THE USE AND EFFECTS OF
STUDDED TIRES IN OREGON

Research Section
State Highway Division
Oregon Department of Transportation

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NOTICE

The attached report entitled "The Use and Effects of Studded Tires in Oregon was prepared during December 1974. The general findings are still entirely valid; however, because of inflation, changes in traffic volumes, and a difference in studded tire use and in rates of pavement wear, numerical values relating to costs and pavement overlay requirements are different when updated to January 1981.

The average statewide seasonal use of studded tires was 9.2 percent for the winter of 1973-74, the latest year available when the report was prepared. The percentage increased to 9.7 percent for the winter of 1974-75, decreased to 8.8 percent for the winter of 1975-76, decreased further to 5.8 percent for 1976-77 and decreased still further to 4.7 percent for 1977-78. Due to the costs involved in taking the studded tire census, no counts have been made since the winter of 1977-78. The lower studded tire counts for the last two years the census was taken can be contributed partly to milder winters during those years but another contributing factor is that many road users are finding all-weather radial tires provide acceptable traction for winter driving.

The latest measurements indicate average wear for concrete pavements of 0.032 inches per one hundred thousand studded tire passes and for asphalt pavements 0.073 inches per one hundred thousand studded tire passes. The estimated rates of wear used in the 1974 report were 0.026 for concrete pavement and 0.066 for asphalt pavement.

Since the studded tire census has not been conducted since the winter of 1977-78, information is not available to make a detailed estimate of the number of lane miles of pavements that will require overlays prior to their normal expected service life because of studded tire wear. The 1974 estimate was that 93 lane miles per year of overlays would be required because of this wear. The reduction in use of studded tires noted during the more recent years would, in turn, reduce the number of lane miles of overlay neccessitated by stud wear. However, the cost of asphalt pavement materials has increased dramatically during the intervening years. A precise estimate of cost is not available since the percentage of studded tire use is not current. As an approximation, annual costs are in a similar range to the $1.5 million estimated in February 1977.

Mentioned in the report, but perhaps not with appropriate emphasis, is the damage that studded tires cause to pavement markings. The reflective quality of raised pavement markers is vulnerable to studded tire abrasion, requiring the replacement of many markers each year. Also, painted lines must be renewed more frequently because of the wear.

It remains clear that the hazards created by studded tire wear far outweigh the benefits associated with studded tire use.

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THE USE AND EFFECTS OF STUDDED TIRES IN OREGON

SUMMARY

During the past 11 years the use of studded tires has increased from a novelty to an estimated average of 20 percent for the Northern States in which snow and ice is expected. An alarming amount of surface wear in the wheel paths of the highway pavements has accompanied the increase in studded tire use. In Oregon, the use of studded tires, first authorized in 1967, increased to a statewide average of 9.2 percent for the winter of 1973-74. Here, too, the surfaces are showing wear, particularly severe on highways carrying high traffic volumes.

Studded tires have been found to decrease the stopping distance of vehicles operating on soft glare ice and densely packed snow. The major decrease occurs when ice forms on pavement surfaces at temperatures near freezing. As the temperature drops, the decrease in stopping distance on icy pavements diminishes. When temperatures fall below zero degrees Fahrenheit, tests show there is little difference in stopping distance between studded and unstudded tires.

Starting traction is improved through the use of studded tires when operating on soft glare ice. As with stopping distances, the advantage diminishes as temperatures decrease.

When studded tires are installed on all four wheels of a vehicle, a significant cornering performance is realized. When only the driving wheels have studded tires, no significant improvement in cornering is detected.

Unfortunately, these advantages are realized at the expense of a number of disadvantages during the 90-plus percent of the time the roads have other than an ice

coating. Tests show the use of studded tires on wet or dry concrete pavements results in an increase in stopping distances over normal highway tires. On wet or dry asphalt pavements, studded tires provide comparable stopping distances to conventional tires.

In recent years great improvements have been achieved in imparting skid-resistant surfaces to all types of pavements to provide a greater safety to the motoring public. Studded tires have eliminated the safety surfaces in very few years of service thereby increasing the accident potential. One season's wear caused a 34 percent reduction in skid resistance on a new concrete pavement in Oregon.

The continued usage of studded tires on heavily traveled highways causes rutting of the wheel tracks of pavement lanes. Some ruts have been found to be one-half-inch or more in depth. Water ponding in these ruts increases the potential for hydroplaning and loss of vehicle control. Also, water is splashed and sprayed onto vehicles in adjacent lanes, increasing the possibility of accidents. In freezing weather, the ruts created by studded tires fill with ice and snow which cannot be readily removed by snow plows. These snow and ice filled ruts create driving hazards for all motorists using the facility.

Pavement markings applied to delineate driving lanes, pavement edges, and crosswalks are being obliterated by studded tires, reducing their overall safety effectiveness. Markings have to be reapplied more frequently and, since this cannot be done in wet or snowy weather, a season often passes without the protection of the painted lines.

In recent years the public has often expressed concern over highway noise. Therefore, it is significant that noise levels on stud damaged pavement are approximately one-and-one-half times that of normal pavement.

Finally, those entrusted with the protection of the public investment in the highway system cannot overlook the costs involved in replacement of the abraded pavement surfaces. It is estimated that costs to overlay stud worn pavements will be approximately $1.1 million annually on the Oregon State Highway System. This cost must be borne by the road user. It utilizes tax revenues that are badly needed for the improvement and maintenance of the overall highway system.

RECOMMENDATIONS

Extensive studies conducted in the United States and in the Provinces of Canada have determined that there is no net safety benefit associated with the use of studded tires. That is, the benefits obtained through shorter stopping distances and improved traction during the small portion of the time that the roads are ice covered are more than offset during the remaining time by the disadvantages of increased stopping distances on wet or dry pavement due to loss of texture, increased splash and spray from water ponding in the rutted areas, the hazard of hydroplaning on water ponded in the rutted areas, and the loss of pavement markings. Therefore, it is recommended that, in the absence of further legislative action in 1977, the use of studded tires be prohibited on Oregon highways after April 30, 1977. Prior to April 30, 1977, it is suggested the authorized use of studded tires continue as at present; from November 1 through April 30 of each year.

It is further recommended that present work directed toward the development of alternative winter driving aids be promoted and encouraged. It has been demonstrated that tires having garnet-grit embedded in the tread rubber performed comparably to studded tires on ice. The wear caused by the garnet-grit tires is almost imperceptable, as it is with standard highway tires. By precluding the use of studded tires, new incentive will exist toward the refinement and development of alternative winter driving traction aids.

INTRODUCTION

The Europeon and Scandinavian countries are credited with the initial market exposure to the tungsten carbide studded tire around 1959. Interest quickly spread, and by 1962 the major rubber companies in North America were taking steps to include the winter studded tire as a part of their program. About 30 thousand studded tires were sold in the United States in the winter of 1963-64. Sales during the winter of 1972-73 were about six million units. Following the wide-spread acceptance and use of studded tires, excessive wear of the pavement surfaces began to concern highway officials. Motorist safety is, and has always been, a primary concern of highway administrators. Recognizing the potential hazards caused by the use of studded tires in the form of hydroplaning on water ponded in wheel track ruts and loss of lane markings, a number of studies were initiated to evaluate the overall safety effects of studded tire use.

A tire stud is a small unit, similar to a rivet, containing a tungsten carbide core mounted in either a metal or plastic sheath. These studs are inserted into preformed holes in the tire tread and are held in place by a flange on the sheath. The top of the stud protrudes from the tread of the tire so that it penetrates the surface with which it comes in contact. Tungsten carbide has a hardness of nine on a rating scale in which the diamond has a hardness of 10. The aggregates from which our highways are constructed have hardnesses ranging between five and six in Oregon. With this difference in hardness, the gradual chipping away of pavement caused by the high speed impact of studs contacting the surface is readily visualized. To make the studs somewhat less damaging, the tire and stud manufacturers have produced studs that are more rounded than previous ones and also that protrude a lesser distance from the surface of the tire. Although these improvements have reduced the amount of wear that studs cause, the damage is still extensive.

The purpose of a number of these studies was to compare the traction characteristics of the studded tire with other more conventional tire systems. Included were normal highway tires, snow tires, and chains. Studies were made on ice at different temperatures, on loose and packed snow, and on bare pavements both in wet and dry conditions. Major emphasis was on stopping distances at different vehicle speeds; however, some studies included measures of starting traction and cornering ability with the different systems. Studies on studded tires included an evaluation of the number of studs needed in a tire. Tests were made on tires having as few as 52 studs and as many as 366 studs or more. Also, the number of rows of studs in a tire was varied. Using stopping distances on glare ice as the criteria for comparison, it was found that the addition of 100 studs per tire achieved a fairly marked improvement in stopping distances. When the number was increased above 100, the increase in benefit was gradually reduced. Except, perhaps, for special cases, the industry has adopted approximately 100 studs per tire in four rows as a standard. Tests utilizing high numbers of studs per tire show greater improvement in having more rows per tire than in having more studs per row.

The results of the aforementioned tests for stopping distances show that on ice, chains are more effective than studded tires, but studded tires are more effective than either snow tires or highway tires. In soft snow the studded tires offer no improvement over conventional winter tires. Further, it was found that studded tires offer little benefit on extremely cold ice, at zero degrees Fahrenheit or below. It was found the use of studded tires on wet or dry concrete pavements results in increased stopping distances of up to 27 percent. On wet or dry asphalt concrete pavements, studded tires provide comparable stopping distances to conventional tires. The results of tests to evaluate starting traction are similar to those obtained for the stopping distances; the use of studs being an advantage on glare ice, but on other surfaces there is little or no benefit. Again, on glare ice, the use of studded tires on all four wheels improved the cornering capability of the vehicles.

Over a period of years, a number of studies have shown the safety benefit of prominent lane and shoulder markings. Although the use of chains and the sanding of highways cause a rapid abrasion of lane markings, these practices are only applied when there is an actual need whereas the use of studded tires is continual throughout the season. The result is, the effectiveness of lane markings is appreciably reduced by the use of studded tires.

Studies to determine the factors contributing to the phenomenon of hydroplaning have found that the thickness of the water film and the polished characteristics of the pavement surface are highly significant. Both of these conditions are aggravated by the use of studded tires; the texture built into the pavement surface is abraded away to leave a polished aggregate and the wear caused by the studs create ruts which permit a thicker water film to exist on the highway surface.

In evaluating the overall use and effect of studded tires, it is necessary to consider all aspects, year-around, of that use. It is because of the brief periods that studs provide some benefit compared to the preponderance of time during which they are a disadvantage that studies have concluded there is no net safety benefit to the use of studded tires. The State of Oregon has very diverse climatic conditions ranging from the coastal area in which there is no need for studded tires to portions of the eastern part of the state in which their usefulness is much higher than the national average. In the heavily populated Portland Metropolitan Area and in the upper Willamette Valley area the usefulness of studded tires is intermediate. The hilly residential districts in the Portland Metropolitan Area, combined with the prevailing climatic conditions have combined to make studded tire use quite popular, being about 11 percent. This relatively prevalent use in an area of extremely heavy traffic volumes has caused highway administrators to become greatly concerned with the pavement conditions. Although about 15 percent of the vehicles are equipped with studded tires in the eastern portion of the state, the total traffic volumes are much lower. The net effect is that the wear, although significant, is not as critical. In the portion of the state that is west of the Cascades and south of McMinnville, excluding the narrow strip along the coast, the use of studded tires is relatively low, being around 4.3 percent. Studded tire use on the coastal strip averages about 1.5 percent.

At the present time, the best alternative to the studded tire is a tire chain. Obviously the chain has the disadvantage of being less convenient that the studded tire since it is used only when needed. The sanding of roads is more effective in reducing stopping distances and in increasing traction than is the studded tire.

Main highways and intersections are usually sanded during times that ice is threatening. This, of course, does not solve the problem on driveways and residential side streets. The use of radial tires is claimed by many to be very effective in providing good traction and reduced stopping distances on ice.

Other alternatives to the studded tire are in various stages of development. If the use of studded tires were to be phased-out, this would add incentive to speed the development of these, or other, alternatives. Among the things being evaluated is the limited-slip differential, the anti-lock braking mechanism, the use of oil-extended natural rubber in tire treads, the effect of tread design, and the effect of tread compound. Also in the developmental category would be the use of garnet-grit embedded in the tire tread. In addition, work is being done on tire chains that would be more easily installed, and that would provide a smoother ride. It is very likely that completely satisfactory alternatives to the studded tires could, and would, be quickly developed if studded tires were prohibited.

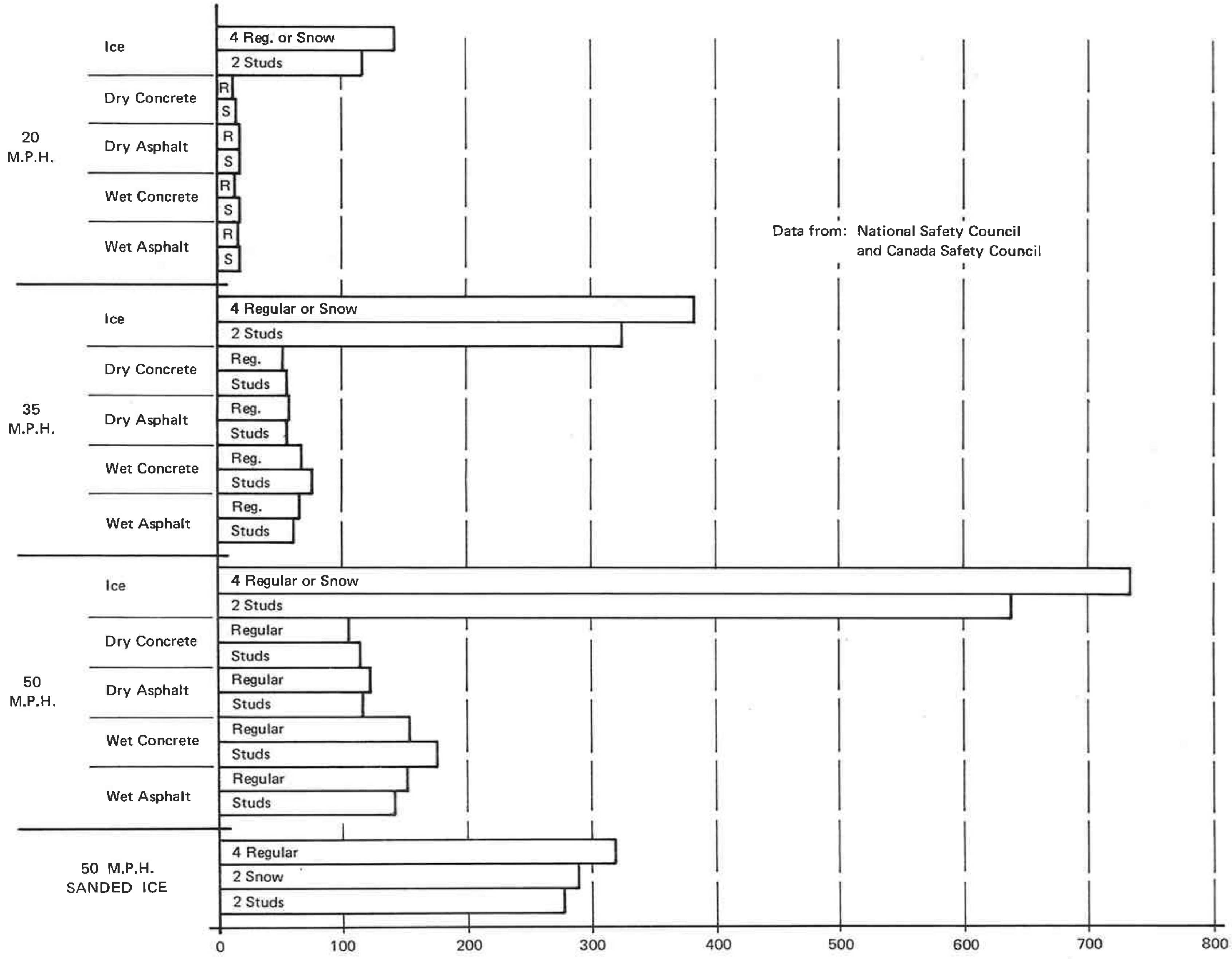
The concern over studded tire use has been National in scope. With the exception of a few states in which snow and ice rarely occur, highway administrators have been concerned with the effect of studded tires on their highways. The gravity of the situation prompted Federal Highway Administrator Norbert T. Tiemann to express his concern in a letter to the governor of each of the states. The letter, dated August 27, 1974, suggests that each state consider banning or restricting the use of studded tires because of the damage to the highways that occurs and the related hazards to the motorist resulting from that highway damage.

In a recent survey conducted by the American Association of State Highway and Transportation Officials, it was found that studded tires are now prohibited in **six** states; Hawaii, Louisiana, Michigan, Minnesota, Mississippi, and Oklahoma. In addition, the questionnaire indicated that ten other states would propose to ban studded tire use during the coming legislative session. These states are Deleware, Iowa, Kentucky, Maine, Massachusetts, Missouri, New Hampshire, Pennsylvania, South Dakota, and Washington. Several other states will propose further restrictions on the periods of time during which studded tire use is permitted.

STOPPING DISTANCES AND TRACTION

Many variables enter into the discussion of stopping distances and the effect of studded tires on stopping distances. A factor is the surface on which the tire acts. The surface may be ice, loose or packed snow, wet or dry concrete, or wet or dry asphalt pavement. On the ice covered surfaces, the temperature was found to be an important factor, being very slick at 32 degrees Fahrenheit and becoming much less so as the temperature is reduced to zero. Another variable has been the vehicle speeds at which the tests were run. Included in the variables is the distance the studs protrude from the surface of the tire and the number of studs used on the tires. Still other variables entering into the tests are whether the pavements are new or old; the difference generally being whether the surface is textured or polished, and whether the tires are new or worn. Because of these many variables, precise comparisons between different series of tests are not always possible, however, the trends of different tests are generally similar.

The overall safety advantages of studded tires have been evaluated comprehensively by the National Safety Council, the Province of Ontario, the State of Minnesota, and others. These studies were considered conclusive, and no attempt has been made in Oregon to repeat the traction and brake friction tests performed and reported by other agencies. Figure 1 summarizes typical results comparing a number of the variables that are involved in stopping distances. These studies



Data from: National Safety Council
and Canada Safety Council

FIGURE 1. MEAN STOPPING DISTANCE AT 20° F (FEET) (After Brakes Applied)

compare four regular or snow tires with vehicles having studded tires on the rear and highway tires on the front. On ice, the studded tires offer an approximate 15 percent reduction in stopping distances. It can be noted from the Figure that stopping distances on concrete pavements are generally increased by the use of studded tires. Also shown is the fact that sanding is much more effective in reducing stopping distances on ice than studded tires. Worthy of note is that even with studded tires the stopping distance on ice is approximately 4.8 times as great as from the same speed on wet concrete. At an ice temperature of 32 degrees Fahrenheit this factor would be still greater. For some drivers, the use of studded tires creates a false sense of security which may be a hazard in itself.

Table 1 was taken from test results performed by the National Safety Council. It compares stopping distances from 20 mph at 25 degrees Fahrenheit ice temperature and includes both new and used unstudded tires and tires having varying numbers of studs. Included in the comparison is the use of reinforced chains. As can be seen, stopping distances are reduced somewhat by increasing the numbers of studs within the range included in these tests. Although not highly significant, the tires

TABLE 1

STOPPING DISTANCES FROM 20 MPH AT 25 F ICE TEMPERATURE, 1966

Tire Mfg.	Tire Tread[a]	No. Studs	Condition	Stopping Distance (ft)	Improvement Over New (%)		Reduction in Improvement Over New (%)[b]	
					Hwy Tread	Snow Tread	Hwy Tread	Snow Tread
C	Highway	–	New	162	–	–	–	–
	Snow	–	New	151	7	–	–	–
	Studded snow	48	New	133	18	12	–	–
	Studded snow	72	New	129	20	15	–	–
	Studded snow	144	New	118	27	22	–	–
	Studded snow	48	Worn	151	7	0	61	100
	Studded snow	72	Worn	143	12	5	40	67
	Studded snow	144	Worn	126	22	17	19	23
	Highway w/reinforced chains	–	New	85	48	44	–	–

[a] Highway tread on front wheels, indicated tread on rear wheels.
[b] After 5000 mi wear.

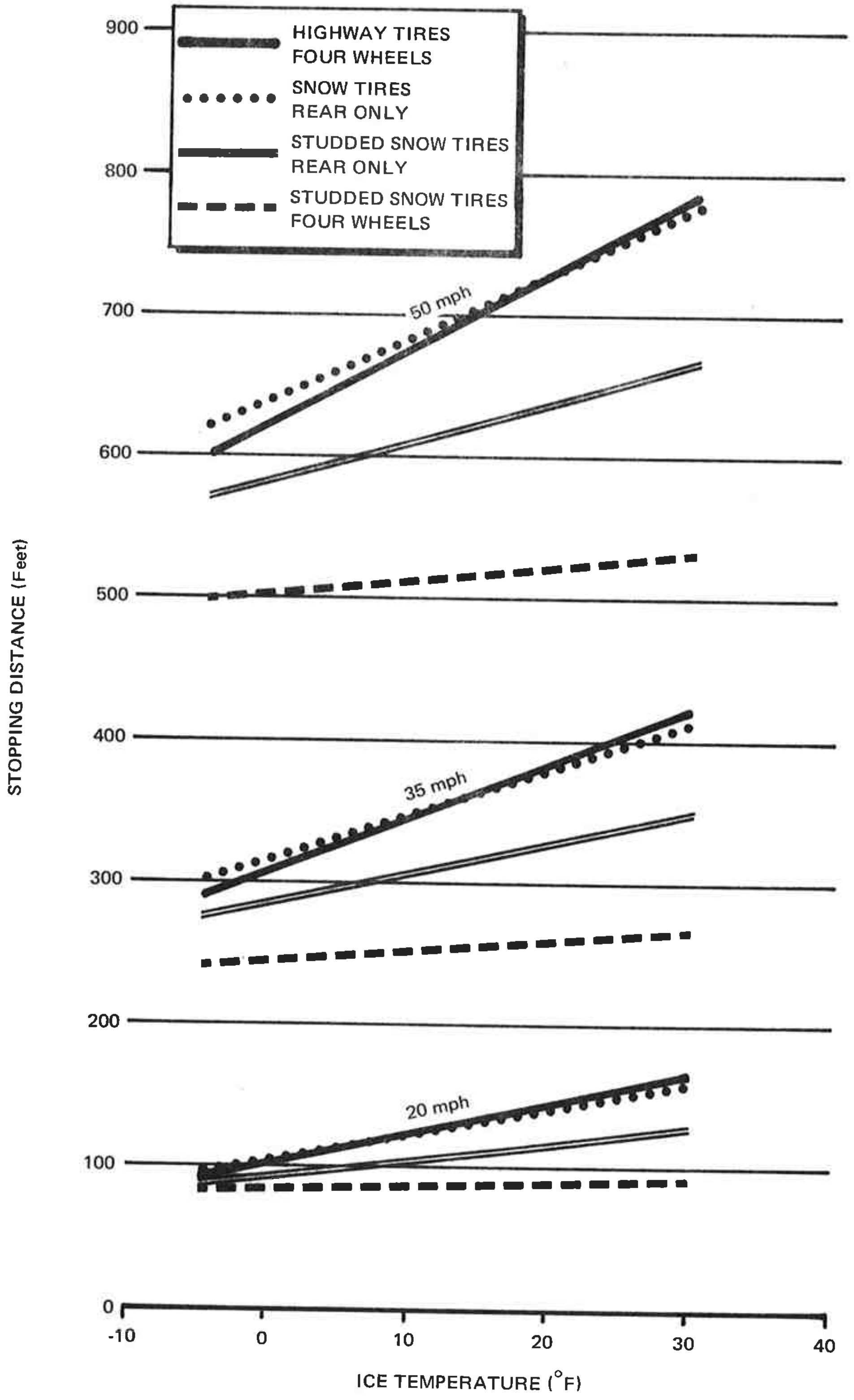
(From Reference 6)

having greater numbers of studs retained more of their effectiveness when worn than did the tires with fewer studs. As used in these tests, a worn tire was one having been driven for 5,000 miles. The Table shows that chains are very effective in reducing stopping distances.

Figure 2, comparing studded and unstudded tires at different ice temperatures, was taken from the Canada Safety Council Study "Effectiveness of Studded Tires". It can be noted the curves tend to converge at colder temperatures. Some tests have indicated there is no benefit to studded tires at zero degrees Fahrenheit and below. The lines indicate average values for a great number of tests, however there is appreciable scatter between individual test results. Slight variations in the studs or the tread rubber or possibly the texture of the ice surface could be expected to cause appreciable scatter about the mean values.

Tests of different tires on snow showed still greater variation than on ice. The density or the degree of compaction of the snow is extremely variable and repetitive tests found it difficult to duplicate previous conditions precisely. However, the tests indicated that on loose snow there was no benefit to studded tires over normal snow tires. On extremely densely packed snow having a glazed surface, the effect was the same as on ice.

In a very limited demonstration of garnet-grit tires compared to studded tires conducted on an ice arena in Beaverton, Oregon on May 16, 1974, the average stopping distance at ten mph was found to be 37.2 feet for garnet-grit tires and 38.7 feet for studded snow tires. These tests were conducted on ice that was reported to be seven degrees Fahrenheit. The demonstration was intended to compare partially worn snow tires along with the studded tires and garnet-grit tires; however, these tires slipped so much during the acceleration run they could not attain even a five



From the Canada Safety Council Study "Effectiveness of Studded-Tires".

FIGURE 2. STOPPING DISTANCE VERSUS ICE TEMPERATURE

mph speed in the small ice arena. Although the tests were by no means conclusive, they did indicate the garnet-grit tire is comparable in effectiveness to the studded tire. The studded tires were reported to have been used one season, but were in good condition. The garnet-grit tires had been driven about 200 miles prior to the tests. The amount of garnet in the tread was reported to be ten percent by weight of rubber.

CLIMATOLOGICAL CHARACTERISTICS AND ROAD CONDITIONS

Since extensive studies have shown that studded tires are effective only on ice or densely packed snow, an evaluation of their benefit must relate to the amount of time that these conditions exist on the highways. Faced with the wide variations in winter climate that exist in Oregon, such an analysis is difficult to make. In some areas of the State, icy conditions are extremely unlikely, however, other regions have relatively frequent conditions which might lead to icy roads. Information on freezing weather and precipitation was taken from the US Department of Commerce publication "Climatological Data" for a number of weather stations in Central, Eastern, and Willamette Valley sections of Oregon. From these records, the days were listed on which freezing temperatures followed measurable precipitation the previous day. Data were tabulated for the six-months period, November through April, for the three most recent winters. This information was listed for stations at Portland, Salem, Bend, Baker, La Grande, and Roseburg. The records from Central and Eastern Oregon reveal a rather frequent occurrence of having freezing temperatures following precipitation. These conditions would include both snow formation and ice; the records do not distinguish between the two. Also, there would be many days in which the precipitation would have evaporated before the freezing occurred on the following day. The records are not detailed enough to make an analysis of whether ice did in fact occur, but rather, they indicate the possibility that ice may have formed on the road. Analysis of data from the Valley stations indicates there is far less likelihood of freezing weather and precipitation coming together, however, there is still a rather frequent potential for that condition to exist. The stations chosen for analysis were considered typical of conditions in the portion of the State where freezing is a problem, however, it is recognized that other localities may have more or less freezing weather than those selected. And, freezing conditions are practically non-existant along the coastal strip. Motorists from this area would only encounter icy conditions as they traveled from the coast into the coast range passes. The average values over the last three winters for the six-months winter season are as follows:

Station	Freezing Days Following Measurable Precipitation
Baker	29%
Bend	25%
La Grande	26%
Roseburg	12%
Portland	7%
Salem	11%

It should be emphasized that studded tires would not be beneficial during a great deal of this time since the precipitation may have evaporated or the condition may be in the form of snow as opposed to ice. The values, however, do demonstrate the uncertainty of weather conditions during the winter season. Another item of note is that these percentages represent the number of days having freezing temperatures and not the percentage of time during which ice may exist. There are many days during which temperatures drop below the freezing level for a brief period in the early morning, whereas during most of the day, temperatures are above freezing.

A better measure of the actual period during which studded tires would be beneficial is the road condition analysis. The records of the Oregon State Highway Division were summarized for a six-year period between 1966 and 1972 with the following overall statewide results. In terms of day-miles, where a day-mile is defined as the reported road condition multiplied by the number of road miles for which that condition existed, the highway mileage was bare and dry 62 percent of the time, bare and wet 26.2 percent of the time, snow or slush covered 9.3 percent of the time, and ice covered 2.5 percent of the time. These values are a composite of the total State Highway System and obviously they would not necessarily be appropriate in any particular locality. However, viewing the State as a whole, they do demonstrate the small proportion of time that studded tires are beneficial to the road user.

PAVEMENT WEAR ON OREGON HIGHWAYS

Following the legislative authorization that permitted the use of studded tires in Oregon, which was effective April 19, 1967, their use gained rapid acceptance. Although no measurements of pavement wear were made during the early years of use, surface abrasion became apparent on the heavily traveled highways after a period of about two years. The 1967 legislation authorized the use of studded tires between the dates of October 1 and May 31. Because of concern for the wear that was observed upon the surfaces of the heavily traveled highways, the 1971 Legislature reduced the authorized period of operation by two months. Studded tires are now permitted from November 1 through April 30. Early observations of the surface erosion found depressed wheel tracks as shown in Figure 3 and the loss of pavement texture as shown in Figure 4. In Figure 4 the transverse broom marks are clearly

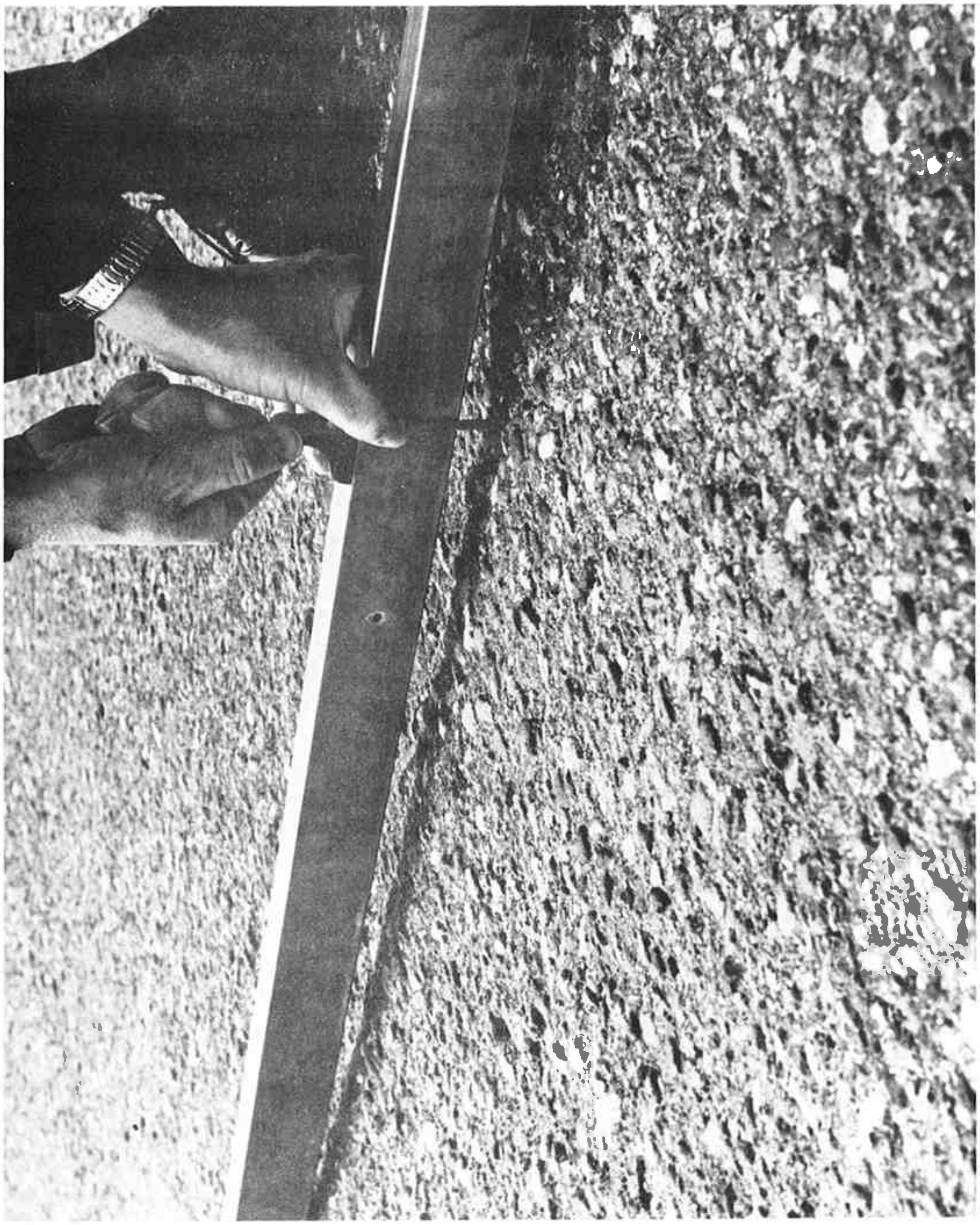


Figure 3. Studded tire wear on asphalt concrete pavement.

Figure 4. Effect of studded tires on portland cement concrete pavement.

visible between the wheel paths, whereas in the wheel paths, the surface texture has been completely eroded away leaving polished aggregate. The depth of the depression shown in Figure 3 is three-fourths inch. As can be seen in the photograph, the asphalt cement is eroded away from the larger aggregate particles leaving protruding aggregate on the surface. These protruding aggregate particles then eventually become loosened and are lost so that the total surface is removed.

In an effort to gather more precise measurements of pavement wear, a photo procedure was initiated in which a tight-wire served as a reference and the shadow of that wire provided a profile of the pavement wheel track at the point of measurement. By making measurements seasonally, the amount of change, or wear, could be detected. To provide a fixed reference, steel monuments were embedded into the pavement surface two feet each side of the center of the wheel track, making a span of four feet. In this way, subsequent measurements were taken at precisely the same points, thus providing a means of evaluating the progressive wear.

A shadow-box was constructed which included a metal frame spanning 48 inches between monuments which supported the tight-wire. A 35 mm camera was mounted a distance of 17 inches above the pavement surface directly above the tight-wire. A synchronized photo strobe-light was mounted at a 45 degree angle between the verticle and the horizontal. This technique provides a true-to-scale measure of the distance between the tight-wire and the pavement surface; that is, the vertical distance from the wire to the pavement surface is pictured accurately as the distance between the wire and the shadow of the wire on the photograph. By taking pictures after different seasons of stud use and plotting these as wheel track profiles, the progressive wear of the pavement surface was determined.

During the fall and winter of 1971-72, photo sites were established at 19 highway locations. Of these, 14 included lanes in opposite directions so that monuments were installed at 33 different wheel track sites. These sites were photographed in April of 1972 to establish wheel track profiles, thus providing a reference against which future wheel track wear could be measured. During the summer of 1972, two more sites were established and still later, in the spring of 1974, eight more pairs of monuments were installed on recently completed I-5 pavements north of Woodburn. For the original photo sites, pictures were taken during spring and fall of 1972, the spring of 1973, and the spring and fall of 1974. Two winters of studded tire use were thus covered. For those sites that were established later, the pictures were taken at the same seasonal intervals after installation.

In selecting the photo sites, an attempt was made to find locations representative of the various highways within the State. Emphasis was given to the highways in the Portland Metropolitan Area since this is where the wear was particularly noticeable, however, sites were also located in the other geographical portions of the State and both major highways and minor highways were sampled. The location of these photo sites and the type of pavement surface for each is listed in Table 2.

The monuments were formed from three-fourths-inch diameter steel bars one and three-fourth inches long. These bars were cemented with epoxy into holes that had been drilled into the pavement surfaces. The bars were expected to provide a permanent reference from which measurements of the wear could be established, and in the case of the concrete pavements this was always the case. However, in the asphalt pavements there is evidence some of the monuments shifted during the period of years so that the original reference is unsure. During periods of warm weather the action of heavy traffic sometimes causes asphalt concrete pavements to migrate slightly.

TABLE 2

STUD WEAR MEASUREMENT PHOTO SITES

Photo Site No.	Lane	Route No.	Mile-Post	Location	Pavement Materials
1-A 1-B	Northbound Southbound	I-205	5.70	East Portland Freeway near West City Limits of West Linn	Concrete
2-A 2-B	Southbound Northbound	US 99E	8.30	Pacific Highway East - 2 miles south of Milwaukie toward Oregon City	Asphalt
3-A 3-B 4-A 4-B	Northbound, Rt. Southbound, Rt. Northbound, Lt. Southbound, Lt.	I-5	283.5	Pacific Highway - 2 miles north of Baldock Safety Rest Area near Wilsonville	Concrete
5-A	Eastbound	US 20	23.0	Central Oregon Highway - 22 miles east of Bend near Millican	Asphalt
6-A 6-B	Southbound Northbound	US 97	170.0	The Dalles-California Highway - 30 miles south of Bend, 2 miles south of Lapine	Asphalt
7-A 7-B	Westbound Eastbound	ORE 38	26.0	Umpqua Highway at Sawyer Rapids, 26 miles east of Reedsport toward Drain	Asphalt
8-A 8-B	Eastbound Westbound	I-80N	42.25	Columbia River Highway - 20 miles west of Hood River. Between Bonneville and Cascade Locks.	Asphalt
9-A 9-B	Northbound Southbound	I-5	38.0	Pacific Highway - 10 miles north of Medford	Asphalt
10-A	Eastbound	ORE 66	58.0	Green Springs Highway - North Green Spring Jct. about 2 miles from Klamath Falls toward Ashland.	Asphalt
11-A	Eastbound	ORE 140	67.0	Lake of the Woods Highway - west of Crater Lake Highway Jct. about 3 miles from Klamath Falls toward Medford.	Asphalt

TABLE 2
(Continued)

Photo Site No.	Lane	Route No.	Mile-Post	Location	Pavement Materials
12-A	Eastbound	ORE 214	3.30	Silver Creek Falls Highway - near Salem.*	Asphalt
13-A 13-B	Southbound Northbound	I-5	307.9	Pacific Highway - 0.5 miles south of Washington state line.	Asphalt
14-A 14-B	Eastbound Westbound	US 30	4.25	Lower Columbia River Highway between NW 44th Ave. & NW Yeon Ave. in Portland.	Asphalt
15-A 15-B	Eastbound Westbound	US 26	72.95	Sunset Highway west of the SW Jefferson Street interchange in Portland.	Asphalt
16-A 16-B	Southbound Northbound	ORE 10	4.1	Beaverton-Hillsdale Highway, between SW Shattuck Rd. & SW 50th Ave. in Glencullen (Portland).	Asphalt
17-A 17-B	Westbound Eastbound	I-80N	205.9	Old Oregon Trail - 1 mile from Pendleton near west city limits.	Concrete
18-A	Southbound	US 97	22.0	The Dalles-California Highway - 22 miles south of Washington state line.	Asphalt
19-A 19-B	Southbound Northbound	ORE 26	93.5	Warm Springs Highway - 10 miles north of Warm Springs. 24 miles northwest of Madras toward Mt. Hood.	Asphalt
20-A	Northbound, Rt.	I-5	297.10	Pacific Highway - SW Terwilliger Blvd. U'xing in Portland.	Concrete

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* Section was transfered to Marion County when the North Santiam Highway was relocated.

TABLE 2
(Continued)

Photo Site No.	Lane	Route No.	Mile-Post	Location	Pavement Materials
21-A	Northbound, Rt.	I-5	296.0	Pacific Highway - SW 26th Ave. O'xing in Portland.	Concrete
22-A	Northbound (Center)	I-5	277.64	Pacific Highway - 4 miles south of Baldock Safety Rest Area between Woodburn and Wilsonville.	Concrete
22-B	Northbound (Left)				
23-A	Northbound (Left Shoulder Test Strip)				
23-B	Northbound (Left Shoulder)				
24-A	Southbound (Center)				
24-B	Southbound (Left)				
25-A	Southbound (Shoulder)				
25-B	Southbound (Shoulder Test Strip)				

This apparently affected the monuments at several of the photo sites, thus voiding data from these sites. All of the monuments embedded in concrete pavements and part of those embedded in asphalt pavements appear to provide fixed reference points as intended.

The photographic procedure results in an analysis which requires physical measurements to obtain the wear. An attempt was made to scale the values to the closest 50th of an inch. This is approximately the width of an ink line used to plot the profiles so that in lightly traveled areas where the wear was minor the lines sometimes lie one on top of another. This lessens the accuracy of measurement somewhat. Measurements were generally made at three-inch intervals across the center two-feet of the wheel track and for most purposes an average of these values was used.

The wheel track profiles were also scanned to obtain maximum wear. A one-season value as high as 0.2 inches was found, however, values of around 0.1 inch would be more typical for maximum wear for one season. In portland cement concrete pavements, values as high as 0.1 inch were found at several sites for one-season maximum wear. A more typical maximum wear on the concrete would be 0.06 inches. The very high values that sometimes appear may be caused by the loss of a particular piece of aggregate indicating an excessive amount of wear that may be localized. Values as low as 0.01 inches were found as maximums on both portland cement concrete and asphalt concrete pavements; usually in areas where traffic is relatively light. The average values for the center two feet of the wheel track profiles were approximately one-half of the maximum values.

The amount of wear on the pavement is clearly a function of the number of passes of studded tire vehicles and of the type of pavement material. The wear is greater on asphalt pavements than on portland cement concrete pavements. Portland cement concrete pavements wear more rapidly when they are new than after the aggregate becomes exposed. This initial wear on the portland cement concrete pavements results in a loss of the non-skid texture that was provided during construction. This rapid early loss of pavement texture is shown in Figure 5. These pictures are from mosaics of the center portion of two wheel paths on identical concrete pavement. The upper photo shows a lane before being subjected to traffic and the lower photo the condition after one season of studded tire use. The prominent transverse broom marks were completely eroded away during the one winter. The measured skid resistance of the worn lane is 34 percent lower than that of the non-traveled lane.

The Oregon studies did not provide a means by which the wear caused by sanding materials could be measured, however, work done by the American Oil Company for the State of Minnesota determined that no measurable wear occurred with unstudded snow tires in the absence of abrasive sand and barely measurable wear in the presence of sand. The use of tire chains tends to cause pavement wear, however, the vehicle miles traveled with tire chains is very low. Because of these factors, it is not unreasonable to assume all measurable pavement wear was caused by studded tires. In metropolitan areas having heavy traffic volumes and frequent stud use, the amount of wear is very significant. On rural highways having light traffic volumes, the stud wear is not of great concern.

STUDDED TIRE CENSUS

To determine the extent of the use of studded tires on Oregon highways, counts were made at 25 different locations on the state highway system at periodic intervals

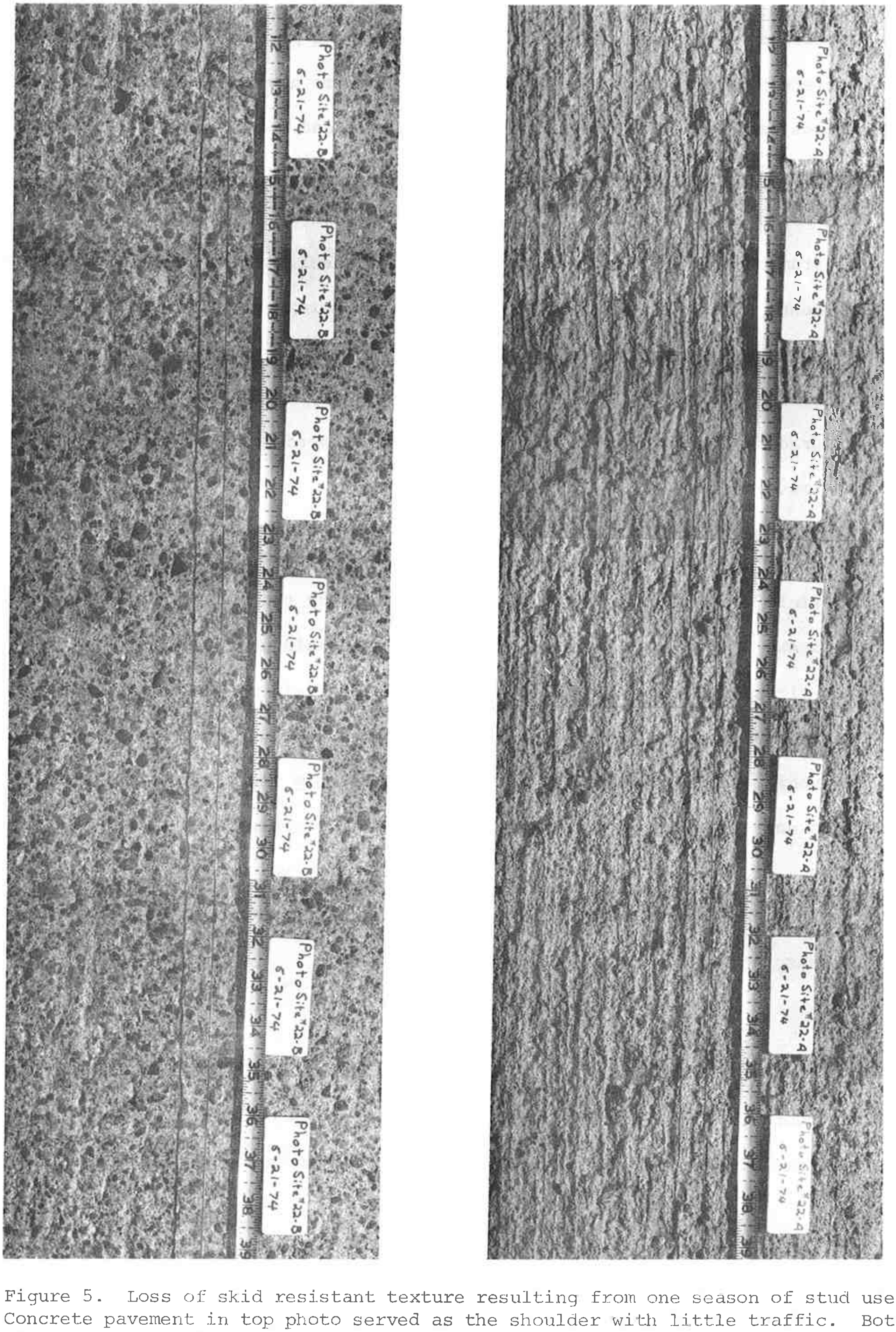


Figure 5. Loss of skid resistant texture resulting from one season of stud use. Concrete pavement in top photo served as the shoulder with little traffic. Bottom photo is of identical pavement that carried freeway traffic for one winter.

during the winter season. During the winter of 1971-72, counts were made monthly beginning in November and continuing through April. Thus, the counts were made each month during which stud use was legal in the State. During the winter of 1972-73, counts were made during the months of December, February, and April. Data for the other months was estimated using the monthly count of the previous year as a basis for interpolation. Again during the winter of 1973-74, three counts were made; approximately at mid-November, mid-January, and mid-March. The numbers of studded tire vehicles for the intermediate months were estimated from previous counts.

Selection of the sample sites was made by considering: (1) population and traffic density; (2) road use characteristics such as commuter travel, farm to market travel, intercity travel, and interstate travel; (3) weather conditions and severity of winter weather. Counts consisted of total traffic and those vehicles using studded tires. The samples consisted of a six-hour daytime count, usually including peak period hours. During the surveys, the vehicles having studded tires were detected by the sound they made in passing. Each stud equipped vehicle was considered to have studded tires on the rear wheels only, since very few have studded tires on all four wheels. The locations at which the studded tire counts were made are shown in Table 3. The location is identified by the name of the highway followed by more specific information on the site. Also included are the average percentages of studded tire vehicles counted at each station during the 1973-74 winter season. The percentage of vehicles having studded tires builds up during November and December as they are installed and then gradually declines during March and April as they are again removed. The values shown as the percentage of use are the average values for the six-month period during which their use is authorized.

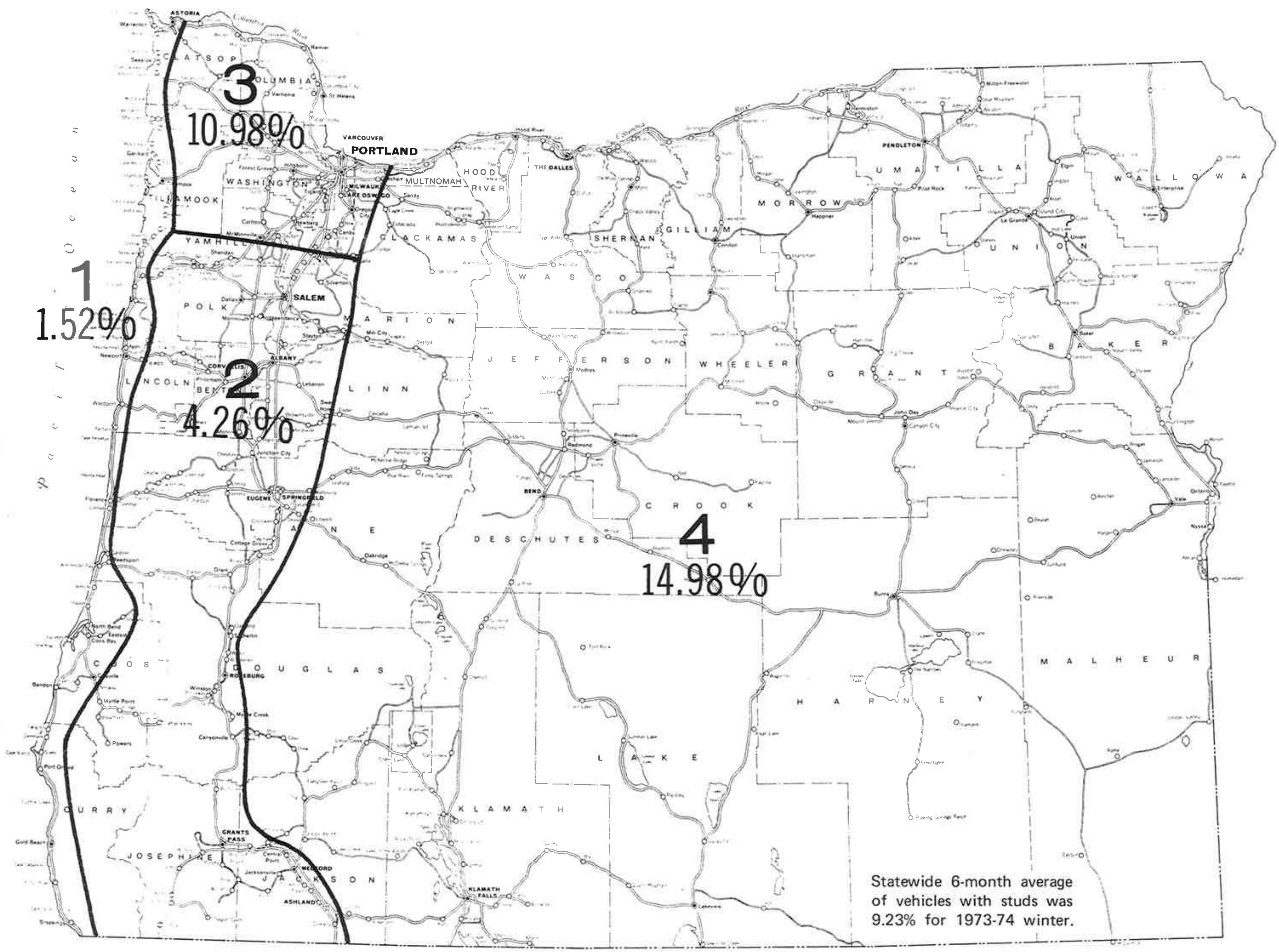
TABLE 3

STUDDED TIRE CENSUS LOCATIONS

Station No.	Route No.	M. P.	Location	% of Veh. With Studs, 1973-74 Count
1	ORE 10	3.77	Beaverton Hillsdale; Raleigh Hills	12.19
2	US 26	72.94	Sunset; SW Jefferson Street (Portland)	10.09
3		2.90	Beaverton-Tigard; near South City Limits, (Beaverton)	11.48
4	I-80N	1.80	Columbia River; NE 28th Avenue (Portland)	12.67
5	US 99E	8.12	Pacific Highway East; 2 miles south of Milwaukie	4.60
6	ORE 34	0.44	Corvallis-Lebanon; 0.4 miles east of Corvallis	2.86
7	ORE 22	2.82	North Santiam; Holland Drive SE, Salem	4.96
8	I-105	7.00	Eugene-Springfield; Springfield	2.46
9	ORE 140	13.20	Lake of the Woods; near Brownsboro, 13.20 miles from Jct. of Crater Lake Highway	12.35
10	I-5	10.17	Pacific Highway Southbound; Siskiyou Safety Rest Area	4.38
11	I-5	93.12	Pacific Highway; 3 miles north of Summit Canyon Creek Pass	4.42
12	I-5	117.45	Pacific Highway; 2 miles south of Shady	5.13
13	I-80N	82.53	Columbia River; O'xing, Hostetler Way (The Dalles)	14.85
14	ORE 58	50.61	Willamette; 15 miles east of Oakridge	9.12
15	US 97	243.10	The Dalles-California; 40 miles south of Chemult	11.04
16	US 97	134.80	The Dalles-California; 2 miles north of Bend	22.30
17	US 20	22.02	Central Oregon; near Millican, 26 miles east of Bend	19.23
18	US 20	133.26	Central Oregon; Whiting Slough, 1 mile east of Burns	17.11
19	I-80N	130.22	Columbia River; 7 miles west of Arlington	16.05
20	I-80N	211.00	Old Oregon Trail; 3 miles SE of Pendleton	17.69
21	I-80N	308.00	Old Oregon Trail; 4 miles SE of Baker	22.93
22	US 20	252.60	Central Oregon; White Settlement, 6 miles east of Vale	6.51
23	ORE 82	20.62	Wallowa Lake; North Albany Street in Elgin, 20 miles NE of La Grande	19.27
24	US 101	65.55	Oregon Coast; North City Limits of Tillamook	1.21
25	US 101	190.25	Oregon Coast; Jct. Florence-Eugene Highway (Florence)	1.74
			Statewide Average	9.23

In analyzing the stud census data from the 25 counting stations, it was found that a general pattern was established creating four geographic areas in the State. These four areas reflect the variety of winter weather conditions that exist. The boundaries for the four geographic zones are shown in Figure 6. Zone 1 is a narrow coastal strip. Zone 2 includes the upper Willamette Valley, the Umpqua Basin, and the Rogue Basin. Zone 3 is the lower Willamette Valley and the lower Columbia River area. Zone 4 includes the Cascade Range, Central and Eastern Oregon. Shown on the map are the six-months average percentages of studded tire vehicles within each zone for the 1973-74 traffic count. The statewide average value, taking into account the vehicle miles driven in the various zones, is 9.23 percent for the 1973-74 winter.

The studded tire counts were used, in combination with the traffic volume tables, to estimate the total number of vehicle miles traveled on the state highway system by stud equipped vehicles. All of the state highways; interstate, primary, and secondary were grouped by the counting station which had been designated for the section. The vehicle traffic for each highway was obtained from annual traffic volume tables developed by the Oregon Highway Division. The traffic volume tables give the average daily traffic (ADT) at various locations on the highway. By multiplying the ADT by the length of the highway section, the daily vehicle miles for that particular section are obtained. The total vehicle miles for the highway therefore represents total highway use. The total for all highways assigned to a counting station provides the total studded tire use for that particular area. Since the ADT and the corresponding daily vehicle miles obtained from the traffic volume tables are annual averages, adjustments were made to reflect the lesser amount of traffic during the winter months.



Statewide 6-month average of vehicles with studs was 9.23% for 1973-74 winter.

FIGURE 5. MAP OF GEOGRAPHIC AREAS FOR STUDDED TIRE CENSUS

Percentages derived from the ratio of vehicles with studded tires to the total vehicles for each counting station were then applied to the adjusted daily vehicle miles for that section of highway. The daily vehicle miles were multiplied by the number of days in the month to arrive at monthly vehicle miles and then by the six months of authorized use to provide an estimate of total traffic and traffic with studded tires.

Information on vehicles using studded tires and the vehicle miles traveled with studded tires is summarized in Tables 4 and 5 for the 1973-74 winter season. Table 4 provides an estimate of the number of passenger cars in each of the four geographic areas of the State, the seasonal average percentage of vehicles with studs for each of the areas, and the number of passenger cars having studded tires in the various geographic areas. The number of passenger cars in the area was obtained from registrations of the Motor Vehicles Division. The percentage of vehicles with studs is a seasonal average of those counting stations within each of the geographic areas. Using these average percentages of vehicles with studs, the number of passenger cars with studs was calculated.

Table 5 expresses stud use in terms of the vehicle miles traveled on State highways with studded tires. The travel in each zone is shown in thousands of vehicle miles and these values were used to determine, in combination with the percentage of vehicles with studs, the season vehicle miles driven with studded tires. The calculations resulted in an estimate of over 380 million vehicle miles driven with studded tires on the state highway system in Oregon during the 1973-74 winter. Although greater precision would result from having more counting stations and a more frequent count, these values are considered adequate for practical use.

TABLE 4

TOTAL VEHICLES
and
VEHICLES WITH STUDDED TIRES, 1973-74

Geographic Area	Number of Passenger Cars in Area	% of Vehicles With Studs	Number of Passenger Cars With Studs
1	91,976	1.52	1,397
2	533,431	4.26	22,705
3	405,886	10.98	44,509
4	454,439	14.98	68,091
State Total	1,485,732	Avg. 9.23	137,169

TABLE 5

VEHICLE MILES
and
VEHICLE MILES WITH STUDS, 1973-74 WINTER

Geographic Area	Season Vehicle Miles in Thousands Total All Vehicles	Season Vehicle Miles in Thousands Vehicles with Studs
1	257,946	3,897
2	1,496,002	63,676
3	1,138,305	124,938
4	1,274,472	190,961
State Total	4,166,725	383,472

REGIONAL ANALYSIS OF WEAR

The amount of wear attributable to studded tire use varies with the traffic volume, the percentage of vehicles having studded tires, and with the type and quality of pavement. Nationwide studies indicate other factors, as well, influence the amount of wear caused by studded tires. Among these are the type of stud, the type of aggregate used in the pavement, and the speed of vehicle travel. It has been observed in other studies, and confirmed by observation in Oregon studies, that wheel track wear is not excessive in areas of light traffic, nor in areas of relatively heavy traffic if that traffic is traveling at slow speed. It is on pavements carrying high volumes of high speed traffic that the wear is particularly objectionable.

In several controlled tests conducted in other states to determine the amount of wear for a given number of studded tire passes, the nature of the tests generally required slow speed operation. This results in an indication of a lower rate of wear than that found in actual practice from the Oregon photo sites. As one might expect, a highly significant factor in the amount of wear is whether a vehicle is braking, traveling at constant speed, or accelerating. The wear is exceptionally high in areas in which acceleration is taking place, but deceleration also causes much more wear than constant speed travel. Still another factor that seems to influence the amount of wear is whether or not the wheel is under power as opposed to coasting freely. In some of the controlled tests to measure wear, the wheel was powered externally so that the studded tire rolled freely along the pavement surface. The resultant wear in this type of test is lower than that found from actual highway measurements under normal traffic.

In the Oregon studies of pavement wear, data considered to be reliable was obtained from 24 different photo sites. Eight of these were in concrete pavment and 16 in asphalt pavement. For each site the average wear over the center two feet of the wheel path was used as the value for that site. These values were divided by the number of studded tire passes to obtain a factor which provided the amount of wear in inches per 100 thousand studded tire passes. These values were then processed by averaging the eight stations in concrete pavements and the 16 stations in asphalt pavements to get values of wear in each pavement type. The resultant values on Oregon highways indicate average wear for concrete pavement of 0.026 inches per 100 thousand studded tire passes and for asphalt pavements 0.066 inches per 100 thousand studded tire passes. To aid in visualization, these values indicate slightly less than 1/32 inch per 100 thousand studded tires in concrete pavements and slightly more than 1/16 inch per 100 thousand studded tire passes for asphalt pavements. These rates of wear are lower than those found by Maryland, New Jersey, and Montreal, but higher than projections made by Minnesota and Washington State University.

Among the Oregon photo sites, as much as 0.12 inches of wear was measured during the 1973-74 winter on asphalt pavements. On portland cement concrete pavements, wear of 0.04 inches was measured at two sites for the 1973-74 stud season. If studded tire use continues, these rates of wear will lead to an early need for replacement or overlay of these pavements.

The amount of wear that can, or should, be tolerated prior to overlaying of pavement does not have any fixed or simple answer. No wear whatsoever would be a desirable condition for purpose of highway drainage. As the amount of wear progresses, the likelihood of accidents increases. The early wear results in a loss of pavement texture, reducing the coefficient of friction between pavement and tire which results in increased stopping distances. As the wear progresses, the worn wheel paths accumulate water which creates additional hazards. Primarily, these hazards are those of hydroplaning and the splash and spray of water reducing the visibility of other motorists. If the wheel track wear is allowed to proceed to an excessive value, the steering of the vehicle is influenced, thus causing still another form of hazard. A significant factor influencing safety is that motorists often drive closer to the center line to avoid rutted wheel paths.

Although three-fourths inch or perhaps even one inch of wear in the wheel tracks could exist before serious steering problems develop for motorists, because of the other factors that grow increasingly hazardous as the wear develops, a desirable limit for wheel track wear is considered to be one-half inch. With this limiting value of acceptable wear, it is possible to determine the number of years of service available from the highway surfaces considering the traffic volumes and the percentage of that traffic utilizing studded tires. Pavements deteriorate and eventually need replacement for causes other than stud wear and in instances where traffic volumes are light or stud use is minor, the pavement replacement would not be necessitated just because of stud use. Pavements fail because of fatigue; developing cracking, ravelling, spalling, and undesirable roughness under the effects of traffic loads over a period of years. Because of these influences, occasional overlays are required regardless of stud use. The normal service life expectancy however, is approximately 25 years for portland cement concrete pavements and approximately 14 years for asphalt concrete pavements. In instances where the pavement wear from studded tires would be less than one-half inch during the road life expectancy, no direct pavement replacement costs would be attributable to the studded tire use. However, studded tire use would contribute to other costs prior to this time. Such things as pavement markings, and the additional motorists costs from increased accident frequency resulting from loss of surface texture, hydroplaning and other related surface problems would be affected.

In contrast, some pavements in the Portland Metropolitan Area carrying exceptionally heavy traffic, about 11 percent of which use studded tires, will reach the one-half inch desirable limit of wear in as little as three years. This condition would require over four overlays during the normal 14 year pavement life for asphalt concrete pavements. Other sections of highway will serve varying numbers of years prior to their needing overlayment. In the determination of those highways that will need overlays, it was assumed the traffic volume increases would be at the rate of three percent per year, a value approximately equal to the increase in population, and that the percentage of vehicles using studded tires remained the same as the winter of 1973-74. With these assumptions, it is estimated 1,242 lane miles of asphalt pavement and 125 lane miles of concrete pavements on the state highway system will require maintenance prior to the expiration of their normal service lives. This total of 1,367 lane miles includes sections of two-lane, four-lane, and six-lane highways and represents about 433 miles of highway. In terms of lane miles, the total is approximately 7.3 percent of the highway system. The anticipated service of these pavements varies from an estimated 21 percent of the normal expected service life up to 86 percent of the normal expected service life.

The estimate indicates 657 lane miles of asphalt pavements and 120 lane miles of concrete pavements in the Portland Metropolitan Area would serve something less than their normal service life. In Central and Eastern Oregon, 568 lane miles of asphalt pavements and five lane miles of portland cement concrete pavements would need attention prior to their normal service lives. The major portion of this latter mileage is on I-80N from Tunnel Point, east of Portland, to The Dalles. The other principal mileage in the central and eastern portion of the State is along US 97 from Redmond to south of Bend and another section near Klamath Falls. Other short sections of highways are affected.

For the 1,367 lane miles affected, the service lives would range from approximately three years to 12 years for the asphalt pavements and from about seven years to 17 years for the portland cement concrete pavements. The effect of the stud wear, therefore, is estimated to require an average annual resurfacing of 82 lane miles on asphalt pavements and 11 lane miles on concrete pavements that would not be required were it not for studded tire use. The cost of this resurfacing, beyond what would be necessary for the normal service life, is approximately $1.1 million per year. This estimate is based on placing a minimum practical thickness of asphalt concrete over the existing pavement surface to eliminate the ruts and restore a smooth riding surface. No additional structural strength would be added to the surface. At the present stage of development, there is no feasible way of repairing the rutted wheel paths without overlaying the entire pavement. For purpose of the estimate, a 1.25 inch thickness was assumed and a 25 percent allowance was made for leveling and shoulder transitions. With these assumptions, the resurfacing would require 590 tons of asphalt concrete per lane mile. For applying thin overlays in areas of heavy traffic, an estimated price of $20 per ton, in place, was utilized. This estimate is for pavement resurfacing costs on the state highway system only; it does not include costs to the cities and counties, nor does it include costs related to traffic lane marking replacements. Because of the typically lower traffic volumes and slower speeds on city streets and county roads, it is not expected the replacement costs for these jurisdictions would be excessive, however no evaluation of wear was made on other than the state highway system.

No precise cost evaluation can be made for the loss of pavement lane markings. The raised markers suffer damage and lose their reflectivity thus reducing their effectiveness. Traffic paint is worn quickly from the highway surface under the action of studded tires. The painted markings suffer extensively from sanding operations as well as from studs, so a division of responsibility is not possible. Probably the main costs related to loss of lane markings is in increased accident frequency, however there is no way to isolate the cause of these accidents with certainty, therefore this cost can only be recognized and not evaluated precisely.

The additional costs to the road user resulting from studded tire use are easily recognized, but difficult to calculate in total effect. It is known that accident frequency increases as loss of skid resistant texture on pavements is reduced. The use of studded tires quickly removes the skid resistant texture from portland cement concrete pavements. Thus, an element of increased accident frequency would result. Hydroplaning results when vehicle tires lose contact with the pavement surface by riding on top of a water film. The rutting resulting from studded tire use allows water to pond in the wheel tracks, thus providing a water film which increases the likelihood of this phenomenon. The cause of accidents is sometimes attributed to being blinded by splash and spray of water from other vehicles on the road. The ruts worn by studded tires contribute to this problem. Records over a long period of time indicate the value of lane markings in controling traffic. The loss of these markings contributes to higher accident frequencies. Still another factor influencing studded tire costs is the fact that stopping distances on wet and dry pavement is longer with studded tires than without. Therefore, it can be anticipated that the accident frequency would be increased on wet and dry pavements for those vehicles being equipped with studded tires. Offsetting a portion of these costs, of course, is the improved performance on ice-covered surfaces that studded tires provide.

Studies made in Minnesota and Ontario, Canada during the period in which studded tire use was permitted and after studded tires were prohibited, indicate that the overall wintertime accident frequency was not appreciably affected by the ban.

CONCLUSIONS

This report has summarized the advantages and disadvantages of studded tire use as determined by various agencies in the United States and Canada. Studies have demonstrated that on ice or densely packed snow, studded tires provide an advantage in reducing stopping distances and increasing traction over regular highway tires or snow tires. However, it was found that the use of sanding material or the use of chains each provides better performance than studded tires when applied to ice. On materials other than ice or very densely packed snow, studded tires offer no improvement over non-studded tires and in the case of wet or dry concrete pavements they are a disadvantage.

Satisfactory alternatives to the studded tire are in varying stages of development. Among the more promising is the winter-tread tire having garnet-grit embedded in it. Tests to date indicate this tire has stopping capability on ice comparable to the studded tire and the wear created by it is far less than has been experienced with studded tires. Also, radial tires, and in particular radial snow tires, have been reported to provide exceptional traction and cornering capability on icy surfaces. A distinct advantage to the radial tire is the fact that they are mounted on all four wheels and cornering capability is enhanced over the use of highway tires on the front and studded tires on the rear wheels. Work is continuing with rubber formulation and tread design to improve the traction provided by more conventional highway tires and winter tires. Also, the benefits of the limited-slip differential and the anti-lock brake mechanism are being studied for the advantages they provide on slick surfaces.

The disadvantages of studded tire use are numerous, but they fall into the categories of motorist safety and cost. Items affecting motorist safety are:

1. Loss of non-skid pavement texture;
2. Loss of lane markings;
3. Increased splash and spray from vehicles traveling in water filled wheel paths;
4. Increased potential for hydroplaning on water collected in the worn wheel paths; and
5. Increased stopping distances on wet and dry concrete pavement for studded tire vehicles.

Ultimately, all costs related to studded tire use are the road user's costs; however, they may be viewed in the categories of accident costs and maintenance costs. The accident costs are reflected in vehicle repairs, medical costs, and insurance premiums. The highway maintenance costs are those of repaving stud-worn pavements and replacing lane markings.

If the present rate of studded tire use were to continue, it is estimated that 1,367 lane miles on the Oregon state highway system would require maintenance prior to the expiration of the normal service life of the pavements. This wear would require the resurfacing of approximately 93 additional lane miles per year because of studded tire use and the cost of this resurfacing would be approximately $1.1 million per year. Costs related to the accelerated abrasion of lane markings are recognized, however it is difficult to assign responsibility for damage precisely between studded tire use and sanding operations.

Careful evaluation of the National studies on studded tire effects and, particularly, evaluation of the Oregon studies on pavement wear and climatological conditions have led to the conclusion that it is in the best interest of the Oregon road user to prohibit the use of studded tires after providing an additional two-year period for the refinement of alternative winter driving traction aids.

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