by the Highway Department.
4. Only about one-third of one percent of the respondents refrained from driving because of icy or snowy road conditions.
5. Tire type used during the winter can be correlated, to a degree, with vehicle and owner characteristics such as auto size, body style and model year; and with owner age, sex and annual mileage.

6. Regarding nonaccident performance, respondents indicated that studded tires had a slight advantage over snow tires in terms of susceptibility to sliding.

Accident reports collected during the 5½ month study period totaled about 4,500. This contrasts with the nearly 60,000 accidents that occurred in Minnesota during the periods in 1970 when studded tires were legal. The accident reports were provided principally by the Minnesota Highway Patrol, with participation by the police departments of the metropolitan cities of Minneapolis and St. Paul, together with nine other municipalities. Some of the findings and conclusions from the accident study as reported by Cornell included the following:

1. Twenty-one percent of all accidents during the study period were precipitated by vehicles sliding on ice or snow. Thirty percent of the single vehicle accidents were precipitated by sliding. Of all autos in accidents, 14 percent were said to have been involved due to slippery winter road surfaces.
2. Accidents caused by sliding on slippery winter road surfaces were, on the average, less severe than others, as measured by the degree of injury and by depth of penetration of the vehicle upon impact.
3. The probability of precipitating an accident due to sliding on snowy or icy roads was least for studded tire vehicles, followed by snow tire vehicles, then regular tire vehicles.
4. Accident rates which showed advantages for studded vehicles even on roads that were primarily bare suggest that there are extraneous effects that influence the results. After adjustments were made to attempt to correct for these extraneous effects, the adjusted sliding accident rates showed a slight advantage for studded tires over snow tires, with both the studded and snow tires outperforming regular tires.
5. In accidents attributed to sliding, the most frequent preimpact behavior was loss of directional control. Of all trigger vehicles (those causing accidents) that were involved due to sliding, 69 percent were considered to be associated with loss of directional control. Twenty-eight percent were associated with prolonged stopping distance and only three percent with reduced acceleration. Stopping distance is therefore seen to be of less significance than generally supposed.
6. On dry roads, regular tires performed best with regard to preimpact rotation, and studded tires were poorer than both reg-

ular and snow tires. On wet surfaces there was little difference in preimpact rotation among the three tire types. On snow-covered roads both snow tires and studded tires were better than regulars; and only on ice-covered roads were the studded tires superior with respect to preimpact rotation.

7. For vehicles that precipitated accidents because of sliding, studded-tire vehicles usually performed better than snow-tire vehicles, and snows were usually better than regulars in terms of reduced impact speed and preimpact rotation. For driver injury, studded-tire vehicles had an apparent advantage, with little difference between snow-tire vehicles and those with regular tires. These tire effects were most evident in single vehicle accidents.

Analysis of Cornell Study

The research conducted by Cornell Aeronautical Laboratory (CAL) attempted to determine if studded tires were of sufficient value to provide real world benefits in normal usage. The factors causing accidents and affecting their severity are so numerous and complex that it is extremely difficult to isolate and quantify the effect of any single factor such as tire type. It was determined that a major obstacle to drawing inferences about tire effects was the apparent presence of driver effects which correlated with tire type and thus influenced the results that might otherwise have been ascribed to tires. No way was found to completely eliminate the influence of variables that were extraneous to tire type.

The data from the CAL study indicate that on icy or snowy roads the use of studded tires provides some observable, though slight, advantages over other tires in terms of accident precipitation, vehicle behavior in emergencies and driver injury. Results reflecting sliding accident rates, when corrected for extraneous effects, showed studded tires to have only "a mild advantage over snow tires on snowy or icy roads during the winter months" (December through March).

Because of the apparent extraneous effect of driver characteristics upon accident precipitation, any increase in the number of traffic accidents on snowy and icy roads that might occur if studded tires were replaced with unstudded snow tires would be slight when compared to the total number of accidents normally occurring in Minnesota.

Accident severity and preimpact behavior may be similarly affected by extraneous driver-associated influence, as in the case of accident precipitation, but the exact nature and extent of such effects are not known. Because of these uncertainties together with the limited data in many categories, the degree of increase in accident severity that might occur if studded tires were replaced by unstudded tires cannot be reliably estimated. In any event, the effect of tire type upon accident severity and preimpact behavior is probably limited by the already lower-than-average severity of winter accidents that has been induced, in part at least, by increased driver care.

The CAL report concludes that as one result of conditions encountered in the study (i.e. accident complexity, uncontrolled sampling, and driver effects), the data developed were judged to be of such nature as would not permit "overall quantitative estimates of studded tire effects in terms of accidents prevented, lives saved, etc." Contributing to that conclusion is the fact that the data available for determining the accident rates and other performance ratings in the report are frequently so few in number that the reliability of the results and conclusions is uncertain.

Summary of Studded Tire Issue

The CAL study, by design, takes into account only the facts and relationships disclosed for the limited study period, primarily in the winter months. Time did not permit including consideration of those other conditions that prevail during the remainder of the year nor of adverse effects on traffic that are induced by pavement wear caused by studs. When all these aspects are taken into account with respect to overall, year-round traffic safety, the relatively slight advantage that can be attributed to studded tires on the basis of the CAL study becomes less significant.

In light of the fact that 75 percent of all Minnesota winter travel in 1969-70 was on bare pavements where studded tire provide no benefit and only about 13 percent of the winter travel was on icy roads where studs could potentially be beneficial, it is not reasonable to conclude that, in the overall, any advantages of studded tires on ice would be offset by their disadvantages on bare pavements.

On the other hand, since the use of studded tires is presently practically eliminated from Minnesota roads, the accelerated surface wear problem has been substantially arrested, and the prospective need for a program of rehabilitation of stud-worn pavement surfaces greatly diminished. Measurements of pavement wear experienced this past winter, 1971-72, have shown a dramatic decline. Of nine test points measured on October 20, 1972 and compared with the measurements in the fall of 1971, seven showed no measurable wear, while only two showed slight wear, a maximum of 0.02 inch, a range of wear comparable with summer time wear readings. Observations of surface wear will be continued, but experience thus far has confirmed the predictions of the American Oil tests. At this point in time, indications are that normal usage of sand and salt together with unstudded tires do not pose a serious threat of pavement surfaces in Minnesota.

Many motorists, viewing this issue from only the standpoint of personal winter driving experiences, regard the position of highway engineers and administrators in opposing the use of studded tires as an unreasonable and unsympathetic attitude, merely equating the dollar cost of pavement damage against human lives. Engineers, administrators and legislators alike are not only vitally concerned about the public safety but also are responsible for preservation of the public property. Since funds for highway maintenance and construction are not without limit, the administrators of these funds are concerned that each expenditure will yield a maximum return in public safety and convenience. With continuing use of studded tires, funds that would ultimately have to be expended for repair or prevention of road damage caused by studs and the year-round hazards they create could be more productive of safety for all motorists if utilized for construction of new and safer roads or for safety improvements on existing roads.