tion is found not to exist, or cannot be established, the minimum allowable marking material coefficient of friction could be given as the minimum allowable pavement friction for the sections of highway under consideration, irrespective of the existing or design pavement surface friction.

CONCLUSIONS

A data base for a large variety of pavement marking materials was established. A wide range of skid resistance levels was found, the lowest levels were for the hot extruded thermoplastic and the chlorinated rubber base paints that were used in the study. Glass beads and premixed beads and sand increased the skid resistance of the marking materials significantly. Spray thermoplastics provided higher skid resistance levels than hot extruded thermoplastics, due in part to the coarser texture produced by the spraying application. In the field both daily and seasonal variations in skid resistance were observed, and these variations should be accounted for in any field evaluation of marking materials.

The effect of accelerated laboratory polishing on marking material surfaces is much different from that on aggregate or unmarked pavement samples. Polishing tends to decrease the frictional resistance of beaded surfaces but tends to increase the frictional resistance of some unbeaded surfaces. Any laboratory evaluation of marking materials should include a light polishing to condition the samples. Accelerated weathering is not necessary as a conditioning step in a laboratory evaluation. Sample preparation is extremely important and should duplicate field application procedures as closely as possible. Preparation techniques can have a greater effect on BPN values than will differences in materials.

The marking materials studied in this project were grouped into six types: traffic paints, hot spray thermoplastics, hot extruded thermoplastics, preformed plastic, temporary tapes, and two-part systems. In analyzing the data and developing the predictor equations for skid resistance in terms of texture and BPN data it was necessary to treat each type separately. This resulted in six data sets, some of which were too small to provide significant correlations.

Predictor equations were developed by using linear regression techniques to predict SN_{64} from BPN values. Correlation coefficients for the more successful of these equations ranged up to 92. In some instances the prediction was improved by the inclusion of the macrotexture profile RMS.

When applied to pavements, marking materials cause a local reduction in skid resistance. The resulting differential frictions can create a hazard for drivers of automobiles and other four-wheel vehicles if the materials are applied to large areas such as gores, legends, and stop bars. Such applications should be avoided when possible, although a tentative design procedure has been developed for selection of materials that give safe levels of skid resistance. Current standards for such configurations should be reviewed in light of this finding. Lane delineation lines do not present a hazard for drivers of four-wheeled vehicles, even when the marking material skid resistance is extremely low. Almost any application of pavement marking materials will create a potential hazard for riders of single-track vehicles. Recommendations for minimum allowable levels of marking material skid resistance for safe operation of single-track vehicles could not be established. However, the skidding hazard presented by pavement markings to riders of single-track vehicles should be weighed against the safety benefit provided by the marking in the form of roadway delineation and warnings of safety hazards.

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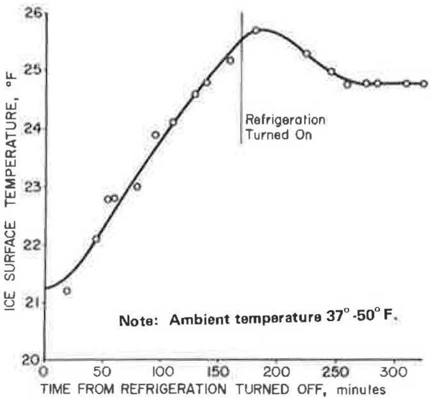
Tire Testing at Low Speed on an Ice Rink

GORDON F. HAYHOE AND JOHN J. HENRY

Procedures are described for measuring the performance of tire traction on an ice rink. Results are given from driving traction and locked wheel braking tests conducted at various speeds by using a modified road friction tester. Maximum test speed was restricted to 12 mph (19 km/h) by the small surface area of the ice rink, but the locked wheel braking results obtained are shown to be representative of higher speed tests if the test speed used is high enough that the tire force approaches its limiting (minimum) value. To enhance test repeatability, the sensing element of the transducer used to measure surface temperature should be completely frozen into the ice just below the surface. The ice surface should also be conditioned by running preliminary tests until the tire force measurements have reached a stable value. Contamination and damage to the ice surface from studded tire tests are described, and their effects on tire force generation and test repeatability are discussed.

Figure 1. Temperature response of ice surface with refrigeration equipment turned off.



When measuring the performance of tires on an ice course constructed out-of-doors, problems of obtaining repeatable results often are encountered because of variable weather conditions. In addition, such test courses are difficult to construct and maintain in good condition, and, to a large extent, the prevailing weather conditions determine the scope and planning of the test program. The use of an enclosed ice rink largely overcomes these problems and provides a convenient means of measuring tire performance on ice. But, the use of an enclosed area and the testing on an artifically maintained surface introduced new problems, and old ones were made more acute. This paper discusses some of the problems encountered while conducting a test program in an ice rink as part of evaluation of winter driving traction aids for the National Cooperative Highway Research Program (NCHRP). The main problems that arose were in accurately measuring ice surface temperature, in ensuring that speed effects did not introduce bias into the results, and in dealing with contamination of the ice surface.

A major objective of the project was to specify and, if necessary, develop a set of test procedures for measuring the performance of highway vehicles under adverse winter conditions. Procedures for measuring tire performance on ice have been in use for many years [see, for example the National Safety Council and Sapp (1,2)], and most of the tests conducted during the NCHRP project were run according to established practice. The majority of the published results, however, deal with tests conducted on ice courses constructed out-of-doors, and the test results presented in this paper were selected from the final NCHRP report (4) to emphasize the problems that may be encountered when a test program is relocated to an indoor ice rink.

GENERAL TEST CONDITIONS

Testing was conducted in the Pennsylvania State University Ice Pavilion, which comprises an ice rink completely enclosed by a metal structure. Except that ambient temperature determines, to some extent, the surface temperature of the ice, environmental conditions had little effect on the characteristics of the ice surface. The ice area, which measured 200x100 ft (61x30.5 m), is surrounded by a guard fence, and a free run-on to the ice was not possible. All maneuvering, therefore, had to be done on the ice, which restricted speeds to an absolute maximum of 15 mph (24 km/h) and for normal testing to no more than 12 mph (19 km/h). Suitable entry and exit lanes would increase possible test speeds considerably.

The ice surface was prepared by using a Zamboni ice conditioning machine. This vehicle is designed to cut back and remove the top layer of the ice surface and then lay down a thin film of hot water. After the water has frozen, the resulting surface is smooth. About an hour is required for surface temperature to stabilize, and conditioning of the complete area requires about 20 min.

With the refrigeration equipment set to run normally, ice temperature varied between 21° and 16°F (-6° and -9°C), depending on the ambient temperature. If ambient temperature is sufficiently high, ice temperature can be varied by turning the refrigeration equipment on and off. Response time is long enough for tests to be carried out at essentially constant temperature while the temperature is changing. Figure 1 shows the results from an experiment where the refrigeration equipment was turned off for 3 h and then turned on at half power. The maximum rate of temperature change was approximately 1.7°F (1°C)/h.

ICE TEMPERATURE MEASUREMENT

Although an ice rink is generally more convenient to use than an ice course constructed out-of-doors, the measurement of ice temperature was found to be a critical factor in obtaining satisfactory test results. The first consideration is that minimum temperatures in a rink will not be as low as those attainable with an outdoor facility under similar climatic conditions. For example, the lowest ice temperature measured in the rink was 16°F (-9°C), which occurred when the ambient temperature in the rink was 10°F (-12°C) and the outside temperature was 0°F (-18°C). Test results cannot, therefore, be obtained at very low temperatures and, in order to determine the relation between tire performance and ice temperature with an accuracy equivalent to that obtainable in outdoor testing, either ice temperature must be measured more accurately or more tests must be run. Temperature can vary across the ice surface by as much as 4°F (2°C), which means that it is important to measure ice temperature as closely as possible to the area of ice used for testing, and preferably to make simultaneous measurements at points distributed over the test area.

During preliminary tests ice temperature was measured by pressing a thermistor probe against the ice. It became apparent, however, that the measurements were not consistent, even when standardized procedures were carefully followed. Various methods of holding the probe on the surface were also tried, including freezing the probe onto the ice, but to no satisfactory effect.

In an effort to determine the causes of the inconsistent measurements, the temperature gradient in the ice and in the air adjacent to the surface were measured by using seven thermocouple junctions fixed to a short length of circuit board. The assembly was frozen into the ice with the first junction 1/8 in (0.3 cm) above the concrete base of the ice rink. Figure 2 shows junction temperatures measured on two occasions. The fourth junction was located very close to the ice surface, and heat transfer along the circuit board and thermocouple leads undoubtedly affected the measurement, but the first three junctions show a linear temperature gradient that may be extrapolated to give surface temperature. Although the junction temperatures show, to a large extent, the temperature gradient in the thermocouple assembly, it is evident that a steep gradient exists in the air adjacent to the ice surface. This may account for some of the inconsistency noted during early tests because the gradient will vary with ambient temperature and thus vary

Figure 2. Temperature gradients at ice surface.

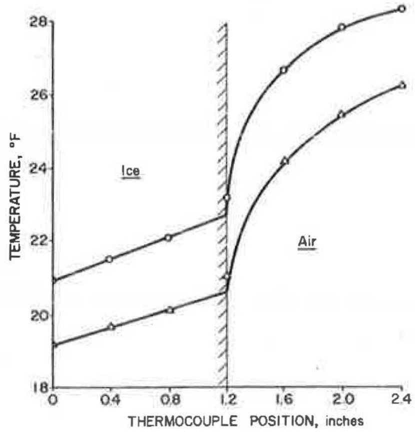


Figure 4. Braking performance of locked wheel against ice surface temperature.

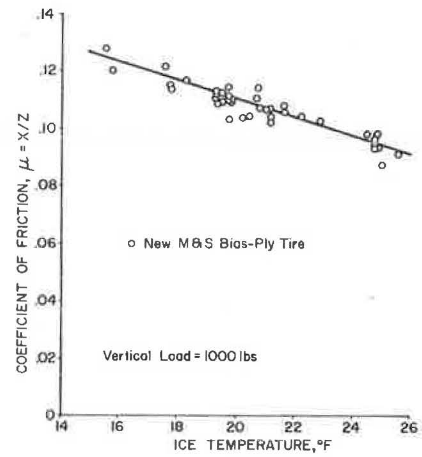
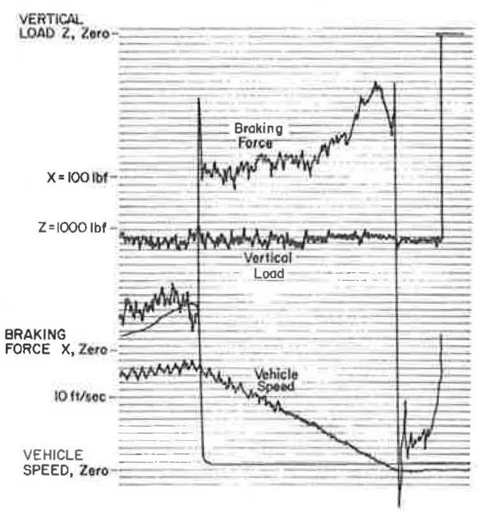


Figure 3. Oscillograph recording of increase in locked wheel friction as speed decreases.



heat input to a probe pressed onto the surface. The effect will be exaggerated as the device that holds the probe onto the surface becomes longer. A further effect is that movement of a vehicle on the ice causes mixing of the air and consequent variations in probe temperature. For example, with the probe frozen onto the ice surface, an increase of 1°F (0.5°C) was induced by driving a car past the probe at a distance of 5 ft (1.5 m), although exhaust gas from the vehicle also may have influenced the rise in temperature.

Because of the shallow temperature gradient that exists in the ice, accurate and consistent results are obtained if the temperature probe is frozen into the ice just below the ice surface, and all temperatures quoted later were obtained by this method. In general, a thermistor probe with digital read-out equipment was used, but a mercury thermometer, used as a back-up, was found to be satisfactory.

LOCKED WHEEL BRAKING TESTS

The Pennsylvania State Mark III Road Friction Tester was used to measure locked wheel braking forces. This tester is of the single-wheel trailer type (3), with the test wheel mounted on a six-component strain-gauged hub. A test typically consisted of 10 skids repeated over a given section of ice, during which braking and vertical forces were monitored. The forces were then measured and averaged and the coefficient of sliding friction was calculated. The standard deviation of braking-force measurements during a test was typically 2.5 lb (11 N) for unstudded tires. Vertical load was nominally 1000 lb (4.45 kN).

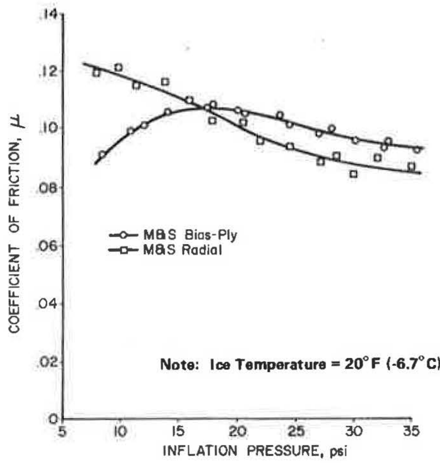
Succeeding tests were run over the same section of ice and, although a test session was always started on a smooth, newly conditioned surface, two or three tests were generally required to stabilize tire force at a reasonably constant value. The effect, however, was variable--on some occasions, the results of the second test of 10 skids were as much as 7 percent lower than the results of the first. On other occasions, both the first and second tests gave the same result.

While obtaining a satisfactory ice condition, the minimum speed for conducting a test was also determined. This was done by driving the tester over the ice as in a normal test, locking the test wheel, and then shifting into neutral. A typical output as the tester decelerated to zero is shown in Figure 3, where the characteristic increase in friction as speed decreases can be seen. Subsequent tests were run in excess of the speed at which the trace leveled out.

Test variability is an important consideration, and consequently a series of tests were run with a new mud and snow (M&S) bias-ply tire, broken in for 200 miles, to determine the precision that can be expected from ice rink tests. Two tests generally were run during a single session and results were obtained for ice temperatures in the range of 25° to 16°F (-4° to -9°C) and over a wide range of ambient temperature and relative humidity. The results, plotted against ice temperature, are shown in Figure 4, where it can be seen that dispersion of the data about a mean squared straight line is quite small, with 95 percent confidence intervals of the order of 5 percent. A systematic variation due to ambient temperature or relative humidity could not be found in the data and it was felt that the dominant causes of variation were day-to-day changes in the tester characteristics and inaccuracies in ice temperature measurement. [For a discussion of possible sources of data variation, see the final NCHRP report (4).]

Despite the day-to-day variation in test results, the braking test procedure itself was extemely sensitive, as is shown in Figure 5, which gives results from tests run with a M&S bias-ply tire and a M&S radial-ply tire, both of which have the same tread pattern. During the tests with each tire,

Figure 5. Variation of locked wheel braking performance with inflation pressure.



inflation pressure was varied from 8 to 35 psi (55 to 240 kPa). The two tires show similar behavior in the range of 18-35 psi (123-240 kPa), but below 18 psi (123 kPa) their behavior is markedly different. The figure illustrates how variations in tire pressure about a nominal test point can affect test results.

STUDDED TIRE TESTS AND ICE CONTAMINATION

Locked wheel braking tests were run with a tire nominally identical to the bias-ply tire used to obtain the results given in Figure 4, except that the tire was fitted with 96 controlled protrusion tungsten carbide studs. Test results from this tire showed wide variation compared with the results from the unstudded tire. From oscillograph traces of individual skid tests it was apparent that studded tire performance can vary by large amounts from skid to skid and during the same skid. There are at least two causes of this behavior: (a) the studs cut grooves in the ice (5), which can decrease performance in subsequent skids over the same section of ice by reducing stud cutting forces and reducing tire frictional forces; or (b) ice chips formed during a skid also can reduce tire frictional forces during subsequent skids.

The first effect was investigated by running a series of studded and unstudded tire tests in sequence. The unstudded tire was run first, followed by the studded tire. The ice was then swept clean of all ice chips and the unstudded tire rerun. The unstudded tire, in passing over a clean but stud-damaged section of ice, produced 12 percent less force than the same tire did in passing over a clean undamaged section of ice.

To investigate the second effect, a test was first run on clean ice with the unstudded tire, and then ice chips from the side of the rink were packed into the tire tread and a further test was run. This produced contamination of the ice surface when the ice chips were released from the tire tread during the initial skids. This contamination was similar to that produced by studded tire tests. Figure 6a shows an oscillograph trace from the first test where peaking of the brake force is apparent when the wheel locks or spins down. In contrast, a trace from the second test on contaminated ice (Figure 6c gives no indication of peaking) and a loss of performance is evident during the initial stages of the skid. The extent to which contamination produced during a skid affects performance for that particular skid is unclear, but the ice rink results show that subsequent skids can be seriously affected--and the results also explain the general absence of large peak forces in studded tire tests.

Figure 6. Oscillograph traces of locked wheel braking tests: (a) M&S tire, clean ice; (b) M&S studded tire, clean ice; and (c) M&S tire, contaminated ice.

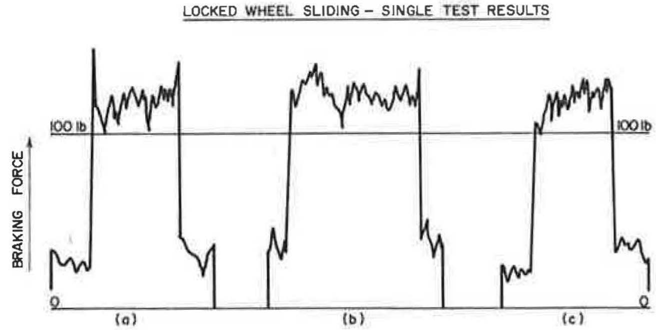


Table 1. Comparison between locked wheel braking tests conducted at Stevens Point and at ice rink.

Tires on Rear Wheels	Ice Temperature (°F)	Coefficient of Friction: Stevens Point	Ice Rink	Difference (%)
M&S	25	0.0789	0.0795	2.0
	26	0.0761	0.0764	0.4
Studded M&S	25	0.1159	0.0987	16
	26	0.1144	0.1317	14
M&S on road friction tester	20.4	0.0877	0.0843	3.4

The preceding discussion is based on contamination from studded tire tests, but exactly the same problems arise if the contamination is brought in from outside. For example, if the test vehicle is driven to the rink over snowy roads, it is almost impossible to clean the tires and the underneath of the vehicle sufficiently well to stop the problem from occurring.

STOPPING DISTANCE TESTS

The Winter Driving Hazards Program (WDHP) conducted by the National Safety Council (NSC) at Stevens Point in 1976 included a series of locked wheel stopping distance tests with studded and unstudded M&S tires. In cooperation with NSC and Kennametal Corporation, the same tires were later loaned to the NCHRP project. The tires were fitted to a car of the same model as used at Stevens Point, and locked wheel stopping distance tests were conducted on the ice rink. Initial speed for the WDHP tests was 20 mph (32.2 km/h), but 10 mph (16.1 km/h) was the highest safe speed that could be attained on the ice rink. The Stevens Point data were plotted as stopping distance against temperature, and a mean square straight line equation was computed. Stopping distance at the appropriate temperature was then calculated from the straight line equation. In the ice rink test series, one test consisted of 10 stops from a speed of 10 mph (16.1 km/h), all run over the same section of ice. To compare the two sets of results, stopping distances were converted to mean deceleration and are listed in Table 1.

Considering the small number of data points taken in the ice rink tests, the agreement with NSC data is remarkably good for the unstudded tires and is well within the scatter of the NSC results. A later

Figure 7. Traction drive assembly showing motor drive detail.

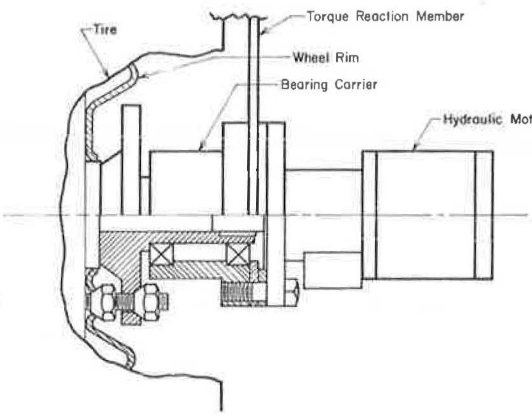
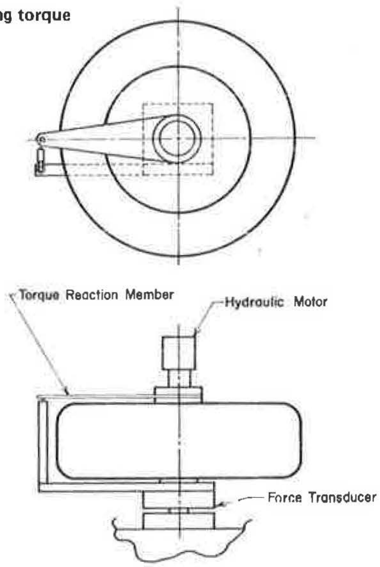


Figure 8. Traction drive showing torque reaction assembly.



test in the ice rink that used a road friction tester did not give such good correlation (see Table 1), but the agreement is still close enough to indicate that tests at slow speeds on an ice rink do not introduce serious errors into the measurement of tire performance, at least for ice temperatures of 20°F (-6.7°C) and above.

On the other hand, the test results with studded tires show relatively poor agreement, but the difference is of the same order as the scatter in the Stevens Point data. There was no apparent difference between the test conditions in the two studded tire tests in the ice rink. The major part of the difference in measured performance was tentatively attributed to the effects of contamination of the ice surface.

DRIVING TRACTION TESTS

Driving traction tire forces were also measured by using the road friction tester. In order to do this, a torque drive was designed, built, and fitted to the test trailer. The drive consists of a high torque, low speed hydraulic motor driven by a variable speed hydraulic pump, with motive power supplied by a 5-hp (3.7-kW) gasoline engine. The hydraulic motor is mounted on extended wheel studs, as shown in Figure 7, and reaction torque is passed around the tire to the wheel hub side of the force transducer, as shown in Figure 8. By constructing the device in this way, it was not necessary to isolate the motor from the wheel in the longitudinal direction as normally is done with driven wheel transducer assemblies. When braking tests are carried out, the motor shaft is withdrawn from the intermediate drive shaft and a spacer placed between the motor and the bearing carrier.

The test procedure adopted to measure traction force was to drive the test wheel at a constant speed and vary vehicle speed in order to vary wheel slip ratio. Both traction and locked wheel braking tests were run over the same section of ice so that the two modes of operation could be compared. Vehicle speed was varied between tests but was held constant during each pass over the ice. The average coefficient of friction for each pass was measured and plotted against wheel slip speed (where slip speed is the speed at which the tire contact patch slides over the ice). Traction results were also plotted against wheel slip ratio.

Figure 9 gives results obtained with the M&S bias-ply tire and, in common with other published data, shows reduced performance in traction compared with braking. As the force of locked wheel braking is a function of slip speed, and reduces to a constant value with increased speed, it might seem reasonable that the same functional relation applies to traction. This, however, is clearly not the case, and a different functional relation is required to account for the difference between braking and traction. Rolling resistance losses and pressure distribution in the contact patch are both factors that can conceivably modify traction forces, and most likely do have an effect, but a more plausible explanation of the gross behavior shown in Figure 9 is provided if tire friction on ice is considered to be predominantly dependent on the thermodynamic processes that control the generation of a water film in the tire-ice interface. Bowden and Tabor (6) give experimental evidence that water formation is a factor in sliding friction on ice, and the NCHRP final report (4) discusses the possible mechanisms of tire force generation on ice. Further work has shown that a stable water film can be formed and maintained under a sliding tire by the energy generated in viscous shearing of the fluid film, and that the forces that arise from fluid shear stresses match experimental results over certain ranges of tire operating conditions.

For comparison with the bare M&S tire, a number of tests were run with the studded M&S tire. In this test series, the traction and braking tests were run over a fairly small area of ice in four alternating sets so that the results would not be unduly biased by surface contamination and stud damage. No attempt was made to clean the ice surface between tests, although care was taken not to pass over exactly the same track too many times. Comparison of Figures 9 and 10 for locked wheel braking at high speed shows a modest improvement in performance for the studded tire over the bare tire, but performance at low speed was reduced. In traction, the studded tire did not seem to be affected by surface contamination to the same extent as in braking, and a substantial improvement in performance is shown (Figure 11) over almost the whole slip range. At slip ratios of less than 0.5, average studded tire performance was slightly less than that of the bare tire, but as slip ratio increased, traction force decreased less abruptly than with the bare tire. The two tires showed approximately the same performance at a slip ratio of 9, with the studded tire then becoming less effective at zero vehicle speed.

Figure 9. Traction and locked wheel braking results, M&S bias-ply tire.

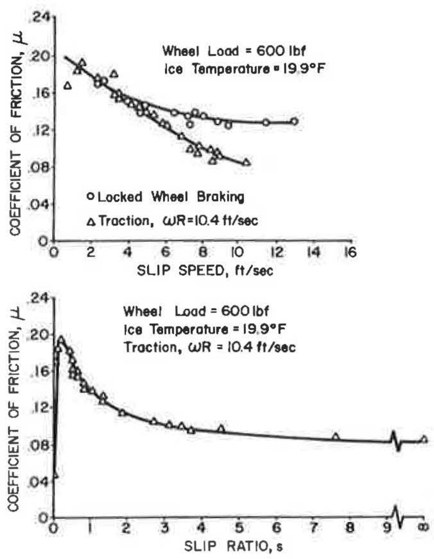
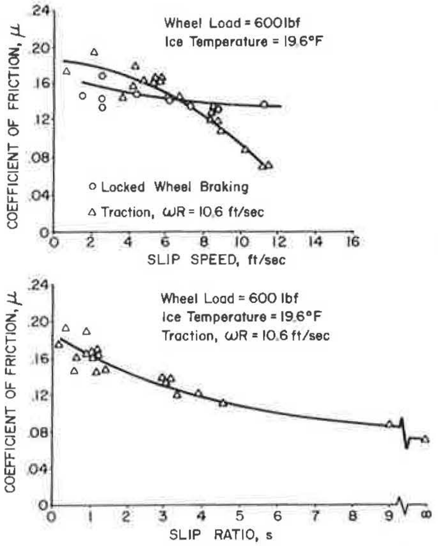


Figure 10. Traction and locked wheel braking results, M&S bias-ply studded tire.



Immediately following the studded tire tests, a number of tests were run with the bare M&S tire over the contaminated section of ice. The results are given in Figure 12, which shows that performance was reduced compared with the tests on clean ice, particularly for traction at low slip ratios.

CONCLUSION--IMPLICATIONS OF THE TEST RESULTS

The results presented show that accurate and repeatable results can be obtained from tire tests conducted in an ice rink, providing a set procedure is followed carefully. Of primary importance is the accurate measurement of the temperature of the ice surface and the preliminary working of the ice surface to obtain limiting performance values.

The restrictions in speed imposed by testing in an ice rink are not particularly serious if they are recognized and accounted for in the test procedures. This can take the form of either running tests over a range of speeds to establish the speed relation or, in the case of locked wheel braking, ensuring

Figure 11. Relative driving traction performance of studded and nonstudded tires.

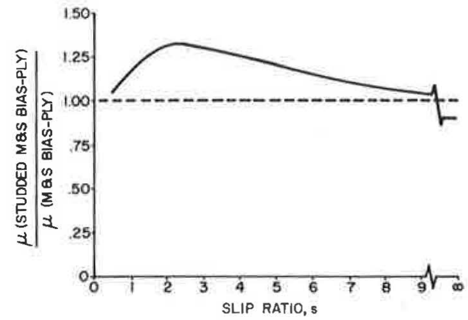
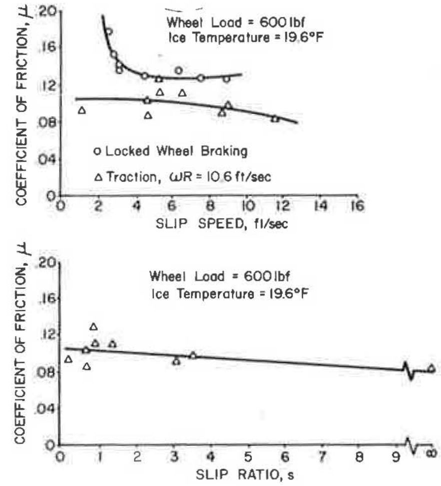


Figure 12. Traction and locked wheel braking results, M&S bias-ply tire, run after studded tire tests.



that the test speed is sufficiently high to give limiting tire performance. When conducting comparative tests, it is particularly important to establish the tire performance-velocity relation because wide variations of this characteristic can exist between different tires.

Contamination of the ice surface by either snow or ice chips significantly affects the peak traction attainable from a tire and can reduce limiting force values if present in sufficient quantities. Also associated with contamination of ice surfaces is the question of how the performance of studded tires should be measured. We found that the repeating of locked wheel braking tests with a studded tire over the same section of ice reduces tire performance. If studded tire use on the highway produces significant contamination, then not only will the performance of the studded tires be reduced, but the performance of bare tires also in use will be reduced. On the other hand, if locked wheel stops and rapidly spinning wheels occur only rarely, the performance measured in standard tests will probably underestimate the true effectiveness of studded tires.

From these considerations three test methods for measuring studded tire performance can be proposed:

1. Run two or three tests to damage and contaminate the ice surface and then run a number of tests from which the average performance will be calculated;
2. Run a number of tests, from which the average performance will be calculated, with each test run on a clean, undamaged section of ice; and
3. Run a number of tests over the same section of ice and average the results from all the tests.

The last procedure is the one usually adopted and it tends to produce variable results. The other two procedures will give significantly different results in locked wheel braking tests, although the results from traction tests should correspond fairly closely. Without knowing the highway conditions over which the studded tires will be used, it is not possible to state which of the three procedures will give the most representative result.

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Determination of Precrash Parameters from Skid Mark Analysis

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This paper presents the results of an experimental study to validate and improve the methods currently used in the reconstruction of accidents to determine precrash parameters from skid marks. This was accomplished by testing six vehicles, three cars and three trucks, that had a variety of tires and loadings on three differing types of pavements. Both severe (wheels locked) and moderate (no wheels locked) stops were made. Prebraking speed, the length of the skid marks produced, stopping distance, and a number of other variables of interest were measured for each stop. Analysis of the experimental data focused on repeatability of skid mark data, validity of the currently used skid mark length versus prebraking speed formula, accuracy of the various methods for measuring tire friction, and tire marks left by nonlocked wheels. The currently used skid mark length versus prebraking speed formula was found to be better for accident reconstruction when using test data from locked wheel stops than were either of two other formulas that were tried. Four methods for measuring tire friction were evaluated. Two of these methods, the American Society for Testing and Materials skid number and an estimate based on a standard table found in the literature, were shown to give incorrect results when used for heavy, air-braked trucks. For some conditions, stops for which none of the vehicle's wheels locked were found to produce tire marks that were longer than those produced during a locked wheel stop. The tire marks generated during nonlocked wheel stops look like light shadowy (visible when viewed along their length but not from directly above) skid marks. Accident investigators must be careful when using light skid marks in the formulas to determine prebraking speed from skid mark length to ensure that the skid marks were made by locked wheels. Otherwise, too high an estimate of the vehicle's prebraking speed may be obtained.

Skid marks have an important role in the National Highway Traffic Safety Administration's (NHTSA) effort to increase vehicular safety on our nation's roads. The study of skid marks left on pavement after an accident has occurred helps experts in accident reconstruction determine the course of events that led to the accident and the precrash parameters of the vehicles involved. These, in turn, help NHTSA develop countermeasures to prevent accidents from occurring and to protect the occupants of vehicles involved in collisions.

Reconstructionists use the analysis of skid marks to help identify impact locations, vehicle trajectories, wheel lockup patterns, deceleration, and prebraking speed. The last three of these important quantities are calculated by means of relatively simple formulas based on a field investigator's report of the number and length of skid marks observed and the type and condition of the pavement on which the accident occurred.

The formulas used by accident reconstructionists are theoretical formulas and in their derivation a number of assumptions are made. If any of these assumptions are invalid, it could lead to errors between what actually occurred and the results of the accident reconstruction. Also, accident investigators frequently use standard tables (1,2) to estimate the coefficient of friction that was acting between a vehicle's tires and the road. These tables need to be checked for possible errors due to differing vehicle types, loading, tire types, and pavement composition.

The overall goal of this study was to increase knowledge of skid marks and to improve the accuracy of formulas and tables that involve them that are used in accident reconstruction. This was done by studying a large number of skid marks produced under controlled experimental conditions. Specifically, this study concentrated on (a) the repeatability of stops that produce skid marks, (b) the validity of the formulas and tables used to relate skid mark length to prebraking speed, (c) the best method of determining the coefficient of friction between the tire and the road for use in skid mark analysis, and