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16. Abstract

This is the second of a series of reports which deals with wheel track rutting in asphalt pavements. Specifically, this report is concerned with the extent of rutting due to studded tires. Significant findings include:

1) Very little research has been done since 1980 in this area, with the exception of work in the Scandinavian countries.

2) Many agencies continue to prohibit or restrict the use of studded tires.

3) Very little new information on percent of vehicles using studded tires or on tire wear studies was available.

4) Factors affecting wear rates were defined.

5) The consequences and benefits of using studded tires were identified.

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Wheel Track Rutting Due to Studded Tires

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1.0 INTRODUCTION

1.1 Background

The use of studded tires has long been recognized as improving traction in highways during the winter months when the roads are often icy. However, they also have been shown to increase road wear on both asphalt and portland cement concrete pavements. This report has been prepared to document the use and effects of studded tires, particularly in terms of producing wheel track ruts.

1.2 Objectives

Specific objectives of this report are to:

1) Quantify the use of studded tires in countries throughout the world. This includes data on

   - Percent of vehicles using studded tires
   - Characteristics of the studs (size and number)
   - Time periods that studded tires are permitted

   This information is summarized in Chapter 2.

2) Summarize the results of road wear studies (field and test track) in each of the following areas

   - Mechanism of pavement wear
   - Rate of pavement wear
   - Factors affecting the wear rate

   These results are presented in Chapter 3.

3) Identify the consequences/benefits of using studded tires such as

   - Increased pavement maintenance to repair ruts, etc.
   - Increased safety problems due to splash and spray

   These results are presented in Chapter 4.

1.3 Scope of Work

In order to accomplish the stated objectives, two major work activities were undertaken. These included:

1) A computer literature search (TRIS). Many of these publications were reviewed and evaluated in the preparation of this report.

2) A survey of agency practices. A survey form (see Appendix A) was developed and mailed to 30 highway agencies, 11 Canadian provinces and territories, and 4 foreign countries (Norway, Sweden, Finland, and West Germany). The responses to the survey are given in Appendix B.

3) A telephone survey of selected tire manufacturers to identify the types and number of studs currently being used. These results are summarized in Appendix D.

2.0 STUDDED TIRES PRACTICES

The data presented in this chapter is the result of an extensive literature review, the survey of selected transportation agencies, and selected calls to studded tire manufacturers. Information was obtained from various agencies in the United States, Canada, and Europe.

2.1 Use of Studded Tires

The results of the survey were used to provide an indication of use of studded tires throughout the United States, Canada and abroad. The results indicate the following agencies permit their use:

United States	Canada	Europe
Alaska	New Brunswick	Sweden
California	Nova Scotia	Norway
Colorado	Quebec	Finland
Connecticut	Saskatchewan	
Delaware		
Idaho		
Indiana		
Iowa		
Kansas		
Maine		
Montana		
Nebraska		
New Jersey		
Nevada		
New York		
North Dakota		
Oregon		
Pennsylvania		
Rhode Island		
South Dakota		
Utah		
Vermont		
Washington		
Wyoming		

It should also be noted that in all cases where studs are permitted, so are chains.

2.2 Percent of Vehicles With Studs

The results of the survey did not provide much useful recent information on use of studded tires. In fact, only a few agencies provided an estimate for current usage. Therefore, heavy reliance was placed on results from the literature (pre-1980) since the actual usage rates are virtually unknown in the USA and Canada.

Historical data on the percent usage by vehicle type (cars and trucks) of studded tires in the United States and abroad is given in Table 2.1. As noted, many states do not allow studded tire use, while usages as high as 60% or more have been reported by the states of Alaska, Montana, and Vermont (TRB, 1975).

Sweden reports that 60% of all vehicles use studs, while 90-95% of cars and 30-60% of trucks use studded tires in Finland (Huhtala, 1978). Provinces in Canada reported usage rates on cars as low as 20-25% and as high as over 50% (Smith & Schonfeld, 1971).

The percentages of use on two versus all four wheels are generally unknown except for Scandinavia and Alaska. In certain countries, the use is mandated on all four wheels if studs are used on any wheel. This is to increase safety as well as acceleration.

A recent survey of studded tire usage in Alaska is given in Table 2.2. As indicated, studded tire usage varies seasonally as well as between years and locations. However, it can be seen that wintertime usage (through March) by light vehicles is between 20 and 35% with roughly one-third of these vehicles being four-wheel drive.

2.3 Characteristics of Studded Tires

As indicated in Figure 2.1, a typical studded tire is essentially a normal winter or all-season tire with studs embedded in the tread. Typical specifications for passenger car studded tires are given in Table 2.3.

Although there were many types of studs found in the literature, all have similar components. These consist of a pin (typically tungsten carbide) surrounded by the stud housing or body (typically steel), which has a flange at its base to hold the stud in the tire tread. Figure 2.2 illustrates the four basic stud types that have been used in the past, while Table 2.4 summarizes the characteristics of each type. Conversations with tire manufacturer/distributor personnel revealed that only the Controlled Protrusion (Type I) stud is currently used in the U.S. The principal reason is that as the stud housing or body wears, coinciding with the tread

Table 2.1. Historical data on the use of studded tires.

Agency		% of Vehicles with Studs	Reference
Canada	Ontario	32	Smith, 1971
	Manitoba	20-25	Smith, 1970
	Quebec	50	Smith, 1970
	Maritime Provinces	50+	Smith, 1970
	Ottawa	48	Smith, 1971
United States	Alabama	1	NCHRP Syn. 32
	Alaska	61	
	Arizona	1	
	Arkansas	1	
	California	NA	
	Colorado	30	
	Connecticut	25	
	Delaware	18	
	Florida	NA	
	Georgia	NA	
	Idaho	27	
	Illinois	12	
	Indiana	10	
	Iowa	25	
	Kansas	7	
	Kentucky	12	
	Maine	NA	
	Maryland	NA	
	Massachusetts	32	
	Michigan	12	
	Missouri	14	
	Montana	60	
	Nebraska	38	
	Nevada	6	
	New Hampshire	30	
	New Jersey	20	
	New Mexico	NA	
	New York	30	
	North Carolina	2	
	North Dakota	32	
	Ohio	20	
	Oklahoma	1	
	Oregon	10	
	Pennsylvania	28	
	Rhode Island	NA	
	South Carolina	3	
	South Dakota	40	
	Tennessee	NA	
	Texas	0	
	Vermont	60	
	Virginia	10	
	Washington	35	
	West Virginia	10	
	Wisconsin	20	
	Wyoming	35	
Finland		Cars: 90-95 Trucks: 40	Lampinen, 1988 Huhtala, 1978
Sweden		60	Keyser, 1970

Table 2.2. Recent counts of studded tire usage in Alaska

Survey Date	Total Vehicles	Studded Tires (one side)	Studs per Vehicle Pass	% Vehicles w/Studs On Some Tires	% Vehicles w/Studs On All Tires	% 4WD Vehicles
a) Fairbanks						
4/18/89	250	81	0.324	28.0	12.4	24.8
5/22/89	319	23	0.072	6.6	0.63	24.0
3/2/90	583	182	0.312	20.4	10.8	34.1
5/7/90	820	121	0.148	11.0	4.10	33.2
7/16/90	1228	101	0.082	5.45	2.77	35.4
1/23/91	1385	402	0.290	19.3	9.75	43.4
b) Anchorage						
5/17/89	1766	143	0.081	6.4	1.7	---
8/21/89	1892	63	0.033	2.9	0.4	---
11/16/89	2361	1142	0.484	36.8	11.5	---
2/14/90	2076	1043	0.502	35.0	14.4	---
8/20/90	2339	112	0.048	3.8	0.9	24.3
c) Juneau						
4/12/89	993	348	0.350	24.8	9.3	32.5
8/1/89	352	28	0.080	6.2	1.7	30.0
3/15/90	1187	512	0.431	30.8	12.1	32.7
6/25/90	1119	40	0.036	2.9	0.45	35.3
1/25/91	650	345	0.531	40.6	16.9	40.6

Figure 2.1. G78x14 studded (R) and unstudded passenger tires (Krukar & Cook, 1972).

Table 2.3. Typical cross-sectional area specifications (NCHRP Syn. 32).

Nominal Car Size	Tire Data		Tire Stud Data		
	Nominal Size	Typical Tread Surface Area (sq. in.)	Typical Maximum Number of Studs	Typical Cross-Sectional Area (sq. in.)	Percent of Tread Surface Area
Compact	B78x13	250	96	.0314	1.25
Intermediate	F78x14	270	96	.0314	1.10
Full Size	H78x15	312	96	.0314	1.00

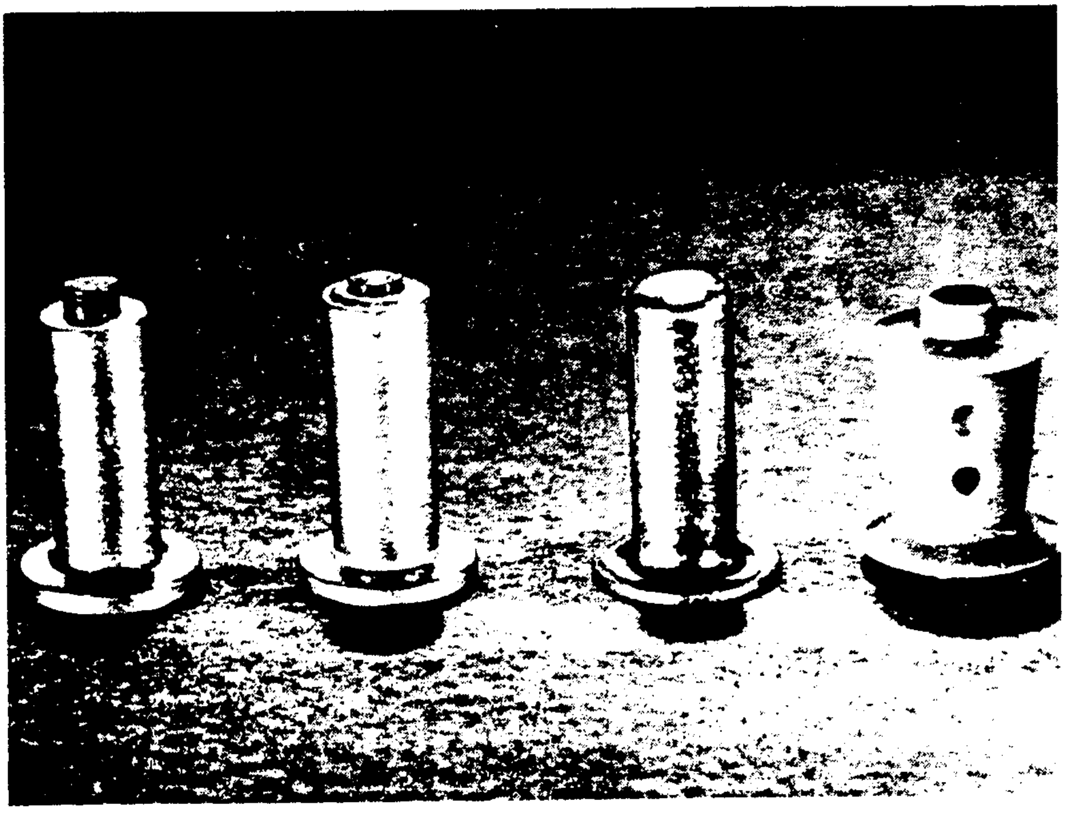


Figure 2.2 Four basic stud types. Left to right: Type III or CV Stud; Type I or CP Stud; Type II or PT Stud; and Type IV or FS Stud (Krukar & Cook, 1973).

Table 2.4. Characteristics of studs (Krukar & Cook, 1972).

Stud Type	Characteristics
Type I - "Controlled Protrusion Stud"	• Carbide pin will move further into stud body if protrusion limit is exceeded • 18% lighter in weight than conventional stud • 5% smaller flange than conventional stud
Type II - "Perma-T-Gripper Stud"	• Pin found in other studs has been replaced with relatively small tungsten carbide chips in a soft bonding matrix enclosed in a steel jacket • Designed to wear within 10% of tire wear, thus maintaining a protrusion of approximately 0.020 in. or less
Type III - "Conventional Stud"	• Tungsten carbide pin • Stud protrusion will increase with tire wear
Type IV - "Finnstop Stud"	• Complete stud of light plastic casing with a tungsten carbide pin • Stud can be adjusted close to the tread rubber eliminating oscillation of the stud • Pin angle contact with road varies little with speed • Plastic housing tends to reduce effect of centrifugal force and heat build-up between rubber and stud • Air cushion can be left under stud to reduce stiffness (floating stud)

wear, the tungsten carbide pin is pushed deeper into the stud housing providing a uniform protrusion length throughout the life of the stud. This benefit is not fully realized with the other stud types since the protrusion length of the stud can vary over time. Figure 2.3 gives the dimensions for the Controlled Protrusion Stud (see Appendix C for further details), while Figure 2.4 illustrates a fifth type of stud which was listed in the literature as being considered for manufacture. The number of studs/tire range from 64 to 120 (see Table D1).

In Sweden, it has been long recognized that the conventional studs cause excessive tire wear. They have therefore developed a new low-noise, reduced road wear ice-stud. It weighs only 0.7 gram, yet reportedly retains ice grip and durability. The reduction in weight is possible due to the use of a new polymer in the stud body (Simonsson, 1990).

2.4 Permitted Use Periods

Based on the results of the literature review the periods of the year to which studded tire use is restricted in the United State and Canadian Provinces is shown in Figure 2.5 (TRB, 1975). Note that in the 1970's 14 states and two provinces had no restrictions and that nine states and one province prohibited the use of studded tires. The remaining states and provinces allow use of studded tires only during the fall, winter, and spring months. The results of the 1990 survey (Table 2.5) showed, for North America, that only three agencies had no restrictions, 25 states/provinces restrict stud use to a given time period, and eight agencies prohibit their use. For those agencies restricting the use of studs to a specific time period, most restrict their use to the period from October through April. Similar results for the European countries surveyed are given in Table 2.6.

2.5 Enforcement

The results of the survey (see Appendix B, Question 7) also investigated the role of enforcement during prohibited periods. Generally, the risk of getting caught is considered low to moderate. Only South Dakota, Washington, Illinois, Minnesota, Nevada, Ontario, and Quebec indicated a high risk. The cost of being cited also varies considerably, with ranges in fines from <$25 to $500 plus vehicle impoundment.

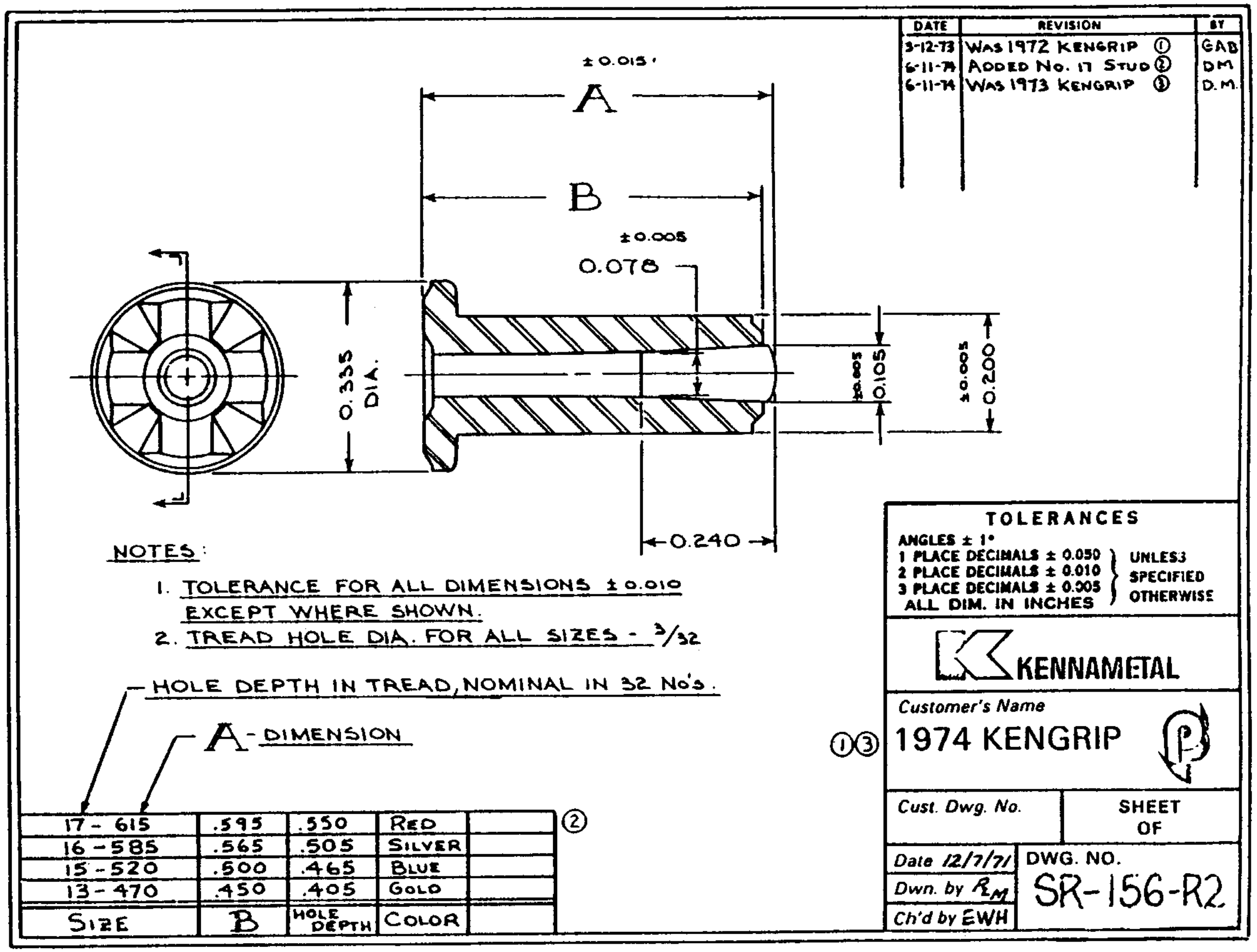


Figure 2.3. Typical dimensions for a controlled protrusion stud (NCHRP Syn. 32).

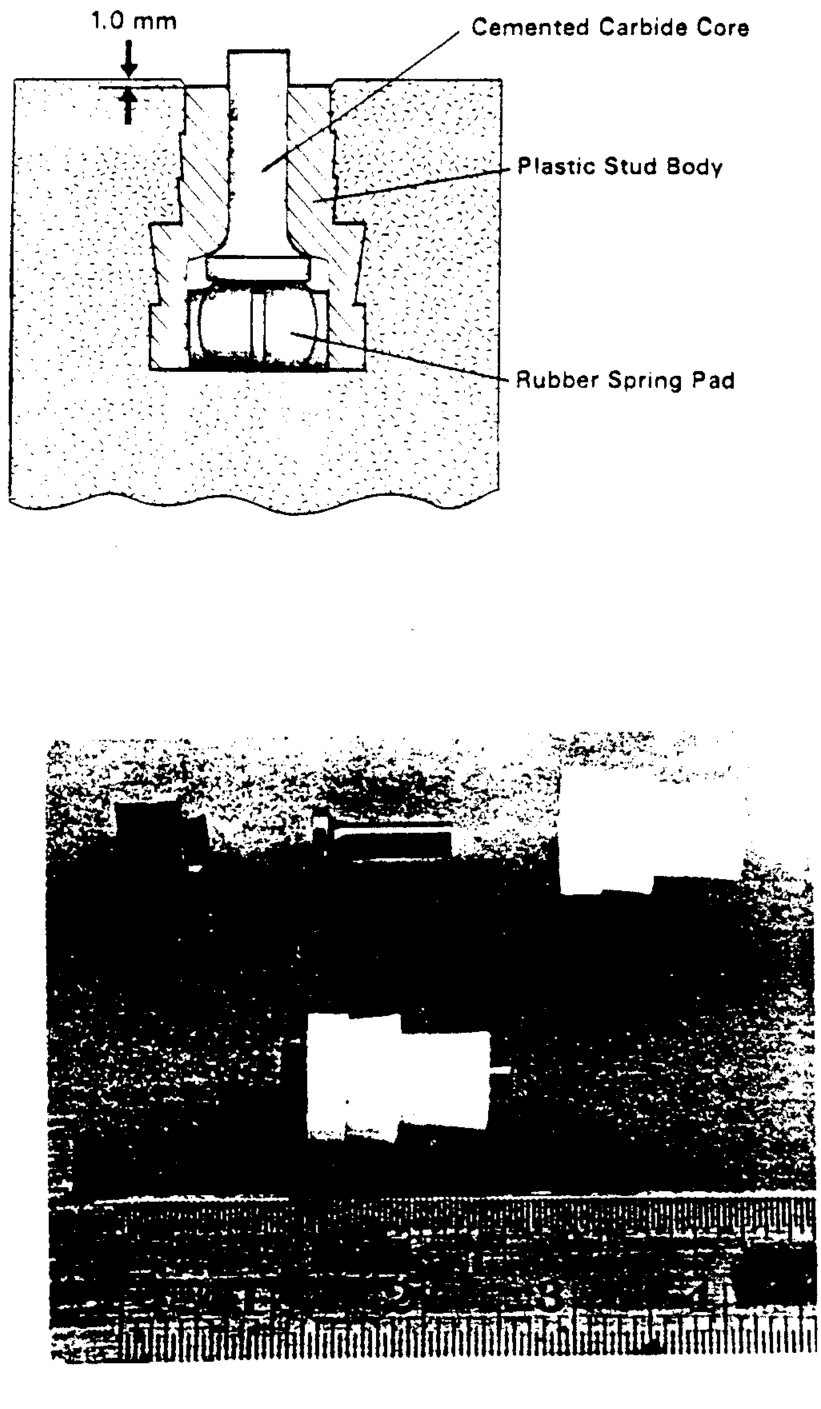
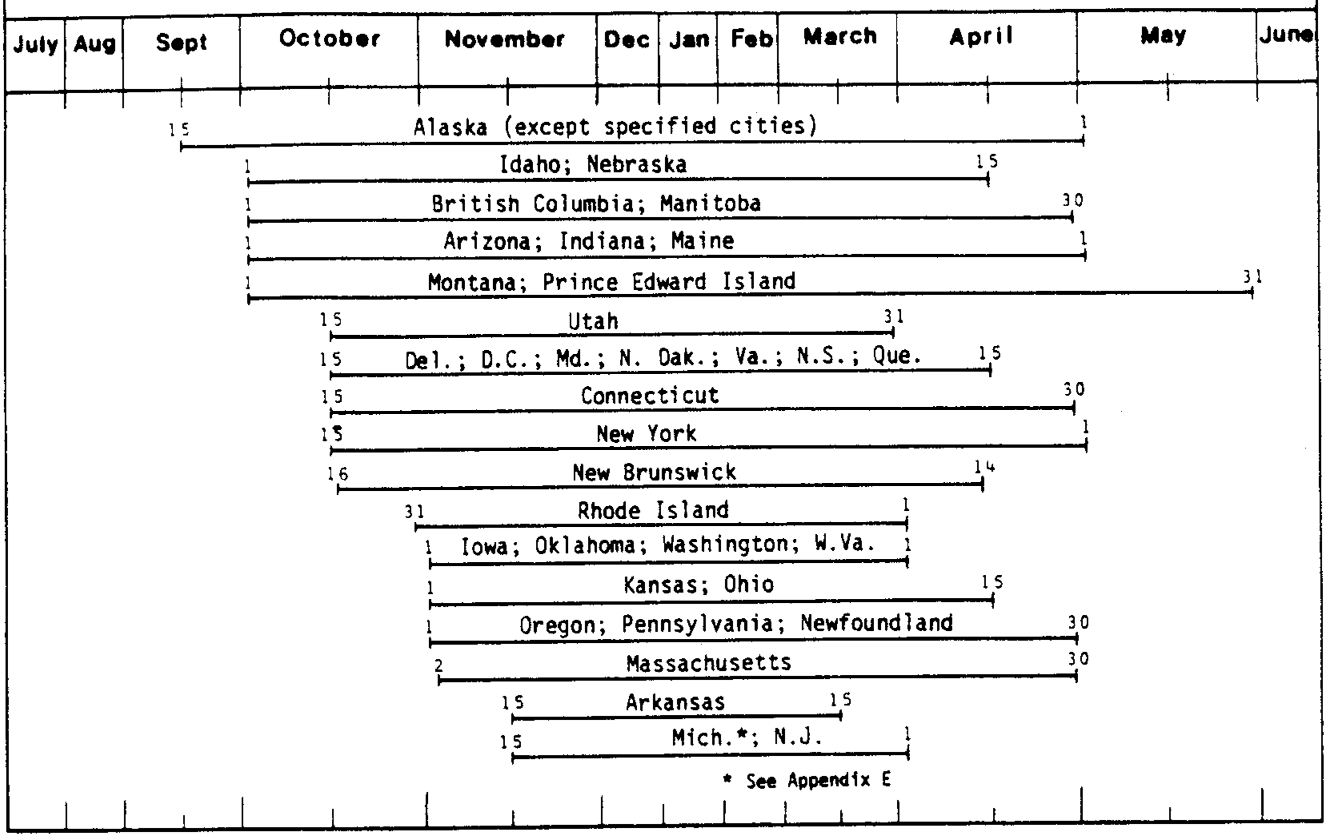


Figure 2.4. Spring-action stud (Fagersta Steels Limited) (NCHRP Syn. 32).

a) No restrictions:

Alabama
Colorado
Georgia
Kentucky
Missouri
Nevada
New Hampshire
New Mexico
North Carolina
South Carolina
South Dakota
Tennessee
Vermont
Wyoming
Alberta
Saskatchewan

b) Restricted to period shown:



c) Prohibited:

California
Florida
Hawaii
Illinois
Louisiana
Minnesota**
Mississippi
Texas
Wisconsin**
Ontario

** Limited use by out-of-state motorists permitted

Sources: American Automobile Association 12-1-74
Federal Highway Administration June 1975

Figure 2.5. Legal restrictions on use of studded tires (NCHRP Syn. 32).

Table 2.5. Restrictions on use of studded tires in the U.S./Canada (August 1990).

a) No restrictions	Colorado	
	Vermont	
	Saskatchewan	
b) Restricted to time period shown	Alaska	Sept. 15 - April 30 (north of latitude 60°N)
		October 1 - April 14 (south of latitude 60°N)
	Connecticut	November 15 - April 30
	Iowa	November 1 - April 1
	Kansas	November 1 - April 5
	Maine	October 1 - May 1
	Nevada	October 1 - April 30th
	New Jersey	November 1 - April 1
	New York	October 15 - May 1
	Rhode Island	November 15 - April 1
	Utah	October 15 - March 15
c) Restricted (period unreported)	California	
	Delaware	
	Idaho	
	Indiana	
	Montana	
	Nebraska	
	North Dakota	
	Oregon	
	Pennsylvania	
	South Dakota	
	Washington	
	Wyoming	
	New Brunswick	
	Nova Scotia	
	Quebec	
d) Prohibited	Arizona	
	Illinois	
	Maryland	
	Michigan	
	Minnesota	
	Alberta	
	Northwest Territories	
	Ontario	

Table 2.6. Restrictions on use of studded tires in Scandinavia (August 1990).

a) No restrictions	
b) Restricted	Sweden - 31 October to Easter Finland - 1 November to 31 March
c) Prohibited	Germany

3.0 ROAD WEAR STUDIES

This chapter summarizes, based on the literature, the results of studies from throughout the world to identify the cause (mechanism) of pavement wear owing to studded tires, the rate of pavement wear, and factors which affect the rate.

3.1 Cause of Pavement Wear

The results of the literature review indicated that the mechanism of wear is primarily by abrasive action. Nieme (1978) has summarized the mechanism best, as shown in Table 3.1. Which of the four possible cases is most important is still open to debate. In Alaska, it is generally felt that the primary mechanism of studded tire wear is by scraping off the mastic and abrasion of the aggregate.

3.2 Factors Affecting Wear Rate

Several factors have been identified as affecting the pavement wear rate. Keyser (1970) has prepared (in Table 3.2) an excellent summary of these factors. In addition, Keyser (1972) stated the most important factors to be wheel load, stud protrusion, temperature, and humidity.

Figure 3.1 shows the effect of pavement type on wear rate. The "regular" bituminous pavements consisted of fine-graded mixtures for thin overlays with 85-100 penetration asphalts while the "high type" bituminous pavements contained either rubber or asbestos admixtures and 85-100 asphalts. The "regular" pavements contained a filler while no filler was present in the "high type" pavements. For both tests (on a test track and typical highway pavements), the wear rate was considerably greater for asphalt concrete compared with portland cement concrete pavements. Aggregate type also had an effect for the portland cement concrete pavements. Other factors, as shown in Table 3.3, can also affect the wear rate. In addition, as shown in Figure 3.2, the wear rate in acceleration can be 2 1/2 times the wear rate in deceleration.

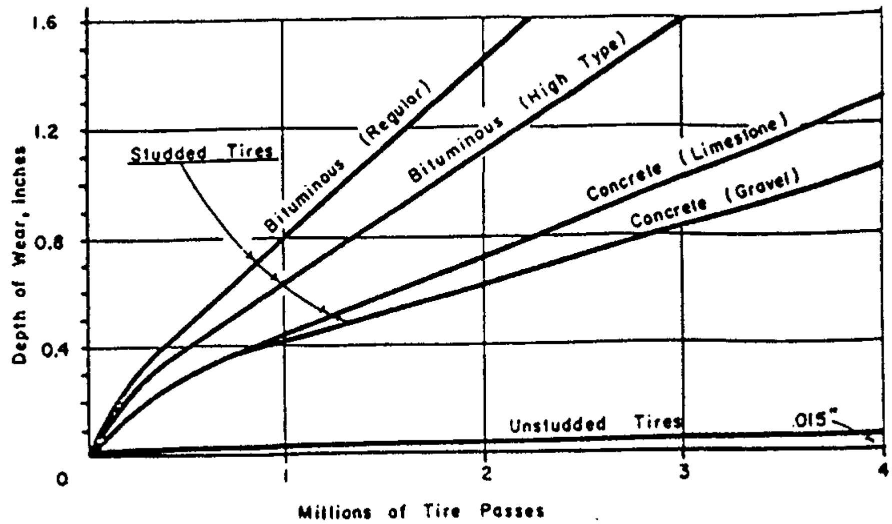
Figure 3.3 shows the effect of stud type on the average rate of wear on a test track under 542,000 wheel passes. In all cases, the wear rate was greatest during the initial 160,000 wheel passes. Wear rates then decreased to only 11 to 31% of the initial rates during the final 220,000 wheel passes. Type I and III studs caused much greater wear than type II studs.

Table 3.1. Cause of pavement wear under studded tires (after Niemi, 1978).

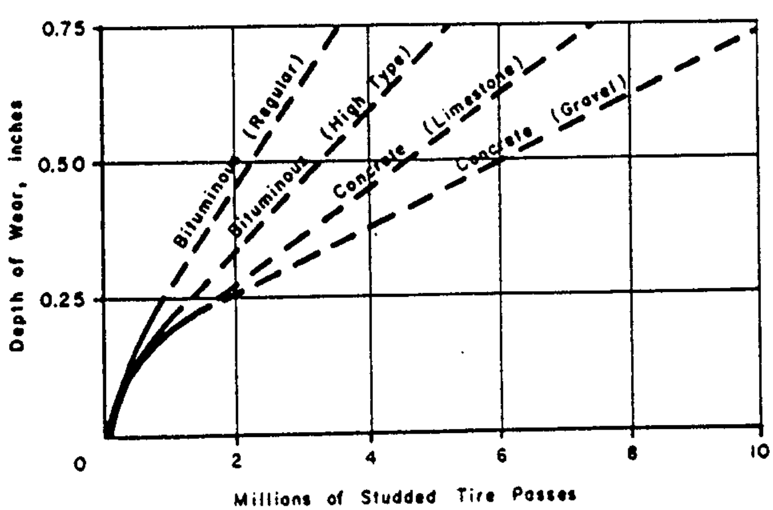
Cause	Description
1	The scraping action of the stud produces marks of wear on the mastic formed by the binder and the fine-grained aggregate.
2	The aggregate works loose from the pavement surface as a result of scraping by studs.
3	Scraping by the stud produces marks of wear on stones. Only in very soft aggregate does a rock fragment wear away completely by this action.
4	A stone is smashed by the impact of a stud and the pieces are loosened by the scraping action of the stud.

Table 3.2. Factors affecting pavement wear (Keyser, HRR 331, 1970).

Factor	Component	Characteristic
Vehicle, tire, and stud	Vehicle	Type and Weight Axle load Number of studded tires (front, rear)
	Tire	Type (snow or regular with or without stud receiving holes) Pneumatic pressure Age Configuration of studs Number of studs
	Stud	Type (material, shape) Protrusion length Orientation of studs with respect to tire wear
	Stud wear vs. tire wear	
Pavement	Geometry	Cornering (curve, sharp turn) Straight section Intersection Slope (up and down)
	Surfacing Material	Type and characteristics (bituminous mixtures, surface treatment, precoated chipping, portland cement, hardness) Age
	Surface Condition	Surface texture and profile Icy Compacted snow (compactness) Sanded or salted icy surface Slush
Environment	Humidity, temperature	Wet, dry, humid
Traffic	Volume	Number of passes and composition
	Speed	
	Wheel track	Width Distribution of wheel load
	Contact mode	Start (normal, abrupt) Stop (normal, abrupt) Acceleration (rate) Deceleration (rate) Spin Skid
Measure	Method and precision	



a) Wear rates of pavement specimens at test track



b) Wear rates of pavements of typical Minnesota highways

Figure 3.1. Relationship of studded tire induced wear vs. pavement type; Minnesota research (Keyser, HRR 352, 1971).

Table 3.3. Effect of Factors on Resistance of Asphalt Pavement to Wear by Studded Tires (Keyser, HRR 352, 1971).

Factors	Influence on Wear	Wear Ratio
Penetration of bitumen[a] 60 vs 300	Significant	1:1.3
Bitumen content[a] 5 vs 7 percent (opt. at 7 percent)	Very significant	1:1.8
Type of aggregate[b] Lamprophyre vs limestone	Very significant	1:1.6
Mix type[b] Special mix vs sheet	Very significant	1:1.8
Voids in mix[a] 3 vs 7 percent	Significant	1:1.4
Uniformity[a] Asphalt concrete variation	Variation	X ± 42 percent
Vehicle Speed[a] 60 to 80 km/hr	Not significant	--
Vehicle Weight[a] Car vs truck	Very significant	1:1.9
Tire pressure[a]	Not significant	--
Temperature[c] 37 ± vs 50 F	Very significant	1:1.5

[a]Data taken from Norwegian studies
[b]Data taken from Keyser's work
[c]Data taken from Finnish studies

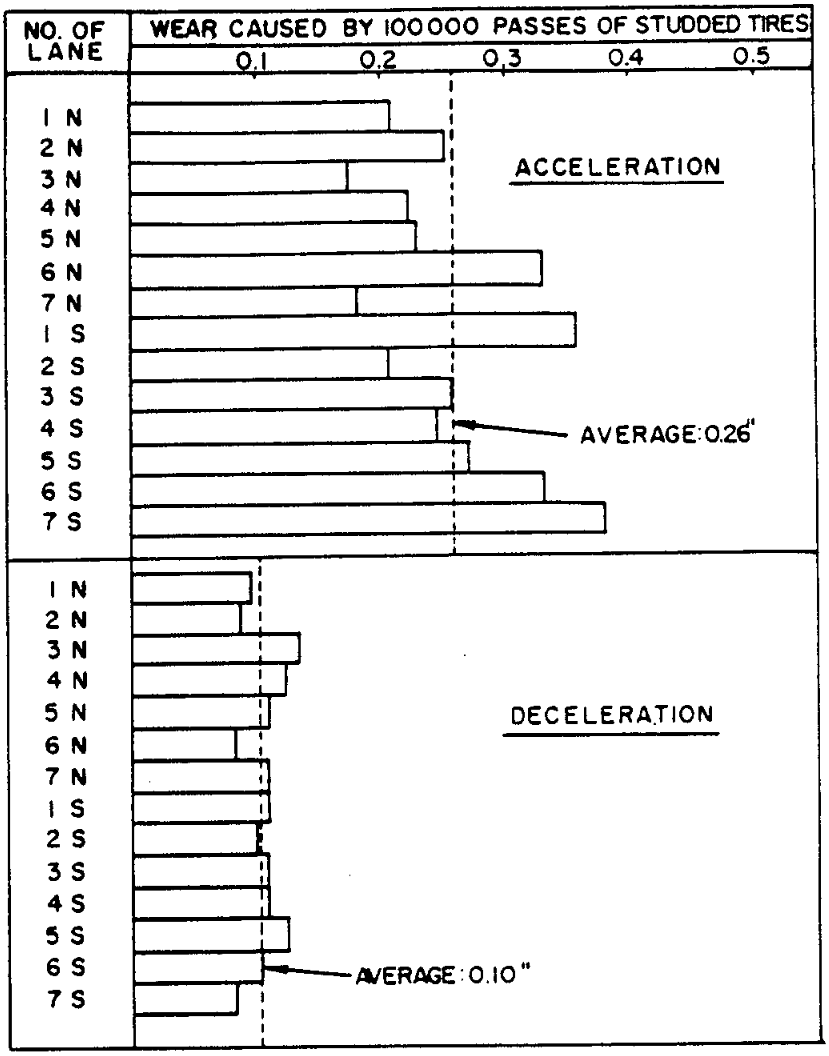
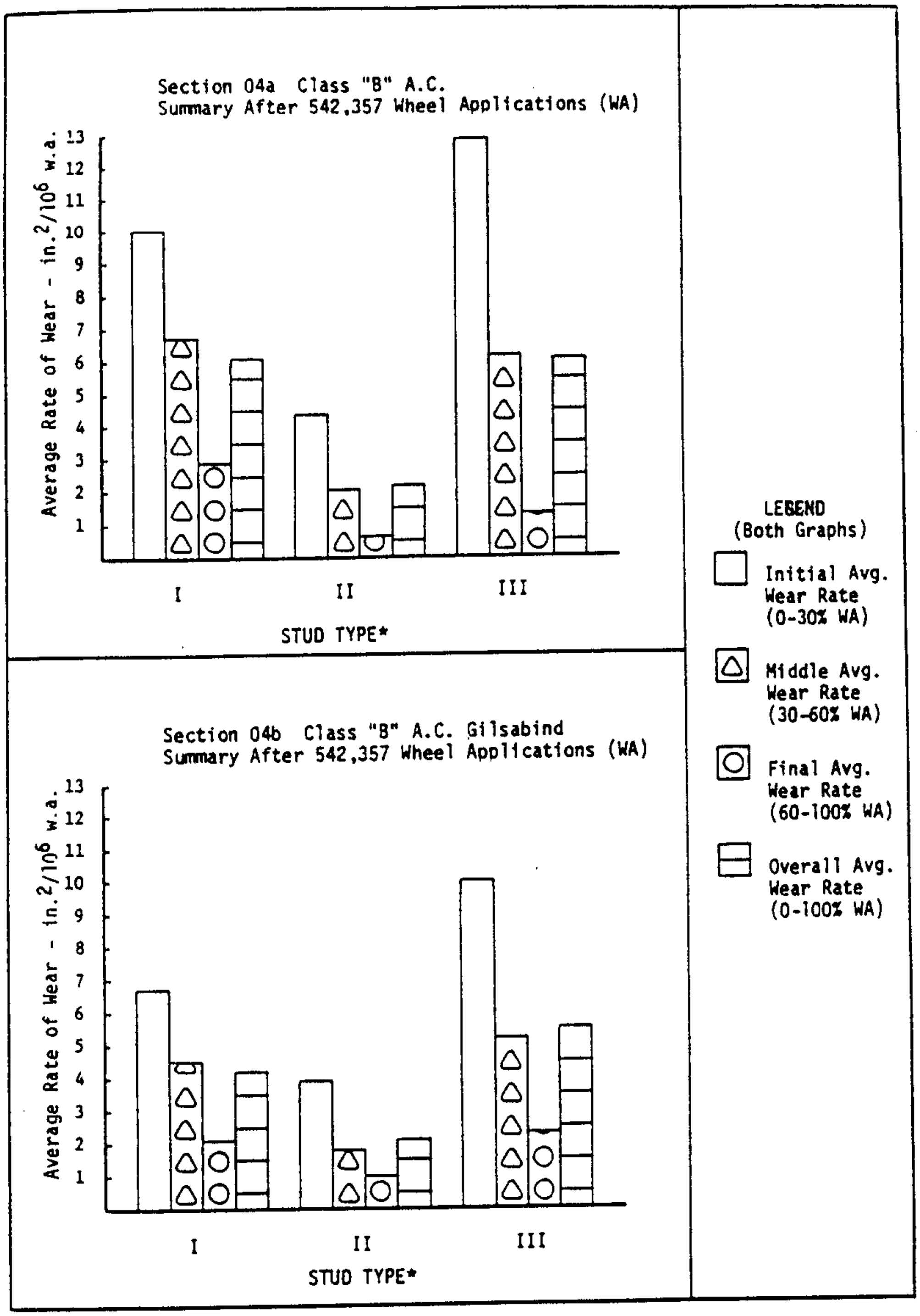


Figure 3.2. Relationship between acceleration and deceleration on portland cement concrete (Keyser, HRR 352, 1971).



* Wear Rate Due to Unstudded Tires Insignificant or Immeasurable.

Figure 3.3. Effect of Stud Type on Wear for Asphalt Concrete Pavements (Krukar and Cook, 1972).

Finally, temperature affects wear rates for asphalt concrete. The work by Krukar and Cook (1973) shows the lowest wear rate at or near 0°C. Increases in pavement wear as pavement temperatures go below 0°C are reportedly associated with increased tire hardness and pavement stiffness. As temperature decreases, pavement stiffness increases, as does the force required to push the stud into the tire so that tire so that it is flush with the pavement surface. Thus, at low temperatures, the combination of high stud force and increased pavement brittleness may result in increased wear rate. However, in Alaska it has been observed that wintertime frost and ice formation on roadways in colder cities such as Fairbanks can provide a protective surface coating and greatly reduce the low temperature wear rates.

The rate of wear reportedly increases when the pavement is wet (Keyser, 1970).

3.3 Pavement Wear Studies

The number of pavement wear studies is quite limited. However, both the literature review and survey did yield some basic information as shown in Table 3.4. In general, these results indicate:

1) Reported wear rates vary considerably between agencies. This likely is due to differences in percentages of vehicles with studded tires, and to materials differences.
2) Pavement type has a great effect on pavement wear. Asphalt surfaces wear at a faster rate than portland cement concrete.
3) In areas of acceleration and deceleration, pavement wear increases substantially.
4) Mixes with larger, more durable aggregates wear less.

In addition, other factors were shown to influence the wear rate. These are given in Table 3.5.

Table 3.4. Summary of road wear studies.

a) Literature

Reference		Rate of Wear (in./passes)	Avg. Rate/ 100,000 passes
Quebec (1967)		0.25/100,000	0.25
Quebec (1970)	Acceleration	0.36-0.44/100,000	0.40
	Deceleration	0.18-0.20/100,000	0.19
	Normal	0.11/100,000	0.11
Germany (19XX)		0.11/120,000	0.09
Finland (1988)		.15-.2/10,000 AADT	
Sweden (Keyser, 1970)		0.5/40,000 AADT	
Maryland		0.28-1.07/100,000	0.7
Minnesota		1.5/4,000,000	0.04
Oregon (ODOT, 1974)	Concrete	0.026/100,000	0.03
	Asphalt	0.066/100,000	0.07

b) Survey

Reference	Rate of Wear (in./passes)	Avg. Rate/ 100,000 passes
California	0.0005-0.0018/1000	0.12
Connecticut	0.08/1,000,000	0.01
Maryland	0.028-0.107/10,000	0.68
New Jersey	0.05 per year for 5400 AADT per lane	
New York	0.009-0.016/year PCC pavements 0.022-0.025/year ACC pavements	
Oregon	0.032/100,000 PCC pavements 0.073/100,000 ACC pavements	.03 .07
Norway	SPS[a]: AC = 25, Topeka = 15, Mastic stone = 10-15, PCC = 10	
Sweden	35 g/vehicle (4 studded tires)/km driven	

[a]SPS = g/cm (specific wear in grams worn out of the surfacing when a car with 4 studded wheels drives a 1 km distance)

Table 3.5. Factors affecting studded tire wear.

Factor	Variable	Comments
Traffic (ADOT)	Normal	Standard wear
	Acceleration	Increases wear rate by 300%
	Deceleration	Increases wear rate by 200%
Surface Type (ADOT)	Bare pavement	Increases wear rate*
	Snow pack	No wear

*Amount not reported.

4.0 IMPACTS OF STUDDED TIRE USE

The impacts of studded tire usage are twofold: 1) increased costs to the agencies through accelerated pavement wear as well as through safety problems created by the wheel track ruts and 2) benefits derived through increased traction during icy conditions which either improve safety or allow increased speeds. The use of studded tires is somewhat dependent on the agency's ice control practices. For example, heavy salt use for a "bare pavement" policy reduces icy road concerns in exchange for increased vehicle and bridge corrosion effects. This section of the report discusses each of these impacts, and is based on the results of the literature review and of the survey of agencies.

4.1 Economic Impacts

The survey of agencies clearly indicated that increased pavement wear was the major concern of most agencies. Safety problems due to increased wear of pavement markings were another concern. However, in most cases the improved stopping distance and/or maneuverability associated with studded tire use generally offset any negative impacts.

Though costs were not requested in the survey, the literature has some data which is useful in defining the economic impacts (Table 4.1). Though most of this information is from Scandinavia, it clearly indicates substantial costs associated with pavement wear, but a potential benefit due to improved (not reduced) safety and reduced winter maintenance (e.g., sanding) costs.

Table 4.2 also provides information on the additional costs associated with the continued use of studded tires on municipal roads and streets in Ontario. As indicated, not only does the cost for pavement maintenance increase, but significant costs can be realized in replacing traffic markings.

Table 4.3 summarizes the impacts of studded tire usage. Clearly the primary reason people use studded tires is for improved maneuverability and control under icy conditions.

4.2 Benefits of Studded Tires

Clearly the primary benefit of studded tires is improved traction (apparent) and hence improved safety. This is noted in the survey of agencies; however, little documentation was provided to substantiate the benefits.

Table 4.1. Annual cost effects of studded tires on pavement wear and safety (for a ban on studded tires).

Agency	Pavement Wear Costs	Winter Maintenance Costs	Accident Costs
Oregon DOT (1974)	+1.1 million	NA	NA
Finland (Pelkonen, 1978)	+175 to 250 million mks	-44 million mks	-0 to 190 million mks
Sweden (VTI - 1988/89)	+160 to 250 million SEK (national roads)	NA	-560 to 1160 million SEK (switch to snow tires)
	+95 to 150 million SEK (municipal roads)	NA	-1230 to 2590 million SEK (switch to summer tires)

Notes:

6 SEK = 1 U.S. dollar
4 mks = 1 U.S. dollar

\+ Increase in costs
\- Decrease in costs

NA = Not available

Table 4.2. Estimate of additional agency costs in Ontario due to the continued use of studded tires (Smith and Schonfeld, HRR 331, 1970).

Financial Year	Department of Highways				Municipalities				Grand Total
	New Pavement Construction[a]	Resurfacing and Patching[b]	Traffic Marking[c]	Total	New Pavement Construction[d]	Resurfacing and Patching[e]	Traffic Marking[f]	Total	
1970-71	608,000	589,000	1,078,000	2,275,000	458,000	470,000	1,078,000	2,006,000	4,281,000
1971-72	625,000	1,533,000	902,000	3,060,000	469,000	1,226,000	902,000	2,597,000	5,657,000
1972-73	855,000	4,298,000	778,000	5,931,000	641,000	3,438,000	778,000	4,857,000	10,788,000
1973-74	683,000	5,769,000	302,000	6,754,000	512,000	4,615,000	302,000	5,429,000	12,183,000
1974-75	625,000[g]	5,960,000[g]	325,000[g]	6,910,000	469,000	4,768,000	325,000	5,562,000	12,472,000
1975-76	625,000[g]	2,250,000[g]	1,325,000[g]	4,200,000	469,000	1,800,000	1,325,000	3,594,000	7,794,000
1976-77	625,000[g]	8,569,000[g]	1,325,000[g]	10,519,000	469,000	6,855,000	1,325,000	8,649,000	19,168,000
1977-78	625,000[g]	18,607,000[g]	1,325,000[g]	20,557,000	469,000	14,886,000	1,325,000	16,680,000	37,237,000
1978-79	625,000[g]	8,578,000[g]	325,000[g]	9,528,000	469,000	6,860,000	325,000	7,654,000	17,182,000
Total	5,896,000	56,153,000	7,685,000	69,734,000	4,425,000	44,918,000	7,685,000	57,028,000	126,762,000

[a]Costs include both concrete and bituminous pavements.
[b]Costs include additional costs of providing more wear-resistant surfaces for the normal resurfacing program.
[c]Additional cost of providing more permanent traffic markings for both new pavements and existing ones.
[d]Taken as 75 percent of corresponding King's Highway figures.
[e]Taken as 80 percent of corresponding King's Highway figures.
[f]Taken as 100 percent of corresponding King's Highway figures.
[g]Estimated figure based on continuance of department's construction and resurfacing program at about the level of preceding years.

Table 4.3. Impacts of studded tire usage.

a) Consequences

Factor	Consequences
Effect on Safety	• Increased rutting, ponding and hydroplaning • Increased splash and spray
Effect on Pavement	• Destruction of pavement markings • Increased rutting • Build up of snow and ice in ruts

b) Benefits

Factor	Benefit
Effect on safety	• Improved stopping distance on ice • Improved maneuverability on ice
Effect on pavement	• None identified

The literature review shows mixed results. Smith et al. (1971) shows a minor benefit in terms of stopping distance on asphalt pavements and mixed benefits on concrete pavements (Table 4.4). This is also shown in Figures 4.1 and 4.2 for wet and dry pavements. However, Figure 4.3 clearly indicates the benefits of studded tires on ice (i.e., significantly improved stopping distances). Finally, it is clear from Figure 4.4 this decrease in stopping distance is not due to increased pavement skid resistance. Work by Smith et al. (published in HRR 352) shows that in most cases the skid resistance decreases with increasing use of studded tires.

Results of a recent skid survey done in Alaska in the summer of 1987 indicated that higher traffic areas were more polished and had lower skid numbers by late summer. However, pavement age was not a factor, so total number of stud passes were not a factor. The conclusion was that studs roughen the pavement and that normal tires polish the pavement (Ryer, 1988).

Table 4.4. Stopping distances from report for the Canadian Safety Council (Smith et al., HRR 352, 1971).

Stopping Distances from 50 miles per hour (in feet) Under Various Road Conditions	Dry Asphalt	Wet Asphalt	Dry Concrete	Wet Concrete	Glare Ice 0°C
Highway tread on 4 wheels	121	151	105	154	640'
Snow tire tread on rear wheels	118	148	106	165	620'
Studded snow tire on rear wheels	117	142	115	177	580'
Studded snow tire on 4 wheels	116	149	122	195	500'

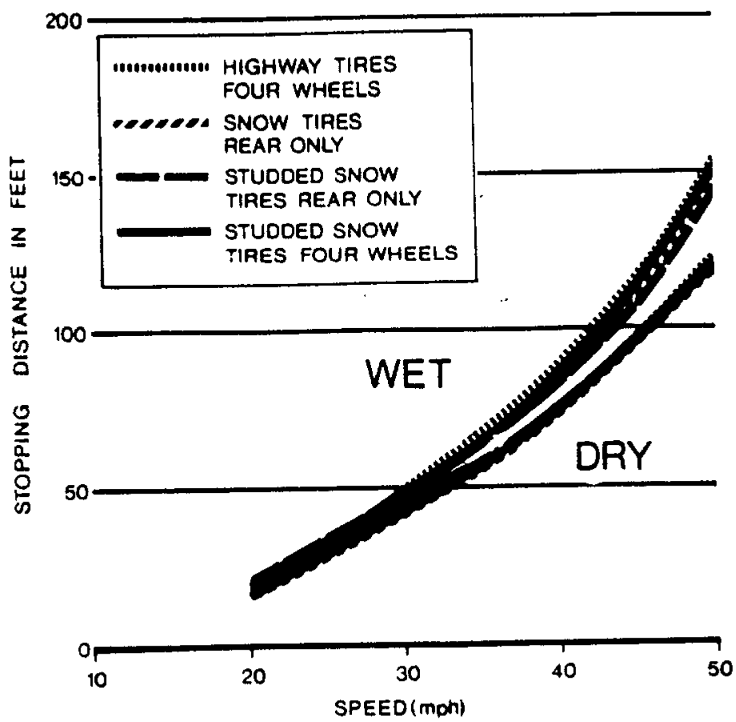


Figure 4.1. Stopping distance versus speed for cars traveling on asphalt pavement (Smith, et al., HRR 352, 1971).

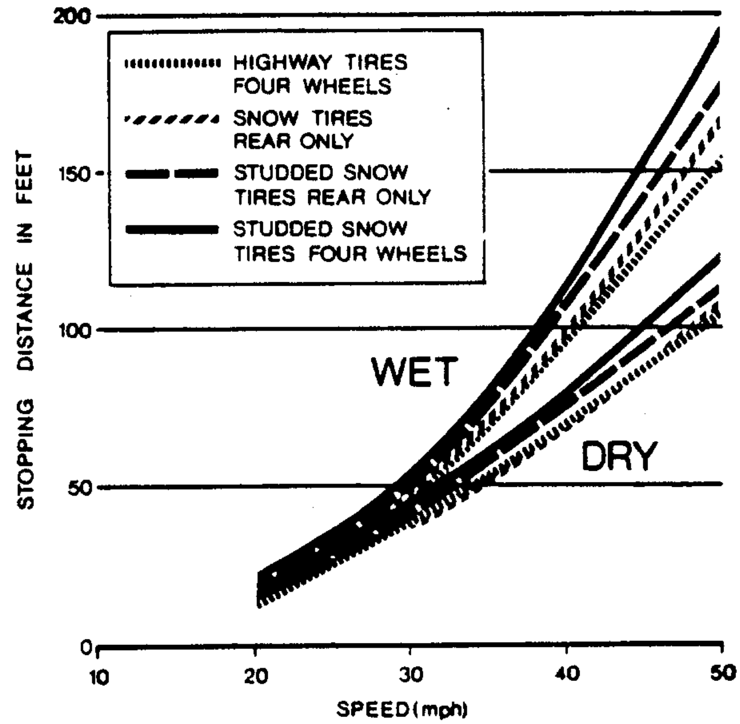


Figure 4.2. Stopping distance versus speed for cars traveling on concrete pavement (Smith, et al., HRR 352, 1971).

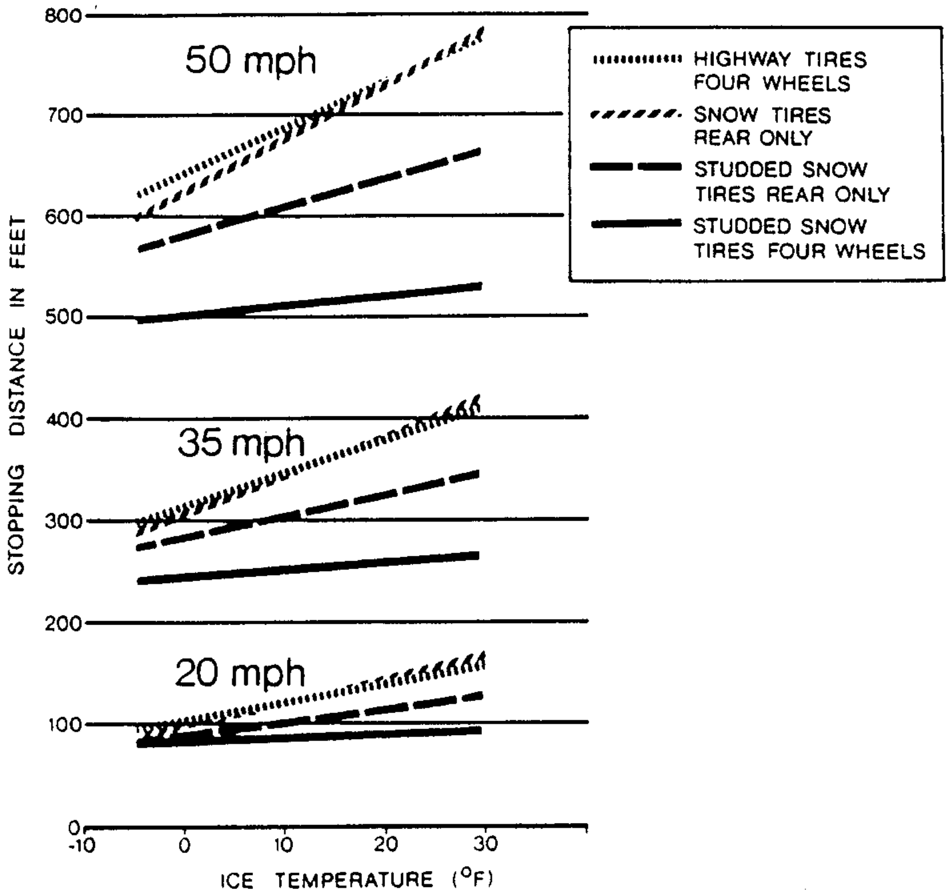


Figure 4.3. Stopping distance versus ice temperature for four cars traveling at 20, 35, and 50 mph (Smith et al., HRR 352, 1971).

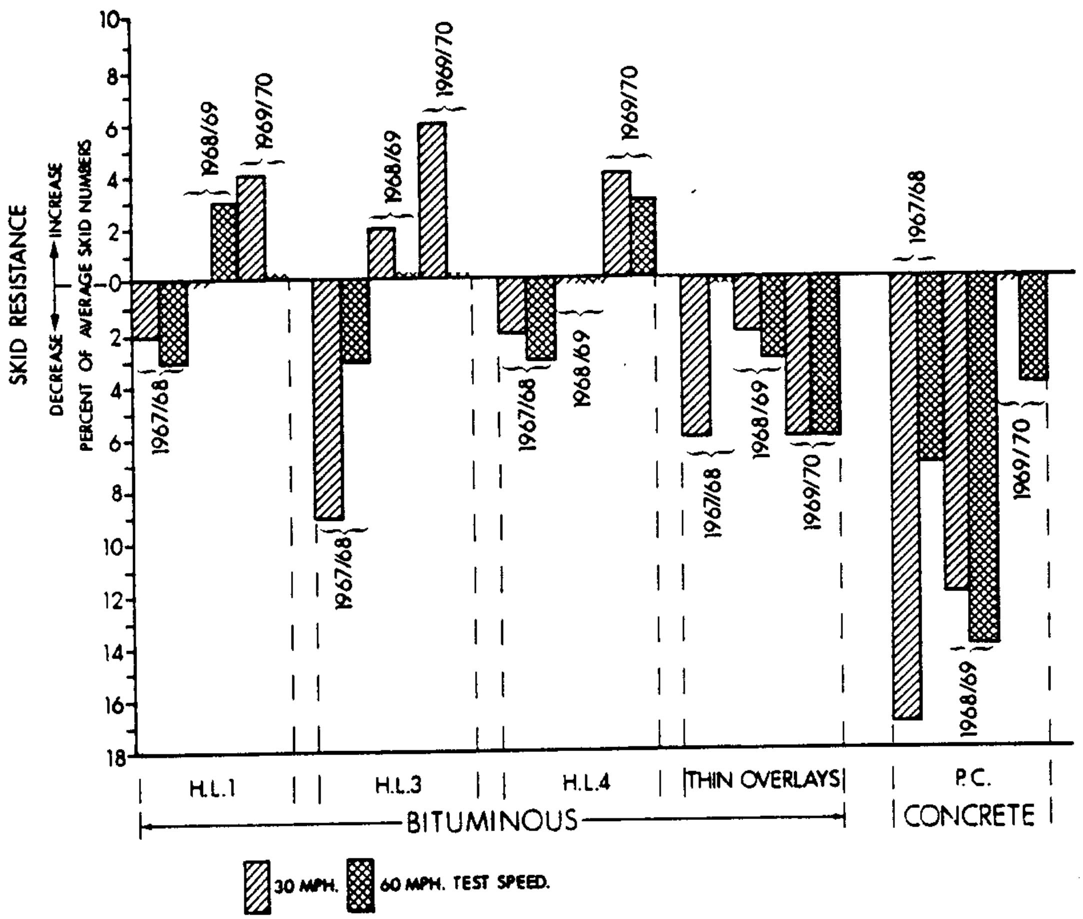


Figure 4.4. Changes in skid resistance of some pavements in Ontario with increasing use of studded tires (Smith and Schonfeld, HRR 352, 1971).

5.0 SUMMARY

This report presented a summary of the results of a literature review and survey of agencies on the use and effects of studded tires. Significant findings include the following facts:

1) Very little research has been done since 1975 in this area, with the exception of the Scandinavian countries.
2) Many agencies continue to prohibit or restrict the use of studded tires.
3) Very little new information on percent of vehicles using studded tires or on tire wear studies was available. Agencies basically do not know the rates of stud use.
4) Factors affecting wear rates were defined (e.g., pavement type, temperature, acceleration and deceleration areas).
5) The consequences and benefits of using studded tires were identified, but remain largely unquantified.
6) Telephone conversations with the manufacturers/distributors revealed that only the controlled protrusion type stud is currently used in the U.S.

Car owners continue to spend millions each year on studded tires for perceived or real benefits. Benefits associated with new tire types, radials instead of bias-ply tires, all-season treads vs. the older summer and winter treads, have not been evaluated in the USA. The shift from rear axle to front axle drive would also increase the effectiveness of studs on the drive axles, since the front axles perform much of the braking work. Therefore the above conclusions may no longer be valid.

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APPENDIX A

SURVEY FORM

Alaska DOT & PF
Survey on Use of Studded Tires

Agency ______________________ Reported by ______________________

Address ______________________ Title ______________________

Date Completed ______________________ Phone ______________________

Pavement damage due to the use of studded tires can be a serious problem. The purpose of this survey is to obtain information on the use of studded tires and other traction devices, and their effects on pavement wear. We would appreciate your input to complete this survey. If necessary, please use estimates of studded tire usage.

---

1. Does your State/Province permit studded tire use? Yes ☐ No ☐

2. Do you permit tire chain use? Yes ☐ No ☐

3. Do you ever require chain use, as for mountain passes, or steep grades? Yes ☐ No ☐

4. If chains are sometimes "required" do you allow studded or snow tires in lieu of chains? Yes ☐ No ☐

5. At such times, are studded tires considered better than snow tires? Yes ☐ No ☐

6. Has your agency conducted any recent surveys of studded tire usage in the different seasons? Yes ☐ No ☐

   If you have, what were the results, as:

   ____% of passenger vehicles with studs
   ____% of light trucks with studs

   or: Number of studded tire passes per 100 vehicle passes ____

If you have more extensive surveys, what were the results?

Vehicle Type	Season	
Vehicle Type / Studs on	Summer % Use	Winter % Use
Autos - 2 wheels - 4 wheels Light Trucks - 2 wheels - 4 wheels		
All Vehicles: Studded tires passes per 100 vehicle passes		

7. <u>Studded Tire Ban Enforcement</u>:

If a motorist chooses to drive with studded tires during a prohibited period, what is his risk and cost of being cited for such use?

Risk: Low ☐ Moderate ☐ High ☐

Cost: Low (<$25) ☐ Moderate ☐ High (>$50) ☐

8. Have you ever completed any studies on pavement wear due to studded tires?
   ☐ Yes
   ☐ No

   Have you ever completed any studies on pavement wear due to chains?
   ☐ Yes
   ☐ No

   If yes, please complete the following:

   a. What was the average pavement wear rate (e.g., inches wear/number of vehicles) ____________________
   b. What other factors have you found to affect the wear rate?
      ☐ Stopping
      ☐ Starting
      ☐ Aggregate and mix type
      ☐ Pavement type
      ☐ Other: ____________________
   c. Please send copies of recent reports (1980 to present)

APPENDIX B

SUMMARY OF RESPONSES

Table 1. Questions 1 through 5.

Q1: Does your state/province permit studded tire use?
Q2: Do you permit tire chain use?
Q3: Do you require chain use, as for mountain passes or steep grades?
Q4: If chains are sometimes "required", do you allow studded or snow tires in lieu of chains?
Q5: At such times, are studded tires considered better than snow tires?

State, Province or Country	Q1	Q2	Q3	Q4	Q5
Alaska	Yes	Yes	No	N/A	N/A
Arizona DOT	No	Yes	Yes	No	N/A
California DOT	Yes	Yes	Yes	Yes	No
Colorado DOH	Yes	Yes	Yes	Yes	Yes
Connecticut DOT	Yes	Yes	No		No
Delaware DOT	Yes	Yes	Yes	Yes	No(a)
Idaho Transp.	Yes	Yes	Yes	Yes	Yes
Illinois DOT	No	Yes	No		
Indiana DOT	Yes	Yes	No	Yes	Yes
Iowa DOT	Yes	Yes	No		No
Kansas DOT	Yes	Yes	No		
Maine DOT	Yes	Yes	No(b)		
Maryland DOT	No	Yes	Yes	Yes	No
Michigan DOT	No				
Minnesota DOT	No	Yes	No		
Montana DOH	Yes	Yes	Yes	Yes - studded tires	Yes - for ice only
Nebraska Dept. of Roads	Yes	Yes	No		Yes
Nevada DOT	Yes	Yes	Yes	No	Yes
New Jersey DOT	Yes	Yes	No		
New York DOT	Yes	Yes	No	No	No
North Dakota DOT	Yes	Yes	No		
Oregon DOT	Yes	Yes	Yes	Yes	Yes
Pennsylvania DOT	Yes	Yes	No		Yes - for ice only
Rhode Island DOT	Yes	Yes	No		
South Dakota DOT	Yes	Yes	Yes	Yes	
Utah DOT	Yes	Yes	Yes	Yes	
Vermont AOT	Yes	Yes	No	N/A	N/A
Washington DOT	Yes	Yes	Yes	Yes - studded tires	N/A
Wisconsin DOT	No	Yes	No	No	N/A
Wyoming Hwy Dept.	Yes	Yes	Yes	Yes	No

Table 1. continued

Q1: Does your state/province permit studded tire use?
Q2: Do you permit tire chain use?
Q3: Do you require chain use, as for mountain passes or steep grades?
Q4: If chains are sometimes "required", do you allow studded or snow tires in lieu of chains?
Q5: At such times, are studded tires considered better than snow tires?

State, Province or Country	Q1	Q2	Q3	Q4	Q5
Alberta Transp. & Util.	No	Yes	Yes	No	N/A
Manitoba DOH&T	Yes	Yes	No	N/A	N/A
Newfoundland DOT	Yes	Yes	No	No	Yes
New Brunswick DOT	Yes	Yes	No	N/A	N/A
NW Territories Dept. of PW&H	No	Yes	Yes	No	Unknown
Nova Scotia DOT	Yes	Yes	No	N/A	N/A
Ontario Ministry of Transp.	No	Yes	No	N/A	N/A
Quebec	Yes	Yes	No	N/A	Unknown
Saskatchewan Hwys & Transp.	Yes	Yes	No		
Finland	Yes	Yes	No	N/A	N/A
Norwegian Road Res. Lab.	Yes	Yes	No	N/A	Yes
Swedish Road & Traffic Res. Inst.	Yes	Yes	No	N/A	N/A
West Germany	No	Yes	Yes	No	No

(a) Only on glare ice

(b) Some local ordinances require motorists to have snow tires on vehicle or have tire chains available in vehicle when traveling in winter weather.

(c) Agencies not responding:

New Hampshire DOH
Massachusetts DOPW
Ohio DOT
New Mexico SHD

British Columbia
Yukon Territory

Table 2. Question 6

Q6: Has your agency conducted any recent surveys of studded tire usage in the different seasons?			
State, Province or Country	Usage Survey	Estimated % of vehicles with studs	
		Passenger Cars	Light Trucks
Alaska	Yes	36.7 (a)	37.2 (a)
Arizona DOT	No		
California DOT	No		
Colorado DOH	No		
Connecticut DOT	No		
Delaware DOT	No		
Idaho Transp.	No		
Illinois DOT	No		
Indiana DOT	No		
Iowa DOT	No	8.5	-
Kansas DOT	Yes	(b)	
Maine DOT	No		
Maryland DOT	No		
Michigan DOT			
Minnesota DOT	No		
Montana DOH	No		
Nebraska Dept. of Roads	No	2.4 - 4.2	-
Nevada DOT	No		
New Jersey DOT	No		
New York DOT	No		
North Dakota DOT	No		
Oregon DOT	Yes	6% of both cars & trucks	
Pennsylvania DOT	No		
Rhode Island DOT	No		
South Dakota DOT	No		
Utah DOT			
Vermont AOT	No		
Washington DOT	No		
Wisconsin DOT	No		
Wyoming Hwy Dept.	No		
Alberta Transp. & Util.	No		
Manitoba DOH&T	No		
Newfoundland DOT	No		
New Brunswick DOT	No	10	-

Table 2. continued

Q6: Has your agency conducted any recent surveys of studded tire usage in the different seasons?			
State, Province or Country	Usage Survey	Estimated % of vehicles with studs	
		Passenger Cars	Light Trucks
NW Territories Dept of PW&H	No		
Nova Scotia DOT	No		
Ontario Ministry of Transp.	No		
Quebec	No		
Saskatchewan Hwys & Transp.	No		
Finland	Yes	97	30
Norwegian Road Res. Lab	Yes	97	60
Swedish Rd & Traf. Res. Inst.	Yes	61-94 (c)	- (d)
West Germany	Yes	5-60	0

(a) Anchorage, November 1989.
(b) Studies no longer applicable. Very few studded tires currently operating in Kansas.
(c) Varies with portion of country. Highest in north.
(d) Studs are not allowed on vehicles with a weight exceeding 3500 kgs.

Table 3. Question 7

Q7: If a motorist chooses to drive with studded tires during a prohibited period, what is his risk and cost of being cited for such use?

State, Province or Country	Risk	Cost
Alaska	Low	< $25
Arizona DOT	Low	
California DOT	Low	High(a)
Colorado DOH (b)		
Connecticut DOT	Moderate	High
Delaware DOT	"Nil"	
Idaho Transp.	Moderate	High
Illinois DOT	High	High
Indiana DOT	Moderate	(c)
Iowa DOT	Low	Low
Kansas DOT	Low	Low
Maine DOT	Low	(d)
Maryland DOT	Moderate	High
Michigan DOT		
Minnesota DOT	High	Moderate
Montana DOT	Low	
Nebraska Dept. of Roads	Moderate	Low
Nevada DOT	High	Moderate
New Jersey DOT	Moderate	Moderate
New York DOT	Low	Low
North Dakota DOT		
Oregon DOT	Moderate-High	Moderate
Pennsylvania DOT	Moderate	Moderate-High
Rhode Island DOT	Moderate	Low
South Dakota DOT	High	Moderate
Utah DOT	Low	
Vermont AOT (b)	-	-
Washington DOT	High	Moderate
Wisconsin DOT	High	High
Wyoming Hwy Dept.	-	-
Alberta Transp. & Util.	Low	
Manitoba DOH&T	Low	Moderate
Newfoundland DOT	Moderate	Moderate

Table 3. continued

Q7: If a motorist chooses to drive with studded tires during a prohibited period, what is his risk and cost of being cited for such use?		
State, Province or Country	Risk	Cost
New Brunswick DOT	Moderate	Low
NW Territories Dept. of PW&H	Low	Low
Nova Scotia DOT	Moderate	Moderate
Ontario Ministry of Transp.	High	High
Quebec	High	High
Saskatchewan Hwys & Transp. (b)		
Finland	Moderate	Moderate
Norwegian Road Res. Lab.	Moderate	High
Swedish Road & Traf. Res. Inst.	Moderate	High
West Germany	Moderate	Low

(a) The fine for the first offense is $100 max.
(b) No prohibited period.
(c) Ranges from $1 to a max. of $500 + vehicle impoundment.
(d) Fine varies from $25 to $100.

Table 4. Question 8

Q8: Have you ever completed any studies on pavement wear due to studded tires or chains?		
State, Province or Country	Studded Tires	Chains
Alaska	No	No
Arizona DOT	No	No
California DOT	Yes	No
Colorado DOH	No	No
Connecticut DOT	Yes	No
Delaware DOT	Yes	No
Idaho Transp.	No	No
Illinois DOT	No	No
Indiana DOT	No	No
Iowa DOT	Yes	No
Kansas DOT	No	No
Maine DOT	No	No
Maryland DOT	Yes	No
Michigan DOT		
Minnesota DOT	Yes	
Montana DOH	Yes	No
Nebraska Dept. of Roads	No	No
Nevada DOT	No	No
New Jersey DOT	Yes	No
New York DOT	Yes	No
North Dakota DOT	No	No
Oregon DOT	Yes	No
Pennsylvania DOT	Yes	No
Rhode Island DOT	No	No
South Dakota DOT	Yes	No
Utah DOT	No	No
Vermont AOT	No	No
Washington DOT	Yes	No
Wisconsin DOT	Yes	No
Wyoming Hwy Dept.	No	No
Alberta Transp. & Util.	No	No
Manitoba DOH&T	No	No
Newfoundland DOT	No	No
New Brunswick DOT	No	No

Table 4. continued

Q8: Have you ever completed any studies on pavement wear due to studded tires or chains?		
State, Province or Country	Studded Tires	Chains
NW Territories Dept of PW&H	No	No
Nova Scotia DOT	No	No
Ontario Ministry of Transp.	Yes	No
Quebec	No	No
Saskatchewan Hwys & Transp.	No	No
Finland	Yes	No
Norwegian Road Res. Lab	Yes	Yes
Swedish Road & Traf. Res. Inst.	Yes	No
West Germany	Yes	Yes

Table 4. continued

Q8(cont'd): a) What was the average wear rate?
b) What other factors affect wear rate?
c) Most recent research report.

State, Province or Country	Wear Rate	Stopping	Starting	Factors Affecting Wear Rate: Aggregate & Mix Type	Factors Affecting Wear Rate: Pavement Type	Factors Affecting Wear Rate: Other	Most Recent Research Report
Alaska							
California DOT	0.0005" - 0.0018"/1000 vehicles			X			March 1979
Colorado DOH	Don't Know			X	X		
Connecticut DOT	0.08"/million vehicles			X	X		1972
Iowa DOT	Not determined			X	X		
Maryland DOT	Car: 0.028"-0.107"/10,000 vehicles (flexible pavement) 0.013"-0.052"/10,000 vehicles (rigid pavement)						
	Truck: 0.050"-0.174"/10,000 vehicles 0.022"-0.174"/10,000 vehicles						
Minnesota DOT							
New Jersey DOT	1.25mm/yr. for 5400 AADT per lane			X	X		
New York DOT	0.009"-0.016"/year for PCC pavements 0.022"-0.025"/year for ACC pavements						
Oregon DOT	0.032"/100,000 stud passes for PCC 0.073"/100,000 stud passes for AC						
Pennsylvania DOT	0.5"/5000 directional vehicles	X	X	X	X		
Washington DOT							1980
Wisconsin DOT	Not given	X	X	X	X		
Ontario Ministry of Transp.	Look in TRB circa 1975-80						

Table 4. continued

Q8(cont'd): a) What was the average wear rate? b) What other factors affect wear rate? c) Most recent research report.							
State, Province or Country	Wear Rate	Stopping	Starting	Factors Affecting Wear Rate			Most Recent Research Report
				Aggregate & Mix Type	Pavement Type	Other	
Finland	35 g/vch/km or .3 to .4 mm/1000 ADT	X	X	X	X	Speed, stud weight, stud protrusion	
Norwegian Road Res. Lab	SPS(a):AC=25, Topeka(b)=15, Mastic stone = 10-15, PCC = 10	X	X	X	X	Wet or moist surfacing: doubles the wear	
Swedish Road & Traf. Res. Inst.	Avg: 35 g/vehicle(4 studded tires)/km driven	X	X	X	X	Temperature, moisture(wet/dry surfacing), speed	

(a) SPS = g/cm passenger car (specific wear in grams worn out of the surfacing when a car with 4 studded wheels drives a 1 km distance).
(b) Topeka = high performance bit. surf.

Table 5. Question 9

Q9: What are the major costs or consequences to your department of using studded tires?

State, Province or Country	Increased Pavement Wear	Safety Problems	Other
Alaska	X	X	
California DOT	X		
Colorado DOH	X		
Connecticut DOT	X	X	
Delaware DOT	X	X	
Idaho Transp.	X		
Indiana DOT	X		
Iowa DOT	X		
Kansas DOT	X		
Maine DOT	X		Wear evident in wheel tracks of concrete pavements
Montana DOH	X	X	
Nebraska Dept. of Roads			Little because of small usage
Nevada DOT			Unknown
New Jersey DOT	X	X	
New York DOT	X	X	
Oregon DOT	X	X	
Pennsylvania DOT	X	X	Accidents on dry pavements
Rhode Island DOT	X	X	
South Dakota DOT	X	X	
Utah DOT	X	X	Increased stopping distance on dry pavement
Vermont AOT			None identifiable
Washington DOT	X		
Wyoming Hwy Dept.	X		
Alberta Transp. & Util.	X		
Newfoundland DOT		X	
New Brunswick DOT	X		
NW Territories Dept of PW&H			Unknown
Nova Scotia DOT		X	May increase stopping distances on certain (bare) surfaces
Ontario Ministry of Transp.	X	X	Hydroplaning
Quebec	X	X	
Saskatchewan Hwys & Transp.			No major costs
Finland	X	X	Dirt, dust, noise
Norwegian Road Res. Lab	X	X	Environmental impact
Swedish Road & Traf. Res. Inst.	X		
West Germany	X	X	Rolling noise

Table 6. Question 10

Q10: What are the primary benefits of using studded tires?				
State, Province or Country	Increased Safety	Increased Traction	Increased Speeds	Other
Alaska	X	X	X	
California DOT		X		
Colorado DOH		X		
Connecticut DOT				Decreased stopping distance under icy conditions only
Delaware DOT (a)	X	X	X	
Idaho Transp.		X		
Indiana DOT		X		
Iowa DOT (b)				
Kansas DOT		X		
Maine DOT				No surveys conducted on this subject
Montana DOH (c)		X		Probably no benefit except under certain icy conditions
Nebraska Dept. of Roads	X			
Nevada DOT				Unknown
New Jersey DOT				Few perceived benefits
New York DOT		X		
Oregon DOT		X (c)		
Pennsylvania DOT	X	X	X	Under ice conditions
Rhode Island DOT		X		
South Dakota DOT		X	X	
Utah DOT			X	
Vermont AOT	X	X	X	
Wyoming Hwy Dept.	X	X		
Alberta Transp. & Util.	X	X		Increased directional stability
Newfoundland DOT	X	X		
New Brunswick DOT	X	X		
NW Territories Dept of PW&H				Unknown
Nova Scotia DOT	X (d)	X		
Ontario Ministry of Transp.			X	
Quebec				Some benefits on icy road conditions
Saskatchewan Hwys & Transp.				No significant benefits
Finland	X	X	X	Less salt is needed for road maintenance
Norwegian Road Res. Lab		X	X	Better maneuverability
Swedish Road & Traf. Res. Inst.	X		(e)	
West Germany	X	X	X	

(a) On glare ice conditions
(b) None: their reduction of safety is greater than the benefits
(c) Only effective on ice when temperatures are near freezing
(d) Under certain conditions
(e) Do not want people to drive faster if they have studded tires

Table 8. Question 11

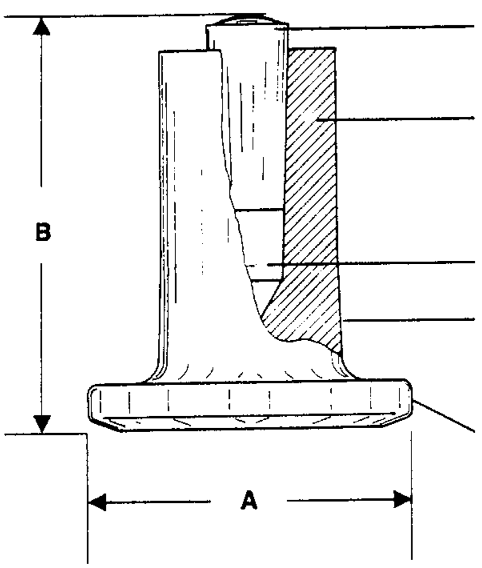
Q11: Are you interested in receiving a copy of the survey results?	
State, Province	Copy of
Alaska	
Arizona DOT	NR
California DOT	Yes
Colorado DOH	Yes
Connecticut DOT	Yes
Delaware DOT	No
Idaho Transp.	NR
Illinois DOT	Yes
Indiana DOT	Yes
Iowa DOT	Yes
Kansas DOT	Yes
Maine DOT	Yes
Maryland DOT	Yes
Michigan DOT	NR
Minnesota DOT	Yes
Montana DOH (a)	Yes
Nebraska Dept. of Roads	Yes
Nevada DOT	Yes
New Jersey DOT	Yes
New York DOT	Yes
North Dakota DOT	Yes
Oregon DOT	NR
Pennsylvania DOT	Yes
Rhode Island DOT	No
South Dakota DOT	Yes
Utah DOT	Yes
Vermont AOT	Yes
Washington DOT	Yes
Wyoming Hwy Dept.	Yes
Alberta Transp. & Util.	Yes
Manitoba DOH&T	Yes
Newfoundland DOT	Yes
New Brunswick DOT	Yes
NW Territories Dept of PW&H	Yes
Nova Scotia DOT	Yes
Ontario Ministry of Transp.	Yes
Quebec	Yes
Saskatchewan Hwys & Transp.	NR
Finland	Yes
Norwegian Road Res. Lab	Yes
Swedish Road & Traf. Res. Inst.	Yes
West Germany	Yes

APPENDIX C

CONTROLLED PROTRUSION STUD INFORMATION

road grip™

ROAD GRIP studs are the result of many years of research; developement and testing.



1. Our Carbide Pins, are designed for uniform abrasive wear. We use only the highest quality raw materials with a exceptionally high proportion of virgin tungsten carbide. This ROAD GRIP quality is to guard against cracking so commonly found in other pins. The carbide pin is dome shaped to prevent the studs from breaking and chiping at the edges during the critical breaking period; and tapered to allow for a uniform pin movement.

2. The steel jacket is sintered so it's lighter. This helps minimize stud weight and impact force thus reducing heat build up.

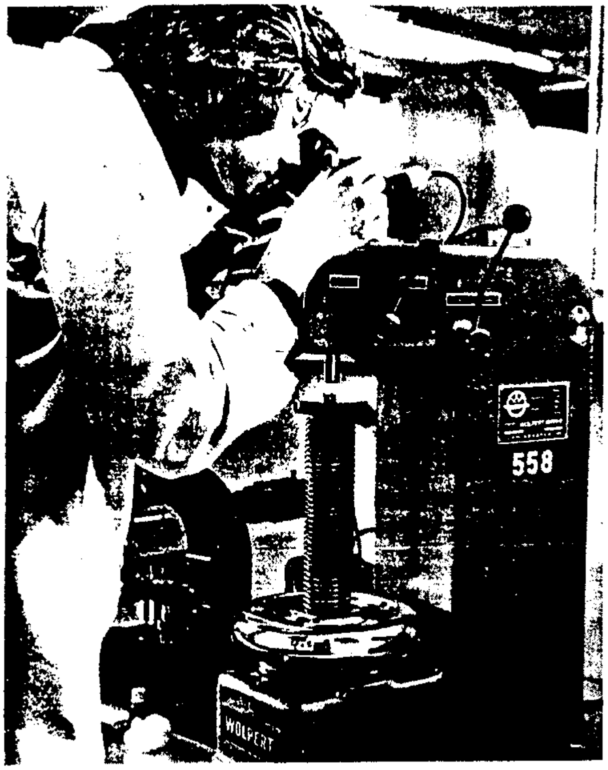
3. The sintered jacket head is specially designed to prevent tire cracking throughout normal tire wear.

4. The hole design of the sintered jacket together with the tapered carbide pin help maintain consistantly proper pin protrusion for the life of the tire.

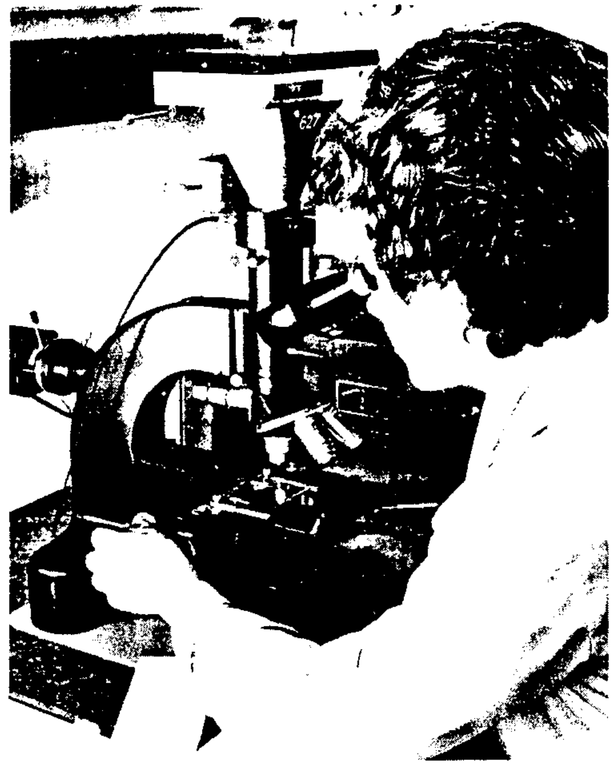
5. ROAD GRIP studs are coated to prevent rusting and to provide color-coding for easy size identification.

We are one of the few companies that has both the jackets and carbide pins manufactured in one plant. The highly sophisticated production methods, combined with the most advanced quality control system results in the finest stud available on the market.

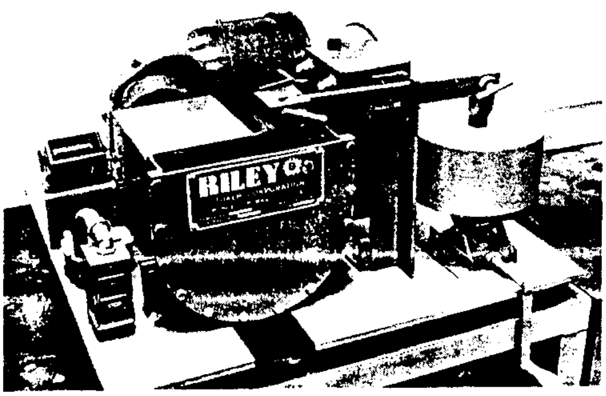
road grip™



HARDNESS TESTS. Carbide Pins and Sintered Jackets are subjected to Rockwell tests for hardness.

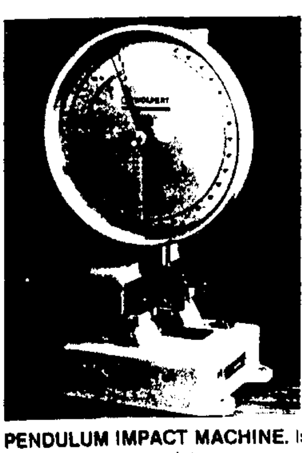


MICROSCOPE. Microconstructural tests are performed on carbide pins for structured consistency.



RILEY-STOKER. Riley-Stoker wear resistance tests evaluate the nature of pin wear for use in todays tires.

COERCIVITY MEASUREMENT. Magnetic coercivity testing of the carbide pins assures a consistent quality during pin production.



Intensive research and development coupled with the most advanced quality control methods, justify the ROAD GRIP Tire Studs as being recognized throughout the world for their quality.

PENDULUM IMPACT MACHINE. Impact measurements to test the required consistency of the sintered [illegible] jackets and to test the breaking strength of the [illegible]

ROAD TESTS. Continuous tests are carried out in Germany, Austria and the United States under various weather and road conditions to evaluate the [illegible] ROAD GRIP [illegible]

road grip™

ROAD GRIP Tire Stud Program

	European size	T.S.M.I.	Dimensions (MM) A	Dimensions (MM) B	Weight (Lbs) per thousand
Single flange studs	6,5–11	–	6,5	11	3.1
	6,5–12	–	6,5	12	3.4
	6,5–13	–	6,5	13	3.6
Single flange studs	7,5–11	No. 12	7,5	11	3.7
	7,5–12	No. 13	7,5	12	3.9
	7,5–13	No. 15	7,5	13	4.2
	7,5–15	No. 16	7,5		
Single flange studs	9 –11	No. 12	9	11	4.3
	9 –12	No. 13	9	12	4.7
	9 –13	No. 15	9	13	5.1
	9 –14	–	9	14	5.3
	9 –15	No. 16	9	15	5.6
	9 –16	No. 17	9	16	5.8
Single flange studs	10 –13	–	10	13	5.6
	10 –14	–	10	14	5.9
	10 –15	–	10	15	6.2

Should you have any special requirements such as different size or design, please contact our sales department.

HEADQUARTERS

Bruno Wessel, Inc.

BRUNO WESSEL, INC.
In Ohio (216) 666-6700 (800) 869-1908
1245 S. Cleveland-Massillon Road #226
Akron, Ohio 44321

DISTRIBUTED BY:

APPENDIX D

TELEPHONE INTERVIEWS WITH TIRE MANUFACTURERS/DISTRIBUTORS

Table D1. Contacts with Tire Manufacturers/Distributors

Company	Comments
Firestone (800) 356-4644	96 studs/tire for passenger car radial snow tire 104-120 studs/tire for import passenger car radial snow tire
Tru Wheel (800) 426-1630	80-100 studs/tire
Goodyear (800) 321-2136	80-100 for 13-15" passenger car radial
Les Schwab (503) 752-3413	Controlled protrusion stud is the only stud on market; 80-110 studs/tire
Bruno Wessel (800) 869-1908	Controlled protrusion stud is the only stud imported into the U.S.
Wholesale Distributors (800) 223-1299	No information
Empco (800) 388-6880	No information
The McGee Company (303) 777-2615	Controlled protrusion stud is the only stud available in the U.S.