

PAVEMENT WEAR MEASUREMENTS
TO QUANTIFY
STUDED TIRE DAMAGE

STATUS REPORT
DECEMBER 1975

Bureau of Structures, Materials,
and Applied Mechanics Research
Division of Research and Development
New Jersey Department of Transportation

ABSTRACT

Since the fall of 1973 the Research unit of the Department of Transportation has been monitoring pavement wear on the state highway system to determine the amount of damage caused by studded tire usage. Three monitoring sites were established in the northern regions of the state on newly constructed sections of Interstate Routes 30 and 287. Two of the sites have bituminous concrete surfaces with the third having a portland cement concrete surface.

Current results of the monitoring effort indicate that pavement wear in the wheelpath areas of the average highway in northern New Jersey has occurred at an annual rate five times greater than would be expected if studded tires were not used. These wear statistics substantiate previous predictions that the average highway in studded tire use areas would require resurfacing after 10 winter seasons. This critical time period has already passed with the end of the 1974-75 winter. A rough estimate of the minimum resurfacing costs now facing the Department for damage accrued on the state highway system is \$56,000,000.

TABLE OF CONTENTS

	<u>Page</u>
Abstract.	i
Table of Contents	1
Background.	2
Monitoring Sites.	3
Measurement Method for Pavement Wear.	4
Figure 1	5
Traffic and Wear Data for Monitoring Sites.	6
Table 1.	7
Table 2.	7
Table 3.	9
Effects of Pavement Wear.	10
Figure 2	11
References.	18
Appendix I Traffic Data	20
Appendix II Statistical Evaluation	23
Appendix III Memorandum -"Pavement Damage from Studded Tire Usage".	27

BACKGROUND

On June 15, 1965, the New Jersey Division of Motor Vehicles authorized provisional approval for studded tire usage on the state highway system. An important stipulation included in the original regulation stated that studded tire approval must also have the concurrence of the Department of Transportation. Subsequently, the Department began an elaborate evaluation of the overall effect of allowing studded tires on the state highway system. Consideration was given to a multitude of factors relating to highway safety and in particular the anticipated problem of accelerated pavement wear. To obtain wear data a test track was constructed and periodic depth measurements taken in wheelpatch areas through several thousand vehicle passes. Skid resistance of the test track was also monitored. A report documenting the Department's findings was then issued in the fall of 1966.(i)*

The trends established by the 1966 measurements indicated the studded tires could cause excessive pavement wear and loss in skid resistance. These findings were considered sufficiently conclusive at the time to recommend that all studded tire provisional approvals issued by the Division of Motor Vehicles be rescinded. Unfortunately, this recommendation was not accepted by the Division of Motor Vehicles.

In the years that followed, many other highway agencies conducted extensive studies of studded tire pavement damage and the general effect of studded tire usage on highway safety. Perhaps the most comprehensive of these studies was undertaken by the Ontario Department

*Numbers in parenthesis denote references listed at the end of the report.

of Highways. As a result of their findings, the Ontario Provincial Parliament banned the use of studded tires effective May 1, 1971. Studies conducted by Minnesota and others - including Michigan, Wisconsin, New York, Pennsylvania, Ohio, Washington and Iowa, were also instrumental in banning studded tires in several northern states.

As reports on these various efforts by other agencies were issued, copies were forwarded to the New Jersey Division of Motor Vehicles. In spite of this extensive additional data generally supporting a significant net disadvantage to use of studded tires, Motor Vehicle maintained its position of refusing to effect the rescinding.

In November 1973 the Department of Transportation initiated a program to measure the pavement wear occurring on New Jersey highways. The fundamental objective was to obtain sufficient information to determine the amount of damage studded tires have actually caused on our route system. To this end, monitoring sites were established at three separate locations in northern New Jersey. The manner in which the monitoring effort has been conducted and the data gathered thus far are described in this report.

MONITORING SITES

Each of the three sites used to measure pavement wear have been established on Interstate Highways. One site is located in the highly urbanized area of Hackensack on Route I-80 which at that point is a 10 lane, bituminous concrete highway carrying approximately 99,700

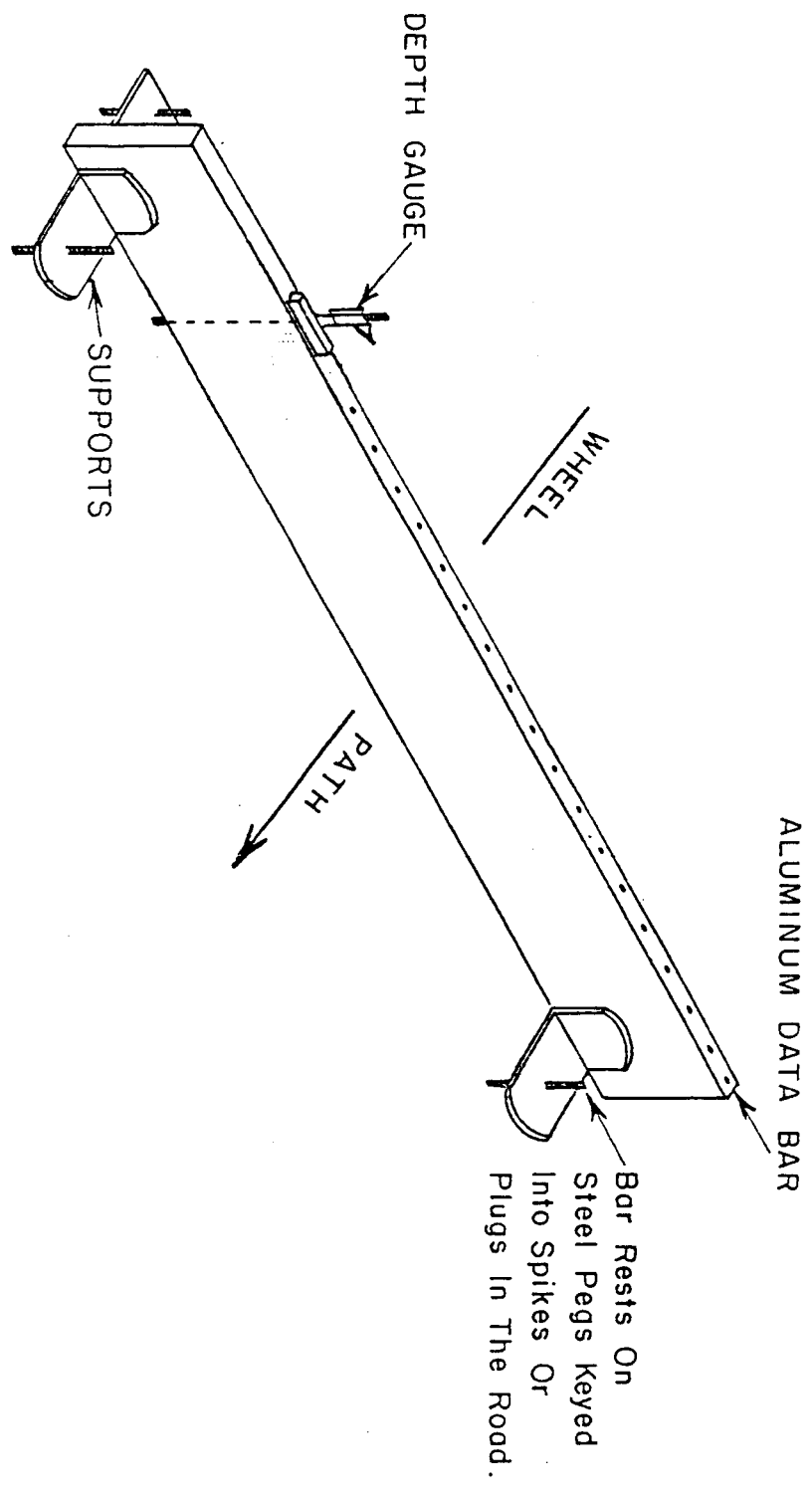
(1974 AADT) motor vehicles daily. A section of Interstate Route I-287 in Bound Brook serves as the second site. Route I-287 at the Bound Brook location is a 6 lane bituminous concrete facility handling a daily traffic volume of 60,000 (1974 AADT) motor vehicles.

The third monitoring area is located on Interstate Route I-30 in the vicinity of Hope, a rural town in the northwestern part of the state. At Hope, Route I-30 is a 6 lane portland cement concrete highway which carries approximately 14,800 (1974 AADT) automobiles and trucks daily. This section of Route I-30 was constructed in 1973 and monitoring of studded tire pavement wear was begun immediately after its opening to traffic. The surface pavement at the other two monitoring sites was also new as overlays had been made just prior to the initiation of the wear measurements.

MEASUREMENT METHOD FOR PAVEMENT WEAR.

Each pavement wear site consists of five cross sections positioned approximately 25 feet apart in the outside lane, outside wheelpath of a tangent portion of the highway. Wear measurements were made once every two months with a depth gauge capable of measuring to the nearest 0.001 of an inch. The gauge was mounted on an aluminum bar used as a straightedge datum and measurements were made at four inch intervals across the wheelpath. (See Figure 1) The bar was keyed to two spikes or plugs inserted into the pavement at the center and outer edge of the lane. Elevation measurements were made on all spikes to determine their vertical movements with time. The aluminum bar was later improved by adding supports at either end. These supports

FIGURE 1
MEASURING DEVICE FOR PAVEMENT WEAR



stabilize the bar and improve the ease of positioning the bar over the spikes or plugs.

Average wear measurements were calculated from the measurements taken within the actual wheelpath area. The location of the wheelpath was determined from painting lines placed across the traffic lane. As the lines wore, the actual wheelpath area was verified. The width of the wheelpath area was generally in the order of 36 inches.

TRAFFIC AND WEAR DATA FOR MONITORING SITES

Table 1, Studded Tire Applications, shows the yearly accumulated studded tire vehicle passes for the wear measurement sections. The Route I-80 (Hope) and I-287 (Bound Brook) traffic data were calculated from the 1974 AADT and previously established studded tire usage percentages. The Route I-80 (Hackensack) traffic data were calculated from traffic counts taken for experimental pavement sections immediately east of this location. All calculations for the 1975 data are contained in Appendix I (calculations for 1974 data were performed in the same fashion).

Table 2, Pavement Wear Measurements, presents the average wheelpath wear for the pavement sites monitored. The data for Winter 1973-74 represents the period November 15, 1973 to April 1, 1974 (136 days). Data for Summer 1974 represents the period April 2, 1974 to November 14, 1974 (229 days). The Winter 1974-75 data is for the period November 15, 1974 to April 1, 1975 (136 days). The Summer 1975 data pertains to the period April 2, 1975 to November 14, 1975 (229 days). In each case differences in cross section depth measurements between the start and end of the period were computed to obtain average wear.

Table 1
Studded Tire Applications

<u>Location</u>	<u>Total Studded Tire Vehicle Passes Winter 1973-74 (136 days)**</u>	<u>Total Studded Tire Vehicle Passes Winter 1974-75 (136 days)**</u>
Rt. I-80 (bit.) Hackensack	67,000*	105,250
Rt. I-80 Hope	32,400	35,350
Rt. I-287 Bound Brook	95,200	105,900

* Data for 86 days of studded wear as pavement was resurfaced early in the 1973-74 winter period.

** Values rounded to nearest 50 vehicle passes.

Table 2
Pavement Wear Measurements

<u>Location</u>	<u>Average Wear (inches)</u>			
	<u>Winter 1973-74 (136 days)</u>	<u>Summer 1974 (229 days)</u>	<u>Winter 1974-75 (136 days)</u>	<u>Summer 1975 (229 days)</u>
Rt. I-80 (bit.) Hackensack	0.022*	0.002	0.033	0.009
Rt. I-80 (con.) Hope	0.022	0.006	0.019	0.003
Rt. I-287 (bit.) Bound Brook	0.033	0.002	0.037	0.010

* Data for 86 days of studded wear as pavement was resurfaced early in the 1973-74 winter period.

A statistical analysis was made on Winter 1974-75 wear data to determine measurement precision. The analysis is contained in Appendix II. The results of this statistical evaluation indicate that the 95% confidence level for each value of wheelpath average wear is ± 0.002 inches.

Average wear measurements of Table 2 show that greater pavement wear occurs during the winter studded tire period than occurs during the summer non-studded tire period. Based on traffic data from the Route I-80 Experimental Pavement Project(2), traffic volumes at the test sites decrease slightly in the winter months as compared to the summer months. Since the winter studded tire periods (136 days) are shorter than the summer non-studded tire periods (229 days) and since winter conditions are least conducive to deformation type wear (rutting in bituminous pavements) this greater wear during a relatively lower volume traffic period is attributed to studded tires.

The data gathered from the monitoring sites has been used to determine pavement wear rates for both studded and non-studded tires. Table 3, Pavement Wear Rate, shows the extrapolated wear per one million vehicle passes for each tire type. The computation of these rates is explained in Appendix I. The large wear rate of the concrete section is believed to be due to the initial wearing of the broomed texture surface. The wear rate for studded tires is seen to be many times greater than that for non-studded tires. One can safely conclude from this data that studded tires are indeed causing accelerated wear of New Jersey pavements.

Table 3
 Pavement Wear Rate
 (Wear/1,000,000 Vehicle Passes)

<u>Location</u>	Studded Tire Wear Rate*		Non-Studded Tire Vehicle Wear Rate	
	<u>Winter 1973-74</u>	<u>Winter 1974-75</u>	<u>Summer 1974</u>	<u>Summer 1975</u>
Rt. I-80 (bit.) Hackensack	0.313	0.318	0.001	0.008
Rt. I-80 (conc.) Hope	0.590	0.497	0.012	0.007
Rt. I-287 Bound Brook	0.336	0.307	0.001	0.006

*Winter studded tire wear rates are based on winter wear measurements corrected for wear that might be attributable to non-studded tire use. Pavement wear data for summer months had to be used to effect the corrections. This approach should be adequate for the concrete site but in all probability, resulted in slightly lower than actual wear rates (studded tire) being reported for the bituminous sites.

EFFECTS OF PAVEMENT WEAR

Since vehicle placement in a traffic lane tends to be relatively constant, the abrasive action of studded tires on the pavement surface is concentrated in the narrow wheelpath areas. This action creates a trough-like pattern in the pavement. Eventually the troughs can become so deep that they pose a major hazard to driving safety. The wheelpath ruts begin to interfere with steering control during lane changes. Water retained in the troughs in wet weather permits tire hydroplaning and the associated loss of braking and steering control. Visibility during such periods also suffers as passing vehicles cause water splash to adjacent lanes.

To combat these hazards at some point the pavement must be resurfaced. The general consensus among highway engineers is that resurfacing becomes an absolute necessity when the average depth of wear in the wheelpath reaches 1/2 inch. Figure 2 illustrates the usual condition of the wheelpath when resurfacing is required.

In the spring of 1974 the Department's Research Division prepared for budgeting purposes an estimate of funds required for a major program to rehabilitate studded tire damaged pavements on the state highway system. By that time studded tires had been in legal use in New Jersey for nine successive winters.

The Research Division determined that in northern and central areas of the state where studs were generally used, an average highway pavement would most likely reach the critical 1/2 inch of rut wear after 10 winter seasons. It then predicted that by the end of the 1974-75 winter nearly one half of the state highway system would actually require resurfacing to correct studded tire

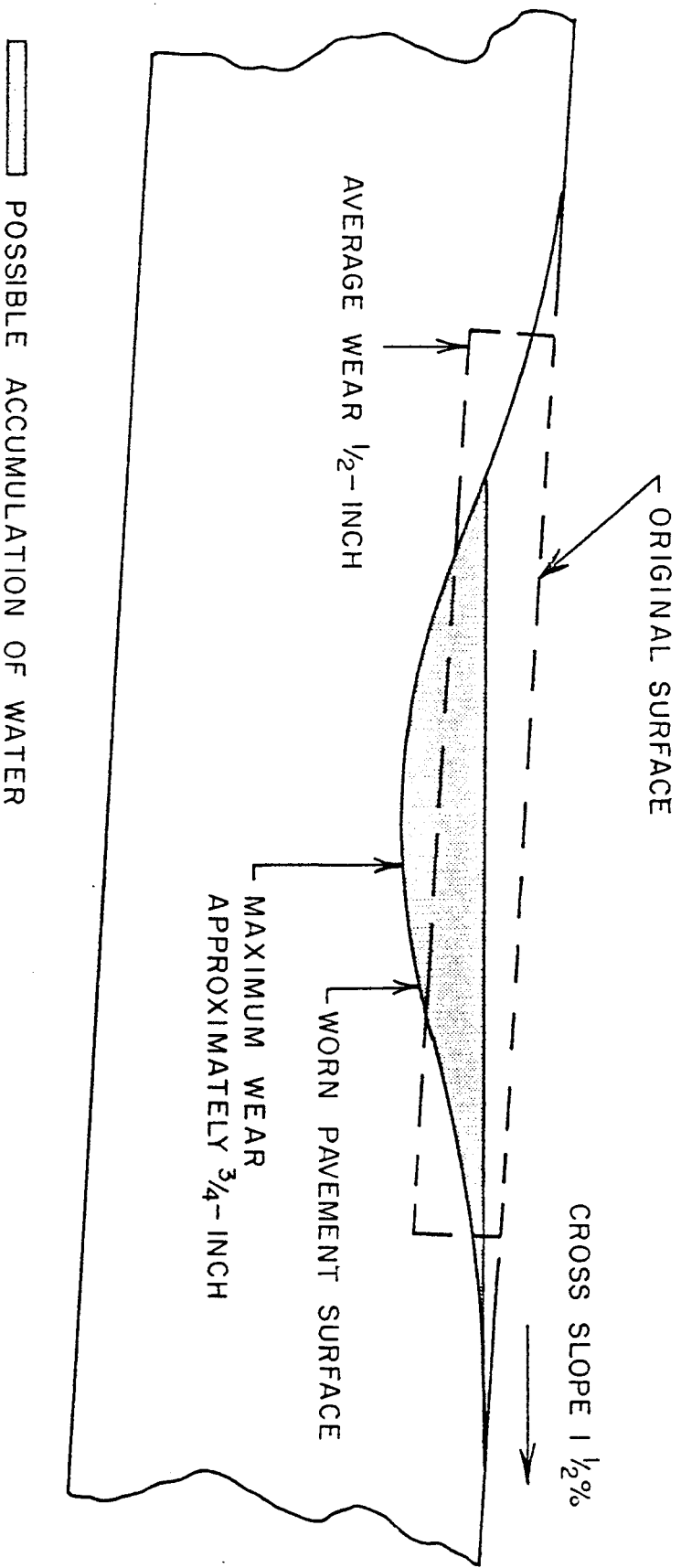


FIGURE 2

ILLUSTRATION OF PAVEMENT CONDITION WHEN RESURFACING IS REQUIRED*

*Figure taken from January 1975 report on studied tire wear prepared by Iowa State Highway Commission.

damage. A minimum of \$56,000,000 was estimated as being needed for this resurfacing program if private contractors were used. The price tag was considered very conservative as it did not include costs for shoulder elevation adjustments, inlet raisings, and re-striping. Additionally, no attempt was made to include the funding needs for the county and municipal roads which make up more than 90% of the total road mileage in New Jersey.

The various factors considered in Research's appraisal of pavement damage are highlighted in Appendix III which is a copy of internal correspondence between the Research and Maintenance units.

In arriving at their cost estimate, Department researchers elected not to use the wear data from the three monitoring sites as only one winter of measurements had been gathered by that time. Instead they based their assessments on wear rates recorded by the Province of Ontario for pavements with materials similar to those used in New Jersey. The Canadian data were not applied directly but modified to correct for traffic differences between New Jersey and Ontario. However, in spite of the corrections, there were admittedly some reservations concerning the applicability of the Ontario information. Fortunately, with much more data now being available from the New Jersey monitoring sites, the appropriateness of the Ontario wear rates can be checked.

The data of Table 3 provides the specific means for checking the adequacy of Research's previous wear assessments. Only the statistics for the bituminous sites are usable, however, as wear recorded thus

far at the concrete site has been limited to the surface finish. In a concrete pavement the roughened surface finish (0.03 inch in average depth on New Jersey highways) wears at a much higher rate than the rest of the pavement and such rates would be inappropriate for predicting long term wear. For the bituminous sites, Table 3 on page 8 indicates average wear rates of approximate 0.320 inches/million vehicle passes for studded tires* and 0.005 inches/million vehicle passes for non-studded tires. These wear statistics are used below to determine the amount of wear that has occurred per year on the average highway in central and northern New Jersey.

Known Information:

Studded Tire Wear Rate = 0.320 inch/ 10^6 vehicles

Non-Studded Tire Wear Rate = 0.005 inch/ 10^5 vehicles

Average Daily Traffic Per Lane (Period 1965-1975) = 5400 vehicles/lane

Average Number of Days Per Year Studded Tires Were in Use (Period 1965-1975) \approx 160 days/year

Average Percentage of Vehicles in Central and Northern New Jersey Equipped with Studded Tires During Winter (Period 1965-1975) = 14% (current percentage about 18%)

*Normally, the studded tire wear rates recorded for the bituminous sites would also be considered too preliminary for direct use in predicting long term wear. Research investigations performed by the Minnesota DOT indicates the wear rate for the first one to two hundred thousand studded tire passes is about twice that for the exceedingly larger number of subsequent vehicle passes needed to produce 1/2 inch of wheelpath wear. Thus, it would seem that estimates of accrued studded tire damage should be based on 1/2 the rate values of Table 3. A countering effect exists, however, in that the rutting occurring on our monitoring sites has been predominately from vehicles equipped with the newer controlled protrusion studs(4). These studs have been found to produce 30 to 50% less wear than the older type studs(5) that were sold for 8 out of 10 years that studded tires have been in legal use in New Jersey. The direct application of the wear rates of Table 3 is therefore considered appropriate for estimating accumulated studded tire damage on our highways.

Calculation of Average Annual Wear:

Average Annual Wear = Winter Wear Due to Studded Tires + Winter Wear Due to Non-Studded Tires + Summer Wear Due to Non-Studded Tires

$$\begin{aligned} \text{Average Annual Wear} &= \frac{0.320}{106} \times 160 \times 5400 \times 0.14 + \\ &\quad \frac{0.005}{106} \times 160 \times 5400 \times 0.86 + \\ &\quad \frac{0.005}{106} \times (365-160) \times 5400 = 0.039 + 0.004 + 0.006 \\ &= \underline{0.049 \text{ inches/year}} \end{aligned}$$

The preceding calculations indicate that our bituminous pavements in northern New Jersey have been wearing at a rate five times greater than would be expected if studded tires were not used (0.049 versus 0.010). Further, the specific wear rate of 0.049 inches/year establishes that these pavements would have reached the critical 1/2 inch of mean rut wear after a little more than 10 years of traffic. This is essentially the same length of time previously predicted for all pavement types using the Ontario wear measurements (In Ontario bituminous and concrete pavement exhibited the same wear rates). It follows then that the wear rates recorded for the Department's monitoring sites support the validity of Research's prior estimate of a minimum of \$56,000,000 being needed after the 1974-75 winter to correct studded tire damage on the state highway system.

The actual impact of this repair bill, as well as, the associated life expectancy of only ten years for a pavement's surface can best be appreciated by considering what pavement durability would have been without studded tires. If studs had not been permitted on

winter tires, the average New Jersey highway in our northern and central regions should have lasted about 19 years before requiring its first resurfacing, with subsequent resurfacings being needed at 10 to 12 year intervals. This 19 year figure is based on past resurfacing schedules (12 years for bituminous pavement and 30 years for concrete pavements) and information concerning the pavement make up of the state highway system (approximately 60% of the system with bituminous concrete surface, 40% with portland cement concrete surface). Consideration of these factors, indicates that much of the estimated \$56,000,000 in repair costs actually represents public funds which never would have been required, at any time, if studded tires had not been legalized in New Jersey.

Another concern regarding the excessive wear from studded tire usage is in the area of pavement skid resistance. The Department is under a mandate from the Federal Government to take steps to insure that an adequate level of skid resistance is being developed and maintained on the highway system. In portland cement concrete, an efficient means of achieving good initial skid resistance has been to form a roughened surface texture in the concrete while it is plastic. Unfortunately, with winter applications of studded tires this texture on the average roadway is totally removed in wheelpath areas after less than one year of traffic. Without studs the skid

resistant texture would be expected to last some 4 years.* A somewhat similar problem occurs with bituminous pavements. The Department has developed a high skid resistant bituminous mixture which it began to use on a large scale basis during the summer of 1975. However, this new mixture produces a very pervious pavement surface that apparently has much less resistance to wear than the Department's standard, high density mixtures. Thus, a very promising means of improving motorist safety may be thwarted by the adverse effects of studded tires.

The current consequences of past decisions to allow use of studded tires are indeed very real and have to some degree been quantified in this report. It is difficult, however, to speculate with any justifiable confidence as to what the Department might expect

*Using the concrete pavement wear rates of Table 3 and considering a texture depth of 0.08 inches and a current average daily traffic volume per lane of 5700 with an 18% studded tire usage during 136 days per year, the following establishes the time needed to eliminate the anti-skid properties of the surface texture:

With Studs:

$$\text{Time} = 0.08 \div \left(\frac{0.545}{106} \times 136 \times 5700 \times .18 + \frac{0.010}{106} \times 136 \times 5700 \times 0.86 \right) = \frac{0.08}{0.10} = .8 \text{ years}$$

Without Studs:

$$\text{Time} = 0.08 \div \left(\frac{0.010}{106} \times 365 \times 570 \right) = \frac{0.08}{0.02} = 4 \text{ years}$$

in the future. The fact that present controlled protrusion studs are less abrasive to pavements than past stud types definitely offers some hope for lower repair costs in the future. Also, there is the possibility that the new "winter radial" type tires with their improved rubber compounds will displace studs as the public's desired winter driving traction aide. Unfortunately, if a significant amount of stud usage still continues these mitigating effects may be completely countered by reduced wear resistance of our bituminous surfacings.

References

1. Evaluation of Studded Tires, New Jersey State Highway Department, Bureau of Structures and Materials, 1966.
2. Baker, R. F. and Quinn, J. J., Ninth Interim Report - Experimental Pavement Project, New Jersey Department of Transportation, 1971.
3. A Research Summary Report for the Minnesota Legislature, The Effects of Studded Tires, Minnesota Department of Highways, March 1971.
4. Letter of April 29, 1974 from Director of New Jersey Motor Vehicles Division, Mr. John Waddington to the New Jersey Commission of Transportation, Mr. Alan Sagner.
5. Sneer, T. L. and Gorman, S. W., Laboratory Evaluation of Pavement Damage Caused by Studded Tires, Salt and Abrasive Sand, Supplemental Report - Test 5A10, Research and Development Department, American Oil Company, June 15, 1971.

APPENDICES

Appendix I
Traffic Data for Studded Tire
Wear Measurement Sites

Route I-80 (bituminous) Hackensack

A. Winter Studded Tire Wear Rate

Traffic data obtained from Route I-80, Station 2-1-10, experimental test sections.

Outside eastbound lane 4636 automobiles per day

1974 percentage of studded tire vehicles 16.7%

4636 veh/day x 0.167 stud. veh/day = 774 stud. veh/day

136 days for studded tires x stud veh/day = 105,250 vehicles

Studded tire wear rate per million vehicle passes:

$$\begin{aligned} \text{STUDED TIRE WEAR RATE} &= \frac{\text{TOTAL WINTER WEAR} - \text{WINTER WEAR DUE TO NORMAL TIRES}}{\text{NUMBER OF STUDED TIRE PASSES}} \times 10^6 \\ &= \frac{0.038 - \left(\frac{136}{229}\right) (1-0.167) \quad 0.009}{105,250} \times 10^6 = 0.318'' \end{aligned}$$

B. Summer Non-studded Tire Wear Rate

$$= \frac{\text{SUMMER WEAR}}{\text{NUMBER OF VEHICLE PASSES}} \times 10^6$$

$$= \frac{0.009}{1,061,650} \times 10^6 = 0.009''$$

Route I-80 (concrete) Hope

A. Winter Studded Tire Wear Rate

Traffic data obtained from 1974 AADT for this route near Hope.

One way AADT = 7,400

Outside lane 26%

$7,400 \times 0.26\% = 1,924$ auto & trucks/day outside lane

Automobile per day 70%

$1,924 \times 0.70 = 1,347$ vehicles/day

1974 percentage of studded tire vehicles 19.3%

$1347 \text{ vehicles/day} \times 0.193 = 260$ studded vehicles/day

$136 \text{ days for studded tires} \times 260 \text{ studded vehicles} = 35,350$
studded vehicles

Studded tire wear rate per million vehicle passes:

$$= \frac{0.019 - \left(\frac{136}{229}\right) (1-0.193) 0.003}{35,350} \times 10^6 = 0.497''$$

B. Summer Non-studded tire Wear Rate

$$= \frac{0.003}{440,600} \times 10^6 = 0.007''$$

Route I-287 (bituminous) Bound Brook

A. Winter Studded Tire Wear Rate

Traffic data obtained from 1974 AADT for this route near
Bound Brook.

One way AADT 30,000 vehicles

Outside lane 26%

$30,000 \times 0.26 = 7,800$ vehicles in outside lane

Automobiles per day 70%

7,800 vehicles x 0.70 = 5,460 automobile/day

1974 Percentage of studded tire vehicles 14.0%

5,460 automobiles x 0.14 = 764 studded vehicles/day

136 days for studded tires x 764 = 103,900 studded vehicles

Studded tire wear rate per million vehicle passes:

$$= \frac{0.037 - \left(\frac{136}{229}\right) (1-0.140) 0.010}{103,900} \times 10^6 = 0.307''$$

B. Summer Non-Studded tire Wear Rate

$$= \frac{0.010}{1,736,200} \times 10^6 = 0.006''$$

APPENDIX II

Determination of Precision of Wear Measurement

To investigate the precision of the depth gauge operator and wear measuring system, a statistical analysis was made of wear measurements taken at the same cross sections, three times in the same day. Eleven different cross sections were used for the statistical evaluation. The first set of measurements were arbitrarily considered the base readings to compare with the other two groups of measurements. The second group of measurements were made without moving the datum bar from its position during the first group of measurements. Any differences between these two groups thus represents the error associated with the depth gauge and operator. The third group of measurements were made after removing the bar, and replacing it. Any difference between the base readings and the third group therefore represents the error associated with the gauge, operator and the replacement of the bar, i.e. the complete measurement procedure. The variability of the complete procedure is used to determine a precision statement to be used for future field measurements.

Statistical Evaluation of the Difference Between Data Groups 1 & 2 (variability of gauge and operator only)

The average difference in measurements between groups was calculated as:

$$\bar{X}_{\text{DIFF}} = \frac{\sum (X_1 - X_2)}{N} = -0.0014 \text{ INCHES}$$

and the standard deviation (individuals) was calculated to be:

$$\sigma_{\text{Diff.}} = \sqrt{\frac{N \sum X^2 - (\sum X)^2}{N(N-1)}} = 0.0053$$

This evaluation will not be carried further due to the limited application of this test of the particular measurement procedure.

Statistical Evaluation of the Differences Between Data Groups 1 & 3
(variability of the complete measurement process)

The average differences in measurements between groups was calculated to be:

$$\bar{X}_{\text{Diff.}} = \frac{\sum (X_1 - X_3)}{N} = 0.000594 \text{ inches}$$

and the standard deviation (individuals) was calculated to be:

$$\sigma_{\text{Diff.}} = \sqrt{\frac{N \sum X^2 - (\sum X)^2}{N(N-1)}} = 0.0073 \text{ inches}$$

The standard error of the mean was calculated to be:

$$\sigma_{\bar{X} \text{ Diff.}} = \frac{\sigma_{\text{Diff.}}}{\sqrt{N}} = 0.00082 \text{ inches}$$

Before developing the precision statement, it is necessary to confirm that no unwanted or unexplained component of variance was present in these measurements. This is done by checking that the difference between the Group 1 and Group 3 readings is, on the average, zero (or not significantly different from zero). For a t-test of the mean of these differences against zero,

$$t = \frac{\bar{X} - \mu}{\sigma_{\bar{X}}}$$

in which

\bar{X} = mean difference

μ = 0 (for this test)

$\sigma_{\bar{X}}$ = standard error of the mean

from the data

$$N = 78$$

$$\bar{X} = 0.000594 \text{ inches}$$

$$\sigma = 0.0073 \text{ inches}$$

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{N}} = 0.00082 \text{ inches}$$

and then

$$t = 0.72$$

For $N=78$ and a two-tailed significance level of 95%, the critical value of $t = 1.99$. Since this is greater than the calculated value of $t = 0.72$, it is concluded that the mean difference of 0.000594 inches is not significantly different from zero and we can now proceed to develop the precision statement for future measurements.

The precision statement for the average wheelpath wear at a particular site is given by:

$$\bar{X} \pm \frac{t\sigma}{N}$$

in which \bar{X} = average wear (average difference between previous and present readings) at that site

t = student t , two tailed, 95% level

σ = standard deviation associated with complete measurement process (0.0073 from Group 1 & 3 data)

N = number of wheelpath measurements

for the Department's three monitoring sites, the precision statements can be calculated as follows:

Route I-80, Hackensack: $0 \pm \frac{1.99 \times 0.0073}{\sqrt{59}} = \pm 0.0019 \text{ inches}$

Route I-80, Hope: $0 \pm \frac{1.99 \times 0.0073}{\sqrt{38}} = \pm 0.0023 \text{ inches}$

Route I-237, Bound Brook: $0 \pm \frac{1.99 \times 0.0073}{\sqrt{55}} = \pm 0.0019 \text{ inches}$

When the number of wheelpath measurements is between approximately 40 and 60, the precision statement (at the 95% confidence level) for average wheelpath wear will be very close to ± 0.002 inches. This value is judged to be satisfactory for any future measurements.

MEMORANDUM

TO: Mr. C. Edson

APPENDIX III

FROM: Mr. Kenneth C. Afferton

Bureau of Maintenance

Chief, Bureau of Structures.

Materials & Applied Mechanics
Research

SUBJECT: Pavement Damage from Studded Tire Usage

DATE: June 19, 1974

On several occasions we have discussed the problem of studded tire induced damage to New Jersey roadways. The gravity of the problem is such that Research, acting through the Commissioner's office, has several times requested Motor Vehicles to rescind the regulation which allows studded tire use. In spite of what might be considered overwhelming data to support the request, Motor Vehicles has maintained its position of refusing to effect a rescinding. The latest refusal came this spring after the Department supplied Director Waddington with data from Minnesota, Ontario, and an NCHRP study documenting the lack of any real safety benefits to the driving public when using studded tires.

In view of this continuing opposition from the Motor Vehicles Bureau, it is now evident that the Department must begin to think seriously of budgeting for the extra pavement rehabilitation work necessitated by studded tire damage. As you know, the most substantial manifestation of this damage is the wear occurring in the wheelpaths. It has been stated by many experts in the field when the wheelpath rut depths reach 1/2 inch the pavement must be repaired to preclude a preponderance of wet weather accidents involving tire hydroplaning on water lying within the ruts. The extent to which New Jersey pavements have progressed to the 1/2 inch wear level and the associated cost of correcting the condition, of necessity, can only be roughly estimated.

The Department to my knowledge has unfortunately not maintained any formal survey of wheelpath wear since the legalization of studded tire use. A test track study conducted by Research in 1965 did yield some wear data but the severe nature of that study prevents such information from being used for precise predicting of long term wear levels. Wheelpath damage data from other sources must be used for estimating purposes until a pavement monitoring program now being initiated by Research is fully operational.

In recent years many highway agencies have conducted studies of pavement damage associated with studded tire use. Perhaps the most comprehensive of these studies have been those undertaken by the Ontario Department of Highways. My staff and I personally believe that there is sufficient evidence to consider a fair amount of Ontario's wear data applicable to New Jersey pavements.

Discussions with the Ontario researchers indicated that Ontario and New Jersey use approximately the same type of asphaltic and portland cement in their road construction. There are also similarities in the type of aggregates used. The coarse and fine aggregates in the wearing surface of most of New Jersey highways are relatively hard and extremely durable. Although many of Ontario's pavements are constructed with soft limestone aggregates, Ontario also has a substantial number of pavements with the harder aggregates, such as traprock and silica sand. Consequently, under like studded tire use, one would expect these latter pavements and those in New Jersey to exhibit similar wear characteristics.

Based on the preceding rationale, the 1969 Ontario report (Pavement Wear Due to Studded Tires and Economic Consequences in Ontario - Highway Research Record 331) on studded tire damage was reviewed to extract wear measurements for hard aggregate pavements. Wear measurements were based on a six month per year studded tire usage which is equivalent to the use period that has predominated in New Jersey since studded tires were first legalized. In the 1969 report the hard aggregate roads, characterized by a mean AADT of 6200 per lane and an average studded tire use percentage of 14 percent, had average wear rates of 1.43 mm per year. A research sampling of parking lots and selected routes in central and northern New Jersey indicates that during the 1973-74 winter from 15 to 20 percent of autos in this State were equipped with studded tires. The 14 percent figure for the Ontario routes would seem a good approximation of the overall use percentage for New Jersey during the period from 1965 to the present. New Jersey's average per lane AADT during this same period was approximately 5400 for the state highway system.

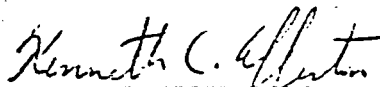
Considering the above cited similarities and the fact that pavement wear is a linear function of vehicle passes, the wear data for Ontario can be applied to this State by merely accounting for the differences in mean AADT's. Accordingly, the average wear rate for New Jersey highways due to studded tire use should be approximate 1.25 mm per year ($1.43 \times 5400/6200$). On this basis it is apparent that the typical state highway will have reached the critical 1/2 inch rut depth after ten (10) years of winter use of studded tires. By the end of the 1974-75 winter New Jersey roads will have been subjected to that 10 years of studded tire traffic. Accordingly, a substantial number of miles of roadway will then be in need of rehabilitation.

The total lane miles of excessively rutted, studded tire worn pavement actually warranting repair work by the 1975 construction season can be estimated. From Department records we know the state highway lane miles in 1965 was 5998. Since that time it is reasonable to assume the Department has annually resurfaced in the order of 200 lane miles of that original pavement mileage. It follows that the number of lane miles possessing the same wearing surface since 1965 should be 4,198 ($5998 - 1800$). However, approximately one-third of this roadway mileage falls within the southern part of the State (Region 4) where stud usage, in all probability, is well below that for the remainder of New Jersey. Therefore the best estimate of the total lane miles of the state system requiring repair of studded tire wear damage is 2,800 ($2/3 \times 4,198$).

The cost to rehabilitate the damaged pavement can be established by assuming a particular method of repair. For bituminous concrete wearing surfaces, it is likely that a 3/4 inch surface milling followed by a 1 inch bituminous overlay would be an appropriate method. For portland cement concrete surfaces, the repair technique would probably be the placement of two one inch lifts of bituminous concrete, with the first lift serving as a leveling course. On a per square yard basis the two repair methods should have very nearly the same total cost. If repairs were accomplished by contract an in place cost of about \$25/ton would incur for bituminous concrete during 1975; a materials cost of approximately \$15/ton would probably characterize repair via maintenance forces.

Based on the preceding assumptions and considering an in place weight of bituminous concrete of 150 lbs/ft³, each lane mile of studded tire damaged pavement would cost the Department in 1975 approximately \$20,000 to rehabilitate by contract and \$12,000 (excluding labor) with its own maintenance personnel. If the total mileage of state highways exhibiting excessive wheelpath wear were upgraded during 1975, it is estimated that the overall cost would be 56 million dollars by contract and 33.5 million by maintenance operations. These are, to say the least, large sums of money and yet are not all inclusive as they exclude costs for shoulder elevation adjustments, inlet raisings, and restriping.

The above data does not possess the degree of exactness I would like to provide. However, I trust it is sufficient for your staff to begin planning for the substantial repair effort ahead. As our new program of monitoring pavement wear begins to yield pertinent information I will attempt to sharpen our predictions. Until that time, I would be most willing to discuss the details of what is now being offered.


Kenneth C. Afferton

KCA:kam

cc: H. Carballo
K. Rosser
J. Freidenrich
D. W. Gwynn ✓
J. Schuyler