# Evaluation of Winter Vehicle Traction with Different Types of Tires

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Studded tires have been used during winter to increase vehicle traction force for reasons of safety. Past experience and factual data have shown that the problems of accelerated pavement wear and airborne dust have been caused by the use of studded tires. The use of studded tires has been prohibited in some countries and in some states in the United States. Recently, the Bridgestone Tire Company designed and examined a new type of tire, called the Blizzak, to improve winter vehicle traction and minimize pavement wear. To adopt this new type of tire in Alaska, the Alaska Department of Transportation and Public Facilities conducted a preliminary field study to compare the new tires with the studded tires in terms of stopping distance on packed snow and icy surfaces in Fairbanks and Anchorage in January 1994. More comparative tests of the Blizzaks, studded tires, and all-season tires were conducted in March 1994 by the University of Alaska in Fairbanks and Anchorage. The vehicles used in these tests were mid-size front-wheel-drive cars, large rear-wheel-drive cars, and half-ton full-size rear-wheel-drive pickup trucks. Field tests included 40.3-km/hr (25-mph) stopping distances, starting traction and times to reach 40.3 km/hr (25 mph), maximum cornering speeds on short-radius curves typical of intersections, and hill climbing ability. From field test results, it was concluded that Blizzaks may be used during winter to replace studded tires in Alaska.

Studded tires have been used during winter to increase vehicle traction force for reasons of safety. The use of studded tires has caused accelerated pavement wear, airborne dust, and environmental noise; these factors have been stated by researchers in the United States (*1,2*), Canada (*3*), Japan (*4*), Sweden (*5*), Germany (*6*), France (*7*), and other countries. In Alaska most of the pavement rutting on Alaska's roadways have been caused by studded tires according to winter versus summer season wear measurements. Vehicle owners continue to buy studded tires, expecting that the gains in traction and braking and reductions in travel time justify the added costs for tires and for semiannual changeovers.

Because of the problems of accelerated pavement wear and airborne dust caused by studded tire abrasion of paved roadway surfaces, a number of states, Canadian provinces, and countries have banned studded tires. In Japan the use of studded tires was recently banned primarily to reduce the amount of airborne dust (*4*). New tire tread types were then examined in an attempt to improve the wintertime traction benefits of nonstudded tires. One such type is the "Blizzak" (brand) tire developed by Bridgestone Tire Company. To compare the traction benefits of this new tire with currently available studded and nonstudded all-season tires, the Alaska Department of Transportation and Public Facilities (AKDOT&PF) first compared stopping distance tests on hard-packed snow surfaces at Fairbanks and Anchorage International Airports in January 1994. Results of these initial test runs indicated that the performance of the new tire type was excellent in comparison with that of studded tires. These results provide information useful to the state as well as the general public in making decisions about buying winter tires.

In March 1994 the University of Alaska Fairbanks (UAF) and the University of Alaska Anchorage (UAA) were requested by AKDOT&PF to perform a comparative testing program of the different winter tire types, including the Bridgestone Blizzak tires and studded and all-season tires purchased from Firestone, Michelin, and Goodyear. Field tests were conducted to consider the effects of tire type, vehicle type, surface condition, driver, and temperature. This paper summarizes research activities and results obtained through this study.

The main objective of the study was to investigate the traction performance of different types of tires. The tires tested included the Blizzak tire from Bridgestone and two brands each of studded and nonstudded all-season tires purchased from Firestone, Michelin, and Goodyear. Surfaces tested included old snowpack, freshly packed snow, old surface ice deposits, and newly prepared glare ice surfaces. Test vehicles included full-size rear-wheel-drive sedans, full-size half-ton pickups, and compact front-wheel-drive cars.

## DATA COLLECTION

During field experiments, various tests were conducted at Anchorage and Fairbanks, including stopping distance, starting traction, and cornering speed, with different surface conditions, different vehicle types, and different drivers. At least three repeated runs were made for each combination of vehicle types, tire types, surface conditions, test sites, and drivers to minimize possible biases. Average data were obtained from the repeated runs.

### Test Sites

Anchorage tests were done on the taxiway at the Birchwood Airport, located 32 km (20 mi) northeast of Anchorage, and on Jewel Lake, a small lake on the south side of Anchorage. Airport and lake sites were selected to avoid traffic interference and traffic effects on the surfaces being tested.

Fairbanks tests were done on the taxiway end at Fairbanks International Airport. To add data on actual road surfaces, additional stopping and starting traction tests were done on snowpack-covered low-volume sections of the Chena Lake access road and the Old Nenana Highway.

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## Tests

*Stopping Distance*

The measured stopping distances of the vehicles were obtained after applying and attempting to lock the brakes from an initial speed of 40.3 km/hr (25 mph). Because of the antilock braking systems (ABS) used, full locked-wheel skids did not occur, but braking continued until the vehicle was stopped. The maximum braking forces were also recorded during each test with a *g* analyst force meter.

*Starting Traction and Hill Climbing Ability*

Test vehicles were started from 0 and accelerated to 40.3 km/hr (25 mph) as quickly as possible without excessive wheelspin. The time to reach 40.3 km/hr (25 mph) was recorded with stopwatch, and the maximum *g*-forces were also recorded. The *g*-forces were then converted to maximum grades that the vehicle would be able to climb with the various surface conditions, vehicles, and tires. In fact, the value of *g*-force is the acceleration or deceleration of the vehicle. (The mathematical relationship between the maximum *g*-forces and hill climbing ability will be described later.)

*Maximum Cornering Speed*

Two curves with radii of 7.6 m (25 ft) and 15.3 m (50 ft), were marked with traffic cones. The curves were approached at various speeds to determine the maximum speed around the corner without skidding. Cornering speeds were observed, and the maximum cornering *g*-forces (centrifugal accelerations) were recorded at or near the maximum cornering speed. Because cornering speeds were difficult to observe while keeping the vehicle on course, cornering speeds were also calculated for the turn radius and recorded *g*-forces. This approach eliminated the errors from wheelspin and observer errors.

## Test Vehicles

Three different types of vehicles were used, all of which were selected from the state equipment fleet to represent 1993 or 1994 models.

*Front-Wheel-Drive Intermediate-Size Car*

Chevrolet Lumina models with ABS on all four wheels were used in UAF and UAA tests. A Ford Taurus was used by AKDOT&PF for the stopping distance test.

*Two-Wheel-Drive Half-Ton Full-Size Pickup Truck*

Chevrolet trucks with ABS on the rear axle only were used. Rear-axle ABS is typical of late-model trucks and acts to prevent the rear axle brakes from locking up before the front and causing a skid. This system is inactive below 32.2 km/hr (20 mph), according to Chevrolet.

*Rear-Wheel-Drive Full-Size Four-Door Car*

A Ford Crown Victoria was tested in Anchorage, and a Chevrolet Caprice was used in the Fairbanks tests. Both vehicles had four-wheel ABS systems.

## Tires Tested

Three types of tires were included in the test program. So that accurate comparisons between tire types could be obtained, all tires were premounted on rims and tire sets were exchanged in sets of four at the test site. Different tire types were compared on the same vehicles.

*Blizzak Tires*

The Blizzak tire is a winter tire with a special soft rubber compound that incorporates microbubbles to provide tiny gripping edges on ice.

*Studded Winter Tires*

Firestone studded "Town and Country" brand and Goodyear brand studded tires were tested.

*All-Season Tires*

All-season tires are marketed for year-round use and generally have many sipes or gripping edges to provide good traction on snow and ice. Michelin XGT-4 and Firestone Supreme brands were tested.

## Surface Conditions

*Packed Snow*

The surface at the Birchwood Airport taxiway test site was hard snowpack at the start of the tests. Snowfall during the testing period necessitated daily snow removal, resulting in a surface best described as newly packed snow covered over old snowpack. At Fairbanks the taxiway was covered with old and very hard snowpack, as were the local roads tested. Fairbanks had events of freezing rain during the previous winter, which further hardened the surface snowpack.

*Ice*

Tests on ice at Anchorage were done on Jewel Lake. After removing the snowcover, the ice surface was found to be very rough. To prepare it for the skid tests, the surface was conditioned with a "Zamboni"-type machine, which melts and levels the surface as for an ice skating rink. This surface was probably smoother than any road surface that a motorist will encounter. At Fairbanks the taxiway was prepared for the ice tests by being sprayed with water and refreezing overnight.

*Bare Pavement*

Tests on bare pavement surfaces were conducted at Birchwood Airport in Anchorage and Old Nenana Highway in Fairbanks to compare the stopping distances and starting traction for all tires.

### Temperatures

Most tests were conducted under near-freezing temperatures. Air temperatures varied between 24 and 36°F, and surface temperatures varied from 25 to 32°F. The time required to test each vehicle with each tire type and then to change tires for the next test run resulted in some temperature effects on the comparative results. Attempts were made to randomize the tests to avoid a temperature bias.

## STOPPING DISTANCE TESTS

### Tests Conducted by AKDOT&PF

In January 1994 preliminary field tests were conducted by AKDOT&PF in Anchorage and Fairbanks to compare the stopping distance performance between Blizzaks, studded tires, and all-season tires. For the tests conducted in Anchorage, a Taurus car was used. The surface conditions were sanded snow, packed snow, and packed ice. Initial speed was 40.3 km/hr (25 mph). Table 1 gives the test results. From the table, it is seen that on a sanded snow surface, stopping distances were almost the same for the studded tires and Blizzaks; on packed snow, compared with the studded tires, the Blizzaks shortened stopping distance by 33 percent; on packed ice, the Blizzaks shortened stopping distance by 5 percent.

At the Fairbanks test site, three types of vehicles were used: sedan, wagon, and van. The surface conditions were icy, and the initial speed was 64.4 km/hr (40 mph). Table 2 presents the test results, which indicate that the Blizzaks had the shortest stopping distances, followed by studded tires and then all-season tires. The average stopping distances for Blizzaks, studded tires, and all-season tires are presented in Table 2. The average data were obtained by combining all vehicles tested in Fairbanks. The average 64.4 km/hr (40-mph) stopping distances were 36.9 m (121 ft) for Blizzaks, 43 m (141 ft) for studded tires, and 54.6 m (179 ft) for all-season tires.

### Tests Conducted by UAF

For the field tests conducted in Fairbanks, three surface conditions were used: packed snow, ice, and bare pavement. Test results are given in Table 3.

*Packed Snow Surface*

Test results under packed snow conditions are presented in Table 3 with all test site data averaged. The table indicates that Blizzaks gave about 15 percent shorter stopping distances on the full-size car but about a 15 percent greater stopping distance on the pickup than either the studded or all-season tires. Using the average of all data from the three Fairbanks sites on hard packed snow and three testing vehicles as shown in Table 3, it was concluded that all tire types gave equal stopping distances.

*Icy Surface*

The stopping distances on ice were typically two to three times longer than distances on packed snow. Test results were obtained at the Fairbanks International Airport test site. From the results in Table 3, stopping distances were shortest for the studded tires, followed by the Blizzaks and then the all-season tire types. The average 40.3 km/hr (25-mph) stopping distances were 32.3 m (106 ft) for the studs 36.0 m (118 ft) for the Blizzaks, and 39.0 m (128 ft) for the all-season tires. In comparison with the Blizzaks, studs shortened stopping distances by 15 percent, and all-season distances were greater by 8 percent.

*Bare Pavement Surface*

Stopping distance tests were conducted at the Old Nenana Highway test site. Only a pickup truck was tested at this site. Two drivers were asked to drive the testing vehicle, a man and a woman. To show statistic differences between tires, driver type was combined and the final results are given in Table 3. It can be concluded that on bare pavement, no significant differences were found between tires, in terms of stopping distance, even though the Blizzaks and all-season tires showed stopping distances 5 and 2 percent shorter, respectively, than studded tires.

**TABLE 1 Stopping Distances for 40.3 km/hr (25 mph) from Preliminary Tests, Anchorage, for Taurus Vehicle (m)**

| | Sanded Snow | Packed Snow | Packed Ice | Average |
|---|---|---|---|---|
| Blizzak Tire | 10.7 | 13.0 | 28.2 | 17.3 |
| Studded Tire | 10.8 | 19.2 | 29.7 | 19.9 |

**TABLE 2 Stopping Distances for 64.4 km/hr (40 mph) from Preliminary Tests on Ice, Fairbanks (m)**

| | Sedan | Wagon | Van | Average |
|---|---|---|---|---|
| Blizzak Tire | 39.0 | 33.6 | 38.1 | 36.9 |
| Studded Tire | 43.9 | 36.6 | 48.5 | 43.0 |
| All-Season Tire | 53.4 | 45.1 | 65.0 | 54.6 |

TABLE 3 Stopping Distances for 40.3 km/hr (25 mph) on Packed Snow, Ice, and Bare Pavement, Fairbanks (m)

| | Front Wheel Drive Car (Lumina w. anti-lock brakes) | 2 Wheel Drive F. S Pickup (Chevy w. anti-lock brakes) | Rear Wheel Drive Car (Caprice w. anti-lock brakes) | Average |
|---|---|---|---|---|
| Packed Snow Surface | | | | |
| Blizzak Tire | 19.0 | 24.2 | 15.5 | 19.6 |
| Studded Tire | 19.6 | 20.9 | 18.1 | 19.6 |
| All-Season Tire | 19.5 | 21.0 | 17.5 | 19.4 |
| Icy Surface | | | | |
| Blizzak Tire | 31.7 | 37.2 | 39.2 | 36.1 |
| Studded Tire | 25.6 | 35.5 | 35.9 | 32.4 |
| All-Season Tire | 32.2 | 46.6 | 38.7 | 39.2 |
| Bare Pavement Surface | | | | |
| Blizzak Tire | N/A | 5.0 | N/A | 5.0 |
| Studded Tire | N/A | 5.2 | N/A | 5.2 |
| All-Season Tire | N/A | 5.1 | N/A | 5.1 |

## Tests Conducted by UAA

Three surface conditions were tested by UAA: packed snow, ice, and bare pavement. A summary of test results is given in Table 4.

### *Packed Snow Surface*

The stopping distance test results were obtained from the site on the taxiway at the Birchwood Airport. Data from Table 4 indicate that the front-wheel-drive car had longer stopping distances for all types of tires. The averaged data from three vehicles indicate that the Blizzaks were slightly superior [by 0.3 m (1 ft)] to studded tires and better [by 3.4 m (11 ft)] than the all-season tires in 40.3-km/hr (25-mph) stopping distances.

### *Icy Surface*

Stopping distance tests on an icy surface were conducted on Jewel Lake and covered only the Blizzaks versus studded tires. Using average data with vehicle type combined, studded tires

TABLE 4 Stopping Distances for 40.3 km/hr (25 mph) on Packed Snow, Ice, and Bare Pavement, Anchorage (m)

| | Front Wheel Drive Car (Lumina w. anti-lock brakes) | Rear Wheel Drive 1/2 T. Pickup (Chevy w. anti-lock brakes) | Rear Wheel Drive Car (Crown Victoria w. anti-lock brakes) | Average |
|---|---|---|---|---|
| Packed Snow Surface | | | | |
| Blizzak Tire | 15.4 | 10.6 | 11.3 | 12.4 |
| Studded Tire | 16.1 | 11.0 | 11.2 | 12.8 |
| All-Season Tire | 16.9 | 16.2 | 14.5 | 15.8 |
| Icy Surface | | | | |
| Blizzak Tire | 29.6 | 20.3 | 30.5 | 26.8 |
| Studded Tire | 19.6 | 25.5 | 26.4 | 23.8 |
| All-Season Tire | N/A | N/A | N/A | N/A |
| Bare Pavement Surface | | | | |
| Blizzak Tire | N/A | N/A | 3.4 | 3.4 |
| Studded Tire | N/A | N/A | 5.3 | 5.3 |
| All-Season Tire | N/A | N/A | 3.3 | 3.3 |

again reduced stopping distances by 11 percent over the Blizzaks.

*Bare Pavement Surface*

Bare pavement tests were limited to the full-size Ford Crown Victoria sedan. As indicated in Table 4, these tests indicated increased stopping distances for the studded tires compared with any of the nonstudded tire types. The studded tires had about 40 and 42 percent longer stopping distances than the Blizzaks and all-season tires, respectively.

## STARTING TRACTION TESTS

The main purpose of the starting traction tests was to compare the times required for a vehicle to start from zero and accelerate to 40.3 km/hr (25 mph) with different types of tire. Tests were conducted in Fairbanks by UAF and Anchorage by UAA on packed snow, icy, and bare pavement surfaces.

### Tests Conducted by UAF

Field data for the UAF tests are presented in Table 5.

*Packed Snow Surface*

Field tests were made at the Fairbanks International Airport, Chena Lake access road, and Old Nenana Highway test sites. According to the data in Table 5, for the Blizzaks and all-season tires, the front-wheel-drive car had the best traction, followed by the full-size pickup, and then the rear-wheel-drive car. For the studded tires, the full-size pickup showed the shortest time to reach 40.3 km/hr (25 mph) from zero, and the rear-wheel-drive car, again, took the longest. To eliminate the effect of vehicle type, starting traction data from different vehicles were averaged; they are presented in Table 5. The average starting times to reach 40.3 km/hr (25 mph) for vehicles with studded tires and with Blizzaks were about 9.12 and 9.6 sec, respectively. Vehicles with all-season tires took about 10.5 sec to reach 40.3 km/hr (25 mph). Basically, there was no significant difference between the Blizzaks and studded tires.

*Icy Surface*

In the experiment on an icy surface, only the Fairbanks International Airport test site was used because of the weather condition limitation. As might be expected, and is indicated in Table 5, starting traction tests on ice were very dependent on the operator and the vehicle, in addition to the tire. Front-wheel-drive cars were superior to rear-wheel-drive cars. Blizzaks and studded tires were about equal on the pickup and were superior in starting time to all-season tires by about 40 percent. For the average of all vehicles in Table 5, Blizzak starting times to reach 40.3 km/hr (25 mph) were about 18 percent longer than for studded tires but were about 13 percent less than times for the all-season tires.

*Bare Pavement Surface*

Bare pavement tests were conducted at the Old Nenana Highway test site. The testing vehicle was the pickup truck driven by a man and a woman, respectively. Test data are given in Table 5, with all drivers combined. As indicated in the table, the Blizzaks gave slightly quicker starts, of about a 7 percent reduction in time needed to reach 40.3 km/hr (25 mph), than the studded tires and all-season tires, which had the same starting traction performance.

**TABLE 5 Starting Traction Times on Packed Snow, Key and Bare Pavement, Fairbanks (sec)**

| | Front Wheel Drive Car (Lumina w. anti-lock brakes) | 2 Wheel Drive F. S Pickup (Chevy w. anti-lock brakes) | Rear Wheel Drive Car (Caprice w. anti-lock brakes) | Average |
|---|---|---|---|---|
| Packed Snow Surface | | | | |
| Blizzak Tire | 8.88 | 9.50 | 10.41 | 9.60 |
| Studded Tire | 9.27 | 8.53 | 9.57 | 9.12 |
| All-Season Tire | 10.06 | 10.42 | 10.99 | 10.49 |
| Icy Surface | | | | |
| Blizzak Tire | 12.70 | 13.00 | 17.53 | 14.41 |
| Studded Tire | 9.94 | 12.63 | 13.01 | 11.86 |
| All-Season Tire | 12.94 | 19.08 | 18.03 | 16.68 |
| Bare Pavement Surface | | | | |
| Blizzak Tire | N/A | 3.52 | N/A | 3.52 |
| Studded Tire | N/A | 3.74 | N/A | 3.74 |
| All-Season Tire | N/A | 3.73 | N/A | 3.73 |

**TABLE 6 Starting Traction Times on Packed Snow, Ice, and Bare Pavement, Anchorage (sec)**

| | Front Wheel Drive Car (Lumina w. anti-lock brakes) | Rear Wheel Drive 1/2 T. Pickup (Chevy w. anti-lock brakes) | Rear Wheel Drive Car (Crown Victoria w. anti-lock brakes) | Average |
|---|---|---|---|---|
| Packed Snow Surface | | | | |
| Blizzak Tire | 5.68 | 7.20 | 5.91 | 6.26 |
| Studded Tire | 6.24 | 7.35 | 6.60 | 6.73 |
| All-Season Tire | 6.16 | 9.45 | 8.72 | 8.11 |
| Icy Surface | | | | |
| Blizzak Tire | 15.60 | 12.37 | 19.09 | 15.69 |
| Studded Tire | 8.34 | 18.54 | 14.37 | 13.75 |
| All-Season Tire | N/A | N/A | N/A | N/A |
| Bare Pavement Surface | | | | |
| Blizzak Tire | N/A | N/A | 3.04 | 3.04 |
| Studded Tire | N/A | N/A | 3.39 | 3.39 |
| All-Season Tire | N/A | N/A | 3.05 | 3.05 |

### Tests Conducted by UAA

Field data for the UAA tests are summarized in Table 6.

#### *Packed Snow Surface*

Field tests were conducted at the Birchwood Airport test site. As indicated in Table 6, the front-wheel-drive car showed the best starting traction when compared with the rear-wheel-drive pickup and rear-wheel-drive car. The average starting times for Blizzaks, studded tires, and all-season tires were about 6.2, 6.8, and 8.1 sec, respectively. The Blizzaks started slightly faster, with about a 9 percent reduction in the time needed to reach 40.3 km/hr (25 mph) compared with the studded tires.

#### *Icy Surface*

In Anchorage, completed field data for the icy surface were obtained for Blizzaks and studded tires. Field tests were conducted at the Jewel Lake test site. As presented in Table 6, significant differences in starting times among vehicle types were observed, meaning that starting times on ice were dependent on the vehicle. Using the average data from all vehicles, the Blizzaks showed about a 12 percent longer starting time, in comparison with the studded tires.

#### *Bare Pavement Surface*

Only the full-size Ford Crown Victoria sedan was used in the bare pavement tests at the Birchwood Airport test site in Anchorage. Test results are summarized and presented in Table 6. The Blizzaks and all-season tires showed the same starting traction performance and were better than the studded tires by about a 10 percent reduction in time needed to reach 40.3 km/hr (25 mph).

## CORNERING SPEED TESTS

The main purpose of the cornering tests was to estimate the maximum speed of a vehicle moving along a given curve with packed snow or icy surface. The impact of tire type can be evaluated from cornering tests. Vehicles used for cornering tests were the same ones for stopping distance and starting traction tests. Maximum cornering speeds for different types of tires were tested on curves with inside radii of 7.6 and 16.3 m (25 and 50 ft) in Fairbanks and Anchorage. Longer-radius curves were not possible because of the widths of the available test areas, but speeds for any other curve can be easily calculated by Equation 1. Observed speeds were reported by the vehicle operators but were not extremely precise because of the dual tasks of avoiding skidding while checking speeds. Data on the maximum speeds observed and the maximum *g*-forces measured came from three to six test runs for each combination of tires and vehicles. The *g*-force data were measured by the instrument called g Analyst made by Valentine Research, Inc. The calculated maximum cornering speeds were based on the maximum cornering *g*-force measurements recorded during testing. Conversions were made by the following equation from the 1990 AASHTO policy manual on geometric design of highways and streets (*8*).

$$\text{Maximum cornering speed (mph)} = \sqrt{\text{radius (ft)} \times g \times 15} \qquad (1)$$

The lateral *g*-forces on snow typically were between 0.25 and 0.4; *g*-forces on ice were between 0.1 and 0.2. At the point of skidding these forces are equivalent to the side friction factors as used for highway curve designs. Because of tire spin and errors on the observed speeds, the *g*-forces and calculated speeds based on Equation 1 are considered more accurate and were used for analysis and reporting of test results as summarized in Table 7 for the Fairbanks and Anchorage tests. The data in the table were obtained by averaging data from all vehicles and runs for both right and left turns. On packed snow and icy surfaces, no significant differences were found among the Blizzaks, studded tires, and all-season tires in

**TABLE 7 Maximum Cornering Speeds (km/hr)**

| | | |
|---|---|---|
| Fairbanks Tests | | |
| 7.6 m (25 ft.) Curve: | Packed Snow | Ice on Pavement |
| Blizzak Tires | 19.5 | 16.3 |
| Studded Tires | 17.5 | 15.8 |
| All-Season Tires | 19.0 | 16.6 |
| 15.3 m (50 ft.) Curve | Packed Snow | Ice on Pavement |
| Blizzak Tires | 27.7 | 22.9 |
| Studded Tires | 25.6 | 21.9 |
| All-Season Tires | 27.7 | 22.1 |
| Anchorage Tests | | |
| 7.6 m (25 ft.) Curve: | Packed Snow | Ice on Pavement |
| Blizzak Tires | 19.3 | N/A |
| Studded Tires | 18.0 | N/A |
| All-Season Tires | 18.4 | N/A |
| 15.3 m (50 ft.) Curve: | Packed Snow | Lake Ice - Glazed |
| Blizzak Tires | 23.7 | 16.4 |
| Studded Tires | 23.7 | 17.9 |
| All-Season Tires | 23.8 | N/A |

terms of maximum cornering speed. The only exception was the testing on glare ice in Anchorage, for which maximum cornering speeds for the studded tires were about 1.4 km/hr (0.9 mph) higher than for the Blizzak tires. On all other surfaces there were no significant differences, although the nonstudded tire types outcornered the studs by about 1 mph on average.

## HILL CLIMBING ABILITY TESTS

The hill climbing ability of a vehicle can be evaluated by maximum $g$-forces. As shown in Figure 1, for the maximum slope on which a vehicle can climb, the following equation is obtained:

$$m\, g\, \mu \cos \beta_{max} = m\, g \sin \beta_{max} \qquad (2)$$

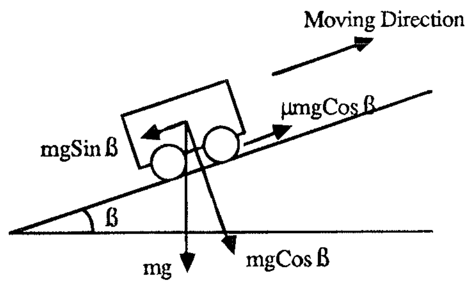


**FIGURE 1 Forces of vehicle reaching maximum climbing ability ($\beta = \beta_{max}$).**

where

$m$ = mass of the vehicle,
$g$ = natural acceleration,
$\mu$ = coefficient of rolling resistance, and
$\beta_{max}$ = degree of maximum slope.

The maximum traction or maximum $g$-force, $G_{max}$, can be obtained when $\beta$ is 0, as shown in Figure 2. In this case, the following equation is obtained:

$$m\, G_{max}\, g = m\, g\, \mu$$

or

$$\mu = G_{max} \qquad (3)$$

By combining Equations 2 and 3, the following relationship is obtained:

$$G_{max} = tg(\beta_{max}) \qquad (4)$$

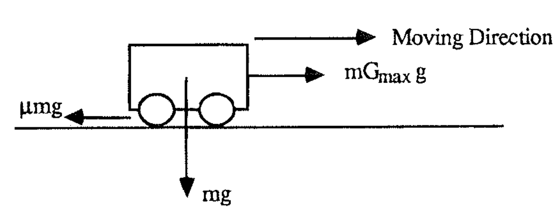


**FIGURE 2 Forces of vehicle on level surface ($\beta = 0$).**

**TABLE 8 Maximum Starting Grades at Maximum $g$-Forces (%)**

| Fairbanks Results: | Packed Snow | Ice on Pavement |
|---|---|---|
| Blizzak Tires | 16 | 11 |
| Studded Tires | 16 | 12 |
| All-Season Tires | 15 | 10 |

| Anchorage Results: | Packed Snow | Lake Ice - Glazed |
|---|---|---|
| Blizzak Tires | 18 | 10 |
| Studded Tires | 16 | 11 |
| All-Season Tires | 15 | N/A |

Maximum highway grades or hill climbing ability of a vehicle can be calculated from Equation 4 if the maximum $g$-forces are available.

Field tests were conducted in Fairbanks by UAF and in Anchorage by UAA on packed snow and icy surfaces. The maximum $g$-force data were collected during starting traction tests in Fairbanks and Anchorage. Various vehicles with Blizzaks, studded tires, and all-season tires were tested for three to six repeated runs on given test sites. The average data of maximum $g$-forces or maximum starting grades were obtained from different vehicles and runs and are presented in Table 8. For tests in Fairbanks, by converting the maximum $g$-forces to hill climbing ability, it was concluded that the Blizzaks and studded tires would climb a grade up to 16 percent on packed snow and 11 percent on ice. The all-season tires would climb up to 15 percent on packed snow and 10 percent on ice. Maximum highway grades are generally 8 percent or less. Test results in Anchorage were almost identical. The hill climbing ability of a vehicle on bare pavement was controlled more by engine power than by tire type, as none of the test vehicles had the power needed to reach wheelspin on bare pavement.

## CONCLUSIONS

### Stopping Distance

On packed snow, all tire types were about equal in stopping distances; on ice, all stopping distances were 2 to 3 times greater than on packed snow and 7 to 10 times greater than on bare pavement. In comparison with all-season tires, on average the Blizzaks shortened stopping distances on ice by about 8 percent, whereas the studded tires reduced stopping distances on ice by about 17 percent. On bare pavement, the Blizzaks and all-season tires were superior to studded tires by 2 to 35 percent.

### Starting Traction

On packed snow, the Blizzaks and studded tires were about equal and gave slightly quicker starts, taking 10 to 20 percent less time to reach 40.3 km/hr (25 mph), than did all-season tires; On ice, the Blizzaks lessened times to reach 40.3 km/hr (25 mph) by about 13 percent; studded tires reduced it by 29 percent over all-season tires. On bare pavement, the Blizzaks showed slightly better traction performance, by about 6 to 9 percent, than did studded tires, and about the same traction performance, as all-season tires.

### Cornering Speed

On packed snow and icy surfaces, no significant differences were found among the Blizzaks, studded tires, and all-season tires in terms of maximum cornering speed. Cornering tests were not done on bare pavement because of the vehicle rollover potential.

### Hill Climbing Ability

The maximum grades that might be climbed by the different tire types during winter were calculated from the maximum $g$-forces obtained during starting traction tests. On packed snow, the Blizzaks, studded tires, and all-season tires would climb grades up to 15 or 16 percent. On ice, these tires would climb 10 to 12 percent grades. Field tests did not show significant differences among these tires.

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