ENGINEERING AND ADMINISTRATIVE CONSIDERATIONS IN CONSTRUCTING, MAINTAINING, AND TESTING SKID-RESISTANT PAVEMENTS

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Certain legal considerations, safety obligations, engineering concerns, and administrative problems are identified that must be addressed by the engineer-administrator in relation to constructing and maintaining pavements with adequate skid resistance properties and testing those skid properties. The monetary effect of claims against the state resulting from skidding accidents is of concern. This problem is further complicated by the fact that some Florida courts have recently abolished the concept of contributory negligence and replaced it with the doctrine of comparative negligence, which has complicated the state's responsibilities. The safety obligations of any state highway department include identifying high accident sites, improving maintenance, and providing a clear roadside policy. The engineer-administrator, in considering skid resistance, must be concerned with (a) testing for skid resistance, (b) various design and construction problems involved in providing a skid-resistant pavement, and (c) inability to attain or maintain skid resistance levels that are being advanced as recommended minimums in various publications. The engineer-administrator must also be concerned with the shortage of materials and the increased cost of importation, particularly in light of the energy crisis, and be aware of possible reductions in the frictional needs of traffic.

•CARLSON (1) has discussed the increasing instances of claims brought against highway departments and highway officials for liability because of injuries received in wet weather skidding accidents and has reviewed recent court decisions in this field. Because of the experience in California, the highway administrators in Florida are deeply concerned over the effect of Chapter 73.313 of the Laws of Florida. This Act, in essence, waives the sovereign immunity of the state effective January 1, 1975, for tort claims up to $50,000 for any injury to any 1 person or $100,000 for any 1 incident or occurrence. Amounts in excess of this would require passage of a claims bill.

LEGAL CONSIDERATIONS

During fiscal year July 1, 1969, through June 30, 1970, there was in effect in Florida a temporary waiver of sovereign immunity. As a result of this waiver, approximately 40 lawsuits were filed against the Florida DOT. During that 1-year period, we had 1 attorney busy full time defending those suits. In addition, we have had another attorney assisting on several cases. Since the time of that sovereign immunity waiver, the Supreme Court of Florida has abolished the concept of contributory negligence and replaced it with the doctrine of comparative negligence. Contributory negligence is a common law doctrine in which the negligence of the plaintiff completely bars any

Publication of this paper sponsored by Legal Resources Group Council and Group 2 Council.

recovery by the plaintiff against the defendant. As an example, if a plaintiff should go off the road and become injured as a result of faulty maintenance of the highway by the department, but it can also be shown that he or she was negligent in that he or she had been drinking and thus had impaired reflexes, he or she may not recover under the doctrine of contributory negligence in a suit against the department. Comparative negligence, on the other hand, is a doctrine in which the negligence of the respective parties is apportioned and the damages of each party would then be shared in proportion to the negligence. Thus, in the last example, if the department's fault in negligence were determined to constitute approximately 50 percent of the cause of the accident and the intoxication 50 percent of the cause of the accident, the department would share in 50 percent of injuries to the plaintiff. We expect that, as a result of the doctrine of comparative negligence by the supreme court, the number of cases against the department will increase.

Of utmost concern to administrators is the possible difficulty in obtaining adequate insurance coverage. As a result of the waiver of sovereign immunity, the highway department must consider carrying insurance to cover claims. The advantages of having insurance coverage are that the premium is budgetable, does not add an increased work load on the staff, and permits convenient handling. These advantages must be measured against the cost. Florida's experience with the 1-year waiver of sovereign immunity would indicate that the cost of the department's handling claims, considering its size and exposure, would be considerably less expensive than its carrying liability insurance with proper limits.

Another concern must be the training of the investigating officer. In all too many instances, an investigating officer notes that the vehicle skidded on pavement before the accident and lists "slippery pavement" as a contributory cause of the accident. A pavement can be considered deficient in skid resistance only in relation to the demand of traffic upon it. Skidding will occur on a dry pavement of high skid resistance if a sufficiently violent maneuver (such as braking to a stop from 60 mph in 100 ft or negotiating a 200-ft radius curve at 60 mph) is attempted. Such demands can arise in an emergency or as a result of extremely poor driving, but the resulting skid cannot be blamed on the pavement. It is only when skidding at curves is caused by maneuvers that are within the range of normal demand (accelerating, braking, or cornering by a majority of drivers under normal conditions) or intermediate demand (last-minute braking or steering corrections caused by inattention, misjudgment, or unusual incidents) that pavement skid resistance should be considered inadequate. Neither can skidding caused by normal braking or cornering on a wet pavement with adequate skid resistance be attributed to the pavement if the vehicle is deficient in such respects as bald tires, improper brake adjustment, faulty steering components, poor suspension, and the like.

Another concern of our attorneys in defending the department against liability suits is that all records of the department are open to the public. For this reason, whenever we identify and make a record of a slippery pavement during our statewide inventory of pavement conditions or during our spot hazard investigations, the department is placed in special jeopardy until the problem is corrected.

Attorneys defending the department in liability cases also are concerned about the influence on juries of published recommended minimum skid numbers (SNs). The Federal Highway Administration and most highway departments have been careful not to publish "magic numbers" that indicate poor skid resistance because they recognize that a pavement can be deficient in skid resistance only in relation to the demand of traffic upon it. Several researchers, however, have not felt so restrained. Even though the publications are careful to point out that the relative skid resistance demand on a pavement is the most important factor concerning the minimum skid resistance that should be applied, both NCHRP Report 37 (2) and NCHRP Report 154 (3) have published recommended minimum "magic numbers." NCHRP Report 154 (3) lists its "magic numbers" on the basis of the 99th percentile of the demand of drivers that use a site. Using this criterion, the report recommends a SN_{40} value of 55 for certain driving conditions. Because of the aggregates available in Florida, I am not certain (in fact, I have severe doubts) that this level of skid resistance can be either attained or maintained under high-volume traffic.

SAFETY OBLIGATIONS

It is obvious that highway departments have certain safety obligations. Among these are identifying high accident sites, improving maintenance, and providing a clear roadside policy. Two other areas that the highway departments are going to have to support are improved driver education and vehicle inspection programs.

ENGINEERING CONCERNS

The engineer-administrator, in considering the overall skid resistance problem, must be concerned with (a) testing for skid resistance, (b) various design and construction problems involved in providing a skid-resistant pavement, and (c) the inability to attain or maintain the skid resistance levels that are being advanced as recommended minimums in various publications.

The major engineering concern in testing for skid resistance is the repeatability and reproducibility of the test procedure and equipment. Most highway agencies in the United States measure pavement skid resistance with locked-wheel, pavement skid testers in general conformance with ASTM Method E 274. However, the repeatability of measurements by this type of tester and the correlation between testers of this type are generally not adequate.

A degree of uncertainty must be accepted with any measurement because of imperfections in the measurement process and the variability of the item being measured. NCHRP Report 151 (4) had as its objectives developing and verifying methods for improving the ability to measure reliably the skid resistance of wet pavement surfaces. The approach involved (a) contacts with skid tester owners to collect information on test equipment and operating procedures, (b) conducting laboratory and field experiments to determine the effect of specific variables on skid resistance measurements, (c) computer simulation studies on the influence of equipment dynamics on skid testing performance, (d) developing tentative recommendations for reducing variability in skid resistance measurements, and (e) conducting a 2-week skid tester correlation program to verify and modify the tentative recommendations.

The primary activity that led to the essential findings of the project was the planning and conducting of a skid tester correlation program at Pennsylvania State University from October 2 to 13, 1972. Nine state highway departments, 2 universities, and 1 county provided skid testers and crews for participation in the program. During the first part of the program, each of the 12 testers made 5 skid tests on each of 4 pavement surfaces at speeds of 40, 30, 50, and 40 mph for 80 tests per tester. An average of 5 tests was considered the measured SN for a particular speed, pavement surface, and tester. After completing the first series of tests, a tabulation of the data indicated a standard deviation of 4.08 from the mean SN for all testers in the condition in which they arrived and operated in accordance with their normal procedure. The range of mean SN values for all testers was as high as 24 for a particular surface. After corrective measures including force and load calibrations, installation of standard water nozzles and ASTM E 17 tires from a single production batch, and procedural adjustments were applied, each tester repeated the entire series of tests. The standard deviation from the mean of the second set of data was reduced to 1.24 and further reduced to 1.04 after temperature corrections were applied. Table 1 gives the reduction in standard deviations that resulted from various corrective measures. If results are to be meaningful very careful calibration of both the testers and the procedures must be made.

Highway administrators also must be concerned with varying pavement conditions. Skid resistance of pavement is not an absolute value; it depends on conditions during tests and on the testing method. It particularly depends on the wear characteristics of the aggregate in the pavement and the amount of debris, including rubber accumulation or oil drippings, on the pavement.

In Florida, a fatal accident occurred that appears to have been the result of inadequate cleaning of a completed construction site. The construction involved excavating a portion of the pavement and temporarily storing backfill material on the pavement. When the construction crew completed its work, it cleaned up the construction

Table 1. Reduction in standard deviations with various corrective measures.

Corrective Measure	Standard Deviation
Testers in "as arrived" condition	4.08
Data evaluation procedures corrected	3.25
Uniform watering nozzles and tires mounted	2.83
Force and load calibration	1.53
Correction for zero drift	1.24
Correction for temperature drift	1.04

site, which included shoveling all loose material from the pavement and light brushing with a broom. Nevertheless, a red clay stain was left on the pavement. That night there was a light rain, and a driver who attempted a passing maneuver at that spot went out of control and was fatally injured.

Concerning the design and construction problems in providing a skid-resistant pavement, the engineer must be concerned with the critical nature of the asphalt content, the critical nature of the voids content in the aggregate, the shape factor of the aggregates, and any postconstruction consolidation resulting in wheel-path rutting.

ADMINISTRATIVE CONCERNS

The energy crisis and the general shortage of materials are making it increasingly difficult to meet the demands of highway construction, particularly those related to providing a skid-resistant surface. In Florida, as in many other parts of the United States, naturally occurring aggregates are primarily limestone. Aggregates with suitable skid resistance must be imported. We are currently importing slag material and other aggregates from as far away as Tennessee. The administrator must be concerned with the increased cost of importing these aggregates and the difficulty in obtaining them.

One area in which the engineer-administrator must place increased emphasis is the reduction of frictional needs of traffic. The fuel shortage, which has caused a reduction in speed limits and traffic volumes, has been a blessing in disguise. We have already seen evidence of sharp reductions in fatalities over the Christmas and New Year weekends. It is impossible to determine how much of this reduction was due to the lesser amount of traffic on the highways and how much was due to the reduced speeds. Regardless, it appears that a major portion of the reduction must be attributed to the reduced speeds because neighboring states that had presumably the same reduction in total traffic volumes but have not reduced their traffic speeds have not enjoyed the same reduction in fatal accidents. When the fuel crisis is over, serious consideration must be given to maintaining these reduced speeds for safety reasons.

Other efforts must be made to further reduce the frictional needs of traffic. These are primarily related to geometric design and an improved knowledge of traffic operations, driver behavior, and vehicle characteristics.

A list of remedies for skidding risk would not be complete without a discussion of several possibilities that either reduce the frictional needs of traffic or decrease the frequency of their occurrence. Although AASHTO recommendations are largely followed in new highway designs, they should be applied also to existing highways to improve sight distances, reduce grades (particularly those near and at intersections), and provide superelevation where there is none. A systematic program to gradually improve road geometry, which, in contrast to skid-proofing, produces lasting results and very likely also reduces accidents that are not due to skidding is urgently needed. High-accident sites need to be identified and maintenance improved. The large number of skid marks in built-over areas clearly suggests that providing a single access to several business establishments along a highway might have advantages and certainly would reduce the frequency of brake applications, which cause skidding and increase collision risk. Drivers could do much to create a greater margin between friction availability and demand by reducing speed when pavements are wet and by starting early and executing smoothly vehicle maneuvers. More sophisticated driver training methods may provide a partial solution to this problem, but the development and use of all aids that feed needed information to the driver, protect him or her from distractions (particularly at locations and in situations that call for rapid decision-making), assist him or her to make the correct decisions, and help control the vehicle accordingly should be vigorously promoted. All such improvements reduce the danger of skidding and its consequences.

After we have done all we can on the pavement to improve its frictional characteristics and to reduce the frictional needs, we must go a step further and provide a clear roadside policy, and, I want to make a final plea that all concerned recognize the need for improvements in vehicle and tire design, vehicle inspection programs, and driver education programs.

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