CORRECTIVE PROGRAMS FOR IMPROVING SKID RESISTANCE

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•THE major elements of a successful corrective program for improving skid resistance are (a) a responsible attitude toward providing skid-resistance roads, (b) a knowledge of the level of friction needed, (c) a reliable friction-measuring method, and (d) technical knowledge of the materials and methods used in providing corrective action.

RESPONSIBLE ATTITUDE

What is a responsible attitude toward providing skid-resistant roads? First, we must be convinced that slippery roads do in fact cause accidents. Frequently, we blame drivers for accidents that have been caused primarily by slick roads. If we cannot admit that roads are sometimes at fault, further research is futile.

Second, we must believe that the attempt to build high-skid-resistance roads is a good investment. Because it is our business to know about the dangers of driving on wet roads, we tend to minimize the hazards presented by such a driving situation. For example, we know that if we drive on wet pavements on well-worn tire treads, extreme caution should be exercized. To what extent is the public aware of this danger? To what extent do good tires lessen the danger?

Third, we must realize that certain materials tend to become slippery. Such materials must be used either cautiously or not at all in the construction of roads. This is not an impractical suggestion. For example, aggregates that should not be used in the surface courses of high-volume high-speed roads might be used in blends or alone on low-volume low-speed roads.

There are, of course, other items that help form what we call "responsible attitude," but suffice it to say that without the proper attitude our knowledge is of little value in developing a sound anti-skid program.

FRICTION NEEDS

Although agencies that have been working in the anti-skid field for some time are in general agreement that a skid number of 40 represents a road that is on the borderline of becoming slippery, frictional needs vary with different roads and under different circumstances. A list of the specific requirements of the various states has been prepared and indicates that some states do not have specific requirements for skid resistance but only adhere to certain guidelines (1).

At present the Franklin Institute is conducting a study to determine pavement friction coefficients required for the driving tasks. The specific objectives of this project are (a) to develop an approach for determining driver behavior under normal driving conditions and emergency or panic situations; (b) to conduct driver behavior studies and develop a procedure for determining frictional needs of traffic for any given condition or situation; and (c) to use the developed procedure to recommend minimum service values of skid resistance for general classes of highways and traffic conditions. Not only will the Franklin Institute give us recommended minimum service values for skid resistance of general classes of highways and traffic conditions, but it will also develop an approach that can be used by the individual states to determine what level of friction is needed on specific highways at specific locations. The project is scheduled to be completed in early 1972. This work is greatly needed and will be a giant step forward in the provision of skid-resistant roads.

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RELIABLE FRICTION-MEASURING METHOD

We are all familiar to some degree with friction-measuring methods such as the ASTM skid trailer, the stopping-distance, and the decelerometer. We need to improve those measuring tools and to increase our understanding of their output. At Pennsylvania State University, a study is in progress on locked-wheel pavement skid tester correlation and calibration techniques. The objective of this program is:

> . . . the development and verification of methods for improving the ability to measure the skid properties of pavement surfaces with skid testers constructed in general conformance with ASTM Method E 274-69. The research should be directed toward determining the reasons for the differences between results obtained with testers of essentially the same design and the resolution of these differences. Consideration should be given to such test and equipment variables as methods of wetting the test tire path, tester dynamics, and the lateral positions of the test tire path.

Individual agencies could make a worthwhile contribution if they researched the effects of water depth, temperature, and seasons on the friction values produced by the various test devices.

CORRECTIVE ACTION

There are six items that will be discussed in this section: superelevation, special spot improvement, resurfacing, pavement grooving, elimination of sharp curves, and "other" techniques.

Superelevation

In Virginia, the highway department alerts the Research Council when a location experiences skid accidents. These locations are checked with a skid-test trailer and are recommended for resurfacing if the skid number is 40 or below. On occasions we find that the skid numbers are rather high, but we suspect that some other condition, such as insufficient superelevation in a curve, contributes to skid accidents.

The AASHO curve design policy is based on the assumption that the curve is on level grade; that is, there is no vertical curve involved with a horizontal curve. At several locations where skidding accidents have occurred, the road had a skid number of more than 40 and the superelevation conformed to the AASHO design policy; however, these locations were on a right horizontal curve on a negative vertical grade. The grade was such that the elevation of the left front wheel was lower than that of the right rear wheel. Thus, a certain type of reverse superelevation resulted. This problem will be discussed in further detail later in the paper.

Special Spot Improvement

A good example of a special spot improvement occurred just recently. A plant mix that was placed during late summer became overly dense in spots, particularly in the wheelpaths of both the positive and negative grades on a hill. The weather was too cold to permit the resurfacing of these areas, and it did not seem to be the type of condition that could be corrected by a normal heater planing operation. A gang of teeth was dragged along the pavement under a heater planer, just in back of the flame. The results were excellent. The surface now resembles that of a grooved pavement, and it is felt that this location has certainly been made safe for the winter months.

Resurfacing

Historically, most of the roads that have been found to be slippery in Virginia have been made from polish-susceptible aggregates. For some time a policy has existed in Virginia that prohibits the use of mixes made of 100 percent polish-susceptible aggregates in the surface course of high traffic roads. The Virginia aggregates that have been found to be susceptible to polishing are limestones and dolomites, which are common throughout the valley area of the state. This area stretches from Winchester to

Bristol, a distance of 320 miles. The belt varies in width from 10 to 50 miles; however, it affects a belt of over 100 miles because quarry operators would much rather process the limestone than the harder, more skid-resistant aggregates. Consequently, 100 percent skid-resistant aggregates originally had to be imported into this area for the resurfacing of most primary highways.

However, to try to make use of local materials, the Council established a research project in which imported polish-resistant material was blended with the local polish-susceptible materials. The experiments confirmed the belief that a blend of these materials would provide a skid-resistant road if the coarse portion of the blend was composed of polish-resistant aggregates.

The blending of aggregates in the maintenance resurfacing program has met with great success and has been used extensively. For some time the polish-resistant aggregates used in the blends were natural materials, such as granites and sandstone, and most of them were imported from other parts of the state. More recently, lightweight aggregates have been used in the blends. The lightweight aggregates are expanded shales and are produced in several parts of the limestone area.

Three or four years ago the Council started experimenting with the sprinkle system. This is a technique in which highly skid-resistant aggregates are precoated with an asphaltic material and then sprinkled immediately behind the paver. Problems in setting up the machinery for this technique were anticipated, but a dump truck equipped with a chemical spreader was backed up to the paver without causing damage. In the sprinkle system, 100 percent limestone is used in the hot plant mix and some 3 to 5 lb/yd^2 of the skid-resistant aggregate is sprinkled on top of it. The skid-resistant aggregates that have been used are both natural and lightweight. This method also has met with great success.

For many years a thin sand overlay has been used to deslick pavements in Virginia (2). Many other states use thin sand overlays and all seem to have encountered one problem: Occasionally on high-speed roads with heavy traffic volumes, the mix undergoes scaling. It is believed that scaling is a result of stripping caused by hydrodynamic pressures.

Another type of resurfacing that seems to hold great promise is an open type of mix. Engineers in Texas have been working in this field for several years; and it would seem that, if strength and durability could be incorporated into this type of mix, it would contribute greatly to the building of skid-resistant pavement because of its excellent water draining properties.

Another resurfacing technique is the application type of surface treatment. This technique has been used very little for deslicking pavements in Virginia because high traffic volume roads are Virginia's greatest problem with skidding accidents. Also, Virginia has not been able to develop surface treatments on high traffic volume roads to the point where they are durable enough to be economical.

Pavement Grooving

In areas where wet-weather accidents have become prevalent, many state highway departments have been grooving their pavements in an effort to increase skid resistance and thus reduce accidents. Where accident data are available, it can be shown that the numbers of accidents have been reduced by 30 to 60 percent.

Pavement grooving is the process of making shallow cuts of a uniform depth, width, and shape in the surface of a pavement. Grooving differs from texturing in that the latter is a process of lightly sawing or scouring a pavement to expose a new surface. The terminology associated with pavement grooving includes the terms pitch, width, and depth. The pitch is the distance between the grooves, the width is the groove opening, and the depth is measured from the pavement surface to the bottom of the groove. Pavement grooving is usually accomplished by automated equipment that uses diamond-studded blades gang-mounted on a single shaft and that cuts a path about 2 ft wide. The machines are capable of grooving at a rate of 5 to 30 ft/min depending on the hardness of the pavement aggregate and the number and size of grooves.

Pavements can be grooved either transversely or longitudinally, but more often they are grooved longitudinally. Grooves placed longitudinally with the roadway have proved to be the most effective in increasing the directional control of a vehicle. The automobile tires apparently penetrate into the grooves and form a mechanical interlock that helps hold the vehicle in alignment with the roadway. Where heavy films of water are encountered, the grooves tend to channel the excess water away and thus reduce or eliminate the potential for hydroplaning.

The grooving process is practical on roadway surfaces where the skid resistance is slightly below an acceptable level; it is not generally satisfactory for very slippery pavements. Pavement grooving may be beneficial in several typical situations: in areas where the geometric alignment of the roadway contributes to a rash of wet-weather accidents; in areas where heavy rainfall causes excessive water depths; on pavement locations frequently subjected to strong crosswind currents; and at locations such as sharp exit ramps where there is a quick transition from high speed to a sharply reduced speed coupled with turning.

Although agencies have reported that pavement grooving reduces accidents, the same agencies report that skid resistance may not be significantly changed. This is probably because most skid trailers measure only the braking coefficient of friction and do not indicate side slip or cornering traction. Tests conducted at Wallops Island by the National Aeronautics and Space Administration indicated that, although longitudinal grooving increased the braking coefficient of friction by only a small amount, the cornering traction around a 500-ft radius curve was 3 to 4 times more than that obtained on an ungrooved pavement.

Several factors affect the performance and durability of the grooving. The groove spacing is important; the closer the grooves are, the more apt the pavement surface is to spall. There seems to be no problem, however, when the grooves are spaced on $^3/_4$-in. centers. If an aggregate is soft, the grooves will not stand up under the effect of heavy traffic, particularly under chains and studded tires. Although grooving has been associated chiefly with concrete pavements, it is entirely possible to groove bituminous surfaces providing they are old pavements with a high aggregate content. Soft aggregates in both bituminous or portland cement concrete surfaces may contribute to a limited effective service life of only 6 months under moderate to heavy traffic.

Frequently, concern has been expressed over the effect of water freezing in these pavement grooves, but both laboratory and field observations indicate that this condition does not produce spalled concrete in the shallow grooves. Also, traffic has a natural tendency to keep the grooves clean. Some complaints have been encountered regarding the effect of grooving on vehicle steering, but this problem does not appear to exist when the grooves are kept in perfect alignment. A more severe problem associated with pavement grooving is the resulting slurry, which may run across an adjacent pavement lane, or the resulting dust when the slurry dries. These hazards can be eliminated by specifying a slurry pickup device on the cutter, which pumps all debris to the shoulder area.

Pavement grooving has apparently been accomplished in a good many states with notable success. It can be expected that average costs for this service will run between \$0.95 to \$1.30/yd^3 depending on the area and the availability of contractors. Several specialists are available for this service, and some local contractors can also perform this work. The grooved pavement should perform satisfactorily for several years before retreatment is required.

Elimination of Sharp Curves

It is common knowledge that hills, curves, and heavy volumes of traffic contribute to high accident rates. These specific troublesome areas are generally pinpointed from an analysis of traffic data accumulated by accident review teams, traffic analysts, or state police. In many instances, it is perfectly obvious that a sharp curve is a problem area, and analysis is not necessary.

The Interstate and primary highway systems constructed in recent years are generally free from such deficiencies because of design criteria. However, older and secondary road systems present a problem. The highway designer can contribute much to the solution of this problem by providing a highway of uniform design; that is, a driver experiencing uniformly moderate curves should not be expected to negotiate a suddenly encountered sharp curve without trouble. The radius of curvature should not suddenly change within a curve, particularly on a superelevation.

Some curvature problems can be corrected by local anti-skid treatments; but if the problem is severe, realignment may be the only solution. If the area is hazardous, realignment should definitely be programmed. There is no way to evaluate the potential cost of such an undertaking on a large scale because many factors would have to be considered and each location would have to be evaluated separately for the type and extent of redesign and reconstruction required.

Other Techniques for Providing Skid Resistance

Several agencies have reported limited success with the use of chemical compounds that etch the pavement surface. These are generally concentrated solutions of hydrochloric or hydrofluoric acids that are diluted with water in the field and applied to the pavement surface with simple spray equipment. After a period of initial reaction, the solution is washed from the roadway surface. No pretreatment of the pavement such as washing or brushing is required. As a result of the chemical reaction, the pavement surface takes on a sandpaper texture and is cleansed of oil deposits and other dirt. The cost is relatively low, approximately 4 to 5 cents/yd^2 for materials alone. The results are not very durable, however, and an improvement in skid resistance is generally limited to a 6-month period; therefore, the treatment has to be applied once or twice yearly.

The use of this material can be dangerous. The concentrated acid is very strong, and even outdoors it must be handled with extreme caution. Heavy, protective clothing must be worn by the workmen, and masks must be worn to prevent the inhalation of dangerous fumes. This process should be undertaken only with extreme caution.

Other materials used in the restoration of pavement surfaces are synthetic aggregates and undeveloped highly skid-resistant natural aggregates. Some research has been conducted on the use of synthetic aggregates, and the resultant skid resistance has been good. However, these synthetic materials are usually made from high silica raw materials and this material, when encountered in natural aggregates, also produces good skid resistance. Therefore, it appears that equally good skid resistance can be attained from both high silica, synthetic aggregates and natural aggregates. At present, the cost of the synthetic aggregates is quite high. Highway departments should be urged to encourage the development of untapped aggregate sources that have potentially good skid-resistance properties. These sources have not been developed, in many instances, because of the necessary costs in opening a source and in crushing and processing a harder than average material. As our natural aggregate supply dwindles, we must encourage the development and production of new sources and generally expect that the costs are going to be somewhat higher than previously encountered. The improvement will be well worth the cost.

REFERENCES

1. An Inventory of Existing Practices and Solutions to Slippery Pavements—1969. Highway Research Circular 106.
2. Britton, W. S. G., and Dillard, J. H. Use of Thin Sand Overlays in Virginia. Highway Research News, No. 4, 1963, pp. 42-48.