National Cooperative Highway Research Program

NCHRP Synthesis 203

Current Practices In Determining Pavement Condition

A Synthesis of Highway Practice

Transportation Research Board
National Research Council

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Current Practices in Determining Pavement Condition

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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 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 designers, materials engineers, planners, and others concerned with measuring the condition of existing pavements for the purpose of planning maintenance, rehabilitation, or reconstruction. Information is presented on the various practices in use for the collection, reporting, and application of pavement condition data for their service in pavement management systems (PMS) in the United States and Canada, focusing on four primary measures of pavement condition: distress, roughness, structural capacity, and friction resistance evaluations.

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.

Nearly all transportation agencies are using or are in the process of implementing PMS for scheduling rehabilitation and maintenance activities. These systems require data on pavement condition and structural capacity. This report of the Transportation Research Board describes the types of equipment being used by state transportation agencies to obtain these data and how the data are used to affect decision making by transportation managers.

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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The Principal Investigators responsible for the conduct of this synthesis were Sally D. Liff, Manager, Synthesis Studies, and Stephen F. Maher, Senior Program Officer.

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

CURRENT PRACTICES IN DETERMINING PAVEMENT CONDITIONS

SUMMARY

Since the days of ox-drawn wagons and corduroy roads, road bosses and superintendents have been concerned with providing functional, solidly built roadways. Today's transportation agency managers perpetuate this concern as they strive to provide the traveling public with functional, cost-effective, and structurally sound highways. To accomplish this, transportation managers must have comprehensive, timely information on the conditions of their existing pavements.

Transportation agency managers have widely recognized the value of a pavement management system (PMS) in providing sound, comprehensive pavement condition information to assist in decision making. Nearly all state agencies in the United States, and the provincial governments in Canada, have recently been involved in developing, expanding, or enhancing a PMS. The enactment of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 specifically requires that states have a PMS.

The steps in developing a comprehensive, functional, and structural PMS are generally well established: several guidelines have been published, or proposed, on national and world scopes. The Federal Highway Administration (FHWA), the American Association of State Highway and Transportation Officials (AASHTO), the American Public Works Association (APWA), and the World Bank have all actively provided direction and encouragement in PMS development.

A comprehensive database is one of the key elements in a PMS. The database must contain reliable, objective, and timely information to provide the transportation manager with logical output and feedback to assist in making planning and budget decisions. A PMS database must contain a comprehensive inventory of an agency's highways, which have been segmented into identifiable management sections. Any information contained in the database must be attributed to one of the designated segments or sections and must include pavement condition and traffic loadings, which are basic needs for PMS conditions.

Pavement condition surveys are important in providing information to monitor how well a particular pavement section is serving highway users. When condition data are collected, pavement performance can be evaluated and prediction models can be developed to assist in evaluating design methods and estimating future needs.

Pavement condition surveys are also useful in evaluating the functional and structural condition of an existing pavement. Condition surveys include four basic types of information: ride quality or roughness, physical distress, structural capacity, and friction measurements.

This synthesis summarizes the current practices used in determining the condition of pavements. A comprehensive questionnaire was developed and distributed to the states, the District of Columbia, and the Canadian provinces. Replies were received from 50 states, the District of Columbia, and 9 Canadian provinces. All of the responding agencies indi-

cated that they have a PMS in operation or are in the process of implementing one. Nearly all of the replies indicated that the agencies are performing data collection activities in one or more of the four areas of pavement condition evaluation.

The methods and procedures used for the collection of roughness data and friction testing are the most standardized practices being followed. Both use of the South Dakota type profiling device and reporting of roughness data in terms of the International Roughness Index (IRI) have increased sharply.

Many of the agencies evaluate structural capacity, but practices vary widely in programming, conducting, and reporting procedures. Structural evaluation information is primarily used for project-level design development rather than for the network-level testing needed for a PMS.

Nearly all of the agencies perform friction testing, or skid testing, and American Society of Testing Materials (ASTM) test methods are commonly employed. Only a few of the agencies perform friction testing on a continuous, annual, network-survey basis. Testing is performed in compliance with FHWA Safety Requirements and as part of research and materials evaluation.

The widest variation of practices occurs in the collection and use of pavement distress information. Many of the agencies have recently updated their procedure manuals. The field survey procedures and the type, extent, and severity of distresses collected vary greatly. The methods and numerical values used for establishing the condition of a pavement segment (which incorporate distress data) allow little opportunity for exchange of performance data among agencies (e.g., some agencies use a deduct system for distress using a 0 to 100 scale with 100 being excellent, while other agencies use an opposite scale where 0 is considered to be excellent).

As pavement management systems become more fully developed in coming years, the attendant improvements will broaden the benefits of these systems. This can be accomplished by improving data quality, establishing reliable location reference systems, extending standardization efforts to include distress and structural evaluation, implementing procedures developed by the Strategic Highway Research Program, and facilitating the dissemination and exchange of pavement condition information.

CHAPTER ONE

INTRODUCTION

BACKGROUND

A 10-year National Highway Program *(1)* dated January 1955 showed a total road and street system in the United States of 3,348,000 miles. At that time, there were 48 million cars and 10 million trucks in use. In contrast, *Highway Statistics, 1988 (2)* showed a road and street system of 3,871,000 miles, which constituted a 16 percent increase in mileage in 33 years. Over the same period, the number of automobiles had increased to 141 million and trucks to 42 million. These numbers represent huge increases of vehicles (194 percent increase—cars, 320 percent increase—trucks) traveling on a system that grew by only 16 percent.

Another document published in 1955, "Needs of Highway Systems," *(3)* contained a far-sighted statement that was used to provide an interpretation of roadway needs: "It is not possible to 'complete' a highway in the sense that it can by a single construction operation be made forever adequate. From the very day that highway facilities are opened to traffic they begin the course of deterioration and obsolescence that eventually leads to necessary reconstruction or replacement."

These 1955 documents were largely instrumental in the landmark passage of the Federal-Aid Highway Act of 1956 *(4)*, which inaugurated the construction of the present interstate system. At about the same time the interstate system was being planned, the highway engineering community was assessing the size and weight problem associated with the design of roadway pavements. A road test conducted in Maryland in 1950 and 1951 identified the need for extensive additional research. This need for research evolved into the American Association of State Highway Officials (AASHO) and the Western Association of State Highway Officials (WASHO) Road Tests *(5, 6, 7)*.

The results of the AASHO Road Test subsequently shaped the nature of pavements being constructed and maintained. Results included the development of a set of relationships between axle loads and the performance of various thicknesses of pavement surfaces, bases, and subbases. The Road Test also resulted in the development of an objective methodology that enables pavement performance to be evaluated over a known time period by using a Present Serviceability Index (PSI) *(8)*.

The use of a serviceability index sharply contrasted with many of the planning and management philosophies in use up until that time. A typical 1950 planning report *(9)* describes efforts to evaluate sections of roadway as follows:

> The field engineers, each one possessed of long years of experience in highway work were told to avoid slavish dependence on numerical quantities of condition, and were, at all points, to exercise their best judgment as to adequacy or inadequacy of each road section to perform its anticipated functions.

The evolution of evaluating pavements from a best-judgment approach to more objective methods is described in *Pavement Management Systems (10)*, which is one of the first books "written to provide some basic understanding of the principles of planning, designing, constructing and maintaining pavements."

Pavement Management

There are a number of definitions for pavement management and for pavement management systems (PMSs). As defined in *National Cooperative Highway Research Program* (NCHRP) *Report 215 (11)*, "pavement management, in its broadest sense, encompasses all the activities involved in the planning, design, construction, maintenance, and rehabilitation of the pavement portion of a public works program. A pavement management system is a set of tools or methods that assist decision-makers in finding optimum strategies for providing and maintaining pavements in a serviceable condition over a given period of time."

NCHRP Synthesis of Highway Practice 135 (12) used the following definitions from an American Association of State Highway and Transportation Officials (AASHTO) publication *(13)* to provide a common basis of understanding:

> Pavement Management (PM) is the effective and efficient directing of the various activities involved in providing and sustaining pavements in a condition acceptable to the traveling public at the least life cycle cost. Examples of these activities include, but are not limited to, the following as they relate to pavements:
>
> - planning
> - design
> - monitoring
> - maintenance
> - reconstruction
> - budgeting and programming
> - construction
> - research
> - rehabilitation.

A Pavement Management System (PMS) is an established, documented procedure treating many or all of the pavement management activities listed above in a systematic and coordinated manner. It consists of five essential elements structured to serve decision-making responsibilities at various management levels.

1. Pavement surveys related to condition and serviceability
2. Data base containing all pavement related information
3. Analysis scheme
4. Decision criteria
5. Implementation procedures

The latest update of the *AASHTO Guidelines for Pavement Systems (14)* contains a Federal Highway Administration (FHWA) definition for PMS: "a set of tools or methods that can assist decision-makers in finding cost-effective strategies for providing, evaluating and maintaining pavements in a serviceable condition."

Most guidelines for the development of PMS caution against collecting huge amounts of data simply because such collection is automated or available. A World Bank publication *(15)* offers criteria for selecting data items for inclusion in a roadway management information system. These criteria deal with relevance, reliability, affordability, and appropriateness. For a PMS, reliability of data is essential and is determined by the data's accuracy, spatial coverage, completeness, and currency.

Considerable development activity has resulted from an FHWA regulation *(16)* that required all state agencies to have an acceptable PMS in place by January 1993. This development activity has enhanced and broadened the state agencies' ability to evaluate and exchange pavement performance and design information.

The FHWA's *Highway Performance Monitoring System (HPMS) Field Manual (17)* outlines the procedures to be used by states to report information about the extent and physical condition of the state's highway system. Among the objectives the HPMS manual addresses is the evaluation of changes in characteristics and performance based on detailed, section-specific data. These data are to be compatible with other data systems to permit meaningful comparisons. Information available from a well-planned and developed PMS will enable agencies to achieve both national and local objectives in delivering acceptable highway services.

The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 has broadened the scope of the federally mandated implementation of PMS. Prior to ISTEA all states were required to implement a PMS by January 1, 1993. The ISTEA extends this mandate by requiring that all roadways eligible to receive Federal-Aid monies be covered by a PMS by January 1, 1995, regardless of whose jurisdiction they are under.

Synthesis Objectives

Five essential elements are needed to produce information from PMS that meets the needs of various management levels:

- A data base to contain all pavement-related information,
- Pavement surveys related to condition and serviceability,
- An analysis scheme,
- Decision criteria, and
- Implementation procedures.

The condition of existing pavement is an indispensable input to PMS. Four primary measures of pavement condition need to be surveyed to support PMS implementation procedures: roughness, distress, structural capacity, and pavement friction. This synthesis determines the current practices and the state of the art in gathering and use of pavement condition data.

Scope

Pavement condition can be determined in many different ways. Some methods are based entirely on ride quality or the effect of road roughness, whereas others include factors such as distress, skid resistance, and deflection. Composite indexes, which incorporate various other factors, are also used.

This synthesis addresses the measurement or collection, reporting, and use of pavement condition data including roughness, friction resistance, distress, and structural evaluation.

Methodology

Over the last few years the development of PMS and the methods and equipment used to obtain pavement condition data have advanced rapidly. Methods of using PMS data to provide the information output for management use in decision making have also improved.

To determine the state of the art, a questionnaire was developed and distributed to transportation agencies in the 50 states, the District of Columbia, and the Canadian provinces. A sample questionnaire is in Appendix A.

The questionnaire is organized into five parts that could be separated and distributed within each agency to the appropriate functional group responsible for the subject activity. The subjects of the five parts are Pavement Management, Pavement Distress Surveys, Pavement Roughness Surveys, Pavement Structural Capacity, and Pavement Friction Testing. Tabulations of the replies to each part are contained in Appendices B through F, respectively. Appendix G contains a tabulation of the particular unit(s) within each agency that responded to the questionnaire.

The questionnaire contains general questions about the status of PMS activities in each agency, its location referencing system, and how each agency uses PMS data. More specific questions address the types of equipment used in surveys and methods of operation employed in gathering each type of condition data.

Completed questionnaires were received from 50 states, the District of Columbia, and 9 of the Canadian provinces. Replies to the questionnaires were interpreted, tabulated, and analyzed to determine current practices employed by the responding agencies.

CHAPTER TWO

PAVEMENT MANAGEMENT SYSTEMS

PMS STATUS

The first section of the questionnaire was directed at obtaining general information about the state and province PMS practices, the methods used for location referencing for system inventories, the types of condition data collected, and the methods of PMS data storage and usage.

A majority of the agencies responded that they have a PMS. However, only half of those with a PMS stated that they have an established PMS policy. A PMS policy would include an agency's method of incorporating PMS data into its programming and budgeting decision-making processes. The responses to the questionnaire indicate that the states were moving to comply with FHWA regulations requiring a PMS by January 1993.

Data Management

For an agency's PMS to be effective, the agency must develop and maintain a historical record of the condition of site-specific manageable pavement segments. Ideally, the records should include information about maintenance and rehabilitation work performed on the individual control or management sections. Without this type of historical information base, a PMS cannot be used for its intended purposes. Historical information can be contained in various printed reports, stored in separate or combined computer files, or maintained in a number of other forms.

Of the responding agencies, 50 reported that they store roadway management information on a mainframe, 9 replied that they use personal computers (PCs), and 1 currently uses hard copy but plans to upgrade to a PC. Many of the agencies are on-line, which means that their data files are readily accessible through use of mainframe terminals. Twenty-eight agencies indicated that their PMS information is kept in separate, nonintegrated files. Maintaining data in separate files can create problems in future merging attempts. The files must have a common key so data can be merged and integrated into management information reports. Variation in the location referencing system used to collect and store the individual files can also cause problems.

Location Referencing

Mileposting (and similar methods) is the most common method of dividing continuous roadway lengths into sections or segments for referencing roadway information. Mileposting is the practice of referencing data and/or location to the cumulative logged mileage along a particular route, usually beginning at some political or physical boundary such as a county line or an intersection. Thirty-eight agencies use some form of mileposting for reporting data, but only 30 physically mark milepost locations on part or all of their highways. Use of the term mileposting is subject to interpretation because various types of devices are used to geographically mark the mile points in the field, and several agencies use the terms "reference post" or "marker" for milepost. In addition, mileposts are frequently located at variable distances apart because of errors in placing or replacing markers.

Similar information concerning location referencing was collected and reported in *NCHRP Synthesis 158 (18)*, which deals with wet pavement accidents. The report noted wide variation in the methods of identifying the location of accidents and in the accuracy of the location used in accident reporting. It should be recognized that accurate reference systems for collecting and storing data in PMS databases should be established and maintained to ensure integrity and validity of management reports.

A number of states indicated that they plan to adopt segmenting for their location referencing. A location reference system based on link-nodes, or segments, is very adaptable to computerized databases and to establishing segment keys. Segments can be easily adjusted for changes in alignment or for subdividing segments to accommodate changes in section homogeneity. Most PMS data are more easily handled when based on a homogeneous section of roadway.

State transportation agencies are also expressing an increased interest in Geographic Information Systems (GIS). In the past, linear databases were used to track most highway data. With the rapid development of Global Positioning System (GPS) equipment and methods, obtaining coordinate information has become more practical and will facilitate adoption of GIS. The use of GIS-related PMSs will enhance the presentation and analysis of data through the mapping and sorting capabilities available.

Condition Surveys

The agencies were asked to indicate what types of pavement condition data they collected as part of their PMS function. Table 1 shows a tabulation of the replies from 60 agencies.

Nearly all agencies surveyed collect roughness and distress data for use in PMS. Most agencies also collect friction data, but friction data collection was not reported as part of a PMS in most cases. Apparently the agencies regard friction test data as being related to specific program areas, such as wet-weather accident reduction. Many of the agencies have indicated that they test these data in relation to accidents, research, materials evaluation, and other factors. Agencies reported that they also conduct structural testing to provide project-level design information and to satisfy other purposes at specific locations. The following chapters detail the four major types of condition data.

Pavement Condition Information Uses

The final group of questions concerning PMS activities was directed at obtaining general information on the availability of PMS data within the agency and the uses of PMS data.

TABLE 1

CONDITION DATA COLLECTED FOR PMS

Pavement Condition Type	Number of Agencies
Distress	58 [a]
Roughness	59
Structural	23 [b]
Friction	43 [c]

[a] Includes 2 agencies reporting that PCR is collected.
[b] Includes 3 agencies reporting data collected as a distress and 3 agencies collecting data for project purposes.
[c] Includes 5 agencies reporting testing by request, by sample, or selected locations.

Within an agency, the assignment of responsibility for pavement condition information varies widely. Eighteen agencies indicated that condition information is available on the mainframe; of those 18, nine indicated that PMS data are available through a particular functional unit of the agency. Other agencies related that PMS information is available and is located in one or more of the various functional units commonly found in typical highway organizations. Table 2 contains a tabulation of the respondents' replies concerning availability of PMS information.

An earlier synthesis report on pavement management practices *(12)* contained a breakdown on management responsibilities of the 51 agencies surveyed in 1986. A comparison of that information and information in Table 2 shows that there has been little change in assignment of PMS responsibilities. The increased emphasis on the importance of PMS and the broader scope and improved technology in PMS operation have not resulted in appreciable organizational changes since the 1986 survey.

The questionnaire also asked about the use of pavement condition data from PMS for planning and scheduling maintenance work, for project design, and for planning and budgeting. Thirty-eight agencies use condition data for planning maintenance work on an annual basis; 19 agencies responded that they do not use condition data for these tasks, but 4 of the 19 indicated that they are actively developing methods or planning to use the data for maintenance work; 43 agencies use condition data in project design; and 51 of the 60 agencies use PMS pavement condition data for planning and budgeting purposes. Two agencies are in the planning stages for using the data for design planning and budgeting.

SUMMARY

Of the 60 agencies surveyed, 58 indicated that they have a PMS in place; 24 of the 58 have developed a policy statement for their agency.

Many of the agencies store PMS information on mainframes; however, half of the agencies store the various data in separate data files. To make the fullest and most efficient use of the information, the files should be integrated using a common inventory of roadway sections to store data.

Mileposting is a common method for referencing information from the field into the databases. About one-third of the states and provinces do not have milepost references or other field identification markers, which creates a potential problem in relating field data collection to accurate entry of these data into PMS databases.

Nearly all agencies collect some form of pavement roughness and distress information. Most agencies also conduct

TABLE 2

PAVEMENT MANAGEMENT DATA SOURCES

General Location	Number of Agencies
Mainframe	22[a]
PMS Functions	8
Planning Functions	8
Materials, Testing, and Research	7
Highway Needs, Planning File	3
Maintenance	2
Other	5
Periodic Reports	5

[a] Indicates that PMS data are generally available to persons with access to the mainframe.

friction testing, but about one-third do not consider this activity to be part of their PMS function. Twenty-three agencies perform structural evaluations, predominantly for use in specific project design rather than for comprehensive PMS network data.

The intent in developing and maintaining a PMS is to provide a central, reliable source of information for multiple users. Based on the number of agencies reporting PMS data use for maintenance, design, planning, and budgeting, the intended purpose of PMS is being served.

CHAPTER THREE

DISTRESS EVALUATION

INTRODUCTION

Physical distress is a measure of the road surface, and subsurface, deterioration caused by traffic, environment, and aging *(14)*. The type, amount, and severity of distress occurring within a portion of roadway are used as indicators of how well that roadway is performing its intended function of transporting goods and people. Currently, there are no nationally accepted standards for either the procedures or equipment to be used in collecting distress information.

Distress data are usually collected by type, extent, and severity. Distress types tend to fall into three general categories, regardless of roadway surface type: cracking, surface deterioration, and distortion. However, the ways in which the specific distress types, severities, and extents are defined vary by the geographic location and the types of distress generally prevalent in an agency's pavements.

Efforts to standardize the collection of pavement distress data have been underway since the mid 1970s. One of the early attempts at standardizing the collection of pavement distress data came in 1976 when a pavement condition rating report *(19)* and an Airfield Pavement Distress Identification Manual *(20)* were published by the United States Air Force.

The next step in standardizing the collection of pavement distress data came in March 1979, when the FHWA published the *Highway Pavement Distress Manual for Highway Condition and Quality of Highway Construction Survey (21)*. This manual provided definitions of distress types, severities, and measurement techniques for the pavement types of jointed plain concrete pavement (JPCP), jointed reinforced concrete pavement (JRCP), continuously reinforced concrete pavement (CRCP), and asphalt concrete surfaced pavement (ACP).

In July 1979 the U.S. Army Construction Engineering Laboratory published *Technical Report M-268: Development of a Pavement Condition Rating Procedure for Roads, Streets, and Parking Lots, Vol. II: Distress Identification Manual*, by M.Y. Shahin and S.D. Kohn. This manual provided definitions of distress types, severities, and measurement techniques for asphalt surfaced pavement and jointed concrete pavement.

In 1982 the monitoring and evaluation of various in-service pavements across the country was performed as part of the Long Term Pavement Monitoring (LTPM) Program, which was sponsored by the FHWA. The use of a standard procedure for evaluating pavement distress was necessary to permit comparison of pavement performance among the cooperating agencies. Building on the FHWA's 1979 Highway Pavement Distress Identification Manual, Lytton, Rauhut, and Darter developed the *Long Term Pavement Monitoring Data Collection Guide (22)*. Agencies across the United States used this guide to evaluate the condition of LTPM sites.

The next development in standardizing pavement distress data collection came in 1985 when the FHWA published the *Pavement Condition Rating Guide (23)*. Developed by Zaniewski, Hudson, and Hudson, this guide presents a pavement distress survey procedure that combines a large number of pavement distresses into several distress types to reduce the time and cost of data collection efforts.

The most recent efforts to develop standardized methods of collecting pavement distress data have been made as part of the Strategic Highway Research Program (SHRP), for use on sites being evaluated under the Long Term Pavement Performance (LTPP) studies project. The *Distress Identification Manual for the Long-Term Pavement Performance Studies (24)*, developed by SHRP in 1990, has evolved from a combination of the 1979 FHWA Distress Identification Manual, the 1982 LTPM Data Collection Guide, and the 1985 Pavement Condition Rating Guide with extensive state Department of Transportation (DOT) experience and input.

The SHRP manual represents the latest and most comprehensive approach to a national standard for distress data collection. Although the SHRP manual was not the reference used for this study, it should be noted that this manual was updated in 1993 (SHRP-P-338). The information relative to this discussion is essentially the same in both versions. Table 3 compares the distress types recorded in each of the reports mentioned previously. This table shows that the following distress types are common to all of the manuals:

- Asphalt Surfaced Pavements—Longitudinal, transverse, alligator, block, and reflection cracking; potholes; rutting; bleeding; raveling/weathering; and lane-shoulder separation.
- Jointed Concrete Pavements—Longitudinal, transverse, and durability "D" cracking; faulting of transverse joints; and blowups.
- Continuously Reinforced Pavements—Durability "D" cracking.

Although the distress names are the same from manual to manual, the ways in which distresses are identified, severity levels are defined, and the extents are measured are different in each manual.

Table 3 also contains a number of distresses that are found in four of the five manuals for ACP and JCP, and three of the four manuals for CRCP. This would indicate that these distresses are also of importance and should be considered when developing a group of standard distress types. This group includes the following distresses:

- Asphalt Surfaced Pavements—Patch/patch deterioration, shoving, and polished aggregate.
- Jointed Concrete Pavements—Corner breaks, joint seal damage, longitudinal and transverse joint spalling, joint load transfer deterioration, map cracking and/or scaling, popouts, AC patching, PCC patching, lane-shoulder separation, and water bleeding and pumping.
- Continuously Reinforced Concrete—Longitudinal and transverse cracking, map cracking and/or scaling, popouts, blowups, punchouts, AC patching, PCC patching, spalling of

TABLE 3
STANDARD PAVEMENT DISTRESSES COLLECTED—HISTORICAL

Distress Type	FHWA 1979	ARMY 1979	LTPM 1982	FHWA 1985	SHRP 1990
Asphalt Surfaced					
Longitudinal Cracking	X	X	X	X	X
Transverse Cracking	X	X	X	X	X
Alligator Cracking	X	X	X	X	X
Block Cracking	X	X	X	X	X
Edge Cracking	-	X	-	X	X
Reflection Cracking	X	X	X	X	X
Sealed Cracks	-	X	-	X	-
Potholes	X	X	X	X	X
Patch/Patch Deterioration	X	X	-	X	X
Skin Patch	-	X	-	X	-
Shoving	X	X	-	X	X
Swell	X	X	-	X	-
Depressions	X	X	-	X	-
Corrugations	X	X	-	X	-
Rutting	X	X	X	X	X
Bleeding	X	-	X	X	X
Ravel/Weathering	X	X	X	X	X
Polished Aggregate	X	X	-	X	X
Lane-Shoulder Dropoff	X	X	-	-	X
Lane-Shoulder Separation	X	-	X	X	X
Water Bleeding and Pumping	X	-	-	-	X

longitudinal joints, lane-shoulder separation, and water bleeding and pumping.

When a standard distress manual is ultimately accepted, the distresses included must be well identified, distress severity levels must be defined by measurable means [i.e., an ACP transverse crack with a width of 6 mm (1/4 in.) would be low severity, etc.], and the extents must be recorded in a manner that allows future use of the data for objective measures for research, development, and design. The manual should be useable for windshield and walking surveys as well as for automated surveys.

Efforts to standardize the collection of pavement distress data continue. The American Society for Testing Material (ASTM) has adopted the Pavement Condition Index (PCI) for airfields (ASTM D5340) and is in the process of developing Standards for Distress Identification that should reflect the SHRP distress manual and the American Public Works Association (APWA) PAVER Manual.

DISTRESS DATA COLLECTION

The survey responses show a lack of standardization not only in the types of pavement distress data collected, but also in the methods used to collect the distress data. These methods include windshield surveys, shoulder surveys, walking surveys, and automated surveys using sensors, video, or film

TABLE 3 (CONTINUED)

Distress Type	FHWA 1979	ARMY 1979	LTPM 1982	FHWA 1985	SHRP 1990
Jointed Concrete					
Longitudinal Cracking	X	X	X	X	X
Transverse Cracking	X	X	X	X	X
Corner Breaks	X	X	-	X	X
"D" Cracking	X	X	X	X	X
Joint Seal Damage	X	X	-	X	X
Spall Longitudinal Joint	X	X	-	X	X
Spall Transverse Joint	X	X	-	X	X
Faulting Transverse Joint	X	X	X	X	X
Faulting Longitudinal Joint	X	X	-	-	-
Joint Load Transfer Deterioration	X	-	X	X	-
Blowups	X	X	X	X	X
Map Cracking and Scaling	X	X	-	X	X
Polished Aggregate	X	-	-	X	X
Popout	X	X	-	X	X
Reactive Aggregate	X	-	-	-	-
AC Patching	X	X	-	X	X
PCC Patching	X	X	-	X	X
Patch Adjacent Slab Deterioration	X	X	-	X	-
Depressions	X	-	-	-	-
Swell	X	-	-	-	-
Lane-Shoulder Dropoff	X	X	-	-	X
Lane-Shoulder Separation	X	-	X	-	X
Water Bleeding and Pumping	X	X	X	-	X
Rutting	-	-	-	-	X

cameras to record pavement distress conditions. Table 4 shows a summary of the methods used to collect data and the methods of defining the pavement area to be surveyed. Some agencies survey 100 percent of the pavement surface, or a pavement lane, while others designate a predetermined representative sample.

During windshield surveys, a survey team travels over the section being surveyed and attempts to collect distress data while viewing the pavement through the windshield of a vehicle traveling in traffic. These surveys provide very general data on distress. Windshield surveys are performed by 18 of the responding agencies, at speeds ranging from 8 to 88 kph (5 to 55 mph). Of the responding agencies, 16 survey 100 percent of their system, while 2 use sample sections between 30.5 and 91.5 m (100 ft and 300 ft) in length. Windshield distress surveys include those performed while using an Automatic Road Analyzer (ARAN) system to collect other pavement condition information.

Shoulder surveys are performed by a survey team traveling in a vehicle along the shoulder and collecting distress data by viewing the travel-lane pavement. Compared with the windshield surveys, this type of survey tends to provide more

TABLE 3 (CONTINUED)

Distress Type [a]	FHWA 1979	LTPM 1982	FHWA 1985	SHRP 1990
Continuously Reinforced Concrete				
Longitudinal Cracking	X	-	X	X
Transverse Cracking	X	-	X	X
"D" Cracking	X	X	X	X
Map Cracking and Scaling	X	-	X	X
Polished Aggregate	-	-	X	X
Popouts	X	-	X	X
Reactive Aggregate	X	-	-	-
Blowups	X	X	-	X
Construction Joint Deterioration	X	-	-	X
Punchouts	X	-	X	X
AC Patching	X	-	X	X
PCC Patching	X	-	X	X
Patch Adjacent Slab Deterioration	X	-	X	-
Localized Distress	X	-	-	-
Faulting Longitudinal Joint	X	-	-	-
Spall Longitudinal Joint	X	-	X	X
Spalling	X	-	-	-
Swell	X	-	-	-
Depressions	X	-	-	-
Lane-Shoulder Dropoff	X	-	-	X
Lane-Shoulder Separation	X	X	-	X
Water Bleeding and Pumping	X	X	-	X
Rutting	-	-	-	X

[a] The 1979 U.S. Army Manual, Technical Report M-268, did not contain distresses for CRCP.

TABLE 4

SUMMARY OF DISTRESS DATA COLLECTION METHODS

Data Collection Method	Number of States	Number of Provinces
Windshield	14	4
Shoulder	9	0
Walking	9	1
Combination	8	4
Automated	8	0

TABLE 5

AUTOMATED DISTRESS DATA COLLECTION EQUIPMENT AT AMES, IOWA

Equipment	Manufacturer	Collection Method
ARAN	Highway Products Int.	Keyboard
AREV	Pavement Management Services	Video/Voice
ARIA	MHM Associates	Video
KJ LAW 8300A	K.J. Law Engineers, Inc.	Keyboard
Laser RST	IMS	Laser Sensors
PAS-1	PAVEDEX, Inc.	Video
PAVETECH	PaveTech, Inc.	Video
PDI-1	Roadman-PCES, Inc.	Linear Video
ROAD PROFILER	South Dakota DOT	Acoustic Sensors
ROADRECON	PASCO USA, Inc.	35mm Film
VIDEOCOMP	VideoComp	Video

SOURCE: Proceedings of the Automated Pavement Distress Data Collection Equipment Seminar, June 1990.

complete and accurate information, since the survey teams are usually traveling more slowly. Shoulder surveys are performed by 9 of the responding agencies, at speeds ranging from 8 to 24 kph (5 to 15 mph). Four of these agencies cover 100 percent of their systems, while the other five cover approximately 10 percent of their systems.

Walking surveys are conducted by a survey team traveling on foot along the section being surveyed and recording the distress observed and/or measured. These surveys tend to be more detailed than a shoulder survey and require more survey time. In some instances survey teams may even draw distress maps of the section. Ten agencies conduct walking surveys. Eight of these agencies use representative samples of their management section, one surveys only specific projects, and one did not respond to that part of the questionnaire. When representative samples are used, they range in size from 30.5 to 161 m (100 ft to 0.1 mile).

An additional 12 agencies use some combination of the aforementioned methods, while 8 use some form of automated system.

Agencies conduct automated surveys by using a survey system that automatically records the pavement distress on the section. Available automated systems use 35mm photography, video technology, and noncontact sensors. Automated survey systems first appeared in the United States in the early 1980s and have been continually updated and refined.

In 1986 FHWA sponsored a project to evaluate the available automated survey systems by using these automated systems to collect distress data on SHRP's LTPP sites. The systems evaluated under this project were the PASCO ROADRECON systems, the GERPHO device, the IMS Laser RST, and the ARAN device. FHWA compared these devices with several variations of manual survey methods *(25)*.

The PASCO ROADRECON systems and the GERPHO device both used 35 mm film to record distress on the pavement's surface. In addition, the PASCO ROADRECON Unit that was evaluated had the capability to record transverse profile and roughness.

The Laser RST uses laser sensors mounted on a transverse bar to measure texture, roughness, transverse profile, and cracking.

The ARAN device measures roughness, transverse profile, cross-slope, and grade. The ARAN is also equipped with video cameras to record a general highway view and a view of the pavement surface.

FHWA conducted manual surveys in accordance with the PAVER *(26)* and Concrete Pavement Evaluation System (COPES) *(27)* survey methods. Data were recorded using both manual recording and automated entry with data loggers.

The 1987 FHWA report *(25)* of the systems evaluated stated that the PASCO ROADRECON and GERPHO systems provided a permanent record of the highest quality, most detailed data, in the most cost-effective manner. It was also found that these systems could be used for network- and project-level pavement management purposes.

In 1990 FHWA sponsored the Automated Pavement Distress Data Collection Equipment Seminar in Ames, Iowa *(28)*. At this seminar, 11 suppliers and operators of automated pavement distress data collection equipment demonstrated their equipment. Table 5 lists the types of exhibited equipment. (Of the four systems evaluated in the 1986 FHWA study, only the GERPHO device was not present at this seminar.)

Of the equipment demonstrated at the Ames seminar, one item uses 35mm film, six use video cameras, two use noncontact sensors, and two use manual keyboard entry for recording pavement distress. Some of the systems using video cameras have combined capability with other measuring methods such as sensors, voice input, etc. Table 6 summarizes the types of equipment present at the Iowa seminar.

The LTPP studies that started in the SHRP program and continue under the direction of FHWA use an automated

TABLE 6

DATA COLLECTION METHODS DEMONSTRATED AT AMES, IOWA

Data Collection Method	Number of Vendors
35mm Film	1
Video Cameras	6
Sensors	2
Keyboards	2

SOURCE: Proceedings of the Automated Pavement Distress Data Collection Equipment Seminar, June 1990.

TABLE 7

DISTRESS SURVEY FREQUENCIES AND METHODS

	Method (Number of Agencies)					
Frequency	Total	Windshield	Shoulder	Walking	Automated	Combination
Annual	28	9	4	6	5	4
Biennial	17	5	5	1	3	3
Triennial	4	2	-	-	-	2
Every 4 Yrs.	1	-	-	-	-	1
Planned '92	1	-	-	-	-	1
Unknown	9	3	-	3	1	2

system to collect a 35mm film record of pavement distress. As the trend toward automation develops, states, counties, and municipalities are beginning to use this and other automated data collection systems.

In 1991, NCHRP Project 1-27, "Video Image Processing for Evaluating Pavement Surface Distress" *(29)*, was completed. The objective of this 2-year project was to develop a system to process video images to identify type, extent, and severity of distress present. The resulting system employs image processing and pattern recognition techniques, and shows potential for identifying cracking on both asphalt and PCC surfaces. This system can be used on both isolated and pattern cracking. It can also be used to determine joints from cracks on PCC pavements.

SURVEY METHODS

Sixty agencies responded to the questionnaire for this synthesis. Of the reporting agencies, 49 use some form of distress manual, with 41 of them using manuals that are unique to their agencies. In addition, two agencies use the 1979 FHWA Manual, five use the 1990 SHRP Manual, and one uses the 1989 HPMS Manual. Figure 1 shows the types of manuals used.

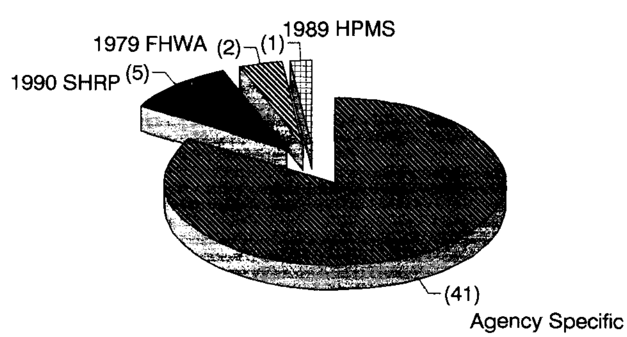

FIGURE 1 Distress manuals used by responding agencies.

As with the distress manuals, there is a great deal of variability in the frequency of distress surveys and in the methods used by the responding agencies. Frequencies range from annual to none, and survey methods range from windshield surveys to automated surveys. Table 7 shows the variation in survey frequencies and methods.

Both the designation for survey sections and the sampling intervals vary greatly among agencies—16 agencies using homogeneous sections, 12 use predetermined sections, 15 use projects or construction sections, 3 perform continuous surveys, 6 use segments, and 4 use some other method. A homogeneous section is a section in which the individual portions of the section all have the same pavement cross-section, construction history, rehabilitation history, traffic levels, and underlying soil conditions. Predetermined sections are sections with arbitrarily set beginning and ending points, such as a block, mile, half-mile, etc. Thirty-six agencies sample 100 percent of the sections, 9 collect one sample per mile, 3 take samples at the mileposts, and the remaining 12 use sampling techniques that are unique to their agency.

Of the distress data recorded, the measurement of rutting is most rapidly becoming automated. Twenty-nine agencies are using automated equipment to collect rutting measurements, with 15 of those agencies using the 3-sensor devices and 13 using devices with 5 or more sensors. Of the remaining agencies, 16 use a straightedge of varying lengths, 9 use a visual estimate, and 6 do not collect rutting data. Figure 2 shows the methods used to measure rutting.

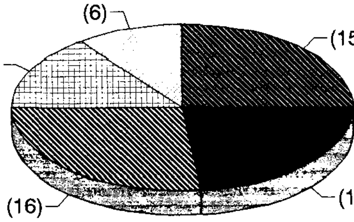

FIGURE 2 Rut measuring methods.

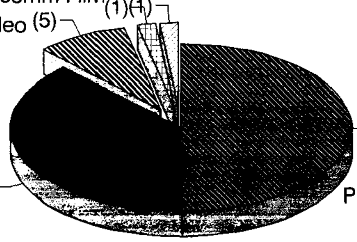

FIGURE 3 Distress data recorded.

Twenty-nine of the agencies reported that they record distress data on paper or preprinted forms, 22 record the data on PCs, 5 use video, 1 uses 35mm film, and 1 does not record these data. When asked if the data are recorded automatically, 32 answered no, 18 stated that they use a keyboard in a vehicle, and 6 use video. Figure 3 is a chart of the methods used to record distress data in the field.

When surveyed as to the amount of crew training performed, 11 agencies responded that they do no formal crew training, 3 provide less than 1 day's training, 16 train between 1 and 5 days, 18 train for between 1 and 3 weeks, 5 train for between 1 month and 2 years, and 7 did not specify the length of their training. Figure 4 shows the amount of crew training given by the agencies.

Twenty-seven of the agencies perform random resurveys for quality assurance purposes, 4 compare their findings to the previous year, 7 perform quality assurance in the office, and 20 have no quality assurance program for distress surveys. Figure 5 shows a distribution of the types of quality checks in use.

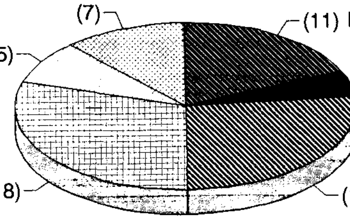

FIGURE 4 Crew training.

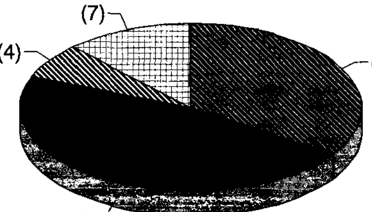

FIGURE 5 Distress quality assurance.

Many of the agencies generate some type of index as the output from the distress surveys—24 agencies generate a Distress Index, 13 compile a PSI or Present Serviceability Rating (PSR), 11 generate priority ratings, and 10 generate indices in some other manner. These indices, or ratings, are developed using a number of different methods—18 of the agencies use formulas, 10 use some type of deduct system, 9 use some type of weighting factors, 4 use tables, 9 use unique methods, and 9 do not use indices or ratings.

Some of the agencies combine the distress indices, or ratings, with other indices or ratings. Of the agencies that combine indices, 17 combine distress ratings with roughness ratings, 5 agencies combine distress with roughness and Friction Number or accident data, 8 agencies combine distress with roughness and Structural Number or data, and 6 combine distress with roughness and average daily traffic. Of the questionnaire respondents, 17 agencies do not combine distress with anything.

TABLE 8

DISTRESS SURVEY, UNITED STATES

Agency	Survey Method Used	Survey Manual	Method to Determine Distress Rating	Distress Rating Combined With?	Method or Formulae
Alabama	walk	yes	weight factors	roughness	formula
Alaska	shoulder	yes	distress state table	roughness, frost	compare with 240 condition states
Arizona	walk	yes	no response	roughness, structural, traffic	no response
Arkansas	walk	yes	deduct point system	roughness	Rigid=0.65 defects+0.35 ride, Flexible=1/2 power (ride x defects)
California	walk	yes	pavement condition category	roughness	over/under decisions
Colorado	windshield	no	no response	roughness	condition matrix
Connecticut	photo log	yes	weight factors	roughness, AADT	dr+ri+adt+class
Delaware	windshield	yes-SHRP	weight factors	Ride Comfort Index	PSI=75%(SDI)+25%(RCI), also safety and traffic
Dist. of Columbia	windshield	yes	table	no response	no response
Florida	shoulder	yes	deduct points	not used	seperate rating for ride, rutting, cracking.
Georgia	walk	yes-(flexible)	deduct from 100	not used	not used
Hawaii	windshield	yes-(Caltrans)	distress severity and extent	not used	not used
Idaho	shoulder	yes	cracking index	PSI (SDP)	50% roughness (0-5)+50% cracking (0-5)
Illinois	windshield, Int. walk	yes	CRS 0-9	na	na
Indiana	windshield	yes-HPMS	PSR 0-5, HPMS	not used	na
Iowa	shoulder	yes	PCR 0-100	roughness, friction, structural	formula with coefficient
Kansas	shoulder	yes	Woodward-Clyde methodology	roughness	based on distress state
Kentucky	windshield, shoulder	no	assigned demerits	roughness, friction, traffic	point assignment
Louisiana	video	yes-(draft)	under development	roughness	under development
Maine	video/ARAN	yes	PCR 0-5	not used	na
Maryland	shoulder	yes	weight factors, deduct values	roughness	priority matrix
Massachusetts	windshield/ARAN	no	formulae	roughness	PSI=0.65DI+0.35PSR
Michigan	semiautomatic	no	remaining service life (RSL)	not used	threshold values
Minnesota	shoulder	yes	weight scale 0-4	roughness	PQI= square root (PSR X SR)
Mississippi	video	yes-SHRP	formula	roughness	PCR=100*(12-IRI /12)*(Dmax-DP/Dmax)^2
Missouri	video	no	condition score 0-20	roughness	PSR= (2 x roughness score) + (condition score)
Montana	walk/shouder	yes	under development	roughness	PSI reduced by degree of rutting
Nebraska	windshield/walk	yes	NSI (similar to PCI)	roughness	PMS Manual procedure
Nevada	walk	yes	formula	roughness, friction	AASHO Road Test Formulas
New Hampshire	windshield/ARAN	yes	formula	no response	no response
New Jersey	windshield/ARAN	yes-SHRP	weighting factors 0-5	roughness, traffic	PI=0.6*RQI+0.3*SDI+0.1*TF
New Mexico	walk	yes-FHWA	tables	roughness, traffic, accidents	formulas
New York	windshield	yes	score summaries	not used	no response
North Carolina	windshield, shoulder, walk	yes	deduct values	roughness	deduct value in distress index
North Dakota	video	yes	deduct values	roughness	1/3 distress+1/3 ride+1/3 age=composite index (0-5)
Ohio	walk	yes	deduct values	roughness, friction	not combined, independent consideration
Oklahoma	automated	yes	no response	planning	no response

TABLE 8 (CONTINUED)

Agency	Survey Method Used	Survey Manual	Method to Determine Distress Rating	Distress Rating Combined With?	Method or Formulae
Oregon	windshield, (Int.-shoulder)	yes	deduct values	not used	not used
Pennsylvania	shoulder	yes	deduct values	roughness	PSRcurve=OPI=.45RI+.30SI+.20DI+.05SFI
Rhode Island	windshield, walk	yes	formula	roughness	proprietory software
South Carolina	windshield	yes	distress values, models	roughness, structural values	PQI= 1.158+0.138(PDI)(PSI)
South Dakota	windshield	yes	distress data elements	roughness, structural, traffic	ranking process
Tennessee	walk	yes-FHWA	not used	not used	not used
Texas	windshield, walk	yes	utility factors	roughness	tables, equations
Utah	shoulder	yes-SHRP	DI=5.0 -0.13(C+P)1/2pwr.	roughness, structural, skid	under development
Vermont	automated	yes	no response	roughness, friction	formula
Virginia	windshield	yes	rating factors	ride rating	ride considered seperate
Washington	shoulder	yes	deduct values	no response	developing new process
West Virginia	windshield, shoulder	no	not used	not used	not used
Wisconsin	shoulder	yes	work factors	no response	no response
Wyoming	windshield	no (plan SHRP)	no response	none	not used

CANADIAN PROVINCES

Agency	Survey Method Used	Survey Manual	Method to Determine Distress Rating	Distress Rating Combined With?	Method or Formulae
Alberta	windshield, video log	yes-SHRP, Ontario	weight factors	roughness, structural	PQI=f(RCI+SAI+VCI)
British Columbia	walk	yes	proposed PI=RI+SI+DI	roughness, structural	developing
Manitoba	windshield	yes	condition ratings	not used	not used
New Brunswick	windshield, walk	yes	formula	roughness, structural	PN =0.4PN ride+0.35PN distress+0.25PN strength
Nova Scotia	windshield, shoulder, walk	yes-RTAC	weight factors	not used	roughness
Ontario	windshield	yes	formula	roughness	DMI=(Si+Di)Wi; severity, density, weighting
Prince Edward Isle	windshield	yes	formula, table	roughness, structural	PQI=composite pavement quality index
Quebec	windshield	no	expert system	roughness, structural, other	na
Saskatchewan	windshield, shoulder, walk	no	no response	no response	no response

SUMMARY

Although efforts to standardize distress evaluation have been ongoing since the 1970s, much work still needs to be done. Currently there is little evidence of standardization in the collection or definition of distress. However, in some areas trends are beginning to appear. Table 8 summarizes agency distress survey practices.

No process stands alone as a real trend in the identification survey sections; however, 57 percent of the agencies perform 100 percent samples of the survey sections identified.

Most agencies conduct distress surveys either annually or biennially. The methods used to perform these surveys do not currently show a strong trend, although agencies are using automated survey systems more frequently than reported in *Synthesis 126 (30)*, with approximately half of the agencies now using some type of automated equipment to collect rutting data.

The majority of agencies record distress data on paper or preprinted forms, although a number of agencies are using PCs.

The amount of survey crew training varies from 1 day to 2 years. Approximately one-third of the agencies do not have a quality assurance program for distress surveys.

Approximately 80 percent of the agencies use either a distress index, serviceability index/rating, or a priority rating as the output for the distress survey. No trend appears to be evident in the way these indices or ratings are developed, although formulas are used more frequently than other methods. Over two-thirds of the agencies combine their distress index or ratings with other indices or ratings. The most often used additional index is roughness.

CHAPTER FOUR

ROUGHNESS EVALUATION

DEVELOPMENT OF EVALUATION METHODS

Ride quality consistently has been found to be a strong measure of the ability of pavements to serve the traveling public. For many years, state agencies reported highway system extent and physical condition information to FHWA in accordance with the HPMS Field Manual *(17)*. Until 1988, states could report the pavement condition component as a PSR, which could be based on a subjective rating of the pavement in accordance with a 0 to 5 scale containing verbal descriptions of condition and supplemented with a judgment of ride.

The 1987 edition of the HPMS Field Manual added a data field that required a pavement roughness measurement for each HPMS section and included an appendix that described the equipment, calibration/correlation, and data collection procedures. This landmark requirement provided state agencies with the ability to compare roughness data from across the United States *(17)*.

During the AASHO Road Test, conducted from 1956–60 *(31)*, AASHO developed a pavement serviceability concept that approximated the sentiments of the traveling public by using several serviceability panels comprised of a cross-section of highway users. These panel members rode over a number of roadway sections that represented different levels of road roughness. Each panel member rated each of the road segments traveled, and AASHO used the ratings of each panel member to establish a PSR for each segment and an overall PSR scale.

The use of serviceability panels to monitor the performance of a pavement during the life of the Road Test was impractical. Therefore, it was necessary to develop a means of approximating the PSR results through objective measurement of pavement characteristics. After extensive analysis of the PSR results, AASHO selected the pavement characteristics that best represented pavement serviceability—longitudinal profile variation, cracking, and patching. These characteristics were applied to both concrete and flexible pavements. For flexible pavements, AASHO included the additional measurement of transverse profile variation (rutting). The objective measurements selected were then statistically combined to permit the calculation of a PSI, which produces ride quality through longitudinal profile variation data.

The need for a method to measure longitudinal profile variation led to a simplified profiling device developed by and named for William N. Carey, Jr., Henry C. Huckins, Rex C. Leathers, and other engineers. The CHLOE Profilometer is a trailer-mounted contact profiler that uses a set of small tandem wheels placed 20.3 cm [8-in.] apart to measure slope variance of the pavement's surface.

The CHLOE Profilometer was a more objective method of measuring road roughness than the Bureau of Public Roads (BPR) Roughometer, a response-type device which had been developed much earlier. The BPR Roughometer consists of a single-wheel trailer that measures the vertical movement of a dampened leaf-spring wheel by means of a mechanical integrator. Because of the electromechanical counts, the device must be operated slowly along the pavement. The output is a summary statistic expressed in in./mile.

Following the development of the PSI concept, and the recognition of roughness as a predominant measure of pavement service quality, other types of road roughness measuring equipment were developed. Historically, the equipment that has been used to measure pavement roughness can be categorized into two general types—response type road roughness measuring systems (RTRRMSs) and profilers.

RTRRMSs are devices that determine the pavement's roughness by measuring its effects on the movement of a vehicle or a wheel. Some of these devices have accelerometers on one of the axles, or they may measure the vertical movement of a vehicle's body in relation to the axle. Some examples of RTRRMSs are the BPR Roughometer, the Mays Ride Meter, the ARAN, the PCA Ride Meter, and the Cox Ride Meter. Until the late 1980s, most highway agencies used some type of RTRRMS to measure roughness. The response type equipment requires constant attention to the mechanical and operating conditions during testing and is usually operated at a constant speed (e.g., 40 mph).

Profilers (sometimes called profilometers or profilographs) are instruments designed to produce a continuous signal or trace related to the true profile of the pavement surface. A simple example is a rolling straightedge, which records a midpoint deviation. Other examples of this type of device are the California Profilograph, the Reinhart Profilograph, and the Ames Profilograph. Figure 6 shows a California type Profilograph, which is most often used for checking pavement surfaces for specification compliance. The California Profilograph is usually hand-propelled at walking speeds and is not practical for surveying long distances.

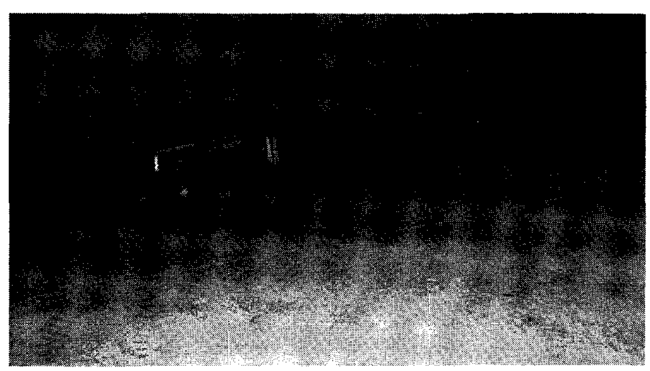

FIGURE 6 California profilograph.

Early models of the GM Profilometer also obtained elevation measurements through a small following wheel in contact with the pavement in the wheelpath. The vertical elevations of the wheel were measured many times in small increments and processed mathematically to obtain a single numeric describing the condition of the wheelpath.

More recent profiles are equipped with noncontact sensors that use lasers, light beams, and acoustics to obtain profile information, rather than mechanical devices that contact the pavement. These types of profilers are capable of measuring profiles at traffic speeds and were in use in a few states by the mid 1980s. Examples of these devices include the newer K.J. Law Profilometers, the South Dakota type Road Profiler, and the IMS Laser RST. Figure 7 shows one of the SHRP Profilometers supplied by K.J. Law.

FIGURE 7 SHRP profilometer.

Janoff developed an equation for correlating longitudinal profile with rideability. [This work was reported in *NCHRP Report 275 (32)* and *NCHRP Report 308 (33)*]. Janoff conducted this study in five states using serviceability panels, contact and noncontact profilometers, and a Mays Ride Meter. In his study, Janoff converted the longitudinal profile measurements taken with a profiler into a Ride Number that matches the Mean Panel Ratings (MPRs) of the serviceability rating panels. The resulting equation makes it possible for agencies to use objective measures of a pavement's longitudinal profile to determine its acceptability to the traveling public.

Because many of the states were using RTRRMSs at this time, Janoff's research also analyzed RTRRMSs to determine their correlation with the MPR. He found that the correlation for bituminous pavements was very high, nearly as close as the correlation between the profilometers and the MPRs. However, on the portland cement concrete and composite pavements he found the correlation to be fair to poor. Because the concrete and composite pavements used in the tests did not include pavements with higher roughness, the correlation may have been affected. The correlations and equations developed by Janoff were major steps in the pursuit of an objective and standardized means of evaluating pavement roughness.

At about the same time that Janoff was performing his correlation work, the World Bank and others sponsored the International Road Roughness Experiment (IRRE) to establish guidelines for conducting and calibrating road roughness measurements. The resulting World Bank Technical Paper Number 46 *(34)* further advanced the standardization of road roughness technology by developing an international standard for measuring and reporting road roughness, the International Roughness Index (IRI), and by grouping the various methods for measuring road roughness into four classes based on the ability of each class to precisely measure IRI.

The IRI is a standardized roughness measurement that is calculated by mathematically applying a reference quarter car simulation (RQCS) to a measured profile. Based on extensive research, the World Bank established RQCS parameter values that best represented roughness-related measuring equipment being used worldwide *(35, 36)*. The IRI is measured in units of meters/kilometer or in./mile can easily be related to those measurements obtained by RTRRMSs. This index is very useful for relating a roughness measure to overall ride quality (which is obtained at highway speeds).

Because IRI is a characteristic of the longitudinal profile of a wheelpath, and not a characteristic of a piece of equipment, the index is time-stable. This index is directly measurable by a number of profilometric methods, and it correlates extremely well with the measures of RTRRMSs, as well as with subjective opinion. The World Bank has studied the relatedness of IRI to subjective opinions *(34)*, and ASTM is currently developing IRI standards for the United States.

In establishing IRI as a reporting standard, the HPMS report *(17)* established four classes of approaches for measuring road roughness based on the ability of each method to precisely and accurately measure IRI:

Class I — **Precision Profiles.** In a Class I survey, the longitudinal profile of the wheelpath is measured manually using a rod and level. Transportation Road Research Laboratory (TRRL) Beam, Face Dipstick (shown in Figure 8), or similar high-precision device. The measured profile is used as a basis for calculating the IRI. A Class I survey provides the highest level of precision and repeatability.

Class II — **Other profilometer methods.** In a Class II survey, the profile of one or both wheelpaths is measured using either contact or noncontact prolifometers that have been calibrated on sections with profiles determined from a Class I survey.

Class III — **IRI estimates from correlation equations.** A Class III survey is performed using an RTRRMS or other roughness device such as a rolling straightedge. The measures from these devices must be correlated with IRI using equations developed experimentally for each device. The equipment used in a Class III survey must be calibrated to sections whose profiles have been determined from a Class I or Class II survey.

Class IV — **Subjective ratings and uncalibrated measures.** Class IV surveys use subjective evaluations of the roadway that are produced by either riding over the section or by conducting a visual inspection. These evaluations are then roughly correlated with IRI through the use of roadway descriptions for various IRI values. These surveys are considered to be "calibration by description." An uncalibrated RTRRMS may also be used.

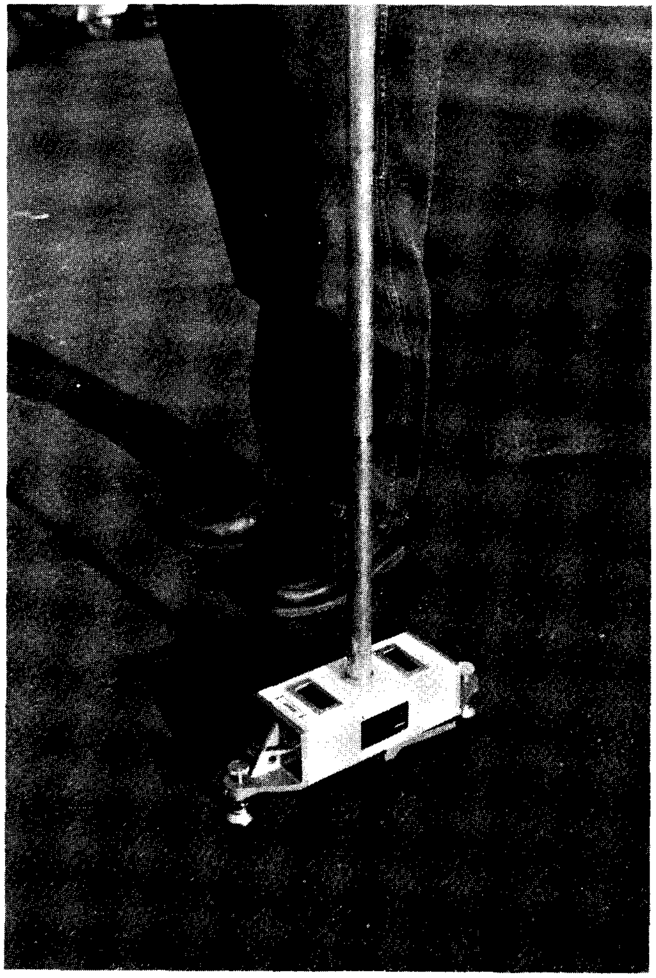

FIGURE 8 Face Dipstick.

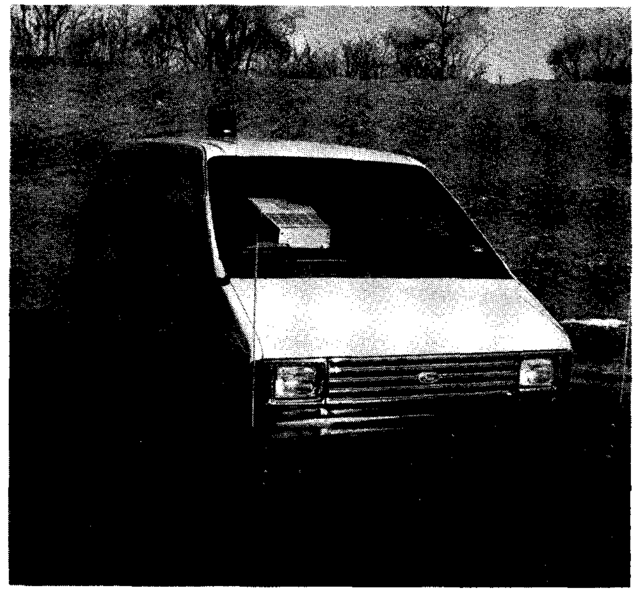

FIGURE 9 South Dakota Road Profiler.

SURVEY EQUIPMENT USED

In 1986, *NCHRP Synthesis 126 (30)* reported that a majority of the states were using RTRRMSs to measure pavement roughness. Since then there has been a strong movement among the states to use a noncontact acoustic road profiler similar to the one developed by the South Dakota DOT. Figure 9 shows one version of the South Dakota type Road Profiler. The front bumper contains three sensors and two accelerometers. In the previous synthesis, South Dakota was the only state that reported its use, whereas in the survey responses for this synthesis, 34 units were in use in 25 agencies. Table 9 compares the equipment usage findings of the two syntheses.

Road profilers are seeing wider usage for a number of reasons. First, FHWA now requires the roughness on HPMS sites to be reported in IRI. Although this measurement can be taken using an RTRRMS, it would require the establishment of correlation factors with a Class I or Class II method; the road profilers can obtain IRI data much more easily. In addition, road profilers require minimal calibration/verification compared to the RTRRMSs, which require frequent calibration. Overall, road profilers are very economical.

Many of the states and provinces continue to use their existing equipment and supplement their capability with other systems. Among the agencies responding, 10 use more than one type of roughness testing equipment to conduct their roughness surveys.

The majority of agencies calibrate their equipment using either the HPMS guidelines, correlation procedures, or test sections. Of these methods, 3 of the agencies use the HPMS guidelines contained in the *Highway Performance Monitoring System Field Manual (17)*, Appendix J, issued in 1987; 20 use correlation procedures; and 24 use established test sections.

The HPMS guidelines recommend procedures for collecting pavement performance data for the test sites included in the HPMS. These guidelines adopt the survey procedure classifications established at the IRRE, require roughness data to be reported in IRI, and establish equipment calibration procedures for Class II and III roughness surveys.

Of the agencies using correlation procedures, six correlate with Class II systems and three correlate with other South Dakota type Profilometers.

Of the agencies using test sections for calibration, 11 use a Dipstick to measure the longitudinal profile of the test section. Manufactured by the E.W. Face Company, the Dipstick measures the difference in elevation between a series of points that are 1 ft apart. Originally developed to measure warehouse concrete floor flatness, the Dipstick consists of an inclinometer built into a rectangular case with two feet at the ends spaced 1 ft apart. The device is equipped with a cane-like handle that permits the operator to "walk" the instrument down a survey line. At each turn the elevation is recorded by internal electronics that convert the inclination angle into an elevation difference at the 1-ft interval. These differences are then used to determine the true profile of the test section, and the RQCS is used to compute IRI over the profile. The Dipstick method is a Class I method.

SURVEY PROCEDURES

Though the responding agencies survey the various portions of their highway systems for roughness or profile using a variety of schedules and cycles, the majority of them tend to survey either annually or biennially. Table 10 shows the breakdown of the survey frequencies.

TABLE 9

ROUGHNESS MEASURING EQUIPMENT USAGE, 1986 AND 1991 *(36)*

	Number of Agencies Using	
Equipment Type	**1986**	**1991**
GMR Profilometer (K.J. Law)	4	3
South Dakota Road Profiler	1	25
K.J. Law 8300	0	3
Cox CS8000 Ultrasonic	0	8
Mays/PCA/Cox Ride Meters	32	22
ARAN	0	10
BPR Roughometer	4	0
Others	0	2

TABLE 10

NETWORK SURVEY FREQUENCY

Survey Frequency	Entire System	Interstate Network	Primary Network	Other Network
Annual	22	27	21	19
Biennial	13	14	15	18
Triennial	2	1	1	2
Other	12	2	3	4

When surveying 2-lane roads, 38 agencies survey in only one direction, while 15 survey in both directions. On 4-lane highways, 37 agencies survey the outside lane in both directions, 7 survey one lane in one direction and 8 survey all lanes in both directions.

The surveys are conducted at speeds ranging from 5–60 mph (see Table 11) with production rates ranging from 27 to 350 lane miles (LM)/day (see Table 12).

TABLE 11

NETWORK SURVEY SPEEDS

Survey Speeds	Agencies
45-50 mph	27
Posted Limit	11
Other (5-60 mph)	12

In general, the current trend in survey procedures appears to be to survey the higher systems, such as the interstate, annually with the rest of the network being surveyed annually or biennially. The roughness, or profile is measured while surveying one direction on 2-lane roads and the outside lane in both directions on 4-lane roads at speeds of 40–55 mph, or at the posted speed limit.

TABLE 12

NETWORK SURVEY PRODUCTIVITY

Survey Productivity	Agencies
300-350 LM/Day	9
200-250 LM/Day	16
65-125 LM/Day	13
27-40 LM/Day	4

DATA HANDLING

Among the responding agencies, there is a definite trend toward the use of IRI for reporting road roughness—20 agencies report only in IRI units, 11 agencies report in IRI and

TABLE 13

PAVEMENT ROUGHNESS, UNITED STATES

Agency	Equipment Type	Data Units	Calibration Procedure
Alabama	SDP (International Cybernetics)	IRI	HPMS procedures
Alaska	SDP, RD, PC	IRI	calibration guage
Arizona	Mays	no response	correlate with Profilometer
Arkansas	Mays	in/mi	test track
California	Cox	no response	test track
Colorado	ARAN	IRI	test sites
Connecticut	TechWest+SDP	arb.-1to1000	calibration site run monthly
Delaware	ARAN, PURD	IRI, RMSV	manufacturer recommendations
District of Columbia	Mays (Rainhart)	IRI	correlate with Class 2
Florida	SDP (International Cybernetics)	IRI-conv. PSI (SV)	with CHLOE for PSI (Slope Variance)
Georgia	Mays (mod-Ga)	no response	no response
Hawaii	Cox	ridescore	per HPMS (World Bank)
Idaho	SDP (International Cybernetics)	IRI/PSI	no response
Illinois	SDP (Ill.mfg)	IRI	test sensers
Indiana	Cox/Prof, Prorut (spring92)	ridescore (IRI-92)	correlation loop, once per month
Iowa	SDP (International Cybernetics)	IRI	correlate with CHLOE
Kansas	Mays (Rainhart)/SDP (Internaional Cybernetics)	IRI	MAYS/SDP/Dipstick
Kentucky	Mays (Rainhart)	RI	test sections monthly/Profilometer yearly
Louisiana	contract	IRI	contract
Maine	ARAN	IRI	surveyed test sections/test sensors
Maryland	KJLaw 8300	IRI	In-house
Massachusetts	ARAN	IRI, RMSVA	Dipstick/survey test sections (9)
Michigan	Inertial Profilometer (Michigan DOT)	IRI	self-calibrating
Minnesota	SDP (MinnDOT)	IRI	self-calibrating
Mississippi	SDP (Pave Tech/2 International Cybernetics)	IRI	multiple runs/Dipstick/SHRP sites
Missouri	ARAN	RMSVA (IRI-10sts)	internal/10 calibration sites periodically
Montana	SDP (International Cybernetics)	IRI, profile, rut depth	against other SDP at Users Group Meeting
Nebraska	SDP (Nebraska)	IRI	against other SDP at Users Group Meeting
Nevada	Cox	IRI, slope variance	per HPMS/Dipstick/calibrated sections
New Hampshire	ARAN	RCI, SDI, RRI	test sections(9)/Dipstick
New Jersey	ARAN	ARAN	test sections(6)/Dipstick
New Mexico	ARAN/PhotoLog-roughness	IRI< raw data	rod and level survey
New York	SDP (contract)	IRI	test sections/Dipstick
North Carolina	SDP	IRI	not necessary
North Dakota	SDP in Video Tech Van	IRI	weekly over test strip
Ohio	KJLawProfilometer/MDR8300/Mays (Rainhart)	IRI, PSI	against Profilometer
Oklahoma	SD style/Mays	IRI	Mays frequently, SDP not needed

TABLE 13 (CONTINUED)

Agency	Equipment Type	Data Units	Calibration Procedure
Oregon	SDP	IRI	plan Dipstick-just purchased equip
Pennsylvania	SDP/Mays	IRI	test sections/Dipstick
Rhode Island	SDP (ConnDOT)	IRI	see ConnDOT
South Carolina	Mays (Rainhart)/SDP (Internaional Cybernetics)	IRI	test sections/Dipstick
South Dakota	SDP (SDDOT)	IRI, PSR	test segments/Dipstick
Tennessee	no survey		
Texas	Siometer	SI	test sections
Utah	Cox	RI to IRI	standard section weekly
Vermont	IMS (contract)	IRI	no response
Virginia	SDP (Internatioal Cybernetics)/MDR8300 (KJLaw)	IRI	test sections vs. KJLaw
Washington	SDP/Cox	IRI	no response
West Virginia	KJLaw Profilometer/Mays	IRI	Mays to Profilometer
Wisconsin	SDP	IRI	system check
Wyoming	SDP	IRI	Annual users group/daily test sections

CANADIAN PROVINCES

Agency	Equipment Type	Data Units	Calibration Procedure
Alberta	Cox (CS8000 Ultrasonic)	RCI	CGRA-Roadmeter to RCI
British Columbia	na		
Manitoba	na		
New Brunswick	Mays	IRI, RCI	IRI from MDR/special calibration section
Nova Scotia	Roadmeter-NSDTC	counts/kilometer	20 control sections/rating panel/road meter
Ontario	PURD (Roadware)	RMSVA	standard sections
Prince Edward Isle	PURD	RCI	RCI/panel correlation, test sections twice/year
Quebec	PCA/Mays	IRI	TAC specifications/RRMR response to IRI
Saskatchewan	Cox (Ultrasonic)	RCI	standard sections monthly

other data units, and 14 agencies do not report IRI reporting roughness in other forms. Other forms of data reported include Ridescore, in./mile, and Root Mean Square Vertical Acceleration.

The trend in data collection and reporting is to collect the data for both wheelpaths and report those data as an average of the wheelpaths. Thirty-seven of the agencies handle the data in this manner, 5 agencies measure and report roughness only in the right wheelpath, and 10 report only for the left wheelpath.

Once an agency collects the data for a section of pavement, these data are processed and summarized for reporting. Twenty-seven of the agencies use a uniform increment, such as 0.1 mile; 21 agencies report the data by section; and 6 report data for both.

The majority of agencies, 39, store raw data in PC files, 11 still use hard copy, and 3 store data on tape. Once the data arrive in the office, they are summarized for the reporting section—31 of the agencies store these data on mainframe computers, 19 use PCs, and 1 still uses hard copy.

Overall the current trend in data collection and reporting is to collect IRI data for both wheelpaths, reporting the average of the wheelpaths. The raw data are collected and stored in PC files. In the office, the data for a uniform increment of roadway are processed and reported and the processed data are stored on mainframe computers.

SUMMARY

In the United States and Canada, the road roughness measuring community is progressing toward standardization of data reporting, equipment, and techniques for measuring equipment calibration. Table 13 summarizes agency roughness survey practices.

The IRRE and the HPMS guidelines helped spur the move toward use of the IRI, and have established uniform, practical procedures for calibrating measuring equipment. In addition, the guidelines have established a uniform basis for communication and information exchange among users, and the development of the four classes of roughness survey has related the procedures and equipment being used in terms of accuracy and data reporting.

The current trend in road roughness surveys is to conduct the surveys using a Class II profiler, with the South Dakota type, noncontact acoustic road profiler being the most common. These surveys are performed more frequently on the higher type systems, such as the interstate, with speeds ranging from 45–55 mph. The roughness measurements are collected in both wheelpaths while surveying in one direction on 2-lane roads, and in both outside lanes when surveying 4-lane roadways. The data are reported in IRI for some uniform increment of roadway, while the agencies maintain the data on personal and mainframe computers.

CHAPTER FIVE

STRUCTURAL CAPACITY

The structural capacity of a pavement denotes the pavement's ability to carry traffic loadings with minimum distress or deformation. A structural evaluation of a pavement can be performed to assess the pavement's structural capacity and to determine the pavement's ability to perform satisfactorily under current and projected traffic loadings. Determination of the structural capacity is useful in providing information for the design and selection of rehabilitation alternates for asphalt concrete overlays and in planning rehabilitation of portland cement concrete pavements to locate possible voids under the slabs and to evaluate load transfer properties at joints.

Agencies can conduct a structural evaluation of an existing pavement by using equivalent thickness values, by measuring surface deflections, or by performing a mechanistic layer analysis. Most of the methods used for structural evaluation require some type of pavement measurements, whether destructive or nondestructive. Destructive tests involving coring and sampling provide pavement layer thickness and material properties are needed; however, nondestructive (NDT) test methods are generally preferred. A majority of the questionnaire respondents have the capability to do this type of testing.

NDT methods evaluate structural capacity by measuring the pavement response to a known applied load. The most commonly used measurement is the surface deflection of the pavement under some type of controlled loading. Equipment in use includes those devices that apply loads by slow-moving known wheel weights and those that use stationary, vibratory, or falling weights. Agencies obtain measurements for peak rebound deflection under an applied load and usually for a measure of the curvature of the deflection basin. These measurements can then be used to estimate the properties of existing layers for use in pavement analysis and rehabilitation design. *NCHRP Report 327 (37)* details the use of NDT data for this purpose for flexible pavements. *NCHRP Synthesis 126 (30)* provides a more complete description of deflection equipment.

EQUIPMENT

Equipment is readily available for conducting the three common load application tests. The Benkelman beam is a low-cost method used to measure rebound deflections under a test vehicle as the vehicle moves away from a probe on the end of a static beam. This process is slow and requires lane closure. Several automated versions measure deflections under moving loads in a manner similar to that of a Benkelman beam. These automated processes mechanically place the beam or sensors stationary on the ground and use the moving, carrying vehicle to apply the load. After the deflection measurements are taken, the beam is picked up and advanced to the next measuring point. Examples of this equipment include the California Deflectometer and the La Croix Deflectograph.

A second type of equipment, known as a falling weight deflectometer (FWD), drops a known mass from a known distance to impart a load on the pavement. Deflections are then measured with a line of geophones or seismometers. FWDs include the Dynatest FWD, the KUAB FWD, and the Phoenix FWD.

A third type of equipment employs a vibratory load that is generated hydraulically or by counterrotating masses. Deflections under variable applied loadings are also obtained with a line of geophones. The Road Rater and the Dynaflect both employ vibratory loads.

EQUIPMENT TYPES USED

Forty-four of the agencies responding to the questionnaire use one or more of the NDT pieces of test equipment. Two agencies use a Benkelman beam. One agency currently has no equipment but is in the procurement process. Several other agencies also indicated that they are procuring added devices.

Table 14 summarizes the type of equipment in use. A comparison with similar information in *Synthesis 126 (30)* showed a strong increase in use of FWD equipment and reduced use of the vibratory load types, such as the Road Rater or Dynaflect. Reported use of the Benkleman beam also dropped from 14 to 2 users, although the Benkelman beam is still used by a number of the responding agencies.

Most of the agencies use a one- or two-person crew, exclusive of traffic control, to operate equipment during deflection testing. Some agencies use more crew members, but those crew members perform other duties during the deflection test period such as traffic control, faulted joint measurements, and distress evaluation. Ten agencies use a 1-person crew, 24 agencies use a 2-person crew, 8 agencies use a 3-person crew, 4 agencies use a 4-person crew, and 13 agencies use a 5-person crew. Most agencies manage deflection testing as an independent function and provide appropriate traffic control from sources used for other lane-closure purposes.

Traffic control requirements during deflection testing are handled as a lane-closure operation or a slow-moving operation in accordance with the Manual for Uniform Traffic Control Devices (MUTCD). When agencies test high-level highway pavements, they commonly use several arrow boards and shadow vehicles.

Most of the automated deflection-measuring equipment in use has fairly complex instrumentation that requires periodic calibration. Many of the devices contain built-in calibration procedures and external sensor-check procedures that were developed by the manufacturers. The need for equipment calibration, operation requirements, and skilled crew training has influenced the type and extent of deflection-testing programs conducted. In many agencies the deflection-testing function is considered to be research, or special testing.

TABLE 14
STRUCTURAL CAPACITY EQUIPMENT *(30)*

Type	1991 Agencies	Number of Units	1986* Agencies	Number of Units
Dynatest	20	39	1	1
KUAB	4	4	-	-
Phoenix	1	1	1	1
Unknown FWD	9	10	4	4
Dynaflect	18	30	20	22
Lane Wells — Geolog	2	5	-	-
Road Rater	5	7	5	5
Benkelman Beam	7	26	17	17

* Does not include Canadian provinces.

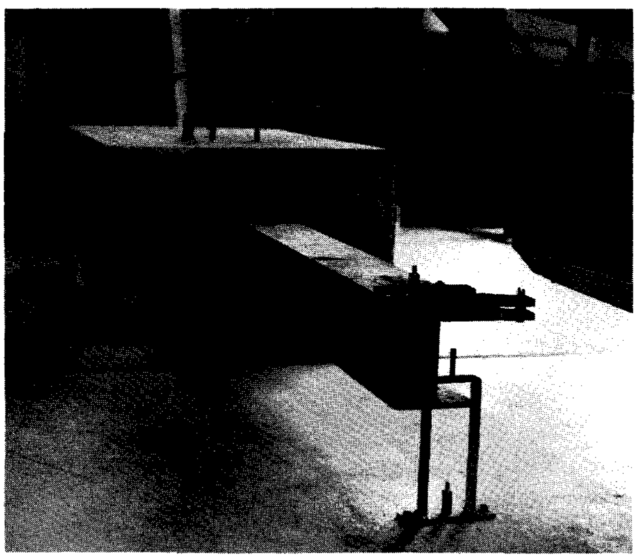

FIGURE 10 Deflection reference site.

The SHRP LTPP program included the periodic measurement of deflections on the test section as part of the pavement condition data. The FWD method was selected, and four Dynatest devices were obtained. The program made extensive efforts to evaluate the equipment and establish uniform testing procedures for use across the United States and Canada. In a draft report, the results of the effort describe detailed calibration procedures, which consist of first calibrating the FWD deflection and load transducers against reference devices. This part of the procedure is called "reference calibration." The calibration of the FWD deflection sensors is then further refined by a process called "relative calibration." Though these procedures were written for the Dynatest device, they can be adapted to other FWDs with minor modifications. The site facilities required for the reference calibration have been established in each of the four SHRP regions: St. Paul, MN; Reno, NV; Harrisburg, PA; and College Station, TX.

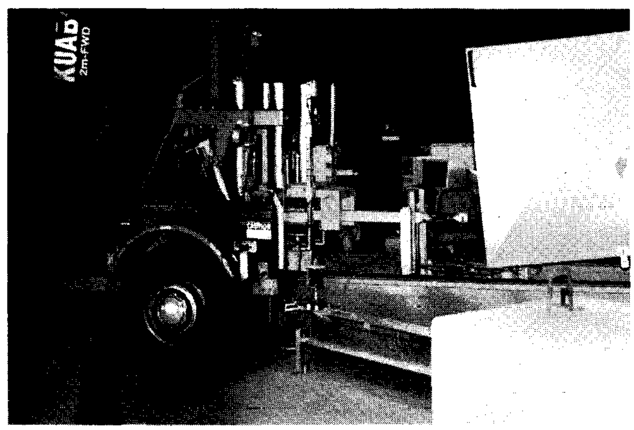

FIGURE 11 Reference site with FWD in place.

Use of the reference calibration procedures will supplement current calibration procedures and will greatly improve the consistency and reliability of deflection test results among agencies and equipment. Figure 10 shows one of the reference sites in Pennsylvania. Figure 11 shows an FWD positioned on the reference slab.

SURVEY PROCEDURES

Most structural capacity evaluations are performed primarily on a project-level basis. Project-level surveys are localized surveys performed for rehabilitation design purposes, while a network-level survey involves sampling at some interval over a network or entire highway system. Thirty-five of the agencies are conducting tests on a project-level basis, and 13 are conducting both project-level and network-level testing. Two agencies report conducting only network-level testing, and one reports performing only research testing. The number of project related test miles done each year ranges from 12 to 700

TABLE 15

ANNUAL PROJECT TEST MILEAGE

Number of Agencies	Miles
9	0-100
9	100-200
7	201-500
6	501-1,000
1	over 1,000
10	various

miles. Table 15 shows the project related test mileage by various agencies.

Ninety percent of the agencies doing deflection testing perform tests at uniform intervals throughout the project or network section length. Table 16 contains a tabulation of the intervals used.

Eight agencies reported that they used sampling procedures in establishing test locations; however, there was little agreement in the procedures used. The amount of production reported also varied widely—18 of the agencies reported less than 150 data points per day, another 18 reported from 200 to 400 data points per day, 15 agencies were testing up to 100 days per year, and 13 were testing over 100 days per year.

DATA REPORTING AND USE

Of 51 responding agencies, 35 reported that they recorded deflection test data on PCs. Another 5 agencies recorded on tape or a combination of tape and PCs, and 11 used hard copy. Twelve of the states reported that they upload the deflection test data to their mainframes for storage.

The questionnaire replies concerning use of deflection data were not sufficiently detailed to enable more than a general assessment. Twenty-five agencies appear to be using a method to back calculate layer modulus. Others are using empirical relationships to derive overlay requirements, determining remaining life, or convert deflection values to structural equivalencies. At least seven agencies perform routine tests on concrete pavements to evaluate load transfer properties at joints and to locate potential voids under slabs.

While the specific ways in which agencies handled structural capacity data were unclear, the end use of the data could be determined from responses to the questions. Forty-two agencies are using deflection test data for design. An additional two agencies are developing procedures and plan to use the data for design. Nine agencies use deflection test data to assist in establishing seasonal loads, and nine agencies use the data to set load limits. Eight agencies reported using joint load transfer data in concrete pavement rehabilitation planning.

SUMMARY

About 90 percent of the agencies are equipped to perform structural capacity evaluation using automated test equipment

TABLE 16

DEFLECTION TEST INTERVALS

Project Level		
Agencies	Intervals	
3	<30 m	(<100 ft)
8	61-81 m	(200-265 ft)
14	152-162 m	(500-528 ft)
5	268-402 m	(880-1,320 ft)
Network Level		
Agencies	Intervals	
5	<268 m	(<880 ft)
1	305 m	(1,000 ft)
3	1,610 m	(5,280 ft)

TABLE 17
PAVEMENT STRUCTURAL CAPACITY, UNITED STATES

Agency	Equipment Type	Survey Type Network/Project	Equipment Calibation	Calibration Frequency
Alabama	Dynatest-9000	project	no response	no response
Alaska	Dynatest-8000	project	manufacturer	no response
Arizona	Dynatest	project	manufacturer	annually
Arkansas	Dynatest-8600	network, project	manufacturer	biennially
California	Dynaflect, Lane-Wells GeoLog	project	load cell, test section	annually
Colorado	FWD-Foundation Mechanics	project	manufacturer	annually
Connecticut	Benkleman Beam	project, research	no response	no response
Delaware	no testing			
District of Columbia	Coring			
Florida	FWD, Dynaflect	project, rehabilitation	sensors	monthly
Georgia	Dynatest-8000	project	manufacturer	quarterly
Hawaii	Dynatest	none		
Idaho	Dynatest-8000	network, project	SHRP sites, center	annually
Illinois	Dynatest	project	manufacturer, ASTM	annually
Indiana	Dynaflect,Dynatest	project	SHRP	annually
Iowa	Foundation Mechanics, Road Rater-M400	network	manufacturer, test section	annually
Kansas	Dynaflect, GeoLog	project		monthly
Kentucky	Road Rater-M2000	project	sensors	annually
Louisiana	Dynaflect, FWD	project	no response	no response
Maine	Road Rater-400B	project	sensor check	3 times per year
Maryland	Road Rater, FWD	project	FWD to Florida, RR-sensors	FWD-6 month; RR- monthly
Massachusetts	no testing			
Michigan	KUAB	research	manufacturer	as needed
Minnesota	Dynatest	project	sensor check	3 times per year
Mississippi	Dynaflect, SIE,Inc.	project	Dynaflect setup	twice per day
Missouri	Dynatest	project	sensors	annually
Montana	RoadRater-400B, Foundation Mechanics	project	manufacturer	annually
Nebraska	FWD	project	internal	daily
Nevada	Dynatest+(procuring second)	project	SHRP	annually
New Hampshire	no testing			
New Jersey	no testing			
New Mexico	nr			
New York	none (procuring)			
North Carolina	Dynatest	project	tower	no response
North Dakota	FWD	project	manufacturer	biennially
Ohio	Dynatest-M8000, Dynaflect	project	sensors	twice per day
Oklahoma	FWD, Benkleman Beam	network, project	sensors	twice per year
Oregon	Dynatest-M8000	project	manufacturer	annually

TABLE 17 (CONTINUED)

Agency	Equipment Type	Survey Type Network/Project	Equipment Calibation	Calibration Frequency
Pennsylvania	Phoenix-M10000, KUAB-2M-33	project	SHRP	twice per year
Rhode Island	Benkleman Beam	project	no response	no response
South Carolina	Dynatest-M8000	project	relative	varys
South Dakota	Dynaflect-GeoLog	network, project	sensors	3 time per year
Tennessee	Dynatest-M8000	project	manufacturer	every three years to manufacturer
Texas	Dynatest, Dynaflect, Benkleman Beam	network, project	correlate units, plan SHRP	annually; biweekly
Utah	Dynaflect	network, project	standard sections	monthly
Vermont	FWD	network, project	others	no response
Virginia	Dynatest-M8000	project	sensors	bimonthly
Washington	Dynatest-9000	project	sensors	weekly
West Virginia	Dynaflect, GeoLog	project	manufacturer	each use
Wisconsin	KUAB-2M	project	operations program	quarterly
Wyoming	KUAB, Dynaflect	network, project	sensors, plan SHRP	2 to 3 years; SHRP annually

CANADIAN PROVINCES

Agency	Equipment Type	Survey Type Network/Project	Equipment Calibration	Calibration Frequency
Alberta	Dynaflect-DM00E	network, project	equipment manual	three weeks
British Columbia	FWD, Benkleman Beam	yes	relative and absolute	relative monthly; absolute yearly
Manitoba	Benkleman Beam	network, project	none	no response
New Brunswick	Dynaflect	yes	sensors	weekly
Nova Scotia	Dynaflect	project	equipment manual	daily
Ontario	Dynaflect (contract)	project	contractor	no response
Prince Edward Isle	Dynaflect (Geolog)	network	sensors	daily
Quebec	Dynaflect/FWD	network, project	calibration device	daily
Saskatchewan	Benkleman Beam	project	vehicle weighed, beam check	weekly

of the falling weight or vibratory type. Most of the testing is performed to develop data for use in project design rather than for more extensive testing for network PMS users. The types of data analysis being used vary widely as do the reported calibration practices. Table 17 shows the various agency structural capacity testing practices.

CHAPTER SIX

PAVEMENT FRICTION

Meyer and Goodwin have defined pavement skid resistance as the horizontal force developed when a tire that is prevented from rotating slides along the pavement surface *(38)*. Pavement friction, or skid resistance, is usually thought of as a wet pavement characteristic and is important in providing safe operating conditions for vehicles traveling over the pavement. Safety requirements promulgated by FHWA require the states to have specifications and standards that result in the construction of new pavement surfaces with adequate friction characteristics. The state is also required to monitor pavement surfaces in service to ensure that adequate levels of friction are maintained.

The inclusion of pavement friction measurements in a PMS allows an agency to monitor an important safety condition of the pavements on its system. The ability of a roadway to provide an adequate friction level between the pavement surface and a vehicle tire is a primary concern in providing safe operating conditions. Through a PMS database, the level of friction provided on a pavement section can be related to other types of data to identify and evaluate accident locations. Considerable research on the pavement-tire-vehicle relationship has been conducted over the past 25 years, and the technical literature dealing with the topic is extensive *(38, 39, 40)*.

Friction measurements can be determined by using a number of methods, including portable friction testers, the use of automobiles with various braking systems, and equipment built to measure friction under operating conditions. The locked-wheel trailer is by far the most popular equipment used for highway pavement friction testing performed in accordance with ASTM test methods. Because of the use of ASTM test methods, friction testing has become the most standardized pavement condition measurement effort conducted by the agencies. ASTM Test Method E-274, and accompanying standards, prescribes equipment, test tires, water application, test speeds, and reporting requirements.

Because friction properties on airport runway pavement are very critical, testing is usually more frequent. Test data are accumulated by traveling at high speeds over continuous lengths of pavement. Several types of available equipment employ a set of special smooth tires set at a specified angle that develops a measured side force as the tires are towed along the pavement. The MuMeter and SCRIM are examples of these towed devices. Several manufacturers build automobiles with yawed tire devices built into the vehicles.

EQUIPMENT TYPES AND OPERATION

The responding agencies currently report using 84 pieces of equipment to measure pavement friction. The locked-wheel trailer is the most predominate and is used by 51 of the 60 agencies responding. Alberta and Arizona make use of the MuMeter, and Quebec uses a SCRIM. Forty-five of the agencies perform tests at 40 miles per hour. Six of the agencies indicated that they also test at higher or posted speeds, and three test at 50 miles per hour. Of the 60 agencies, 50 reported that they test in accordance with ASTM E-274.

Two types of standard test tires are available under ASTM Standards. The most popular is the ribbed tire, which is believed to resemble treaded passenger tires in permitting water to escape from under the tire. However, a number of states expressed a renewed interest in use of the blank, or bald, test tire; this tire can be used to get a better indication of pavement macrotexture and to determine pavement speed gradients, which are used to evaluate the relationship of friction to test speeds. The bald tire is also a better indicator of "worst" condition (i.e., the driver of a vehicle with worn, treadless tires). Of the agencies reporting tire type, 49 use a ribbed test tire and 4 use a bald tire. Of the 49 agencies that use a ribbed tire, 10 also use a bald tire in testing for research, special projects, and/or safety related tests.

Although some variation exists in the manufacture of the locked-wheel testers being used, as shown in Figure 12, the overall process of collecting pavement friction is by far the most standardized pavement condition measurement now being obtained. Figure 13 depicts one of the most common friction testers operated by the Pennsylvania DOT.

Thirty-seven agencies operate their friction test equipment with 2-person crews, 17 use a 1-person crew, and 1 agency has 3 people on the tester.

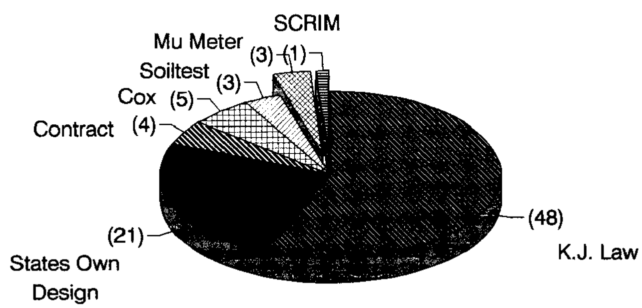

FIGURE 12 Friction testers.

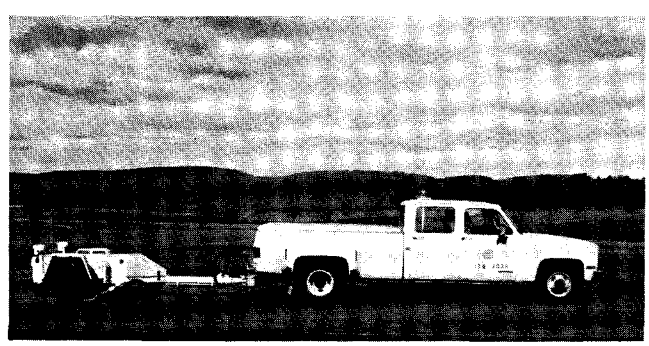

FIGURE 13 Typical friction tester.

Equipment Calibration

Friction-testing equipment requires the same high level of calibration and correlation as other sophisticated test instruments. To ensure that consistent reliable test results are obtained, methods have been developed to routinely calibrate testers on a selected periodic basis. Twenty-eight of the agencies reported that they routinely used calibration methods with force plates employing air bearings, ball bearings, or other devices. One agency used a torque device, and five used selected test surfaces. Figure 14 shows a friction-test trailer wheel sitting on a calibration plate.

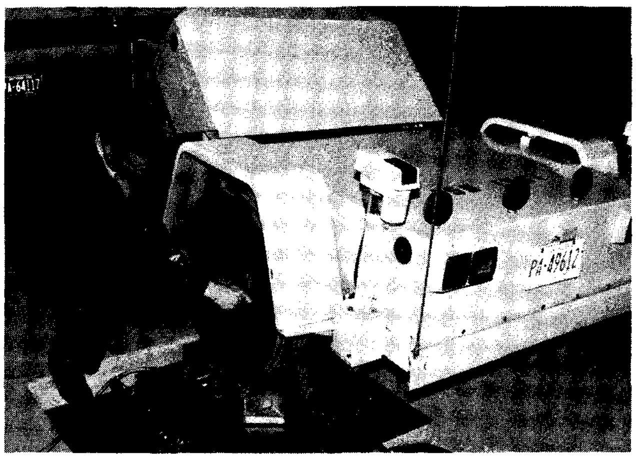

FIGURE 14 Friction test trailer and calibration plate.

Twenty agencies reported that they send their equipment to regional test centers for correction on an annual, biennial, or triennial basis. Six agencies are participating in an ASTM/ARML program where standard calibration is provided at the agency's site.

SURVEY PROCEDURES

Most friction tests are run in the left wheelpath of the lane being tested. The left wheelpath of the traffic lane is considered to receive more wheel passes due to passing maneuvers; because of this, the left wheelpath is more polished, resulting in the lowest friction level found across the lane width. Thirty-four agencies test in the left wheelpath, eight test in the right, and five agencies test in both wheelpaths.

Agencies run tests at various longitudinal intervals. Ten agencies test at a 1-mile interval, 17 test at half-mile intervals, and 11 test between a tenth-of-a-mile and a half-mile. Twelve agencies reported that intervals vary.

On two-lane roadways, 30 agencies test the outside lane and 20 agencies test both lanes. On highways with four or more lanes, 40 agencies report that they test both outside lanes, 6 agencies test all lanes, and 3 agencies test only one lane.

DATA REPORTING

The results of friction tests are reported and stored in a number of ways, with individual test results being the most basic. Forty agencies report on this basis. Thirty-four agencies report on the basis of a section of roadway, and 10 agencies report on a per-mile basis. Many of the agencies use a combination of two or three of the reporting intervals.

Of the agencies reporting, 27 store friction test data on mainframes, 20 agencies use PCs, and 5 use hard-copy reports. Most states indicated that their friction test data are available from a number of storage mediums.

SUMMARY

The majority of the 60 agencies included in the survey have a friction-testing program. Several agencies perform testing by contract, and one agency is in the process of acquiring test equipment. The agencies have a combined number of 84 pieces of test equipment. Equipment maintenance, equipment calibration, and testing are conducted in conformity with well-developed, standardized procedures. Table 18 summarizes pavement friction testing by the agencies.

Overall the current agency friction-testing programs appear to be at about the same level of activity as found in previous surveys *(18)* over the past 10 years. When compared to the collection of roughness, distress, and structural capacity data, the collection of friction data is the most standardized pavement condition information.

The survey questionnaire was not designed to obtain specific information concerning use of friction test data. Six agencies responded that friction test results were included when pavement condition ratings were combined. This would indicate that most agencies use the body of friction test data as an independent factor, or as part of a safety program activity.

TABLE 18
PAVEMENT FRICTION/SKID, UNITED STATES

Agency	Equipment Type	Calibration Method	Calibration Frequency	Comments
Alabama	K. J. Law	force plate, test center	monthly, biennially	
Alaska	contract	no response	no response	
Arizona	Bison Mu Meter	standard surface	daily	
Arkansas	K. J. Law R-30	test track	quarterly	
California	Cox towed trailer	ASTM E-556	as needed, annually, biennially - test center	curves, bridges, intersections
Colorado	K. J. Law	test center	every 2 years	
Connecticut	K. J. Law 1290	force plate	yearly	no inventory tests
Delaware	Soil test (modified)	ASTM E-556	annually	
Dist. of Columbia	no report for friction testing			
Florida	K. J. Law	force plate, test center	monthly, annually	
Georgia	Soil test	x-y air bearing	yearly	
Hawaii	Acquiring equipment			
Idaho	IDOT locked wheel	ball - bearing platform	monthly	
Illinois	IllDOT, ASTM	torque arm	every 2 weeks	
Indiana	trailer	calibration track, force plate	force plate monthly	
Iowa	K. J. Law	air - bearing plate, test pads, test center	weekly, biweekly, triennially	interstate tested annually
Kansas	K. J. Law 1270	no response	no response	
Kentucky	K. J. Law	test center	annually	
Louisiana	K. J. Law 1270	force plate, test center	biennially	
Maine	Me.DOT 2 wheel trailer	ball - bearing platform	annually	
Maryland	K. J. Law 8274	force plate	monthly	
Massachusetts	K. J. Law	air - bearing plate	annually	
Michigan	MiDOT 2 wheel trailer	test center	annually	about 10,000 tests per year
Minnesota	K. J. Law	test center	biennially	
Mississippi	K. J. Law 1290	ASTM	annually	not part of PMS, not inventory basis
Missouri	K. J. Law 1270	internal check, test center	triennual	
Montana	contract	ASTM E-556, test center	annual to test center	
Nebraska	K. J. Law 1290	force plate	annually	
Nevada	Cox	field test, test center	every 6 months, annually	
New Hampshire	Maine DOT	ARML	every 18 months	
New Jersey	ASTM trailer	ASTM	annually	
New Mexico	K. J. Law	test center	biennially	
New York	ASTM trailer	force plate	3 times per year	
North Carolina	K. J. Law 1270, 1290	no response	no response	
North Dakota	contract	force plate	annually	test 1/5 of 7,330 miles biennially
Ohio	K. J. Law, ODOT	test center	annually	
Oklahoma	K. J. Law	on-board check	daily	
Oregon	K. J. Law	test center	undetermined	new test equipment

TABLE 18 (CONTINUED)

Agency	Equipment Type	Calibration Method	Calibration Frequency	Comments
Pennsylvania	K. J. Law 1270	ASTM E-556	every 6 months	
Rhode Island	K. J. Law 1290	no response	no response	testing by contract with FHWA
South Carolina	K. J. Law 1290	force plate	every 6 months	
South Dakota	K. J. Law	force plate	annually	
Tennessee	K. J. Law	ASTM	annually	
Texas	TexDOT ASTM	test center	annually	
Utah	trailer	test center	biennially	
Vermont	K. J. Law 1290	test center	every 2-3 years	testing by contract with FHWA
Virginia	K. J. Law	force plate	weekly	
Washington	Cox	platform, test center	monthly, biennially	
West Virginia	K. J. Law 965	test center	annually	
Wisconsin	K. J. Law	air - bearing plate	monthly	
Wyoming	K. J. Law 1270	test center	biennially	

CANADIAN PROVINCES

Agency	Equipment Type	Calibration Method	Calibration Frequency	Comments
Alberta	Mu Meter MK 3	Mu Meter board	every 2-3 weeks	
British Columbia	British Pendulum	ASTM	special projects	
Manitoba	none			
New Brunswick	none			
Nova Scotia	ASTM trailer	ASTM	prior to use	
Ontario	K. J. Law	platform	annually	
Prince Edward Isle	No response for friction			
Quebec	SCRIM	mechanical/electrical	annually	
Saskatchewan	Saskatchewan Trailer	no response	annually	

CHAPTER SEVEN

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The survey questionnaire dealt with five topics regarding pavement condition: pavement management, distress surveys, roughness surveys, structural capacity evaluation, and friction testing (see Appendix A). Each of the 60 replies from U.S. state agencies and Canadian province agencies was reviewed individually and then tabulated to permit study of the combined practices used in determining pavement condition. As a result of reviewing current literature on pavement condition evaluation practices and the information obtained from the questionnaire response, the following conclusions were made:

- All of the agencies indicated that they have, or are in the process of developing, a PMS and that they are collecting pavement condition data. A majority of the agencies are also actively expanding or enhancing their present systems to improve methods for collecting condition information. Only about half of the agencies have established a written PMS policy.
- The functional responsibility for a PMS, or parts of a PMS, is assigned to many different locations within the organizations of the agencies, as is the custody for various evaluations and information.
- About 85 percent of the agencies store PMS data on a mainframe computer. About half of the agencies indicated that PMS data are maintained in separate files.
- The agencies employ a variety of location reference systems, with about half of the agencies using some form of mileposting. Several agencies indicated that they are going to adopt a link-node, or segment, system that is more adaptable to database management. Some of the agencies using mileposting have not placed mile markers in the field, and others have only marked the interstate or primary mileages.
- All of the agencies collect one or more types of pavement condition information. The most universal types of information collected are roughness and friction data; most agencies collect this information. The measurements of roughness and friction are also the most standardized methods of data collection.
- In response to FHWA-HPMS reporting requirements, agencies have largely moved toward use of IRI units to express roughness measurements. The number of agencies using South Dakota type Road Profiler equipment to collect roughness data has also increased sharply. In 1989, eight states used SD Road profilers; the 1994 survey indicates that 24 states now use the device.
- Agencies generally perform structural evaluations for a project-oriented purpose rather than for PMS network surveys. Deflection test data are used in a variety of ways to determine structural capacity or overlay requirements. Structural testing requires lane-closure traffic protection commensurate with the type of facility being tested, and test results are sensitive to temperature, season, and moisture conditions. Testing methods and interpretation of data are exacting and time-consuming, which limits the capability to acquire the amount of data needed for a network PMS.
- Almost all of the agencies have friction-testing equipment and conduct tests in conformance with ASTM standards. Many of the agencies have not integrated friction activities into their PMS, and most of the test programs are oriented toward accidents, research, special projects, or materials evaluation.
- The greatest variation in the type and amount of data collected, the method of collection, and the ways the data are used occurs in the area of pavement distress. Most agencies have developed or revised reasonably current manuals for use in conducting distress surveys; however, there is little standardization in the types, extents, and severity of distress data collected. Survey procedures vary widely—from observation through the windshield of a moving vehicle to detailed automated surveys. There is also little uniformity in the way distress data are used in developing pavement condition ratings.

RECOMMENDATIONS

Based on the conclusions drawn during the preparation of this synthesis, the following are suggested practices for determining pavement condition.

- It appears that PMSs will continue to be enhanced and become more fully developed in the coming years. Agencies will then review the function and organizational location for the assignment of PMS responsibility. As condition data improve in quality, the PMS broadens to serve a wide variety of functions within an agency, the capabilities and services of a PMS can be disseminated and easily obtained.
- Agencies would be well advised to review their location reference system practices. It is important to collect good PMS data, but those data also need to be accurately related to field location. The establishment of a location referencing system is central to the accuracy of data collection and the reliability of the information output. Manageable sections of homogeneous pavements with similar traffic and location can be established and adequately marked in the field to permit collection of site-specific data and to allow users to identify the source of information in the field.
- The degree of standardization being developed in roughness and friction evaluation might also be achieved in distress and structural evaluation. Better general agreement on some of the basic distress types, and on the extent and severity to be determined, would facilitate the exchange of information in pavement performance and evaluation between agencies. A reasonable consensus should also be attempted in the use of deflection test data.
- Extensive research and development has been directed at establishing the procedures for pavement condition evaluation

being used in the LTPP project as part of the SHRP. Several of the agencies have adopted the SHRP distress manual and are using other SHRP methods that are applicable to PMS. Agencies are encouraged to incorporate SHRP methods to facilitate the exchange of pavement condition information and to use the benefits that accrue from the SHRP effort.

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APPENDIX A

Survey Questionnaire

NCHRP Synthesis Topic 22-07 Survey

PART A - General Pavement Management

Pavement condition data are normally collected uniformly across a given functional system or network. The entire system is usually made up of links or sections of various lengths which are managed as units. The followying questions are directed at your agency's current method of collecting, storing and using pavement condition data. Subsequent parts of the questionnere deal with specific types of condition data including distress, roughness, structural capacity and friction.

Name of agency: ____________
Name of respondent: ____________
Title: ____________
Address: ____________
____
____
Phone number: ____________

A-1 Do you have a pavement management system in your agency? yes / no

A-2 Does your agency have an established policy or procedural statement concerning pavement management? yes / no

A-3 How do you store your agency's roadway information?

Hard copy ____
Personal computer ____
Main frame ____
Other ____

A-4 If your files are computerized, how is the information stored and accessed?

Separate files ____________
Some files can be combined ____________
All files are accessible (customized reports) ____________
Are PMS files "On Line" ____________

A-5 What type of location referencing system do you use for your road inventory?

Link-node (segments) ____________
Control section ____________
Mile posting ____________
Stationing ____________
Other ____________

A-6 Are location references physically marked in the field? yes / no
How are they marked? ____________

NCHRP Synthesis Topic 22-07 Survey   Agency Reporting:____________

Part A. Continued

A-7 What condition data are collected for the sections in the road inventory?

Roughness ____________
Friction ____________
Structural capacity ____________
Distress ____________
Other ____________

A-8 Briefly describe how and where pavement condition information is available in your agency.

____
____
____

A-9 Are pavement condition data used in planning or scheduling maintenance work?

Daily ____
Weekly ____
Annually ____
Not used ____
Comments: ____________
____

A-10 Are pavement condition data used in project design? yes / no

Comments: ____________
____

A-11 Are pavement condition data used in planning and budgeting? yes / no

Comments: ____________
____

APPENDIX A (Continued)

NCHRP Synthesis Topic 22-07 Survey

PART B - Pavement Distress Surveys

Please answer the following questions about your agency's pavement distress survey activities as part of pavement management operations.

Name of agency: ______________________________
Name of respondent: ______________________________
Title: ______________________________
Address: ______________________________
____
____
Phone number: ______________________________

B-1 Does your agency perform distress surveys? yes / no
What is the frequency of your distress surveys? ________________

B-2 How are the distress surveys performed?

Windshield drive through ________ Speed ________
Shoulder drive through ________ Speed ________
Walking ________
Automated ________ Speed ________

B-3 Do you have a manual that describes your distress survey procedures and indicates the type, severity and extent of distress collected? yes / no

If you have a manual and you will return a copy with this questionaire, please skip to question B-9 and check "Manual enclosed".

Manual enclosed ____

B-4 How do you subdivide your pavements into suitable sections for the collection of distress data?

Link-node (segment) ____________
Control sections ____________
Homogeneous length* ____________
Predetermined length ____________
Other ____________

* If you answered homogeneous length, what is your definition of homogeneous length?
____
____
____

B-5 Do you perform a 100% survey or do you survey sample lengths? 100% / sample lengths
If you answered sample lengths, please explain your procedures to select your sample.
____
____
____
What are your sample lengths? ______________________________

NCHRP Synthesis Topic 22-07 Survey Agency Reporting:__________

PART B. Continued

B-6 What distress information is collected for bituminous surfaces?

DISTRESS TYPES	UNITS OF MEASURE	SEVERITY LEVELS	EXTENT LEVELS

APPENDIX A (Continued)

NCHRP Synthesis Topic 22-07 Survey   Agency Reporting:____________

PART B. Continued

B-7 What distress information is collected for jointed concrete pavement?

DISTRESS TYPES	UNITS OF MEASURE	SEVERITY LEVELS	EXTENT LEVELS

NCHRP Synthesis Topic 22-07 Survey   Agency Reporting:____________

PART B. Continued

B-8 What distress information is collected for continuously reinforced concrete pavement?

DISTRESS TYPES	UNITS OF MEASURE	SEVERITY LEVELS	EXTENT LEVELS

NCHRP Synthesis Topic 22-07 Survey   Agency Reporting:____________

Part B. Continued

B-9 If you include rutting in your distress survey, how do you obtain the information?

Observation ______________________
Measurement ______________________

B-10 If you measure rutting, please briefly describe your procedure.

____
____
____
____

B-11 How are distress data recorded in the field?

Paper form __________________
Preprinted paper form __________________
Electronic recording ____________ Type ______________
Other method ____

B-12 If you use automated distress surveys, please indicate the system used.

____
____
____
____

B-13 What size crews are used for distress surveys? __________________

B-14 What is the crew productivity? ____________ miles/day

B-15 Are the crews given distress survey training? yes / no

B-16 If yes, how long is the training period? ______________________

B-17 Do you have a quality assurance procedure to monitor the information collected? yes / no

B-18 If yes, please briefly describe the procedures.

____
____
____
____

NCHRP Synthesis Topic 22-07 Survey   Agency Reporting:____________

Part B. Continued

B-19 What type of rating or index is produced from the distress survey?

Maintenance needs ____
Distress index (PCI, PCN, PCR, etc.) ______________________________________
Priority rating ____
Other ____

B-20 Please describe your method (formulae) for determining a rating or index, including weight factors.

____
____
____
____

B-21 Do you combine a distress information index with other pavement condition information?

Roughness ____________________________________
Friction ____________________________________
Structural ____________________________________
Other ____________________________________

B-22 Please describe your method (formulae), including weight factors, for determining a combined condition rating (Composite Index).

____
____
____
____

APPENDIX A (Continued)

NCHRP Synthesis Topic 22-07 Survey

Part C - Pavement Roughness Surveys

Please answer the following questions about your agency's pavement roughness survey.

Name of agency: ____________________
Name of respondent: ____________________
Title: ____________________
Address: ____________________
____
____
Phone number: ____________________

C-1 What type of equipment does your agency use to collect roughness data?

Name, type and manufacturer	Number of units
____________	________
____________	________
____________	________
____________	________

C-2 How frequently do you survey your pavements?

Network	Number of miles	Frequency
______	________	________
______	________	________
______	________	________
______	________	________

C-3 What data are collected?

Units (IRI, etc.) ____________________
Measurement interval (data points per unit) ____________________
Right wheel path ____________
Left wheel path ____________
Average ____________

Direction: 2 lane: one / both
4 lane: one / both outside / all

C-4 How are the data reported?

Uniform increments ____________________
Section length summary ____________________
Hardcopy _______ Computer disk _______ Tape _______ Other _______

C-5 What are the operating characteristics?

Usual survey speed _______
Average lane miles per day _______

NCHRP Synthesis Topic 22-07 Survey Agency Reporting: ____________

Part C. Continued

C-6 How are the data stored?

Hard copy _______
Personal computer _______
Main frame _______

C-7 What procedures are used to calibrate or correlate the equipment?

____
____
____
____

APPENDIX A (Continued)

NCHRP Synthesis Topic 22-07 Survey

PART D - Pavement Structural Capacity

Please answer the following questions about your agency's activities in performing pavement structural capacity evaluations.

Name of agency: ____________________
Name of respondent: ____________________
Title: ____________________
Address: ____________________
____
____
Phone number: ____________________

D-1 What type of equipment does your agency use to evaluate pavement structural capacity?

Name, type and manufacturer	Number of units	Crew size
________	________	________
________	________	________
________	________	________

D-2 Where do you perform structural evaluations?

	Number of miles	Frequency
Network surveys	________	________
Project surveys	________	________

D-3 What are the operating characteristics?

Uniform testing throughout sections _______ Interval _______
Sampling program _______
Sample size _______ Interval _______
Sample location _______
Average data points produced per day _______
Days per year testing ____________
Traffic control used ____________________
____

D-4 How are the data reported?

Drop point _______
Test location _______
Section _______
Hardcopy _______ Computer disk _______ Tape _______ Other _______

NCHRP Synthesis Topic 22-07 Survey Agency Reporting:__________

Part D. Continued

D-5 How are the data stored?

Hard copy _______
Personal computer _______
Main frame _______

D-6 How are the data analyzed?

Back calculation of layer moduli ____________________
Other ____________________

Comment: ____________________

D-7 How is your structural evaluation equipment calibrated?
____
____

How frequently?
____
____

D-8 How are the data used?

Overlay design ____________________
Seasonal load limits ____________________
Load limits ____________________
Other ____________________

Comment:
____
____
____

APPENDIX A (Continued)

NCHRP Synthesis Topic 22-07 Survey

PART E - Pavement Friction Testing

Please answer the following questions about your agency's activities in performing pavement friction testing.

Name of agency: ____________________
Name of respondent: ____________________
Title: ____________________
Address: ____________________
____
____
Phone number: ____________________

E-1 What type of equipment does your agency use to collect friction data?

Name, type and manufacturer	Number of units	Crew size
________	________	________
________	________	________
________	________	________

E-2 What are the operating characteristics?

Usual Test Speed _______ Test by ASTM standards? yes / no
Lane miles tested per day _______
Number of days testing per year _______
Tire type used: ribbed / bald / both
If bald or both, please explain.
____
____
____
Calibration method ____________________ Frequency ____________________

E-3 What data are collected?

Testing interval ____________________
Test in right wheel path ____________________
Test in left wheel path ____________________
Test in both wheel paths ____________________
Direction: 2 Lane - one / both
4 or more lanes - one / both outside / all

E-4 How are the data reported?

Individual tests ____________________
Summary per mile ____________________
Summary per section ____________________

E-5 How are are the data stored?

Hard copy _______ Personal computer _______ Main frame _______

APPENDIX B

General Pavement Management

State/Agency	Have a Pavement Management System A-1	PMS Policy or Procedure A-2	Information Stored A-3	Computer Files Accessed A-4	Location Reference System A-5	References Marked A-6	Roughness Information A-7	Friction Information	Structural Information	Distress Information
Alabama	yes	no	mf, pc	online	milepost, control section	y-mp	yes	yes	project	yes
Alaska	yes	yes	mf	online	segment	y-ref. mo.@15m	yes	yes	no	yes
Arizona	yes	yes	mf, pc	partial online	milepost	y-mp	yes	yes	no	yes
Arkansas	yes	no	mf, pc, hc	online	milepost	mileposts	yes	yes	no	yes
California	yes	yes	mf	partial online	milepost	markers	yes	no response	no response	yes
Colorado	yes	no	mf, pc, hc	separate files, reports	milepost	reference points	yes	no	no	yes
Connecticut	yes	no	mf, pc	online	milepost	no	yes	proposed	no	yes
Delaware	yes	yes	pc	separate files	milepost	no	yes	yes	no	yes
District of Columbia	yes	no response	pc	online	street, block	intersections	yes	selected	no response	yes
Florida	yes	yes	mf	online	milepost	no	yes	yes	rehabilitation	yes
Georgia	yes	no response	mf, hc	separate files	milepost	mileposts	no	yes	no	yes- flexible
Hawaii	yes	no	pc, hc	separate files	odometer miles	no	yes	no	no	yes
Idaho	yes	yes	mf, pc, hc	online	milepost, segment	mileposts	yes	yes	no	yes
Illinois	yes	no	mf	Interstate online	segment (in development)	mileposts	yes	no	no	yes
Indiana	no	no	mf, pc, hc	separate files	milepost	mile markers	yes	yes	no	no
Iowa	yes	yes	mf, hc	online	control section	mileposts	yes	yes	yes	yes
Kansas	yes	yes	mf	online	milepost	no	yes	no	no	yes
Kentucky	yes	yes	mf	separate files	milepost	mileposts	yes	no response	no response	yes
Louisiana	yes	yes	mf, pc	main frame link	control secction	no- physical features	yes	yes	no	yes
Maine	yes	yes	mf, pc	separate files	segment	no	yes	no	no	yes
Maryland	yes	no	pc	relational	milepost	no- crossroads	yes	yes	no	yes
Massachusetts	yes	yes	pc, hc	no response	milepost	yes- 0.1 mile	yes	yes	no	yes
Michigan	yes	no	mf	separate files	control section, milepost	no (video link)	yes	yes	no	yes
Minnesota	yes	yes	mf	online	reference post (milepost)	mile marker	yes	no	yes	yes
Mississippi	yes	no	pc	separate files	segment, county log mile	yes- pavement stripe	yes	request	request	yes
Missouri	yes	no	mf, pc, hc	online	log mile	no- key events	yes	no	no	yes
Montana	yes	yes	mf, hc	separate files	milepost	mileposts	yes	yes	yes	yes
Nebraska	yes	no	mf, pc, hc	online	control section, milepost	reference posts	yes	yes	project	yes
Nevada	yes	yes	mf, hc	separate files	milepost	mile markers	yes	yes	no	yes
New Hampshire	yes	no	mf, pc	separate files	station	no	yes	sample	no	yes
New Jersey	yes	yes	mf	separate files	milepost	mileposts	yes	yes	no	yes
New Mexico	yes	yes	mf	online	all	mileposts	yes	yes	no	yes
New York	yes	yes	mf	separate files	control section, milepost	mileposts	yes	request	no (planned)	yes
North Carolina	yes	no	mf, pc, hc	separate files	milepost	mileposts- Interstate only	yes	yes	yes	yes
North Dakota	yes	no	pc	separate files	milepost	reference posts	yes	yes	no	yes
Ohio	yes	yes	mf	separate files	county route log	mile markers	yes	yes	no	yes
Oklahoma	no	no	mf, pc, hc	separate files	county control section, subsection	no	yes	yes	no	yes
Oregon	yes	yes	mf, pc.hc	separate files	milepost	mileposts	yes	yes	no	yes
Pennsylvania	yes	yes	mf	online	segment	segment markers	yes	yes	no	yes
Rhode Island	yes	yes	mf	no response	milepost	no	yes	yes	no	yes
South Carolina	yes	no	mf, pc	online	milepost	mileposts- Interstate only	yes	yes	yes	yes
South Dakota	yes	yes	mf	seperate files	milepost	reference posts	yes	yes	yes	yes
Tennessee	yes	no	mf	separate files	segment	no	yes	yes	no	PCR
Texas	no response	no	mf	online	milepost, control section	reference posts	yes	yes	yes	yes
Utah	yes	yes	mf, pc, hc	separate files	milepost	mileposts	yes	yes	yes	yes
Vermont	yes	yes	pc	separate files	milepost, control section	mileposts	yes	yes	yes	yes
Virginia	yes	yes	mf, pc	online	milepost (planning to use segments)	Interstate only	yes	request	request	yes
Washington	yes	no	mf, pc	pc copies distributed	milepost	mileposts (partial)	yes	yes	no	yes
West Virginia	yes	no	pc	custom reports	milepost	reference posts	yes	no	no	PCR
Wisconsin	yes	no	mf, hc	online	features as reference points	no	yes	yes	no	yes
Wyoming	partial	no	mf, pc	limited online	milepost	mileposts	yes	yes	yes	no (planned)
Alberta	yes	yes	mf, hc	online	control sections, segments	no	yes	yes	yes	yes
British Columbia	yes	no	hc, (future PC)	no	segments, kilometer posts	kilometer posts	yes	no	yes	yes
Manitoba	no	no	mf, hc	seperate files	mileposts, control sections	4 kilometers when marked	yes	no	yes	yes
New Brunswick	yes	no	mf, pc, hc	seperate files	control sections	control section signs	yes	no	yes	yes
Nova Scotia	no (developing)	no	mf, pc, hc	seperate files	mileposts, control sections, segments	no (developing)	yes	yes	yes	yes
Ontario	yes	yes	mf, hc	online	linear reference system	no- landmarks	yes	no	no	yes
Prince Edward Isle	yes	no	mf	online	control sections, subsections	yes	yes	no	yes	yes
Quebec	no	no	mf	seperate files	segments	segments	yes	no	yes	yes
Saskatchewan	yes	yes	mf, pc, hc	online	control sections, stations	no	yes	yes	yes	yes

APPENDIX B (Continued)

State/Agency	Condition Data Available A-8	Data Used for Maintenance A-9	Data Used for Design A-10	Data Used for Planning, Budgetin A-11
Alabama	annual report	annual	yes	yes
Alaska	mainframe	annual	no	yes
Arizona	Materials Section	no (developing)	yes	yes
Arkansas	Program and Contracts Division	no (planning)	no (plan)	no (plan)
California	PMS, Maintenance Division	annual	yes	yes
Colorado	Engineering Districts, Maintenance Section	weekly	yes	yes
Connecticut	reports	annual	yes	yes
Delaware	no response	no	no	yes
District of Columbia	Department of Public Works	annual	yes	yes
Florida	mainframe, planned reports	no	yes	yes
Georgia	mainframe, reports	no	no	yes
Hawaii	Materials, Testing and Laboratory, pc, hc	annual (special)	no	no
Idaho	mainframe	no	yes	yes
Illinois	mainframe	annual	yes	yes
Indiana	Research Division	no	no	no
Iowa	mainframe	annual	yes	yes
Kansas	Materials and Research, LAN	annual	yes	yes
Kentucky	Pavement Management Branch, mainframe	no	yes	yes
Louisiana	Pavement Management Engineer	no	no	no
Maine	Pavement Management Section	annual	yes	yes
Maryland	annual report	annual	yes	yes
Massachusetts	Traffic, Planning, Development	annual	yes	yes
Michigan	pc linked mainframe	no	no	no
Minnesota	mainframe, report	annual	yes	yes
Mississippi	Research and Development, PLanning	no (planning)	no	no
Missouri	Pavement Management Section, Planning Developme	annual	yes	yes
Montana	Pavement Management Section	varies	yes	yes
Nebraska	Pavement Management System, mainframe	annual	yes	yes
Nevada	Materials Test Division, Data Processing	annual	yes	yes
New Hampshire	Pavement Management System	annual	no	yes
New Jersey	Pavement Management Group, mainframe	annual	yes	yes
New Mexico	mainframe	annual	yes	yes
New York	Planning Division, Technical Services Division	annual	yes	yes
North Carolina	Pavement Management Unit, mainframe	annual	yes	yes
North Dakota	Planning Division	no	yes	no
Ohio	Technical Services Bureau	annual	yes	yes
Oklahoma	Highway Needs Study file	no	no	yes
Oregon	Pavement Unit	annual	yes	yes
Pennsylvania	mainframe	annual	yes	yes
Rhode Island	Planning, mainframe	no	yes	no
South Carolina	Pavement Management System, Research and Materi	no (developing)	no (developing)	no (developing)
South Dakota	Planning, Data Services	daily	yes	yes
Tennessee	Planning, mainframe	no	no	yes
Texas	Maintenance and Operations Division	annual	no	yes
Utah	annual report	annual	yes	yes
Vermont	pc, hc	annual	yes	yes
Virginia	mainframe, reports	annual	yes	yes
Washington	Materials Laboratory, pc	annual	yes	yes
West Virginia	Inventory, HPMS, Project Tracking File	no	no	yes- Expressways
Wisconsin	mainframe	annual	no	yes
Wyoming	Pavement Management System Engineer, Planning	no	yes	yes
Alberta	mainframe	annual	yes	yes
British Columbia	Planning, Operations, Program Services	annual	yes	yes
Manitoba	mainframe	annual	yes	yes
New Brunswick	Planning Branch	annual	yes	yes
Nova Scotia	Materials Lab	no	yes	yes
Ontario	mainframe	annual	no	yes
Prince Edward Isle	mainframe	annual	yes	yes
Quebec	annual reports	annual	yes	yes
Saskatchewan	GIS/HIS,PMIS	annual	yes	yes

APPENDIX C

Pavement Distress

State/Agency	Perform Distress Surveys? B-1	Method Used? B-2	Speed Performed	Manual Used B-3	Survey Sections B-4	100% Survey or Sample B-5	Sample Length	Is Rutting Obtained? B-9/10	Method to Record Data B-11	Survey Automation B-12
Alabama	yes	walk	walk	yes	no response	no response	no response	SDP, 4-foot straightedge	preprinted paper	not used
Alaska	yes-50% per year	shoulder	10 mph	yes	segment	100%	not applicable	SDP-3 sensor	pc	laptop/DMI
Arizona	yes	walk	walk	yes	predetermined length	at milepost	100'	4 foot straightedge	pc	laptop
Arkansas	yes-Interstate, primary-biennial	walk	walk	yes	predetermined length	one per 2 miles average	100' flexible, 300' rigid	4 foot straightedge	pc	planned
California	yes-biennial	walk	walk	yes	homogeneous section	2 per mile flexible, 100% rig	200'	visual	pc	laptop
Colorado	yes-annual	windshield	50 mph	no	homogeneous section	100%	0.1 mile section	ARAN-27 sensors	pc	ARAN
Connecticut	yes-annual	photo log	4.4 mph	yes	homogeneous section	number of frames/section	frame summary	not used	35mm film	workstation
Delaware	yes-biennial	windshield	30 mph	yes-SHRP	maintenance road number	100%	not applicable	not used	electronic	ARAN
Dist. of Columbia	yes	windshield	10 mph	yes	predetermined length	100%	not applicable	visual	preprinted paper	no report
Florida	yes-annual	shoulder	5 mph	yes	homogeneous section	100%	not applicable	6-foot straightedge	preprinted paper	not used
Georgia	yes-annual	walk	walk	yes-(flexible)	project	sample for one-mile segment	representative 100'	visual, string line	paper	not used
Hawaii	ves	windshield	5-55 mph	yes-(Caltrans)	predetermined length	100%	not applicable	visual	paper	not used
Idaho	yes-annual	shoulder	5-55 mph	yes	control section	one per section	500'	visual (also SDP)	paper	not used
Illinois	yes-biennial	windshield/walk Interstate	travel speed	yes	homogeneous section	at mile post	500'	SDP on Interstate	preprinted paper	not used (evaluating)
Indiana	yes-annual	windshield	55 mph	yes-HPMS	no response	no response	no response	no response	paper	not used
Iowa	yes-biennial	shoulder	0-3 mph	yes	control section	sample	0.5 mile per 5 mile or 10%	4-foot gauge	paper	not applicable
Kansas	yes-annual	shoulder	15 mph	yes	one-mile segment	three samples/segment	100' random	visual, string line	electronic	IC-MDR4010
Kentucky	yes-annual	windshield, shoulder	40,10 mph	no	construction section	100%	not applicable	foot straightedge	preprinted paper	not used
Louisiana	yes-annual (contract)	video	highway speed	yes-(draft)	homogeneous section	100%	not applicable	rut bar, 5 sensors	video	Pavedex
Maine	yes-biennial	video/ARAN	highway speed	yes	segment	one per mile, minimum two	100'	ARAN	pc	semiautomated
Maryland	yes-annual	shoulder	10-15 mph	yes	predetermined length	100%	0.2 mile	visual	preprinted paper	not used
Massachusetts	yes	windshield/ARAN	40 mph	no	continuous	100%	1.0 mile	visual	pc	ARAN keyboard
Michigan	yes-biennial	semiautomatic	no response	no	homogeneous section	100%	0.1 mile	3 sensor profilometer	video	work stations
Minnesota	yes-50% per year	shoulder	5 mph	yes	homogeneous section	1/mile	500'	SDP/3 sensors	preprinted paper	not used
Mississippi	yes-annual	video	highway speed	yes-SHRP	homogeneous section	2/mile	500'	SDP/3 sensors	video	Pavedex
Missouri	yes-Interstate, Primary -annual- other trienni	video	no response	no	predetermined length	100%	0.02 mile	ARAN-13 sensors	video	ARAN video
Montana	yes-biennial	walk/shouder	30 mph	yes	control section	1/mile	200'	SDP/3 sensors	paper	not used
Nebraska	yes-annual	windshield/walk	40 mph	yes	control section	100%	reference mile	SDP/3 sensors	electronic	not used
Nevada	yes-annual	walk	walk	yes	one-mile segment	rating section	1000 sf flexible, 10 slabs rigi	4-foot rut gauge	preprinted paper	not used
New Hampshire	yes-Interstate annual-other biennial	windshield/ARAN	30-50 mph	yes	continuous	100%	not applicable	ARAN	pc	ARAN keyboard
New Jersey	yes-annual	windshield/ARAN	40 mph	yes-SHRP	continuous	100%	0.2 mile	ARAN	pc	ARAN keyboard
New Mexico	yes-annual	walk	walk	yes-FHWA	control section	random	0.1 mile	visual, 4-foot straightedge	preprinted paper	not used
New York	yes-annual	windshield	highway speed	yes	control section	100%	not applicable	not used	preprinted forms	not used
North Carolina	yes-Int. annual-other biennial	windshield/shoulder/walk	15-25 mph	yes	homogeneous section	100% flexible, sample rigid	rigid-0.1 mile	SDP-major roads	preprinted paper	not used
North Dakota	yes	video	55 mph	yes	predetermined length	1/mile	500'	SDP/3 sensors	pc	PAVETECH
Ohio	yes-multi-lane annual	walk	walk	yes	homogeneous section	1/mile	200'	half-lane straightedge	paper	not used
Oklahoma	yes-biennial	automated	45-55 mph	yes	control section	100%	no response	IMS/laser sensors	pc	IMS
Oregon	yes-biennial	windshield, Interstate-shoulder	15/30 mph	yes	project	100%	100' increments	visual, straightedge	preprinted paper	not used
Pennsylvania	yes-50% per year	shoulder	5 mph	yes	segments	100%	average 1/2 mile segments	visual, SDP/3 sensors	preprinted paper	not used
Rhode Island	yes- three year cycle	windshield/walk	posted speed	yes	homogeneous section	100% windshield and sample	last 200'	visual	preprinted paper	not used
South Carolina	yes-annual	windshield	40-50 mph	yes	one mile section	100%	0.1 mile maximum incremen	SDP	pc	modified SDP
South Dakota	yes-triennial	windshield	(FWD crew)	yes	predetermined length	1/mile at mile marker	area visible at stop	SDP	pc	not used
Tennessee	for design	walk	walk	yes-FHWA	project	100%	project	ARAN (previous data)	na	not used
Texas	yes-annual	windshield/walk	15 mph	yes	segment	100%	average 2 mile sections	straightedge, string line	pc, paper	ARAN video
Utah	yes-biennial	shoulder	5-10 mph	yes-SHRP	predetermined length	1/mile at milepost	500'	6-foot straight edge	pc	not used
Vermont	yes-annual	automated	40 mph	yes	control sections	100%	not applicable	IMS/lasor sensors	electronic	IMS
Virginia	yes-biennial	windshield	5 mph	yes	homogeneous section	100%	section	visual	pc	not used
Washington	yes-annual	shoulder	5-10 mph	yes	control section	100%	average 1 mile subsection	visual, 6-foot straightedge	preprinted paper	not used
West Virginia	not used-pilot 1991	windshield/shoulder	variable	no	homogeneous section	pilot	not used	no response	paper	not used
Wisconsin	yes-biennial (CRC-annual)	shoulder	5 mph	yes	predetermined length	1/mile	500'	SDP/3 sensors	preprinted paper	not used
Wyoming	not used-plan for 1992	windshield	55 mph	no-(plan SHRP)	predetermined length	at milepost	100-400'	SDP/3 sensors	pc	SDP Data Logger
Alberta	yes	windshield/video log	8/50 mph	yes-SHRP, Ontari	control, inventory section	100%	+250 meters	ARAN	video	ARAN
British Columbia	yes-annual	walk	walk	yes	segment, control section	100% proposed	currently sample	rut depth gauge, 2 meter	paper	ARAN (trial)
Manitoba	yes-annual	windshield	55 mph	yes	control section	100%	variable	visual	paper	not used
New Brunswick	yes-1/3 per year	windshield/walk	30 mph	yes	control section	100%, sample	500 meters (2nd & 8th sectio	MDR-5 sensors	pc	not used
Nova Scotia	yes-as required	windshield/shoulder/walk	50 mph	yes-RTAC	segment	100%	variable	ARAN (planned)	paper	ARAN
Ontario	yes-biennial	windshield	30 mph	yes	homogeneous length	100%	variable	template	paper	not used
Prince Edward Isle	yes-triennial	windshield	25-50 mph	yes	homogeneous length	100%	+300 meters	visual, 1/2-lane straightedg	preprinted paper	not used
Quebec	yes-annual	windshield	40 mph	no	predetemined length	100%	100 meters	not used	electronic	not used
Saskatchewan	yes- every four years	windshield/shoulder/walk	25 mph	no	control section	100%	variable	rut bar-9 sensors	pc	PURD

APPENDIX C (Continued)

State/Agency	Survey Crew Size B-13	Production Rate B-14	Crew Training B-15/16	Survey Quality Check B-17/18	Survey Rating Output B-19	Method to Determine Distress Rating B-20	Distress Rating Combined With? B-21	Method or Formulae B-22
Alabama	2	12 mpd	3 weeks	random check	distress index	weight factors	roughness	formula
Alaska	2	100 mpd	1 week	PMS engineer field checks	relative pavement condition comparis	distress state table	roughness, frost	compare with 240 condition states
Arizona	2	100 mpd	2 months	supervisor checks, compare prior yea	priority rating	no response	roughness, structural, traffi	no response
Arkansas	2	not applicable	yes-variable	not used	distress index	deduct point system	roughness	Rigid=0.65 defects+0.35 ride, Flexible=1/2 power (ride
California	16 total	125 mpd	1 month	team leader, random check	priority rating	pavement condition category	roughness	over/under decisions
Colorado	3	130 mpd	2 weeks	correlation, data edits	pavement condition rating	no response	roughness	condition matrix
Connecticut	not applicable	31 mpd	2 days	rerate 10%	distress score 0-100	weight factors	roughness,AADT	dr+ri+adt+class
Delaware	3	5-50 mpd	as needed	not used	surface distress index	weight factors	Ride Comfort Index	PSI=75% (SDI)+25% (RCI), also safety and traffic
Dist. of Columbia	2	9 mpd	1 week new, 2 days experienc	random check, replicate survey	pavement condition rating	table	no response	no responce
Florida	2	27 mpd	1 week	not used	rut+crack rating	deduct points	not used	separate rating for ride, rutting, cracking
Georgia	2	no response	2 days	not used	priority rating	deduct from 100	not used	not applicable
Hawaii	2	30-50 mpd	not used	not used	priority rating	distress severity and extent	not used	not applicable
Idaho	2	150-200 mpd	2 weeks	compare with previous year	distress rating	cracking index	PSI (SDP)	50% roughness (0-5)+50% cracking (0-5)
Illinois	Interstate-2, other 5	Interstate-30 mpd	Interstate 3days, other 2 days	spot sample, compare previous year	condition rating survey	CRS 0-9	not applicable	not applicable
Indiana	2	250 mpd	1 week	not used	present serviceability rating	PSR 0 to 5, HPMS	not used	not applicable
Iowa	4	12mpd (0.5 mile sample	6 hours	compare with previous year	pavement condition rating	PCR 0-100	roughness, friction, structur	formula with coefficient
Kansas	2	60 mpd	1 week	compare two teams	distress index	Woodward-Clyde methodolog	roughness	based on distress state
Kentucky	2	80 mpd	2 years (seasons)	compare with previous years	demerit point score	assigned demerits	roughness, friction, traffic	point assignment
Louisiana	2	225 mpd tape	yes-unknown	yes-consultant contract procedures	pavement condition rating	under development	roughness	under development
Maine	1	80 mpd	1 or 2 days	random review of rater work	pavement condition rating	PCR 0-5	not used	na
Maryland	3	no response	2 days	computer trends, random comparison	priority rating	weight factors, deduct values	roughness	priority matrix
Massachusetts	2	75 mpd	2 or 3 days	field spot check	distress index (DI)	formulae	roughness	PSI=0.65DI+.35PSR
Michigan	1 per workstation	4-5 mpd	1 week per pavement type	random check	distress index	remaining service life (RSL)	not used	threshold values
Minnesota	2	40 mpd	3 days	not used	surface rating (SR)	weight scale 0-4	roughness	PQI= square root (PSR X SR)
Mississippi	not applicable	not applicable	no response	random 5%	distress rating	formula	roughness	PCR=100(12-IRI /12)(Dmax-DP/Dmax) squared
Missouri	2 field, 1 office	200 mpd	yes	random check	priority rating	condition score 0-20	roughness	PSR= (2 x roughness score) + (condition score)
Montana	1	30 lane mpd	7-10 days	random check, resurvey	priority	under development	roughness	PSI reduced by degree of rutting
Nebraska	3	35 mpd	2 weeks	check 1/3 of sections rated	distress index	NSI (similar to PCI)	roughness	PMS Manual procedure
Nevada	2	20 mpd	4 hours	field check	distress modes and repair strategies	formula	roughness, friction	AASHO Road Test Formulas
New Hampshire	2	45 mpd	ongoing	not used	surface distress index	formula	no response	not used
New Jersey	3	80 mpd	6 months	project-level selections confirmed	surface distress index	weighting factors 0-5	roughness, traffic	PI=0.6 RQI+0.3 SDI+0.1 TF
New Mexico	2	30-40 samples/day	1 week	random check	distress rating	tables	roughness, traffic, accidents	formulas
New York	2	50-100 mpd	2 days	office audit	raw scores	score summaries	not used	not used
North Carolina	2	40-50 mpd	2 days	random check	distress index	deduct values	roughness	deduct value in distress index
North Dakota	3	100 mpd	not used	not used	distress score (0-99)99=new	deduct values	roughness	1/3 distress+1/3 ride+1/3 age=composite index (0-5)
Ohio	1	50-100 mpd	with experienced crew	not used	pavement condition rating	deduct values	roughness, friction	not combined, independent consideration
Oklahoma	2-3	50-80 mpd	yes	no response	not implemented	no responce	planning	no response
Oregon	2	variable	1 day	not used	rating score, description of condition	deduct values	not used	not applicable
Pennsylvania	2	16 mpd	2 days	compare with last year, 5% Q/A surv	maintenance needs, pavement index	deduct values	roughness	PSR curve=OPI=0.45 RI+0.30 SI+0.20 DI+.05 SFI
Rhode Island	3	15/25 mpd	2-3 days	alternate crew resurvey	pavement condition rating	formula	roughness	proprietary software
South Carolina	1-2	100 mpd	permenant crew members	no response	pavement distress index	distress values, models	roughness, structural values	PQI= 1.158+0.138 (PDI)(PSI)
South Dakota	3 (with dynaflect)	100 mpd	1 week	not used	not used separate index	distress data elements	roughness, structural, traffi	ranking process
Tennessee	1	per project	not used	design field view	none	not applicable	not applicable	not applicable
Texas	2	50 m/d	1 to 3.5 days	resurvey random samples	unadjusted visual utility base	utility factors	roughness	tables, equations
Utah	2	50 m/d	1 month	check results	distress index	DI=5.0 -0.13(C+P)1/2pwr.	roughness, structural, skid	under development
Vermont	3	varies	yes	dipstick, mays meter	distress index, priority rating	not used	roughness, friction	formula
Virginia	2/3	15 m/d	1 day	resurvey random samples	distress maintenance rating	rating factors	ride rating	ride considered seperate
Washington	2	50-100 m/d	1 week	occasional field check	distress index, priority rating	deduct values	no response	developing new process
West Virginia	2	na	pilot testing	not applicable	pilot development	not applicable	not applicable	not applicable
Wisconsin	2	50 m/d	2 days	duplicate random ratings	pavement distress index (0-100)	work factors	no responce	no response
Wyoming	2	200 mpd	as required	not used	remaining service life	no response	none	not applicable
Alberta	1-2	100 mpd	2 weeks	check video tapes	visual condition index	weight factors	roughness, structural	PQI=f (RCI+SAI+VCI)
British Columbia	3 (also Benkleman Beam)	3 mpd (with BB)	ongoing	not used	used subjectively	proposed PI=RI+SI+DI	roughness, structural	developing
Manitoba	3	300 mpd	on-the-go	compare panel ratings	surface condition rating	condition ratings	not used	not used
New Brunswick	2	50 mpd	5 days	crews overlap	surface distress index	formula	roughness, structural	PN =0.4 PN ride+0.35 PN distress+0.25 PN strength
Nova Scotia	6	no response	1/2 to 1 day	not used	pavement condition rating	weight factors	not used	roughness
Ontario	2	35 mpd	on-the-job	yes-history	distress manifestation index	formula	roughness	DMI=(Si+Di)Wi; severity, density, weighting
Prince Edward Isl	1	25 mpd	2 weeks	yes-edit	surface distress index	formula, table	roughness, structural	PQI=composite pavement quality index
Quebec	2	100 mpd	2 weeks	yes-resurvey	diagnot usedstic of distress causes	expert system	roughness, structural, other	not applicable
Saskatchewan	2 automated/4 manual	60 mpd	3 weeks	not used	distress index	no responce	no response	no response

APPENDIX D

Pavement Roughness

State/Agency	Type of Roughness Survey Equipment C-1	Number of Units	Networks Surveyed C-2	Number of Miles	Frequency of Surveys	Data Collection Units C-3	Measurement Interval	Wheelpaths Measured
Alabama	SDP (International Cybernetics)	1	all	11,000	biennial	IRI	0.5 mile	average
Alaska	SDP, RD, PC	1	no response	2,600	1/2 per yr	IRI	1 mile	average
Arizona	Mays	3	all	7,400	annual	no response	no response	average
Arkansas	Mays	2	Interstate, primary, other	6,285-9,800	biennial-4 to 5 years	in/mi	0.1 mile	average
California	Cox	6	all	15,000	biennial	no response	no response	average
Colorado	ARAN	1	all	10,950	biennial	IRI	100 points/mile	r/l/ave
Connecticut	TechWest+SDP	2+1	all	7,700	annual	arbitrary-1 to 1,000	52.8 feet	average
Delaware	ARAN,PURD	1	all	no response	biennial	IRI, RMSV	4 inches	average
District of Col.	Mays (Rainhart)	1	all	1,100	biennial	IRI	no response	average
Florida	SDP (International Cybernetics)	5	no response	no response	annual	IRI-conv.PSI (SV)	no response	average
Georgia	Mays (mod-Ga)	8	no response	no response	no response	no response	no response	no response
Hawaii	Cox	1	all	938	biennial	ridescore	1 mile	average
Idaho	SDP (International Cybernetics)	1	all	5,000	annual	IRI/PSI	1 foot	both, average
Illinois	SDP (Ill.mfg)	1	Interstate, other	1,900-17,000	annual-biennial	IRI	no response	right
Indiana	Cox/Profilometer, Prorut (spring92)	1+1	all	13,000	annual	ridescore (IRI-92)	0.1 mile	average
Iowa	SDP (International Cybernetics)	1	all	10,000	1/2 per year	IRI	1 foot	both, average
Kansas	Mays (Rainhart)/SDP (International Cybernetics)	3+1	all	11,000	annual	IRI	0.1 mile	MDR left, Mays average
Kentucky	Mays (Rainhart)	6	all	25,000	annual	RI	0.1 mile	average
Louisiana	contract	no response	Interstate, primary, other	840+3,120-10,7	biennial-4 to 5 years	IRI	continuous	both, average
Maine	ARAN	1	all	8,500	biennial	IRI	8 inches	both, average
Maryland	KJLaw 8300	1	all	6,000	annual	IRI	0.1 mile	right
Massachusetts	ARAN	1	all	3,000	1/3 per year	IRI, RMSVA	0.2 mile	average
Michigan	Inertial Profilometer (Michigan DOT)	1	all	10,000	annual	IRI	3 inches	right
Minnesota	SDP (MinnDOT)	1	no response	14,000	1/2 per year	IRI	1 foot	left
Mississippi	SDP (Pave Tech/2 International Cybernetics)	1+2	all	12,000	annual	IRI	1 foot	left
Missouri	ARAN	1	Interstate, primary, secondar	9,800-22,500	annual-1/3 per year	RMSVA (IRI-1,000	0.02 mile	average
Montana	SDP (International Cybernetics)	1	all	8,200	biennial	IRI, profile, rut dept	1 foot	average
Nebraska	SDP (Nebraska)	1	all	10,000	annual	IRI	1 foot	left
Nevada	Cox	1	all	11,494	annual	IRI, slope variance	counts/ mile	average
New Hampshire	ARAN	1	Interstate, other	278-3,718	annual-biennial	RCI, SDI, RRI	0.1 mile	average
New Jersey	ARAN	1	all	2,100	annual	ARAN	0.01 mile	average
New Mexico	ARAN/PhotoLog-roughness	1+2	Interstate, other	999-10,706	annual-biennial	IRI, raw data	no response	average
New York	SDP (contract)	no response	sample	1,000	biennial	IRI	no response	right
North Carolina	SDP	1	primary	8,000	annual	IRI	1 foot	left
North Dakota	SDP in Video Tech Van	1	all	8,600	annual	IRI	1 foot	right
Ohio	KJ Law Profilometer/MDR8300/Mays (Rainhart)	1+1+1	all	19,000	biennial	IRI, PSI	0.2 mile	left
Oklahoma	SDstyle/Mays	1+1	all	18,400	biennial	IRI	0.01 mile	average
Oregon	SDP	1	no response	no response	no response	IRI	1 foot	average
Pennsylvania	SDP/Mays	4+4	Interstate, PCN, other	1,200-42,000	annual-biennial	IRI	1 foot	average
Rhode Island	SDP (ConnDOT)	1	all	no response	part annual	IRI	no response	average
South Carolina	Mays (Rainhart)/SDP (International Cybernetics)	1+2	all	7,900	annual	IRI	no response	average
South Dakota	SDP (SDDOT)	2	all	8,204	biennial	IRI, PSR	1 foot	left
Tennessee	no survey							
Texas	Siometer	16	all	27,400	annual	SI	0.2 mile	average
Utah	Cox	1	all	5,800	annual	RI to IRI	no response	average
Vermont	IMS (contract)	varies	all	3,000	biennial	IRI	no response	left
Virginia	SDP (Internatioal Cybernetics)/MDR8300 (KJ La	1+1	planning	no response	no response	IRI	0.1 mile	left
Washington	SDP/Cox	1+1	all	8,000	annual	IRI	16 inches	average
West Virginia	KJ Law Profilometer/Mays	1+1	all	2,500	annual	IRI	6 inches	both, average
Wisconsin	SDP	1	all	13,400	1/2 annual	IRI	1 foot	left
Wyoming	SDP	1	all	7,200	annual	IRI	1 foot	left
Alberta	Cox (CS8000 Ultrasonic)	2	primary, secondary	18,000	3 to 4 years	RCI	200 to 500 meters	average
British Columbia	not applicable							
Manitoba	not applicable							
New Brunswick	Mays	1	arterials, collectors	3,000	biennial	IRI, RCI	continuous	average
Nova Scotia	Roadmeter-NSDTC	3	infrequent			counts/kilometer	continuous	average
Ontario	PURD (Roadware)	1	all	14,000	biennial	RMSVA	not applicable	average
Prince Edward Isle	PURD	1	all	2,065	1/3 per year	RCI	50 meters	average
Quebec	PCA/Mays	4+1	all	12,000	annual	IRI	not applicable	average
Saskatchewan	Cox (Ultrasonic)	3	designed pavement/oil treate	7,000/5,100	annual/ 5 years	RCI	kilometer	average

APPENDIX D (Continued)

State/Agency	Lane Surveyed Two-Lane Roads	Lanes Surveyed Four-Lane Roads	Uniform Length Data Reported C-4	Section Summary Data Reported	Data Collection Means	Roughness Survey Speed C-5	Production Rate Lane Miles Per Day	Data Stored C-6	Equipment Calibration C-7
Alabama	one	both outside	no response	section	hc	55 mph	300	mf, pc, hc	HPMS procedures
Alaska	one	one	yes	no response	pc	5-55 mph	200	pc	calibration guage
Arizona	one	one	mile point	no response	pc, tape, hc	50 mph	300	mf, pc, hc	correlate with Profilometer
Arkansas	one	both outside	no response	section	tape	30-50 mph	no response	mf, pc, hc	test track
California	both	all	no response	section	pc	no response	no response	mf	test track
Colorado	one	both outside	0.1 mile, 1 mile	section	pc	50 mph	300	pc, hc	test sites
Connecticut	both	both outside	no response	section	hc	20-40 mph	100	mf	calibration site run monthly
Delaware	one	both outside	0.02 mile	0.2 mile	pc	30 mph	5 to 50	pc	manufacturer recommendations
District of Col.	one	one	n	block	hc	15-25 mph	no response	pc	correlate with Class 2
Florida	one	both outside	section	varys	pc	30, 40, 50 mph	27+distress	mf	with CHLOE for PSI (slope variance)
Georgia	no response	no response	no response	no response	no response	no response	no response	no response	no response
Hawaii	both	all	lane mile	mile	hc	posted	200	pc, hc	per HPMS (World Bank)
Idaho	one	both outside	no response	homogenous section	hc	50 mph	200	no response	no response
Illinois	one	both outside	0.1 mile graph	no response	hc	50 mph	300	mf, pc	test sensors
Indiana	one	both outside	0.1 mile summary	homogenous section	hc	30, 50, 60 mph	250	pc	correlation loop, once per month
Iowa	one	both outside	no response	section	pc, hc	55 mph	100	mf, pc, hc	correlate with CHLOE
Kansas	one	both outside	0.1 mile	no response	pc	50 mph, SDP-any	250	mf, pc	MAYS/SDP/Dipstick
Kentucky	both	all	no response	yes	hc	50 mph	300	mf	test sections monthly/Profilometer yearly
Louisiana	one	both outside	mile	no response	pc, hc	posted	225	pc	contract
Maine	one	one	section	no response	pc	25-50 mph	100	mf, pc	surveyed test sections/test sensors
Maryland	both	both outside	yes	section	pc	40 mph	200	pc	in-house
Massachusetts	one	both outside	no response	no response	pc	40 mph	75	pc, hc	Dipstick/survey test sections (9)
Michigan	one	both outside	0.1 mile	no response	pc	posted	350	pc	self-calibrating
Minnesota	one	both outside	0.1 mile	no response	pc	55 mph	200	mf	self-calibrating
Mississippi	one	both outside	yes	section	pc, hc	posted	200	pc, hc	multiple runs/Dipstick/SHRP sites
Missouri	one	both outside	yes	section	pc	50-60 mph	250	mf, pc	internal/10 calibration sites periodically
Montana	both	all	section	no response	pc	50 mph	200	mf	against other SDP at Users Group Meeting
Nebraska	one	both outside	yes	no response	mf, pc, hc	50 mph	75	mf, pc, hc	against other SDP at Users Group Meeting
Nevada	both	both outside	no response	per mile	tape, hc	posted	100	mf, hc	per HPMS/Dipstick/calibrated sections
New Hampshire	one	both outside	no response	section	pc, hc	posted	no response	mf, pc, hc	test sections (9)/Dipstick
New Jersey	one	one	0.2 mile	no response	pc	40 mph	80	mf	test sections (6)/Dipstick
New Mexico	one	one	no response	no response	pc	no response	no response	mf	rod and level survey
New York	one	both outside	no response	section	pc	posted	no response	mf, pc	test sections/Dipstick
North Carolina	both	both outside	0.1 mile	no response	hc	posted	80	pc	not necessary
North Dakota	one	both outside	1 mile	no response	pc	55 mph	300	pc	weekly over test strip
Ohio	one	both outside	yes	no response	pc, tape	50 mph	225	mf	against Profilometer
Oklahoma	one	both outside	yes	no response	pc	50 mph	65	mf, pc	Mays frequently, SDP not needed
Oregon	one	both outside	yes	0.1 mile	pc	50 mph	no response	pc, hc	plan Dipstick-just purchased equip
Pennsylvania	one	both outside	no response	section	pc, hc	45 mph	125		test sections/Dipstick
Rhode Island	one	both outside	yes	no response	pc, hc	posted	125	hc	see ConnDOT
South Carolina	both	both outside	0.1 mile	no response	hc	SDP-45, Mays-50 mph	200 Mays, 100 SDP	pc, hc	test sections/Dipstick
South Dakota	both	both outside	yes	yes	pc, hc	posted	300	mf, pc, hc	test segments/Dipstick
Tennessee									
Texas	one	both outside	yes	yes	pc, hc	50 mph	200	mf, pc, hc	test sections
Utah	one	both outside	yes	1 mile	pc, hc	55 mph	200	mf, pc	standard section weekly
Vermont	one	no response	no response	no response	pc	40 mph	no response	no response	no response
Virginia	both	all	yes	0.1 mile	pc, hc	55 mph	40 for HPMS sample	pc, hc	test sections vs. KJ Law
Washington	one	both outside	yes	0.1 mile	pc	50 mph	no response	mf, pc	no response
West Virginia	one	both outside	no	yes	pc, hc	40 - 60 mph	10	pc, hc	Mays to Profilometer
Wisconsin	both	both outside	no response	yes	pc, hc	25 - 65 mph	240	mf, hc	system check
Wyoming	one	one	yes	mile point	pc, hc	posted	200	mf, pc, hc	Annual users group/daily test sections
Alberta	both	all	average RCI	continuos section	hc	50 mph	120	mf, hc	CGRA-Roadmeter to RCI
British Columbia									
Manitoba									
New Brunswick	both	all	yes	yes	pc, hc		560	pc(MDR), hc	IRI from MDR/special calibration section
Nova Scotia	both	all	no response	yes	pc, hc	50 mph	na	pc, hc	20 control sectios/rating panel/road meter
Ontario	one	both outside	10 meters	average/1,000 meter	pc, hc	na	na	mf, pc, hc	standard sections
Prince Edward Isle	one	no response	50 meters	yes	pc, hc	40 mph	40	mf, hc	RCI/panel correlation, test sections twice/ye
Quebec	one	both outside	100 meters	yes	pc	40 mph	100	mf	TAC specifications/RRMR response to IRI
Saskatchewan	one	both outside	kilometer	continuous section	hc	50 mph	300	mf, pc	standard sections monthly

APPENDIX E

Pavement Structural Capacity

State/Agency	Type Equipment Used D-1	Number of Units	Crew Size	Network/Project Survey Tests D-2	Frequency of Testing	Uniform Testing D-3	Test Intervals	Sampling Size Used
Alabama	Dynatest-9000	1	3	project	as needed-150 miles/year	yes	no response	no response
Alaska	Dynatest-8000	5	1	project	as needed	yes	250-300 feet	no
Arizona	Dynatest	1	4	project	200 projects, twice a year	yes	5 per mile, all lanes	no
Arkansas	Dynatest-8600	1	2	network, project	75 network miles/year, 24 project miles/year	yes	10 per mile	yes-8 per mile
California	Dynaflect, Lane-Wells GeoLog	1+3	1	project	2300 miles/year	yes	0.01 mile	yes- 0.1 mile
Colorado	FWD-Foundation Mechanics	1	1	project	as needed	yes	0.1 to 0.2 mile	no
Connecticut	Benkleman Beam	1	3	project, research	no response	no response	no response	no response
Delaware	no testing							
District of Col.	coring							
Florida	FWD, Dynaflect	2+3	2	project, rehabilitation	as needed	yes	1/4 mile	no
Georgia	Dynatest-8000	1	1	project	varys	yes	0.1 mile	no
Hawaii	Dynatest	1	2	none	not used	yes		
Idaho	Dynatest-8000	1	5	network, project	15 to 60 network miles/year, 100 project miles/year	yes	0.1 mile	yes
Illinois	Dynatest	1	2	project	500 miles/year	yes	200 feet	500 feet
Indiana	Dynaflect, Dynatest	2+2	1	project	as needed	yes	100 feet	no
Iowa	Foundation Mechanics, Road Rater-M40	2	4	network	'10,000 miles, Interstate every third year, other miles every	yes	30 per section	no
Kansas	Dynaflect, GeoLog	1+1	3	project	500 mile/year	yes	0.1 mile	no
Kentucky	Road Rater-M2000	1	2	project	20 projects per year	yes	0.1 mile	no
Louisiana	Dynaflect, FWD	1+1	3	project	by request	yes	no response	yes
Maine	Road Rater-400B	1	2	project	225 mile/year, prior to overlay	yes	250 feet	no
Maryland	Road Rater, FWD	2+1	3	project	600 mile/year, 116 projects	yes	500 feet	no
Massachusetts	no testing					yes		
Michigan	KUAB	1	1	research	no response	no response	no test format adopted	
Minnesota	Dynatest	3	1-2	project	before and after rehabilitation	yes	0.1 mile	no
Mississippi	Dynaflect, SIE, Inc.	2	2	project	250 mile/year	yes	500 feet	no
Missouri	Dynatest	1	4	project	as needed	yes	no response	yes
Montana	RoadRater-400B, Foundation Mechanics	1	1	project	700 mile/year	yes	880 feet	no
Nebraska	FWD	1	2	project	300 mile/year	yes	no response	yes
Nevada	Dynatest+(procuring second)	1	2	project	150 mile/year	yes	0.1 mile	no
New Hampshire	no testing					yes		
New Jersey	no testing					yes		
New Mexico	nr					yes		
New York	none (procuring)					yes		
North Carolina	Dynatest	1	2	project	overlays, special projects	yes	500 feet	no
North Dakota	FWD	1	2	project	200 mile/year	yes	200 feet	no
Ohio	Dynatest-M8000, Dynaflect	1+2	1	project	700 mile/year	yes	300 feet rigid, 200 feet flexible	no
Oklahoma	FWD, Benkleman Beam	1+1	2+3	network, project	1,000 mile every 2 years	yes	1,000 feet	no
Oregon	Dynatest-M8000	1	4	project	varys	yes	250 feet	yes
Pennsylvania	Phoenix-M10000, KUAB-2M-33	1+1	1+1	project	95 mile/year	varies	varies	varies
Rhode Island	Benkleman Beam	1	6	project	one per month	yes	200 feet	no
South Carolina	Dynatest-M8000	1	2	project	varys	yes	500 to 2,500 feet	no
South Dakota	Dynaflect-GeoLog	1	3	network, project	700 mile/year, 8204 in 3 years	yes	mile	no
Tennessee	Dynatest-M8000	1	2	project	varys	yes	0.1 mile	3 per site
Texas	Dynatest, Dynaflect, Benkleman Beam	13+2+2	2	network, project	14,000 network miles/year, 1000 project mile/year	yes	5 points per section	no
Utah	Dynaflect	1	2	network, project	5,800 miles biennually, 200 project mile/year	yes	1 mile network, 0.1 mile project	no
Vermont	FWD	1	2	network, project	300 network mile/year, 300 project mile/year	yes	1/4-1/2 mile	no
Virginia	Dynatest-M8000	1	2	project	request only	yes	100 feet/ 2 mile, 250 feet/ 2-5 mile, e	no
Washington	Dynatest-9000	1	1	project	no response	yes	0.05 mile	no
West Virginia	Dynaflect, GeoLog	1	2-3	project	20 mile/year- twice		uniform	10 per mile
Wisconsin	KUAB-2M	1	1-2	project	40 to 80 mile/year	no response	no response	no response
Wyoming	KUAB, Dynaflect	1+2	3	network, project	1,000 network mile/year, 100 project mile/year	yes	0.5mi+500ft	varies
Alberta	Dynaflect-DM00E	1	2-3	network, project	235 network mile/year, 235 project mile/year	y	200, 500 feet/mile	no
British Columbia	FWD, Benkleman Beam	1+6	3-5	yes	no response	y	40m	no
Manitoba	Benkleman Beam	10	3	network, project	7,200miles in 3 years, 100miles/year	yes	mile	no
New Brunswick	Dynaflect	2	2	yes	3,000miles in 3 years	yes	200m	no
Nova Scotia	Dynaflect	2	2	project	600 miles/year	yes	50m	no
Ontario	Dynaflect (contract)	1	2	project	20mile/year	no response	no response	no response
Prince Edward Isle	Dynaflect (Geolog)	1	2	network	700 mile/year	yes	200m	no
Quebec	Dynaflect, FWD	4+1	3+1	network, project	600mile/year, 100 mile/year as needed	yes	100m	yes
Saskatchewan	Benkleman Beam	5	2	project	no response	yes	200m	2,000m

APPENDIX E (Continued)

State/Agency	Sample Interval	Sample Location	Average Data Points/Day	Days Testing per Year	Traffic Controls Used	Drop Point Data Reported D-4	Test Location Reported	Section Data Reported	Data Recorded	Data Stored D-5
Alabama	no response	no response	varies	40	lane closure, arrow board	yes	yes	yes	pc, hc	pc, hc
Alaska	no	no	2,000	210	urban	yes	yes	yes	pc	pc
Arizona	no	no	100	60	signs, cones	no	yes	no	pc	mf, pc
Arkansas	100 feet	yes-near instrumentation	no response	365	signs, 2 flaggers	yes	yes	yes	pc, hc	pc, hc
California	lane mile	outer wheelpath	300-400	continuous	varies with traffic, geometry	no	yes	yes	hc	project file
Colorado	no	no	200	varies, project needs	shadow vehicle in front, arrow board in back	yes	yes	no	pc, hc	pc
Connecticut	no response	no response	no response	no response	no response	no response	no response	no response	hc	hc
Delaware										
District of Col.										
Florida	no	no	140	no response	2-lane- flagger; 4-lane- arrow board, shadow truc	no	yes	no	pc	pc
Georgia	no	no	no response	no response	no response	no	yes	no	hc	pc
Hawaii										
Idaho	0.1 mile	outer wheelpath	100-150	60	crash truck, 2 sign trucks	yes	yes	no	pc	pc
Illinois	no	outer wheelpath	75	175	lane closure, crash truck	yes	yes	yes	tape, hc	pc, hc
Indiana	no	no	no response	150, 60	shadow truck, 1 to 3 arrow boards, signs	yes	yes	yes	pc, hc	pc, hc
Iowa	no	no	600	32, April, May	2 or 3 safety vehicles	no	milepost	control	hc	mf, hc
Kansas	no	no	varies	May to October	2 vehicles, 2 flaggers, sign board, signs	yes	yes	yes	tape	mf, pc
Kentucky	no	no	200	20	shadow trucks, arrow boards, signs	no	yes	yes	tape	mf
Louisiana	no response	no response	no response	no response	no response	no response	no response	yes	hc	no response
Maine	no	no	40	65	crash truck with arrow board, arrow board on tes	no	yes	no	pc, hc	pc
Maryland	no	no	no response	140	yes	no	no	no	hc	hc
Massachusetts										
Michigan					lane closure				pc	pc
Minnesota	no	no	300	160	2 crash trucks, arrow board, mobile operation	yes	no	no	pc	mf
Mississippi	no	no	250	25	MUTCD for slow moving operations	no	yes	yes	pc, hc	pc
Missouri	varies	na	na	na	moving operation, 2 shadow trucks	no	yes	no response	pc	mf
Montana	no	no	200	125	flaggers	yes	yes	no	pc	pc, hc
Nebraska	random	random	250	150-200	in busy areas, flaggers	yes	yes	no	pc, hc	mf
Nevada	no	no	no response	no response	yes	yes	no	no	pc, hc	pc, hc
New Hampshire										
New Jersey										
New Mexico										
New York										
North Carolina	no	no	no response	no response	yes	yes	yes	no	pc, hc	pc, hc
North Dakota	no	no	300	120	truck, arrow board	no	yes	no	pc	hc
Ohio	no	no	340	235	crash truck, cones, arrow board	no	yes	no	tape, pc, h	mf, pc, hc
Oklahoma	no	no	300	20-40	2 crash trucks with arrow boards	yes	yes	yes	pc, hc	mf, pc, hc
Oregon	varies	varies	varies	varies	no response	yes	yes	yes	pc, hc	pc, hc
Pennsylvania	varies	varies	80	90	yes	yes	yes	yes	pc, hc	pc, hc
Rhode Island	no	no	6	12	flaggers, cones	no	yes	yes	hc	hc
South Carolina	no	no	100	50	2-lane, flaggers; 4-lane, arrow board, 2 crash tru	yes	yes	no	pc	pc
South Dakota	no	no	125	70	lead vehicle with flashers, arrow board on tester	no	yes	no	pc	mf, pc, hc
Tennessee	varies	varies	varies	varies	arrow board	yes	no	yes	hc	hc
Texas	no	no	150	300	2-lane-lead and shadow vehicle; shadow on divid	yes	yes	yes	tape,pc,hc	mf,pc,hc
Utah	no	no	30	100	2 shadow trucks	no	yes	yes	pc, hc	mf,pc,hc
Vermont	no	no	no response	summer only	yes	no response	no response	no response	pc	pc
Virginia	no	no	20-25 mile/day	200	yes	no	yes	yes	pc, hc	pc, hc
Washington	no	no	200	60-100	flaggers, shadow truck	yes	yes	no	pc, hc	pc
West Virginia	random	random	100	4	standard requirements	no	yes	no	hc	hc
Wisconsin	no response	no response	70	25	flaggers, shadow truck	no	yes	no	pc, hc	pc
Wyoming	500 feet	no	50	100	Interstate-shadow truck, arrow board; 2 lane-flag	yes	yes	yes	pc	pc
Alberta	no	no	150	80	flaggers, signs, arrow board	yes	yes	yes	hc	mf,hc
British Columbia	no	no	200	year round	flaggers, lane closure	no	yes	yes	hc	hc
Manitoba	no	no	80	30	flagger	no	yes	no	hc	mf,hc
New Brunswick	no	no	250	80	shadow vehicle, flagger	no	no	yes	pc, hc	mf, pc
Nova Scotia	no	no	no response	180	moving workplace	no	yes	no	pc, hc	pc, hc
Ontario	no	no response	no response	no response	as required	no	yes	no	pc, hc	pc, hc
Prince Edward Isle	no	no	150	40	shadow vehicle	no	yes	yes	hc	mf, pc
Quebec	1 per 1,100m	no response	120	no response	shadow vehicle	no	yes	no	pc,tape,hc	mf
Saskatchewan	no	no	200	50	signs and lights	no	yes	yes	pc, hc	mf, pc, hc

APPENDIX E (Continued)

State/Agency	Analysis Method D-6	Equipment Calibation D-7	Calibration Frequency	Data Used for Design D-8	Data Used for Seasonal Limits	Data Used for Load Limits	Other Data Uses
Alabama	back calculation	no response	no response	yes	no	no	
Alaska	back calculation	manufacturer	no response	yes	yes	no	
Arizona	correlate performance	manufacturer	annual	yes	no	no	
Arkansas	ELMOD, ELCON, ROADHOG	manufacturer	biennial	yes	yes (research)	yes	concrete joint load transfer
California	Caltrans-GE	load cell, test section	annual	yes	no	yes	routine for rehabilitation; concrete joints
Colorado	other	manufacturer	annual	yes	no	no	
Connecticut	no response	no response	no response	no response	no response	no response	specific research project deflection tests
Delaware							
District of Col.							
Florida	correlate with plate bearing	sensors	monthly	yes	no	no	soil support; resilient modulus for rehabilitation desi
Georgia	back calculation	manufacturer	quarterly	no	no	no	supplement visual rating and coring
Hawaii							
Idaho	back calculation (version 4.0)	SHRP sites, center	annual	yes	no	no	
Illinois	back calculation, also void analysis	manufacturer, ASTM	annual	yes	some	yes	rehabilitation evaluation
Indiana	back calculation, joint transfer, surface modulus	SHRP	annual	yes	no	no	
Iowa	effective thickness	manufacturer, test section	annual	yes	no	no	PMS PCR equations
Kansas	Asphalt Institute MS-17		monthly	yes	no	no	
Kentucky	back calculation; Kentucky analysis	sensors	annual	yes	no	no	condition assessment
Louisiana	no response	no response	no response	no response	no response	no response	
Maine	back calculation; Chevron Elastic Theory	sensor check	3 times per year	yes	no	no	
Maryland	FWD-back calculate; RR-Asphalt Institute	FWD to Florida, RR-sensor	FWD-6 month; RR- monthly	yes	no	no	concrete joints
Massachusetts							
Michigan	back calculation	manufacturer	as needed	planned			
Minnesota	maximum deflection	sensor check	3 times per year	yes	no	yes	
Mississippi	empirical-deflection/overlay	Dynaflect setup	twice per day	yes	no	no	
Missouri	yes	sensors	annual	no	no	no	research
Montana	Chevron deflection	manufacturer	annual	yes	research	research	PSI curves
Nebraska	back calculation	internal	daily	yes	no	no	
Nevada	back calculation (version 4.0)	SHRP	annual	yes	no	yes (specific)	
New Hampshire							
New Jersey							
New Mexico							
New York							
North Carolina	back calculation; in-house deflection proceedure	tower	no response	yes	no	no	
North Dakota	back calculation	manufacturer	biennial	yes	no	no	
Ohio	back calculation; 2-layer theory; concrete joints	sensors	2 per day	yes	no	no	locating underseal locations; research
Oklahoma	back calculation; ELMOD, ELSDEF; ODOT deflection prog	sensors	2 per year	no (plan)	no	no	critical locations
Oregon	back calculation; concrete load transfer	manufacturer	annual	yes	no	no	
Pennsylvania	back calculation; concrete load transfer	SHRP	2 per year	yes	yes	yes	joints; voids
Rhode Island	AASHTO-T256	no response	no response	no	no	no	back calculate resilient modulus
South Carolina	back calculation, convert to stiffness index	relative	varies	yes	no	no	
South Dakota	sensors 1 and 2 used for strength	sensors	3 per year	yes	no	no	PSR; prioritize
Tennessee	back calculation	manufacturer	every three years to manufacture	yes	no	no	
Texas	back calculation; compute strength	correlate units, plan SHRP	annual; biweekly	yes- optional	yes (occasional)	yes	joint load transfer
Utah	investigating	standard sections	monthly	yes	yes	yes	predict fatigue failure
Vermont	back calculation	others	no response	yes	no response	no response	
Virginia	Pennsylvania deflection basin method	sensors	bimonthly	yes	yes	yes	rehabilitation
Washington	back calculation	sensors	weekly	yes	no	no	
West Virginia	Pennsylvania deflection basin method	manufacturer	each use	yes	no	yes	
Wisconsin	back calculation	operations program	quarterly	yes (experimental)	yes	no	load transfer research
Wyoming	reviewing	sensors, plan SHRP	2 to 3 years; SHRP annually	yes	no	no	structural capacity
Alberta	structural index	equipment manual	3 weeks	yes	yes	no	PMS; research
British Columbia	back calculation for FWD; statistical for deflections	relative and absolute	relative- monthly; absolute yearl	yes	yes	no	
Manitoba	other	none	no response	yes	yes	no	
New Brunswick	other	sensors	weekly	yes	yes	yes	
Nova Scotia	other	equipment manual	daily	yes	yes	yes	
Ontario	back calculation	contractor	no response	occasional	no	no	joint stabilization
Prince Edward Isle	other	sensors	daily	no	no	no	network programming; overlays; seasonal loads
Quebec	calculate overlay depth	calibration device	daily	yes	yes	no	structural capacity; establish priority
Saskatchewan	no response	vehicle weighed, beam chec	weekly	yes	no	no	

APPENDIX F

Pavement Friction Testing

State/Agency	Equipment Used E-1	Number of Units	Crew Size	Testing Speed E-2	Test by ASTM	Production Rate Lane miles per day	Test days per year	Test tire used	Calibration Method	Calibration Frequency
Alabama	KJ Law	1	2	40 mph	yes	150 lmpd	100	ribbed	force plate, Test Center	monthly, biennial
Alaska	contract	1	1		no		45	no response	no response	no response
Arizona	Bison Mu Meter	1	2	40 mph	yes	100 lmpd	60	bald (side friction)	standard surface	daily
Arkansas	KJ Law R-30	2	1	40 mph	yes	220 lmpd	128	ribbed	test track	quarterly
California	Cox towed trailer	3	2	posted	yes	160 lmpd	175	ribbed, bald research	ASTM E-556	as needed, annual, biennial- Test Cente
Colorado	KJ Law	1	1	40 mph	no	160 lmpd	10-50 (request)	ribbed	Test Center	2 years
Connecticut	KJ Law 1290	1	2	40 mph	yes	no response	10-20	ribbed, bald research	force plate	yearly
Delaware	Soiltest (modified)	1	2	40 mph	yes	100 lmpd	75	ribbed	ASTM E-556	annual
Dist. of Columbia	no report for friction testing									
Florida	KJ Law	4	1	40 mph	yes	200 lmpd	50	ribbed, bald safety	force plate, Test Center	monthly, annually
Georgia	Soiltest	2	1	40 mph	yes	100 lmpd	250	ribbed, bald-accidents, textur	x-y air bearing	yearly
Hawaii	Aquiring equipment									
Idaho	IDOT locked wheel	1	2	40 mph	no	100-200 lmpd	80	ribbed	ball-bearing platform	monthly
Illinois	IllDOT ASTM	3	2	40 mph	yes	by projects	175-200	ribbed, bald (note)	torque arm	every 2 weeks
Indiana	trailer	2	1	40, 50 mph	yes	200 lmpd	80	ribbed, bald specials	calibration track, force plate	force plate monthly
Iowa	KJ Law	2	2	40 mph	yes	100 lmpd	32	ribbed, bald specials	air-bearing plate, test pads, Test Cent	weekly, biweekly, triennial
Kansas	KJ Law 1270	1	1	40, 55 mph	yes	60 lmpd	100	ribbed	no response	no response
Kentucky	KJ Law	1	1	40 mph	yes	10 lmpd	20	ribbed, trying bald	Test Center	annual
Louisiana	KJ Law 1270	1	1	40 mph	yes	70 lmpd	160	ribbed	force plate, Test Center	biennial
Maine	Maine DOT 2-wheel trailer	1	2	40 mph	yes	new pavement, specials	20	ribbed	ball-bearing platform	annual
Maryland	KJ Law 8274	2	2	40 mph	yes	200 lmpd	160	ribbed	force plate	monthly
Massachusetts	KJ Law	2	2	40 mph	yes	requests	no response	ribbed	air-bearing plate	annaul
Michigan	MiDOT 2-wheel trailer	1	2	40 mph	yes	varies	150	ribbed	Test Center	annual
Minnesota	KJ Law	2	2	50 mph	yes	200 lmpd	60	ribbed	Test Center	biennial
Mississippi	KJ Law 1290	1	1	40 mph	yes	40 lmpd	80	ribbed	ASTM	annual
Missouri	K. L. Law 1270	1	3	40 mph	yes	50-150 lmpd	varys	ribbed	internal check, Test Center	triennual
Montana	contract	1	1	40 mph	yes	no response	'60	ribbed	ASTM E-556, Test Center	annual to test center
Nebraska	KJ Law 1290	1	1	40 mph	yes	45 lmpd	120	ribbed	force plate	annual
Nevada	Cox	1	2	40 mph	yes	120 lmpd	35	ribbed	field test, Test Center	6 month, annual
New Hampshire	contract Maine DOT	1	2	40 mph	no	150 lmpd	10	no response	ARML	18 month
New Jersey	ASTM trailer	4	2	40 mph	yes	60 lmpd	60	ribbed	ASTM	annual
New Mexico	KJ Law	1	2	varies	yes	250 lmpd	no response	ribbed	Test Center	biennial
New York	ASTM trailer	1	2	posted	yes	20 lmpd	90	ribbed	force plate	3 times per year
North Carolina	KJ Law 1270, 1290	2	1	40 mph	yes	no response	200	bald	no response	no response
North Dakota	contract	1	2	40 mph	yes	1,500 lane miles per yea	no response	ribbed	force plate	annual
Ohio	KJ Law, ODOT	2	2	40 mph	yes	100-150 lmpd	no response	ribbed	Test Center	annual
Oklahoma	KJ Law	1	2	40 mph	yes	no response	no response	ribbed	on-board check	daily
Oregon	KJ Law	1	2	40 mph	yes	200 lmpd	40	ribbed	Test Center	undetermined
Pennsylvania	KJ Law 1270	3	2	40 mph	yes	50 lmpd	160	ribbed	ASTM E-556	6 month
Rhode Island	KJ Law 1290	1	2	40 mph	yes	varies	6-10	ribbed	no response	no response
South Carolina	KJ Law 1290	2	1	40 mph	yes	100 lmpd	150	ribbed	force plate	6 month
South Dakota	KJ Law	1	2	40 mph	yes	150 lmpd	70	ribbed	force plate	annual
Tennessee	KJ Law	2	2	40 mph	yes	250 lmpd	120	ribbed	ASTM	annual
Texas	TexDOT ASTM	6	2	40 mph	yes	150 lmpd	180	ribbed	Test Center	annual
Utah	trailer	1	2	40 mph	yes	150 lmpd	100	ribbed	Test Center	biennial
Vermont	KJ Law 1290	1	2	40 mph	yes	varys	varys	ribbed	Test Center	2-3 years
Virginia	KJ Law	2	2	40 mph	yes	100 lmpd	year round	bald, ribbed	force plate	weekly
Washington	Cox	1	2	50 mph	yes	200-300 lmpd	no response	ribbed	platform, Test Center	monthly, biennial
West Virginia	KJ Law 965	1	2	posted	yes	20 lmpd	180	ribbed	Test Center	annual
Wisconsin	KJ Law	1	2	40 mph	yes	no response	60	ribbed	air bearing plate	monthly
Wyoming	KJ Law 1270	1	2	40 mph	yes	150 lmpd	60	ribbed	Test Center	biennial
Alberta	Mu Meter MK 3	1	2	40 mph	yes	45 lmpd	80	ASTM MU Meter	MU Meter board	every 2-3 weeks
British Columbia	British Pendulum	1	1		yes	no response	no response	no response	ASTM	special projects
Manitoba	none									
New Brunswick	none									
Nova Scotia	ASTM trailer	1	1		yes	56 lmpd	10	no response	ASTM	prior to use
Ontario	KJ Law	1	2	50 mph	yes	100 lmpd	100	ribbed	platform	annual
Prince Edward Isle	no response									
Quebec	SCRIM	1	2	40 mph	no	300 lmpd	90	bald	mechanical/electrical	annual
Saskatchewan	Saskatchewan Trailer	1	1	40 mph	yes	special projects	15	ribbed	no response	annual

APPENDIX F (Continued)

State/Agency	Friction Test Interval E-3	Wheelpath Tested	Lanes Tested on Two-lane	Lanes Tested on Four-lane	Individual Test Data Reported E-4	Test Reports per Mile	Test Reports per Segment	Test Data Stored E-5	Comments
Alabama	mile	left	one	both outside	yes	no	yes	mf/pc/hc	
Alaska	mile	no response			yes	no	no	pc	
Arizona	milepost	left	one	both outside	500 feet	no	no	mf/pc	
Arkansas	1/2 mile	left	one	both outside	yes	no	no	mf/pc/hc	
California	spot	left	one, both	special investigation	yes	no	no	mf/pc/microfiche	curves, bridges, intersections
Colorado	varies	left	one	one	yes	yes	yes	pc/hc	
Connecticut	varies	left	both	all	some	no	yes	pc	no inventory tests
Delaware	1/2 mile	left	both	both outside	yes	yes	yes	mf/hc	
Dist. of Columbia									
Florida	3-5 per mile	left	one	both outside	no	no	no	mf	
Georgia	1/2 mile	right, left, both	both	both outside	yes	yes	yes	mf/hc	
Hawaii							yes		
Idaho	1/2 mile	left	one	both outside	no	no	yes	mf/pc/hc/disk	
Illinois	0.1 first mile, then 1/2 mi	both (note)	no response	no response	yes	yes	yes	mf/pc	
Indiana	mile	left	one	both outside	milepost	no	yes	pc/hc	
Iowa	varies	left	both	both outside	yes	no	yes	mf/hc	Interstate tested annually
Kansas	5 per mile	left	both	both outside	occasionally	no	yes	mf/hc	
Kentucky	no response	left	both	both outside	no	no	yes	pc	
Louisiana	varies	left	both	both outside	yes	no	yes	mf/pc/hc	
Maine	500 feet	both	both	both outside	yes	no	yes	hc	
Maryland	0.3 mile	no response	both	both outside	no	no	yes	pc/hc	
Massachusetts	1/2 mile	no response	one	both outside	yes	no	no	pc/hc	
Michigan	construction project	left	both	all	no	no	yes	pc	about 10,000 tests per year
Minnesota	0.1 mile	left	both	both outside	yes	no	no	mf	
Mississippi	1/2 mile	left	one	both outside	yes	no	yes	pc/hc	not part of PMS, not inventory basi
Missouri	0.1-0.3 mile	left	both	both outside	yes	no	yes	mf	
Montana	1/2 mile	left	one	both outside	yes	no	yes	pc/hc	
Nebraska	1/2 mile	left	one	both outside	no	no	yes	mf	
Nevada	mile	left	both	both outside	yes	yes	no	mf/hc	
New Hampshire	mile	both	one	both outside	yes	no	yes	hc	
New Jersey	no response	left	one	both outside	no	yes	no	mf/mag tape	
New Mexico									
New York	0.1 mile	left	both	all	yes	yes	no	mf	
North Carolina	1/2 mile	right	one	both outside	yes	no	no	hc	
North Dakota	1/2 mile	no response	one	both outside	yes	yes	yes	pc/hc	Test 1/5 of 7330 miles biennially
Ohio	varies	left	one	both outside	yes	no	yes	mf	
Oklahoma	1/2 mile	right	one	both outside	yes	no	no	pc/hc	
Oregon	1/2 mile	no response	one	both outside	yes	no	no	mf/pc	new test equipment
Pennsylvania	segment (average 1/2 mile	left	one	both outside	yes	no	yes	mf/hc	
Rhode Island	1/2 mile	left	one	both outside	yes	no	no	pc/hc	testing by contract with FHWA
South Carolina	0.3 mile	left	one	both outside	yes	no	no	pc/hc	
South Dakota	mile	left	both	both outside	yes	yes	yes	mf/pc/hc	
Tennessee	no response	right	both	both outside	no	yes	no	mf	
Texas	1/2 mile	right	one	both outside	yes	no	yes	hc/mf	
Utah	mile	right	one	both outside	yes	yes	yes	mf/pc	
Vermont	1/2 mile	left	one	both outside	yes	no	no	pc/hc	testing by contract with FHWA
Virginia	mile	left	one	one	yes	no	yes	pc/hc	
Washington	mile	left	one	both outside	yes	no	no	mf/pc/hc	
West Virginia	15 tests per site	right	one	both outside	no	no	yes	hc	
Wisconsin	0.1 mile	left	both	all	no	no	yes	mf/hc	
Wyoming	varies with friction numbe	left	both	both outside	yes	no	yes	pc/hc	
Alberta	180 meters	right	both	all	yes	no	yes	mf/hc	
British Columbia	as required	no response	no response	no response	yes	no	yes	hc	
Manitoba									
New Brunswick									
Nova Scotia	varies	both	both	all	yes	no	no	hc	
Ontario	varies	right	one	both outside	yes	no	yes	pc/hc	
Prince Edward Isle									
Quebec	5,10 or 20 meters	right	one	one	yes	no	no	pc	
Saskatchewan	no response	left	no response	no response	yes	no	no	pc/hc	

APPENDIX G

CONTACTS WITHIN RESPONDING AGENCIES

State/Province/Agen	Response Source Title	Unit	Address
Alabama	Pavement Management Engineer	Bureau of Materials and Tests	1409 Coliseum Bld., Montgomery, AL 36130
Alaska	Pavement Management Engineer		5800 E. Tudor Rd., Anckorage, AK 99507
Arizona	Pavement Services Engineer		1221 N.21 St. Ave., MD 068R, Phoenix, AZ 85009
Arkansas	Pavement Management Engineer		P. O. Box 2261, Little Rock, AR 72203
California	Chief	Office of Pavement and Maintenance Management	1120 N St., Sacramento, CA 95814
Colorado	Sr. Transportation Specialist		4201 E. Arkansas Av., Rm. 212, Denver,CO 80222
Connecticut	Director of Research and Materials	Bureau of Highways	24 Wolcott Hill Rd., P.O.Box A, Wethersfield. CT 06129
Delaware	Pavement Management Engineer		PO Box 778, Dover. DE 19903
District of Columbia	Chief	Pavement Management Branch	4701 Shepherd Parkway, S.W., Washington, DC 20032
Florida	Pavement Evaluation Engineer		PO Box 1029, Gainesville, FL 32602
Georgia	Chief	Research and Development Branch	15 Kennedy Dr., Forest Park, GA 30050
Hawaii	Materials, Testing and Research Engineer		2530 Lifelike Highway, Honolulu, HI 96819
Idaho	Pavement Engineer		3311 W State St., Boise, ID 83707
Illinois	Engineer of Pavement Technology		126 E. Ash St., Springfield, IL 62704
Indiana	Chief	Division of Roadway Management	100 N. Senate Ave., Indianapolis, IN 46204
Iowa	Ass't Special Investigations Eng.	Central Materials Laboratory	800 Lincolnway, Ames, IA 50010
Kansas	Pavement Management Engineer		2300 Van Buren, Topeka, KS 66611
Kentucky	Pavement Management Engineer		702 State Office Bldg., Clinton and High St., Frankfort, KY 40622
Louisiana	Pavement Management Engineer		1201 Capitol Access Road, Baton Rouge, LA 70804
Maine	Pavement Management Engineer		Child St., Station 16, Augusta, ME 04333
Maryland	Chief	Soils and Foundation Division	2323 West Joppa Rd., Brooklandville, MD 21022
Massachusetts	Pavement Management Engineer		10 Park Plaza, Rm. 4150, Boston, MA 02116
Michigan	Transportation Engineer	Materials and Technology Division	PO Box 30049, Lansing, MI 48909
Minnesota	Pavement Management Engineer	Materials and Research Laboratory	1400 Gervais Ave., Maplewood, MN 55109
Mississippi	Research and Development Engineer		PO Box 1850, Jackson, MS 39215
Missouri	Pavement Management Engineer		P.O. Box 270, Jefferson City, MO 65102
Montana	Supervisor, Pavement Management Sectio	Materials Bureau	2701 Prospect Ave., Helena, MT 59620
Nebraska	Highway Management Coordinator		PO Box 94759, Lincoln, NE 68509
Nevada	Assistant Director	Planning	1263 S. Stewart St., Carson City, NV 89712
New Hampshire	Pavement Management Engineer		John O. Morton Bldg., P.O.Box 483, Hazen Dr., Concod NH 03302
New Jersey	Principle Engineer	Research	1035 Parkway Ave., Trenton, NJ 08625
New Mexico	Pavement Management Engineer		PO Box 1149, Sante Fe, NM 87504
New York	Chief	Pavement Management System Development	1220 Washington Ave., Bldg. 7A, Room 501A, Albany, NY 12232
North Carolina	Data Collection Engineer	Pavement Management	PO Box 25201, Raliegh, NC 27611
North Dakota	Senior Engineer	Planning Division	608 East Boulvard Ave., Bismark, ND 58505
Ohio	Pavement Management Engineer		25 South Front st., Room 506, Columbus, OH 43215
Oklahoma	Senior Research Project Manager	Research and Development Division	200 N. E. 21St., Oklahoma City, OK 73105
Oregon	Pavements Engineer	Pavements Unit	800 Airport Rd., Salem, OR 97310
Pennsylvania	Chief	Roadway Management Division	T&S Bldg., Harrisburg, PA 17120
Rhode Island	Supervising Civil Engineer	Planning Division	State Office Bldg., Providence, RI 02903
South Carolina	Pavement Management Engineer		PO Box 191, Columbia, SC 29202
South Dakota	Pavement Management Engineer		700 East Broadway Ave., Pierre, SD 57501
Tennessee	Pavement Management Engineer		1000 James K. Polk Bldg., Nashville, TN 37243
Texas	Engineer of Pavement Management		125 East 11th. Street, Austin, TX 78701
Utah	Pavement Management Engineer		4501 South 2700 West, Salt Lake City, UT 84119
Vermont	Pavement Management Engineer		133 State St., Montpelier, VT 05602
Virginia	Research Scientist	Virginia Transportation Research Council	Box 3817, University Station, Charlottesville, VA 22903
Washington	Pavement and Soils Engineer		1655 South 2nd Ave., Tumwater, WA 98507
West Virginia	Pavement Management Engineer	Planning and Research	Bldg. 5, Room A-863, Capitol Complex, Charleston, WV 25305
Wisconsin	Pavement Management Supervisor	Materials Center	3502 Kinsmar Blvd., Madison, WI 53704
Wyoming	Pavement Management Systems Engineer		P.O. Box 1708, Cheyenne, WY 82002
Alberta	Pavement Systems Engineer		4th Floor, Twin Atria Bldg., 4999-98th. Ave., Edmonton, Alberta, Canada, T6B 2X3
British Columbia	Pavement Design Engineer		4A - 940 Blanshard St., Victoria, BC, Canada, V8W 3E6
Manitoba	Director	Materials and Research	1181 Portage Ave. (Annex), Winnepeg, Manitoba, Canada, R3G 0T3
New Brunswick	Senior Systems Engineer	Planning Branch	PO Box 6000, 2nd. Floor, Kings Place, Fredericton, New Brunswick, Canada, E3B 5H1
Nova Scotia	Planning Engineer, Studies	Planning Division	P.O.Box 186, Halifax, Nova Scotia, Canada, B3J 2N2
Ontario	Manager	Pavement Design, Evaluation and Management Secti	Surveys and Design Office, West Bldg. 2nd Floor, 1201 Wilson Ave., Downsview, Ontario, Canada M3
Prince Edward Isle	Engineering Technician		P.O.Box 2000, 11 Kent St., Charlottetown, PEI, Canada, C1A 7N8
Quebec	Engineer	Planning	700, boul. St-Cyrille Est, Quebec, Quebec, Canada
Saskatchewan	Director	Technical Research Branch	1855 Victoria Ave., Regina, Saskatchewan, Canada S4P 3V5

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THE TRANSPORTATION RESEARCH BOARD is a unit of the National Research Council, which serves the National Academy of Sciences and the National Academy of Engineering. It evolved in 1974 from the Highway Research Board, which was established in 1920. The TRB incorporates all former HRB activities and also performs additional functions under a broader scope involving all modes of transportation and the interactions of transportation with society. The Board's purpose is to stimulate research concerning the nature and performance of transportation systems, to disseminate information that the research produces, and to encourage the application of appropriate research findings. The Board's program is carried out by more than 270 committees, task forces, and panels composed of more than 3,300 administrators, engineers, social scientists, attorneys, educators, and others concerned with transportation; they serve without compensation. The program is supported by state transportation and highway departments, the modal administrations of the U.S. Department of Transportation, the Association of American Railroads, the National Highway Traffic Safety Administration, and other organizations and individuals interested in the development of transportation.

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Transportation Research Board
National Research Council
2101 Constitution Avenue, N.W.
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