158

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
SYNTHESIS OF HIGHWAY PRACTICE 158

WET-PAVEMENT SAFETY PROGRAMS

TRANSPORTATION RESEARCH BOARD
National Research Council

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

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The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the National Research Council and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are the responsibilities of the National Research Council and the Transportation Research Board.

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The members of the technical committee selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and, while they have been accepted as appropriate by the technical committee, they are not necessarily those of the Transportation Research Board, the National Research Council, the American Association of State Highway and Transportation Officials, or the Federal Highway Administration of the U.S. Department of Transportation.

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PREFACE

A vast storehouse of information exists on nearly every subject of concern to highway administrators and engineers. Much of this information has resulted from both research and the successful application of solutions to the problems faced by practitioners in their daily work. Because previously there has been no systematic means for compiling such useful information and making it available to the entire highway community, the American Association of State Highway and Transportation Officials has, through the mechanism of the National Cooperative Highway Research Program, authorized the Transportation Research Board to undertake a continuing project to search out and synthesize useful knowledge from all available sources and to prepare documented reports on current practices in the subject areas of concern.

This synthesis series reports on various practices, making specific recommendations where appropriate but without the detailed directions usually found in handbooks or design manuals. Nonetheless, these documents can serve similar purposes, for each is a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems. The extent to which these reports are useful will be tempered by the user's knowledge and experience in the particular problem area.

FOREWORD

By Staff
Transportation Research Board

This synthesis will be of interest to pavement engineers, safety officers, and others interested in wet-pavement safety programs. Information is provided on the programs used by a number of agencies in gathering data and correcting areas of potential wet-weather accidents.

Administrators, engineers, and researchers are continually faced with highway problems on which much information exists, either in the form of reports or in terms of undocumented experience and practice. Unfortunately, this information often is scattered and unevaluated, and, as a consequence, in seeking solutions, full information on what has been learned about a problem frequently is not assembled. Costly research findings may go unused, valuable experience may be overlooked, and full consideration may not be given to available practices for solving or alleviating the problem. In an effort to correct this situation, a continuing NCHRP project, carried out by the Transportation Research Board as the research agency, has the objective of reporting on common highway problems and synthesizing available information. The synthesis reports from this endeavor constitute an NCHRP publication series in which various forms of relevant information are assembled into single, concise documents pertaining to specific highway problems or sets of closely related problems.

Wet-pavement accidents continue to be of concern to highway agencies. This report of the Transportation Research Board summarizes agencies' programs in areas such as accident reporting, vehicle testing, friction testing, corrective actions for problem areas, and tort liability and gives some general guidelines for the content of a wet-pavement safety program.

To develop this synthesis in a comprehensive manner and to ensure inclusion of significant knowledge, the Board analyzed available information assembled from numerous sources, including a large number of state highway and transportation departments. A topic panel of experts in the subject area was established to guide the researcher in organizing and evaluating the collected data, and to review the final synthesis report.

This synthesis is an immediately useful document that records practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As the processes of advancement continue, new knowledge can be expected to be added to that now at hand.

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George W. Ring, Engineer of Design, Transportation Research Board, assisted the NCHRP Project 20-5 Staff and the Topic Panel.

Information on current practice was provided by many highway and transportation agencies. Their cooperation and assistance were most helpful.

WET-PAVEMENT SAFETY PROGRAMS

SUMMARY

The subject of wet-pavement accidents continues to be a major concern for agencies responsible for transportation, safety, and motor vehicle operations. The elements most commonly considered to cause an accident include the driver and vehicle, the environmental conditions, and the pavement condition.

The National Transportation Safety Board issued two reports in 1980 that addressed the magnitude of the problem of highway accidents on wet pavements and reviewed the states' and the Federal Highway Administration's activities as part of skid-resistance programs. The reports found that fatal accidents occurred on wet pavements more often than might be expected and recommended that attention should be given to developing objectives for conducting activities and furthering research in wet-weather friction.

The objective of this synthesis is to update the knowledge and activities under way in the area of wet-pavement accidents. A search of the literature was made and a questionnaire was developed about wet-pavement accidents to determine the practices being followed, identify areas of concern, and find the ongoing research activities.

A total of 56 replies were received in response to a questionnaire about wet-pavement safety programs, which was sent to the states, U.S. territories, and Canadian provinces. All 50 states, the District of Columbia, the Virgin Islands, and four Canadian provinces responded.

All of the agencies replying have an accident-reporting system in operation in their government. However, the units assigned the responsibility for the system vary widely. There is no uniformity in the requirements for accidents that must be reported or in the determination of who is responsible for making the report. Even when only those agencies that require a police report are considered, there is still no uniformity in reporting requirements or in the mechanics of identifying probable accident causes. Tire condition on vehicles involved is noted by only about half of the agencies.

The methods for identifying the location of an accident and the accuracy of the location used in accident reporting vary widely. The entry of accident report data into data bases occurred within one month to one year in about three-fourths of the agencies. Other agencies entered data more promptly, within days or weeks, and some agencies entered data annually or took longer.

Vehicle inspections are required annually by 24 agencies, no vehicle inspections are required in 28 agencies, and 4 require only a vehicle emissions inspection. When tire tread depth was a part of the vehicle inspection, a minimum of $\frac{1}{16}$ in. was required by 75 percent of the agencies.

Nearly all of the agencies have a friction-testing program in place and in operation. A total of 72 friction testers are used and calibrated in a fairly uniform manner.

Assignment of responsibility for the friction program function varies widely from agency to agency, with a wide assortment of unit titles given.

About two-thirds of the agencies have policies or procedures to take action as a result of friction tests. The threshold for the point at which action is required is not uniform. Likewise, there are 28 agencies that indicated that there was no time period for action to be taken as a consequence of friction test results, and 16 agencies gave no response. Twelve agencies had some time requirements for action to occur. A full range of corrective actions, including signing, seal coats, open-graded friction courses, and resurfacing, were employed by most of the agencies. Grinding, grooving, and milling were also used.

Most agencies had requirements for obtaining new-pavement friction properties using aggregate and mixture design controls. Tining of concrete pavement surfaces was also required by a substantial majority of agencies.

Accident studies made before and after pavement surface correction were employed in about half of the agencies, and nearly all of the studies indicated an improvement in the statistics for accidents after corrective action.

A part of the questionnaire dealt with wet-weather accident litigation, and the responses indicated that two-thirds of the agencies believed that tort suits were not a significant problem. The diversity of the responses and the severity of the problem in some agencies indicated that more intensive review is needed.

CHAPTER ONE

INTRODUCTION

BACKGROUND

The phenomenal increase in the volume and speed of highway traffic that has occurred since World War II has been accompanied by a parallel increase in the occurrence of highway accidents. The factors contributing to the occurrence of these accidents that historically have been studied have generally been placed in three major categories that are related to increased speed and volume. They are: (a) the roadway and its environment, (b) the vehicle and its characteristics, and (c) the driver and his or her behavior.

Much research has been done in each of these areas, and a wealth of information has been accumulated on various aspects of accident causation. Some of this information has been grouped in specific categories and has been used in programs aimed at reducing accident occurrence and/or severity. Meanwhile, some information has remained scattered in the literature or in the files of highway agencies and there have been few attempts to apply it, either because of its illusive, unspecific nature or because of the inability, for one reason or another, to apply it to real-life situations.

Reported studies (*1*) have indicated that most accidents (perhaps more than 80 percent) may be attributed to human factors, and only 3 to 5 percent may be attributed to vehicular characteristics or failures, with the exception of tire condition. The remaining 10 to 15 percent of accidents may be related to the roadway and its environment. This percentage alone represents thousands of human injuries and millions of dollars in property damage annually. The roadway and its environment, however, is also the area in which engineering improvements based on research can be most successful in reducing the number and severity of accidents.

This synthesis is directed at the subject of wet-pavement accidents. Research has indicated that a major factor in wet-pavement accidents may be the lack of adequate friction between the tire and the pavement surface. When the pavement is wet, emergency or panic braking or turning maneuvers may cause the vehicle tires to slide because of the lower friction between the tires and the pavement. If the water film on the pavement surface is abnormally thick or the vehicle speed is high, or both, the tires may lose contact with the pavement surface and ride on the water film, resulting in the loss of vehicle control. This phenomenon is known as hydroplaning (*2*). The relation between adequate traction on wet pavements and highway safety was researched and reported on by Moyer (*3*) in the 1930s and became the focus of intensive research efforts following the great increase in vehicle ownership and highway travel at high speeds

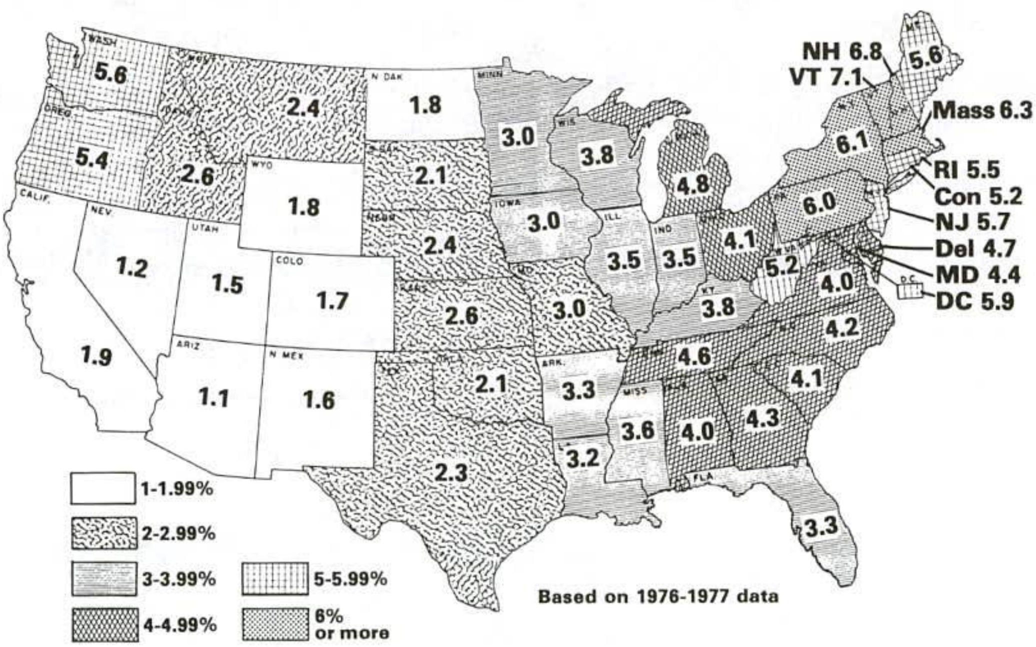

FIGURE 1 Percentage of wet time in each state except Alaska and Hawaii (*17*).

after World War II. The research dealt with several aspects of tire-pavement interaction, including field and laboratory methods of measuring road surface friction (*4, 5*), comparison and correlation of the different measuring methods (*5, 6*), and relationships of road surface properties to skidding accidents (*5, 7*). Research efforts culminated in the convening of the First International Skid Prevention Conference in Charlottesville, Virginia, in 1959, and the Second International Skid Prevention Conference in Columbus, Ohio, in 1977 (*5, 7*).

The proceedings of these conferences contain a wealth of material that has remained useful and has been the basis for further research efforts. Other significant research efforts included investigations in the areas of skid resistance requirements (*8*), friction needs (*9*), pavement surface texture measurement and evaluation (*10, 11*), pavement materials and designs (*12*), pavement treatments (*13–15*), and seasonal and short-term variations in skid resistance (*16*). Much knowledge has been accumulated and documented on this subject in the United States, Western Europe, and many other countries. Synthesis 14 (*2*) was one major attempt at synthesizing the knowledge on this subject in 1972. Most states have initiated skid-resistance (or pavement surface friction) research programs that have included means of measuring wet-pavement surface skid resistance, the determination of methods to provide adequate friction on new-pavement surfaces, and ways to improve friction on existing surfaces that were deemed in need of improvement. Despite all the efforts that have been expended, only limited success has been achieved in preventing skidding accidents. Wet-pavement accidents continue to be a problem.

SCOPE

This synthesis includes a general discussion of the extent of the knowledge accumulated in the area of wet-pavement friction measurement, pavement surface corrections, available accident data, procedures used to identify potential accident sites, evaluation and decision making, and documentation relating to these aspects of wet-pavement accident reduction.

APPROACH

This report updates Synthesis 14 (*2*), not only adding or modifying information on wet-pavement tire friction but also discussing what some agencies have done to alleviate the problems it causes.

The National Transportation Safety Board (NTSB) (*17*) reported on fatal highway accidents on wet pavements in 1980. The NTSB was interested in the magnitude of the wet-pavement accident problem nationwide and wanted to learn the significance of accident locations and characteristics.

One of the solutions to prevent or mitigate the severity of accidents is to provide an adequate friction level on highway and road surfaces. Because friction levels are normally adequate on dry pavement surfaces, accident studies involving friction can be narrowed to wet surfaces.

Accident problem areas on roads and streets are usually identified by comparing accident rates. Accident rates are determined by relating numbers of accidents at a specific location to the traffic exposure, which is determined by multiplying the number of vehicles using a specific road segment over a period of time by the length of the road segment.

The data needed to calculate the average accident rate are usually collected, but the relationship between accidents occurring when the pavement is wet and the amount of traffic exposure that is confined to that period is often not readily available. However, the NTSB (*17*) limited the study to fatal accidents from the National Highway Traffic Safety Administration's Fa-

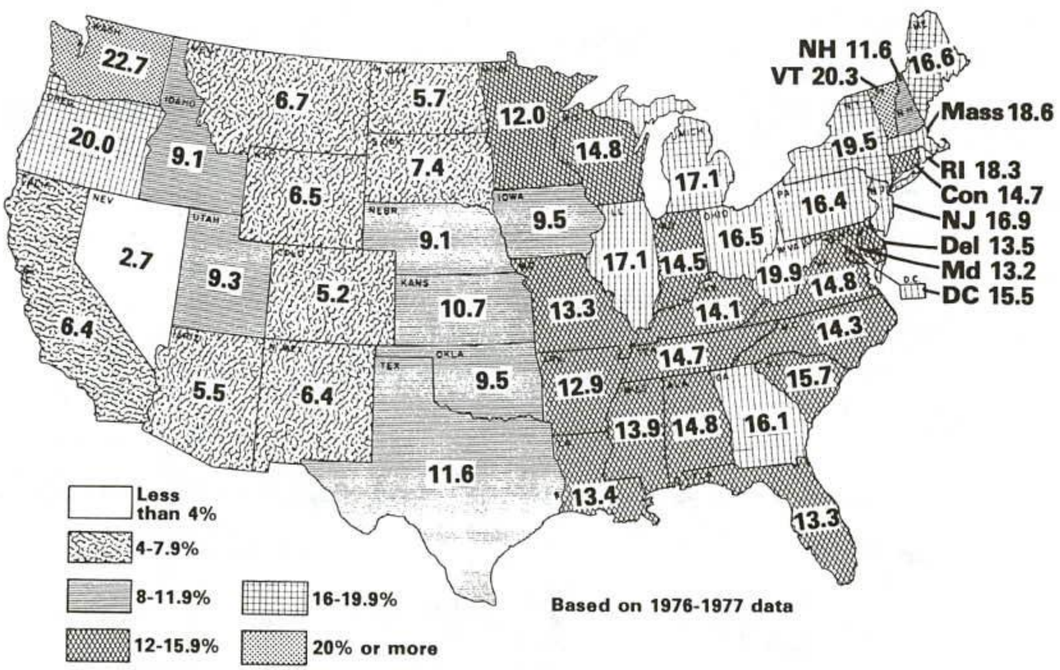

FIGURE 2 Percentage of fatal accidents on wet pavement in each state except Alaska and Hawaii (*17*).

tal Accident Reporting System. The wet-pavement exposure was determined by using precipitation data from the National Weather Service (Figure 1). The study developed a "wet fatal accident index" (WFAI) using fatal accidents and wet pavement to reflect the relative severity of the problem in each state (Figure 2).

$$\text{WFAI} = \frac{\text{Percentage of fatal accidents on wet pavement}}{\text{percentage of wet time}}$$

The WFAIs of all states were included in a statistical analysis that calculated mean WFAI = 3.54 with a standard deviation = 0.82. A plot of observed percentages of wet-time and fatal accidents on wet pavement and expected values is shown in Figure 3.

Once the magnitude, location, and characteristics of wet-pavement accidents are defined, other factors, such as human, vehicle, and roadway/environment involvement, can be studied to determine their contribution to the accident rates.

The NTSB concluded that wet-pavement accidents occur 3.9 to 4.5 times more than might be expected from data averages (*17*). It was recommended that efforts be made to promote the use of weather data to develop programs to reduce accidents on wet pavements and to do further research into the relationship of accidents and wet pavements.

A second report issued by NTSB (*18*) contained the results of an investigation of 12 wet-pavement accidents, a review of the skid-resistance programs in 10 states, and the responses received to a Federal Highway Administration (FHWA) proposed rule making. Included in the findings was the NTSB comment that there was a lack of systematic application of proven principles and practices by the states and FHWA to address the wet-pavement accident problem.

OBJECTIVE

Most of the information contained in this synthesis was obtained by analyzing the responses received to a questionnaire distributed to the 50 states, the District of Columbia, Puerto Rico, the Virgin Islands, and the 10 Canadian provinces. Responses were received from all 50 states, the District of Columbia, the Virgin Islands, and 4 of the 10 Canadian provinces.

There were a total of 140 persons identified as participating in completing the questionnaire.

The persons participating fell into the following groups:

Pavements, Friction Testing	39
Accidents, Traffic, Safety	43
Legal-Tort Liability	22
Research	11
Materials	13
Planning	7
Miscellaneous	5
Total	140

The questionnaire was designed to obtain information about accident records and reporting, vehicle information, friction testing, pavement surfaces, tort liability, and research activities. A copy of the questionnaire is included in Appendix A and a summary of the responses is contained in Appendix B.

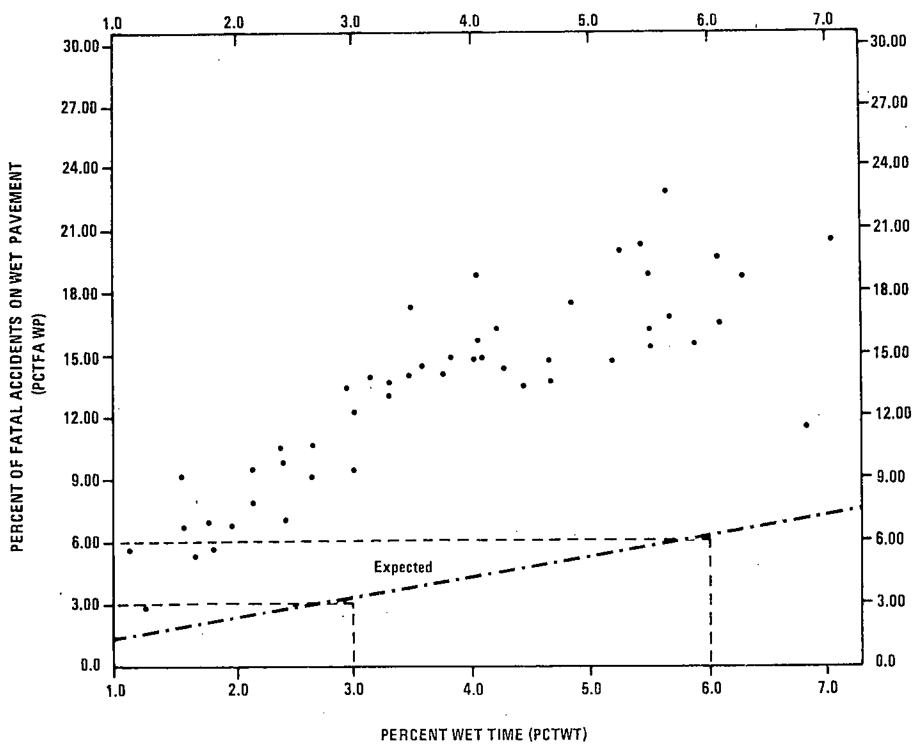

FIGURE 3 Plot of observed percentages of wet-time and fatal accidents on wet pavement and expected values (*17*).

CHAPTER TWO

ACCIDENTS AND VEHICLE FACTORS

FACTORS INVOLVED

When an accident occurs there are a number of complex factors involved, including the driver, the vehicle, the roadway, and the environment. It is desirable to have as complete and as accurate information about each of these variables as possible in order to determine the contributing causes of the accident and provide for their correction. Information is needed to learn if the roadway is a significant contributing cause and, if so, to determine if some action is required to address the roadway conditions contributing to the accident.

The collection and analysis of accident data are vital to identifying locations of highway segments that might have the potential to contribute to accidents. The identification of such sites is usually done by comparing the accident rates of specific segments of highway. Because the accident rate is expressed as the number of accidents occurring per vehicle miles of travel on a specific segment of highway, the accuracy of the rate is dependent on how precisely accidents are located and how comprehensive and accurate the data are that are included in the report.

ACCIDENT-REPORTING SYSTEMS

All of the agencies responding to the questionnaire indicated that they had an accident-reporting system. Beyond that there was very little uniformity in who maintained the system, which accidents were required to be reported, and who was responsible for filing the accident reports.

In the analysis of responses concerning who was responsible for maintaining the accident system, the responses were grouped as much as possible, considering the variation in organizational unit titles. The groupings indicated that 21 states, the District of Columbia, and the four Canadian provinces had the accident system function located in units in the Transportation Department, with titles of traffic engineering, safety, or motor vehicles. Eight states and the Virgin Islands had accident reporting in a Department of Public Safety, and another four states indicated that the state police were responsible. Eleven states had a planning organization responsible, with 1 of the 11 having a separate Department of Planning and the rest having planning in the transportation organization. Another six states indicated that the accident system was a responsibility of the Department of Motor Vehicles, the Department of Revenue, or a similar organization separate from transportation.

Even in those cases in which the accident system was assigned to organizations separate from transportation, nearly all respondents indicated that the data were available or a file containing the data was given to the transportation agency.

TIMELINESS OF DATA

There is considerable range among the states in the time required to enter data into the accident system. Eighteen respondents indicated entry within one month. Twenty-seven agencies reported periods of one to six months before entry. Five agencies indicated delays ranging from six months to one year. Three agencies indicated they had procedures that called for entering data only on an annual basis. One agency reported a two-year backlog and one reported a three-year backlog. One agency did not report a time.

Another way to look at the data would be that only 30 percent of the states enter data within one month. The accident-reporting and data-entry time would be time required before any accident data analysis could be done that might indicate the desirability for friction testing or other investigations. The results of friction testing or site investigation might indicate a need for countermeasures. The countermeasures would in turn require the evaluation, design, and construction of a project. It would appear that some effort to maintain timely data entry and analysis might be beneficial. As technology is developed and accepted, it would be desirable to have on-line reporting of skidding accidents.

REPORTABLE ACCIDENTS

Although there is a wide variation in reporting criteria, all of the agencies indicated that when injury or death is involved in an accident, a report must be filed. Table 1 summarizes information

TABLE 1
REPORTABLE ACCIDENTS

Minimum Vehicle Damage Costs	Number of States	Number of Provinces
All accidents	7[a]	–
$50 - $499	21	–
$500 - $700	19	4
$1,000 and over	1	–
Towing required	3[b]	–
None	1	–

[a]Includes the Virgin Islands
[b]Includes D.C.

supplied describing reporting requirements for accidents involving vehicle damage.

A number of agencies have indicated that they felt that there is a lack of correlation between friction numbers and wet-pavement accidents. This is partly because there are many other interacting factors and partly because many minor accidents are not reportable, being under the required minimums. Many of these are accidents that might be related to the lack of pavement friction. It is also possible that high pavement friction might have minimized the severity of some accidents to the point that these would also not have been reported. Closer study and research in this area may help to explain the interaction of pavement friction level and accident occurrence and severity. If skidding accidents could be separated from other wet-pavement accidents, a better correlation could be expected.

WHO REPORTS ACCIDENTS

Thirty-nine agencies require the police to report accidents and 12 of the 39 also require the drivers involved to report. Another nine agencies require the driver and/or the police to report and eight require only the driver to report.

There is no relationship between the minimum-dollar-amount-of-damages requirement for reportable accidents and who is required to file the report. There is logic in the belief that requiring the police to report accidents would improve the quality and uniformity of the information submitted.

LOCATING ACCIDENTS

Questions were included in the survey to learn how the locations where accidents have occurred are identified and reported. The responses were not readily sorted into data groups because of the varied terminologies used and because the responses were necessarily brief.

Fifty-two percent of the agencies used a milepost system to report and another 24 percent used a variation of a log mile. The remaining 24 percent used nodes or the nearest landmark.

Because accident reports are filed on both state and local systems, there was usually a secondary location system mentioned for urban areas or streets and roads on locally maintained systems.

A majority of the responses to the question about accuracy were given in terms of distance. The largest group of agencies (20) reported locations of accidents within $\frac{1}{100}$ mile. Another 12 had $\frac{1}{10}$ mile. The poorest accuracy was $\frac{1}{2}$ mile.

Eight of the agencies answered the accuracy question by giving percentages that ranged from 40 to 93 percent with a uniform distribution. Another 10 gave descriptive responses such as good (2), fairly good (1), varies (2), as good as report (2), poor to excellent (1), and unknown (2). Only three of the agencies returning the questionnaire did not answer the accuracy question.

When the response to the methods used for locating accidents and the responses for accuracy of the location are considered together, there is concern about how many of the accidents reported are located with sufficient accuracy to satisfy some of the requirements for the uses being made of the data.

ACCIDENT REPORT CAUSES AND CONDITIONS

Probable cause is included in 70 percent of the accident report forms used by the states. Fifteen percent do not include information on probable cause and the other 15 percent have a scattering of replies that indicate some comments might be included in the report.

Once again there is no relationship between who reports the accident and whether accident causes are identified. Even when police are required to submit the accident report, a probable cause is identified in only two-thirds of the agencies.

Weather conditions at the time of the accident are required in all systems.

TIRE CONDITIONS IN ACCIDENT REPORTS

Tire conditions for vehicles involved in accidents are reported about half the time in accident reports. There were 10 agencies that responded that tire conditions are included in accident reports. Another 16 agencies indicated tire conditions were not reported. Twenty-eight answered with a qualified yes, clarifying the answer with comments such as "if defective," "if bald or a blow out," "if causal," and "sometimes." Included in the 28 was one response that said tire information is included if the accident resulted in a fatality. Two agencies did not respond.

It is interesting to note that there is not a more comprehensive interest in tire conditions and their relationships to accidents when there seems to be growing concern on the part of many of the states about hydroplaning. It is also interesting to note that some vehicle inspection procedures do not include minimum requirements for tire conditions.

VEHICLE INSPECTIONS

The vehicle is an important part of the human, vehicle, roadway/environment relationship that is involved in an accident. There are usually concerns and certainly operational necessity that brakes, tires, and steering be functional. There were several questions concerning vehicle inspections included in the survey.

The replies to these questions indicated that 24 of the 56 agencies replying have an annual vehicle inspection required. Twenty-eight had no requirements for periodic vehicle inspections and four indicated they had vehicle emission inspections only.

TIRE TREAD DEPTH

Sometimes an action by the driver, by applying the vehicle brakes in an emergency stop or by a steering maneuver or by both actions, creates forces higher than can be resisted by friction, and skidding thus occurs. In wet-pavement accidents, the ability of the tire pavement interface to develop the friction forces required involves not only the tire and the pavement but also the depth of water. Although rain cannot be avoided, water runoff from pavements can be facilitated and vehicles can be equipped with tires having adequate properties and tread depth to develop the friction capabilities available in the pavement surfaces. Pavement surfaces should be designed to provide adequate macrotexture for the roadway conditions, and the tire tread should contribute to the capability for water removal. Tires have built-in wear bars that are meant to serve as reminders to drivers that when tires are worn to that level, the tires should be replaced to ensure safe vehicle performance.

Because the wear-bar device requires a periodic inspection by the operator, many states in the past have included tire inspection as a part of the required periodic vehicle inspection. As part of the section inquiring about vehicle-inspection practice, a question was asked about required tire tread depths. There was a mixture of responses, with some states indicating tire tread depths are required even though no periodic inspections were required. Presumably these requirements might be discovered during spot checks or in accident situations. Table 2 gives a tabulation of the inspection and tire tread depth responses.

Only about half of the agencies responding indicated some positive action and concern for tread depth. Because tread depth is an important part of the tire-pavement friction development (*19*) and the lack of tread depth contributes to the potential for hydroplaning, it would seem that accident programs should include procedures to adequately monitor and control the tire tread depth on vehicle tires operating on the streets and roadways. What is needed are automatic devices, similar to weigh-in-motion devices, that would facilitate on-roadway monitoring. To be effective, the minimum tread depth at inspection should anticipate a year's average wear based on average annual travel by cars and trucks.

TABLE 2

TIRE TREAD DEPTHS AND VEHICLE INSPECTION

Inspection Requirement	Number of Agencies
Annual Vehicle Inspection Required	28
No Tread Depth Required	5
Required Tread Depth 1/16"	15
Required Tread Depth 3/32"	2
Required Tread Depth 1/8"	2
Visible	4
No Periodic Inspection Required	28
Required Tread Depth 1/16"	7
Required Tread Depth 3/32"	1
No Tread Depth Required	20

CHAPTER THREE

ROADWAY FRICTION

In the context of this report, friction is understood to be the force developed at the tire-pavement interface that resists sliding by tires on pavement surfaces under emergency or panic braking or cornering. The term "skid resistance" has also been used to describe this pavement-tire interaction. The two terms (skid resistance and friction) have been used interchangeably in the literature and will be so used in this report. The problem arises when emergency braking or cornering occurs to prevent a vehicle accident, or at least to minimize the impact of an impending accident.

Skid resistance is usually indicated by multiplying the friction coefficient by 100 and is expressed in terms of a friction number (FN) or skid number (SN).

CONDITIONS

In Synthesis 14 (*2*) it was stated that on dry pavements the skid resistance is always high. In NCHRP Report 37 (*8*) it was stated that friction tests demonstrated conclusively that the dry friction level is either independent of, or increases slightly with, vehicle speed. Therefore, skids on dry and relatively dust- and gravel-free pavements are rare events even at high vehicle speeds. The risk of skidding increases dramatically with speed when pavements are wet.

On a wet pavement, the water film lubricates the surface and reduces direct contact between the pavement surface microtexture and the tire, thus reducing the available friction level. Both the microtexture and the macrotexture are needed to provide the pavement surface with an adequate level of friction. The microtexture (provided by the small surface asperities) affects the level of friction in the tire-pavement contact area, whereas the primary function of the macrotexture (the larger surface asperities) is to provide escape channels for the surface water from the tire-pavement contact area, thereby increasing the friction level. Wet-pavement accidents are likely to be related to deficiencies in the available friction levels. Other factors, including speed, driver behavior, and highway geometrics may also contribute highly to wet-pavement accident occurrence, but the friction factor is of sufficient importance in preventing or mitigating the severity of an accident on a wet pavement that it should be investigated, and a reasonable level of pavement surface friction should be provided.

FRICTION TESTING

Some testing and research has been done on the subject of skid resistance since the car came into wide public use in the 1930s (*3*). However, the subject became of major significance with the advent of still greater numbers of cars traveling at higher speeds in the 1950s. The increase in travel was accompanied by an increase in accident occurrence and awareness of the need for improved safety measures, including providing adequate pavement skid resistance. Skid-resistance research came into focus in the 1950s through the 1970s, resulting in a wealth of information in the literature and in the experience of agencies interested in this subject.

Several skid-resistance measuring procedures were developed and used both in the field and in the laboratory in the 1950s and 1960s (*2, 5*). However, the field testing method that has gained most acceptance is the locked-wheel trailer method, which has been standardized by ASTM as Method E 274 (*20*). This test is made by locking a trailer tire or tires while the trailer is being towed by a truck carrying a water tank to wet the contact surface. The friction between tire and pavement is then measured. The instrumentation must be calibrated, and the measurements are usually made at 40 mph (64 km/h) but can be made at higher or lower speeds.

Other methods, such as the Mu-Meter and side-ways friction tester, are also used in the field to a lesser extent (*2*). In the laboratory, a pendulum tester is commonly used for low-speed friction measurement. This method, known as the British pendulum tester, can also be used in the field, and it has also been standardized by ASTM as Method E 303 (*20*).

Most states have developed skid-resistance testing programs to monitor the wet-surface friction conditions of their highways. Some of these programs are routine and extensive, covering most or all pavements in the state periodically. Other states perform tests only where skidding problems arise or where potential skidding problems are suspected.

The questionnaire sent to the agencies included questions on the extent and type of skid-resistance testing program the agency had. The following paragraphs summarize state responses to questions relative to friction testing.

Testing Programs and Methods

Fifty-three of the 56 agencies responding to the questionnaire have a pavement-friction testing program. One state is in the process of implementing a system and one state indicated that it tests upon request. Only one agency indicated it has no formal program.

TABLE 3

TYPE OF FRICTION TESTER AND MANUFACTURER

Type of Tester	No. of Testers
K. J. Law Locked-Wheel Skid Trailer	38
Locked-Wheel Skid Trailers (built by the agencies using them)	13
Cox & Sons Locked-Wheel Skid Trailer	3
Locked-Wheel Skid Trailer Meeting AASHTO Specifications	2
FMC Locked-Wheel Skid Trailer	2
Soiltest Locked-Wheel Skid Trailer	3
Mu Meter	4
British Pendulum Tester	1
Other	6

The 56 agencies reporting operate 72 friction testers, all testing in accordance with ASTM standards (*20*). Table 3 shows the number of testers reported by type and manufacturer.

There was a wide range of answers in response to a question about intervals between calibration of testing units. All the agencies indicated that they had calibration procedures, but the intervals reported for calibration ranged from daily to "two to three" years. Table 4 shows the range of the time periods reported for calibration. The agencies reporting "other" time periods used terms such as "variable," "as needed," and "when malfunction occurs." Calibration procedures vary.

A majority of the agencies also indicated that they sent their testers to national calibration centers. However, six agencies answered negatively or did not answer this question. Table 5 shows the time periods reported for trips to the calibration centers. It appears that there is a wide variation in the time periods when testers are sent for calibration at the national centers and also when calibration procedures are undertaken as part of the agency's own program.

TABLE 4

RANGE OF TIME PERIODS FOR FRICTION TESTER CALIBRATION

Time Period	Agencies
Daily	2
Weekly	7
Bi-weekly	1
Monthly	10
Six weeks	1
Quarterly	2
Six months	6
Yearly	15
Two to three years	1
Other	11

TABLE 5

TIME PERIODS FOR CALIBRATION AT NATIONAL CENTERS

Period	No. of Agencies
Six months	1
One year	11
Two years	18
Three years	5
Four years	1
Five years	2
Eight years	1
Ten years	1
Other	11
No calibration	5

Testing Speed, Season, and Tires

Although all the agencies operate testers in accordance with ASTM procedures [at 40 mph (64 km/h)], there are occasions when circumstances are such that friction tests are performed at other speeds. Seventeen agencies indicated that they test only at 40 mph. Thirteen agencies said that they sometimes test at other speeds and seven indicated they occasionally or rarely do. The other test speeds used ranged from 20 to 50 mph (32 to 80 km/h).

If friction tests are performed at a speed other than 40 mph, the majority of the states (30) did not adjust the results to a 40 mph value but reported the results at the speed actually used in the test. Sixteen states did indicate that they corrected the test values to 40 mph standards using "appropriate" speed gradients.

About half the agencies reported that they test year round, whereas the other half did spring-summer-fall testing. Only three states indicated that they made a seasonal adjustment on the basis of procedures given in an FHWA report (*21*) or in other studies (*16*), or by using a correlation developed in-house.

Most of the friction testing is performed using ASTM Method E 274 with ribbed tires. Thirty-six agencies use only the ASTM ribbed tire, whereas seven agencies indicated they use a smooth-tread tire occasionally or in special testing. Seven agencies use smooth tires and ribbed tires routinely and three that operate Mu-Meters use only smooth-tread tires. Three agencies did not respond.

The use of the smooth-tread tire tests in conjunction with ribbed tire tests has been reported to be of value in the evaluation of macrotexture that might not be apparent using ribbed tire testing only.

Outside Testing

A question was asked if the reporting agency performs friction testing for local or other agencies. Because friction-testing equipment is not generally available outside of state agencies, answers to this question would give some indication of how widespread the interest in friction testing might be. Nineteen agencies reported that they performed testing for others and 18 said they did not. Another 17 agencies perform tests for others upon request, occasionally, or rarely.

Testing Responsibility

There does not appear to be any consistency among agencies in the assignment of functional responsibility for friction testing. Part of the lack of consistency may be apparent only in organizational nomenclature, because similar functions may be assigned to organizational units that have very different titles yet perform the same functions.

When the organizational units that have friction testing assigned to them are grouped by similar titles, it appears that "Materials and Testing" performs the testing in 15 agencies. The "Materials and Research" organization is a close second, with 11 agencies. A "Research Organization" is used by eight agencies and "Planning" is used in another nine. A "Laboratory" is indicated by three, "Pavement Management" by three, and "Traffic" and "Design" units are each used by one agency. One agency had no function assigned.

Reason for Testing

The reason given for friction testing in 53 agencies is to develop a wet-pavement friction inventory. Thirty-nine agencies also test for research purposes. Four agencies test in response to special requests.

Only 13 of the responding organizations routinely perform "new-pavement" tests and another 3 occasionally test new-pavement surfaces.

Criteria to Evaluate Test Results

It was difficult to sort the responses given about the criteria used to evaluate friction test results. Eleven agencies required an action to be taken if friction test results were below 35, 33, or 30. Twelve agencies indicated a series of action steps keyed to friction numbers of 40, 35, and 30. Seven agencies responded that they used the recommendation of SN_{37} at 40 mph from NCHRP Report 37 (*8*). Most other agencies had actions that gave no indication of criteria for evaluations beyond that a judgment was made by the agency about the disposition of the test results. One state uses SN = 20 for a smooth-tread tire.

Policy or Procedure for Action

Thirty-five agencies have a policy to take actions as a result of friction test results. Seventeen agencies do not and four did not respond to this question.

The threshold and action to be taken as a result of friction tests varied widely. Specific friction test numbers were established for action as follows: by one agency at 40, by one agency at 39, by two agencies at 37, and by eight agencies below 35. Six agencies compiled a list when SNs are below 35 and recommended SNs remedial pavement action at 30. Five agencies indicated they used a criteria table with treatment guidelines.

Other agencies did not provide SN limits by number but indicated actions taken were: "sign or overlay" (three), advice (four), varies (two), and "low numbers, resurface" (one).

Thirteen agencies gave no answer or indicated that no thresholds or actions were used.

Time Period for Corrective Action

The majority of the agencies do not appear to have time periods that govern the corrective actions that might be required. Eleven agencies indicated that some time requirements for actions were observed and there was no response from the rest.

NEW-PAVEMENT SURFACES

Most of the agencies (42 of 56) indicated that they had some type of requirement for their new-pavement surfaces to obtain adequate friction properties. Nine agencies indicated that they had no problem because of the characteristics of their aggregates, and no response was received from two agencies.

Eighteen agencies use requirements for aggregates as the means to obtain adequate friction properties on new bituminous surfaces. Five agencies said they used records of friction history to determine which aggregates and bituminous mixes would provide adequate friction.

Eleven states indicated that they used open-graded friction courses and another 10 indicated that they used mix design procedures to control friction properties.

Thirty-two agencies responded that they had specifications for producing tine finishes on concrete pavement to obtain friction properties. Texture requirements were used by four states. Nine states indicated that they did not construct concrete pavements.

Only five agencies said they did not evaluate friction properties of new pavements. Thirty-five agencies said they do evaluate friction properties of new pavements, and another 13 said they sometimes evaluated new pavements or they determined properties by sampling or through their periodic inventory.

The agencies were asked who was responsible for controlling the factors that determine friction properties of new-pavement surfaces. Twelve states indicated that a materials and research function was involved. Four states had only a material function assigned. In the rest of the responses no more than two states had a similar function responsible for pavement friction. Functional areas in the agencies responsible for friction included design, materials, construction, maintenance, research, safety, and pavement management. The functional areas were sometimes combined.

It appears that most states have adopted similar measures to obtain adequate friction in new pavements. However, the states' assignment of the responsibility for the development and monitoring of pavement friction has been placed in widely varying functions.

CORRECTIVE ACTIONS FOR PAVEMENTS

Twenty-five agencies indicated that action to address pavement surfaces was necessary as a result of friction test results. Thirteen more indicated that they required action in some cases. Seventeen agencies indicated they required no action as a result of friction tests.

The actions taken by 46 agencies include signing and resurfacing. Open-graded friction courses, thin overlays, or seal coats are placed by 34 states. Grooving of pavement surfaces is performed by 27 agencies to facilitate water drainage and to increase friction. Milling is used by 24 agencies to restore surface texture and to provide friction faces on aggregates. Grinding is done by 18 agencies to restore ride and texture.

BEFORE-AND-AFTER ACCIDENT STUDIES

One method used to evaluate the effectiveness of corrective actions taken on pavement surfaces is to compare before-and-after accident records for similar time periods on the same sections. This type of comparison is also used to develop a cost-benefit ratio by comparing the reduction in cost of accident to the cost of the pavement surface improvement.

Twenty-four agencies indicated that they perform "before-and-after" studies. Ten of the 24 agencies had a reduction in accidents as a result of the actions taken and 12 agencies believed that they had obtained positive results. Ten agencies indicated that the "before-and-after" studies included the determination of economic benefits. Nine of the 10 agencies obtained positive benefits.

CHAPTER FOUR

TORT LIABILITY

TORT

The breach of a legal duty is the major issue in most tort liability cases. Neglecting a duty can be either wrongful performance (misfeasance) or the omission of a required performance (nonfeasance). Permitting a condition to exist that interferes with the public right of reasonably safe travel may legally be considered only a nuisance but can still cause liability (*22*).

The critical issue in tort litigation is the care with which highway responsibilities are exercised. One has the responsibility to act in a manner that is reasonable, based on information at hand and resources available. One of the strongest types of evidence will be the agency's own guidelines and policies. Relevant are directives of superior agencies, guidelines and policies of other agencies (demonstrating the state of the art), engineering practice, research results, etc.

When a known hazard cannot be eliminated immediately, there is at least the duty to warn motorists. The duty to take action arises when notice is received. Technically, the filing of a police report is a notice to the jurisdiction. Hence, rapid and effective communication between agencies is essential. The duty to act, however, may be construed to exist even if the agency did not know but should have known of the existence of a hazard. This concept implies the necessity for regular inspection of the roadway network.

Rational procedures for ranking proposed corrections of substandard or hazardous highway sections should be established and followed. They should be based on the potential for reducing the number and severity of accidents. Improvements with the best cost-benefit ratio must be given the highest priority, and although scheduling is subject to budgeting constraints, the agency must be prepared to show that it used and consistently applied logical ranking and programming procedures (*22*).

STATE AGENCIES' RESPONSES TO TORT LIABILITY

Thirty of the 56 agencies responding indicated that they had litigation as a result of wet-weather accidents. Ten agencies reported none and four did not respond to this question. Another 12 agencies indicated that little if any litigation had occurred.

Only 16 agencies believed that litigation was a significant problem and 33 agencies said there was not a problem with litigation. Seven did not respond to this question.

Of the 16 agencies that indicated there was a significant problem with wet-weather accident litigation, 8 provided comments that offered some insight into the extent and nature of the problems.

The eight states included individual comments such as: "100 claims have been related to friction number and/or wet weather" and "20 to 25 claims have been related to snow, ice, pooled water, frost heave." Specific comments included: "three cases in 1986," "two cases settled since 1981 at $750,000 with others pending," "several favorable defense verdicts and two or three claims settled favorably," "some claim for signs," "any litigation is a problem," and "there were 'no settlements yet.'"

Several questions were included in the questionnaire to try to obtain some indication of the relative exposure of the agencies to litigation and also to learn if there is a measure of citizen protection from agency negligence. Nineteen agencies said they had no protection from litigation or that they had waived immunity. Seven agencies indicated that they had claim boards or a similar system to respond to citizen complaints. Seventeen agencies had some form of protection from suits; eight had sovereign immunity or some form of sovereign immunity. Nine states had other protection and five had some form of limited protection. Eight agencies did not respond to the question.

There was no clear-cut consensus to the responses to the question concerning the rights of citizens in the case of an agency's negligence. Thirty-two agencies indicated that the driver's rights were protected, but only five of these agencies indicated the nature of the protection. Two agencies had claim boards and three agencies said that they can allow themselves to be sued. There were five agencies that indicated there was no recourse for citizens. Nineteen agencies did not respond.

A careful review of responses to this part of the questionnaire would seem to indicate that there is a wide range in both the perception and the reality of litigation involving wet-weather accidents.

The questions and answers in the questionnaire merely scratched the surface concerning the breadth and depth of the potential litigation problem involving wet-weather accidents. It would seem imperative that this subject be investigated and defined more fully to learn why 1 agency has 100 claims and 33 other agencies indicate litigation is not a significant problem.

CHAPTER FIVE

RESEARCH ACTIVITIES

Thirty-four agencies reported that they have had wet-pavement-related research activities. The research topics included surface friction (23 agencies), friction testing (22 agencies), and wet-pavement accidents (19 agencies). Twenty agencies indicated that they have no research activities.

Even though 34 agencies indicated they have had research activities, there were only 16 agencies that released research reports within the past five years. This would seem to indicate that there is some slowing of activity in the wet-pavement safety-related research area.

The general topics for many of the reports that were issued included aggregates, sprinkle treatments, pavement surfaces, and friction. There were a number of agencies that returned reports with the completed questionnaires. Titles and dates of these reports have been included in Appendix C with a brief abstract or summary of the contents. Several agencies also included additional information on their policies, procedures, guidelines, etc. (Appendix D).

Only 17 agencies reported that they have research currently under way. Not all of the agencies that have current research activities mentioned the subject of their research; however, there were 12 agencies that gave the research subject areas they are working on. The research subjects included three studies directed at asphalt concrete mix design and one study dealing with achieving adequate friction in pavement surfaces. Three projects are studies to determine long-term friction number trends. One other study is in a similar area to monitor pavement friction. A number of studies involve construction techniques to obtain adequate surface properties, such as tine finishing for concrete pavements, sprinkle treatments for asphalt pavement, and the use of aggregate blends to improve friction in asphalt pavements.

Only three research activities are reported to be directed at the topic of wet-pavement accidents. Two other projects are described as wet-pavement accident studies and one consists of a data base development to link accident and friction number data files. The sparse number of projects reported in the subject area of wet-weather accidents is difficult to reconcile with the relatively numerous comments received in a general information section that asked for the respondents' feelings in regard to wet-weather accidents. The responses are discussed in the next chapter.

If the subject areas and the proposals for the studies reported under way are carefully reviewed, it is likely that half of the 15 projects reported would not be considered as research projects but would be considered to be monitoring. If this estimate is valid, then the percentage of agencies with current research activity would be as little as 15 percent.

CHAPTER SIX

GENERAL INFORMATION

A set of questions was included in the survey under the heading "General Information" in an attempt to receive comments from the respondents that might give an indication of their feeling about wet-pavement accidents.

The first question in the general section asked for the respondents' feelings about problems related to wet-pavement accidents or for any general remarks that they would like to give. More than two-thirds of the respondents offered comments.

An attempt was made to draw an inference from the 37 comments received that would give a general indication of the feelings of the responders. The interpretations were then grouped into similar expressions of feeling in a general subject area.

This process of interpretation showed that about 20 percent of the agencies are concerned that there is little or no correlation between wet-weather pavement friction and accidents. Both the number and the strength of the comments merit serious attention.

Upon close inspection of the information supplied in the section on accident records, there is an indication that there could be a problem in relating reported accident data to pavement friction properties at a specific accident site. The data reported and entered in the accident files could come from accident location determinations that are not sufficiently accurate. There are potential problems with the timeliness of reporting and the conditions of the pavement at the time of an accident. The determination of pavement friction properties at the accident site is dependent on location and must also be related to the pavement condition at the time of the accident. The literature has many studies that relate wet-pavement accidents to friction properties (*9–11*), and there are also many studies that show that altering pavement properties has effected accident reductions (*23–25*). This subject should be resolved in light of the significant number of agencies that question if a correlation exists.

Other comments received include a concern about pavement drainage and hydroplaning (4), rutting (3), and testing with smooth-tread tires (2). Presumably the interest in smooth-tread tires and their use could be either in relation to vehicles involved in accidents or in relation to the use of smooth-tread tires in friction testing.

The second question asked for an expression of feelings on areas requiring additional investigation. Twenty-two replies were received, which was not as high a response level as that obtained for the first question; however, it was still considered significant because the reply was optional. The third question asked for specific subjects that need investigation. The replies to the second and third questions were combined. The replies were grouped into the following topics requiring additional investigation (the number of agencies suggesting the topics is given in parentheses):

Rutting, Hydroplaning, Smooth-Tread Tire Testing	(12)
Mixes, Aggregates, Polishing, Texture	(4)
Correlation of Friction, Driver, Vehicle Alignment	(2)
Intersections (what type of accident does friction level solve?	(2)
Paving Equipment and Friction	(1)
Temperature and Friction Number	(1)
Low-Speed Testing	(1)

Only four agencies reported participating in a conference dealing with accidents or pavement friction in the last three years. Forty-four agencies specifically answered the question in the negative. The other eight replies had no response to this question.

In view of the comments received about accident correlations and wet-pavement friction and the suggested topics for research, there may be a need indicated for increased technology transfer and training in this area.

CHAPTER SEVEN

GUIDELINE CRITERIA FOR WET-PAVEMENT SAFETY PROGRAMS

Based on the reported activities and experiences of the states and on available research information, the following guidelines are suggested for a wet-pavement safety program.

A successful wet-pavement safety program requires that a number of diverse activities occur in a quality-controlled, ongoing, coordinated effort. The activities include the collection and processing of sufficiently comprehensive accident reports with accurate identification of location. An overall wet-pavement safety program should include the following characteristics:

- Comprehensive signed location referencing system.
- Well-defined requirements for accident reporting and a suitable data base for storing data.
- Friction-testing plan for new and in-service pavements.
- Material controls for new pavements and construction practices that have been demonstrated to obtain adequate friction properties initially and to keep those properties over the useful life of the pavement.
- A policy to establish acceptable pavement friction levels and correction procedures when levels are inadequate.
- Vehicle requirements that include minimum tire tread depths.
- An annual training program for the persons involved in the varied activities of a wet-pavement safety program.

It does not appear that the accident locations are being reported with sufficient accuracy. Responses to questions about accuracy were so widespread that it is doubtful that accuracies are known. Agencies should adopt a systematic method to mark and maintain a highway and street location reference system. The location reference system should be signed in the field, and training should be given to police and emergency personnel so that they understand and use the system. The location reference system should be adaptable to computer data base entry, storage, and retrievability.

There should be a national guideline adopted that specifies which accidents should be reported and who should report them. Any accident that results in a death or in an injury that requires treatment should be required to be reported by law enforcement officers.

Accidents that result in damage to any vehicle that requires towing should also be required to be reported by law enforcement officers. Other accidents that result in damages of more than a minor amount (perhaps $400 in 1988) to one of the vehicles involved should be required to be reported by the drivers involved.

Accident reports should include information about the general physical condition of the vehicles involved, and specific information should be included in the report about tire tread condition. The weather and pavement conditions at the time of the accident should be reported in easily understood, simple categories such as rainy, snow-covered, wet, or dry.

The accident report should also describe the circumstances that contributed to the accident in sufficient detail to enable an accident analyst to judge the contribution of the pavement or the roadway characteristics to the accident.

There should be a single functional organization that is charged with maintaining the accident data base and with receiving, analyzing, and entering accident data into the data base within a reasonable time period after the accident report is received. It would seem that a time limit of one month from receiving the report until the data are available in the data base would be reasonable.

The wet-pavement safety program should include a program for the measurement of friction properties on both new and in-service pavement surfaces. The agency charged with the program should have an adequate number of friction testers that are operated and calibrated in accordance with ASTM procedures. National calibration services are available and could be used to ensure that testing is adequate. Local calibration should also be used and may be preferred.

The friction program should include measurements to be made to monitor the properties of pavement surfaces during construction to ensure that material properties, construction controls, and drainage are sufficient to obtain adequate initial surface friction. Research information is readily available that describes the pavement macrotexture required for surface drainage, the microtexture required to obtain and maintain adequate friction levels, and the performance characteristics of various aggregate types. This information should be used to control the materials used and the mixture designs for new-pavement surfaces.

Each agency should develop a written policy to describe the procedures to follow when friction test results are unacceptable. The policy should include requirements that describe the conduct of the friction-testing program, the actions that should occur for various friction test results, who specifically is responsible to take the prescribed action, and the time limit for the action to be taken.

Most agencies are currently using many of the corrective actions that are applicable to low-friction areas. Signing can be erected almost immediately and serves as a prompt interim action that can be taken until a more permanent correction can be made.

The corrective actions to be taken at an accident location should be developed by a multidisciplinary team considering roadway geometrics, traffic flow and performance, and pavement surface properties. The most cost-effective actions can then be scheduled for the site.

Some of the permanent pavement surface improvements include grinding and grooving concrete surfaces. These procedures demonstrated remarkable accident-reduction potential. Milling, seal coats, or surface treatments have been used to correct asphalt pavement surfaces. The use of carefully designed and constructed open-graded friction courses has proved to be a positive surface correction. Normal resurfacing is also a positive correction action, provided that all of the requirements for materials and construction are employed to obtain adequate new-pavement friction properties.

Periodic training for personnel and policy reviews are important activities that are not now generally included as part of wet-pavement safety programs. The various personnel involved in the coordinated program activities should receive training in an annual effort to maintain skill and teamwork in program execution.

CHAPTER EIGHT

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

- All of the agencies reporting have an accident record system.
- There is no uniformity in the functional assignment of the responsibility for maintaining the accident record system among the agencies.
- There is no agreement about who should report accidents or about which accidents should be reported.
- Even when police officers are involved in reporting accidents, only about two-thirds of the agencies' reports include information on probable causes or contributing factors. For example, tire conditions are noted only about half the time.
- About half the agencies reported accuracy for accident location between $1/10$ and $1/100$ mile, using variations of a milepost system or log miles. Other agency replies to questions about accuracy indicated varying degrees of uncertainty or very little confidence in or awareness of the accuracy.
- The replies indicated that the time periods for accident data entry into data systems varied from one agency entering "on-time," to delays up to one year, to annual entry. The majority of the agencies enter accident data in periods ranging from one month to six months.
- Vehicle inspections are required annually by only 24 of the agencies responding.
- Fifty-three of the reporting agencies have friction-testing programs. The reporting agencies operate 72 friction testers. A good many of the agencies perform friction tests for local or other agencies within their state or province. There are some variations in the utilization of friction test results, in the policies and procedures employed, in the requirements for action to be taken, and in the form of action.
- Virtually all the agencies calibrate their testers, but the time periods vary widely for most agencies from weekly to yearly. Most agencies send their testers to national calibration sites at one- to three-year intervals.
- A majority of the agencies test at 40 mph using ribbed tires. A significant number of states test at speeds other than 40 mph. Some agencies correct their results to report at 40 mph using speed gradients or they use custom-developed correction curves. Others report results with the test speed noted.
- Very few agencies adjust friction test results for seasonal effects. About half of the agencies test all year and the rest limit testing to the spring-summer-fall period.
- There is no consistency among agencies about who is responsible for friction testing.
- Nearly all agencies perform friction testing for wet-pavement inventory purposes, and two-thirds of the agencies test for research purposes.
- The criteria used to evaluate test results have little uniformity, but policies for action do exist in 60 percent of the agencies.
- Threshold and action point values established for friction test results by the agencies also vary widely. Only 10 agencies have designated time periods that apply to taking corrective actions.
- There is a wide range in the replies to questions concerning tort liability. A few states reported a relatively high number of cases involving considerable money, whereas 13 agencies reported that no suits have been encountered to date.
- There is a relatively low level of reported research activity in the wet-pavement accident area or pavement friction area. Much of the activity under way is of the monitoring or experimental type.
- Fewer than 10 percent of the agencies reported that they had participated in conferences that included information on accidents or pavement friction in the past three years.

RECOMMENDATIONS

- Efforts should be made to improve the quality of the data in the accident-reporting systems. More consistent requirements should be established for accidents that must be reported and for the contents of the accident reports, which should improve the reliability of the data base.
- Accident reports should contain fairly specific location data within 0.01 mile, so that pavement friction tests and on-site locations are made in the right place. The location data are also a factor in determining where unusually high numbers of accidents are happening. Studies should be undertaken to determine the requirements for adequate location referencing systems to improve accident data.
- There has been little implementation or technology transfer effort in the past three years. Efforts have continued to improve pavement surface technology, construction techniques, and materials. Timely seminars and training to continue a high level of technology in wet-pavement accidents and pavement friction should be planned and held. There should also be more emphasis on making drivers aware of the need for extra caution in wet-weather driving.

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APPENDIX A

SURVEY OF PRACTICE

1. Reply by State or Agency

2. Prepared by:
   - Subject Area:
   - Name:
   - Title:
   - Phone No:

3. Accident Records
   - a. Does your state have an accident-reporting system?
   - b. Where is the function responsible for maintaining accident records located within the agency?
   - c. What accidents must be reported?
   - d. Who must file accident reports?
   - e. Is weather and pavement condition (wet or dry) at time of accident included in accident report?
   - f. Are accident probable causes recorded?
   - g. Are vehicle tire conditions reported and recorded?
   - h. How are the locations of accidents recorded in the system?
   - i. What is the accuracy of accident location reporting?
   - j. How timely is the entering of accident information into the system?

4. Vehicle Inspections
   - a. Is there a requirement for periodic vehicle inspections?
   - b. What are the time periods?
   - c. Are minimum tire tread depths required?
   - d. What are the minimum depths?

5. Friction Testing
   - a. Does your state have a pavement friction (skid) testing program?
   - b. How many and what type of friction testers do you operate?
   - c. Do you test in accordance with ASTM procedures?
     - (1) Do you calibrate your equipment?
     - (2) At what interval do you calibrate?
     - (3) Have you had your equipment to national calibration centers (Texas, Ohio)?
     - (4) At what interval?
     - (5) Do you perform tests at various speeds?
     - (6) Do you test with ribbed tires?
     - (7) Do you test with bald tires?
   - d. Do you perform tests throughout the year or at other time periods?
     - (1) Do you adjust friction test results for season?
     - (2) Do you adjust friction test results for speed?
     - (3) What is your basis for adjustments?
   - e. Do you perform friction tests for local agencies or other agencies?
   - f. Where is the function responsible for friction testing located in your agency?
   - g. Do you perform friction tests for purposes of:
     - Wet-weather accidents?
     - Pavement inventory?
     - Research efforts?
     - New-pavement acceptance?
     - Other purposes?
   - h. What criteria are used to evaluate friction test results?
   - i. Do you have a policy or procedure to take action as a consequence of friction test results?
   - j. At what thresholds, and what actions are taken?
   - k. Are time periods used to control actions taken?

6. Pavement Surfaces
   a. Are actions to address pavement surfaces required as a result of friction test results?
   b. What types of pavement surface actions are taken:
      Signing?
      Grooving?
      Seal Coat/Surface Treatment?
      Resurfacing?
      Grinding?
      Milling?
      Other?
   c. Are friction properties a consideration in the construction of new-pavement surfaces?
   d. How are bituminous pavement surfaces designed and constructed with friction properties?
   e. How are concrete pavement surfaces designed and constructed with friction properties?
   f. What functions within your state are responsible for pavement surface friction properties?
   g. Have pavement surfaces been evaluated for friction properties when new?
   h. Have before-and-after accident analyses been done when pavement surface actions have been taken?
   i. What results were obtained?
   j. Have accident analysis studies done before and after included economic analysis?
   k. What results were found?

7. Tort Liability
   a. Has there been litigation as a result of wet-weather accidents?
   b. Are these a significant problem?
   c. What have been the results in settlements to date?
   d. Are legal measures (laws and regulations) provided to protect the state against litigation?
   e. Do these measures protect against state negligence?

8. Research Activities
   a. Have there been wet-weather safety-related research activities in your state?
      In wet-pavement accidents
      Friction testing
      Pavement surface friction
   b. Have you released any research reports in the last five years?
   c. Is there currently any research under way?

9. General Information
   a. What is your feeling regarding the problem of wet-weather accidents and what general remarks or recommendations would you like to give?
   b. Do you feel some areas require additional investigation?
   c. Specific subjects?
   d. Has your state participated in or held any recent (last three years) accident or pavement friction conferences?
   e. Would you please forward any literature or publications that are available that would provide more elaboration for the responses to the questions?

APPENDIX B

SUMMARY OF QUESTIONNAIRE RESPONSES

Agency	Accident Records[a] Responsible Organization	Reported Accidents	Who Files Report	Weather & Pavement Condition?	Probable Cause?	Tire Condition?	Accident Location?
Alabama	Dept. of Public Safety	PI or PD min. of $50	Dept. of Public Safety	Yes	Yes	Yes	MP on rural & Int.; link-node in cities & counties
Alaska	Dept. of Public Safety	PI or PD >$500	Driver or investigating officer	Yes	Yes	Yes, if contributing factor	Route & MP
Arizona	Traffic Studies Br.; Traffic Eng. Admin.	>$500	Law enforcement agencies	Yes	No	Only on fatal accident reports	MP nos. & road & street names
Arkansas	Arkansas State Police, Accident Records Section	All	Investigating officer	Yes	No, but first harmful event is.	Only if signs of distress are present	Route, sec., log mile, streets, dist. from intersection.
California	Traffic Eng., Hdq. Div.	All except PD-only under $500	Calif. Hwy. Patrol & contracted local law enf. depts.	Yes	Yes	If considered a causal factor by reporting officer	MP & direction
Colorado	Dept. of Revenue	PI or PD >$500	Investigating enforcement agency	Yes	No	No	MP for state system, addressing system for counties and cities
Connecticut	Bur. Planning Inventory & Data Div.	PI or PD >$600 to one individual	Police & all interested parties	Yes	Yes	No	Route and cumulative mileage
Delaware	Bureau of Traffic	PI or fatality or PD >$250	Local & state law enforcement	Yes	Sometimes	Sometimes	MP on state roads
Florida	Dept. of Hwy. Safety & Motor Vehicles	PI or death, hit/run with damage,alcohol or drugs, veh. requires towing	Law enf. officer	Yes	Yes	Yes	County & city. Node nos. are entered but referencing system not maintained
Georgia	Office of Traffic Eng. & Safety	All	Police	Yes	Yes	Maybe	Mile log system
Hawaii	Traffic Branch, Traffic Safety Section	PD >$300	County police	Yes	If known or can be determined	Yes	Route MP or dist. & direction from reference
Idaho	Office of Hwy. Safety, Accident Records	PI or PD >$250	Investigating agency	Yes	Yes	Yes	Segment code & MP on state system; street code on local
Illinois	Div. of Traffic Safety	PI or PD >$250	Parties involved & police	Yes	No	No	Mile log or intersection
Indiana	Indiana State Police, Accident Records Sec.; IDOT Division of Traffic	All	State Police	Yes	Uncertain	Uncertain	Approx. position by mileage

[a]PD=property damage; PI=personal injury; MP=milepost

Agency	Accident Records[a]						
	Responsible Organization	Reported Accidents	Who Files Report	Weather & Pavement Condition?	Probable Cause?	Tire Condition?	Accident Location?
Iowa	Office of Driver Services, Motor Vehicle Division	PI or PD >$300	All drivers; and officers, if investigated	Yes	Yes	Only if officer reports as veh. defect	At or between nodes or MP
Kansas	Bur. of Trans. Planning	>$500	Local auth. or Hwy. Patrol	Yes	Yes	Not normally	Route, county, sec., distance
Kentucky	Div. of Traffic	PD $200 or more	Police agency	Yes	Various factors reported	Only if contributing	County, route, MP
Louisiana	Dept. of Public Safety (State Police)	All	State Police	Yes	In certain cases	Yes	Route, MP
Maine	Bureau of Planning	PI or death or PD >$300 combined	Drivers & investigating officers	Yes	Yes	No	Node-link
Maryland	SHA, Off. of Traffic, Bur. of Accident Studies	None, but police report fatal, PI, & towed vehicle	None	Yes	Yes, generally	No	Log mile
Massachusetts	Dept. of Public Safety, Registry of Motor Veh.	PI & PD >$1000	Operator	Yes	Operator opinion	No	Nearest landmark
Michigan	Dept. of State Police	PI or death or PD >$200	Driver involved	Yes	Yes	No	Reference to intersections, RR, boundary
Minnesota	Dept. of Public Safety	PI or PD >$500	Persons involved	Yes	Yes	No	MP
Mississippi	Transportation Planning Div.	PI or PD >$200	Drivers involved & investigating officer	Yes	Yes		Mile marker & intersection
Missouri	Dept. of Hwys. & Transportation	All on state hwy. system	Police	Yes	Yes	No	County, route, log mile
Montana	Dept. of Justice, Hwy. Patrol	Fatal, PI, or PD >$250	Investigating officer and drivers	Yes	Yes	No	Yes
Nebraska	Highway Safety Division	Fatal, PI, or PD to one party >$500	Investigating officer and drivers	Yes	No. Contributing circumstances indicated	Optional	Route and ref. post or by city
Nevada	Safety Engineering	PD >$350	All drivers involved	Yes	Yes	No	MP and street reference
New Hampshire	Dept. of Safety and DOT Acc. Statistics Group	PI or PD >$500 combined	Drivers or veh. owners	Yes	Only on police report	Only on police report if a factor in acc.	Actual location
New Jersey	Bureau of Accident Records	Fatal, PI, or PD >$500	Police	Yes	Contributing circumstances	Sometimes	Route, MP, direction

[a]PD=property damage; PI=personal injury; MP=milepost

	Accident Records[a]						
Agency	Responsible Organization	Reported Accidents	Who Files Report	Weather & Pavement Condition?	Probable Cause?	Tire Condition?	Accident Location?
New Mexico	Planning Bureau	All	Law official	Yes	Yes	Yes	System by MP
New York	Dept. of Motor Vehicles	Fatal, PI, or PD >$600	Police and driver	Yes	Yes	Sometimes	State ref. nos., local link node
North Carolina	Div. of Motor Veh., Traffic Records Sec.	Fatal, PI, or PD >$500	Police	Yes	Yes	Yes	County, road, MP
North Dakota	Drivers License Division	Fatal, PI, or PD >$600	Drivers	Yes	Yes	Optional	MP or county or city nodes
Ohio	Dept. of Hwy Safety, Acc. Records Sec.	Fatal, PI, or PD >$150	Police and drivers	Yes	Yes	Sometimes	Mileage log point, nearest cross route
Oklahoma	Dept. of Public Safety, Traffic Eng. Division	Fatal, PI, or PD >$300	Police and drivers	Yes	Yes	Sometimes	Reference point
Oregon	Traffic Eng. Section	Fatal, PI, or PD >$400	Drivers	Yes	Yes	No	Route and MP
Pennsylvania	Center for Hwy. Safety	Fatal, PI or vehicle towed	Police or drivers	Yes	Yes	Sometimes	
Rhode Island	Planning Division	Fatal, PI, or PD >$300	Driver	Yes	No	No	Reference to intersections
South Carolina	Div. of Admin., Hwy. Safety Off., Traffic Records Sec.	Fatal, PI, or PD >$200	Investigating officer or driver with insurance co. verification	Yes	Yes	No, unless considered a contributing factor	MP on state; grid for counties and cities
South Dakota	Planning Div., Office of Local Asst., Acc. Records Sec.	Fatal, PI, or PD $500 per person or $1000 per accident	Investigating officer	Yes	Yes	No, unless considered a contributing factor	MP on state trunks, coordinates on others
Tennessee	Planning Div.	All >$250	Enforcement agencies	Yes	Yes	Sometimes	County, route, log mile
Texas	Transp. Planning Div.	Fatal, PI, or PD >$250	Driver or law enforcement agency	Yes	Yes	Only if considered defective	County, route, control sec., MP
Utah	Div. of Safety	PI or PD >$400	Investigating agency	Yes	No	Yes, if defective	State route, MP
Vermont	Planning Div.	PD >$500	Police and drivers	Yes	Yes	If defective	Route, town. MP
Virginia	Traffic Eng.	PI or PD >$500	Police	Yes	Not specific	No, but can be veh. defect	Paper MP
Washington	Safety Data Off.	PI or PD >$500 combined	Investigating officer and drivers	Yes	No	Yes	Alphanumeric code and MP

[a]PD=property damage; PI=personal injury; MP=milepost

Agency	Accident Records[a]: Responsible Organization	Reported Accidents	Who Files Report	Weather & Pavement Condition?	Probable Cause?	Tire Condition?	Accident Location?
West Virginia	Traffic Eng. Div.	Fatal, PI, or PD >$250	Police and operator or owner	Yes	Contributing	No	County, route, MP; city street or intersection
Wisconsin	Div. of Motor Vehicles	Fatal, PI, or PD $500 per vehicle	Police or drivers	Yes	Yes	Yes	Route and distance from intersection
Wyoming	Highway Safety Branch	PI or PD $500	Drivers and investigating officer	Yes	Yes	No, but can be	Rural MP, urban coordinates
District of Columbia	Bur. of Traffic, Traffic Safety Division	PI or fatality or towed vehicle	Police. Also, veh. owners file insurance forms >$200 damage	Yes	Yes	No	
Virgin Islands	Dept. of Public Safety	All	Dept. of Public Safety	Yes	Yes	Sometimes	Road name and MP
Alberta	Transp. Safety Branch	Fatal, PI, or PD >$500	RCMP	Surface Yes, weather No	Partially	No	Distance to key point
Nova Scotia	Traffic Division	All >$500	Drivers involved	Yes	Yes	Yes	Paper MP
Ontario	License and Control Branch	Fatal, PI, or PD >$700	Police	Yes	No, but condition recorded	Yes	Linear using bridges and intersections
Saskatchewan	Traffic Safety Eng. Branch	PI, or PD >$500	Police	Yes	Yes	If contributing factor	MP

[a]PD=property damage; PI=personal injury; MP=milepost

	Vehicle Inspections				Friction Testing						
Agency	Required?	Time Period	Tread Depth Req.	Minimum Depth	Friction Testers	Calibration Interval	National Calib. Ctr.	Interval	Speeds Besides 40	Ribbed Tires Test	Bald Tires Test
Alabama	No				1 LWT	Monthly	Texas	2 yr	Rare	Yes	Sometimes
Alaska	No				Developing program						
Arizona	Emissions only	Annual			2 MuMeters	Weekly	Yes	10 yr	No	No	Yes
Arkansas	Yes	Annual	No		1 KJ Law, 1 U. Ark.	Weekly	No		No	Yes	No
California	No				1 KJ Law, 2 Cox, plus portables	6 mo.	Texas	2 yr	Yes	Yes	Special only
Colorado	Emissions only	Annual	No		1 KJ Law	Annually	No (planned)	2-3 yr	No	Yes	No
Connecticut	No		Yes	1/16	1 LWT	Annually	Yes	2 yr	No	Yes	Sometimes
Delaware	Yes	Annual	Yes		1 Soiltest	Annually	Ohio	2 yr	Yes	Yes	No
Florida	No				4 KJ Law	30-45 days	Yes	2 per year	Sometimes	Yes	Sometimes
Georgia	No				2 Soiltest	Annually	Yes	Infrequent	Special studies (30 and 50 mph)	Yes	Yes (texture study)
Hawaii	Yes	Pvt.-annual Comm.-6 mo.	Yes	1/16	1 KJ Law	6 mo.	Texas	4 yr	No	Yes	No (special studies)
Idaho	No				1 LWT	Weekly	Yes	5 yr	Yes, calibrated under 40 for urban	Yes	No
Illinois	No		No		2 AASHTO	Monthly	Yes	2-3 yr	Infrequent	Yes	Yes
Indiana	No				2 FMC	Monthly Daily Annually	Ohio	Annually	Yes	Yes	Planning
Iowa	No		Yes	1/16	2 KJ Law	Weekly	Yes	3 yr	Yes	Yes	Yes
Kansas	No				2 KJ Law	Annually	Texas	2 yr	Yes, 55	Yes	No
Kentucky	No				1 KJ Law	Annually	Ohio	3 yr	Yes, 25 and 50	Yes	No
Louisiana	Yes	Annual	Yes	3/32	1 LWT	Annually	Texas	Annually	No	Yes	No
Maine	Yes	Annual	Yes	3/32	1 LWT	Annually	Yes	Not specific	No	Yes	No
Maryland	Emissions only	Annual	Yes, at resale	1/16	2 KJ Law	Monthly	Ohio	Annually	Yes (special)	Yes	Yes (special only)
Massachusetts	Yes	Annual	Yes	1/16	1 KJ Law	Annually	Yes	2-3 yr	Yes	Yes	No
Michigan	No		Yes	1/16	2 LWT	Annually	Ohio	Annually	Yes, 20	Yes	Sometimes
Minnesota	No				2 KJ Law	Variable	Texas	2 yr	Yes, 55	Yes	No

	Vehicle Inspections				Friction Testing						
Agency	Required?	Time Period	Tread Depth Req.	Minimum Depth	Friction Testers	Calibration Interval	National Calib. Ctr.	Interval	Speeds Besides 40	Ribbed Tires Test	Bald Tires Test
Mississippi	Yes	Annual	Yes	0.004	1 KJ Law	6 mo.	Texas	Annually	Yes, 20, 30, 50	Yes	No
Missouri	Yes	Annual	Yes	Visible tread pattern	1 KJ Law	Monthly	Texas	3-6 yr	Yes, 55 and other special	Yes	No
Montana					1 KJ Law	As needed	Texas		No	Yes	No
Nebraska	No				1 KJ Law	Annually	Texas	2 yr	Yes	Yes	Exp. or res. only
Nevada	Emission in some areas	Annual	No		1 KJ Law, 1 Cox	Annually	Texas	2 yr	Yes	Yes	No
New Hampshire	Yes	6 mo. if >6 yr; 12 mo. if <6 yr	Yes	1/16	1 LWT	Annually	Yes	Not specific	No	Yes	No
New Jersey	Yes	Annual	Yes	1/16	3 Stevens Inst.	Annually	Ohio	Annually	Yes	Yes	No
New Mexico	No				1 KJ Law	Daily	Texas	2 yr	No	Yes	No
New York	Yes	Annual	Yes	2/32	1 KJ Law, 1 in-house	Bimonthly	Ohio	2 yr	Yes, prevailing limit	Yes	Special only
North Carolina	Yes	Annual	Yes	4/32	2 KJ Law, 1 in-house	Law, 2 yr; in-house, monthly			No		Yes
North Dakota	No					Contract with testing agency			No		
Ohio	Random		Yes	2/32	3 KJ Law	Daily (on-board system)	Ohio	Annually	Yes, 20	Yes	No
Oklahoma	Yes	Annual	Yes	2/32	1 LWT	Quarterly	Yes	5-10 yr	No	Yes	No
Oregon	No		Yes	2/16 steering 1/16 other	1 KJ Law	Twice during summer	Yes	When new	Yes, 20	Yes	No
Pennsylvania	Yes	Annual	Yes	1/16	3 KJ Law	Monthly	Yes	Various	Yes, 25	Yes	No
Rhode Island	Yes	Annual	Yes	1/16	1 KJ Law	Unknown	Yes	Unknown	Yes	Yes	No
South Carolina	Yes	Annual	Yes	1/16	2 KJ Law	6 mo.	Ohio	3 yr	No	Yes	No
South Dakota	No				1 KJ Law	Twice during summer	Texas	2 yr	No	Yes	No
Tennessee	No				2 KJ Law	Annually	Ohio	2 yr	Yes	Yes	No
Texas	Yes	Annual; new cars 2 yr	Yes	3/32	4 LWT	Annually	Yes	4 yr	No	Yes	No

	Vehicle Inspections				Friction Testing						
Agency	Required?	Time Period	Tread Depth Req.	Minimum Depth	Friction Testers	Calibration Interval	National Calib. Ctr.	Interval	Speeds Besides 40	Ribbed Tires Test	Bald Tires Test
Utah	Yes	Annual	Yes	4/32	1 LWT	6 mo.	No		No	Yes	Yes
Vermont	Yes	Annual	Yes	3/32	Contract with FHWA	2-3 yr	Yes	2-3 yr	Yes	Yes	No
Virginia	Yes	Annual	Yes	2/32	2 KJ Law	Monthly	Ohio	2 yr	Yes	Yes	Yes
Washington	No		Yes	3/32	1 Cox	Quarterly	Texas	2 yr	Yes	Yes	No
West Virginia	Yes	Annual	Yes	1/16	1 KJ Law	Annually	Ohio	Annually	Yes, 25, 55	Yes	No
Wisconsin	No		No		1 Soiltest	1.5 mo.	Texas, Ohio	As needed	Yes	Yes	No
Wyoming	No				1 KJ Law	Annually	Texas	2 yr	No	Yes	No
District of Columbia	Yes	Annual	Yes	2/32	1 KJ Law (FHWA)				Yes	Yes	No
Virgin Islands	Yes	Annual	Visual								
Alberta	No		Yes	2/32	1 MuMeter	Weekly	No		No	No	Yes
Nova Scotia	Yes	Annual			1 in-house	After each investigation	No		No	Yes	No
Ontario	No		Yes	1/16	1 KJ Law		Ohio	6 mo.	Yes	Yes	No
Saskatchewan	No				1 LWT	Annually	No		Yes	Yes	No

Agency	Friction Testing (continued)								
		Adjustment of Test Results			Purpose of Friction Testing				
	Test Period	For Season	For Speed	Basis[a]	Wet-Weather Accidents	Pavement Inventory	Research	New Pavement Acceptance	Other
Alabama	All year	No	Yes	S.G. or assumption	No	Yes	Yes	No	Special request
Alaska									
Arizona	All year	No	No		Yes (special request)	Yes	Yes	Rarely	
Arkansas	All year (>40°F)	No	No		Yes	Yes	Yes	Not routinely	
California	All year	No	Yes	Correlation with 40 mph	Yes	Yes	Yes	Yes (portable units)	Bridge decks (portable units)
Colorado	Spring through fall	No	No		Yes	Yes	Yes	Yes	
Connecticut	All year	Noted	Yes	Assume S.G. (0.5)	Yes (by request)	Yes (dis-continued)	Yes	Yes	No
Delaware	All year	No	No		Yes	Yes	Yes	No	
Florida	All year	No	No		Yes (by request)	Yes	Yes	Yes	
Georgia	All year	No	No		Yes	Yes	Yes	Yes (no min. established)	Aggregate test section
Hawaii	All year	No	No		Yes	Yes	Yes	No	Litigation
Idaho	Inventory time	No	Yes	Calibrate back to 40 mph	Yes (by request)	Yes	No	No	
Illinois	All year (>40°F)	No	Yes	Actual S.G. or 0.5	Yes	Yes	Yes	Yes (not for acceptance)	
Indiana	All year	Yes	No	b	Yes	Yes	Yes	No (except special cases)	
Iowa	May - Oct.	No	No		Yes	Yes	Yes	No	
Kansas	April - Nov.	No	No		Yes	Yes	Yes	No	New pav't. evaluation
Kentucky	July - Oct.	No	No		Seldom	No	No	No	Det. perf. of surface courses
Louisiana	All year	No	No		Yes	HPMS	Yes	No	Materials related
Maine	Spring, summer, fall	No	No		No	Once	Yes	No	
Maryland	All year (>40°F)	No	No		Yes	Yes	Yes	No	

[a]S.G. = speed gradient

[b]FHWA/IN/RTC 82/1 "Seasonal Variations Study"

	Friction Testing (continued)								
		Adjustment of Test Results			Purpose of Friction Testing				
Agency	Test Period	For Season	For Speed	Basis[a]	Wet-Weather Accidents	Pavement Inventory	Research	New Pavement Acceptance	Other
Massachusetts	April - Dec.	Yes	No	Mass. seasonal research	Yes	Yes	Yes	No	
Michigan	May - Oct.	No	Yes	Correlations	Yes	Yes	Yes	No	
Minnesota	April - Oct.	No	No		Yes (by request)	Limited	Yes	No	Evaluate mix design
Mississippi	All year	No	No		Yes	Yes	Yes	No	
Missouri	March - Nov.	No	Yes	S.G.	Yes (special)	Yes	Yes (special)	No	
Montana	Summer	No	No		Yes	Yes	Yes	Yes	
Nebraska	April - Nov.	No	No		Yes (research)	Yes	Yes	No	
Nevada	Spring, summer, fall	No	Yes	ARS equations	Yes	No	Yes	No	
New Hampshire		No	No		No	Yes	Yes	No	
New Jersey	March - Dec.	No	Yes	S.G. (0.5)	Yes	Yes	Yes	No	Yes
New Mexico	All year	No	No		Sometimes	Yes	Yes	No	
New York	April - Dec.	No	Sometime.	Actual S.G. or 0.5	Yes	Yes	Yes	No	Yes
North Carolina	All year	No	No		Yes	Yes	No	No	No
North Dakota					Yes	No	Yes	Yes	High acc. locations
Ohio	All year (>32°F)	No		Use eq. from national calibration	Yes	Yes	Yes	No	
Oklahoma	All year	No	No		Yes	No	Periodically	No	No
Oregon	All year	No	Yes	Regression analysis on test section	Yes	Yes	Yes	No	Yes
Pennsylvania	May - Nov.	No (time noted)	No (report speed)	If done use S.G.	Yes	No	Yes	No	Yes
Rhode Island	Spring, summer, fall		Yes		Yes	Yes	No	No	No
South Carolina	All year	No	No		Yes	Yes	Yes	No	
South Dakota	May - Sept.	No	No		Yes	Yes	Yes	Yes	
Tennessee	April - Nov.	No	No		On request	Yes	Yes	No	

[a]S.G. = speed gradient

[b]FHWA/IN/RTC 82/1 "Seasonal Variations Study"

Agency	Friction Testing (continued)								
		Adjustment of Test Results			Purpose of Friction Testing				
	Test Period	For Season	For Speed	Basis[a]	Wet-Weather Accidents	Pavement Inventory	Research	New Pavement Acceptance	Other
Texas	All year	No	No		Yes (on request)	Yes (some districts)	Yes	No	
Utah	March - Nov.	No	No		Sometimes	Yes	Yes	No	
Vermont		No	Yes	S.G.	Yes	Yes	Yes	Yes	Lawsuit sites
Virginia	All year (>40°F); WPS April - Aug.	Yes	Yes	Correlation testing	Yes	Yes	Yes	No	Bridge decks
Washington	All year	No	Yes	S.G.	No	Yes (special request)	Yes	Yes (transition only)	
West Virginia	All year	No	Yes	To standardized speeds	Yes	Yes	Yes	Yes	
Wisconsin	May - Oct.	No	No		Yes	Yes	Yes	No	Maintain math. model of FN over time
Wyoming	May - Oct.	No	No		No	Yes	No	No	
District of[b] Columbia					Yes	Yes	Yes	No	
Virgin Islands									
Alberta	May - Sept.	No	No			Yes	Sometimes	No	
Nova Scotia	All year	No	No		Yes	Sometimes	No	No	Examine bleeding sections
Ontario	All year	No	Yes	S.G.	Yes	Yes	Yes	No	
Saskatchewan	May - Oct.	No	Yes	Adjust to 40 mph	No	No	Yes	No	Bridge decks

[a]S.G. = speed gradient

[b]FHWA/IN/RTC 82/1 "Seasonal Variations Study"

Agency	Friction Testing (continued) Criteria to Evaluate Tests	Policy or Procedure to Take Action	Thresholds and Actions	Time to Take Action
Alabama		Not specifically		No
Alaska				
Arizona	Test results below 43 MuMeter number are highlighted for review.	Low friction areas are reviewed to determine need and feasibility of possible actions.	No specific policy established.	May depend on when next overlay is scheduled.
Arkansas	Skid number	Districts are informed of sections with low skid values.	For sections with low skid numbers, skid-resistant resurfacing is considered.	No
California	Office of Traffic Safety notified when SN_{40} is below 30.	Examine accident records and site geometry, then take appropriate action.	Varies	No
Colorado	SN_{40} of 35 or less.	Notify districts.	Advise districts of dangerous areas.	No
Connecticut	Accidents, pavement surface, geometrics, bald tire tests, etc. No official min. but SN_{40} below 35 and bald below 25 are suspicious.	Notify requesting agency but no recommendations.	Based on a number of factors including SN; better signing, or overlay may be done.	Agencies are alerted to seasonal or short-term variations.
Delaware	Traffic volumes, geometry, SN_{40}.	No written policy.	Minimum SN is 35. Action taken is a function of pavement type, geometry, traffic volume, and SN.	Not usually.
Florida	Speed limit above 45 mph, FN 45 or less.	Action taken on combination of FN and accident rates.		
Georgia	Results are shown as SN_{40} below 30, 35, & 40.	Notify traffic and Safety Office and district. SN and accidents are factors in scheduling.	SN_{40} less than 35.	No
Hawaii	Not determined.			
Idaho	Change or range in numbers.	Yes	At 35 section is listed. At 30 section is recommendable.	No
Illinois	Less than FN_{40} = 35.	FN results are part of review.		
Indiana	Trends from past data and 30 as a minimum friction number.	Yes	FN_{40} = 30	One month
Iowa	Pavement Friction Review Committee for sections with SN greater than 37 with some below 30 and equal to or less than 37.	Recommend improvement.	See Appendix C.	
Kansas	Present SN results satisfactory	No		
Kentucky	Transp. Res. Rec. 633	Action taken if conditions are deemed unacceptable.		No
Louisiana	SN equal to or over 35 for new construction.	Action to SC/ST, sign, or resurface in extreme cases	Not clearly established (below SN 30 with high ADT).	No

Friction Testing (continued)

Agency	Criteria to Evaluate Tests	Policy or Procedure to Take Action	Thresholds and Actions	Time to Take Action
Maine	Results are presented to the requester with an informal opinion.	No		
Maryland	FN > 40 - acceptable FN = 35 to 40 - marginal FN < 35 - remedial action	Not directly	FN > 40 - acceptable FN = 35 to 40 - marginal FN < 35 - remedial action	No
Massachusetts	Minimum FN of 33 at 40 mph.	No	No minimum FN required.	No
Michigan	Comparison with past results.	Yes	Special attention given to investigate surfaces with SN at 30 or below.	Yes
Minnesota		Yes (Chief Engineer memo)	Consider corrective measures with SN below 35 or 40.	No
Mississippi	No set criteria; depends on test purpose.	If SN low, notify district.	No thresholds	No
Missouri	No set criteria.	Review sections with low FN, accident history.	No set FN	No
Montana	Comparisons statewide	No	FN 35 and above	
Nebraska		Systematic action to sign low FN sections.	Sign at FN below 35.	Signs put in place until FN is acceptable.
Nevada	Corrected FN threshold values.	Yes	FN 37 - evaluate to determine if increased FN needed.	No written policy.
New Hampshire	Pass-Fail	Failing locations are reported to district maintenance engineer.	Surfaces below SN 35 are treated.	No
New Jersey	NCHRP Report 37	See Appendix C.		No
New Mexico				
New York	Relative comparisons - no specific friction number applied.	No; however, regional traffic and safety engineers take action based on accidents, geometry, and site investigations, which might include SN.		
North Carolina	NCHRP Report 37 (FN 37 at 40 mph).	Signing	Below 37	No
North Dakota	Unknown at this time.	Not yet formulated.	Not yet formulated.	Not yet formulated.
Ohio	Below 30 - poor; 30 to 40 - adequate, depending on traffic and geometry; over 40 - satisfactory	No established policy.	Some type of correction likely where SN = 30.	No
Oklahoma		No		
Oregon	NCHRP Report 37 (see Appendix C).	Yes	Generally at FN_{40} of 37 or less.	No

Agency	Friction Testing (continued) Criteria to Evaluate Tests	Policy or Procedure to Take Action	Thresholds and Actions	Time to Take Action
Pennsylvania	Yes; scaled to traffic and accidents.	Yes	Various	Yes
Rhode Island	Yes (see Appendix C).	Yes	Various	Earliest possible date.
South Carolina	NCHRP Report 37	Yes	If SN is below 37 and there is a high incidence of wet accidents, then investigate further.	No
South Dakota	Action taken below FN 31.	Yes	Action taken below FN 31.	
Tennessee	Above FN 35 - acceptable; FN 30 to 35 - questionable; below 30 - unsatisfactory.	Results are monitored as one of the factors in decision to take corrective action.	Above FN 35 - acceptable; FN 30 to 35 - questionable; below 30 - unsatisfactory.	No
Texas	Each user makes own analysis of the data.	No	No set values.	No
Utah	Less than 35 - unacceptable; 35 to 45 - marginal; greater than 45 - acceptable.	District offices are notified if unacceptable SN values are found.	Signing at 35 until surface is treated.	No
Vermont	Monitor area if SN is 40 or above; inform proper personnel of problem when SN is below 30.	Yes		Yes
Virginia	Based on bald tire FN_{40} minimum of approximately 20.	Yes	Based on bald tire FN_{40} minimum of approximately 20.	No; however, conditions are generally corrected 12-18 months after tests.
Washington	As an indicator.	Unwritten policy; districts are notified of all tests and tests under 35 are highlighted.	Districts responsible to take action if necessary.	No
West Virginia	Varies with purpose of test.	Yes	On bituminous pavement - FN below 40.	No
Wisconsin		Yes, if wet-weather accident site.	If wet accident ratio is over 50% and number of wet accidents is over 5 per quarter mile.	No
Wyoming	FN below 35 considered less than acceptable.	FNs reported to district maintenance engineers for action.	If FN is below 35, apply resurfacing or chip seal.	
District of Columbia	NCHRP Report 37	No		
Virgin Islands				
Alberta	Experience and when FN reaches certain critical levels.		Notify regions to take maintenance action.	No
Nova Scotia		Yes, depending on class of roadway.	See Appendix C.	No
Ontario		No		
Saskatchewan	Critical FN of 37	No		

Agency	Pavement Surfaces[a,b]: Actions Required as Result of Friction Test?	Type of Actions Taken	Friction Considered in New Pavements?	Bituminous Surface Designs for Friction	Concrete Surface Designs for Friction	Have New Surfaces Been Friction Tested?	Before-and-After Analyses for Surface Actions?	Results of Before-and-After Analyses
Alabama	Not necessarily	Sign, resurface, seal coat	To a degree	Use siliceous aggregates	Tine finish	Rarely; include in regular inventory	Not necessarily	
Alaska	In process of developing and implementing a program to evaluate skid resistance.							
Arizona	Yes	Sign, groove, mill, SC/ST, resurface	Yes	Surface types must have known history	Wire tine finish	Yes	Yes	Wet accident rates
Arkansas	No, but results are factor in programming improvements.	Sign, groove, grind, mill, SC/ST, resurface	Yes	Skid-resistant surface	Texture	Yes	No	
California	Yes	Sign, groove, SC/ST, resurface	Yes		FN of 0.3 specified	Yes	Yes	Longitudinal grooves and OGFC reduced wet accidents up to 70%.
Colorado	Yes	Sign, SC/ST, resurface	Yes	OGFC with rubberized AC	Transverse grooving	Yes	Yes	Friction improved
Connecticut	Yes	Sign, groove, mill, SC/ST, resurface	Yes	More use of OGFC	Transverse tining and burlap drag	Yes	Occasionally	Several areas show considerable decrease in accidents
Delaware	Actions not mandated	Sign, groove, SC/ST, resurface	Not specified	Aggregate restrictions > 8000 ADT	Transverse tining	Yes, but not standard	Yes	Accident reduction verified
Florida	Upon safety engineer's rec.	Sign, resurface	Yes	Specify materials and gradation	Not a problem	Yes	Yes	Positive results
Georgia	Actions recommended but not required	Sign, grind, groove, mill, SC/ST, resurface	Yes; frequent tests during construction	Aggregate restriction & mix design	Tine finish; aggregate restriction	Yes	Yes	Reduction in wet accidents after action
Hawaii	No	Groove	No		Tine finish	Yes	No	
Idaho	No	Sign, SC/ST, resurface	Not as a general rule	None; has not been a problem	Tine finish	Yes, during inventory	By request	

[a]SC/ST = seal coat or surface treatment

[b]OGFC = open-graded friction course

	Pavement Surfaces[a,b]							
Agency	Actions Required as Result of Friction Test?	Type of Actions Taken	Friction Considered in New Pavements?	Bituminous Surface Designs for Friction	Concrete Surface Designs for Friction	Have New Surfaces Been Friction Tested?	Before-and-After Analyses for Surface Actions?	Results of Before-and-After Analyses
Illinois	No; actions based on SN		Yes	High friction aggregates for various ADTs	Tining and Astroturf	Yes (not for acceptance)	Yes	Histories
Indiana	Yes	Sign, grind, groove, mill, SC/ST, resurface, other	Yes	Aggregate type and voids		Yes		
Iowa	In some cases	Sign, grind, groove, SC/ST, resurface	Yes	Classify aggregates, use sprinkle treatments	Transverse tining	Yes	In some cases	Accidents reduced
Kansas	No		Yes	Add special aggregates or OGFC with sp. aggr.	Tining	Yes	No	
Kentucky	Yes	Sign, resurface	Yes	Proven surface types	Coarse surface treatment	No	Not recently	Wet pavement accident correlation with friction
Louisiana	In extreme cases	Sign, groove, SC/ST, resurface	Yes	Minimum aggregate polish value	Surface finish, polish value of aggr.	Sample basis	Yes	See Appendix B
Maine	Not routinely	Resurface	Yes	Control of AC		Yes	No	
Maryland	None; regional by policy	Sign, groove, mill, SC/ST, resurface	Yes	Open-graded mixes	Tining or grooving	Sometimes	Limited	Results positive for correction of friction
Massachusetts	Yes	Sign, resurface, open-graded mix	No	Normally no problems		Yes		
Michigan	Yes	Sign, grind, groove, mill, SC/ST, resurface	Yes	Wear index for aggregates	Tining	Yes	Yes	Wet-pavement accidents reduced
Minnesota	Yes	Sign, resurface, texture planing	Yes	Type aggregate and crushing requirement for mix design	Tining	Yes	No	
Mississippi	Not solely on friction	Sign, mill, SC/ST, resurface	Yes	Gradation and crush count	Tining	Yes	No	

[a]SC/ST = seal coat or surface treatment

[b]OGFC = open-graded friction course

	Pavement Surfaces[a,b]							
Agency	Actions Required as Result of Friction Test?	Type of Actions Taken	Friction Considered in New Pavements?	Bituminous Surface Designs for Friction	Concrete Surface Designs for Friction	Have New Surfaces Been Friction Tested?	Before-and-After Analyses for Surface Actions?	Results of Before-and-After Analyses
Missouri	Friction and accidents	Sign, grind, groove, mill, SC/ST, resurface	Yes	Special aggregates and hard AC	Transverse wire comb	Yes, in some cases	Yes; all high hazards before and after	Must have a positive cost-benefit
Montana	No		Yes	Well-graded seal coat aggregates, open-graded mixes	Tining	Yes	Some	
Nebraska	If problems or very low friction	Sign, grind, mill, SC/ST, resurface	Yes	Aggregate and mix design	Various saw texture devices	Yes	Yes	Depends on action taken
Nevada	Yes	Sign, groove, mill, SC/ST, resurface, heat plane	Yes	OGFC	Tining	Yes	Yes	Improved skid resistance
New Hampshire	Yes	Sign, mill, SC/ST, resurface	Yes	Mix design		Yes	No	
New Jersey	No	Sign, grind, mill, resurface	Yes	Mix designs, construction practice	Mix designs, construction practice	Yes	Yes	Positive
New Mexico	Yes	Sign, SC/ST, resurface	No	OGFC	Tining	No	Yes	
New York	Only when high wet accident	Sign, grind, groove, SC/ST, resurface	Yes	Aggregate type	Tining	Yes, ongoing	Yes	Reduced accidents
North Carolina	Normally for low skid nos.	Sign, groove, SC/ST, resurface	No	Historical data	Tining	Yes	Yes	Wet accidents significantly reduced
North Dakota	No		No			Just starting	No	
Ohio	No	Sign, grind, groove, mill, SC/ST, resurface	No	OGFC	Grooving	By request	Yes	Reduced accidents
Oklahoma	No					Yes	No	
Oregon	No	Sign, grind, groove, mill, SC/ST, resurface	Yes	Quality graded aggregates, AC content	Tining	Yes	No	
Pennsylvania	Yes	Sign, grind, groove, SC/ST, resurface	Yes	Aggregate properties specified	Tining	Some	Yes	Positive

[a]SC/ST = seal coat or surface treatment

[b]OGFC = open-graded friction course

	Pavement Surfaces[a,b]							
Agency	Actions Required as Result of Friction Test?	Type of Actions Taken	Friction Considered in New Pavements?	Bituminous Surface Designs for Friction	Concrete Surface Designs for Friction	Have New Surfaces Been Friction Tested?	Before-and-After Analyses for Surface Actions?	Results of Before-and-After Analyses
Rhode Island	Yes	Sign, resurface	Yes	OGFC		No	No	
South Carolina	No, unless other circumstances	Sign, grind, groove, mill, SC/ST, resurface	Yes	Nonpolishing aggregates	Tining	Yes	No	
South Dakota	Yes	Sign, grind, groove, mill, SC/ST, resurface	Yes	Mix design		Yes	No	
Tennessee	Yes	Sign, groove, resurface	Yes	Acceptable aggregate	Tining	Yes, sometimes	No	
Texas	No	Sign, groove, mill, SC/ST, resurface	Yes	Correlation of materials and history	Tining	Yes, experimental	No	
Utah	No	Sign, grind, groove, mill	Yes	OGFC	Tining	Sometimes	Yes	Accidents reduced
Vermont	Yes	Sign, grind, SC/ST, resurface	Yes			Yes	Yes	Accidents reduced 47%
Virginia	Yes	Sign, groove, mill, SC/ST, resurface	Yes	No polishing aggregate	Transverse grooving	Sometimes	Yes	Improvements
Washington	Not required	Sign, groove, resurface	Yes	History, mixes	Tining	Yes	Special projects	Reduced accidents
West Virginia	Not required	Sign, resurface	Yes	Skid-resistant aggregate	Transverse grooving	Yes	Yes	Favorable
Wisconsin	If surface is a problem	Sign, grind, groove, mill, SC/ST, resurface	Yes	Open-graded mixes, experience	Tining	Yes	Yes	Accidents reduced up to 85%
Wyoming	Yes	Sign, groove, SC/ST, resurface	No		Tining	Only on inventory	No	
District of Columbia	Yes	Sign, SC/ST, resurface	Yes	Nonpolishing aggregates	Tining	Yes	No, but planned	
Virgin Islands			Yes	AC design	AASHTO design	No	Yes	
Alberta	Yes	Sign, groove, mill, SC/ST, resurface					No	
Nova Scotia	Yes	Sign, mill, SC/ST, resurface	No			No	No	
Ontario	Yes	Sign, resurface	Yes	OGFC	Tining	Yes	No	
Saskatchewan	No		No	Min. air voids		Yes	No	

[a]SC/ST = seal coat or surface treatment

[b]OGFC = open-graded friction course

APPENDIX C

TITLES, DATES, AND BRIEF SUMMARIES OF REPORTS RECEIVED WITH QUESTIONNAIRE RESPONSES

Literature submitted with questionnaire responses is listed by state, title, year published, and a brief summary or abstract.

California

"Evaluation of Friction Requirements for California State Highways in Terms of Highway Geometrics" by Bobby G. Page and Larry F. Butas, California Department of Transportation, Sacramento, January 1986.

Conclusions: Wet-pavement accident rates were low and uniform for pavements with SN of 26 and higher, but increased substantially for SN from 25 to 17.

Wet-pavement accident rates are greater on curves. Where SN is in the range of 17 to 25, they are 23 times greater than on tangent sections where SN is greater than 25.

Rates are greater on undivided than on divided highways. Rates are greater on grades of ± 3 percent or more, and are greater when ADT exceeds 15,000 VPD.

Recommendations

1. Need further research to check rates at SN = 25.
2. Need to demonstrate that improved surfaces will lower accident rates.

Illinois

1. "A Summary of the Illinois Skid-Accident Reduction Program, March 1984–August 1985" by John E. LaCroix, Illinois Department of Transportation, Bureau of Materials and Physical Research, Springfield.

Conclusions: From the results of this evaluation, it is concluded that Illinois's Departmental Policy TRA-16 is addressing the reduction or elimination of cluster sites. It is shown that:

- Twenty-two percent of all accidents occur on wet pavements. Four percent of all paving contracts contained identified cluster sites.
- Ninety-one percent of all wet-pavement accidents occur in urban areas. Ninety-three percent of all contracts with identified cluster sites involve urban areas.

It is also concluded that reducing friction demand is required as a countermeasure more often than is providing a high-friction mixture.

2. "A Summary of the Illinois Skid-Accident Reduction Program: March 1980–1984," Physical Research Report No. 99 by P.G. Dierstein and J.E. LaCroix, Illinois Department of Transportation, Bureau of Materials and Physical Research, Springfield.

Abstract: This report summarizes the activities of the Illinois Skid-Accident Reduction Program from March 1980 through March 1984. Major policy advancements during the period covered by this report were the enactment of Illinois Department of Transportation Policy TRA-15, Safety Improvement Construction Program, and TRA-16, Skid-Accident Reduction Program. TRA-15 is directed toward identifying high-accident locations and conducting a safety program addressing those and other potentially hazardous locations on a priority basis. TRA-16 is directed toward three basic activities: (1) incorporating adequate skid resistance during construction/rehabilitation; (2) identifying, analyzing, and improving wet-pavement locations; and (3) program evaluation and reporting.

Kansas

1. "Open Graded Asphalt Friction Courses," Kansas Department of Transportation, Bureau of Materials and Research, Final Report, December 1986.

Summary: Constructed seven projects. All performed satisfactorily and maintained excellent friction.

2. "Sprinkle Treatment of Asphalt Surfaces," Demonstration Project No. 50, Wilson County Kansas, Final Report, September 1986.

Conclusion: The sprinkled surfaces had a higher friction than BM-1 control surfaces.

Kentucky

1. "Frictional Performance of Pavements and Estimates of Accident Probability" by J.L. Burchett and R.L. Rizenbergs, Report No. 554, Kentucky Department of Transportation, Division of Research, Lexington, September 1980.

Brief Summary (from Abstract): Estimates of accident reduction were made by combining the relationship between skid numbers and accidents with the distribution of skid numbers for each pavement type. Those reductions were used to calculate benefits which, along with costs of overlay, were used to determine benefit-cost ratios. Benefits exceeded costs for the roads having AADTs greater than 750, 2500, and 5000 and SNs less than 24, 30, and 35, respectively.

2. Kentucky Department of Highways Guidelines for Selecting Slipper Pavements for Consideration for De-Slicking, January 4, 1986.

3. Kentucky Guidelines for Selection of Bituminous Surface Courses, January 26, 1987.

Louisiana

"Evaluation of Highway Safety Improvement Projects in Louisiana 1975–1978" by Zahir Bolouchig Satahkemp and William Waters, Louisiana Department of Transportation, Research and Development Station, Baton Rouge, September 1982.

Summary from Abstract: An accident-based "before-and-after" evaluation procedure was used throughout the study. Project effectiveness was also examined with respect to the relationship between the benefits and costs for each project.

Accident-reduction factors for intersection improvements were found to be 12 percent, 3 percent, 26 percent, and 67 percent (decrease) for total, PDO, injury, and fatal accidents, respectively. The benefit-cost ratio for this category was 6.25, indicating that the benefits derived outweighed the incurred costs on the order of 525 percent.

For the skid-resistant overlays, the accident-ıeduction factors were found to be 12 percent, 9 percent, and 20 percent (increase) for the total, PDO, and injury accidents, respectively. Fatal accidents were reduced by 50 percent. The benefit-cost ratio for the overlay projects was 0.58.

Maryland

1. "Seasonal Variation of Friction Numbers" by J.C. Mitchell, M.I. Phillips, and G.N. Shak, Maryland Department of Transportation, Brooklandville, February 1986.

Brief Summary:

(a) Friction number varies during the year.

(b) No relation between temperature and friction number.

(c) No results for rainfall.

(d) Seasonal changes in friction number vary with surface type.

2. "The Effects of Tire Tread Depth on Friction Numbers of Dense and Open-graded Surfaces" by K. Ananthanarayanan and J.P.S. Munjal, Maryland Department of Transportation, Brooklandville, July 1986.

Abstract: The objective of this study was to develop the relationship between types of surfaces, tire tread depths, vehicle speeds, and tire type as it manifests itself in friction measurement. Seven test sections were selected on MD Route 97, consisting of open- and dense-graded mix. Five different types of tires, three speeds, four tread depths, and seven sites were the total variables. To avoid effects of other variables, other than mentioned above, a normalizing factor was established. These normalized friction numbers were used for analysis.

It was observed that friction number is directly proportional to the tread depth and inversely proportional to the speed. No difference in friction number for new and $^{8}/_{32}$" tires was observed. Belted, radial, and snow tires offered equal skid resistance, whereas the bias tire offered a lower friction number. No definite relationship of friction number with open- and dense-graded courses was observed. The pavement under testing was about 10 years old at the time of the data collection.

3. "Maryland Vehicle Law, TR20-106" written accident report is required to be written by drivers and vehicle owners.

Michigan

1. "An Evaluation of the 1967-68 Skidproofing Program," Report TSD-SS-146-70, Michigan State Highway Commission, Lansing, November 1970.

Abstract: This report (third in a series) is the evaluation of the addition of a skidproofed surface at nine locations throughout Michigan in the fiscal year 1967–68.

The aggregate number of accidents was reduced from 273 during the year "before" to 224 in the year "after." This reduction was primarily due to a reduction of accidents occurring during wet-pavement conditions (120 "before" to 60 "after").

The decreased number of accidents reported during the "after" period was achieved despite an overall 5.1 percent increase in trunkline average daily traffic and was found to be a statistically significant reduction, resulting in a savings of $144,500 to the motoring public. The total cost of skidproofing at all locations was $250,681.

2. "An Evaluation of the 1977 Texturing Program" by Sara Levin, Karen McDonald, and Jack Benac, Report TSD-4390-80, Michigan Department of Transportation.

Abstract: The purpose of this report is to evaluate and analyze the effects of pavement texturing on friction coefficients and on accident experience. Four years of accident data at 12 locations in Michigan were studied; the "before" period includes three years of data (8/74–8/77) and the "after" period includes the data for one year following completion of the projects (11/77–11/78). The control sites, selected for comparative analysis, are geometrically, geographically, and functionally similar to the textured sites.

The results of "before" and "after" friction tests indicate that coefficients of friction were increased by approximately 40 percent. Total accident frequencies increased at both textured and control locations, but neither increase proved significant. While wet accidents increased at both textured and control locations, the increase at the control sites was greater. The number of icy-surface accidents at the textured sites decreased, whereas the number increased at the control sites. Statistical techniques for analyzing these data are employed and discussed within the text.

It is concluded that pavement texturing has had a significant impact on icy-accident reduction and on friction coefficient improvement at the 12 locations studied.

New York

1. "Skid Resistance of Bituminous Pavements Built with Carbonate Aggregates" by R.W. Miller and W.P. Chamberlin, Research Report 77, New York Department of Transportation, Engineering Research and Development Bureau, Albany.

Conclusions (Partial):

1. For limestones with less than 10 percent insoluble residue, the addition of 20 percent to 50 percent noncarbonate particles was associated with improvements in SN_{40} that averaged 5 SNs at 1 MVP and 17 SNs at 13 MVP.

2. Blends with limestones in which the proportion of noncarbonate particles was between 35 and 50 percent resulted in a mean SN_{40} at all levels of traffic approximately 5 SNs higher

than blends in which the proportion was between 20 and 34 percent.

2. "Groove Depth Requirements for Tine Textured Pavements" by J.E. Grady and W.P. Chamberlin, Research Report 86, New York Department of Transportation, Albany, June 1981.

Conclusions (Partial): Skid resistance of concrete pavements textured to produce $\frac{3}{16}$-in.-wide grooves on $\frac{3}{4}$-in. centers begins to decay from an initial value when opened to traffic, but appears to stabilize after passage of about 2 million vehicles. This stability is believed to correspond to equilibrium polishing of the microtexture at a time when the grooves are still sufficiently deep to provide complete drainage. Attempts to improve skid resistance thus should be directed toward practices that will enhance the equilibrium microtexture or ensure that grooves are sufficiently deep to provide complete drainage for the pavement's entire design life, thus mobilizing the equilibrium microtexture.

3. "An Open Friction Course on a Portland Cement Concrete Base: A Four-Year Progress Report" by K.S. Dodge, Research Report 97, New York Department of Transportation, Research and Development, Albany, October 1982.

Conclusions (Partial): Performance of the OFC riding surface has equaled or exceeded the standard 1AF dense-graded top mix, with the exception of joint raveling. Based on data developed during the study, the following conclusions can be drawn:

1. Both pavements provide friction levels well above the desired minimum of $FN_{40} = 32$, with the OFC pavement at an average of 5.4 FNs higher in the driving lane and 0.1 FNs higher in the passing lane.

4. "Open Friction Courses on an Asphalt Concrete Base: A Seven-Year Progress Report" by K.S. Dodge, Research Report 98, New York Department of Transportation, Research and Development, Albany, October 1982.

Conclusions (Partial): After seven years of service, the two OFC pavements continue to equal or exceed the performance of the conventional state top-course pavement. Based on data developed during this study, the following conclusions can be drawn:

1. Aggregate degradation occurred to a greater extent in the OFC mix than in the conventional mix. The internal void structure of both OFC pavements has decreased to half their initial values. Internal drainage of surface water through the OFC mixes became negligible with the closure of surface voids after two years of service.
2. The OFC pavements provided better frictional performance than the conventional top-course mix for at least seven years.
3. The extent to which the OFCs will improve frictional performance appears to depend on traffic volume. Greater benefit occurs where the AADT exceeds 3000 vehicles per lane.

5. "Decay of Tine-Textured Grooves in Rigid Pavements" by J.E. Grady, Research Report 107, New York Department of Transportation, Research and Development, Albany, October 1983.

Conclusions (Partial):

1. Frictional properties of concrete pavements textured to produce $\frac{3}{16}$-in.-wide grooves on $\frac{3}{4}$-in. centers begin to decay from an initial value when opened to traffic, but appear to stabilize after passage of about 2 million vehicles. This stability is believed to correspond to equilibrium polishing of the microtexture at a time when the grooves are still sufficiently deep to provide complete drainage. Attempts to improve frictional properties thus should be directed toward practices that will enhance the equilibrium microtexture or ensure that grooves are sufficiently deep to provide complete drainage for the pavement's entire design life, thus mobilizing the equilibrium microtexture. (This conclusion is unchanged.)

6. "Effect of Sawed-Groove Texturing on Concrete Bridge Decks" by J.E. Grady, Research Report 108, New York Department of Transportation, Research and Development, Albany, September 1983.

Conclusions (Partial): All methods of texturing produced acceptable initial values of friction when tested with a standard ribbed tire, those produced by grinding and tining being higher in general than those produced by sawing. When tested with a smooth tire, ground and sawed textures were superior.

7. "An Open-Graded Friction Course on a Portland Cement Concrete Base" by W.P. Chamberlin and J.E. Grady, Research Report 135, New York Department of Transportation, Research and Development, Albany, August 1986.

Conclusions (Partial): Both open-graded and control mixes maintained an adequate level or 40 mph friction over the evaluation period—i.e., greater than 31—with the OFC consistently 3 to 5 FNs higher. However, when tested with a smooth tire, the difference was consistently 17 to 18 FNs. FN-speed gradients measured between 30 to 50 mph with a standard ribbed test tire averaged 48.6 percent higher for the control surface than for the OFC.

Surfaces of both mixes have developed wheelpath ruts, those in the OFC being slightly higher.

8. "1986 Annual Evaluation Report-Highway Safety Improvement Program" by J.S. Bray, P.J. Hyzy, and J.E. Watson, New York Department of Transportation, Traffic Engineering Standards and Systems Bureau, Albany, December 1986.

Partial Summary: A comparison was performed of the safety impacts of the department's open-graded friction course placed at 4 wet-weather sites with the department's high-friction dense-graded mixes placed at 18 wet-weather sites. Both types of overlays performed well. The high-friction dense-graded mixes reduced wet-weather accidents by 61 percent. The modified open-graded friction courses reduced wet-weather accidents by 100 percent (from 13/year to none). Although this result is highly tentative because of the small sample size and short after periods for the open-graded friction course projects, it argues—in the absence of a better gauge—for the expanded use of open-graded friction courses at surface-related wet-weather accident sites. Higher than expected wet-pavement accidents greatly benefit from antiskid treatments such as open-graded friction overlays and grooving.

Utah

1. "Evaluation of the Effects of Plant Mix Seal Coats on Pavement Condition and Accident Rate" by Gustavo Loza and Douglas Anderson, Final Report, Utah Department of Transportation, Research and Development, April 1986.

Conclusions:

1. In general, Utah's plant mix seal coats are performing well. Significant increases in ride quality have been observed for a majority of the PMSCs placed, and the magnitudes of friction index are adequate in most cases.

2. The measured friction indices for one "local" aggregate source were significantly lower (average 42.3, range 29 to 56) than the other aggregate sources statewide (average 56.3, range 36.7 to 70). Four of the 14 pavement sections evaluated from the local source had average friction indices below the 35 level, which is considered to be unacceptable, whereas none of the 37 other pavements were found to be unacceptable.

3. A much greater overall increase in accidents was found to occur after the placement of the PMSCs for the special data set when compared to all other sections statewide.

2. "Prevention of Early Pavement Deterioration" by D.E. Peterson and M.L. Wiley, Utah Department of Transportation, Materials and Research Section, Salt Lake City, September 1978.

Abstract: This study was done to identify the major forms and causes of early pavement distress and to recommend changes in specifications or policies to prevent the distress. Three major forms of distress in Utah were identified as follows: (a) unstable mixes, (b) transverse cracking, and (c) stripping. (Note: Study is not directly related to wet-pavement safety program.)

3. "Accident Relationship Study: Rut Depth/Pavement Condition" by Doug Anderson et al., Utah Department of Transportation, Division of Safety, Salt Lake City, December 1985.

Abstract: This study was performed to determine the relationship/correlation between roadway pavement rutting and accident rate both for all accidents and for accidents under wet-weather conditions on rural and urban roadways. In addition to pavement rutting, accident rates were evaluated against Friction Index and Pavement Serviceability Index (roughness) under the same weather conditions.

Data for the study were from Utah's Geographic, Pavement Information, and Accident data base files for 1983 and 1984; linked using UDOT's Highway Information System; and statistically evaluated using the SAS Statistical Analysis System.

In all cases, wet or dry pavement and with all rut depths, PSIs, and Friction Indexes, there was little or no correlation between pavement condition and accident rates on the systems evaluated.

APPENDIX D

ATTACHMENTS RETURNED WITH RESPONSES TO QUESTIONNAIRE

Iowa	Policies and Procedures Manual Pavement Friction Evaluation Program
Kentucky	Guidelines for Selecting Slippery Pavements for Consideration for De-Slicking
New Jersey	Administration Process for the Skid Resistance Improvement Program
	Methodology for Identifying Site Candidates
Nova Scotia	Road Friction Guidelines
Oregon	Friction Testing Program Summary
Rhode Island	Pavement overlay for Skid Resistance for Roadways With Speed Limits of 45 MPH or Greater

Iowa Department of Transportation

POLICIES AND PROCEDURES MANUAL

SUBJECT		POLICY NO.
Pavement Friction Evaluation Program		600.01
RESPONSIBLE DIVISION(S), OFFICE(S): Highway Division, Deputy Director-Operations	RELATED POLICIES & PROCEDURES	
EFFECTIVE / REVISION DATE: 11-20-72 / 10-25-85	APPROVAL(S)	

I. Affected Division(s), Office(s): Highway Division--Offices of Materials, Maintenance, and Construction, and the district offices; Bureau of Transportation Safety.

II. Policy Statement and Purpose: It is the policy of the Highway Division to establish a program for conducting friction tests on the interstate and primary road systems, isolate sites with low friction wet weather characteristics, evaluate pavement materials, test construction processes, and determine the effectiveness of maintenance practices designated to increase the frictional coefficient of the pavement surface.

The purpose of this policy is to establish criteria to be used in the evaluation of the frictional characteristics of pavement surfaces and to take action to mitigate low frictional coefficient areas.

III. Authority: This policy is established by the authority of the Director of the Highway Division.

IV. Definitions:

A. The Pavement Friction Review Committee is an advisory body to the Deputy Director-Operations of the Highway Division and is responsible for uniform assessments of frictional data on a statewide basis and for resultant recommendations of remedial action.

The Committee shall be composed of representatives from the Offices of Maintenance, Materials and Construction, and the Bureau of Transportation Safety. The Committee shall establish its internal operating procedures and designate a chairperson. The representative from the Office of Maintenance shall serve as secretary.

B. Form 840002 - "Request for Field Review of Pavements"

C. Other data - Data such as but not limited to various tabulations, correspondence, drawings and photographs.

V. Summary of Responsibilities:

A. The Office of Materials shall be responsible for the establishment of testing priorities, the performance of tests, and test data compilation.

B. The Bureau of Transportation Safety shall be responsible for the preparation of Forms 840002 and the furnishing of supplemental data such as traffic volume and wet weather accident data.

C. The Office of Maintenance shall be responsible for the authorizing and ordering of interim warning signs, the preparation and distribution of the minutes of meetings, and the maintenance of friction review files.

D. The District Offices shall be responsible for the performance of field reviews, the submission of corrective action recommendations, and the implementation of corrective action as directed.

E. The Pavement Friction Review Committee shall be responsible for the:

1. Review of data for pavement sections with the following friction number averages:

   -Greater than 37 with individual numbers below 30

   -Equal to or less than 37

2. Review of district office recommendations.

3. Submission of recommendations for improvement action to the Deputy Director-Operations.

F. The Deputy Director-Operations of the Highway Division shall be responsible for the review of the recommendations submitted by the Pavement Friction Review Committee and for authorizing or recommending improvement actions to be taken.

VI. Procedures:

A. Field Testing Program

1. The Office of Materials shall establish a priority listing of pavement sections to be tested. This listing shall consider traffic volumes, time since last friction tests were performed, and friction values obtained in previous tests.

2. The Office of Materials shall conduct the tests and be responsible for the accuracy of the test data. Tests shall normally be conducted at the rate of two per mile in each direction, with a total of not less than five tests in each direction on each pavement section.

B. Test Data Evaluation

1. The Office of Materials shall provide the computer-printed test reports to the Bureau of Transportation Safety.

2. The Bureau of Transportation Safety shall prepare Form 840002 and other data for pavement sections as required by the following guidelines:

Friction Number Average (both directions of travel):	Action Required:
Greater than 37 and no individual number below 30	No Form 840002 required
Greater than 37 with individual numbers below 30	Prepare Form 840002 and other data
Equal to or less than 37	Prepare Form 840002 and other data

3. Traffic volume and wet weather accident data shall be provided on Form 840002 by the Bureau of Transportation Safety.

4. The Bureau of Transportation Safety shall forward the computer-printed test reports, Forms 840002 and other data to the Office of Maintenance.

5. The Office of Maintenance shall process the test reports, Forms 840002 and other data in accord with the following guidelines:

Friction Number Average (both directions of travel):	Action Required:
Greater than 37 and no individual number below 30	No action required

Greater than 37 with individual numbers below 30	To committee; does not go to district for initial review
Numbers 33 through 37 and no individual number below 30	To committee; does not go to district for initial review
Numbers 33 through 37 with individual numbers below 30	To district for initial review
Numbers 20 through 32	To district for initial review
Any section 19 or less	Order "Slippery When Wet" signs and instruct district on placement. Send Form 840002, test report and other data to district for initial review.

C. Field Review

1. The district office shall conduct a field review of all pavements requested. The geometry of the pavement and the types of traffic maneuvers at locations with less than desirable friction numbers shall be considered in making improvement recommendations.

2. The district office shall make recommendations concerning improvement action on Forms 840002 and return them to the Office of Maintenance.

3. Signs at locations other than those authorized by the Office of Maintenance may be requested by the district office.

D. Improvement Action

1. The Office of Maintenance shall assemble Forms 840002 and other data for review by the committee.

2. The committee shall review Forms 840002 and other data and recommend action.

3. The committee shall review all field recommendations and either concur with the district's recommendations or, if the committee does not concur, provide an alternate recommended action.

4. Following committee action, the secretary shall forward Forms 840002 and other data to the Deputy Director-Operations for review.

5. The secretary shall return to the districts those Forms 840002 for which improvement action is authorized or recommended by the Deputy Director-Operations.

6. The district office shall take the improvement action if it is within the capability of the district forces. Upon completion of the action, Form 840002 shall be returned to the Office of Maintenance showing the date the action was completed.

7. If surface restoration or resurfacing is the recommended action, the highway section involved shall be considered for programming during surface restoration or bituminous surfacing program development. District engineers shall consider these sections when preparing recommendations for projects, and staff engineers shall consider these sections as they evaluate the districts' recommendations and prepare the statewide resurfacing and surface restoration programs.

8. 'Slippery When Wet' signs should be removed after any contract surface restoration work. For work such as seal coating or slurry seals, the signs may be removed by the district office if visual inspection or friction testing indicates correction of the

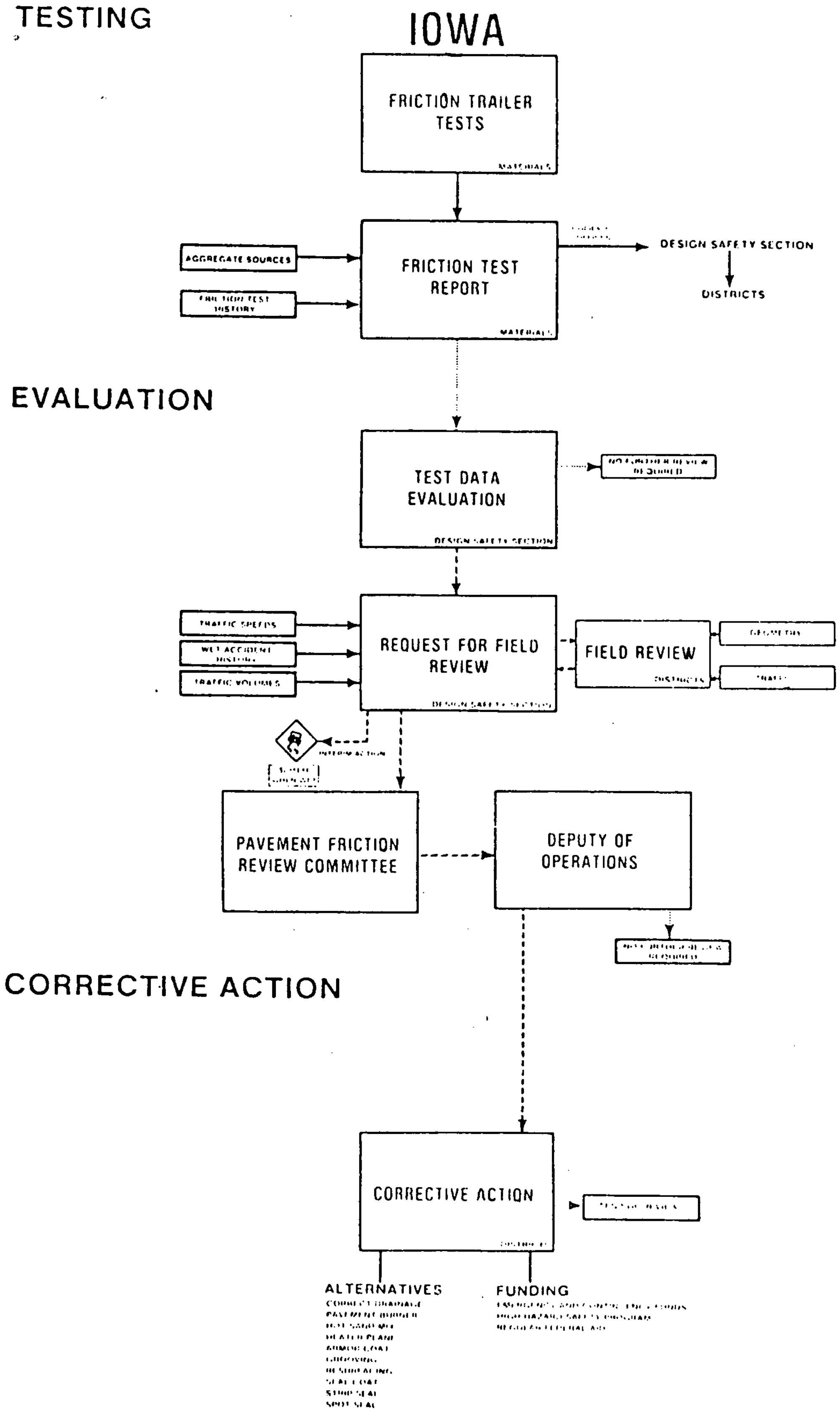
problem. The district should document when the signs are removed and notify the Office of Maintenance. Should there be any question about the effectiveness of the improvement action, the signs should remain in place until the pavement section is retested.

9. The Office of Maintenance shall transmit copies of completed Forms 840002 to the Bureau of Transportation Safety and the Office of Materials.

APPENDIX A

PAVEMENT FRICTION EVALUATION PROGRAM

IOWA



KENTUCKY DEPARTMENT OF HIGHWAYS
GUIDELINES FOR SELECTING SLIPPERY PAVEMENTS
FOR CONSIDERATION FOR DE-SLICKING

The justification and proposed implementation of these guidelines is contained in the attached Justification and Implementation of Proposed Guidelines for Selecting Slippery Pavements for De-Slicking.

I. <u>HIGH VOLUME ROADS</u> --- All Interstates; Other roads with ADT above 10,000

A. Skid number of 28 or lower; or
B. Skid number of 29 or higher and benefit/cost ratio greater than 2

II. <u>MEDIUM VOLUME ROADS</u> --- Roads with ADT of 4,000 to 10,000

A. Skid number of 25 or lower; or
B. Skid number of 26 to 32 and benefit/cost ratio greater than 2

III. <u>MEDIUM LOW VOLUME ROADS</u> --- Roads with ADT of 1,000 to 4,000

A. Skid number of 25 or lower and, if applicable more than 30 percent wet-pavement accidents; or
B. Skid number of 26 to 32 and benefit/cost ratio greater than 2

IV. <u>LOW VOLUME ROADS</u> --- Roads with ADT below 1,000

A. Skid number of 25 or lower and benefit/cost ratio greater than 2

APPROVED: ____________________ DATE: 2/4/86
STATE HIGHWAY ENGINEER

NJDOT ADMINISTRATIVE PROCESS

FOR THE SKID RESISTANCE IMPROVEMENT PROGRAM

<u>Purpose</u>

To significantly reduce the number of wet surface and same direction accidents, thereby, reducing the number of total accidents and accident severity providing a safer roadway surface. The skid overlays implemented as part of the Highway Safety Improvement Program in the past have resulted in significant reductions in wet surface accidents and accident severity as well as reductions in various accident types such as same direction and and fixed object. It is expected that implementation of a Skid Resistance Improvement Program will provide significant safety benefits on the State's highway system.

<u>Objectives</u>

1. To establish a process for identifying sites which need improved skid resistance.

2. To select sites for implementation.

3. To implement the skid resistant improvement projects.

4. To evaluate the results.

A. <u>Identification of Candidate Locations</u>

From statistical analysis of computerized accident data and the Skid Resistance Inventory, certain minimum criteria will be developed to generate a list of candidate sites. These criteria are specified in the attached "Methodology for Identifying Candidate Sites" and will be modified periodically based on engineering judgement and the corresponding success of previously implemented projects. The primary factors in this identification process will be (1) the total wet surface accident frequency for two years and (2) skid numbers below a specific target value. The Safety Section of the Bureau of Traffic Engineering and Safety Programs (TESP) will be responsible for setting the minimum criteria for identifying candidate locations as documented in the attached "Methodology for Identifying Candidate Sites".

B. <u>Selection of Sites</u>

1. The preliminary list of candidate locations developed from the "Methodology for Identifying Candidate Sites" will then be sent to the Division of Roadway Design and the Bureau of Maintenance to

determine the current status of each proposed site. Specific site recommendations from Design and Maintenance will be provided to TESP.

2. The Safety Section will then issue a final list of proposed sites based on the current status, engineering judgement and the specific features of a particular location. A cost estimate of expected accident reduction benefits will be made and shown for each site included on the final site selection list.

3. The Methodology for Identifying Site Candidates and the Administrative Process for the Skid Resistance Improvement Program will be updated on an annual basis.

C. Implementation

The final list of projects will be scheduled for implementation in one of the following three ways.

1. Sites for which design is currently underway will be modified to include a more skid resistant surface as part of the existing state or federally funded project.

2. Spot sites determined to be appropriate and within tonnage limits will be proposed for in-house implementation by State Maintenance forces.

3. Other locations not selected in C. 1 or C. 2 will be advanced to construction by individual contracts or grouped to allow for area-wide construction contracts using categorical safety funds or with other funding, if appropriate.

TESP will determine which of the selected sites will be designed first based on the input from various operating units and a preliminary priority listing which is based primarily on the expected benefits for accident reduction.

For each site proposed for categorical safety funds Design will develop a scope of work which will include logical limits, design criteria and incidental work in accordance with the "NJDOT Operating Procedure for Preliminary Engineering for HES Sites".

Any location on the final list of proposed sites which is not implemented as a project will have the necessary justification documented.

D. Evaluation

Accident evaluations will be conducted for the HES projects and selected locations from C. 1 and C. 2. The actual reductions of the overrepresented type accidents along with the reduction of the severity of all accidents will be tested for significance. This information will be used to develop expected statewide accident reduction values which will be used for the selection and justification of subsequent projects. A benefit/cost analysis will also be prepared which will indicate actual cost effectiveness. The results of these evaluations will be included in the Department's Annual Safety Report.

SKID RESISTANCE IMPROVEMENT PROGRAM

METHODOLOGY FOR IDENTIFYING SITE CANDIDATES

Introduction

This methodology for selecting site candidates was developed to identify locations on the state highway system with the specific safety problem of poor skid resistance. By addressing a specific safety problem, a response can be made quickly and benefits realized sooner. It is expected that the locations identified through this methodology have the worst skid resistance in the State so that funding for this program is best utilized.

Model Development

1. The data sources include the skid inventory file and the motor vehicle accident file. These two computer data files address both low skid numbers (SN_{40}) and high wet accident frequencies. The mileage statistic computer file is also used to obtain the posted speed limit. Since the skid inventory file has five skid numbers for every one mile in each direction, there is a corresponding 0.20 mile section of roadway associated with each particular skid number.

2. All locations with a speed limit of 50 or 55 MPH and a skid number below 31 are identified. It is expected that these 0.20 mile sections represent a potential skid resistance problem due to the high speeds with skid numbers below 31. (The skid number of 31 is lowest the recommended minimum value according to the National Cooperative Highway Research Program Report No. 37, Highway Research Board, Page 54. It is the recommended value for 30 MPH roadways.)

3. The 0.20 mile sections of roadway are merged with the motor vehicle accident file to obtain the wet accident frequency in each direction associated with the appropriate skid number. The wet accident frequency is the total obtained from two years of accident data.

A plot of the skid number vs. the wet accident frequency is the basis of a model which will identify the worst locations based on a combination of the extremities of high wet accident frequency and low skid numbers. The model consists of a series of curves with the wet accident frequency and the skid number as the variables for the formula of each curve. The formula used in the model gives the wet accident frequency a more prominent weight of 4:3 compared to the skid number since the wet accident frequency is a more direct indicator of a skid resistance problem. Each curve in the model also represents a certain percentile rank, i.e., each curve (shown in the attached graph) encloses with the axis a certain percentage of the population which is plotted.

Nova Scotia

Department of Transportation

ROAD FRICTION GUIDELINES

for Each Class of Roadway

Friction Number	Action
HIGHWAYS	
0 - 37	Sign & Correct *
38 - 42	Sign & Review **
Over 42	None
TRUNKS, ROUTES & LOCAL ROADS	
0 - 32	Sign & Correct *
33 - 40	Sign & Review **
Over 40	None

* "Sign & Correct": subject to Department budget but will be done as soon as possible.

** "Sign & Review": roadway to be monitored periodically

Generation of Candidate Sites

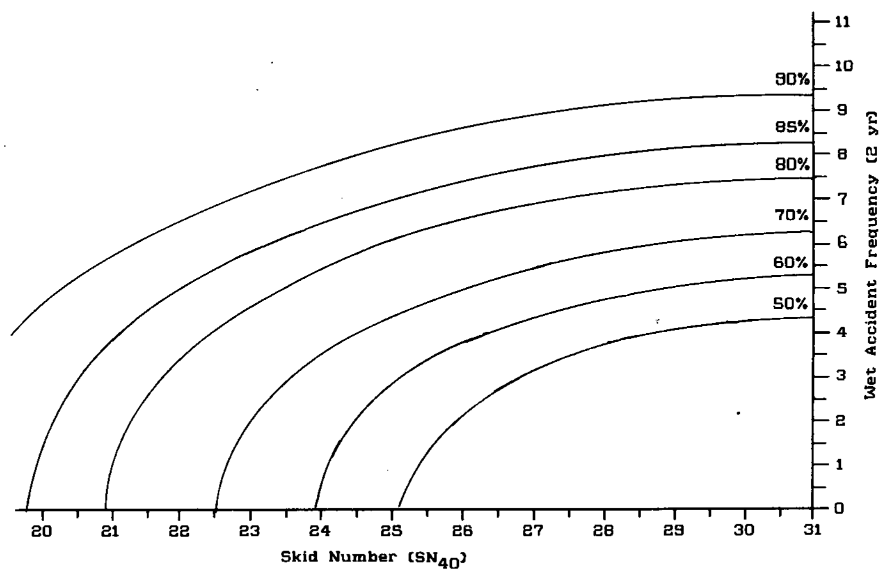
1. The curve representing the 85th percentile is used to focus on only the outermost 15% of the plotted population for further investigation. These locations have the most extreme combination of high wet accident frequency and low skid number. The 85th percentile is the initial criteria since it provides a reasonably sized pool of candidate locations for consideration.

2. The flagged locations are combined into logical limits so that uniform skid resistance will be provided within a problem area. Projects 0.40 miles or more in length will be initiated first so that greater benefits can be realized sooner.

3. An accident analysis of the project length must reveal that the wet surface percentage of the total accidents exceeds the statewide average percentage for a location to be proposed for implementation.

Future Modification

The site selection criteria will be modified periodically to introduce new candidate locations for inclusion in the Skid Resistance Improvement Program. The criteria will be changed based on the success of the program and additional recommendations from FHWA and other units within the Department. The Safety Section from the Bureau of Traffic Engineering and Safety Programs will be responsible for setting the revised site selection criteria for future implementations.



OREGON DEPARTMENT OF TRANSPORTATION

HIGHWAY DIVISION

RESEARCH SECTION

PAVEMENT ANALYSIS UNIT

FRICTION TESTING PROGRAM SUMMARY

AND

FUTURE PROGRAM OUTLINE

JANUARY 1987

HIGHWAY DIVISION - RESEARCH SECTION

FRICTION TESTING PROGRAM SUMMARY

SCOPE - Oregon's present friction testing program on State highways consists of four types of tests:

1. INVENTORY - Testing the entire 7800 mile State highway system including structures where possible. This testing is done on all State highways by taking two tests per mile in the right lane. Due to the amount of testing required, State highways are generally tested on a four-year cycle, with the exception of the freeways, which are tested on alternate years in each direction.

2. ACCIDENT SITE - Testing those sites on the Highway system where the accident history appears to have statistically significant numbers of accidents involving wet or dry skids. These sites are typically 0.2 to 1.0 miles long. Generally, 4 to 6 tests are taken in each lane of the section in the direction of the accidents. These 60 to 70 sites are normally integrated into the inventory work.

3. NEW PAVEMENT - Testing the performance of new pavement materials and methods. These tests include overlays of classes "B", "B mod.", "C", "C mod.", "E", Reclamite, rubberized, and recycled asphaltic concrete mixes. These tests represent approximately 40 sites, mostly in the Willamette Valley, and are tested annually.

4. SPECIAL REQUEST - Testing in response to requests by Highway Regions and Districts, other Highway Sections, and FHWA. Annually, 20 to 30 requests are submitted.

STAFFING - It requires two people to safely and efficiently operate the testing equipment. One of these is a temporary Engineering Aide hired for the duration of the field testing season. At the end of the testing season, the permanent Engineering Technician 1 enters the data on the ODOT computer and uses established programs to adjust the data to standard and produce the necessary reports.

SCHEDULE - Testing usually starts in mid April and ends in November with the Fall rains. The testing equipment is calibrated in the shop at the beginning of the season. A calibration run is done at the beginning of the season and monthly on the test section. The calibration of the equipment has remained constant through the years.

COST - The annual cost for friction testing activities is budgeted at approximately $60,000 per year in the 1987 - 1989 Biennium. This figure includes all equipment and labor for the data gathering.

ANNUAL HIGHWAY INVENTORY

GENERAL USE - A report from this inventory is used to inform the District Maintenance Supervisors of possible friction-related problems in their districts. An annual report is sent to the Districts informing them of possible problems. The District personnel determine if action is needed. This inventory is kept on the ODOT mainframe computer and is now being modified to give more detailed information than in the past. This modification, as well as the decision to add regular structure testing is in response to requests from Justice Department.

LEGAL USE - Data from this inventory is used by the Department of Justice to defend cases against the Highway Division alleging that the pavement was slick due to negligence on the part of the Division ~~(See attached letter.~~). The fact that this is a regular program is valuable in that conditions prior to the incident can be determined. Regular testing has been held to be an indication that the Division is exercising reasonable care in determining the friction values of pavement and by providing a means to identify possible problem locations.

After-the-fact testing can be questioned as to possible bias on the part of the Division or challenged as to whether it truly represents the condition prior to the accident.

ACCIDENT SITE TESTING PROGRAM

Accident site testing is used to determine if pavement friction is really a factor at a site showing significant numbers of skidding accidents. This information will enable Districts and Regions to take appropriate action if necessary.

The legal aspects of accident site testing are the same as for the general inventory tests.

NEW PAVEMENT TESTING PROGRAM

The friction testing of new and modified types of pavements allows the evaluation of their friction performance under actual conditions. These tests can be used to select the best alternative for a situation or to determine if friction-related problems are developing.

SPECIAL FRICTION TESTING PROGRAM

The special testing program is a response to specific requests from the Districts, Research and other Highway Sections, and the FHWA. These requests have continued to grow over the years with the increased interest in pavement management and roadway conditions. Some testing is done in conjunction with current research projects in pavement design and performance.

DISTRICT REQUESTS - The District Maintenance Supervisors will request that testing be done to verify the need for signs warning motorists of possible slick pavements. These requests amount to a small portion of the testing activity.

RESEARCH SECTION - The Research Section uses friction values to evaluate new products and methods of pavement construction. Friction values are currently being used to evaluate thin-surface treatments and PCC brooming patterns.

OTHER SECTIONS - Requests are received from other Sections of the Division to determine the friction values on new pavements and surface treatments. These are usually used to assist in the immediate evaluation of new materials and processes.

FHWA REQUESTS - The Federal Highway Administration requests tests on 6 structures on I - 205 annually. Tests are also being run on 2 other bridges on the State system. This is to monitor the friction values of various deck treatments. There has been some inquiry regarding the monitoring of friction values on new types of pavement.

PROPOSED FRICTION TESTING PROGRAM FOR 1987-1989 BIENNIUM

The proposed 1987 program of friction testing will better reflect the needs of the Regions and Districts as well as conform closely to the guidelines in the attached letter from FHWA. The restructuring of the program will provide a more balanced coverage of the highway system over the years and still meet most of the probable needs for data. The attached spreadsheet gives a comparison of the past and proposed programs.

HIGHWAY INVENTORY

FREEWAYS —— Because there is a greater probability of problems developing in the high-speed high-traffic sections.The frequency of testing on freeways will remain on an alternate-year alternate-direction basis. This will not change the present amount of testing.

PRIMARIES —— Based on the suggestions of FHWA and consultation with Regional Maintenance Engineers it was decided to eliminate rural highway sections with Annual Average Daily Traffic (AADT) values of less than 500 and urban sections with AADT values less than 5000 from the regular testing program.

Problems arising in those sections that are not regularly tested will generally show up in the accident site testing program.

Although the total mileage would be reduced, it is not planned to reduce the testing frequency on primary highways. The four-year testing cycle would remain the same for non-freeway facilities. Freeways would still be tested in the alternate-year alternate-direction pattern.

SECONDARIES - Rural highway sections with AADT values less than 500 and Urban section with AADT values less than 5000 would be not be tested as a part of the regular testing program.

Problems in the sections that are not tested regularly would be addressed in the accident site program.

Due to the overall reduced traffic, the secondary highways would be tested on the same 4-year frequency that is the present practice.

STRUCTURES -- All structures, with sufficient length for testing, on a given highway will be tested as a part of the regular testing program and at the same frequency.

SPECIAL TESTING PROGRAM

REGION/DISTRICT - With the elimination of low-volume sections from the regular testing program it will be ncessary for the District and Regional personnel to monitor these areas for possible problems. If problems arise, they would be tested on a request basis. This is reflected in the projected increase in Region/District requests.

ACCIDENT SITES - This program will continue at the present levels. It will be done on all sites identified as having a significant history of skidding accidents. They would be tested without regard to speed or volume. As the selection process for accident sites is a rate-based process, any problems developing on those low-volume facilities not tested under the inventory program would appear on this list because low-volume facilities, typically, exhibit higher accident rates.

FHWA BRIDGE - This program will continue at the present levels.

PAVEMENT TRACKING - It is anticipated that a closer analysis of the friction characteristics of selected types of pavement will be done in the future. The program in this area has been decreasing due to other priorities and the projected level of activity would restore some of this program. Some of the anticipated activities are:

THIN SURFACE TREATMENTS - Approximately 20 miles of testing on chip seals and thin surface treatments.

OPEN/CLOSED GRADATION — Approximately 10 miles of testing on both types of pavement to compare the two.

RECYCLED PAVEMENTS ——— Approximately 10 miles of testing on recycled pavements.

PROGRAM SUMMARY

Generally, the program as outlined above meets the needs of the various State and Federal Agencies as well as those of the various Sections of the Highway Division. The program as shown on the attached sheet is within the 1987-1989 budget levels submitted for this activity.

DOCUMENTATION OF THE DATA REDUCTION PROCESS
of the OREGON FRICTION TESTING PROGRAM

The friction tester was purchased from K. J. Law in March 1974. At that time, the friction values were recorded graphically on a rolled strip chart. After approximately one year of operation, a data logger was installed to replace the strip chart recorder.

In early December 1975, the friction tester was taken to the Ford Motor Company's proving ground near Kingman, Arizona for calibration. At the test center, the Oregon friction testing crew participated with test center staff in calibrating the left wheel of the test trailer to the National Standard at speeds of 20, 40 and 60 mph on five different textured surfaces with known friction values. The final correlation equations resulting from the calibration were:

SN_{20} (REF)=6.950 + 0.923 SN_{20} OREGON
SN_{40} (REF)=9.782 + 0.880 SN_{40} OREGON
SN_{60} (REF)=9.930 + 0.912 SN_{60} OREGON

In early 1978, it was necessary to switch from the original equipment 14-inch ASTM tire to a 15-inch ASTM E 501 tire. The wider 15-inch tire required two new nozzles of the "modified" type and water a drive pump pulley with fewer teeth to acquire the correct water quantity and dispersion specified by ASTM E 274-79 (AASHTO T 242-84).

In order to determine the new correlation equations for the 15" test tire, the Madras, Oregon airport was used to correlate the friction test trailer because funding problems made it impractical to return to a test center. At the Madras airport five different test strips were selected. Each test strip was tested with the 14" tire at speeds of 20, 40 and 55 mph. These same test strips were then retested using the new 15" ASTM E 501 tire in the same manner used with the 14" tire. Using this information, the following correlation equations were calculated:

SN_{20} (REF)=3.449 + 1.009 SN_{20} OREGON
SN_{40} (REF)=7.453 + 0.881 SN_{40} OREGON
SN_{55} (REF)=5.960 + 0.946 SN_{55} OREGON

These are the equations presently being used to calculate friction values. The most recent visit by AASHTO officials in early February 1987 has shown our calibration to be within the limits set forth by ASTM E 556-82 and AASHTO T 282-84 standards.

For further information contact the Research Section at 378-2318.

PAVEMENT OVERLAY FOR SKID RESISTANCE FOR ROADWAYS WITH SPEED LIMIT OF 45 MPH OR GREATER

1.) All highway segments where the majority of the readings in any lane are less that SN-40 = 26, must be improved at the earliest possible date.

2.) For all highway segments on which more than 50% of the readings in any lane are less than SN-40 = 33, the entire roadway should be improved for skid resistance.

3.) For all highway segments where a significant portion of the readings are between SN-40 = 33 and SN-40 = 40, the roadway should be considered for surface improvements based upon an estimate of future deterioration of SN-40. This estimate shall take into account ADT data and capacity restraints and be based upon any historical trend data currently available.

4.) For any highway section where a majority of the skid readings are greater than SN-40 = 40, the roadway should be investigated for localized surface improvement based upon individual readings for each lane and taking into account such factors as accident experience, ADT, etc.

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