Recommendations for an International Minimum Skid-Resistance Standard for Pavements

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The need for minimum international skid-resistance requirements on roads and highways is apparent from accident statictics in several countries. The interpretation and implementation of any such standards, however, are made difficult by the many variables present with existing test procedures. These include test tire parameters, environmental factors, and particularly the mode of testing (locked-wheel, stopping-distance, deceleration-sensing, brake and side-slip).

It is recommended that a meaningful international minimum standard should specify minimum coefficients of friction irrespective of test method and at two distinct speeds, perhaps 50 and 90 km/hr. Previous work has suggested that the coefficient be specified at two distinct speeds, since pavements which perform similarly at one test speed may have totally divergent coefficients at other speeds. Specifying that these minima are irrespective of test method is an essential criterion for eliminating variations, and is of course a more practical approach since a skid may occur under any condition of braking or cornering. It is believed that this objective can be met with the use of correlation plots between different test modes, such as those already established in Sweden and the Netherlands. Future test programs can serve to establish a comprehensive listing of correlation factors for the successful implementation of any international standard.

•AN inverse relationship between skid resistance on wet roads and accident rates from British statistics (1) illustrates the importance and need for the maintenance of high skid-resistance values. Dutch figures (2) suggest that about 1 percent of all road accidents involve death and 14 percent serious injury, while again British results (3) indicate that the number of accidents involving skidding on wet roads is about 30 percent of all accidents occurring in wet weather. There is therefore both a need to improve the friction potential of highways in general and to establish minimum acceptable skid-resistance values.

The mechanics of the onset of skidding on wet surfaces is now broadly understood (4, 5, 6) and it is possible to select the features of surface texture so that skid hazards are minimized or even eliminated on certain pavement sections (7). The measurement of effective traction, however, presents many problems which have been hitherto unresolved. These problems arise from differences in the mode of testing (whether locked-wheel, stopping distance method, brake or side-slip), the test tire used (size, type, pattern), the design of tester selected, test speed and other environmental factors. Indeed, while there may be a consensus that a certain pavement section is excessively slippy, the exact value of its "slipperiness" as suggested by its measured coefficient of friction is unknown. The high accident rates on wet road surfaces recorded in the above statistical data point to the need for establishing universal minimum standards of acceptable slipperiness, but the anticipation of what these standards might mean and their subsequent interpretation presents difficulties because of the variability in measurement techniques. It has already been established (7) that either two sufficiently different test speeds must be selected for road surfaces, or alternatively one test together with a measurement of skid-resistance/speed gradient.

EXISTING INTERNATIONAL MINIMUM STANDARDS

Figure 1 shows existing international minimum coefficients of friction plotted against test speeds (8, 9, 10). The locked-wheel, stopping-distance and brake slip modes of testing are included for patterned test tires and the side-slip mode for smooth tires. The most significant standards are those suggested by the Permanent International Association of Road Congresses, who recommended a coefficient of friction of 0.45 at 45 km/hr (later 0.40 at 50 km/hr) measured using any test mode.

For historical and other reasons, different countries have been prone to select one basic method of measurement in preference to others. Thus, the British (8) insist on measuring sideforce using a smooth tire with slip angle, and the Swedes (8) measure almost exclusively with a braked wheel and 15 to 17 percent brake slip using a patterned tire. Perhaps the method of locked-wheel braking is the most popular overall method, but in the United States (8) stopping-distance and deceleration-sensing techniques are widely used although almost unknown in Europe. Despite these differences, the minimum coefficients as plotted versus test speed indicate broadly what is and what is not acceptable.

In attempting to reduce the obvious discrepancies which must arise from using different methods of measurement, the Swedes give the following relationships between locked-wheel and brake slip coefficients (8):

$$\text{Concrete Roads:} \quad f_{LW} = 0.7\, f_{BS,\,17\%} - 0.048 \tag{1}$$

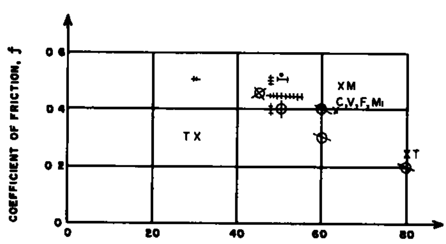
$$\text{Asphalt Roads:} \quad f_{LW} = 0.686\, f_{BS,\,17\%} + 0.016 \tag{2}$$

while the Netherlands State Road Laboratory (8) reports that using patterned tires:

$$f_{BS} = 1.35\, f_{LW} \quad \text{at 20 km/hr} \tag{3}$$

and

$$f_{BS} = 1.15\, f_{LW} \quad \text{at 50 km/hr} \tag{4}$$



SYMBOL	TEST MODE	ORIGIN OF STANDARD	GENERAL NOTATION
⊠	ANY	9TH INTERNATIONAL ROAD CONGRESS	C = CALIFORNIA, (P)LW V = VIRGINIA, (P)SD
⌖	ANY	10TH INTERNATIONAL ROAD CONGRESS	Mi = MISSISSIPPI, (P)SD F = FLORIDA, (P)SD
•	(P)BS	DUTCH STATE ROAD LABORATORY	M = MICHIGAN, (P)LW T = TEXAS, (P)LW
⊘	(P)LW	GERMAN	
Ø	(P)LW	PROPOSED GERMAN	(P)LW = PATTERNED TIRES LOCKED WHEELS
++	ANY	FRENCH	
⊢⊣	(P)LW	ITALIAN	
+++++	(S)s	BELGIAN	(P)SD = PATTERNED TIRES STOPPING DISTANCE
⫧	(S)s	BRITISH MINIMUM (STRAIGHT ROADS)	
ǂ	(S)s	BRITISH MINIMUM (GENERAL)	(P)BS = PATTERNED TIRES BRAKE SLIP
X	(P)LW or (P)SD	AMERICAN	(S)s = SMOOTH TIRES SIDE-SLIP

Figure 1. Existing international minimum coefficients of friction.

These attempted correlations are most useful in establishing minimum international skid-resistance standards.

RECOMMENDATIONS FOR INTERNATIONAL MINIMUM SKID-RESISTANCE STANDARD

It is a well-known fact that the coefficient of sliding friction on a wet road surface decreases with increase of speed in a manner which depends almost exclusively on the size of surface texture. Thus, two pavements (one fine and one coarse) may have the same coefficient of sliding friction at 50 km/hr under wet conditions—but the values at 80 km/hr will be entirely different. The measurement of friction at one speed value is therefore inadequate to characterize pavement performance. It is therefore recommended that a meaningful international minimum standard should specify the minimum coefficient irrespective of test method at two distinct speeds (perhaps 50 and 90 km/hr).

Specifying that these minima are irrespective of the method of measurement is an essential condition for eliminating variations, and of course is a more practical approach since a skid may occur under any condition of braking or cornering. Before this can be accomplished, it will be necessary to specify equations of the type of Eqs. 1 through 4 showing relationships between frictional coefficients obtained for a variety of speeds, road surfaces, and including all modes of testing. Of course, much work remains to be done to propose a universal set of correlation plots, but once completed the establishment of an international standard is a relatively easy matter.

Given an absolute minimum coefficient as criterion at a particular speed, information obtained from these correlation plots will tell which method of testing should yield the minimum coefficient for any type of surface at a particular speed. Assuming that another mode of measurement is used for routine testing, an increment can then be added to the absolute minimum coefficient acceptable at the particular test speed to establish the minimum corresponding to the mode of measurement used. For example, if it is known that locked-wheel testing is the mode of measurement which gives the lowest coefficient on a particular type of surface at 50 km/hr, and if the minimum value prescribed by international standards is 0.4 at this speed, then a highway department which uses 17 percent brake slip should add an increment (perhaps 0.05, this being known from the correlation plots suggested above) to this minimum value. The minimum value which the highway department would recognize when measured with their 17 percent brake slip tester, would then be 0.45.

DISCUSSION AND CONCLUSIONS

The reduction of all existing international standards to one mode of testing based on correlation equations as described above would provide a much more precise set of data than that presented in the Figure 1, and it is certain that the agreement in minimum values for skid resistance would be closer. The reduction procedure would ultimately apply to the nature of road surfaces (asphaltic or concrete) and type of test tire, but in terms of speed dependence at least two distinct test speeds should be preserved. An alternative to this procedure is to specify one speed of testing combined with a prediction of skid-resistance gradient from pavement geometry (11).

The Permanent International Association of Road Congresses has already specified the value of 0.4 at 50 km/hr as the absolute minimum acceptable coefficient of friction obtained with any test mode. The specification of another minimum value at a higher test speed (perhaps 80 or 90 km/hr) would provide an acceptable international standard, and it is hoped that this will be accomplished in the near future. A recent survey of skid-resistance requirements for main rural highways in the United States (12) has suggested somewhat different minimum values of skid-resistance than those proposed by the Permanent International Association of Road Congresses, and the authors have attempted to reduce their recommended values to one speed of testing. While this contribution is worthwhile, it is suggested that the existing international standard of 0.4 at 50 km/hr be adhered to until further refinements are introduced, and in the meantime it can, of course, be extended to include a higher test speed. Further work should therefore concentrate on the development of correlation equations of the type of Eqs. 1 through 4 in this paper, so that the new international skid-resistance standard can be interpreted in terms of local testing modes.

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