PROBLEMS ASSOCIATED WITH ANTI-SKID PROGRAM MANAGEMENT

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•ALTHOUGH the federal government requires states to maintain an anti-skid program, the success of this program depends on the actions of the state and local governments charged with administering the program. Successful management of such a program ultimately depends on the dedication of those people who are responsible for ensuring highway safety.

The 1969 motor vehicle accident statistics released by the National Safety Council (1) may encourage such dedication. In 1969 motor vehicle accidents accounted for 56,400 deaths, 2,000,000 injuries that disabled the victims beyond the day of the accident, and costs totaling $12.2 billion. Figures for the decade are 475,000 deaths, 17,200,000 injuries, and $89.6 billion. It cannot be reasonably claimed that lack of adequate pavement skid resistance contributed significantly to all of the 15.5 million accidents reported in 1969. There is, however, some evidence that a disproportionate percentage of accidents, as related to exposure, occurred on wet pavement surfaces and that an even more disproportionate percentage occurred on snow- or ice-covered surfaces.

Large public works programs cannot be successfully undertaken in today's society without the support of the general public. Therefore, hard-core highway professionals and concerned public officials have a dual job. They must solicit and win the support of the public and then solve the problems discussed at this workshop.

Citizens must be informed of the need for the program and of the benefits they will receive from its successful completion. The average driver must be convinced that his investment of tax dollars in the program will pay dividends in the form of a reduction in the hazards of driving on wet pavements.

Even after adequate motivation both of the public and of those officials responsible for maintaining an anti-skid program has been developed, several questions must first be answered before the program can be undertaken. Two significant ones, not totally unrelated, are, What level of skid resistance is adequate to permit vehicles traveling on the pavement to perform the required maneuvers safely? and How shall the skid resistance of the surface be measured?

FRICTIONAL REQUIREMENTS

The adequacy of the skid resistance of any pavement surface can be measured by the maneuverability of a vehicle passing over that surface. Although this measurement can be calculated accurately on a theoretical basis, the actual value required in any finite instance will be influenced not only by the quality and condition of the surface but also by the quality and condition of the vehicle tires and, often to a large degree, by the behavior of the driver. One widely cited report (2) resulting from a study that gave at least limited consideration to these various requirements recommends that a skid number (defined as the friction coefficient of a tire sliding on a wet pavement times 100) of 37, as measured with a skid trailer in accordance with ASTM Designation E 274 at 40 mph, be considered as the minimum requirement for pavement friction on main rural highways. Although this recommendation has not yet been formally adopted on a national basis by any organization, it appears to reflect the thinking of a number of people or groups who are currently concerned with the measurement of skid resistance and

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who report informally that they consider skid numbers ranging from 35 to 40 as being adequate. The same report, however, suggests that on high-speed roadways where the mean traffic speed is likely to be on the order of 70 mph the skid number measured at 40 mph should be 46. This recommendation is based on the reduction that occurs in skid resistance between tires and a wet pavement surface as the vehicle speed increases. This may not be altogether in accord with the thinking of others (3) who have suggested that a lower skid resistance may be required on a high-speed roadway, where grade and alignment variations are limited and access is controlled, than on a roadway on which vehicle speeds are lower but where steeper grades, sharper curves, and lack of access control are likely to place greater demands on vehicle performance. Studies of actual driver behavior under differing circumstances are extremely limited, and it appears that much more work will be required in this area before a satisfactory rationale for skid resistance criteria can be established.

MEASUREMENT PROBLEMS

The problems associated with the measurement of skid resistance have received far greater attention than have those associated with establishing the desirable level of skid resistance. It is well known that skid resistance has been measured by one technique or another since before the turn of the century (4) and that concentrated studies of the problem and development of equipment have been in progress since the early 1960s (5, 6, 7). Although many techniques have been investigated, the practice of measuring pavement skid resistance using a type of locked-wheel sliding test has been overwhelmingly adopted in the United States. It is appreciated that this is the mode of operation least often experienced by a vehicle and, indeed, is the mode that should be avoided. The emergence of such methods as the predominant ones, however, has apparently been based on ease of performance, reduced required sophistication of test equipment, and a feeling that the locked-wheel mode, although not the normal or desired mode of operation, is in fact the mode existing from the time the vehicle loses traction (and becomes uncontrollable) to the time it regains it or comes to a stop.

The most widely used standardized method of test is that specified in ASTM Designation E 247 in which one or both wheels of a towed trailer may be locked and appropriate measurements can be made from the towing vehicle. Various organizations have built a considerable number of trailers that appear to be amenable to this test method. Two sizable skid correlation studies (8, 9) have been held in which a number of such trailers were involved in tests on surfaces having a wide range of skid resistance. These studies have generally achieved reasonable agreement of test results where the trailers are well-designed and well-built and operated by trained crews and when the test pavement surfaces are watered from an external source so that all trailers are operated under the same condition of pavement wetness. When external watering is discontinued, however, each trailer provides its own wetting of the test surface, and results are extremely variable. Some trailers occasionally measure skid numbers twice as great as those measured by other trailers on the same surface and within a time interval of a few minutes. There is some evidence that, even when the same quantity of water per unit distance traveled is supplied, variation in nozzle design, nozzle location, and even aerodynamic effects of the towing vehicle may have a significant effect on the thickness of the water film actually deposited in front of the test tire and, therefore, on the test results. In establishing an anti-skid program, or programs, it will be imperative that standards be established for the application of water to the pavement surface during testing and that methods be developed for evaluating compliance with such standards. It appears that a great deal of work remains to be done in this area.

Another decision that must be made in establishing an anti-skid program is where, when, and how often measurements shall be made. For a full program, this is likely to involve three separate phases of the problem.

One phase is the conduct of skid resistance measurements at locations where an abnormally high number of accidents occur or at sites that are reported by the public, or particularly by police officers, as being slippery. These measurements make it possible to determine whether inadequate skid resistance is a contributory factor to the accident rate. This is an entirely rational approach and should result in the identification

of surfaces that are clearly inadequate and need remedial treatment. It does not, however, provide information on which long-range planning for major rehabilitation may be based.

An inventory of pavement skid resistance will be required to provide the necessary basis for such planning. This implies that every pavement surface within the system covered by the program should be tested periodically to determine the rate of development of slipperiness and to estimate when remedial treatment would be required. Such a program requires definition of the words "every surface" and "periodically" because both the adequacy of the data collected and the magnitude of the effort required will depend on these definitions. At one extreme, it has been suggested that every highway should be tested at intervals of 1 mile or less and that the tests should be repeated annually. At the other extreme, it has been suggested that one series of tests should be made within the limits of each construction project within the highway system involved and that the entire system within a state should be tested over a 3-year period. Again, there has not been broad agreement as to what will constitute an adequate survey, and there has not been sufficient effort to achieve one. Such decisions must, however, be made before an adequate anti-skid program can be started.

A final phase of a full anti-skid program is acceptance testing of new construction or of remedial treatments applied to pavements determined to be slippery. In the past some pavements have been constructed or resurfaced that were inadequate in skid resistance upon completion. If an anti-skid program is to be successful, such occurrences must be avoided in the future.

REMEDIAL MEASURES

After the decisions have been made as to what constitutes an adequate level of skid resistance and how, when, and where it shall be measured, there remains the problem of achieving and retaining the selected level. The present state of knowledge in this field suggests that the highway engineer, whether he is concerned with initial construction or restorative treatments, can approach the problem in two ways: choice of aggregate and choice of pavement surface texture.

Numerous studies have shown that, other parameters being the same, the type of aggregate exposed in the pavement surface plays an important role—sometimes a predominant role—in the achieved skid resistance (7, 10). These studies have been sufficiently extensive so that in many parts of the country the relative contribution of all readily available aggregates to skid resistance may be known. Where this is not the case, laboratory devices have been developed (11, 12) that permit rapid evaluation of the relative skid resistance of potential aggregates when used in paving mixes. Laboratory evaluation can facilitate decision-making and does not involve expensive and time-consuming field experimentation.

Some areas have an abundance of aggregate that is relatively polish resistant and suitable for construction of pavement surfaces having high skid resistance. In other areas, supplies of such aggregates are limited, are therefore generally more expensive, and must be used selectively. Where such aggregates are nonexistent, attention should be given to the possible use of materials that have not in the past been widely used as general paving aggregates. Some of these materials, particularly some of the expanded aggregates (13), have shown considerable promise of producing satisfactory skid-resistant pavements. Some highway departments that have experimented with materials of this nature have experienced difficulties in arriving at equitable units for payment (due to the low specific gravity of the aggregates) and in specifying proprietary materials. However, solutions to problems such as those may be more readily achieved than solution to the larger problem of providing adequate pavement skid resistance.

Texture of the pavement surface also plays a significant role in pavement slipperiness although it has had less extensive investigation than aggregate (14). Probably the ultimate solution to wet-pavement friction is to allow as little water between the tire and the pavement as is possible. This can readily be demonstrated by comparing skidding performances of vehicles equipped with smooth tires to those equipped with tires having a deep tread (stopping distances at 40 mph may be more than 100 ft longer for

the car equipped with smooth tires). The primary reason for the use of deep-tread designs in tire manufacture is that the grooves in the tread provide an escape route for water. It is generally appreciated that a similar function can be performed by the texturing of the pavement surface, i.e., the provision of escape routes to facilitate removal of water at the tire-pavement interface. The highway engineer may influence the texture of either a new pavement construction or a remedial surface treatment by his choice of aggregate gradation, mix design, and finishing treatment in order to affect beneficially the skid resistance of the resulting surface.

The engineer may also give consideration to the possibility of achieving the desired improvement through altering the existing surface texture rather than by replacing the surface. Of the techniques, such as etching, chipping, and grooving, that have been attempted to date, only grooving has been shown to produce reasonably lasting effects. In a number of cases, the grooving of hazardous sections has been followed by a significant reduction in accident occurrence (15). The reason for this improved performance may not be fully understood because in some cases the grooving operation has not resulted in an equivalent increase in measured skid resistance.

The engineer should always be aware that actions taken to improve the skid resistance of a surface over a short distance, as in spot improvement programs or other forms of maintenance, may create worse hazards than those they were intended to correct. For example, a remedial treatment applied to a curve should be continued at least sufficiently far past the point of tangency of the curve to ensure that a vehicle rounding the curve on something other than the true uniform radius of its lane will have completed its cornering maneuver before it leaves the treated area. If not, the driver may experience a situation where he has a suddenly decreased tractive capacity just as he is making his greatest demand on his vehicle for tractive performance. Similarly, when long patches are applied to a pavement surface, they should be extended over the full width of that surface. It is quite common in many areas to find patches several hundred feet in length that extend over only one-third to one-half of the pavement width, or similar patches covering only one lane of two adjacent traffic lanes. Under such circumstances the driver may be expected, and indeed may be required, to drive with two wheels of the vehicle on the patch and two on the previously existing surface. If under these conditions the surface is wet and the driver either brakes or accelerates heavily, loss of control is almost certain to occur. In any full anti-skid program, policies should be developed and enforced to eliminate the construction of such hazardous situations.

The highway engineer must also consider the effect of geometric design on traction requirements. The provision of adequate pavement surface drainage will minimize the accumulation of water and, hence, improve the skid resistance performance of any surface. In new construction, provision for minimum grades and maximum radius of curvature will decrease the tractive requirements of the motorist. Although it is more expensive than remedial surface treatment, improvement of pavement geometry should be considered at sites where accidents occur frequently.

PERIPHERAL CONCERNS

To this point, the discussion has dealt with aspects of an anti-skid program that may reasonably be considered to be within the control of the highway engineer or administrator. There are a number of peripheral areas over which he does not have control but in which he should have a keen interest and should exercise some influence in their mangement. The most obvious of these has to do with tires.

A single body does not really have a coefficient of friction. It is only when two bodies move in contact with each other that friction is developed. Thus, when we speak of the coefficient of friction (or the skid number) of a pavement surface, we are in fact speaking of the frictional resistance between that surface and something that is moving against it—normally a tire. A change in the properties or condition of either of the bodies can, and usually will, significantly change the coefficient of friction between them.

The automobile tire might be considered to be one of man's great compromises. What does a vehicle owner want when he purchases a tire? It is probably safe to say

that as a minimum he would like the tires he purchases to be (a) so durable that they will last for the lifetime of his vehicle, (b) so skid resistant that they will stop the vehicle on a dime, (c) so "soft" that they will prevent him from feeling any irregularities in the roadway over which he is traveling, and (d) so cheap that the manufacturer will give them to him. Although the latter objective will never be attained, the tire manufacturer can go a reasonably long way toward meeting any of the other three objectives but only at the expense of the remaining objectives. The possibility exists, therefore, that, as more progress is made in improving those characteristics of the pavement that contribute to adequate skid resistance, the tire manufacturer may become less concerned about that aspect of tire performance and concentrate on improving his product with respect to life, ride, or some other desirable quality. Such an occurrence would place the highway engineer in the position of "running to stand still." There are channels through which the highway engineer can make his concerns known to the tire industry and can keep informed concerning trends within that industry. For example, the American Society for Testing and Materials is currently establishing a committee on tires that will be concerned with many aspects of tire performance. The steering committee that has been making the necessary arrangements to establish this committee is well aware of the desirability of participation in the committee's activities by those having highway-oriented interests. It will be most unfortunate if the voice of the highway engineer is not heard in these councils, and it will be his own fault.

With respect to tires, it is not sufficient to ensure that the tire originally placed on a vehicle contributes its fair share to skid resistance. As tires are worn and tread depth is reduced, skid resistance effectiveness is also reduced. One recent study (16) has shown that an inordinately large percentage of vehicles involved in wet pavement accidents had badly worn tires on the rear wheels. If the highway engineer is to be charged, at least morally, with preventing or reducing accidents caused by inadequate skid resistance, he has a reasonable and real interest in the formulation of regulations that specify the wear level at which tires must be replaced, the establishment and operation of inspection procedures to evaluate compliance, and the enforcement of compliance. Some initial steps are slowly being taken in this direction, but much more action is required.

Brief mention was made earlier of the need for a public information program. Perhaps such a program is needed not only to generate public support for an anti-skid program but also to effect beneficial changes in driver behavior. For the past several years I have met, through the National Safety Council, a number of driver educators—some of whom have been actively engaged in this field for a number of years—who are not familiar with such fundamental traction phenomena as the fact that a vehicle sliding with its brakes locked cannot be steered. Some of them have only the grossest appreciation that a wet pavement has less skid resistance than a dry one and no feeling at all for the magnitude of the difference. If this is indicative of the state of knowledge among even a significant part of those whose business it is to understand and to teach the relationship between driver action and vehicle performance, it may be assumed that a vast portion of the driving public has little appreciation of what they ask of the roadway surface and the tires when they perform certain maneuvers and equally little understanding of what they are likely to get. Perhaps it is not too much to hope that in this era of mass communication appropriate informational and educational programs may be able to bring the average driver to such an appreciation and understanding. Such an accomplishment would surely reduce the problem of both the highway engineer and the tire manufacturer.

There is one final topic, perhaps not directly associated with anti-skid program management, with which those contemplating the institution of such a program should be concerned. In a number of states, civil actions for damages in one form or another have been brought against state highway departments by individuals injured in motor vehicle accidents in which some part or all of the allegation has to do with inadequate skid resistance. During recent years, elements of government have increasingly lost their immunity to suit, and it seems almost certain that in the near future it will be generally accepted that a citizen has the right to seek in the courts redress for losses allegedly incurred because of some improper action or inaction on the part of government.

A few suits of the type suggested have already been won by plaintiffs. One of the major problems faced by the plaintiff in such an action is the proof of what should be considered adequate skid resistance. Once adequate minimal skid numbers have been defined by state or other agencies, this burden will be removed from the plaintiff. He will then only have to allege and seek to prove that the skid number on the pavement involved in his accident was below the specified minimum at the time of his accident. The agency defending the suit will have to prove that the skid number of the pavement involved was indeed above that specified or that appropriate actions designed to remedy the inadequacy were being undertaken as expeditiously as possible. In view of the large number of accidents occurring annually, the increasing propensity of those involved to institute litigation, and the apparently increasing view of jurors that the injured should be in some way compensated, the potential for such actions against the state is staggering. Those engaged in the management of an anti-skid program should be aware of this potential and should begin plans at an early stage in the program for defense procedures to be used when such litigation occurs.

SUMMARY

The highway engineer or administrator has to involve himself in the following processes in establishing and managing an anti-skid program.

He must first determine that the problem is a real one that involves loss of life on the highway. He then must commit himself to the program, fully realizing that some of his actions will be economically or politically unpopular. He must sell this dedication to the public so that they will support the program, and in doing so he should attempt to educate the public.

He must determine the level of skid resistance that should be maintained on various elements of the highway system under his jurisdiction. He must decide, preferably in concert with other engineers and administrators from other communities, how the desirable or existing values of skid resistance shall be measured and evaluated. After having agreed on a technique for measurement, he must decide on a measurement program that will involve evaluation of specific locations at which there is other evidence of inadequate skid resistance, reconnaissance of considerable mileage of pavements to determine existing values of skid resistance and trends in performance that will permit scheduling of anticipated remedial treatments, and acceptance of newly constructed surfaces or remedial treatments to existing surfaces.

For each surface found to be inadequate he must choose the treatment to be applied: treatments that may be applied to the existing surface, application of a new surface, or major reconstruction involving improvements in geometric design. He must also be concerned with new construction to see that the geometric design is such as to place the least reasonable demand for skid resistance on the surface and that the materials selected and techniques employed in construction are such as to provide adequate and durable skid resistance. He must exercise care that in applying remedial treatments to eliminate an existing hazard he does not create a new one.

Finally, he should maintain an interest and awareness in those areas that are not under his immediate jurisdiction, particularly the areas of tire design and construction and driver education, and that may have an important influence on the demands placed on the roadway surface. He should exercise such influence as he can in these areas in order that the problems that he faces in his anti-skid program may be minimized.

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