National Cooperative Highway Research Program

NCHRP Synthesis 260

Thin-Surfaced Pavements

A Synthesis of Highway Practice

Transportation Research Board
National Research Council

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Synthesis of Highway Practice 260

Thin-Surfaced Pavements

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Transportation Research Board
National Research Council

Research Sponsored by the American Association of State Highway and Transportation Officials in Cooperation with the Federal Highway Administration

NATIONAL ACADEMY PRESS
Washington, D.C. 1998

Subject Areas
Highway and Facility Design; Pavement Design, Management, and Performance; and Materials and Construction

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NCHRP SYNTHESIS 260

Project 20-5 FY 1995 (Topic 27-08)
ISSN 0547-5570
ISBN 0-309-06123-7
Library of Congress Catalog Card No. 98-67291

Price $26.00

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Transportation Research Board
National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

and can be ordered through the Internet at:

http://www.nas.edu/trb/index.html

Printed in the United States of America

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 report will be of interest to pavement design engineers in local, state, and federal transportation agencies. Pavement, materials, construction, and maintenance engineers will also find it of interest. In addition, it will be of interest to local technology transfer centers and pavement research engineers. This synthesis describes the state of the practice for thin-surfaced pavement project selection and structural design. It does not establish preferential design criteria (e.g., mix design) nor does it systematically evaluate existing design methods.

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.

This report of the Transportation Research Board describes the conditions in which thin-surfaced pavements are considered appropriate, what thin-surfaced pavement types are considered appropriate for given conditions, and the decision criteria used in their selection. Information for the synthesis was collected by surveying state and local transportation agencies and by conducting a literature search, including foreign resources. Case studies and an extensive collection of survey data (appending) are presented.

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 the 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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ACKNOWLEDGMENTS

Donald N. Geoffroy, P. E., Albany, New York, was responsible for collection of the data and preparation of the report.

Valuable assistance in the preparation of this synthesis was provided by the Topic Panel, consisting of Gerald T. "Skip" Coghlan, Deputy Director-Engineering, USDA Forest Service; Edward J. Denehy, Civil Engineer 4, New York State Department of Transportation; J.B. Esnard, Pavement and Geotechnical Design Engineering Administrator, Louisiana Department of Transportation, Engineering Design Division; Asif Faiz, Division Chief, World Bank; Gary L. Graham, Pavement Design Branch Manager, Texas Department of Transportation; Henry Hide, Senior Consultant, Brown & Root TMG, London; John L. Hopkins, Director, Idaho Technology Transfer Center, University of Idaho; Joseph M. Huerta, Group Leader, C & M, Federal Highway Administration; Dennis C. Jackson, State Materials Engineer, Washington Department of Transportation, Materials Lab.; G.P. Jayaprakash, Engineer of Soils, Geology, and Foundations, Transportation Research Board; Bernie McCarthy, Vice President, Industry Affairs, Asphalt Institute; Jim Sorenson, Senior Construction and Maintenance Engineer, Highway Operations Division, Federal Highway Deportment; and Michael C. Wagner, Public Works Director/Highway Engineer, Nicollet County (Minnesota) Public Works Department.

This study was managed by Stephen F. Maher, P.E., Senior Program Officer, who worked with the consultant, the Topic Panel, and the Project 20-5 Committee in the development and review of the report. Assistance in Topic Panel selection and project scope development was provided by Sally D. Liff, Senior Program Officer. Linda S. Mason was responsible for editing and production.

Crawford F. Jencks, Manager, National Cooperative Highway Research Program, assisted the NCHRP 20-5 staff and the Topic Panel.

Information on current practice was provided by many highway and transportation agencies. Their cooperation and assistance are appreciated.

THIN-SURFACED PAVEMENTS

SUMMARY

A thin-surfaced pavement is either a single- or multiple-application bituminous surface treatment or a layer of hot-mix asphalt less than 50 mm (2 in.) thick over an unbound base. It is not an overlay of an existing hard-surfaced pavement, (e.g., a single bituminous surface treatment over an existing asphalt pavement or a thin course, less than 40 mm (1-1/2 in.) of asphalt concrete over an existing asphalt pavement). Many successful roads are built with thin-surfaced pavements, yet, most structural design practices in this country are not applicable to this type of pavement surface. Because a bituminous surface treatment wearing surface has no structural value and most pavement structural design procedures provide for a wearing surface with structural value, there are no structural design procedures directly applicable for a thin-surfaced pavement with a bituminous surface treatment wearing surface. Furthermore, because unpaved and thin-surfaced pavements are the responsibility of local governments with limited resources, it is much more critical that the pavement thickness be adequate for the traffic and environmental conditions, but not so thick that they unnecessarily consume funds that are critically needed for other local purposes.

This synthesis reviews past and current practices for the structural design of these types of pavements. Further knowledge is needed about when these pavements are considered appropriate, which pavements are suitable for given conditions, and the decision criteria used. Research findings from other studies in the United States and abroad were reviewed and incorporated into the synthesis. It is expected that this report will be useful to agencies who identify, fund, and conduct research and to those responsible for the transfer of pavement and paving technology to local officials.

The factors reviewed include, but are not limited to

- Traffic loads and volumes,
- Environmental and climatic conditions (e.g., dust control, temperature, moisture),
- Political reality and public concerns,
- Life-cycle costs and first costs,
- Material availability,
- Performance characteristics, including service life,
- Subgrades and drainage,
- Use of recycled materials,
- Material selection,
- Construction practices,
- Maintenance programs, and
- Management of thin-surfaced pavements.

In achieving the objectives of this synthesis, a special focus was placed on obtaining information on the ability of counties and other agencies responsible for local roads to use the current technology. A survey questionnaire was widely distributed to officials at the county, town, village, and city level of government as well as to each state, the District of Columbia, and Puerto Rico DOTs, the members of the Pavement Standing Committee of the Transportation Association of Canada and federal agencies with responsibility for roads with thin-surfaced pavements.

Of the 286 agencies responding, 160 agencies indicated that they have used thin-surfaced pavements. More than half of the responses were from county level organizations, followed by state and city level organizations.

The survey questions elicited a wide range of responses, which are tabulated in Appendix B and discussed in chapter 3. In summary, most users of thin-surfaced pavements are local governments, and county level agencies use the largest quantities. The person(s) selecting and designing the pavement may be a graduate or professional engineer or one with experience in highway design, construction, or maintenance. The local government generally has limited field and laboratory testing capabilities and the pavement is designed based on experience rather than on a published pavement design methodology.

No single factor influences the decision to apply a thin-surfaced pavement to a section of road. Agencies indicated that the decision is based on the interrelationship of all the factors, consisting of the road classification, traffic volume, the percentage of trucks, local policy, and the funding available. Within this mix, however, traffic volume and available funding were cited as the most important factors considered in deciding to apply a thin-surface pavement to a section of road. These were followed in importance by road classification and the percentage of trucks. The factors least frequently cited were local policies and the ease of implementing a thin-surfaced pavement. The factors considered in choosing between a bituminous surface treatment and a layer of hot-mix asphalt less than 50 mm (2 in.) thick as the wearing surface for a thin-surfaced pavement are traffic volume, the percentage of trucks, road classification, and available funding. Based on the responses, appropriate ranges of traffic volume, and the percentage of trucks were identified for both wearing surfaces as well as the preference for the wearing surface for different road classes.

CHAPTER ONE

INTRODUCTION

PURPOSE AND SCOPE OF THE SYNTHESIS

Many successful roads are built with thin-surfaced pavements, yet, most structural design practices are not applicable to this type of pavement surface. There are numerous excellent references on bituminous surface treatment mix design and construction techniques *(1,2,3,4,5,6)*. However, because a bituminous surface treatment wearing surface has no structural value and most pavement structural design procedures provide for a wearing surface with structural value, no structural design procedures are directly applicable to this situation. Furthermore, because unpaved roads and thin-surfaced pavements are the responsibility of local governments with limited resources, it is much more critical that the pavement thickness be adequate for the traffic and environmental conditions but not so thick that they unnecessarily consume funds critically needed for other local purposes.

The purpose of this synthesis is to review past and current practices for the design of these types of pavements. Further knowledge was sought about the conditions in which these pavements are considered appropriate, which pavements are suitable for given conditions, and the decision criteria used. The objective was not to develop the criteria for when and where to use thin-surfaced pavements nor was it to develop a structural design procedure for thin-surfaced pavements.

The primary focus of this synthesis is to report on the state of the practice with regard to thin-surfaced pavement project selection and structural design and to identify what gaps, if any, exist in the knowledge and in the availability of information for the users of thin-surfaced pavements. The factors reviewed include

- Traffic loads and volumes,
- Environmental and climatic conditions (e.g., dust control, temperature, moisture),
- Political reality and public concerns,
- Life-cycle costs and first costs,
- Material availability,
- Performance characteristics, including service life,
- Subgrades and drainage,
- Use of recycled materials,
- Material selection,
- Construction practices,
- Maintenance programs, and the
- Management of thin-surfaced pavements.

Table 1 is a summary of the distribution of the total mileage in the United States by agency having jurisdiction and the surface type. The information in this table was obtained from Table HM-12 in the 1995 Highway Statistics *(7)* and is current as of October 1996. Thirty-nine percent of the road mileage in the country is unpaved and another 13 percent is paved with a thin bituminous surface less than 25 mm (1 in.) thick. Local governments have jurisdiction and responsibility for 86 percent of the road mileage in the country and more than 50 percent of the mileage for which they are responsible is either unpaved or has a low type surface. In this table, FHWA defines a low type surface as an earth, gravel, or stone roadway with a bituminous surface less than 25 mm (1 in.) thick.

Because such a large portion of the unpaved and low type roadway surfaces are the responsibility of local governments, a special effort was made, in conducting the survey for this synthesis, to obtain information on the ability of counties and other agencies responsible for local roads to use the current technology. Typically, these agencies have an absence of sophisticated laboratories, which has a direct impact on the ability to perform materials evaluations and analytical design procedures.

Lastly, research findings from other studies in the United States and abroad were reviewed and incorporated into the synthesis.

TABLE 1
PUBLIC ROAD AND STREET MILEAGE BY SURFACE TYPE AND JURISDICTION (after *7*)

Jurisdiction	Functional Classification	Type of Surface (Miles) Unpaved	Low	Inter. & High	Total Mileage	Percent of Total Mileage
Federal and State Control	Principal and minor arterials and major collectors	2,805	19,785	537,861	560,451	14
Local Control	Rural and urban principal and minor arterials, major and minor collectors, local	1,536,570	484,011	1,331,194	3,351,775	86
Total		1,539,375	503,796	1,869,055	3,912,226	100
Percent of Total Mileage		39	13	48	100	

TABLE 2
SUMMARY OF AGENCIES RESPONDING TO THE QUESTIONNAIRE

Level of Government	Number Returned	Designs, Constructs, or Maintains Thin-Surfaced Pavements — Yes: Number	Yes: Percent	No: Number	No: Percent
Federal	13	10	77	3	23
State/Province	52	20	38	32	62
County	159	97	61	62	39
City	40	19	48	21	53
Town	20	13	65	7	35
Village	1	0	0	1	100
Metro*	1	1	100	0	0
Total	286	160	56	126	44

*The metro area is included in the city level for analysis and presentation in this report.

QUESTIONNAIRE

To identify the current practices, a questionnaire (duplicated in Appendix A) was developed and widely distributed to obtain information on the factors considered in selecting a roadway for a thin-surfaced pavement, and in the structural design, construction, and maintenance of thin-surfaced pavement to include, but not be limited to:

- Level of government,
- Level of engineering expertise available to the agency,
- Use of a pavement management system,
- Use of a maintenance management system,
- Factors considered in selecting a roadway for a thin-surfaced pavement,
- Use of a written pavement structural design procedure,
- Climatic region,
- Seasonal limitations on weight,
- Volume of traffic,
- Number of trucks,
- Seasonal limitations on tire pressure,
- Factors considered in deciding to apply a thin-surfaced pavement to a roadway,
- Nature of the subgrade soils,
- Type of base and subbase used,
- Type of base stabilizer used,
- Reclamation of the existing base or pavement,
- Type of drainage used,
- Height of the fill or embankment above the surrounding natural ground surface,
- Considerations for selecting the type of thin-surfaced pavement,
- Use of recycled materials, and
- Expected service life.

The questionnaire was distributed to DOTs in each state, the District of Columbia, and Puerto Rico, 61 members of the Pavement Standing Committee of the Transportation Association of Canada, 39 state directors for the National Association of County Engineers (NACE) with a request that they distribute the questionnaire to 10 county highway superintendents in their state, 57 directors of the Local Technical Assistance Program (LTAP) centers with a request that they distribute the questionnaire to 10 town road superintendents in their state, 32 New York State local officials attending workshops on classifying and managing low-volume local roads, and to the field staffs of the US Forest Service and the Bureau of Indian Affairs. The exact number distributed to those responsible for roads cannot be determined because some of the questionnaires were distributed to individuals who do not have a governmental operating responsibility, (e.g., university faculty members of the Canadian Pavement Committee), some county agencies received questionnaires from both their NACE State Director and the LTAP director, and some NACE and LTAP directors did not forward the questionnaire to local government officials. However, potentially, more than 1,100 questionnaires could have been distributed and most likely several hundred were distributed to all levels of government to obtain information on the current practices regarding thin-surfaced pavements.

Table 2 summarizes the responses to the questionnaire. Responses were received from 286 agencies. Figure 1 shows the distribution of the responses by levels of government. In addition, a letter from the Director of the Tennessee Transportation Assistance Program indicated that no major cities or counties in Tennessee use a thin-surfaced pavement. More than half of the responses were received from county level organizations, followed by state and city level organizations. Figure 2 shows a comparison of the uses of thin-surfaced pavements by the different levels of government. Thin-surfaced pavements are used far more by county level agencies than by any other. A complete listing of the agencies responding is shown in Tables B-1 and B-2 in Appendix B.

Overseas Organizations

A major emphasis was placed on obtaining information on the current thin-surfaced pavement practices overseas. Pavement design guides and related information were obtained from the United Kingdom Transportation Research Laboratory; the Central Laboratory of Bridges and Roads of France; Transit New Zealand; the Australian Road Research Board; Saudi Arabia Ministry of Communications; Central Road Research Institute, New Delhi, India; the Council for Scientific and Industrial Research, South Africa; and the Finnish Road

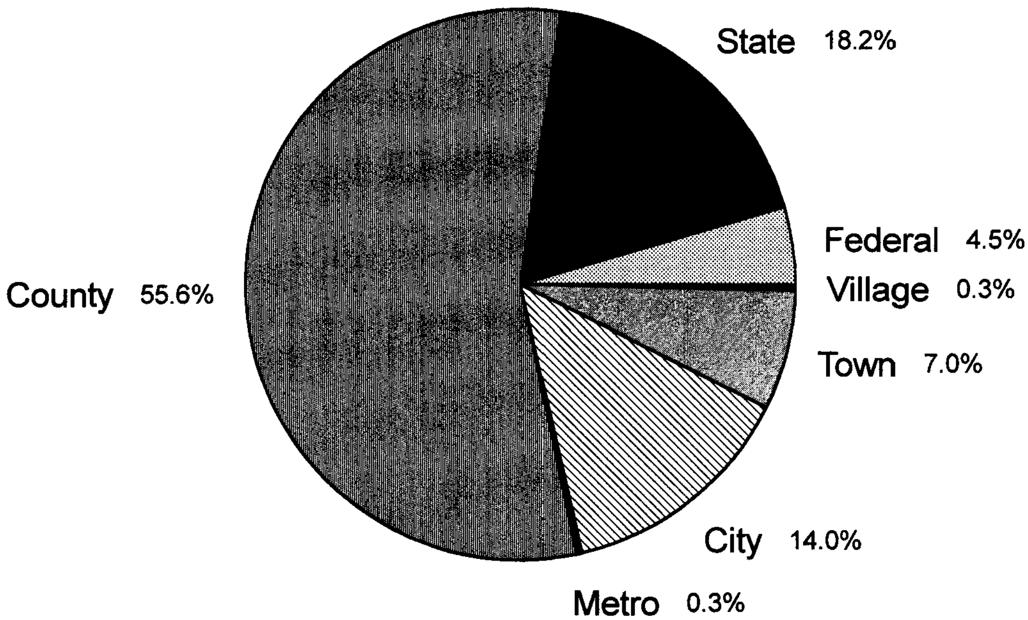


FIGURE 1 Distribution of responses by level of government.

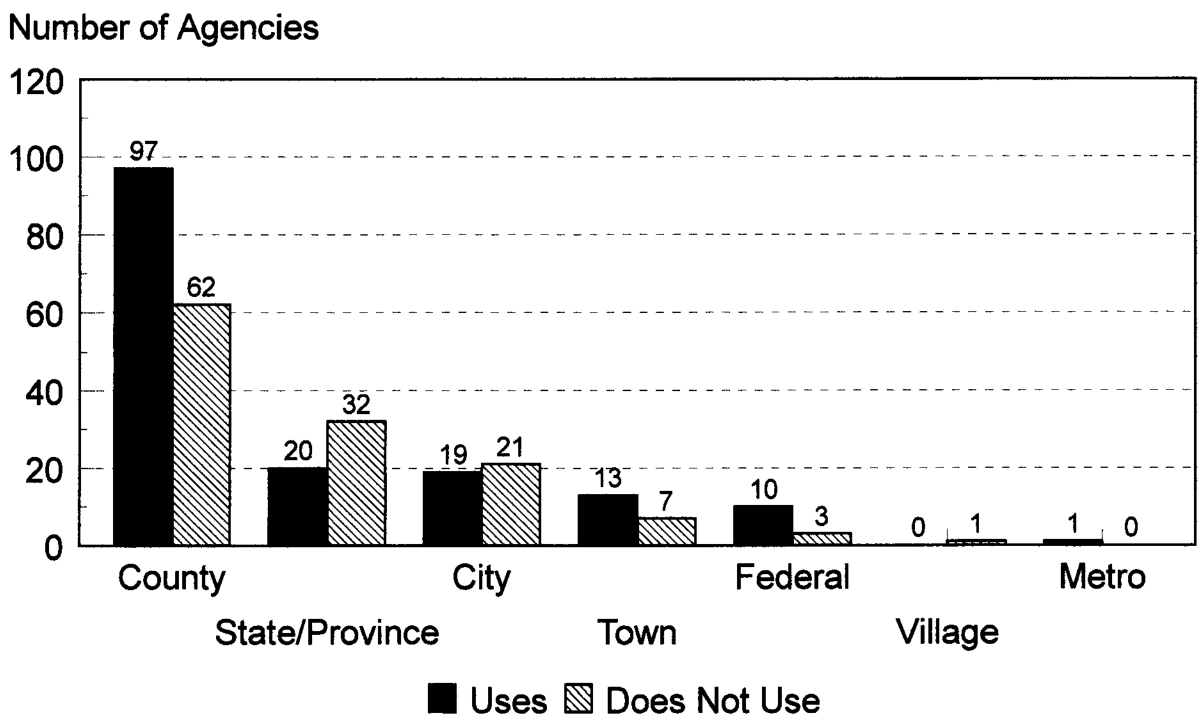


FIGURE 2 Comparison of use by levels of government.

Administration. The overseas information is summarized in chapter 2.

DEFINITION OF TERMS

Terms used in the questionnaire and in the responses to its questions are defined here as they are used in the context of this report.

A thin-surfaced pavement is either a single- or multiple-application, bituminous surface treatment (BST) or a layer of hot-mix asphalt less than 50 mm (2 in.) thick over an unbound base. It is not an overlay of an existing hard-surfaced pavement, (e.g., a single bituminous surface treatment over an existing asphalt pavement or a thin course, less than 40 mm (1-1/2 in.) of asphalt concrete over an existing asphalt pavement). In this report, bituminous surface treatments also include those treatments known as chip seals, asphalt surface treatments, and oil and stone. A surface treatment is a single (SST), double (DST) or triple (TST) application chip seal, a slurry seal, or micro surfacing. Chemical stabilization is the addition of a chemical in the form of lime, lime fly-ash, calcium, sodium or magnesium chloride, portland cement, or an asphalt emulsion to locally available material to increase its strength. Full-depth reclamation is a recycling method where all of the existing wearing surface and a predetermined amount of the underlying materials are pulverized, an additive may be introduced, and the material is shaped and compacted.

ORGANIZATION OF SYNTHESIS

Chapter 1 describes the purpose and scope of the synthesis, introduces the subject of thin-surfaced pavements, describes the questionnaire that was distributed, and reports on the responses to the questionnaire. Chapter 2 describes the thin-surfaced pavement selection and design methodologies in use in the United States, Canada, and overseas. Chapter 3 describes the current practices by government agencies in the United States and Canada. Chapter 4 provides conclusions and is followed by References.

The appendixes contain the questionnaire that was distributed, a listing of responding agencies and their responses where appropriate, and copies of graphs, tables, figures from other publications, and a list of names and addresses where the pavement design guides for overseas organizations can be obtained.

CHAPTER TWO

THIN-SURFACED PAVEMENT WEARING SURFACE SELECTION AND STRUCTURAL THICKNESS DESIGN METHODOLOGIES

INTRODUCTION

One of the findings of the recent National Highway User Survey *(8)* conducted for the Federal Highway Administration was that, ". . . the top priority for improving the nation's highways is to focus on the quality of the roadway surface. This is the factor that will most significantly increase public satisfaction with the highway system." Given that the quality of the roadway surface should be a top concern of an administrator or engineer responsible for the operation and maintenance of any low-volume road, the first question that must be addressed is, should a particular road remain as an aggregate surfaced road or should a wearing surface consisting of a bituminous surface treatment or a thin layer of asphalt concrete be constructed? The second question should be, what is the most cost-effective way to maintain this roadway surface? This chapter presents and discusses the pavement wearing surface selection criteria and thin-surfaced pavement structural thickness design methodologies that are currently available nationally and internationally to assist officials in making those decisions. The information from foreign countries, however, may not be directly transferable to the United States and Canada because differences in climate, soils, and economic conditions are reflected in a different philosophy of pavement design.

International Differences

Millard, in a state of the art review published by the Transport Research Laboratory of the United Kingdom *(9)* identifies three differences between the industrialized countries and the rest of the world.

1. The state of economic and social development when road building occurred. In many instances, the highway infrastructure in the tropics was built in the late 50's or later with financial assistance from the World Bank. One of the premises at that time, was that the increased prosperity from the transportation system would make it possible to fund the necessary maintenance. However, many third-world nations are unable to raise the revenues necessary to build the technical organizations with the skills necessary to effectively maintain the highway system or to regulate the weight of trucks. Furthermore, they do not have the construction technology and equipment that exist in the industrialized countries.
2. Most of the soil cover in the temperate and colder climates of the United States and Canada is either glacial, wind, or water deposits which have evolved to a relatively stable condition. In the tropics, however, where many developing countries are located, the soil forming processes are still active and the surface rocks are deeply weathered.
3. In the tropics, there is intense heat combined with wide variations in temperature and moisture changes.

The above conditions have lead to the development of a pavement design philosophy in the tropics and developing countries where the structural strength of the pavement is provided by strong, well-constructed bases that are robust, capable of carrying heavy load, and with minimal or no maintenance. The sole purpose of the wearing surface is to keep the dust down, and to keep moisture from getting to the base. The wearing surface does not provide structural strength. In contrast, the pavement design procedures in the United States, (e.g., AASHTO Guide for the Design of Pavement Structures, Asphalt Institute's Asphalt Pavement Thickness Design, Corps of Engineers Method) provide for bases of lessor quality and structural strength and for the surface courses to be constructed of the higher quality materials and provide significantly more of the required pavement structural strength.

PAVEMENT WEARING SURFACE SELECTION CRITERIA

There are three commonly used roadway wearing surfaces in the United States and Canada. They are portland cement concrete on rigid pavements, bituminous surface treatment or hot-mix asphalt concrete on flexible pavements, and aggregate on unpaved roads. Thin flexible pavements and aggregate surfaces are normally used on low-volume roads. Thicker flexible and rigid pavements are normally used on moderate to high-volume roadways.

Appendix B of the AASHTO *Guide for Design of Pavement Structures (10)* provides pavement type selection guidelines. The guidelines indicate that the selection of a pavement type is not an exact science but one in which the highway engineer or administrator must make a judgment on many varying factors, such as traffic, soil, weather, use of new or recycled materials, cost of different pavement sections and the availability of funds, performance of similar pavements, availability of local materials and contractor capability, safety, and local preferences. The pavement type selection may be dictated by an overriding consideration for one or more of these factors. Appendix B was not written specifically for thin-surfaced pavements or low-volume roads. However, the following factors listed in the guide are applicable to thin-surfaced pavements and they are discussed below within the context of the roadway wearing surface selection for thin-surfaced pavements.

Traffic

The amount of heavy truck traffic, combined with the moisture conditions of the subgrade, is the major factor in determining the design of the pavement. The worst case is heavy trucks during the spring thaw. Therefore, it is necessary that the current and future traffic volumes be known, including the volume or percentage of trucks. The AASHTO *Guide for Design of Pavement Structures* converts all traffic into an Equivalent 18,000 pound Single Axle Load or 80-kN (18-kip) ESAL. The guide suggests that the maximum traffic level considered for an aggregate-surfaced road is 100,000 ESAL applications over the design life of the road. As an example, in upstate New York, each truck on rural non-interstate highways averages approximately 0.3 ESAL. Trucks with 5 axles or more average over 1.0 ESALs and single unit trucks with 3 axles average over 1.3 ESALs but when all the trucks in the traffic stream are included, the average is about 0.3. The ESALs from cars have an insignificant effect on the structural design of pavements. Eighteen-wheelers alone account for approximately 90 percent of the ESALs in a traffic stream. Therefore, a low-volume road in upstate New York with an average daily traffic (ADT) of 400 vehicles per day with 20 percent trucks accumulates approximately 8,760 ESALs per year or 87,600 over a 10-year period, which approaches the upper limit of 100,000 ESALs suggested by AASHTO for an aggregate-surfaced road. Local engineers can contact the DOT within their state and obtain an estimate of the number of ESALs per truck on roads representative of the roads in their municipality and make a similar estimate.

Soil Characteristics

The load-carrying capacity of the subgrade soil has a major effect on the type of base and subbase materials and the thicknesses of these materials. Generally, granular materials (sands and gravels) or coarse-grained soils have a significantly better load-carrying capacity than fine-grained cohesive soils (silts and clays). Of special concern are those clays that expand or swell with changes in moisture.

Weather

The amount of rainfall, freezing and thawing, and the number of freeze-thaw cycles affect the load-carrying capacity of the subgrade and the pavement structure. Generally, the wetter and colder the climate, the thicker the pavement structure and the more attention to pavement drainage required. Heavy trucks on a roadway surface with a thawing subgrade present the most severe condition. It is not uncommon for a few passes of a heavy truck during the spring thaw to severely rut an inadequately designed low-volume road.

Construction Considerations

Stage construction of the pavement structure or the need to maintain traffic during construction may impact the type of pavement selected.

Recycling

The ability to reuse some existing or old pavement materials may suggest one type of pavement.

Cost Comparison

An economic comparison of the alternative pavements including the initial cost, annual maintenance costs, periodic improvements, salvage value, and vehicle operating costs can be made. All other factors being equal, the pavement type that results in the least life-cycle cost would be selected.

Performance of Similar Pavement in the Area

Past performance of a similar pavement in the area is an excellent guide in predicting the future performance of a pavement type.

Availability of Local Materials or Contractor Capability

The pavement design needs to take into account the local availability of materials and construction capability. If local government forces have the capability to apply a bituminous surface treatment, then that could be a major determining factor in deciding whether the road should remain as an aggregate-surface road or whether a wearing surface should be applied.

Traffic Safety

Several items are included in this factor. First is a comparison of the frictional resistance of a wearing surface compared to an aggregate surface. Second is the dust that occurs on an aggregate-surfaced road, even with the application of chemicals to reduce the dust. Third is the smoothness of a wearing surface compared to an aggregate surface. Unless an aggregate-surface road with moderate traffic (ADT > 250) is bladed frequently, it becomes potholed and washboarded, which can result in significant damage to vehicles and an increase in vehicle operating costs. Finally, pavement markings can be applied to a wearing surface that increases nighttime visibility.

Municipal Preference

A municipality may decide, because of the dust and rough riding characteristics of aggregate-surfaced roads, that it will apply a wearing surface to all its aggregate-surfaced roads.

National Association of County Engineers (NACE)

Chapter 10 in the National Association of County Engineers' *Action Guide on Road Surface Management (11)* provides an example of a cost analysis to aid engineers in deciding whether to apply a bituminous surface treatment to an aggregate-surfaced road or to leave it as an aggregate surface. The example considers the annual maintenance and vehicle operating costs of both options and the initial construction and future resealing cost of the bituminous surface treatment.

New York State Local Roads Research and Coordination Council

The *Manual on the Guidelines for Rural Town and County Roads (12)* developed by the New York State Local Roads Research and Coordination Council suggests that low-volume local roads with an ADT less than 150 vehicles per day can be aggregate surfaced and that those above 150 vehicles per day be asphaltic concrete consisting of either a bituminous surface treatment or a layer of hot-mix asphalt concrete.

Luhr and McCullough

Luhr and McCullough from the University of Texas have used the Pavement Design and Management System developed for the U.S. Forest Service to compare the total costs of aggregate-surfaced, bituminous treatment surfaced, and hot-mix asphalt wearing surfaced roads under different traffic conditions *(13)*. The total costs used in the analysis included the initial construction costs, the cost of a subsequent rehabilitation, the annual maintenance costs, and user costs. They examined traffic levels ranging from 5 vehicles per day to 200 vehicles per day and a mix of traffic consisting of three following types of vehicles:

- Passenger cars,
- Single-unit trucks with a 80-kN (18-kip) single axle, and
- Tractor-trailer combinations with two 151-kN (34-kip) tandem axles.

They found that,

a) For a mix of passenger cars and single-unit trucks,
   - a bituminous surface treatment is more cost-effective than an aggregate-surface road above 45 vehicles per day, which corresponds to about 5 ESALs per day,
   - A hot-mix asphalt wearing surface is more cost-effective than an aggregate-surfaced road above 150 vehicles per day, and is more cost-effective than the bituminous treatment surfaced road above 200 vehicles per day, which corresponds to about 20 ESALs per day.

b) For a mix consisting of 70 percent passenger cars, 10 percent single unit trucks, and 20 percent tractor-trailers,
   - a bituminous surface treatment is most cost-effective at 8 vehicles per day, which corresponds to about 5 ESALs per day, and
   - a hot-mix asphalt wearing surface is more cost-effective at 18 vehicles per day, which corresponds to about 10 ESALs per day.

They concluded that aggregate-surfaced roads are more cost-effective up to 5 ESALs per day, bituminous treatment surfaced roads are most cost-effective in the range from 5 to 20 ESALs per day, and that hot-mix asphalt is more cost-effective over 20 ESALs per day.

Canada

A survey of the current Canadian practice in the design, use, and application of bituminous surface treatments conducted by the Canadian Strategic Highway Research Program (C-SHRP) *(14)*, found that all the Canadian provinces except New Foundland, use a bituminous surface treatment on a granular base structure either as a dust preventive treatment, the wearing surface for a staged construction, or as the base structure for a given design life. The use of a single bituminous surface treatment on a granular base ranged up to an ADT of 400 in Quebec and 1,000 in Ontario. A double-bituminous surface treatment was used on a granular base up to an ADT of 400 in Quebec and 500 in New Brunswick.

MacLeod and Walsh reported on the practices in Northern Canada *(15)*. They indicated that there are three classes of roads. The classes and the policy on the application of a bituminous surface to each class are:

- Class 1—Bituminous surface treatment applied directly to unimproved subgrades. These roads are short-lived structures in which the bituminous surface treatment is the most economical treatment for dust control. The volume of trucks on these roads is generally low.
- Class 2—Bituminous surface treatment applied on top of 75 to 150 mm (3 to 6 in.) of crushed gravel. These roads are light-duty pavements serving moderate traffic volumes with few trucks.
- Class 3—Stage construction in which full depths of base and subbase are initially placed with a bituminous surface treatment wearing surface. Service volumes range from 300 to 700 vehicles per day. When traffic volumes warrant and budgets permit, the bituminous surface treatment is replaced with asphalt concrete.

Australian Road Research Board

The Australian Road Research Board offers the following considerations in selecting the type of surface *(16)*. The choice of the surfacing material for a low-volume roadway is influenced by environmental conditions, accepted local practice, availability of materials, and life-cycle costing of the wearing surface, including maintenance practices and requirements. The purpose for providing a bituminous surface treatment or a thin layer of hot-mix asphalt as a wearing course is to provide a dust-free surface, reduce surface moisture from reaching the pavement or subgrade, reduce the rate of pavement wear (aggregate loss) and maintenance costs, improve the ride qualities, provide a safe, economical and durable all-weather surface, and reduce vehicle operating and maintenance costs. Light and moderately traveled roads (e.g., up to 2,000 vehicles per day), generally have a spray seal applied in rural areas and an asphalt surface in major metropolitan areas.

New Zealand

In New Zealand, virtually all highway traffic is carried on a bituminous surface treatment over unbound granular material *(17)*. Transit New Zealand has a policy of sealing all unsealed state highways by the year 2002 *(18)*.

Finland

There are 60 000 km (37,300 miles) of low-volume roads with an ADT less than 1,000 vehicles per day in Finland. With an ADT under 300, they use a surface dressing with a service life of about 5 years. Their surface dressing is a single bituminous surface treatment consisting of one layer of binder and a top layer of all-in-one aggregate, 0 to 16 mm (0 to 5/8-inch thick). Between 300 and 1,000 vehicles per day, an emulsion gravel is used. They formerly used an oil (a petroleum product not an asphalt emulsion or cutback) gravel mix, but because of environmental concerns with the evaporation of the volatile hydrocarbons they developed an emulsion gravel consisting of a well-graded aggregate with 100 percent passing the 20 mm (0.80 in.) sieve opening and no more than 6 percent passing the 0.0074 mm sieve opening (No. 200). They use a slow-setting emulsion and the residual binder content is usually 3.2 to 3.6 percent *(19)*. The emulsion gravel layer is typically 40 mm (1.5 in.) thick and it is applied on a very dense base. This material will be tested in Minnesota by MnRoads at its pavement test site *(20)*. The surface dressing is applied to a dense base. (Personal communication with Sven-Åke Blomberg at the World Bank).

Kingdom of Saudi Arabia

In Saudi Arabia, where the environment is very hot and dry, thin-surfaced pavements are used on agricultural roads, which have the lowest standards of any classification in the Kingdom. They are designed to provide access to villages and agricultural areas, with safety and economy. The pavement consists of 50 mm (2 in.) of hot-mix asphalt on top of at least 200 mm (8 in.) of granular materials meeting AASHTO classification A-2-4 or better and which has a California Bearing Ratio (CBR) value of 20 or greater. The average annual daily traffic (AADT) on these roads does not exceed 500 vehicles per day with 20 percent trucks. The ESAL applications should not exceed 150,000 over the design period. (Personal communication with Abdullah A. Al-Mogbel, Asst. Deputy Minister for Technical Affairs.)

France

In France, surface dressings are used as the wearing surface on pavements with an ADT of less than 3,000 vehicles per day. Their surface dressings are similar to the bituminous surface treatments used in this country and consist of a cutback or emulsion binder generally with a modifying agent and fine aggregate. They also use bituminous surface treatments on pavements with a total of 200,000 commercial vehicles. This is about 100 commercial vehicles per day per lane for a period of 5 years *(21)*.

COST-EFFECTIVENESS

In 1996, the Transportation Research Board published NCHRP Synthesis of Highway Practice 223: *Cost-Effective Preventive Pavement Maintenance (22)*. A key finding of that study was that the most cost-effective pavement management strategy is to perform preventive maintenance activities on the better-rated pavements first and then fund the rehabilitation or reconstruction of the poorer rated pavements. The least cost-effective strategy is to fix the worst pavement first and neglect preventive maintenance or to apply band-aid treatments to the poorer pavements.

One of the findings of the National Highway Users Survey *(8)* previously quoted was, "Don't just do temporary repairs but repair the road permanently." Road users want the highway agencies to "Do it right the first time" in keeping with the cost-effectiveness principle of Total Quality Management.

The World Bank conducted studies to determine the influence of maintenance policies on the initial pavement strength and life-cycle costs *(23,24)*. They found the following:

1. Vehicle operating costs constitute a large share (75–95 percent) of the total costs of road transportation except where the traffic is very low. Thus, a small percent change in vehicle operating costs is large compared to construction and maintenance costs.
2. Even with good maintenance, vehicle operating costs on gravel roads are between 10 and 30 percent higher than on paved roads.
3. The quality of maintenance has a major impact on costs. In one study, the break-even point for the net present value of the paving investment between an aggregate surface and a paved surface with good maintenance was 310 vehicles per day. With poor maintenance, however, the break-even point was reduced to 80 vehicles per day. Thus, a lower initial cost wearing surface can be cost-effectively used provided it is adequately maintained.
4. When a new pavement is constructed or an existing pavement is replaced, the choice of design strength should take into account the reliability of future maintenance. To compensate for inadequate maintenance, a pavement with a higher strength than would be necessary under normal conditions may be warranted.

TABLE 3

SUGGESTED TRAFFIC VOLUMES OR ESALs FOR DIFFERENT WEARING SURFACES

	Type of Surface		
Organization	Aggregate	Bituminous Surface Treatment	Thin HMA
AASHTO	ESALs < 100,000		
NYS Local Roads Research and Coordination	ADT < 150	ADT > 150	
Luhr & McCullough	ESALs < 5/day	5/day < ESALs < 20/day	ESALs > 20/day
C-SHRP (Quebec)		ADT < 400	
C-SHRP (Ontario)		ADT < 1,000	
Australia		ADT < 2,000 (rural)	ADT < 2,000 (urban)
Finland		ADT < 300	300 < ADT < 1,000 (emulsion gravel)
Saudi Arabia			ADT < 500
France		ADT < 3,000	

As these studies show, the type of roadway surface and the quality of the maintenance have a determining effect on vehicle operating costs. Lewis is currently conducting a study for NCHRP titled, "Road User and Mitigation Costs in Highway Pavement Projects" *(25)* which will address many of the issues in quantifying and forecasting user costs.

SUMMARY OF PAVEMENT WEARING SURFACE SELECTION CONSIDERATIONS

The following is a summary listing of all the factors discussed in the previous section. The reasons given for providing either a bituminous surface treatment or a thin layer of hot-mix asphalt as the wearing surface over an unbound base for a low-volume road are:

- Eliminate dust,
- Provide a smooth surface,
- Increase frictional resistance,
- Increase safety, (e.g., allow pavement markings to be applied),
- Reduce agency maintenance costs,
- Reduce vehicle operating and maintenance costs,
- Reduce the amount of moisture entering the pavement structure,
- Eliminate or reduce the loss of surface aggregate,
- Availability of local materials and work force skilled in applying materials,
- Increased cost-effectiveness, and
- Minimize life-cycle costs.

Table 3 summarizes the suggested traffic volumes or ESALs by various organizations for the three types of wearing surface: aggregate, bituminous surface treatment, and thin hot-mix asphalt. As can be seen from the table, there is wide variation among the different organizations on the amount of traffic that should be placed on each type of surface.

THIN-SURFACED PAVEMENT STRUCTURAL THICKNESS DESIGN METHODOLOGIES

There are several elements involved in designing a pavement, including drainage, the thickness of the pavement structure, the materials to be used, and the mix design for the wearing surface. All of these elements are important to obtain a cost-effective pavement. The scope of this synthesis, however, is limited to the thickness design of the pavement structure and does not include pavement drainage, the design of a bituminous surface treatment, or the mix design for a thin hot-mix asphalt wearing surface. Furthermore, the following discussion of each pavement structural thickness design method is abbreviated and generalized for the purpose of illustrating the approach of the procedure and should not be used for design purposes. The designer should refer to the published procedure and review all of the applicable conditions for its use. Finally, pavement design can never be reduced to a level where one simply picks a thickness out of a chart. The fundamental factors that affect pavement performance, namely, traffic loads, subgrade soil support value, and environment, (i.e., moisture and temperature) are subject to wide variations over the length and life of a pavement. Therefore, it is necessary to compare a pavement design with the design and performance of previously constructed pavements and make an informed engineering judgment as to the adequacy of the design.

General

A bituminous surface treatment wearing surface provides no structural strength to the pavement structure. A wearing surface consisting of a thin-layer of hot-mix asphalt less than 40 mm (1-1/2 in.) thick provides only a little structural strength. Therefore, several of the design methodologies currently used for thin-surfaced pavements are for the structural design of the base and subbase of an aggregate-surfaced roads on which a thin wearing surface is applied.

Yapp, Steward, and Whitcomb reported on a review of the design of aggregate-surfaced roads initiated by the United States Forest Service (USFS) in 1988 *(26)*. Several existing

TABLE 4

EVALUATION OF AGGREGATE-SURFACED ROADWAY DESIGN METHODS (after *26*)

Evaluation Factors Considered	1 COE	2 COE Low Vol.	3 USFS Reg 4	4 USFS Reg 8	5 USFS SDMS	6 USFS Chap. 50	7 & 8 USFS Reg 1 Willamette	9 FHWA Report
Validity for aggregate roads	+	–	+	0	0	–	–	–
Validity for earth-roads	–	+	+	–	–	–	–	–
Inputs make sense	+	+	+	0	0	+	+	+
Standard traffic units	–	–	–	+	+	+	+	+
Varying tire pressure	+	+	+	+	–	–	–	–
Material characterization	+	+	+	+	+	0	0	+
Risk/reliability	–	–	–	–	–	–	–	–
Change failure criteria	–	–	+	+	+	–	–	–
Seasonal haul	–	–	–	–	–	–	+	–
Validated by field experience	–	–	–	+	0	+	+	–
Score	–2	–2	+2	+2	–1	–3	–1	–4

Aggregate-Surfaced Roadway Design Method (columns 1–9)

pavement structural design relationships were identified but all design methods currently available were found to have some serious limitations. In fact, the authors reported that there was considerable disappointment with the current state of existing technology. Nine design methods were reviewed, which included all known design methods then in use within the Forest Service. All of the design methods for aggregate-surfaced roads found in the literature were generally related to each other and typically could be traced back to two basic studies. First, the California bearing ratio (CBR) design method developed by California Division of Highways, and adapted by the Corps of Engineers during World War II for airfields and, secondly, the AASHO Road Test. The authors traced the evolution of each of the nine design methods, reviewed each one, and compared all the methods based on a list of attributes. The nine design methods reviewed were:

1. Army Corps of Engineers Method. This is an aggregate thickness design procedure based on the Corps' work published in *Design of Aggregate-surfaced Roads and Airfields*, TM 5-822-30.
2. Army Corps of Engineers Method. Corps' procedure adapted for low-volume aggregate-surfaced and earth roads published in *Thickness Requirements for Unsurfaced Roads and Airfields*. Technical Report S-70-5.
3. USFS Region 4 implementation of the Corps' rutting equation. For this procedure, rutting was selected as the failure criteria for aggregate roads.
4. USFS Region 8 Analysis Road Management System (ARMS). This design procedure uses existing geologic data as an index to soil properties for input to surface design equations.
5. USFS Surfacing Design and Management System (SDMS). This procedure adopted the 1986 AASHTO *Guide for the Design of Pavement Structures* for bituminous surface treated roads and developed a surfacing guide for aggregate and unsurfaced roads. A computerized version of this procedure was also developed.
6. USFS Chapter 50 Design Method. The Interim Guide for the Thickness Design of Flexible Pavement Structures revised in May 1982.
7. USFS Region 1 seasonal surfacing method. Region 1's modification of Chapter 50. The procedure is for the design of aggregate-surfaced roads considering seasonal haul requirements.
8. Willamette National Forest "Seasurf" design method. A modification of Chapter 50 that incorporates seasonal changes in subgrade soil strength and traffic. Very similar to the Region 1 Method in 7 above. These two methods are combined in the same column in Table 4, which summarizes the evaluation.
9. FHWA Report. An FHWA sponsored report on the design and operation of aggregate-surfaced roads. The report provides three levels of design complexity. The simplest level uses a rut depth model similar to the Corps of Engineers Method described in 2 above, the intermediate level is taken from the 1972 AASHTO *Interim Guide for the Design of Pavement Structures* and the most complex level uses equations from the USFS manual SDMS procedure, described in 5 above.

The evaluation attributes were selected to address the following questions:

- Is the design procedure valid for aggregate-surfaced and earth roads?
- Are the inputs expected to have a major role in pavement deterioration?
- Are standard traffic units, 80-kN (18-kip) ESALs used?
- Can the tire pressure be varied?
- Is the material characterization reasonable?
- Are risk and reliability concepts considered?
- Can the future criteria be changed?
- Is seasonal haul incorporated into the design?
- Has there been any field experience to validate the procedure?

If a design method contained a particular attribute, it received a plus and if it did not, it received a minus. For those cases where it could not be determined, a zero was given. Table 4, adapted from Table 5 in the work by Yapp, Steward, and Whitcomb *(26),* summarizes the author's evaluation of the design methods. Two methods had the highest score of +2, the USFS Region 4 method where rutting is used as the failure criteria and the USFS Region 8 method. The evaluators recommended the Region 4 procedure over the Region 8 procedure because, even though both had the same score, the Region 4 method had more pluses than the Region 8 method.

The following is a discussion of several methods currently used for the structural design of thin-surfaced pavements.

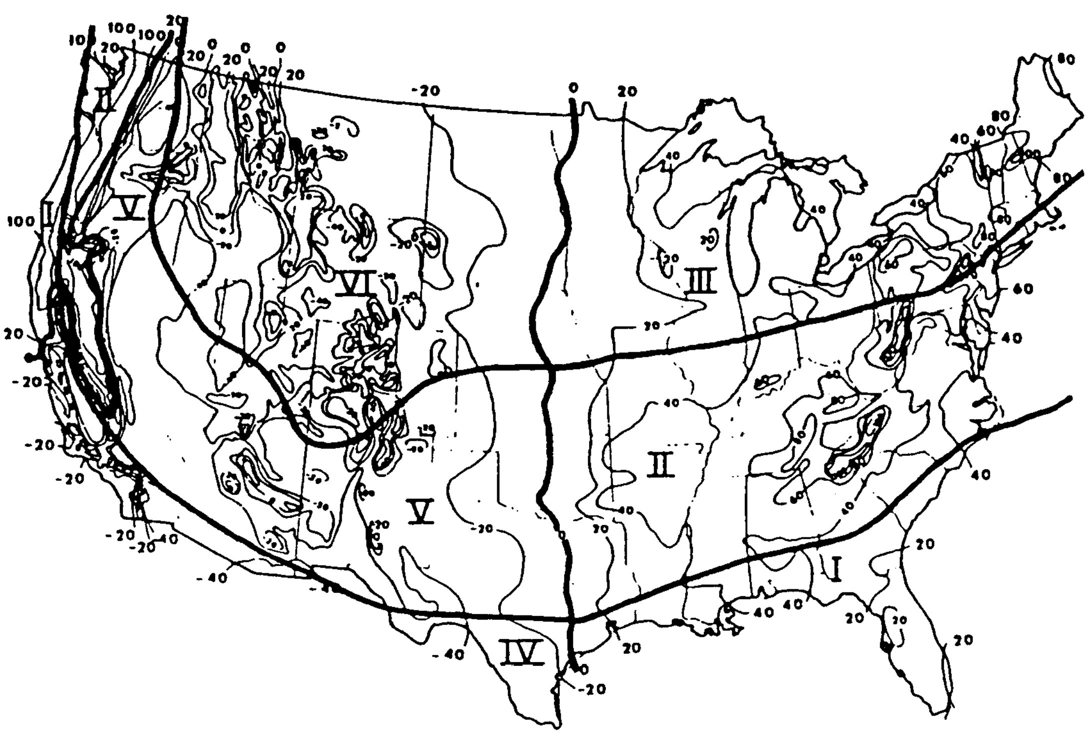
American Association of State Highway and Transportation Officials

Chapter 4 of the AASHTO Guide for Design of Pavement Structures, is not a structural design procedure for thin-surfaced pavements *(10)*. Rather, it provides pavement design procedures for low-volume roads. Only the design procedures for flexible pavements and aggregate-surfaced roads in the guide are presented because they are more closely applicable to thin-surfaced pavements. The input variables for both flexible and aggregate-surfaced pavements are the soil support value, traffic, and environmental considerations.

The subgrade soil support is expressed in terms of the resilient modulus. The resilient modulus is a measure of the modulus of elasticity of the roadbed soil or pavement materials. If it is not practical or possible to test the roadbed soil to determine the resilient modulus, it can be estimated from the soil properties (i.e., moisture content, clay content, and the plasticity index). The CBR of the subgrade can also be estimated using the Unified Soil Classification system and charts that have been developed that correlate the various methods of expressing the soil support value *(27)*. Hall and Thompson *(28)* discuss and summarize many of the techniques for estimating resilient modulus including the use of soil index properties obtained from USDA Soil Conservation Service county soil maps.

Traffic is expressed in 80-kN (18-kip) ESALs for the design life of the pavement.

The environmental conditions (moisture and freeze-thaw) are accommodated by dividing the country into the six climatic regions shown in Figure 3. For each climatic region, the guide provides an estimate of the number of months in each of the four seasons, winter, spring-thaw, spring/fall and summer, reduces the resilient modulus to account for the weakened



REGION	CHARACTERISTICS
I	Wet, no freeze
II	Wet, freeze – thaw cycling
III	Wet, hard-freeze, spring thaw
IV	Dry, no freeze
V	Dry, freeze – thaw cycling
VI	Dry, hard freeze, spring thaw

FIGURE 3 The six climatic regions in the United States *(10)*.

subgrade during the spring thaw and periods of high rainfall and provides an estimate of the resilient modulus for five relative quality levels of the roadbed soils (very good, good, fair, poor, and very poor) for each season. The result is suggested values of the effective roadbed soil resilient modulus for each climatic region and the relative quality of the roadbed soil.

Flexible Pavement

The guide provides two flexible pavement design catalogs for low-volume roads. One catalog is for a reliability of 50 percent and the other is for 75 percent. The catalog that provides 50 percent reliability is appropriate for local low-volume noncritical roads. For higher volume roadways or those that are more critical, the catalog that provides 75 percent reliability should be used.

The traffic is based on the following specific ranges of ESALs for flexible pavements:

- High 700,000 to 1,000,000
- Medium 400,000 to 600,000
- Low 50,000 to 300,000.

Each catalog provides a range of structural numbers. The structural number, SN is:

$$SN = a_1D_1 + a_2D_2 + a_3D_3$$

where

a_1, a_2, a_3 = layer coefficients in the surface, base, and subbase materials, respectively,

and

D_1, D_2, D_3, = thickness (in inches) of the surface, base, and subbase courses, respectively.

The ranges of values for a_1, a_2, a_3 provided in the guide are:

Asphalt concrete surface course, $a_1 = 0.20$ to 0.44,
Granular base material, $a_2 = 0.06$ to 0.14, and
Granular subbase material, $a_3 = 0.06$ to 0.14.

After determining the relative quality of the subgrade soil and estimating the traffic, the designer determines the required SN for the climatic region from one of the two catalogs depending on the degree of reliability desired. After determining SN, alternative pavement sections are tried until the most cost-effective combination of materials is identified that satisfy the SN.

The following example illustrates the use of the Flexible Pavement Catalog for a pavement in the Northeast.

Traffic = 250,000 ESALs, Low range
Environment = Climatic Region III (from Figure 3)
Subgrade soils = Poor
Reliability = 50 percent
From Table 4.6 in Figure 4, the required SN range = 2.3 to 3.0

The pavement materials available and the layer coefficients are:

Table 4.6. Flexible Pavement Design Catalog for Low-Volume Roads: Recommended Ranges of Structural Number (SN) for the Six U.S. Climatic Regions, Three Levels of Axle Load Traffic and Five Levels of Roadbed Soil Quality—Inherent Reliability: 50 percent

Relative Quality of Roadbed Soil	Traffic Level	U.S. Climatic Region					
		I	II	III	IV	V	VI
Very good	High	2.3–2.5*	2.5–2.7	2.8–3.0	2.1–2.3	2.4–2.6	2.8–3.0
	Medium	2.1–2.3	2.3–2.5	2.5–2.7	1.9–2.1	2.2–2.4	2.5–2.7
	Low	1.5–2.0	1.7–2.2	1.9–2.4	1.4–1.8	1.6–2.1	1.9–2.4
Good	High	2.6–2.8	2.8–3.0	3.0–3.2	2.5–2.7	2.7–2.9	3.0–3.2
	Medium	2.4–2.6	2.6–2.8	2.8–3.0	2.2–2.4	2.5–2.7	2.7–2.9
	Low	1.7–2.3	1.9–2.4	2.0–2.7	1.6–2.1	1.8–2.4	2.0–2.6
Fair	High	2.9–3.1	3.0–3.2	3.1–3.3	2.8–3.0	2.9–3.1	3.1–3.3
	Medium	2.6–2.8	2.8–3.0	2.9–3.1	2.5–2.7	2.6–2.8	2.8–3.0
	Low	2.0–2.6	2.0–2.6	2.1–2.8	1.9–2.4	1.9–2.5	2.1–2.7
Poor	High	3.2–3.4	3.3–3.5	3.4–3.6	3.1–3.3	3.2–3.4	3.4–3.6
	Medium	3.0–3.2	3.0–3.2	3.1–3.4	2.8–3.0	2.9–3.2	3.1–3.3
	Low	2.2–2.8	2.2–2.9	2.3–3.0	2.1–2.7	2.2–2.8	2.3–3.0
Very poor	High	3.5–3.7	3.5–3.7	3.5–3.7	3.3–3.5	3.4–3.6	3.5–3.7
	Medium	3.2–3.4	3.3–3.5	3.3–3.5	3.1–3.3	3.1–3.3	3.2–3.4
	Low	2.4–3.1	2.4–3.1	2.4–3.1	2.3–3.0	2.3–3.0	2.4–3.1

*Recommended range of structural number (SN).

FIGURE 4 Flexible pavement design catalog for low-volume roads *(10)*.

Asphalt concrete surface course, $a_1 = 0.44$
Granular base material, $a_2 = 0.14$
Granular subbase material, $a_3 = 0.11$.

First trial pavement section is:

Layer	*Coefficient*	*Thickness (in.)*	*Product*
Surface	0.44	1.5	0.66
Base	0.14	6.0	0.84
Subbase	0.11	12.0	1.32
SN			2.82

The pavement section above results in a SN in the required range. However, a pavement with a 4-in. base course would have a SN of 2.54, which is also applicable. Likewise, using 10 in. of subbase material would result in a SN of 2.60, which is in the range. Several sections that fulfill the required SN should be selected and a cost analysis should be done to determine the most cost-effective section.

The example illustrates two features of the AASHTO flexible pavement design procedure. First, the methodology provides a range of structural numbers and the designer must exercise engineering judgment in selecting a structural number that will provide an acceptable pavement. Second, there are different combinations of surface, base, and subbase materials that will provide an acceptable structural number and the designer should perform an economic life-cycle cost comparison of alternative pavement sections before selecting the pavement section to construct.

Aggregate-Surfaced Pavement

The AASHTO Pavement Design Guide also provides an Aggregate-Surfaced Road Design Catalog. The traffic is expressed in the number of 80-kN (18-kip) ESALs. The traffic is based on the following specific ranges of ESALs for aggregate-surfaced roads:

- High 60,000 to 100,000
- Medium 30,000 to 60,000
- Low 10,000 to 30,000.

The subgrade soil support is expressed in relative terms: very good, good, fair, poor, and very poor. The environmental conditions are categorized by the six climatic regions shown in Figure 3. Figure 5 shows Table 4.10 from the guide, which is the aggregate-surfaced road design catalog. The thickness of the aggregate base, in inches, is taken directly from Table 4.10.

Corps of Engineers Method

The Corps of Engineers flexible pavement design procedure is appropriate for thin asphalt concrete pavements on granular base courses and subbases. The procedure considers traffic, subgrade soil support, freeze-thaw, and the strength of the pavement materials. The anticipated traffic and design loadings are characterized in a Design Index. The Design Index lists ranges of 80-kN (18-kip) axle coverage's for each Design Index number, (e.g., in DI = 5, the number of coverage's

Table 4.10. Aggregate Surfaced Road Design Catalog: Recommended Aggregate Base Thickness (in Inches) for the Six U.S. Climatic Regions, Five Relative Qualities of Roadbed Soil and Three Levels of Traffic

Relative Quality of Roadbed Soil	Traffic Level	U.S. Climatic Region					
		I	II	III	IV	V	VI
Very good	High	8*	10	15	7	9	15
	Medium	6	8	11	5	7	11
	Low	4	4	6	4	4	6
Good	High	11	12	17	10	11	17
	Medium	8	9	12	7	9	12
	Low	4	5	7	4	5	7
Fair	High	13	14	17	12	13	17
	Medium	11	11	12	10	10	12
	Low	6	6	7	5	5	7
Poor	High	**	**	**	**	**	**
	Medium	**	**	**	15	15	**
	Low	9	10	9	8	8	9
Very poor	High	**	**	**	**	**	**
	Medium	**	**	**	**	**	**
	Low	11	11	10	8	8	9

*Thickness of aggregate base required (in inches).
**Higher type pavement design recommended.

FIGURE 5 Aggregate surface road design catalog *(10)*.

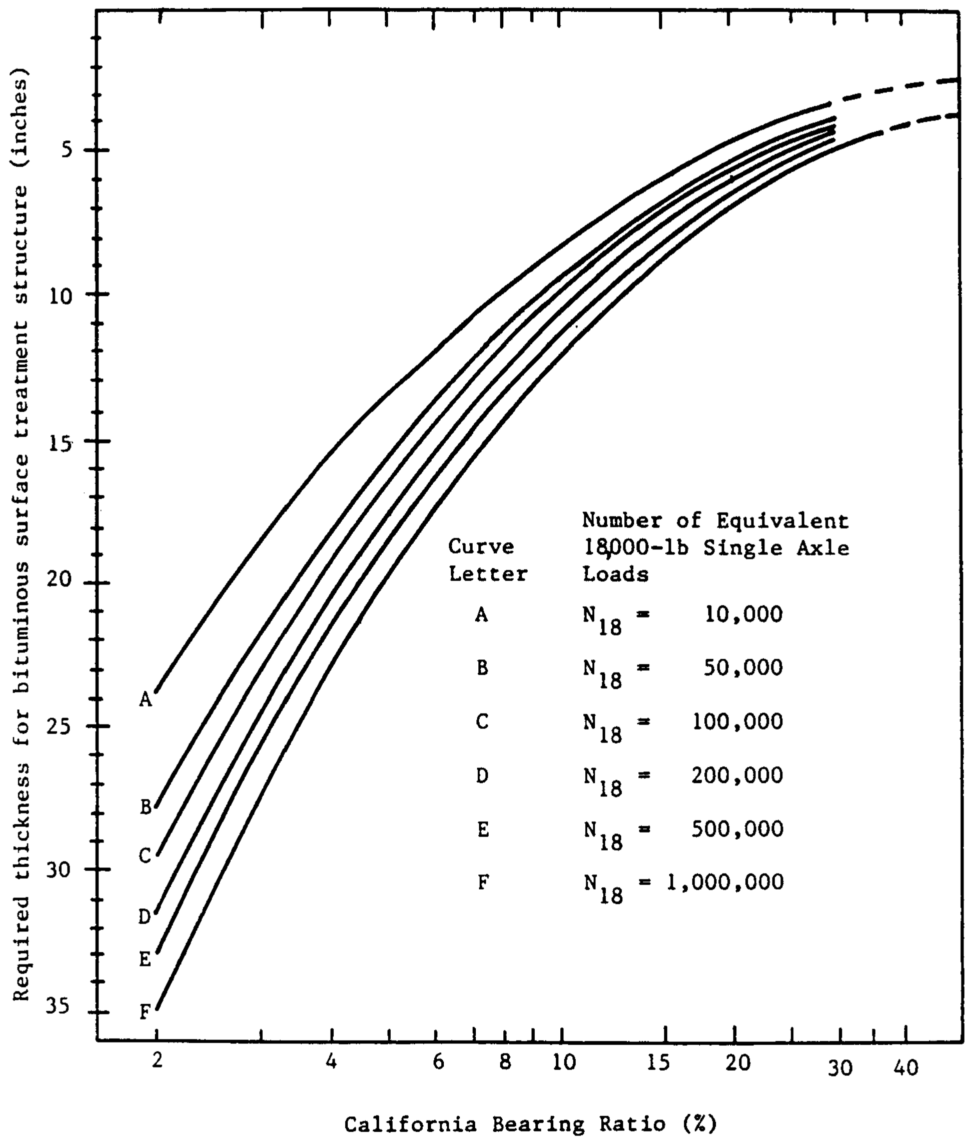


FIGURE 6 Corps of Engineers method thickness design curves for surface-treated roads and aggregate-surfaced roads *(30)*.

ranges from a minimum of 207,000 to a maximum of 980,000). A coverage is defined as a sufficient number of movements or passes of the design vehicle to cover the entire traffic lane with at least one stress repetition. The procedure is based on the CBR and uses a thickness adjustment factor called the load-repetition factor. The design of flexible pavements requires that the designer refer to three manuals for flexible pavement design *(29)*. The Corps of Engineers procedure has been adapted by the National Stone Association and the procedure in their guide is discussed in the next section.

Hudson, McCullough, and Carmichael described the use of the Army Corps of Engineers method for bituminous surface treated and granular roads *(30)*. The following is taken in large part from their report. The Corps procedure is based on equations that give the required thickness for material that is to be placed over underlying material of a given strength, provided that the placed material has a greater strength than the underlying material. The strength of the material is measured by its CBR. The traffic over the design life of the pavement is expressed in terms of 80-kN (18-kip) ESALs as N_{18}. The required thicknesses for various CBR values and ESAL repetitions (N_{18}) are shown in the chart in Figure 6. The thickness scale on the left side of the figure is for bituminous surface treatments wearing surface. The steps for progressing through the design are:

1. The roadbed (subgrade) CBR value and the number of ESALs are entered in Figure 6.
2. If two layers of granular material are used, the CBR of the subbase material is entered in Figure 6 and the thickness of the better material required above it is read off the vertical scale.
3. The thickness of the asphalt concrete is then selected. For bituminous surface treatments the layer thickness is not considered because no structural value is obtained.

Example of the Corps of Engineers Method

Given
Number of ESALs, N_{18} = 500,000
CBR of the Subgrade = 5
CBR of the Subbase = 20

Determine the pavement structural layer thickness for two wearing surfaces:
A. Bituminous surface treatment (BST)
B. 1.5 in. (40 mm) hot-mix asphalt concrete (HMA)

Procedure

Step 1: Enter Figure 6 with CBR of 5 and vertically to Curve E, total thickness of section = 19.0 in. (480 mm)
Step 2: Enter Figure 6 with a CBR of 20 and vertically to Curve E, total thickness above the subbase = 7.0 in. (180 mm).
Step 3: For BST = 0, for HMA = 1.5 in. (40 mm).
Step 4: Thickness of subbase = 19.0 - 7.0 = 12.0 in. (300 mm).
Step 5: For A, base = 7.0 in. (180 mm), for B, base = 7.0 - 1.5 = 5.5 in. (140 mm).

	Section A	Section B
Wearing Surface	Bituminous Surf. Treat.	1.5 in. (40 mm) HMA
Base	7.0 in. (180 mm)	5.5 in. (140 mm)
Subbase	12.0 in. (300 mm)	12.0 in. (300 mm)
Total Thickness	19.0 in. (480 mm)	19.0 in. (480 mm)

FIGURE 7 Example of the Corps of Engineers method.

4. The thickness from step 2 is subtracted from the thickness in step 1 to determine the subbase layer thickness.
5. The thickness of asphalt concrete is subtracted from the thickness obtained in step 2 to obtain the thickness of the base course. For bituminous surface treatments, the base thickness is the thickness determined in step 2.

The example in Figure 7 demonstrates the use of the curves in Figure 6 and the above steps in the Corps of Engineers method.

Table 3.6 in Figure 8 may be used to determine the quality of the granular surfacing material for an aggregate wearing surface. The entries within the table give required CBR strength for the various combinations of ESALs, granular surface thickness, and subgrade CBR. The following example illustrates the use of the table. The traffic, N_{18} = 100,000, the subgrade CBR = 6, and the granular surface will be 12 in. thick. What is the required CBR value of the granular surface? From Table 3.6 in Figure 8, the required CBR value is 63.

National Stone Association Flexible Pavement Design Guide

The National Stone Association (NSA) flexible pavement design procedure is based on the Corps of Engineers Method *(31)*. The soil support is evaluated using the CBR test. If it is not practical or possible to measure the strength of the subgrade soil, the CBR value can be estimated using a chart that correlates the CBR value with different classification systems. NSA recommends the establishment of four categories of subgrade support: excellent, good, fair, and poor, as shown in Table A in Figure 9. The effect of traffic on the pavement is based on an estimate of the magnitude and frequency of traffic loads. The magnitude of the loads is estimated based on three groups:

Group 1—passenger cars, panel and pickup trucks.
Group 2—two-axle trucks loaded, or larger vehicles apparently carrying light cargo.
Group 3—trucks or combination vehicles having three, four, or more loaded axles.

The procedure combines the number of ESALs in the design lane over the design life of the pavement and the mix of traffic to develop a Design Index as the measure of the traffic load as shown in Table B in Figure 10. The basic design thickness for a temperate climate is then determined from Table C in Figure 11. Finally, the thickness is checked for adequacy in frost areas and the design thickness may be increased in those areas where the frost is expected to penetrate into the subgrade. Based on the frost susceptibility of the subgrade soil and the Design Index, a thickness for frost areas is determined from Table E in Figure 12.

Flexible Pavement Structural Section Design Guide for California Cities and Counties

The County Engineers Association of California, the League of California Cities, and the California Department of Transportation, jointly prepared a Flexible Pavement Structural Section Design Guide for California Cities and Counties *(32)*. The current edition was published in January 1979 but a

Table 3.6. Required CBR strength of granular materials.

Number of 18-kip ESALs (N_{18}) (1000's)	Subgrade CBR (%)	Required Granular Layer CBR (%) — Thickness of Granular Surface (in) 6	9	12	15	18	21	24	27	30
10	2	96	62	48	40	34	31	28	26	24
	4	78	50	38	32	28	25	23	21	20
	6	69	44	34	28	25	22	20	19	17
	8	63	41	31	26	23	20	18	17	16
	10	59	38	29	24	21	19	17	16	15
	15	52	33	26	21	19	17	15	14	13
	20	48	31	24	20	17	15	14	13	12
50	2	147	95	73	61	53	47	43	40	37
	4	119	77	59	49	43	38	35	32	30
	6	105	68	52	43	38	34	31	28	27
	8	96	62	48	40	35	31	28	26	24
	10	90	58	45	37	32	29	26	24	23
	15	79	51	39	33	28	25	23	21	20
	20	73	47	36	30	26	23	21	20	18
100	2	178	114	87	73	63	57	52	48	45
	4	143	92	71	59	51	46	42	39	36
	6	126	82	63	52	45	41	37	34	32
	8	116	75	57	48	41	37	34	31	29
	10	108	70	54	46	39	35	32	29	27
	15	95	62	47	39	34	31	28	26	24
	20	87	56	43	36	31	28	26	24	22
500	2	270	175	134	111	97	87	79	73	68
	4	219	141	108	90	78	70	64	59	55
	6	194	125	96	80	69	62	57	52	49
	8	177	115	88	73	64	57	52	48	45
	10	166	107	82	68	59	53	48	45	42
	15	146	94	72	60	52	47	43	40	37
	20	134	86	66	55	48	43	39	36	34
1000	2	325	210	161	134	116	104	95	88	82
	4	263	170	130	108	94	84	77	71	67
	6	233	150	115	96	83	75	68	63	59
	8	213	138	106	88	76	68	62	58	54
	10	199	129	99	82	71	64	58	54	50
	15	176	114	87	72	63	56	51	48	44
	20	161	104	80	66	58	52	47	44	41

FIGURE 8 Required CBR strengths for granular materials *(30)*.

revised version is expected to be completed by the end of 1997. (Personal communication with Robert N. Doty, Caltrans). Even though this guide is not specifically for the structural design of thin-surfaced pavements, its purpose is to provide concise guidance to the designer of city streets and county roads, many of which are suitable for thin-surfaced pavements. The structural design of the pavement is based on the California Department of Transportation method which considers the effects of traffic, the resistance (R-value) of the supporting layer, and the strength of the pavement structure. Guidance is provided to the designer on estimating traffic, determining or estimating the R-value, and the strength of the structural layers.

Asphalt Institute Thickness Design Method

The Asphalt Institute pavement design methodology provides for a full-depth asphalt pavement. A full-depth asphalt pavement is one in which asphalt mixtures are employed for all courses above the subgrade or improved subgrade *(33,34)*. Because a thin-surfaced pavement is defined as a bituminous surface treatment or a layer of hot-mix asphalt less than 2 in. (50 mm) thick over an unbound base, the Asphalt Institute Method is not applicable for the structural thickness design of a thin-surface asphalt pavement.

Table A Soil Support Categories	
General Soil Description	Strength-CBR
Excellent Containing a uniformly high percentage of granular materials • Unified Soil Classes: GW, GM, GC, GP: Some SM, SP, and SC • AASHO Soil Groups: A-1, A-2, some A-3's	15 plus
Good Containing some granular materials intermixed with silt and/or light clay • Unified Soil Classes: SM, SP, SC; some ML, CL, CH • AASHO Soil Groups: A-2, A-3; some A-4's, a few A-6's or A-7's	10–14
Fair Sand clays, sandy silts or light silty clays if low in mica content; may have some plasticity • Unified Soil Classes: ML, CL; some MH, CH • AASHO Soil Groups: Ranging from A-4 to A-7 (low group indices)	6–9
Poor Plastic clays, fine silts, very fine or micaceous silty clays • Unified Soil Classes: MH, CH, OL, OH; (PT unsuitable) • AASHO Soil Groups: Ranging from A-4 to A-7 (higher group indices)	5 or less

FIGURE 9 Soil support categories for the NSA method *(31)*.

Table B

Design Index Categories for Traffic

Design Index	General Character	Daily EAL[1]
DI-1	Light traffic (few vehicles heavier than passenger cars, no regular use by Group 2 or 3 vehicles)	5 or less
DI-2	Medium-light traffic (similar to D1-1, maximum 1000 VPD[2], including not over 10% Group 2, no regular use by Group 3 vehicles)	6–20
DI-3	Medium traffic (maximum 3000 VPD, including not over 10% Group 2 and 3, 1% Group 3 vehicles)	21–75
DI-4	Medium-heavy traffic (maximum 6000 VPD, including not over 15% Group 2 and 3, 1% Group 3 vehicles)	76–250
DI-5	Heavy traffic (maximum 6000 VPD, may include 25% Group 2 and 3, 10% Group 3 vehicles)	251–900
DI-6	Very heavy traffic (over 6000 VPD, may include over 25% Group 2 or 3 vehicles)	901–3000

Notes: [1]EAL = equivalent 18 kip axle loads in design lane, average daily use over life expectancy of 20 years with normal maintenance.
[2]VPD = vehicles per day, all types, using design lane.

FIGURE 10 Traffic design categories for the NSA method *(31)*.

Luhr, McCullough, and Pelzner

Luhr, McCullough, and Pelzner presented a simplified flexible pavement design procedure at the Third International Conference on Low-Volume Roads *(35)*. The procedure is based on controlling subgrade strain. The procedure uses Miner's rule of linear cumulative damage. The heavier loads, [e.g., 213.5-kN (48-kips)] produce more subgrade strain than a lighter load [e.g., 80-kN (18-kips)], and therefore fewer applications of the heavier load are necessary before failure occurs. Likewise, the seasonal variations in the subgrade modulus are accommodated. During the spring thaw, the

Table C*							
Basic Design Thickness Table (Temperate Climate)							
Subgrade Soil		Design Thickness (inches) For Indicated Traffic Intensity Categories					
Class	CBR	DI-1	DI-2	DI-3	DI-4	DI-5	DI-6
Excellent	15	5.0	6.0	7.0	8.0	9.0	10.0
Good	10–14	7.0	8.0	9.0	10.0	11.0	12.0
Fair	7–9	9.0	11.0	12.0	14.0	15.0	17.0
Poor*	3–6	13.5	16.5	18.5	20.5	23.0	26/0
Any class, minimum asphalt surfacing thickness (in.)		1.0**	2.0	2.5	3.	3.5	4.0

*Poor soils should be upgraded or capped with subbase material to improve support to fair or better class.
**Use surface treatments, or increase to 1.5 inches including a prime coat on the compacted stone base if not mixed asphalt is preferred as the surface.

FIGURE 11 Basic design thickness for the NASA method *(31)*.

Table E*						
Design Thickness, Frost Group Basis						
Subgrade Soils	Design Thicknesses (inches) For Indicated Traffic Intensity Categories					
Frost Group	DI-1	DI-2	DI-3	DI-4	D-5	DI-6
F-1	9	10	12	13	15	17
F-2	10	12	14	16	18	20
F-3	15	18	22	25	28	30
F-4	Subgrade Improvement Recommended					

Note 1: Design thicknesses may be conservative except where both adverse moisture conditions and deep freezes are common. F-4 soils should be upgraded to F-3 or better (as noted in Step 3) prior to construction. This operation should be extended to the full depth of frost penetration.
2: Increase minimum surfacing thickness by 1/3 over those shown in Table C.

*Table Devised from Figure 19, U.S. Army TM 5818-2

FIGURE 12 Design thickness for frost in the NSA method *(31)*.

modulus is lower, and the subgrade strain is higher for a given load, and hence fewer load applications can be applied before failure occurs. Failure criteria are rutting and present serviceability index (PSI). Aggregate-surface roads use PSI and rutting and account for aggregate loss, bituminous surface treated roads use PSI only. The discussion included two examples, one for aggregate-surfaced roads and one for bituminous surface treated roads.

Asphalt Recycling and Reclaiming Association and Asphalt Emulsion Manufacturers Association

These associations provide information on the various reclamation methods and the use of asphalt emulsions in reclamation or bituminous surface treatment projects. Neither one, however, provides guidelines on the structural thickness design of thin-surfaced pavements.

Foundation for Pavement Rehabilitation and Maintenance Research

The Foundation does not have guidelines on the structural thickness design of thin-surfaced pavements nor has it done research on the life-cycle costs of maintenance bituminous surface treatments. (Personal communication with W.R. Ballou).

Australia

The Australians have developed three manuals that are applicable to the structural thickness design of thin-surfaced pavements. The address and fax number to obtain these manuals are shown in Appendix D.

The first of these is a pavement design guide for the design of flexible, rigid, and overlay pavements *(36)*. The procedures in this guide are intended for the design of pavements whose primary distress mode is load associated. Where other modes of distress, such as environmental distress, have a significant effect on pavement performance, their effects have to be separately assessed. Freeze-thaw conditions are not discussed in the guide because they do not occur in Australia. Subgrade soil support is evaluated using the CBR. If the CBR cannot be measured in the field, the guide provides the table shown in Figure 13 to assist in selecting the design CBR based on the Unified Soil Classification System description. Traffic is measured using 80-kN (18-kips) single axle loadings. Pavement

Description of Subgrade	Typical CRB Values %		
Material	USC Classification	Well Drained	Poorly Drained
Highly Plastic Clay	CH	5	2–3
Silt	ML		
Silty Clay	CL	6–7	4–5
Sandy Clay	SC		
Sand	SW, SP	15–20	–

FIGURE 13 Typical design CRB values *(36)*.

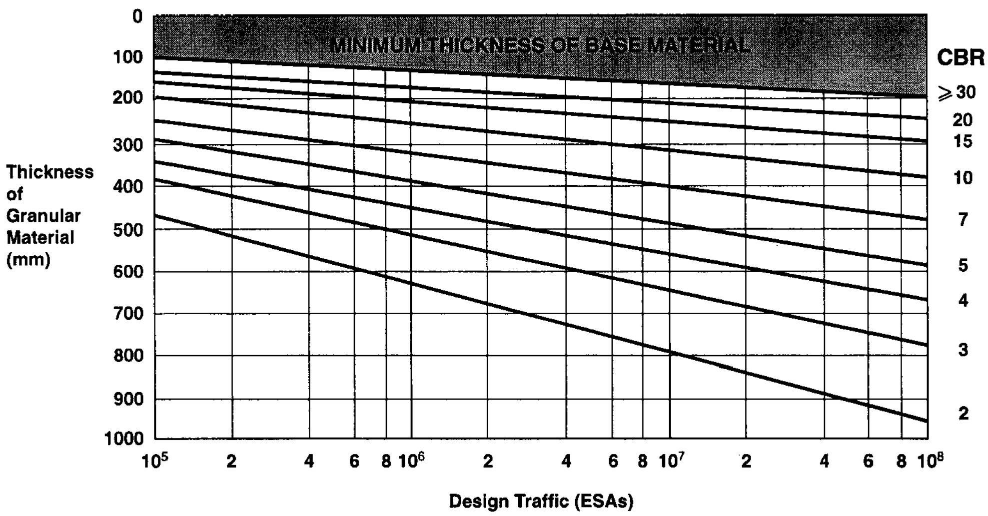


FIGURE 14 Design chart for granular pavements with thin bituminous surface *(36)*.

thickness is determined based on mechanistic procedures. The guide contains a subsection specifically for the thickness design of unbound layers of granular materials that are surfaced with either a bituminous surface treatment or with hot-mix asphalt less than 25 mm (1 in.) thick. The chart shown in Figure 14 is used for the thickness design of granular pavements with a thin bituminous treatment surfacing.

The second manual *(16)* provides the local road practitioner with a practical and understandable guide for the better management of sealed local roads. The "intended reader" of the manual is a junior engineer, works supervisor, or field staff responsible for the construction, maintenance, and rehabilitation of sealed roads. The manual addresses: design and construction of new pavements, maintenance operations, and pavement rehabilitation.

The manual discusses the purpose of the surface or wearing course, the factors influencing selection of the hot-mix asphalt wearing course or bituminous surface treatment, and the advantages and limitations of a bituminous surface treatment.

The third manual *(37)* provides guidance on the care and maintenance of unsealed roads. That manual is referenced because it contains a section on the thickness design of aggregate-surfaced pavements which maybe of interest to some users of thin-surfaced pavements and because it complements the other two references on the structural thickness design of thin-surfaced pavements.

New Zealand

Transit New Zealand recently adopted the state-of-the-art, AUSTROADS pavement Design Guide for designing pavements in New Zealand. (Personal communication from T. Chelliah, Senior Roading Engineer.)

At the Sixth International Conference on Low-Volume Roads, Pidwerbesky described the design of a thin-surfaced forestry arterial road constructed in 1988 *(17)*. The road carried 140 vehicles per day with a maximum gross weight ranging from 40 642 kg (44.8 short tons) to 121 926 kg (134.4 short tons), and a maximum axle load of 15 240 kg (16.8 short tons). The subgrade material was pumice. Temperature ranged from -8°C (17.6°F) to +35°C (95°F) and the annual rainfall is 1500 mm (59 in.). The area experiences 30 days of frost per year.

During construction, the elastic rebound of the subgrade under the loaded lane was evaluated with the Benkleman beam and the dynamic cone penetrometer tests. Where the rebounds exceeded 1.6 mm (1/16 in.), the upper 200 mm (8 in.) of the subgrade was stabilized with lime or cement. Based on the performance of similar roads in the same forest, a granular pavement thickness of 310 mm (12-3/16 in.) was specified. The base course was 200 mm (8 in.) thick using a well-graded aggregate with a maximum particle size of 40 mm (1.6 in.). A single bituminous surface treatment was applied as the wearing surface and a year later, a second bituminous surface treatment was applied.

Beginning in 1989, the condition of the road was monitored. The first annual inspection showed that most of the road was in acceptable condition, except for severe flushing, with surface rebounds in the range of 0.5 to 1.0 mm (0.02 to 0.4 in.) except for one 5 km (3 mile) section where the deflections ranged from 2 to 4 mm (0.08 to 0.16 in.). Flushing is experienced when the asphalt in the mix bleeds to the surface because of hot weather or under the action of heavy loads. Exploratory excavations showed that there was excessive moisture in the section experiencing the 2 to 4 mm deflections and it was caused by inadequate drainage. When the drainage was improved, the surface deflections were reduced to less than 1.5 mm (0.06 in.). Based on the monitoring, the main focus of the subsequent pavement design research has been the development of a new seal coat design procedure appropriate for the loading and environmental conditions. The research concluded that unbound granular pavements with adequate drainage, quality aggregate, and proper construction quality control can carry heavy axle loads of up to 16 257 kg (17.9 short tons) per axle.

South Africa

The Republic of South Africa developed and implemented mechanistic design procedures for both flexible and rigid pavements. The procedure for flexible pavements was implemented in 1978, and subsequent updates were made in 1981 and 1994. South African designers emphasize good foundation support (subgrade) under their pavements. Secondary road pavements typically include approximately 150 mm of subbase under untreated bases *(38)*. Thin-surfaced pavements in the Republic of South Africa, consisting of a bituminous surface treatment or a layer of hot-mix asphalt 20 to 50 mm thick on top of a 150- to 300-mm stone or gravel base, are found on more than 100 000 km and carry up to 12 million 80-kN ESALs (Personal communication with Basie J.P. Nothnagel). Their pavement design guidelines are published in Technical Recommendations for Highways, TRH 4, *Structural Design of Interurban and Rural Road Pavements (39)* and TRH 14, *Guidelines for Road Construction Materials (40)*. The address to obtain these guides is shown in Appendix D. Some agencies use their own designs but generally agencies select a pavement design from a catalog contained in TRH 4 (Personal communication with Basie J.P. Nothnagel).

Two reports at the Sixth International Conference on Low-Volume Roads *(41,42)* describe the development of guidelines and the pavement design catalog for roads that carry up to 400 vehicles per day in South Africa. The guidelines apply to roads where the upgrading is primarily to apply a bituminous surface treatment to keep water out of the pavement structure, to protect the underlying layers from the disruptive effects of traffic, and to provide an all-weather, dust-free riding surface.

The procedure described is as follows:

1. Calculate design traffic and select traffic class. A 20-year design life is used where the alignment is fixed and 10 to 15 years where uncertainty exists. Traffic loading is expressed as cumulative equivalent 80-kN (18-kips) axle loads. Since heavy vehicles, trucks and buses, weigh so much more than cars, for all practical purposes it is sufficient to consider the loading from the heavy vehicles alone and ignore cars.
2. Perform dynamic cone penetration (DCP) testing along the road at the rate of 5 tests per kilometer (0.62 miles). If the road is uniform the spacing can be increased, if it is variable, the spacing should be decreased.
3. Divide the road into uniform sections for upgrading. The preferred length is 1 kilometer (0.62 miles) and the minimum length should be 0.1 kilometer (328 feet).
4. Calculate the representative layer strengths for each section using the results of the DCP testing.
5. Convert the layer strengths to material classifications.
6. Compare the existing pavement structure, which is now expressed in layer thickness and material classifications, with the catalog designs for the traffic class. The comparison will indicate what additional layers, if any, are needed. Materials for the pavement structure are selected based on a combination of structural requirements, availability, economic factors, and previous experience. If no suitable materials are available locally for base or subbase layers, modification or stabilization with lime, cement, lime slag, or other pozzolanic stabilizers may be used to improve the local materials. If the local maintenance capability is poor, it is recommended that less moisture-sensitive materials, or the best material available be used because if potholes or cracks occur and are not repaired speedily, water ingress could lead to substantial failures. Surfacing materials consist of a bituminous surface treatment or hot-mix asphalt. Where the maintenance capability is low or nonexistent, a 25 mm (1 in.) hot-mix asphalt wearing course is recommended.

Table 3 in Figure 15 shows the Catalog of Pavement Structures. One enters the table with the traffic, and the proposed pavement structure and determines the thickness of the different materials making up the pavement structure. The principal mode of failure in South Africa is rutting and the catalog was designed so that the pavement was considered failed at a rut depth of 20 mm (0.8 in.). Table 4 in Figure 16 contains the material properties of the various materials listed in Figure 15.

This design catalog was compared with other catalogs such as the Transport Research Laboratory Road Note 31 *(43)*. The low-volume road catalog developed in South Africa generally has a pavement structure with fewer selected layers and is constructed with lower-quality materials than Road Note 31.

United Kingdom

The Overseas Centre of the Transport Research Laboratory developed and published *Overseas Road Note 31: A Guide to the Structural Design of Bitumen-Surfaced Roads in Tropical*

TABLE 3 Catalog of Pavement Structures

TRAFFIC CLASS	TRAFFIC (E80's)	PROPOSED PAVEMENT STRUCTURES #					
		GRANULAR/GRANULAR		GRANULAR/ CEMENTED	CEMENTED/G RANULAR	CEMENTED/ CEMENTED	ASPHALT SURFACING/ GRANULAR
		DRY/ MODERATE	WET				
E0-1	< 5000	150 G6* 150 G8 150 G9 G10**	150 G5 150 G7 150 G9 G10	150 G5 125 C4 G10	100 C4*** 150 G9 G10	-	25 A[+] 150 G6 G10
E0-2	5 000 - 30 000	150 G5 150 G7 150 G9 G10	150 G4 150 G6 150 G8 G10	-	100 C4 150 G7 G10	-	25 A 150 G6 150 G7 G10
E0-3	30 000 100 000	150 G4 150 G6 150 G8 G10	150 G4 150 G5 150 G6 150 G7 G10	150 G4 125 C4 150 G7 G10	125 C4 150 G5 G10	100 C4° 100 C4 G10	25 A 150 G5 150 G9 G10
E0-4	100 000 - 200 000	150 G4 150 G5 150 G8 G10	150 G3 150 G6 150 G9 G10	150 G4 125 C4 150 G7 150 G9 G10	125 C4 150 G5 150 G7 G10	-	25 A 150 G4 150 G9 G10
E1-1	200 000 - 400 000	150 G4 150 G5 150 G7 150 G9 G10	150 G3 150 G6 150 G8 G10	125 G2 125 C4 150 G9 G10	125 C4 150 G4 150 G7 G10	100 C4° 100 C4 150 G7 150 G9 G10	25 A 150 G4 150 G8 G10
E1-2	400 000 - 800 000	125 G2 150 G6 150 G9 G10	125 G2 150 G5 150 G9 G10	150 G2 125 C4 150 G9 G10	$	125 C4 125 C4 150 G7 150 G9 G10	25 A 150 G4 150 G5 150 G8 G10

 # Double surface treatment assumed on all pavement structures unless otherwise indicated.
** Notation—150 mm layer of G6 quality material. Layers are designated from top to bottom, with the lower being the roadbed material.*
*** Pavement assumed to be supported by in-situ material having a CBR of not less than 3 (G10) and semi-infinite depth.*
**** C4—cementation of G5, G6 material.*
+ 25 mm asphalt.
ϕ Can be combined into one layer of 200 mm thickness.
$ At present, reliable calculations of life expectancy cannot be made for this type of pavement surface.

FIGURE 15 Catalog of pavement structures in South Africa *(41)*.

TABLE 4 Summary of Material Classification (3)

CODE	MATERIAL	ABBREVIATED SPECIFICATIONS
G1	Graded crushed stone	Dense-graded unweathered crushed stone: max.size 37,5 mm 86-88 % of apparent density; fines PI < 4
G2	Graded crushed stone	Dense-graded unweathered crushed stone: max. size 37,5 mm 100-102 % mod. AASHTO; fines PI< 6.
G3	Graded crushed stone	Dense-graded stone + soil binder: max size 37,5 Minimum 98 % mod. AASHTO; fines PI < 6
G4	Natural gravel	CBR > 80 ; PI < 6
G5	Natural gravel	CBR > 45 ; PI < 10 ; max. size 63 mm
G6	Natural gravel	CBR > 25 ; max. size < 0,67 layer thickness
G7	Gravel-soil	CBR > 15 ; max. size < 0,67 layer thickness
G8	Gravel-soil	CBR > 10 ; at in-situ density
G9	Gravel-soil	CBR > 7 ; at in-situ density
G10	Gravel-soil	CBR > 3 ; at in-situ density
C3	Cemented natural gravel	UCS 1,5 to 3,0 MPa at 100% mod. AASHTO; max. size 63 mm
C4	Cemented natural gravel	UCS 0,75 to 1,5 MPa at 100% mod. AASHTO; max. size 63 mm

Note: All CBR values referred to in Table 4 are soaked CBRs.

FIGURE 16 Material classifications for the South Africa catalog *(41)*.

and Sub-tropical Countries (43). The address to obtain this manual is shown in Appendix D. As the title implies, the Road Note gives recommendations for the structural design of bituminous surfaced roads in tropical and subtropical climates and not for England, Scotland, and Wales. It is intended for highway engineers responsible for the design and construction of new pavements and is appropriate for roads that are required to carry up to 30 million cumulative ESALs in one direction.

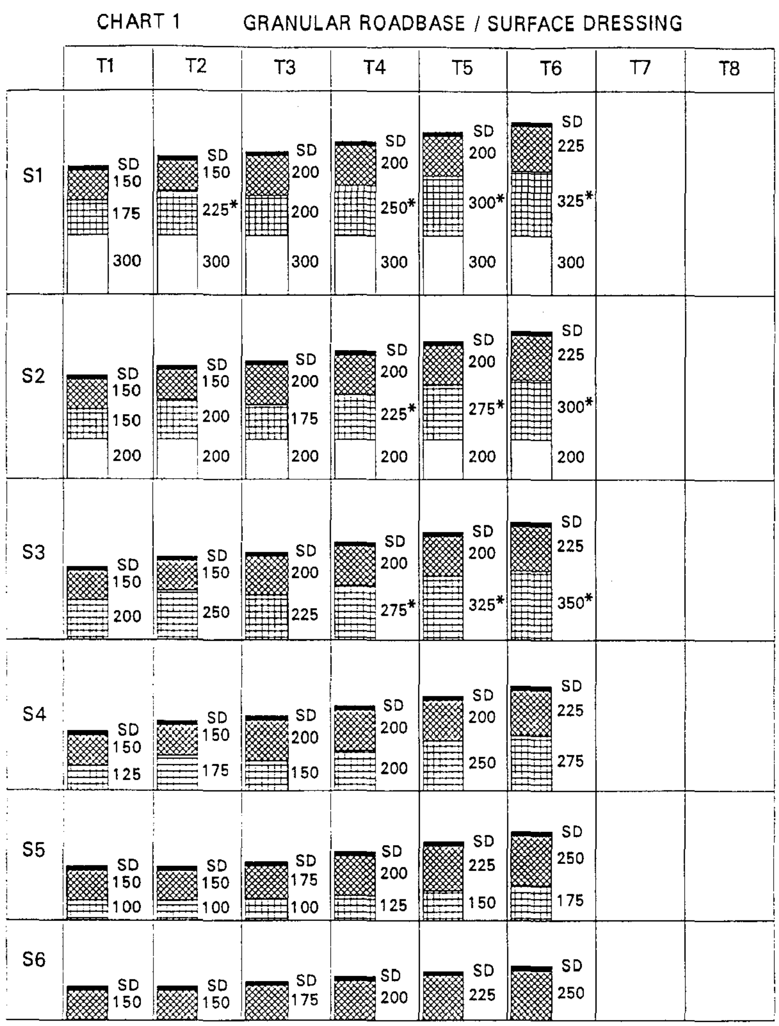
The purpose of the structural design provided is to limit the stresses induced in the subgrade by the traffic to a safe level at which subgrade deformation is insignificant while at the same time ensuring that the road pavement layers themselves do not deteriorate to any serious extent within the design life. The Road Note is only applicable in tropical and subtropical climates because research has shown how different types of roads deteriorate and has demonstrated that some of the most common modes of failure in the tropics are often different from those that occur in the temperate regions.

The pavement designs in the Road Note are based primarily on:

a) The results of full-scale experiments where all factors affecting performance have been accurately measured and their variability quantified.
b) Studies of the performance of as-built existing road networks.

The design process described in the Road Note is:

1. Estimate the amount of traffic and the cumulative number of ESALs that will use the road over its design life.



Note: 1 * Up to 100mm of sub-base may be substituted with selected fill provided the sub-base is not reduced to less than the roadbase thickness or 200mm whichever is the greater. The substitution ratio of sub-base to selected fill is 25mm : 32mm.

2 A cement or lime-stabilised sub-base may also be used.

FIGURE 17 Pavement catalog from Road Note 31 *(43).*

2. Assess the strength of the subgrade soils over which the road will be built.
3. Select the most economical combination of pavement materials and layer thicknesses that will provide satisfactory service over the design life of the pavement.

The Road Note is comprehensive and covers the following topics:

- Estimating traffic volumes and axle loads,
- Determining the strength of the subgrade,
- Embankment construction,
- Drainage,
- Unbound pavement materials,
- Lime and cement stabilized materials,
- Bituminous materials and asphalt concrete,
- Surface treatments, and
- Provides a catalog of pavement structures.

Road Note 31 contains 8 charts similar to Chart 1 shown in Figure 17. Figure 18 contains the key to the Structural Catalogue. For a given traffic class and subgrade strength, one enters the chart and determines the thickness of the different materials making up the pavement section. The Road Note recommends that a double bituminous surface treatment always be used on non-bituminous layers and that the quality of the bituminous surface treatment is greatly enhanced if traffic is allowed to run on the first application for a minimum period of 2 to 3 weeks before the second layer is applied. It also states that it is essential that the bituminous surfacing, 50 mm (2 in.) thick be flexible especially on a granular road base.

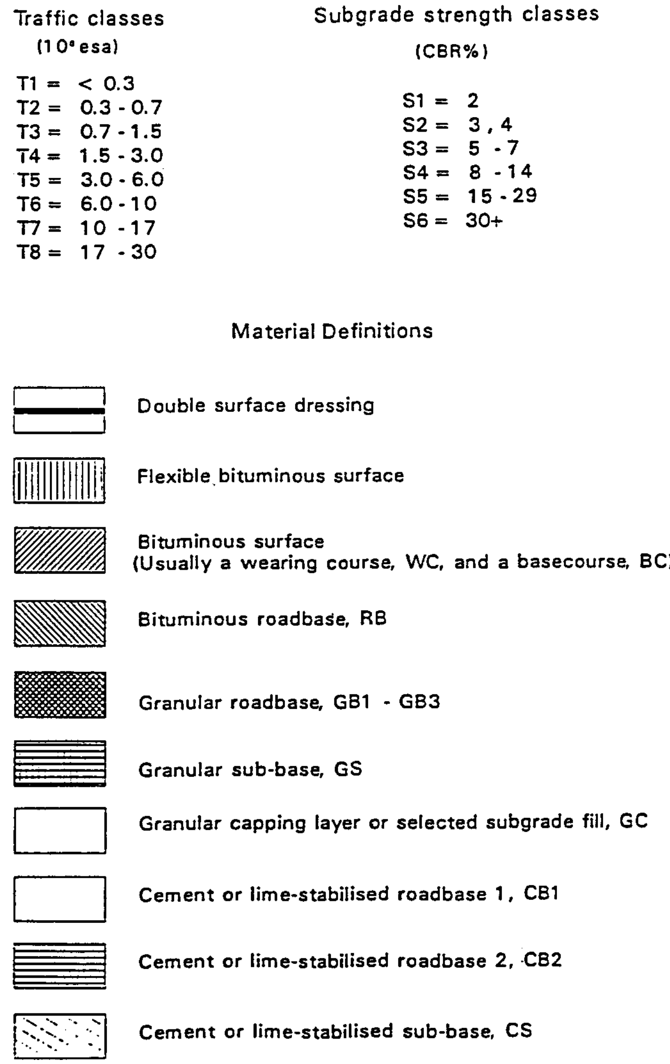


FIGURE 18 Key to the structural catalog in Road Note 31 *(43)*.

India

Dhir, Lal, and Mital reported on the development of a guide by the Central Road Research Institute (CRRI) for the design of pavements for low-volume roads in India which considers traffic of steel-wheeled carts, varying subgrade moisture conditions, and minimum acceptable serviceability levels *(44)*. The purpose of the guide is to provide improved and more cost-effective techniques for the planning, design, construction, and maintenance of low-volume roads.

A traffic index was developed that incorporates the effect of three types of vehicles, solid-wheeled carts; heavy, pneumatic-tired commercial vehicles; and light, pneumatic-tired vehicles. The subgrade strength is expressed as an index that is correlated to CBR. Two sets of pavement design curves were developed for two categories of rural roads. Category 1 roads are associated with relatively high speeds and traffic volumes. Category 2 roads are associated with relatively low traffic volumes and slow-moving traffic. The road work in India continues to be performed with a relatively large degree of manual input. This is especially the case in the construction of low-volume roads.

Singh, Murty, Bhatnager, Bhasin, and Havangi of the CRRI published a working manual on the design and construction of low-volume roads *(45)*. The manual provides detailed directions, including sketches, on how to construct a pavement using locally available materials and equipment. It lists the appropriate tests for the surface, base, and subbase materials and the specification requirements.

France

The following is based on a translation of the Introduction of the Manual for the Creation of Low-Traffic Roads *(46)* provided by the staff of the Transportation Research Board. The design and construction of low-volume roads in France is characterized by the following conditions:

1. The design strategy is not unique and accordingly, varies among different persons, organizations, and jurisdictions. Some may choose a strategy that provides a thinner pavement with an initially reduced investment,

which will eventually be completed by maintenance or stage construction, while others will opt for a thicker pavement with a higher initial cost but which will minimize future costs.
2. Field investigations and studies are often limited.
3. Local materials are used which vary greatly in quality.
4. Freezing and thawing conditions do not receive the same attention that they do on a road with higher traffic volumes.

Because of these conditions, a catalog of predesigned pavement structures could not be provided and the report only offers recommended procedures for accommodating different levels of traffic, subgrade conditions, and materials.

PIARC (World Road Association)

The World Road Association has not published a structural thickness design guide for thin-surfaced pavements. It has published a synthesis of the international practice for surface dressing, otherwise known as bituminous surface treatments *(21)* and a report on the design, construction, and performance of semi-rigid pavements *(47)*. A semi-rigid pavement is defined as a pavement where the bituminous part of the pavement structure is always located above the hydraulically bound part, (e.g., an asphalt overlay of a portland cement concrete pavement), or the construction of the pavement consists of both asphalt layers and portland cement concrete layers.

SUMMARY OF THIN-SURFACED PAVEMENT STRUCTURAL THICKNESS DESIGN METHODOLOGIES

There are no thin-surfaced pavement design methodologies in the United States. However, the Corps of Engineers Method has been adapted for aggregate-surfaced roads and thin-surfaced pavements and AASHTO has developed a low-volume road and aggregate roadway surface thickness catalog based on its procedure. Both AASHTO and the Corps of Engineers methods evaluate subgrade soil support strength, traffic loading, and environmental effects. A critical review made by Yapp, Steward, and Whitcomb *(26)* of adaptations of both of these methods for use by the US Forest Service on aggregate-surfaced roadways identified several shortcomings. One or more of the adaptations had not been validated with field experience, can not incorporate seasonal haul requirements, are not valid for aggregate-surfaced or earth roads, and do not consider risk and reliability concepts.

The Australians, South Africans, and the United Kingdom have each developed design procedures and design catalogs that can be used for thin-surfaced pavements in hot or tropical climates where there is no need to consider the effects of freezing and thawing of the subgrade. The differences in climate, soils, or economic development between these locations and the temperate zone of the North American continent prevents the direct transfer of these procedures to the United States and Canada but they could be adapted for our temperate climate and would be a good starting point for any effort to develop a design procedure or catalog for thin-surfaced pavements.

CHAPTER THREE

PRACTICES OF HIGHWAY AGENCIES

INTRODUCTION

This chapter presents and discusses the findings from the questionnaire returned by the 160 agencies who indicated that they use thin-surfaced pavements. A list of those agencies is shown on Table B-1 in Appendix B. The characteristics of the agencies, including the education and experience of the personnel selecting and designing thin-surfaced pavements, laboratory and field testing capability, means of accomplishing the work, and pavement management and maintenance practices are presented. The factors considered in selecting projects for thin-surfaced pavements and the factors considered in selecting a bituminous surface treatment as the wearing surface are also presented, along with the structural or thickness design procedure used. Finally, the current practices in four specific situations are presented and discussed.

CHARACTERISTICS OF AGENCIES USING THIN-SURFACED PAVEMENTS

Each agency using thin-surfaced pavements was requested to provide information on:

- The agency's level of government,
- The background of the person(s) responsible for *selecting* the pavement projects,
- The background of the person(s) responsible for *designing* the pavement projects,
- The field and laboratory testing capability,
- The means used to construct thin-surfaced pavements,
- The agency's maintenance management system, pavement management system, and preventive maintenance program capabilities, and
- Climatic conditions as indicated by the six climatic regions shown in Figure 3 used by AASHTO in the *Guide for the Design of Pavement Structures (10).*

Level of Government and Geographic Distribution of Agencies Using Thin-Surfaced Pavements

Table 5 shows the distribution of the 160 agencies responding to the survey that use thin-surfaced pavements by level of government and the AASHTO climatic region shown in Figure 3.

Over 60 percent of the responding agencies using thin-surfaced pavements are at the county level of government, the remaining 40 percent are distributed among the federal, state, city, and town levels of government. The distribution among the climatic regions is displayed in Figure 19. The largest number of responding agencies using thin-surfaced pavements are in Climatic Region II, which is generally the mid-Atlantic area of the country and Climatic Region III, which is generally the northeastern part of the country. The agencies in these two regions account for more than 60 percent of the agencies reporting using thin-surfaced pavements. Climatic Region VI, which is generally the upper great plains and the Rocky Mountains, has the lowest number of agencies reporting using thin-surfaced pavements.

Background of Persons Selecting and Designing Thin-Surfaced Pavements

The agencies were asked to indicate the background of the person(s) responsible for *selecting* the pavement projects in the agency. They were provided with the following options:

TABLE 5

CLIMATIC REGIONAL DISTRIBUTION OF AGENCIES USING THIN-SURFACED PAVEMENTS

Level of	Total	AASHTO Climatic Region (Figure 3)					
Government	Number	I	II	III	IV	V	VI
Federal[1]	10	2	3	2	0	3	3
State[2]	20	4	8	6	1	4	7
County	97	12	42	23	12	8	0
City[3]	20	2	4	3	2	8	1
Town	13	0	2	11	0	0	0
All Levels	160	20	59	45	15	23	11

Notes:
[1]The Forest Service Office in Portland, Oregon indicated responsibilities in 4 climatic regions.
[2]States indicating being in more than one climatic region: Mississippi in 2, Washington in 3, Texas in 4, and British Columbia in 5.
[3]Includes the Metro area.

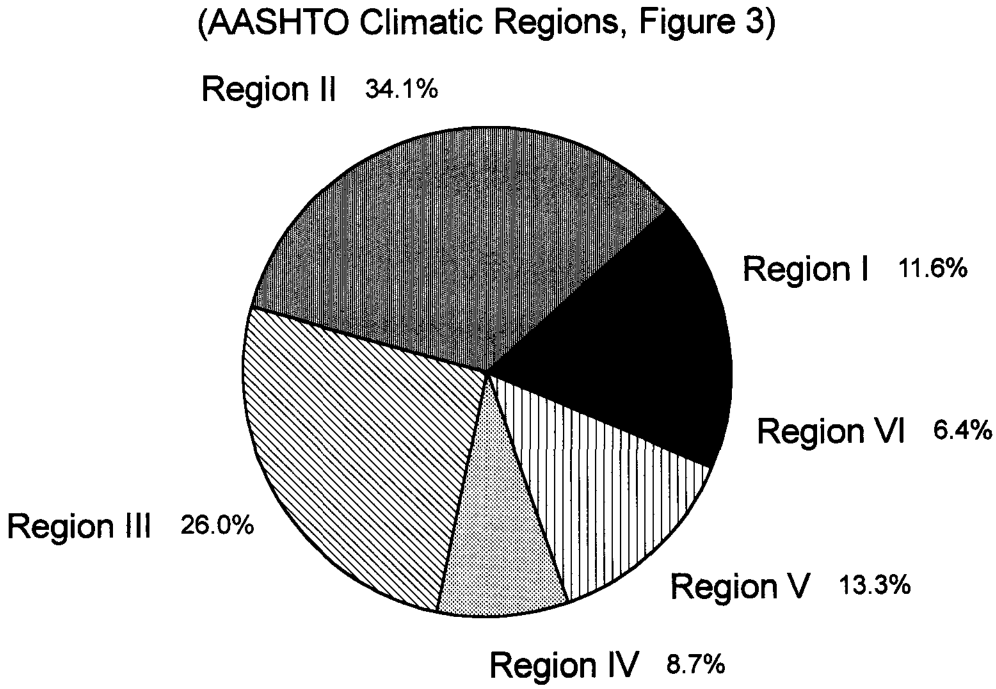


FIGURE 19 Climatic region distribution of agencies using thin-surfaced pavements.

1. Elected or appointed official(s) without a background or experience in highways, (could be one individual or a board),
2. Highway construction or maintenance experience, but no formal technical training,
3. Highway construction or maintenance experience, supplemented by workshops and seminars,
4. Two years formal education in highway, construction or engineering technology, and
5. Graduate or professional engineer with highway design, construction or maintenance experience.

Table B-3 in Appendix B contains the responses to this question. Approximately 55 percent of the persons at all levels of government selecting pavement projects are graduate or professional engineers with highway design, construction or maintenance experience. Another 20 percent of the agencies have personnel with highway design, construction or maintenance experience supplemented by workshops and seminars. In about 10 percent of the agencies, the projects are selected by elected or appointed officials with no experience in highways. The percentages vary considerably depending on the agency's level of government. Eighty percent of the state level agencies reported that their pavement projects were selected by graduate or professional engineers with highway design, construction or maintenance experience, while, this was true of only 38 percent of the town level agencies.

The agencies were asked to indicate the background of the person(s) responsible for *designing* the pavement projects in the agency. They were provided with the following options:

1. Designs prepared by consultants hired by the agency,
2. Recommendations made by a local contractor or vendor,
3. Elected or appointed official without a background or experience in highways,
4. Highway construction or maintenance experience, but no formal technical training,
5. Highway construction or maintenance experience, supplemented by workshops and seminars,
6. Two years formal education in highway, construction or engineering technology, and
7. Graduate or professional engineer with highway design, construction or maintenance experience.

The responses to this question are shown in Table B-4 in Appendix B. Over 61 percent of the agencies indicated that their pavement projects are designed by graduate or professional engineers with highway design, construction or maintenance experience with the percentage ranging from 90 percent for the federal level agencies to a low of 38 percent for the town level agencies. The county agencies were between these two with 54 percent. The next largest response was approximately 14 percent from those agencies who indicated that their pavement designs were prepared by personnel with highway construction or maintenance experience, supplemented by workshops and seminars. The number of agencies selecting the other options was small. Four agencies indicated that they used both consultants and their own staff to prepare designs. One agency indicated that it used both recommendations from vendors and its own staff in preparing the designs of pavement projects.

TABLE 6
SUMMARY OF FIELD AND LABORATORY TESTING DONE BY AGENCIES

		Percent of Agencies Selecting Option			
Level of Government	Total Number	None (1)	Test Pits & Sampling (2)	Construction (6) & (7)	All (8)
Federal	10	30	60	60	40
State	20	0	35	55	100
County	97	31	26	38	28
City	20	15	30	50	55
Town	13	39	54	23	0
All Levels	160	26	32	42	39

Field and Laboratory Testing Capabilities of the Agencies

The agencies were asked to indicate the field and laboratory testing that they did for pavement projects. The options provided were:

1. None,
2. Dig test pits and take samples,
3. Perform CBR tests on the subgrade,
4. Perform CBR tests on the base,
5. Perform resilient modulus testing,
6. Perform sieve analysis and determine moisture contents,
7. Perform compaction tests, and
8. Perform all the basic testing required for pavement design and construction.

Options (2), (3), (4) and (5) are performed in the preconstruction phase, options (6) and (7) are done in the construction phase. The responses are shown in Table B-5 in Appendix B. The results are summarized in Table 6.

The number of agencies that performed all the basic testing for pavement design and construction varied from a maximum of 100 percent at the state level to zero at the town level. Only about one-third of the county level agencies have the capability to take samples and perform routine construction testing while about one-third perform no testing whatsoever and one-third perform all the basic testing. As might be expected, the lowest capabilities exist at the town level. Overall, however, the number of agencies that are capable of performing the field and laboratory testing for pavement design and construction is less than 40 percent of the agencies using thin-surfaced pavements.

Means Used To Construct Thin-Surfaced Pavements

The agencies were asked to indicate how the thin-surfaced pavements they used were constructed. The choices were:

1. Vendors who provide the paving materials,
2. Construction contractors,
3. Agency forces, and
4. A mix of vendor and agency forces.

The responses are shown in Table 7. Some of the agencies selected more than one option, therefore, the sum of the choices exceeds the total number of agencies. Table 8 shows the number of ways used by agencies to construct thin-surfaced pavements.

Contractors are by far the most frequently used means of constructing thin-surfaced pavement by federal, state, and city agencies. At the county level, agency forces are used slightly more frequently than contractors. At the town level, equal use is made of vendors and a mix of vendor and agency forces. One hundred forty-three agencies responded to this question. As shown in Table 8, 101 indicated that they used only one way of constructing thin-surfaced pavements and 31 indicated that they used two ways.

Management Systems

Agencies were asked to indicate if they had a Maintenance Management System (MMS), Pavement Management System (PMS) and a Preventive Maintenance Program (PMP). The results are tabulated in Table B-6 in Appendix B and summarized in Table 9.

Approximately two-thirds of all the agencies have a PMS with the numbers ranging from 54 percent at the town level to 80 percent at the state level. Approximately 2/3 of all the agencies reported having a preventive maintenance program, except at the federal level where 40 percent of the agencies indicated they had such a program. Even though MMSs have been in existence longer than the other two programs, only 50 percent of the agencies reported having an MMS, with the numbers ranging from 35 percent at the city level to 75 percent at the state level.

ROADWAY SURFACE IMPROVEMENT SELECTION CONSIDERATIONS

An agency considers several factors when it decides to apply a thin-surfaced pavement to the road, rather than leaving the road with an aggregate surface or building a thicker pavement. This section reports on the findings based on the responses to Question 7 on the Questionnaire.

TABLE 7

CONSTRUCTORS OF THIN-SURFACED PAVEMENTS

Level of Government	Number of Agencies				
	Total	Vendors	Contractors	Agency Forces	Mix of Vendors and Agency Forces
Federal	10	2	9	2	1
State	20	1	16	6	3
County	97	19	36	40	26
City	20	3	11	5	6
Town	13	5	2	1	5
All Levels	160	30	74	54	41

TABLE 8

NUMBER OF WAYS USED BY AGENCIES TO CONSTRUCT THIN-SURFACED PAVEMENTS

		Number Ways Used by Agencies				
Level of Government	Total Number	None Selected	1	2	3	4
Federal	10	1	6	2	0	1
State	20	2	12	5	0	1
County	97	8	64	18	5	2
City	20	4	10	4	2	0
Town	13	2	9	2	0	0
All Levels	160	17	101	31	7	4

TABLE 9

AGENCIES WITH A PAVEMENT MANAGEMENT SYSTEM, MAINTENANCE MANAGEMENT SYSTEM, OR PREVENTIVE MAINTENANCE PROGRAM

		Percentage of Agencies With				
Level of Government	Total Number	PMS	MMS	PMP	All 3	None
Federal	10	70	70	40	40	10
State	20	80	75	65	55	15
County	97	61	43	70	30	11
City	20	75	35	60	20	10
Town	13	54	69	62	46	23
All Levels	160	65	50	66	34	12

Ranking the Factors Considered in Selecting the Project

The agencies were asked to select from a list of factors and to rank the factors in the order of importance in arriving at their decision to place a thin-surfaced pavement on a section of road. The factors provided to the agencies for ranking were:

- Traffic volume,
- Volume of trucks,
- Classification of the road,
- Costs,
- Public policy, and
- Ease of implementation.

Tables B-7 through B-12 in Appendix B contain the responses by the agencies. Table 10 is a summary of the information in the tables in Appendix B. To determine the overall ranking of a factor by all the agencies, two schemes were used, one based on points and the other based on the number of times that the factor was ranked first. Seven (7) points were assigned to a first place ranking by an agency, 6 points for a second place ranking, and 5 points for a third place ranking, etc. The number of points obtained for each factor for each level of government and the total are shown in Table 10. The number of times that the factor was ranked first by an agency is also listed. The rankings by both schemes for the totals is shown by the bar charts in Figures 20 and 21. The ranking of each factor by each level of government is shown in Table 11.

Traffic volume and costs were ranked either first or second by every level of government using either ranking scheme except at the city level where classification and the volume of trucks ranked second. Public policy and ease of implementation ranked fifth or sixth at every level of government except at the town level where the volume of trucks also ranked fifth based on the number of first place rankings. Generally, public policy ranked fifth at the federal and state level and sixth at the local level. The classification of the road predominately ranked third and the volume of trucks ranked fourth.

The agencies were provided with the opportunity to list other factors they considered in selecting their pavement projects. The following other factors were considered by one or more of the agencies: mitigating erosion; minimizing mobilization costs for grading aggregate surfaced roads; an economics

TABLE 10

RANKING OF FACTORS CONSIDERED IN PAVEMENT PROJECT SELECTION

Level of	Total	Traffic Volume		Truck Volume		Class		Class		Policy		Implement	
Government	Number	Pts	1st	Pts	1st	Pts	1st	Pts	1st	Pts	1st	Pts	1st
Federal	10	49	3	27	1	40	1	65	7	27	2	14	0
State	20	115	10	73	4	80	2	89	6	44	1	17	0
County	97	488	37	314	11	423	23	481	38	222	13	279	12
City	20	81	5	70	6	78	6	76	7	31	1	44	3
Town	13	67	5	48	2	59	5	65	6	23	2	29	3
All Levels	160	800	60	532	24	680	37	776	64	347	19	383	12

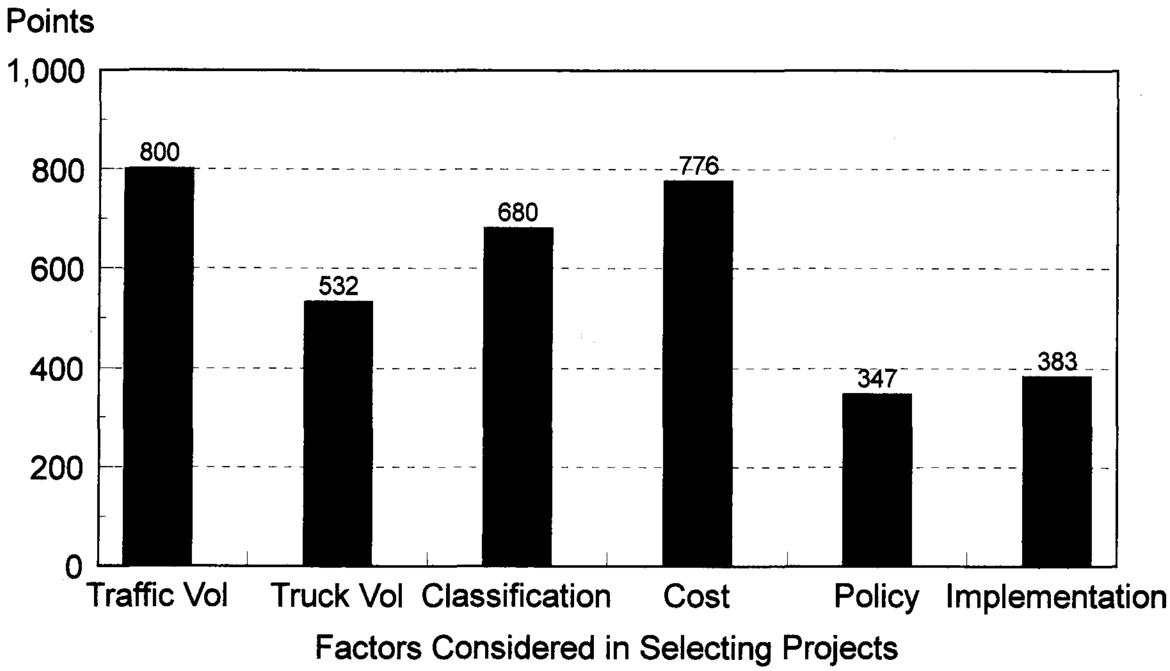


FIGURE 20 Ranking of factors considered in selecting projects—all levels of government based on points.

analysis that incorporates costs; a point system using traffic volume, mix of traffic, and ease of implementation; seasonality of use; operating costs; accident history; availability of right-of-way; and maintenance requirements.

Traffic Volume

The agencies were also asked to indicate the traffic volumes for which they would use a thin-surfaced pavement consisting of either a single- or multiple-application bituminous surface treatment, or a layer of hot-mix asphalt less than 50 mm (2 in.) thick over an unbound base. The responses are tabulated in Table B-13 in Appendix B. A summary of the responses is shown in Table 12.

Some of the agencies responding indicated a range of traffic volume over which they would use thin-surfaced pavements. Others only indicated the lower traffic volume below which they would not use a thin-surfaced pavement while others indicated only an upper limit. Therefore, the number of agencies responding to the question is more than the number of agencies who would use a thin-surfaced pavement for a specific volume of traffic. The bar chart in Figure 22 graphically displays the data in Table 12. There is a slight reduction in use for an ADT of 200 and a 20 percent reduction for an ADT of 400. Forty percent of the agencies would use a thin-surfaced pavement for an ADT greater than 1,000 and 20 percent for an ADT greater than 2,000.

Volume of Trucks

The agencies who selected volume of trucks as a factor they considered were asked to indicate the volumes of trucks for which they would use a thin-surfaced pavement. Most agencies indicated the range that represented the highest percentage of trucks for which they would consider a thin-surfaced pavement. Their responses are tabulated in Table B-14 in Appendix B and summarized in Table 13.

Figure 23 is a bar chart that graphically displays the data in Table 13. All of the agencies responding indicated that they would use a thin-surfaced pavement when the percent of trucks is 5 percent or less, about one-half of those responding would use it when there are 11 to 15 percent trucks and only

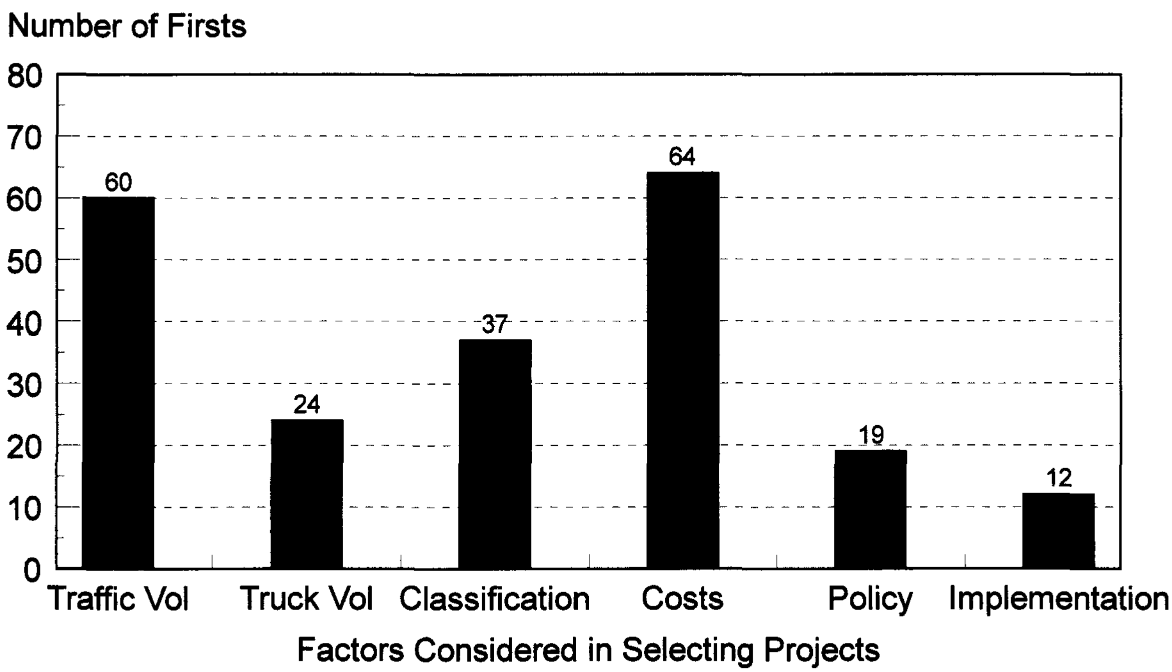


FIGURE 21 Ranking of factors considered in selecting projects—all levels of government based on firsts.

TABLE 11

SUMMARY OF THE RANKING OF FACTORS CONSIDERED IN SELECTING PROJECTS

	All Levels		Federal		State		County		City		Town	
Ranking	Points	Firsts	Points	Firsts	Points	Firsts	Points	Firsts	Points	Firsts	Points	Firsts
First	Traffic	Cost	Cost	Costs	Traffic	Traffic	Traffic	Costs	Traffic	Costs	Traffic	Costs
Second	Costs	Traffic	Traffic	Traffic	Costs	Costs	Costs	Traffic	Class	Class Trucks	Cost	Traffic Class
Third	Class	Class	Class	Policy	Class	Trucks	Class	Class	Costs		Class	
Fourth	Trucks	Trucks	Truck Policy	Trucks Class	Trucks	Class	Trucks	Policy	Trucks	Traffic	Trucks	Impl
Fifth	Impl	Policy			Policy	Policy	Impl	Impl	Impl	Impl	Impl	Trucks Policy
Sixth	Policy	Impl	Impl	Impl	Impl	Impl	Policy	Trucks	Policy	Policy	Policy	

TABLE 12

THIN-SURFACED PAVEMENT PROJECT SELECTION CONSIDERATIONS—VOLUME OF TRAFFIC

Level of Government	Number of Agencies Responding	Percent Of Agencies Who Would Use Thin-Surfaced Pavements for ADT Indicated					
		<100	100–199	200–399	400–999	1000–2000	>2000
Federal	7	86	86	57	43	0	0
State	19	84	89	79	58	42	37
County	76	86	84	83	72	41	17
City	12	100	100	100	100	67	50
Town	10	90	80	50	40	10	10
All Levels	124	87	86	80	69	39	22

11 percent would use a thin-surfaced pavement when the percent of trucks is more than 20 percent.

Road Classification

Those agencies that consider the classification of the road in the selection of thin-surfaced pavement projects were asked to indicate the road classes on which they use these types of pavements. Their responses are shown in Table B-15 in Appendix B and are summarized in Table 14.

Approximately 75 percent of all the agencies selected residential access roads and local collectors for thin-surfaced pavements. Not surprisingly, because of the higher traffic and truck volumes, major collectors, minor arterials,

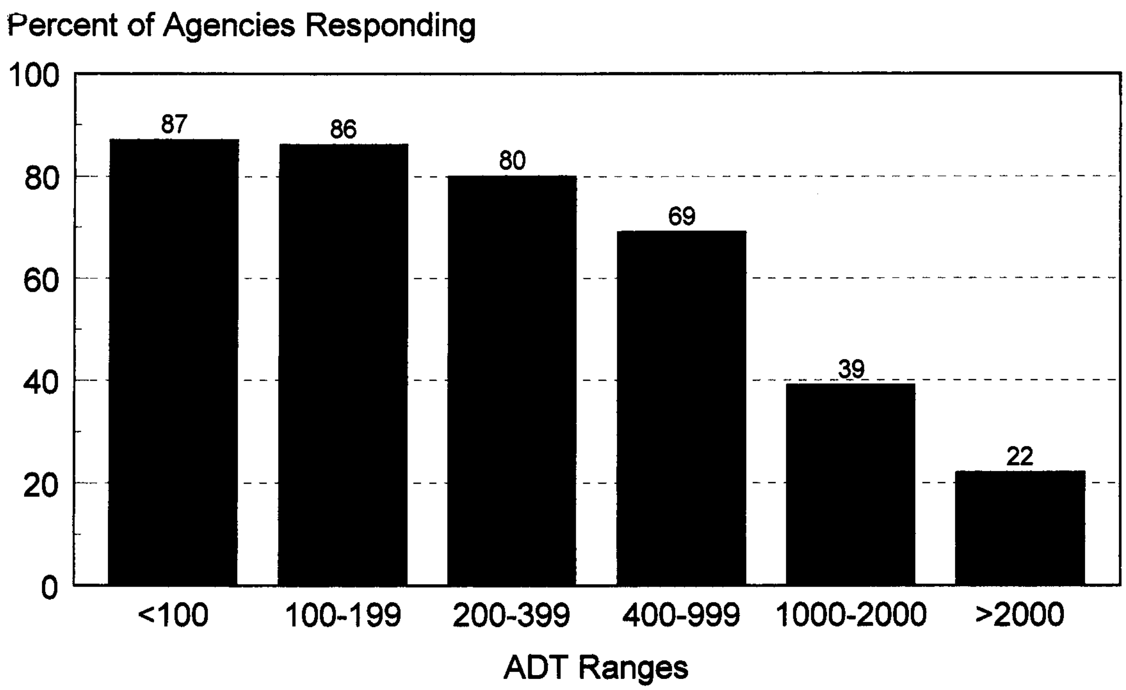


FIGURE 22 Traffic volumes for thin-surfaced pavements.

TABLE 13
THIN-SURFACED PAVEMENT PROJECT SELECTION CONSIDERATIONS—VOLUME OF TRUCKS

Level of Government	Number of Agencies Responding	Percent of Agencies Who Would Use Thin-Surfaced Pavements for a Truck Volume Up to the Percentage Indicated				
		5% or less	6–10%	11–15%	16–20%	>20%
Federal	5	100	100	80	60	60
State	12	100	83	58	17	8
County	61	100	79	48	16	8
City	12	100	67	33	33	8
Town	7	100	86	29	14	14
All Levels	97	100	79	47	21	11

and resource/industrial access roads were selected by less than one-third of the agencies. There are wide variations in use however, among the different levels of agencies. For example, 88 percent of the state agencies indicated they would use thin-surfaced pavements on minor collectors while only 29 percent of the federal level agencies indicated they would. Similarly, 100 percent of the federal agencies indicated they would use a thin-surfaced pavement on a recreational access road while only 20 percent of the city agencies indicated they would. These wide variations are most likely a reflection of the amount of those classes of roads that an agency has and their mission. The federal agencies who responded have, in part, a mission to provide recreation, while that is generally a very minor part of the mission for a city agency.

Economics

Those agencies that identified costs as a factor in selecting projects for thin-surfaced pavements were asked to provide their reasons. The following choices were provided:

1. They have the lowest first cost for a hard-surfaced pavement,
2. We have found that they provide the lowest life-cycle cost,
3. They are inexpensive to maintain, and
4. It is all we can afford on our limited budget.

The responses are shown in Table B-16 in Appendix B and summarized in Table 15. The column headings in the following table correspond to the choices listed above. An agency could select more than one reason, therefore, the total exceeds the number of agencies responding.

Sixty-one percent of the agencies indicated that they used thin-surfaced pavements because they have the lowest first cost for a hard-surfaced pavement and 54 percent indicated that they were selected because that is all they could afford on their limited budget. There were no wide variations among the levels of government except that 91 percent of the towns indicated that a thin-surfaced pavement was all they could afford on a limited budget and 81 percent of the states indicated they

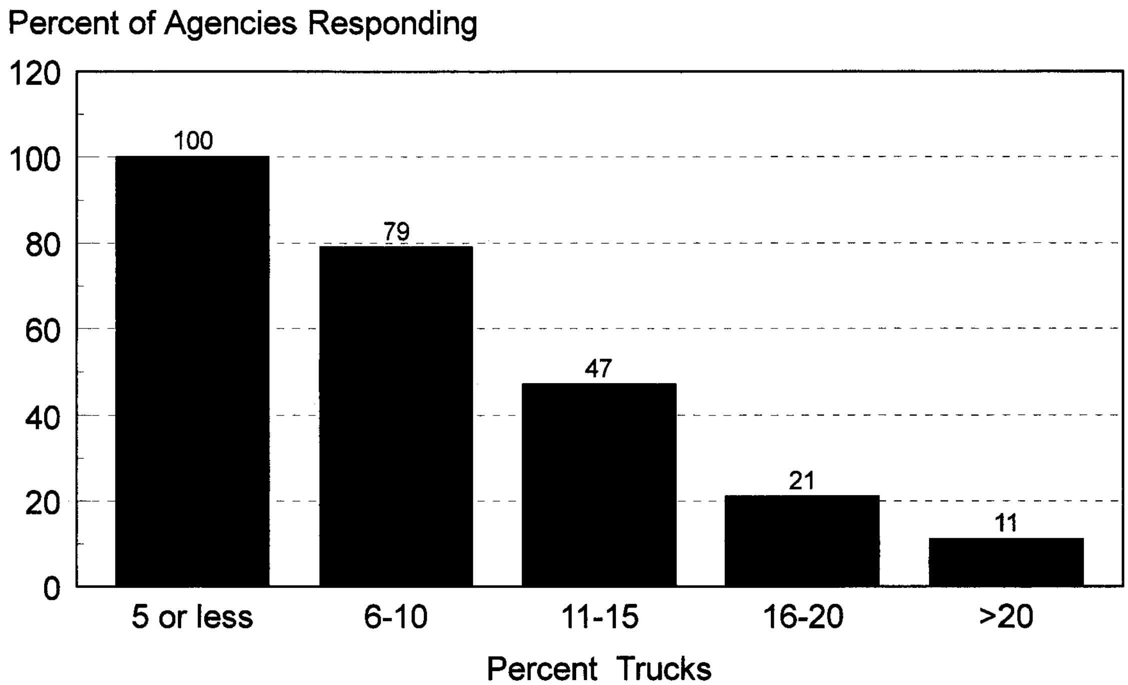


FIGURE 23 Volume of trucks for thin-surfaced pavements.

TABLE 14

ROAD CLASSIFICATIONS WHERE THIN-SURFACED PAVEMENTS WOULD BE USED

Level of Government	Number of Responses	Percent of Agencies Using Thin-Surfaced Pavements for the Classification Indicated								
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Federal	7	14	0	0	100	43	29	29	14	14
State	16	63	63	31	63	75	88	81	19	25
County	79	77	61	25	57	61	76	68	35	29
City	15	93	13	33	20	53	87	60	33	47
Town	10	100	60	30	50	50	70	50	20	0
All Levels	127	76	52	26	55	60	76	65	31	28
Rank Order		1st	5th	8th	4th	3rd	1st	2nd	6th	7th

Column Headings: (1) Residential access, (2) Farm access, (3) Resource/industrial access, (4) Agricultural land access, (5) Recreational land access, (6) Local collector, (7) Minor collector, (8) Major collector, and (9) Minor arterial.

TABLE 15

ECONOMIC REASONS WHY THIN-SURFACED PAVEMENTS ARE USED

Level of Government	Number of Agencies Reporting	Percent of Agencies Selecting Option			
		(1)	(2)	(3)	(4)
Federal	10	50	40	10	40
State	16	81	25	13	50
County	82	63	29	34	51
City	13	54	31	31	54
Town	11	36	0	9	91
All Levels	132	61	27	27	54

TABLE 16

PUBLIC POLICY REASONS GIVEN WHY THIN-SURFACED PAVEMENTS ARE USED

Level of Government	Number of Agencies Responding	Percent of Agencies Selecting Option		
		(1)	(2)	(3)
Federal	5	0	0	100
State	5	20	0	80
County	41	63	39	20
City	7	29	43	29
Town	3	0	33	67
All Levels	61	48	33	34

TABLE 17

REASONS GIVEN WHY EASE OF IMPLEMENTATION OF THIN-SURFACED PAVEMENTS WAS SELECTED

Level of Government	Number of Agencies Responding	Percent of Agencies Selecting Option		
		(1)	(2)	(3)
Federal	4	50	50	50
State	4	50	75	25
County	58	52	84	31
City	7	43	71	57
Town	6	16	100	33
Total	79	48	82	34

selected thin-surfaced pavements because of the low initial costs.

Public Policy

Those agencies who indicated that public policy was a factor in selecting projects for thin-surfaced pavements were asked to indicate the nature of the policy. They were provided with two options and the opportunity to provide a description of their policy if it differed from the options offered. The options were:

1. To eliminate dust and provide a smooth surface, the legislative or executive body, (town board, county legislature, county manager, etc.) has decided that all our roads will have a hard surface consisting of a thin-surfaced pavement,
2. The legislative or executive body has decided that all the roads with permanent residents or businesses will have a hard surface, and
3. Other.

The responses are shown in Table B-17 in Appendix B and summarized in Table 16. The column headings correspond to the options listed above.

The number of agencies responding was only about 40 percent of the agencies who indicated that they used thin-surfaced pavements. About one-half of those indicated that the policy was adopted to reduce or eliminate dust and one-third indicated that the policy was to provide the residents and business with a hard-surface road. About one-third provided other information regarding the policy in their agency. At the federal level other reasons given for using a thin-surfaced pavement were to reduce erosion, control dust and eliminate need for blading, provide a smooth, quiet, dust-free surface, and used on roads for recreational purposes. At the state level the reasons provided were to eliminate dust, avoid chip seal in urban areas, and political considerations. At the county level the reasons given were to reduce complaints, when the ADT was greater than 100 and funding was available, as part of a program to convert aggregate-surfaced roads to bituminous surfaced roads, political considerations, the number of houses and use of the road, used when pavement markings are necessary, and when funds are available. At the town level they are used for ease of maintenance and political considerations.

Ease of Implementation

Those agencies that identified ease of implementation as one of the factors they considered in selecting projects for thin-surfaced pavements were asked to indicate the reasons why. They were provided with the following options:

1. Our personnel are capable of designing thin-surfaced pavements,
2. Thin-surfaced pavements can be constructed by our own crews, and
3. The specifications or purchase order for vendor-in-place paving or construction contracts are simple to prepare.

The responses are shown in Table B-18 in Appendix B and are summarized in Table 17. The column headings in that table correspond to the three options provided.

Eighty-two percent of the agencies responding indicated that the reason they selected thin-surfaced pavements was

TABLE 18

VOLUME OF TRAFFIC AS A FACTOR IN CHOOSING BITUMINOUS SURFACE TREATMENT AS THE WEARING SURFACE

Level of Government	Number of Agencies Responding	Percent of Agencies Who Would Use A Bituminous Surface Treatment as the Wearing Surface for the ADT Indicated					
		<100	100–199	200–399	400–999	1000–2000	>2000
Federal	6	29	29	29	14	0	0
State	16	94	88	81	56	38	6
County	70	93	91	79	40	13	3
City	9	100	100	100	89	44	22
Town	9	100	89	56	0	0	0
All Levels	110	91	88	76	42	17	5

because they could be constructed by their crews, approximately one-half indicate that their personnel were capable of designing thin-surfaced pavements, and one-third indicated the specification or purchase orders were easy to prepare.

Summary of the Factors Considered in Selecting Projects for Thin-Surfaced Pavements

The top three factors considered by agencies in selecting projects for thin-surfaced pavements were costs, traffic volumes, and the classification of the road. The majority of the agencies indicated that they used these pavements because they had the lowest first costs and that it was all they could afford on their limited budgets. Approximately 70 percent of the agencies responding use these pavements where the ADT is 1,000 or less. The majority of the agencies restricted their use to residential access roads, local and minor collectors, and recreational land access roadways.

WEARING SURFACE SELECTION CONSIDERATIONS

Once an agency has decided to apply a thin-surfaced pavement to a section of roadway, the next question is whether they will apply a single or double bituminous surface treatment or a thin layer, less than 50 mm (2 in.) of hot-mix asphalt over an unbound aggregate base. Question 8 in the questionnaire asked the agencies who used thin-surfaced pavements what factors they considered in deciding on a bituminous surface treatment and they were provided with the options listed below. They were not asked to rank the factors.

- Traffic volumes,
- Volume of trucks,
- Road classification,
- Costs,
- Performance experience for similar conditions,
- Type of base course being used,
- Ability to apply bituminous surface treatment with in-house forces,

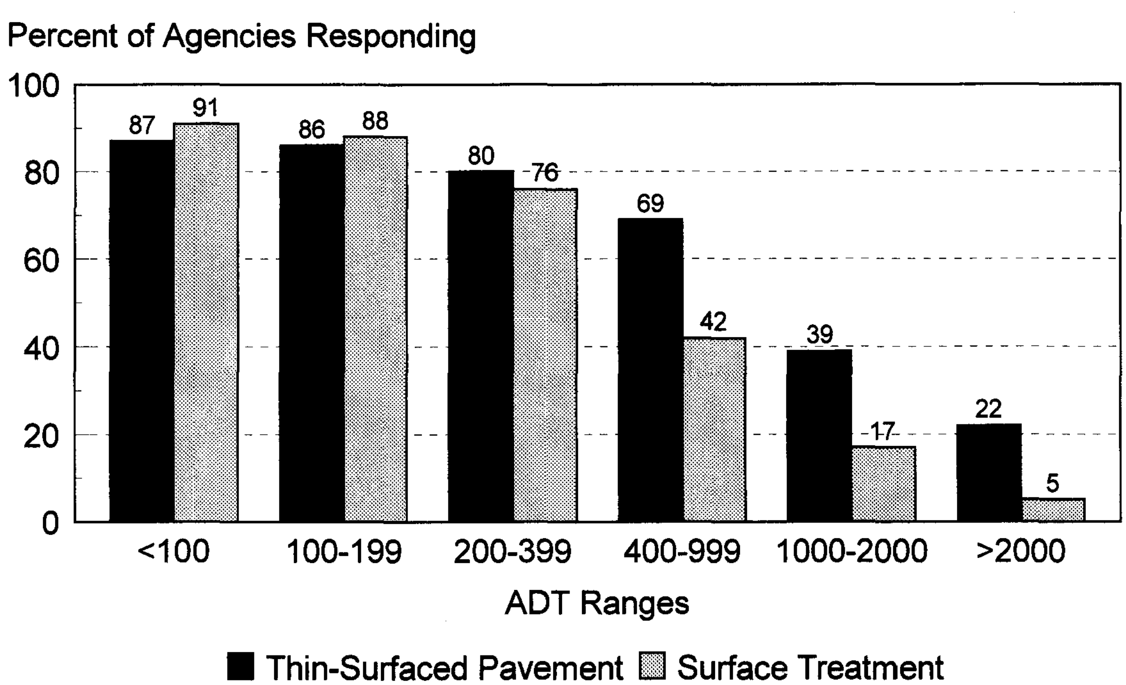


FIGURE 24 Traffic volume for bituminous surface treatments and thin-surfaced pavements.

- Availability of materials, and
- Availability of contractors to do the work.

Traffic Volume

The agencies were asked to indicate the traffic volumes for which they would use a bituminous surface treatment as the wearing surface. Their responses are shown in Table B-19 in Appendix B and summarized in Table 18. Figure 24 compares the traffic volumes at which the agencies would consider a thin-surfaced pavement shown in Table 12 and where they would use a bituminous surface treatment shown in Table 18. This bar graph shows that, if traffic volume were the only consideration, approximately 90 percent of the agencies would use a thin-surfaced pavement for an ADT less than 200 and the wearing surface would be a bituminous surface treatment; 80 percent would use a thin-surfaced pavement for an ADT between 200 and 400 and the wearing surface would be a bituminous surface treatment. However, while 69 percent of the agencies would use a thin-surfaced pavement for an ADT between 400 and 1,000, only 42 percent of those agencies would use a bituminous surface treatment as the wearing surface. The other 27 percent would use a thin layer, less than 50 mm (2 in.), of hot-mix asphalt. As the traffic volumes increase, the number of agencies that would consider a thin-surfaced pavement decreases and the number that would use a bituminous surface treatment decreases at a faster rate.

Volume of Trucks

The agencies were asked to identify the volume of trucks for which they would use a bituminous surface treatment. Their responses are shown in Table B-20 in Appendix B and are summarized in Table 19. Figure 25 compares the truck volumes for thin-surfaced pavements shown in Table 13 with those for bituminous surface treatments shown in Table 19. One hundred percent of the agencies responding would use a thin-surfaced pavement for a truck volume of 5 percent or less

TABLE 19

VOLUME OF TRUCKS AS A FACTOR IN CHOOSING BITUMINOUS SURFACE TREATMENT AS THE WEARING SURFACE

Level of Government	Number of Agencies Responding	Percent of Respondents Who Would Use A Bituminous Surface Treatment as the Wearing Surface for A Truck Volume Up to the Percentage Indicated				
		5 or less	6–10	11–15	16–20	>20
Federal	5	100	80	40	40	40
State	9	100	89	56	22	11
County	51	100	63	27	10	8
City	8	100	63	25	25	13
Town	7	100	86	14	0	0
All Levels	80	100	69	30	14	10

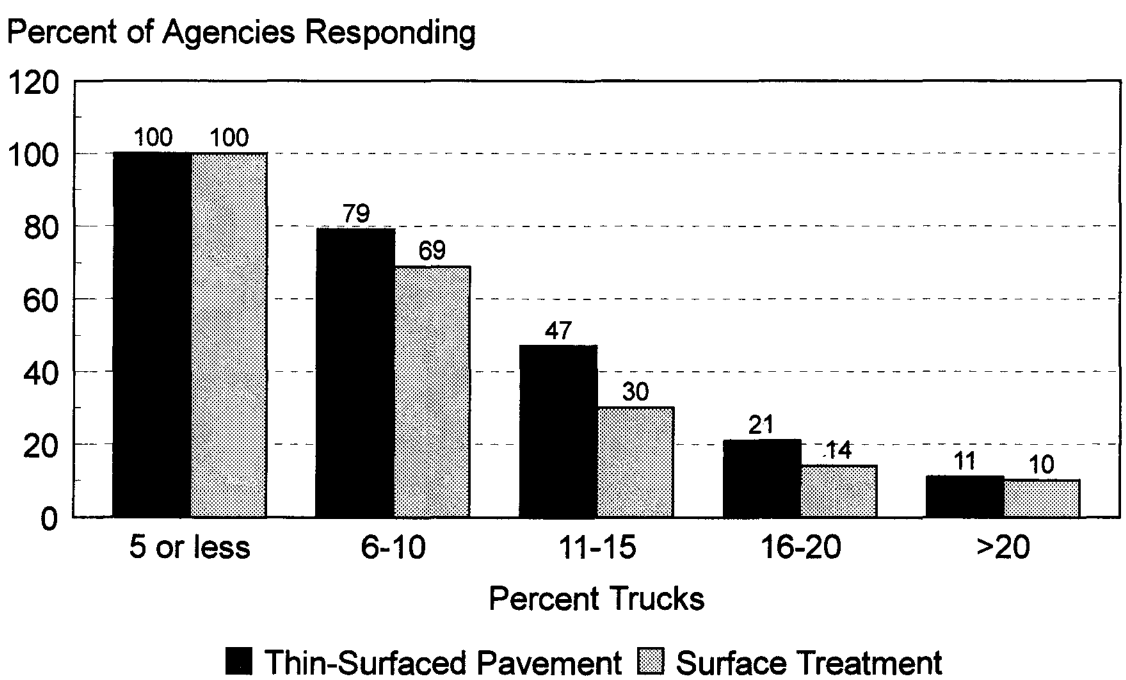


FIGURE 25 Volume of trucks for bituminous surface treatments and thin-surfaced pavements.

TABLE 20
ROAD CLASSIFICATIONS WHERE A BITUMINOUS SURFACE TREATMENT WOULD BE USED

Level of Government	Number of Responses	Percent of Agencies Using a Bituminous Surface Treatment for the Classification Indicated								
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Federal	6	17	0	0	0	100	33	33	67	33
State	14	57	64	43	79	79	71	79	29	21
County	68	66	44	21	41	41	60	57	31	22
City	13	85	8	8	8	46	77	77	31	38
Town	10	90	50	40	40	40	90	60	20	10
All Levels	111	67	41	23	40	50	65	61	32	23
Rank Order		1st	5th	8th	6th	4th	2nd	3rd	7th	8th

Column Headings: (1) Residential access, (2) Farm access, (3) Resource/industrial access, (4) Agricultural land access, (5) Recreational land access, (6) Local collector, (7) Minor collector, (8) Major collector, and (9) Minor arterial.

with a bituminous surface treatment as the wearing surface. Seventy-nine percent would use a thin-surfaced pavement for 6 to 10 percent trucks but only 69 percent would use a bituminous surface treatment for that truck volume. The other 10 percent would use a thin layer, less than 50 mm (2 in.), of hot-mix asphalt. Eleven percent of the agencies would use a thin-surfaced pavement with over 20 percent trucks, and most of those would use a bituminous surface treatment as the wearing surface for that truck volume.

Road Classification

The agencies were asked to indicate the road classifications where they would use a bituminous surface treatment. Their responses are shown in Table B-21 in Appendix B and summarized in Table 20.

Figures 26 and 27 compare the use of a thin-surfaced pavement for each road classification shown in Table 14 with the use of a bituminous surface treatment as the wearing surface for that classification as shown in Table 20. For every classification, except major collector, the percent of the agencies responding who would use a bituminous surface treatment as the wearing surface is slightly less, ranging from 3 to 15 percent. For a major collector, the percent is approximately equal.

Economics

The agencies were asked to indicate the economic reasons for using a bituminous surface treatment as the wearing surface. Their responses are shown in Table B-22 in Appendix B and are summarized in Table 21.

Comparing this table with Table 15, which provides the economic reasons for using a thin-surfaced pavement, indicates that there are no significant differences. The reasons both are selected by the majority of the agencies responding are because they have the lowest first costs and it is all that the agencies can afford on their limited budgets.

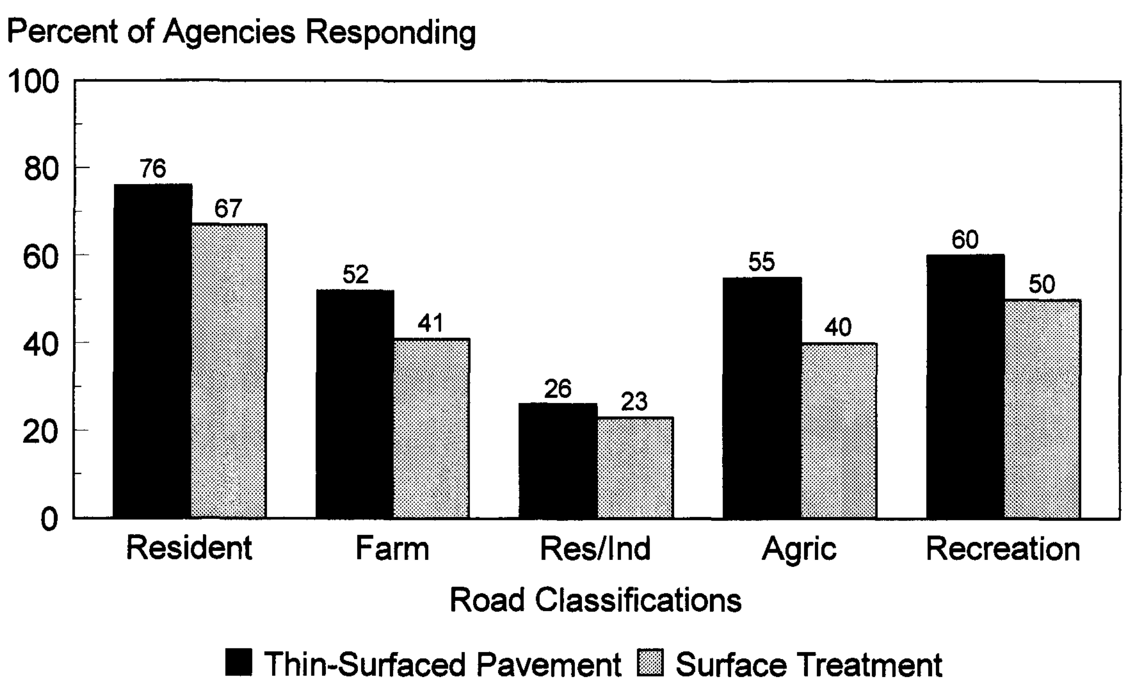


FIGURE 26 Road classification of thin-surfaced pavements and bituminous surface treatments.

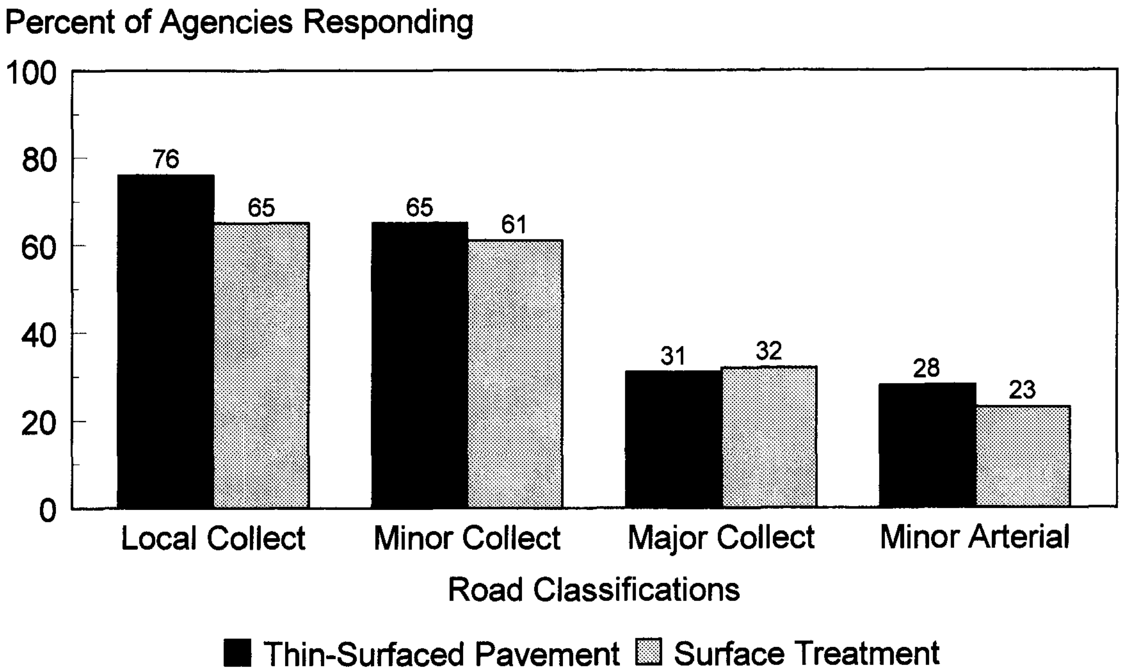


FIGURE 27 Road classification of thin-surfaced pavements and bituminous surface treatments.

TABLE 21

ECONOMIC REASONS FOR USING BITUMINOUS SURFACE TREATMENTS

Level of Government	Number of Agencies Responding	Percent of Agencies Selecting			
		(1)	(2)	(3)	(4)
Federal	9	33	56	0	33
State	13	69	23	15	69
County	73	56	33	27	48
City	12	42	33	17	67
Town	10	40	30	10	60
All Levels	117	53	33	21	52

Column Headings: (1) Lowest first cost, (2) Lowest life-cycle cost, (3) Inexpensive to maintain, and (4) All we can afford.

TABLE 22

OTHER REASONS FOR CONSIDERING BITUMINOUS SURFACE TREATMENTS

Level of Government	Number of Agencies Responding	Percent of Agencies Selecting					
		8E	8F	8G	8H	8I	8J
Federal	10	70	50	10	30	20	10
State	16	75	56	50	50	31	0
County	70	74	43	63	53	27	3
City	13	46	15	38	54	38	15
Town	10	50	80	40	30	20	0
All Levels	119	69	45	52	49	28	4

Column Headings: 8E) Performance experience, 8F) Type of base course, 8G) Ability to apply bituminous surface treatments with in-house forces, 8H) Availability of materials, 8I) Availability of contractors, and 8J) Other.

Other Reasons

In addition to the four factors discussed above, the agencies were offered the options of selecting five other factors they considered in using a bituminous surface treatment as the wearing surface for a thin-surfaced pavement. They were also offered the opportunity to provide any other factor they considered. Their responses to these other five factors are shown in Table B-23 in Appendix B and are summarized in Table 22.

Approximately two-thirds of the agencies responding to this question indicated that experience with bituminous surface treatments in similar situations was a factor in selecting a bituminous surface treatment as the wearing surface. Approximately 50 percent of the agencies cited the type of base course being used, the ability to apply bituminous surface treatments with in-house forces, and the availability of materials as reasons for using a bituminous surface treatment as the wearing surface. Approximately one-fourth of the agencies cited the availability of contractors. Four percent of the agencies cited the type of subgrade soil, whether the roadway had a curb and gutter section, pavement age, pavement condition, and long-term plans.

Summary of the Reasons Used in Selecting a Bituminous Surface Treatment

Traffic volumes, the volume of trucks, the classification of the road, the agency's budget, and experience with bituminous surface treatments in a similar situation are the major considerations used by an agency in selecting a bituminous surface treatment as the wearing surface on a thin-surfaced pavement. Other factors are the ability to apply the bituminous surface treatment with in-house forces, the availability of materials, and the type of base course being used.

APPLICATION OF THIN-SURFACED PAVEMENT AND BITUMINOUS SURFACE TREATMENT CONSIDERATIONS BY AGENCIES

The presentations in the two previous sections discussed each factor separately. However, in actuality, agencies consider several factors together and the influence of one factor on the others when arriving at a decision to use a thin-surfaced pavement or a bituminous surface treatment as the wearing surface. Follow-up telephone contacts were made with approximately one-fourth of the agencies that indicated they used thin-surfaced pavements. This point of the inter-relationship of the factors was emphasized in several of the conversations. The Thurston County Roads and Transportation Services Agency in the State of Washington uses a decision tree that considers, in part, pavement and roadway condition, truck routes, and ADT. (Personal communication, Dave Nichols, Assistant Design Engineer). The City of Brownwood, Texas, has a local ordinance that relates the type of traffic, thickness of the base, and the type of surface. On minor streets and frontage roads, a double bituminous surface treatment is used as the wearing surface. On collectors and thoroughfares, hot-mix asphalt is used as the wearing surface. (Personal communication, R. Keith Pulaski, Assistant Public Works Director). King County Washington Transportation Agency uses a bituminous surface treatment as the wearing surface in rural areas with an ADT of 400 or less and hot- mix asphalt in urban areas and rural areas with a higher ADT. (Personal communication, Jon Cassidy, Supervising Engineer). Caroline County, Maryland, provided a section from their manual that relates road classification and pavement type. Tables 1 and 7 from their manual are shown as Figures C-1 and C-2 in Appendix C. The conversations indicated that, at the local level, there is a close association between classification and traffic volume. Several individuals indicated that they frequently used a bituminous surface treatment where they should be using a hot-mix asphalt wearing surface but that was all their budgets would allow.

THICKNESS DESIGN PROCEDURES

The agencies were asked to identify the thin-surfaced pavement structural or thickness design procedure they use. They were provided with a list of options corresponding to the column headings in Table 23. The responses are shown in Table B-24 in Appendix B and are summarized in Table 23.

Sixty percent of the agencies responding indicated that the thickness and structural design of thin-surfaced pavements was based on experience. Another 35 percent indicated they used the state DOT procedure for their state. The percent using any of the other procedures was very small.

CURRENT PRACTICES FOR SPECIFIC SITUATIONS

The agencies using thin-surfaced pavements were asked to answer questions indicating what they would do for a specific set of conditions. Each question was based on a set of circumstances similar to those encountered by many highway officials. They were instructed to answer the questions as if it was their road in their area with their moisture, temperature, subgrade conditions, material availability, and budget

TABLE 23
THIN-SURFACED PAVEMENT THICKNESS DESIGN PROCEDURE USED

Level of Government	Number of Agencies Responding	Percent of Agencies Responding Selecting Option								
		A	B	C	D	E	F	G	H	I
Federal	7	14	14	14	0	43	0	43	0	14
State	17	53	24	6	0	0	0	35	6	0
County	87	64	8	6	0	0	1	34	1	0
City	14	57	14	21	7	0	0	21	0	0
Town	11	64	9	9	18	9	0	55	0	0
All Levels	136	60	11	8	2	3	1	35	1	1

Column Headings: A) Thickness and structural design based on experience, B) AASHTO Guide for the Design of Pavement Structures, C) Asphalt Institute Method, D) U.S. Army Corps of Engineers Method, E) U.S. Forest Service Method, F) National Stone Association Method, G) State DOT Method, H) Agency Pavement Design Procedure, and I) Other.

constraints. For each situation they were asked to provide the following information:

- Type of subgrade soils generally encountered,
- Type of drainage generally provided,
- Type and thickness of the base material used,
- Type and thickness of the subbase or improved subgrade,
- Type of stabilizing agent used,
- Type and thickness of the wearing surface, and
- The expected performance both with and without preventive maintenance.

The following four situations or cases were presented:

- Case 1—Very low volume farm access road,
- Case 2—Moderate to high volume local access road,
- Case 3—Local collector, and
- Case 4—Low volume industrial/resource access with very heavy trucks.

One hundred fifty-seven agencies provided responses to the questions for one or more of the cases. A list of those agencies and the wearing surface they selected for each case is shown in Table B-25 in Appendix B.

Very Low Volume Farm Access Road-Case 1

This situation is a rural local road providing farm access. The ADT is less than 100 vehicles per day. The truck traffic is about 10 to 15 percent of the ADT and consists of trucks providing services to the farms along the road, (i.e., school bus, milk hauler, feed delivery, fertilizer delivery, snow plows, fire trucks, etc.). The existing road is aggregate surfaced over a native soil base that has deteriorated, becomes easily rutted and corrugated, and is very dusty. The decision has been made to upgrade the road and put a thin hard-wearing surface on it.

A total of 140 agencies provided 151 replies for this case because some agencies provided designs for more than one climatic zone. The wearing surfaces they proposed, sorted by the agency's level of government and climatic region, are shown in Tables B-26 in Appendix B. Table 24 is a summary of the information in Table B-26.

Sixty-two percent of the agencies would provide a bituminous surface treatment for this situation and 9 percent would provide a layer of hot-mix asphalt less than 50 mm (2 in.) for a total of 71 percent providing a thin-surfaced pavement. Most of the remaining 29 percent would provide a layer of hot-mix asphalt equal to or greater than 50 mm (2 in.). The agencies in Climatic Region III are the lowest users of both bituminous surface treatments and thin-surface pavements while the agencies in Climatic Region II and Climatic Region I are the highest users of bituminous surface treatments and thin hot-mix asphalt respectively.

Table B-27 in Appendix B lists the thin-surfaced pavement designs provided by each agency. This table lists the subgrade soils, drainage, wearing surface, base and subbase materials, their thicknesses and stabilizing agents, and expected performance with and without preventive maintenance. Table 25 lists the details for the most frequently used pavement section, which had a double bituminous surface treatment as the wearing surface.

The expected performance ranged from as little as 2 years to more than 10 years. Generally, the expected performance with preventive maintenance was at least 2 years more than the expected performance without preventive maintenance.

Table 26 is a comparison of the percent of agencies indicating they would use a thin-surfaced pavement and a bituminous surface treatment in Case 1 with the percent determined from the responses to the individual factors previously discussed. Based on a traffic volume of less than 100, 87 percent of the agencies previously indicated that they would use a thin-surfaced pavement and 91 percent previously indicated that they would use a bituminous surface treatment. These percentages are higher than the percentage of agencies indicating

TABLE 24

CASE 1: SUMMARY OF WEARING SURFACES

Climatic Region	Number of	Unpaved		Thin-Surfaced Pavement BST		Thin-Surfaced Pavement HMA		HMA = > 2 in.		Other	
(Figure 3)	Responses	No.	%	No.	%	No.	%	No.	%	No.	%
I	18	0	0	9	50	4	22	5	28	0	0
II	53	1	2	42	79	3	6	5	9	2	4
III	38	0	0	16	42	3	8	17	45	2	5
IV	11	0	0	8	73	1	9	2	18	0	0
V	22	1	5	13	59	2	9	5	23	1	5
VI	9	0	0	5	56	1	11	2	22	1	11
Total	151	2	1	93	62	14	9	36	24	6	4

TABLE 25

DETAILS OF MOST FREQUENTLY USED THIN-SURFACED PAVEMENT FOR CASE I

	Number of Agencies			Base Thickness (inches)	
Wearing Surface	Using	With a Crushed Stone or Gravel Base	With a Subbase or Improved Subgrade	Range	Most Frequently Used
Double BST	66	52	34	4 –12	6

TABLE 26

COMPARISON OF THE USES OF THE THIN-SURFACE PAVEMENT AND BITUMINOUS SURFACE TREATMENTS FOR CASE 1

Factor	Source	Thin-Surfaced Pavement Used (%)	Bituminous Surface Treatment Used (%)
	Table 24	71	62
ADT <100	Figure 24	87	91
Vol. of Trucks 10–15%	Figure 25	47	30
Classification-Farm Access	Figure 26	52	41

TABLE 27

CASE 2: SUMMARY OF WEARING SURFACES

Climatic Region	Number of	Unpaved		Thin-Surfaced Pavement				HMA = > 2 in.		Other	
				BST		HMA					
(Figure 3)	Responses	No.	%	No.	%	No.	%	No.	%	No.	%
I	18	0	0	5	28	3	17	10	56	0	0
II	53	0	0	27	51	9	17	14	26	3	6
III	39	0	0	7	18	6	15	24	62	2	5
IV	13	0	0	4	31	4	31	5	38	0	0
V	22	0	0	10	45	3	14	7	32	2	9
VI	10	0	0	3	30	1	10	6	60	0	0
Total	155	0	0	56	36	26	17	66	43	7	5

TABLE 28

DETAILS OF MOST FREQUENTLY USED THIN-SURFACED PAVEMENTS FOR CASE 2

	Number of Agencies			Base Thickness (inches)	
Wearing Surface	Using	With Crushed Stone or Gravel Base	With Subbase or Improved Subgrade	Range	Most Frequently Used
Double BST	39	25	19	4-12	6
1.5 in HMA	23	17	14	4-12	8

that they would use a thin-surfaced pavement and a bituminous surface treatment in Case 1. Conversely, the percentages for the volume of trucks and classification previously indicated are less than those proposed in Case 1. While the percent for an individual factor differs considerably from that proposed for Case 1, if one considers the percentages of all the factors as a range from 52 to 87 percent and 41 to 91 percent, then the 71 percent for thin-surfaced pavements and the 62 percent for bituminous surface treatments are close to the middle of the range.

Moderate to High Volume Local Access Road-Case 2

This situation is a local road providing access to residences, farms, a few small businesses, and a few stores, (dry cleaners, grocery store, video store, hardware store, feed store, etc.). The ADT is between 250 and 350. The truck traffic is about 10 to 15 percent of the ADT and consists of trucks providing services to the homes, farms, and businesses along the road. The existing road was originally an aggregate surface over a native soil base on which a single-application chip seal wearing surface was applied several years ago. The road has deteriorated, and is rutted and potholed. The decision has been made to upgrade the road.

A total of 143 agencies provided 155 replies for this case because some agencies provided designs for more than one climatic zone. The wearing surfaces they proposed, sorted by the agency's level of government and climatic region, are shown in Table B-28 in Appendix B. Table 27 is a summary of the information in Table B-28.

Thirty-six percent of the agencies would provide a bituminous surface treatment for this situation and 17 percent would provide a layer of hot-mix asphalt less than 50 mm (2 in.), for a total of 53 percent providing a thin-surfaced pavement. Forty-three percent of the remaining 47 percent would provide a layer of hot-mix asphalt equal to or greater than 50 mm (2 in.). The agencies in Climatic Region II are the highest users of bituminous surface treatments, while those in Climatic Region III are the lowest users. The agencies in Climatic Region IV are the highest users of thin-hot-mix asphalt.

Table B-29 in Appendix B is a listing of the thin-surfaced pavement designs provided by each agency. This table lists the subgrade soils, drainage, wearing surface, base and subbase materials, and their thicknesses and stabilizing agents, and expected performance with and without preventive maintenance. Table 28 lists the details for the most frequently used

TABLE 29

COMPARISON OF THE USES OF THIN-SURFACED PAVEMENT AND BITUMINOUS SURFACE TREATMENTS FOR CASE 2

Factor	Source	Thin-Surfaced Pavement Used (%)	Bituminous Surface Treatment Used (%)
	Table 27	53	36
ADT 200–400	Figure 24	80	76
Vol. of Trucks 10–15%	Figure 25	47	30
Classification-Local Collector	Figure 27	76	65

TABLE 30

CASE 3: SUMMARY OF WEARING SURFACES

Climatic Region (Figure 3)	Number of Responses	Thin-Surfaced Pavement: Unpaved No.	Unpaved %	BST No.	BST %	HMA No.	HMA %	HMA = > 2 in. No.	HMA = > 2 in. %	Other No.	Other %
I	16	0	0	3	19	2	13	11	69	0	0
II	51	0	0	10	20	6	12	34	67	1	2
III	40	0	0	2	5	4	10	31	78	3	8
IV	14	0	0	1	7	4	29	9	64	0	0
V	18	0	0	4	22	1	6	12	67	1	6
VI	9	0	0	2	22	1	11	6	67	0	0
Total	148	0	0	22	15	18	12	103	70	5	3

pavement section, which had a double bituminous surface treatment as the wearing surface, and the second most frequently used pavement section, which had a 40 mm (1.5 in.) hot-mix asphalt surface.

Table 29 is a comparison of the percent of the agencies who indicated they would use a thin-surfaced pavement and a bituminous surface treatment in Case 2 with the percent determined from the responses to the individual factors previously discussed.

Based on a traffic volume between 200 to 400, 80 percent of the agencies previously indicated that they would use a thin-surfaced pavement and 76 percent indicated that they would use a bituminous surface treatment. These percentages are higher than the percentages of the agencies who indicated that they would use a thin-surfaced pavement and a bituminous surface treatment in Case 2. Likewise, the percentages previously determined for the classification are more than those proposed in Case 2. For this situation, the percentages previously determined from the responses to the individual factors overestimate the percentage of the agencies who would actually use either a thin-surfaced pavement or a bituminous surface treatment.

Local Collector-Case 3

This situation is a local collector with an ADT of about 600 vehicles per day with about 10 to 15 percent trucks. The road collects all the traffic from the other local roads and channels it to a state highway. The road also connects to a county minor arterial and some of the traffic is through traffic going from the county arterial to the state highway. The trucks on the road are about equally divided between 2- or 3-axle, single unit trucks and 3-, 4-, or 5-axle tractor-semitrailer combinations. The existing road is an old aggregate-surfaced road on a native soil base on which, over the years, there has been a cold-mix bituminous surface placed and a couple of chip seal applications (bituminous surface treatments). Presently, the road is severely deteriorated, rutted, raveled, and potholed. Many complaints have been received about the condition of the road. This is an election year and the legislative board has decided to "fix it right, once and for all."

A total of 148 agencies provided replies for this case. The wearing surfaces they proposed, sorted by the agency's level of government and climatic region, are shown in Table B-30 in Appendix B and are summarized in Table 30.

Fifteen percent of the agencies would provide a bituminous surface treatment and 12 percent would provide a thin layer of hot-mix asphalt, for a total of 27 percent. Seventy percent of the agencies would provide a layer of hot-mix asphalt at least 50 mm (2 in.) thick. There is a noticeable decrease in the use of a bituminous surface treatment in Climatic Regions III and IV.

Table B-31 in Appendix B is a listing of the thin-surfaced pavement designs provided by each agency. This table lists the subgrade soils, drainage, wearing surface, base material, stabilizing agent, thickness, subbase material, stabilizing agent, thickness, and expected performance with and without preventive maintenance. Table 31 lists the details for the most frequently used pavement section, which had a double bituminous surface treatment as the wearing surface, and the second most frequently used pavement section which had a 40-mm (1.5 in.) hot-mix asphalt wearing surface. Even though the details for the thin-surfaced pavements are presented, those who would use a thin-surfaced pavement in this situation are in the minority and 70 percent of the responders indicated they would use a thicker layer of hot-mix asphalt.

Table 32 is a comparison of the percent of the agencies who indicated they would use a thin-surfaced pavement and a

TABLE 32

COMPARISON OF THE USES OF THIN-SURFACED PAVEMENT AND BITUMINOUS SURFACE TREATMENTS FOR CASE 3

Factor	Source	Thin-Surfaced Pavement Used (%)	Bituminous Surface Treatment Used (%)
	Table 30	27	15
ADT = 600	Figure 24	69	42
Vol. of Trucks 10–15%	Figure 25	47	30
Classification-Local Collector	Figure 27	76	65

TABLE 33

CASE 4: SUMMARY OF WEARING SURFACES

Climatic Region (Figure 3)	Number of Responses	Unpaved		Thin-Surfaced Pavement BST		Thin-Surfaced Pavement HMA		HMA = > 2 in.		Other	
		No.	%	No.	%	No.	%	No.	%	No.	%
I	16	0	0	6	38	3	19	7	44		0
II	46	5	11	17	37	2	4	21	46	1	2
III	33	4	12	6	18	0	0	21	64	2	6
IV	10	0	0	3	30	0	0	7	70	0	0
V	19	1	5	8	42	0	0	10	53	0	0
VI	10	0	0	5	50	0	0	5	50	0	0
Total	134	10	7	45	34	5	4	71	53	3	2

bituminous surface treatment in Case 3, with the percent determined from the responses to the individual factors previously discussed.

Earlier in this study, 69 percent of the agencies indicated that they would use a thin-surfaced pavement and 42 percent indicated that they would use a bituminous surface treatment with a traffic volume of 600. However, these percentages are more than double the percentage for the agencies responding to Case 3 who indicated that they would use either a thin-surfaced pavement or a bituminous surface treatment in this situation. Likewise, the percentages previously determined for the classification are triple those proposed in Case 3. For this situation, the percentages determined from the previous responses to the individual factors greatly overestimate the percentage of agencies that would actually use either a thin-surfaced pavement or a bituminous surface treatment. The responses to the situation in Case 3 indicates that a thin-surfaced pavement is not the pavement of choice for 70 percent of the responders.

Low-Volume Industrial/Resource Access Road with Very Heavy Trucks-Case 4

This situation is a local road providing industrial/resource access. The ADT is less than 100 vehicles per day. The percentage of trucks is about 25 to 30 percent and consists mainly of one type of truck hauling very heavy loads such as pulp, sand and gravel, coal, or timber.

A total of 121 agencies provided 134 replies for this case. The wearing surfaces they proposed, sorted by the agency's level of government and climatic region, are shown in Table B-32 in Appendix B and are summarized in Table 33.

Thirty-four percent of the agencies responding would provide a bituminous surface treatment and 4 percent would provide a thin layer of hot-mix asphalt, for a total of 38 percent who would provide a thin-surfaced pavement. Fifty-three percent of the agencies would provide a layer of hot-mix asphalt at least 50 mm (2 in.) thick and another 7 percent would leave it as an aggregate surfaced road. There is a noticeable decrease in the use of a thin layer of hot-mix asphalt in all the climatic regions.

Table B-33 in Appendix B is a listing of the thin-surfaced pavement designs provided by each agency. This table lists the subgrade soils, drainage, wearing surface, base and subbase materials, and thickness and stabilizing agents and expected performance with and without preventive maintenance. Table 34 lists the details for the most frequently used pavement section, which had a double bituminous surface treatment as the wearing surface. Even though the details for the thin-surfaced pavements are presented, those who would use a thin-surfaced pavement in this situation are in the minority and 60 percent of the responders indicated they would use a thicker layer of hot-mix asphalt or leave it as an aggregate surfaced road.

In addition, for this situation, the agencies were asked if they imposed seasonal limitations on the use of the roads by the trucks. Table 35 is a summary of the responses.

As might be expected, some of the agencies in Climatic Regions II, III, V, and VI, which experience thawing cycles, impose a seasonal limitation. However, seasonal limitations are used by about 50 percent of the agencies in Climatic Regions III and VI and by about one-third of the agencies in the other two regions. Some agencies indicated that imposing a seasonal limitation on a road is not a viable option because local businesses, industries, and farms depend on the daily delivery or shipment of their materials or goods by trucks. To impose a seasonal limitation would force these operations to close, layoff their employees, etc. Furthermore, agencies that proposed using a thin-surfaced pavement for this case use a seasonal limitation in about the same proportions as the

TABLE 34

DETAILS OF MOST FREQUENTLY USED THIN-SURFACED PAVEMENTS FOR CASE 4

	Number of Agencies			Base Thickness (inches)	
Wearing Surface	Using	With Crushed Stone or Gravel Base	With Subbase or Improved Subgrade	Range	Most Frequently Used
Double BST	32	23	22	4–24	12

TABLE 35

SEASONAL LIMITATION ON THE USE OF THE ROADS BY HEAVY TRUCKS

	Number of Agencies					
Climatic Region (Figure 3)	Responses	Total Imposing	Those using Thin-Surfaced Pavements	Weight	Tire Pressure	Other
I	16	2	1	2	0	0
II	46	12	7	10	1	1
III	33	18	4	18	2	0
IV	10	1	0	1	0	0
V	19	6	3	6	1	0
VI	10	5	3	4	0	1

TABLE 36

COMPARISON OF THE USES OF THIN-SURFACED PAVEMENT AND BITUMINOUS SURFACE TREATMENTS FOR CASE 4

Factor	Source	Thin-Surfaced Pavement Used (%)	Bituminous Surface Treatment Used (%)
	Table 33	37	33
ADT <100	Figure 24	87	91
Vol. of Trucks 25–30%	Figure 25	11	0
Classification-Industrial/Resource Access	Figure 26	26	23

agencies who would use a thicker pavement or leave the road as an aggregate surfaced road.

Table 36 is a comparison of the percent of the agencies who indicated they would use a thin-surfaced pavement and a bituminous surface treatment in Case 4 with the percent determined from the responses to the individual factors previously discussed.

There is fairly close agreement between the number of agencies who said they would use a thin-surfaced pavement and a bituminous surface treatment in this situation with the percentages previously determined for the classification as an industrial/resource access road. However, there is no agreement between the percentages in Case 4 and the percentages obtained from the traffic volume and truck volume graphs.

CHAPTER FOUR

CONCLUSIONS

Approximately 60 percent of the agencies responding to the survey who use thin-surfaced pavements are at the county level of government. The next largest group of agencies who use thin-surfaced pavements are the state and city levels of government, which each comprise approximately 13 percent of the users, and the smallest group of agencies responding to the survey are the federal and town levels of government, which each comprise approximately 7 percent of the users. The largest percentage of responders who use thin-surfaced pavements was 34 percent in AASHTO Climatic Region II, followed by Climatic Region III (26 percent). The smallest percentage were in Climatic Region VI (6 percent) and Climatic Region IV (9 percent). (The location of the AASHTO Climatic Regions is shown in Figure 3.)

There are no thin-surfaced pavement structural or thickness design methodologies in the United States. The procedures currently in use are adaptations of the Corps of Engineer's Method, which had its beginning as an airfield pavement design procedure during World War II, and the AASHTO methodology, which is based on the results of the AASHO Road Test conducted in the late 1950s. Both of these procedures have been adapted by the Corps of Engineers, National Stone Association, United States Forest Service, and AASHTO for aggregate-surfaced roads and low-volume roads. Both procedures evaluate subgrade soil support strength, traffic loading, and environmental effects, which are key factors to be considered in the structural design of thin-surfaced pavements. The National Stone Association adaptation of the Corps of Engineer's Method for their Flexible Pavement Design Procedure is the simplest to use. The adaptation demonstrated in Figure 7 is also relatively easy to use. The AASHTO Pavement Design Guide has a Flexible Pavement Design Catalog for Low-Volume Roads but the pavement thickness is expressed in terms of the Structural Number, which requires at least one further calculation to obtain a pavement section. As might be expected, because the root procedures were not developed for the structural or thickness design of thin-surfaced pavements, these adaptations have limitations. A review made by Yapp, Steward, and Whitcomb of the adaptations of both of the root methods for use by the US Forest Service on aggregate-surfaced roadways, but not as a thin-surfaced pavement, identified one or more of the following as shortcomings: that the procedure had not been validated with field experience, could not incorporate seasonal haul requirements, was not valid for aggregate-surfaced or earth roads, and does not consider risk and reliability concepts.

Australia, South Africa, and the United Kingdom have each developed design procedures and design catalogs that can be used for thin-surfaced pavements in hot or tropical climates where there is no need to consider the effects of freezing and thawing of the subgrade. However, the differences in climate, soils, or economic development between these locations and the temperate zone of the North American continent prevent the direct transfer of these procedures to the United States and Canada. Based on the work done overseas, however, one can conclude that it is technically possible to develop a catalog of thin-surfaced pavement sections suitable for use in the United States. The catalog should be regionalized to account for the varying environmental conditions across the country.

Sixty percent of the agencies responding to the questionnaire indicated that they based the thickness and structural design of their pavements on experience and not on a published procedure. This percentage was fairly consistent at all levels of government except at the federal level. The federal responders indicated they used primarily the US Forest Service Method or the appropriate state DOT procedure. Thirty-five percent of the agencies cited their state DOT pavement design procedure as the basis for their design of thin-surfaced pavements.

Fifty-five percent of the agencies responding indicated that the persons selecting the thin-surfaced pavement projects in their agency are graduate or professional engineers. Another 20 percent indicated that the person selecting the thin-surfaced projects had highway design, construction, or maintenance experience. More than 61 percent of the agencies indicated that their thin-surfaced pavements were designed by graduate or professional engineers. Another 14 percent indicated that the person designing thin-surfaced pavements had highway design, construction, or maintenance experience.

Thirty-nine percent of the agencies indicated that they had the capability to perform all the basic testing for pavement design and construction. Twenty-six percent indicated that they performed no sampling and testing, and the remaining agencies indicated that they performed varying amounts of sampling and testing. The town level of government had the lowest field and laboratory testing capability, while the state level of government had the highest.

Approximately 40 percent of the agencies have a Pavement Management System and a Preventive Maintenance Program, 30 percent have a Maintenance Management System, and 20 percent of the agencies have all three programs. There was not a wide variation among the different levels of government.

Forty-six percent of the agencies using thin-surfaced pavements indicated that they were constructed by contractors, 34 percent were constructed by agency forces, 26 percent by a mix of vendors and agency forces, and the remaining by vendors. Most agencies use only one means of accomplishing the work, while about 25 percent of the agencies use two or more means of accomplishing the work.

TABLE 37

PERCENTAGE OF AGENCIES RESPONDING WHO WOULD USE A THIN-SURFACED PAVEMENT AND A BITUMINOUS SURFACE TREATMENT FOR THE CIRCUMSTANCES INDICATED

Circumstance		Percentage of Agencies Who Would Use	
		Thin-Surfaced Pavement	Bituminous Surface Treatment
ADT	<100	87	91
	100–199	86	88
	200–399	80	76
	400–999	69	42
	1000–1999	39	17
	>2000	22	5
Percent trucks	<5	100	100
	6–10	79	69
	11–15	47	30
	16–20	21	14
	>20	11	10
Classification	Residential	76	67
	Farm	52	41
	Resource/Industrial	26	23
	Agriculture	55	40
	Recreation	60	50
	Local Collector	76	65
	Minor Collector	65	61
	Major Collector	31	32
	Minor Arterial	28	23

There is no one single factor that influences the decision to apply a thin-surfaced pavement to a section of road. Agencies indicated that it is the interrelationship of all the factors, consisting of the road classification, traffic volume, amount of trucks, local policy, and the funding available. Within this mix however, traffic volume and available funding were cited about the same number of times as being the most important factors considered in deciding to apply a thin-surfaced pavement to a section of road. These were followed in importance by the classification of the road and the amount of trucks. The factors least frequently cited were local policies and the ease of implementing a thin-surfaced treatment. Sixty-one percent of the agencies indicated that they used a thin-surfaced pavement because they have the lowest first cost for a hard surface pavement and 54 percent indicated that it was all they could afford on their limited budget. Only 27 percent indicated that thin-surfaced pavements were selected because they provided the lowest life-cycle costs. The factors considered in selecting between a bituminous surface treatment or a layer of hot-mix asphalt less than 50 mm (2 in.) thick as the wearing surface for a thin-surfaced pavement are traffic volume, amount of trucks, classification of the road, and available funding.

Table 37 shows the percentage of the agencies responding who would use a thin-surfaced pavement and a bituminous surface treatment for the traffic volumes, percent trucks, and roadway classifications indicated.

The table indicates how the agencies responded when presented with one factor to consider. This study found, however, that agencies consider the interrelationship of all the factors consisting of the road classification, traffic volume, amount of trucks, local policy and the funding available in arriving at the decision to apply a thin-surfaced pavement to a road and in deciding whether the wearing surface will be a bituminous surface treatment or a thin layer of hot-mix asphalt. The agencies responding to the survey were presented with four cases in which the interrelationship of several factors had to be considered in deciding whether a thin-surfaced pavement might be appropriate. These cases were:

- Very low-volume farm access road,
- Moderate to high-volume local access road,
- Local collector, and
- Low-volume industrial/resource access with heavy trucks.

Based on their responses to these situations, the following conclusions can be drawn:

- Over 70 percent of the agencies would use a thin-surfaced pavement on a farm access road with an ADT of less than 100, about 50 percent would use a thin-surfaced pavement on a local collector with an ADT between 250 and 350, and 27 percent would use a thin-surfaced pavement on a local collector with about 600 vehicles per day.
- There was considerable variation between the number of agencies that indicated they would use a thin-surfaced pavement for a given consideration factor, (e.g., volume of traffic, road classification, etc.) and the number of agencies who proposed using a thin-surfaced pavement for the four specific cases. Generally, the number of agencies proposing to use a thin-surfaced pavement in a specific situation was less than the number who indicated that they would use a thin-surfaced pavement for the given consideration factor.
- The pavement designs proposed for each of the cases varied widely among the agencies in the same climatic region.

It was not uncommon to have one agency propose using a single-application bituminous surface treatment on a crushed stone base and another agency in the same climatic region with the same subgrade conditions propose using 63.5 mm (2.5 in.) or more of hot-mix asphalt for the same situation. In the situation involving the low-volume resource/industrial access road, 7 percent of the agencies proposed leaving it with an aggregate surface, 34 percent would apply a bituminous surface treatment, 4 percent would place a thin-layer less than 50 mm (2.0 in.) thick of hot-mix asphalt, and 53 percent would apply 50 mm (2.0 in.) or more of hot-mix asphalt. When one considers the variations proposed in the type of base and subbase materials and thicknesses, and stabilizing agents, there were very few, if any, duplications in the pavement designs proposed by the agencies. If 120 agencies responded to a situation, there were nearly 120 unique designs proposed. Some agencies would underdesign the pavement, and others would overdesign the pavement. Neither of these extremes is cost-effective.

- Agencies in climatic regions II, III, V, and VI, shown in Figure 3, which experience thawing cycles, impose a seasonal limitation. About 50 percent of the agencies in climatic regions III and VI do so and about one-third in the other two regions. Those agencies that proposed using a thin-surfaced pavement use a seasonal limitation in about the same proportions as the agencies who would use a thicker pavement or leave the road as an aggregate-surfaced road. Some agencies indicated that imposing a seasonal limitation on a road is not a viable option because local businesses, industries, and farms depend on the daily delivery or shipment of their materials or goods by trucks. To impose a seasonal limitation would force these operations to close, layoff their employees, and face other hardships.

Two areas of further study are suggested. There currently is no thin-surfaced pavement structural or thickness design methodology suitable for use in the United States. One area of further study is to consider the development of such a methodology, possibly modeled after the approach used by South Africa and the United Kingdom in developing procedures. The second area is to provide information on the cost-effective approaches to the design, construction, and preventive maintenance of thin-surfaced pavements to local governments. The survey found that the local governments are the largest users of thin-surfaced pavements, yet, as a group, they have the least amount of technical training. Consideration should be given to modeling any effort of this nature on some of the very successful programs provided by the Technology Transfer Centers.

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APPENDIX A

Questionnaire

NCHRP Project 20-5, Topic 27-08

THIN-SURFACED PAVEMENTS

QUESTIONNAIRE

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1. GENERAL INFORMATION
   Agency:____
   Address:____
   City:__________________State/Prov.__________Zip_______
   Person Compiling Response:____________________________
   Title:________________Organizational Location:_____________
   Phone:____________________Fax:____________________

2. PURPOSE

The purpose of this questionnaire is to obtain information on your agency's current practices regarding thin-surfaced pavement project selection and structural design and to determine how it considers the following factors when it decides to apply a thin-surfaced pavement to a road.

- Climatic conditions,
- traffic volumes and weights
- political realities and public concerns,
- life-cycle cost and first costs,
- materials availability,
- performance characteristics,
- subgrades and drainage, and
- use of recycled materials.

3. DEFINITIONS

AASHTO. The American Association of State Highway and Transportation Officials.

ADT. The average daily traffic on the road. As a rule of thumb, if there is one vehicle per minute during the peak hour, the ADT is about 400 vehicles per day.

CBR. California Bearing Ratio. A measure of the support value of the subgrade determined by conducting the California Bearing Ratio penetration test on the subgrade.

Chemical stabilization. A chemical in the form of lime, lime fly-ash, calcium, sodium or magnesium chloride, portland cement or an asphalt emulsion is added to locally available material to increase its strength.

First Cost. The initial design and construction cost of a pavement.

Full depth reclamation. A recycling method where all of the existing wearing surface and a predetermined amount of the underlying materials are pulverized, an additive may be introduced and the material is shaped and compacted.

Life-Cycle Cost. The cost to design, build and maintain a pavement over a specific period of time.

Maintenance Management System. A comprehensive coordinated set of activities associated with the planning, budgeting, coordination, and execution of the numerous tasks involved in maintaining the highway and bridge infrastructure. Typically includes budgeting, work planning, personnel, equipment, scheduling, accomplishment reporting and accounting subsystems.

Pavement Management System. A comprehensive, coordinated set of activities associated with the planning, design, construction, maintenance, and evaluation of pavements.

Preventive Maintenance. Planned maintenance activities done to prevent or delay future pavement deterioration. Typical pavement preventive maintenance activities are crack and joint filling and sealing, slurry seals, micro-surfacing, chip seals, and thin hot mix asphalt overlays which are performed cyclically.

Surface Treatment. A single or double application chip seal, a slurry seal or micro surfacing.

Thin-surfaced pavement. Either a single or multiple application surface treatment over an unbound base, or a layer of hot mix asphalt less than 2 inches thick over an unbound base. A calcium chloride stabilized base is considered to be an "unbound" base because of the weak cementation.

Vendor-in-Place. The purchase price of the materials for a surface treatment or hot mix asphalt includes the application or placement of the product by the vender (seller). Frequently, the vendor provides the specialized equipment and experienced personnel to operate the equipment and the agency forces provide the other activities, (i.e., surface preparation, traffic control, grading shoulders, and possibly trucking, etc.).

Classifications:

Residential Access. Provides access to residences. The traffic volume generated depends on the number of residencies. Year around access for fire trucks, ambulances, and school buses must be provided.

Farm Access. Provides access to a farm's center of operation including the residence. Traffic volume is generally low, but may include occasional heavy trucks and farm equipment.

Resource/Industrial Access. Provides access to industrial, logging and mining operations. Traffic volume can vary and include heavy trucks and significant numbers of employees' cars.

Agricultural Land Access. Provides access to farm land. Traffic volumes are low and vary seasonally.

Recreational Land Access. Provides access to recreational land including seasonal dwellings and parks. Traffic volume can vary with the type of recreation facility and season of the year, and may include recreational vehicles.

Local Collector. Collects traffic from roads of the other classifications and channels it to higher level roads.

Minor Collector. Provides service to and connects smaller communities.

Major Collector. Serves county seats and larger towns not served by the arterial system.

Minor Arterial. Links cities, larger towns and major traffic generators.

4. Does your agency design, construct or maintain thin-surfaced pavements?

❑ Yes ❑ No

If No, thank you for your willingness to participate, but the survey questionnaire is for those agencies who have thin-surfaced pavements. Please return the questionnaire to address listed on page 22. Thank You.

If Yes, please continue.

5. Information About Your Agency

A. Your agency is at what level of government? Check off one box.

❑ Federal	❑ Town
❑ State or Province	❑ Village
❑ County	❑ Other________

B. What is the background of the person(s) responsible for ***selecting*** the pavement projects in your agency? Check off one box.

❑ (1) Elected or appointed official(s) without a background or experience in highways, (could be one individual or a board).
❑ (2) Highway construction or maintenance experience, but no formal technical training.
❑ (3) Highway construction or maintenance experience, supplemented by workshops and seminars.
❑ (4) Two years formal education in highway, construction or engineering technology.
❑ (5) Graduate or professional engineer with highway design, construction or maintenance experience.

C. What is the background of the person(s) responsible for ***designing*** the pavement projects in your agency? Check off one box.

❑ (1) Designs are prepared by consultants hired by the agency.
❑ (2) Recommendations are made by a local contractor or vendor.
❑ (3) Elected or appointed official without a background or experience in highways.
❑ (4) Highway construction or maintenance experience, but no formal technical training.
❑ (5) Highway construction or maintenance experience, supplemented by workshops and seminars.
❑ (6) Two years formal education in highway, construction or engineering technology.
❑ (7) Graduate or professional engineer with highway design, construction or maintenance experience.

D. What field and laboratory testing does your agency do?
Check off as many boxes as are appropriate.

- ❑ (1) None.
- ❑ (2) Digs test pits and take samples.
- ❑ (3) Performs CBR tests on the subgrade.
- ❑ (4) Performs CBR tests on the base.
- ❑ (5) Performs resilient modulus testing.
- ❑ (6) Does sieve analysis and determines moisture contents.
- ❑ (7) Performs compaction tests.
- ❑ (8) Performs all the basic testing required for pavement design and construction.

E. Who constructs the thin-surfaced pavements for your agency?
Check off as many boxes as are appropriate.

- ❑ (1) Vendors who provide the paving materials.
- ❑ (2) Construction contractors.
- ❑ (3) Agency forces.
- ❑ (4) A mix of vendor and agency forces.

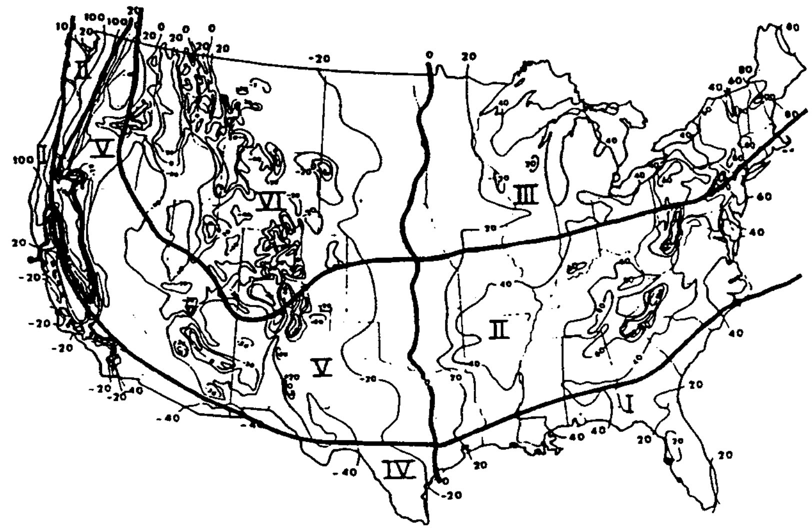
F. Does your agency have a:

Maintenance management system? ❑ Yes ❑ No
Pavement management system? ❑ Yes ❑ No
Preventive maintenance program for thin surfaced pavements? ❑ Yes ❑ No

6. Climatic Conditions

Using the map on page 6 of this questionnaire, please identify the climatic region in which you are located and check the appropriate box below. For Canadian agencies, please extrapolate the zone boundaries north, to identify your climatic region.

- ❑ Region I Wet, no freeze
- ❑ Region II Wet, freeze-thaw cycling
- ❑ Region III Wet, hard-freeze, spring thaw
- ❑ Region IV Dry, no freeze
- ❑ Region V Dry, freeze thaw
- ❑ Region VI Dry, hard-freeze, spring thaw



REGION	CHARACTERISTICS
I	Wet, no freeze
II	Wet, freeze – thaw cycling
III	Wet, hard-freeze, spring thaw
IV	Dry, no freeze
V	Dry, freeze – thaw cycling
VI	Dry, hard freeze, spring thaw

The six climatic regions in the United States
(From AASHTO Guide for Design of Pavement Structures, 1993, Page II-70)

7. Thin surfaced Pavement Project Selection Considerations

Given that a section of road needs work, what factors does your agency consider when it decides to apply a thin-surfaced pavement to the road, rather than leaving it as an aggregate surface or building a thicker pavement? Please check the box for the factors you selected and rank them in order of importance, with 1 being the most important. If two factors have equal importance, assign the same number to both factors. Please circle the appropriate number.

☐ A. Traffic Volume Rank 1 2 3 4 5 6 7

If you checked Traffic Volume, for which traffic levels would you consider a thin-surfaced pavement? Check off as many boxes as are appropriate.

☐ ADT of less than 100
☐ ADT of 100 or more, less than 200
☐ ADT of 200 or more, less than 400
☐ ADT of 400 or more, less than 1000
☐ ADT of 1000 or more, less than 2000
☐ ADT greater than 2000

☐ B. Volume of Trucks Rank 1 2 3 4 5 6 7

If you checked Volume of Trucks, for which of the following volume of trucks, as a percent of ADT, would you consider a thin-surfaced pavement? Check off as many boxes as are appropriate.

☐ Less than 5% of ADT
☐ 6% to 10%
☐ 11% to 15%
☐ 16% to 20 %
☐ Over 20%

☐ C. Road Classification Rank 1 2 3 4 5 6 7

If you checked Road Classification above, for which classifications would you consider a thin-surfaced pavement on a road? Please refer to the definitions on page 2. Check off as many boxes as are appropriate.

☐ (1) Residential Access ☐ (6) Local Collector
☐ (2) Farm Access ☐ (7) Minor Collector

☐ (3) Resource/Industrial Access ☐ (8) Major Collector
☐ (4) Agricultural Land Access ☐ (9) Minor Arterial
☐ (5) Recreational Land Access

☐ D. Costs Rank 1 2 3 4 5 6 7

If you checked Costs above, for which of the following reasons does your agency consider thin-surfaced pavements? Check off as many boxes as are appropriate.

☐ (1) They have the lowest first cost for a hard surfaced pavement.
☐ (2) We have found that they provide the lowest-life cycle cost.
☐ (3) They are inexpensive to maintain.
☐ (4) It is all we can afford on our limited budget.

☐ E. Public Policy Rank 1 2 3 4 5 6 7

If you checked Public Policy above, please indicate the nature of the public policy. Check off as many boxes as are appropriate.

☐ (1) To eliminate dust and provide a smooth surface, the legislative or executive body, (town board, county legislature, county manager, etc) has decided that all our roads will have a hard surface consisting of a thin-surfaced pavement.
☐ (2) The legislative or executive body has decided that all the roads with permanent residents or businesses will have a hard surface.
☐ (3) Other (please describe)____________________
____
____

☐ F. Ease of Implementation Rank 1 2 3 4 5 6 7

If you checked Ease of Implementation above, please indicate the reasons why. Check off as many boxes as are appropriate.

☐ (1) Our personnel are capable of designing thin-surfaced pavements.
☐ (2) Thin-surfaced pavements can be constructed by our own crews.
☐ (3) The specifications or purchase order for vendor-in-place paving or construction contracts are simple to prepare.

☐ G. Other (please describe) Rank 1 2 3 4 5 6 7
____
____

8. Thin Pavement Wearing Surface Considerations

What factors does your agency consider in deciding between a surface treatment and a thin surface course (less than 2 inches) of hot mix asphalt for a wearing surface?

❑ A. Traffic Volumes

If you checked Traffic Volume, for which traffic levels would you consider a surface treatment? Check off as many boxes as are appropriate.

❑ ADT of less than 100
❑ ADT of 100 or more, less than 200
❑ ADT of 200 or more , less than 400
❑ ADT of 400 or more, less than 1000
❑ ADT of 1000 or more, less than 2000
❑ ADT greater than 2000

❑ B. Volume of Trucks

If you checked Volume of Trucks, for which of the following volume of trucks, as a percent of ADT, would consider a surface treatment? Check off as many boxes as are appropriate.

❑ Less than 5% of ADT
❑ 6% to 10%
❑ 11% to 15%
❑ 16% to 20 %
❑ Over 20%

❑ C. Road Classification

If you checked Road Classification, for which classifications would you consider a surface treatment on a road? Please refer to the definitionson page 2 for an explanation of each classification. Check off as many boxes as are appropriate.

❑ (1)	Residential Access	❑ (6)	Local Collector
❑ (2)	Farm Access	❑ (7)	Minor Collector
❑ (3)	Resource/Industrial Access	❑ (8)	Major Collector
❑ (4)	Agricultural Land Access	❑ (9)	Minor Arterial

❑ (5) Recreational Land Access

❑ D. Costs

If you checked Costs above, for which of the following reasons does your agency consider thin-surfaced pavements? Check off as many boxes as are appropriate.

❑ (1) They have the lowest first cost for a hard surfaced pavement.
❑ (2) We have found that they provide the lowest-life cycle cost.
❑ (3) They are inexpensive to maintain.
❑ (4) It is all we can afford on our limited budget.

❑ E. Performance experience for similar conditions.

❑ F. Type of base course being used.

❑ G. Ability to apply surface treatments with in-house forces.

❑ H. Availability of materials.

❑ I. Availability of contractors to do the work.

❑ J. Other (please describe)__________________

____

9. Pavement Structural Design

What thin-surfaced pavement structural or thickness design procedure do you use? Select one box.

❑ A. Thickness and structural design based on experience.
❑ B. AASHTO Guide for the Design of Pavement Structures (year of issue)_____
❑ C. Asphalt Institute Method
❑ D. U.S. Army Corps of Engineers Method
❑ E. U.S. Forest Service Method
❑ F. National Stone Association Method
❑ G. State DOT Method (please identify state)_______________
❑ H. Agency Pavement Design Procedure (please provide a copy)
❑ I. Other (please identify)______________________________

The next four, and final, questions are designed to find out what you would do for a specific set of conditions. Each question is based on a set of circumstances similar to those encountered by many highway officials. Answer the questions as if this was your road in your area with your moisture, temperature, subgrade conditions, material availability, and budget constraints.

10. Case No. 1-This is a rural local road providing farm access. The ADT is less than 100 vehicles per day. The truck traffic is about 10%-15% of the ADT and consist of trucks providing services to the farms along the road, (i.e., school bus, milk hauler, feed delivery, fertilizer delivery, snow plows, fire trucks, etc). The existing road is aggregate surfaced over a native soil base which has deteriorated, becomes easily rutted and corrugated and is very dusty. The decision has been made to upgrade the road and put a thin hard wearing surface on it. What would you do? Please select the appropriate answers below.

☐ A. Have no experience with this situation and cannot answer questions.

B. Please indicate the type of subgrade soils which you generally encounter and for which you are providing the following thin-surfaced pavement design. Select one box.

- ☐ Mainly coarse grained soils, sands and gravels.
- ☐ Mainly fined grained soils, silts and clays.
- ☐ Expansive or swelling clays
- ☐ Both, coarse and fine grained soils
- ☐ Other______________________________

C. What drainage would you provide? Check off as many boxes as are appropriate.

- ☐ Build roadbed higher than surrounding topography
- ☐ Build a crown on the pavement
- ☐ Ditches
- ☐ Edge of pavement underdrains
- ☐ Drainable base beneath the wearing surface
- ☐ Other______________________________

D. What type of base would you provide beneath the wearing surface? Check off one box.

- ☐ Native soil
- ☐ Run-of-bank gravel
- ☐ Crushed stone or crushed gravel
- ☐ Reclaimed asphalt pavement (RAP)
- ☐ Local material chemically stabilized
- ☐ Full depth reclamation

E. How thick would you make the base? Please circle the thickness on the scale below.

4 6 8 10 12 14 16 18 20 22 24

Thickness of base in inches

F. If you checked local material chemically stabilized for the base, what would you use as the stabilizing agent? Check off one box.

☐ Lime	☐ Lime fly-ash
☐ Portland cement	☐ Asphalt emulsion
☐ Calcium chloride	☐ Sodium chloride
☐ Magnesium chloride	☐ Other ____________

G. Would you use a subbase or improved subgrade? ☐ Yes ☐ No

H. If Yes, what material would you use for the subbase or improved subgrade? Check off one box.

- ☐ Run-of-bank gravel
- ☐ Crushed stone or crushed gravel
- ☐ Reclaimed asphalt pavement (RAP)
- ☐ Local material chemically stabilized
- ☐ Full depth reclamation

I. How thick would you make the subbase or improved subgrade? Please circle the thickness on the scale below.

4 6 8 10 12 14 16 18 20 22 24

Thickness of subbase or improved subgrade in inches

J. If you checked local material chemically stabilized for the subbase or improved subgrade, what would you use as the stabilizing agent? Check off one box.

- ❑ Lime
- ❑ Portland cement
- ❑ Calcium chloride
- ❑ Magnesium chloride
- ❑ Lime fly-ash
- ❑ Asphalt emulsion
- ❑ Sodium chloride
- ❑ Other ______________

K. What would you use as the wearing surface? Check off one box.

- ❑ Single application chip seal
- ❑ Double application chip seal
- ❑ Slurry seal
- ❑ Micro surfacing
- ❑ Hot mix asphalt
- ❑ Other (please specify)______________________

L. If you selected, hot mix asphalt, how thick would you make it?

- ❑ 1 inch or less
- ❑ 1-1/4 inch
- ❑ 1-1/2 inch
- ❑ 1-3/4 inch
- ❑ 2 inches

M. Based on your observations and experience, how many years of service would you obtain from this pavement before it deteriorated to a poor condition assuming you provided **regular preventive pavement maintenance**?

- ❑ Less than 2 years
- ❑ 2 to 4 years
- ❑ 5 to 6 years
- ❑ 7 to 8 years
- ❑ 9 to 10 years
- ❑ Over 10 years

N. Based on your observations and experience, how many years of service would you obtain from this pavement before it deteriorated to a poor condition assuming that **pavement maintenance was not provided?**

- ❑ Less than 2 years
- ❑ 2 to 4 years
- ❑ 5 to 6 years
- ❑ 7 to 8 years
- ❑ 9 to 10 years
- ❑ Over 10 years

11. Case No. 2-This is a local road providing access to residences, farms, a few small businesses, and a few stores, (dry cleaners, grocery store, video store, hardware store, feed store, etc). The ADT is between 250 and 350 vehicles per day. The truck traffic is about 10%-15% of the ADT and consist of trucks providing services to the homes, farms and businesses along the road. The existing road was originally an aggregate surface over a native soil base on which a single application chip seal wearing surface was applied several years ago. The road has deteriorated, and is rutted and potholed. The decision has been made to upgrade the road. What would you do? Please select the appropriate answers below.

❑ A. Have no experience with this situation and cannot answer questions.

B. Please indicate the type of subgrade soils which you generally encounter and for which you are providing the following thin-surfaced pavement design. Select one box.

- ❑ Mainly coarse grained soils, sands and gravels.
- ❑ Mainly fined grained soils, silts and clays.
- ❑ Expansive or swelling clays
- ❑ Both, coarse and fine grained soils
- ❑ Other________________________________
____

C. What drainage would you provide? Check off as many boxes as are appropriate.

- ❑ Build roadbed higher than surrounding topography
- ❑ Build a crown on the pavement
- ❑ Ditches
- ❑ Edge of pavement underdrains
- ❑ Drainable base beneath the wearing surface
- ❑ Other________________________________
____

D. What type of base would you provide beneath the wearing surface? Check off one box.

- ❑ Native soil
- ❑ Run-of-bank gravel
- ❑ Crushed stone or crushed gravel
- ❑ Reclaimed asphalt pavement (RAP)

- ❑ Local material chemically stabilized
- ❑ Full depth reclamation

E. How thick would you make the base? Please circle the thickness on the scale below.

4 6 8 10 12 14 16 18 20 22 24

Thickness of base in inches

F. If you checked local material chemically stabilized for the base, what would you use as the stabilizing agent? Check off one box.

❑ Lime	❑ Lime fly-ash
❑ Portland cement	❑ Asphalt emulsion
❑ Calcium chloride	❑ Sodium chloride
❑ Magnesium chloride	❑ Other ______________

G. Would you use a subbase or improved subgrade? ❑ Yes ❑ No

H. If Yes, what material would you use for the subbase or improved subgrade? Check off one box.

- ❑ Run-of-bank gravel
- ❑ Crushed stone or crushed gravel
- ❑ Reclaimed asphalt pavement (RAP)
- ❑ Local material chemically stabilized
- ❑ Full depth reclamation

I. How thick would you make the subbase or improved subgrade? Please circle the thickness on the scale below.

4 6 8 10 12 14 16 18 20 22 24

Thickness of subbase or improved subgrade in inches

J. If you checked local material chemically stabilized for the subbase or improved subgrade, what would you use as the stabilizing agent? Check off one box.

❑ Lime	❑ Lime fly-ash
❑ Portland cement	❑ Asphalt emulsion

❑ Calcium chloride	❑ Sodium chloride
❑ Magnesium chloride	❑ Other ______________

K. What would you use as the wearing surface? Check off one box.

- ❑ Single application chip seal
- ❑ Double application chip seal
- ❑ Slurry seal
- ❑ Micro surfacing
- ❑ Hot mix asphalt
- ❑ Other (please specify)________________________

L. If you selected, hot mix asphalt, how thick would you make it?

❑ 1 inch or less	❑ 1-1/2 inch	❑ 2 inches
❑ 1-1/4 inch	❑ 1-3/4 inch	

M. Based on your observations and experience, how many years of service would you obtain from this pavement before it deteriorated to a poor condition assuming you provided **regular preventive pavement maintenance**?

❑ Less than 2 years	❑ 7 to 8 years
❑ 2 to 4 years	❑ 9 to 10 years
❑ 5 to 6 years	❑ Over 10 years

N. Based on your observations and experience, how many years of service would you obtain from this pavement before it deteriorated to a poor condition assuming that **pavement maintenance was not provided?**

❑ Less than 2 years	❑ 7 to 8 years
❑ 2 to 4 years	❑ 9 to 10 years
❑ 5 to 6 years	❑ Over 10 years

12. Case 3-This road is a local collector with an ADT of about 600 vehicles per day with about 10%-15% trucks. The road collects all the traffic from the other local roads and channels it to a state highway. The road also connects to a county minor arterial and some of the traffic is through traffic going from the county arterial to the state highway. The trucks on the road are about equally divided between 2 or 3 axle single unit trucks and 3, 4, or 5 axle tractor semi- trailers combinations. The existing road is an old aggregate surfaced road on a native soil base on which, over the years, there has been a cold mix bituminous surface placed and

a couple of chip seal applications. Presently, the road is severely deteriorated, rutted, raveled, and potholed. Many complaints have been received about the condition of the road. This is an election year and the legislative board has decided to "fix it right, once and for all". What would you do?

❑ A. Have no experience with this situation and cannot answer questions.

B. Please indicate the type of subgrade soils which you generally encounter and for which you are providing the following thin-surfaced pavement design. Select one box.

- ❑ Mainly coarse grained soils, sands and gravels.
- ❑ Mainly fined grained soils, silts and clays.
- ❑ Expansive or swelling clays
- ❑ Both, coarse and fine grained soils
- ❑ Other______________________________

C. What drainage would you provide? Check off as many boxes as are appropriate.

- ❑ Build roadbed higher than surrounding topography
- ❑ Build a crown on the pavement
- ❑ Ditches
- ❑ Edge of pavement underdrains
- ❑ Drainable base beneath the wearing surface
- ❑ Other______________________________

D. What type of base would you provide beneath the wearing surface? Check off one box.

- ❑ Native soil
- ❑ Run-of-bank gravel
- ❑ Crushed stone or crushed gravel
- ❑ Reclaimed asphalt pavement (RAP)
- ❑ Local material chemically stabilized
- ❑ Full depth reclamation

E. How thick would you make the base? Please circle the thickness on the scale below.

4 6 8 10 12 14 16 18 20 22 24

Thickness of base in inches

F. If you checked local material chemically stabilized for the base, what would you use as the stabilizing agent? Check off one box.

❑ Lime	❑ Lime fly-ash
❑ Portland cement	❑ Asphalt emulsion
❑ Calcium chloride	❑ Sodium chloride
❑ Magnesium chloride	❑ Other __________

G. Would you use a subbase or improved subgrade? ❑ Yes ❑ No

H. If Yes, what material would you use for the subbase or improved subgrade? Check off one box.

- ❑ Run-of-bank gravel
- ❑ Crushed stone or crushed gravel
- ❑ Reclaimed asphalt pavement (RAP)
- ❑ Local material chemically stabilized
- ❑ Full depth reclamation

I. How thick would you make the subbase or improved subgrade? Please circle the thickness on the scale below.

4 6 8 10 12 14 16 18 20 22 24

Thickness of subbase or improved subgrade in inches

J. If you checked local material chemically stabilized for the subbase or improved subgrade, what would you use as the stabilizing agent? Check off one box.

❑ Lime	❑ Lime fly-ash
❑ Portland cement	❑ Asphalt emulsion
❑ Calcium chloride	❑ Sodium chloride
❑ Magnesium chloride	❑ Other __________

K. What would you use as the wearing surface? Check off one box.

- ❑ Single application chip seal
- ❑ Double application chip seal
- ❑ Slurry seal
- ❑ Micro surfacing
- ❑ Hot mix asphalt

❑ Other (please specify)________________________

L. If you selected, hot mix asphalt, how thick would you make it?

❑ 1 inch or less ❑ 1-1/2 inch ❑ 2 inches
❑ 1-1/4 inch ❑ 1-3/4 inch

M. Based on your observations and experience, how many years of service would you obtain from this pavement before it deteriorated to a poor condition assuming you provided **regular preventive pavement maintenance**?

❑ Less than 2 years ❑ 7 to 8 years
❑ 2 to 4 years ❑ 9 to 10 years
❑ 5 to 6 years ❑ Over 10 years

N. Based on your observations and experience, how many years of service would you obtain from this pavement before it deteriorated to a poor condition assuming that **pavement maintenance was not provided?**

❑ Less than 2 years ❑ 7 to 8 years
❑ 2 to 4 years ❑ 9 to 10 years
❑ 5 to 6 years ❑ Over 10 years

13. Case 4-This is a local road providing industrial/resource access. The ADT is less than 100 vehicles per day. The percentage of trucks is about 25%-30% and consist mainly of one type of truck hauling very heavy loads such as pulp, sand and gravel, coal, or timber. What pavement would you provide?

❑ A. Have no experience with this situation and cannot answer questions.

B. Please indicate the type of subgrade soils which you generally encounter and for which you are providing the following thin-surfaced pavement design. Select one box.

❑ Mainly coarse grained soils, sands and gravels.
❑ Mainly fined grained soils, silts and clays.
❑ Expansive or swelling clays
❑ Both, coarse and fine grained soils
❑ Other________________________________

C. Would you impose a limitation on the use of the road by very

heavy trucks during certain seasons?

❑ No ❑ Yes

If yes,
❑ Weight limitation
❑ Tire pressure limitation
❑ Other(Please explain)________________________________

D. What drainage would you provide?Check off as many boxes as are appropriate.

❑ Build roadbed higher than surrounding topography
❑ Build a crown on the pavement
❑ Ditches
❑ Edge of pavement underdrains
❑ Drainable base beneath the wearing surface
❑ Other________________________________

E. What type of base would you provide beneath the wearing surface? Check off one box.

❑ Native soil
❑ Run-of-bank gravel
❑ Crushed stone or crushed gravel
❑ Reclaimed asphalt pavement (RAP)
❑ Local material chemically stabilized
❑ Full depth reclamation

F. How thick would you make the base? Please circle the thickness on the scale below.

4 6 8 10 12 14 16 18 20 22 24

Thickness of base in inches

G. If you checked local material chemically stabilized for the base, what would you use as the stabilizing agent?

❑ Lime ❑ Lime fly-ash
❑ Portland cement ❑ Asphalt emulsion
❑ Calcium chloride ❑ Sodium chloride
❑ Magnesium chloride ❑ Other______________

H. Would you use a subbase or improved subgrade? ❑ Yes ❑ No

I. If Yes, what material would you use for the subbase or improved subgrade? Check off one box.

- ❑ Run-of-bank gravel
- ❑ Crushed stone or crushed gravel
- ❑ Reclaimed asphalt pavement (RAP)
- ❑ Local material chemically stabilized
- ❑ Full depth reclamation

J. How thick would you make the subbase or improved subgrade? Please circle the thickness on the scale below.

4 6 8 10 12 14 16 18 20 22 24

Thickness of subbase or improved subgrade in inches

K. If you checked local material chemically stabilized for the subbase or improved subgrade, what would you use as the stabilizing agent? Check off one box.

❑ Lime	❑ Lime fly-ash
❑ Portland cement	❑ Asphalt emulsion
❑ Calcium chloride	❑ Sodium chloride
❑ Magnesium chloride	❑ Other ______________

L. What would you use as the wearing surface?

- ❑ Single application chip seal
- ❑ Double application chip seal
- ❑ Slurry seal
- ❑ Micro surfacing
- ❑ Hot mix asphalt

- ❑ Other (please specify)________________________

M. If you selected, hot mix asphalt, how thick would you make it?

❑ 1 inch or less	❑ 1-1/2 inch	❑ 2 inches
❑ 1-1/4 inch	❑ 1-3/4 inch	

N. Based on your observations and experience, how many years of service would you obtain from this pavement before it deteriorated to a poor condition assuming you provided **regular preventive pavement maintenance**?

❑ Less than 2 years	❑ 7 to 8 years
❑ 2 to 4 years	❑ 9 to 10 years
❑ 5 to 6 years	❑ Over 10 years

O. Based on your observations and experience, how many years of service would you obtain from this pavement before it deteriorated to a poor condition assuming that **pavement maintenance was not provided?**

❑ Less than 2 years	❑ 7 to 8 years
❑ 2 to 4 years	❑ 9 to 10 years
❑ 5 to 6 years	❑ Over 10 years

****

THANK YOU FOR YOUR ASSISTANCE

Please return to:

Donald N. Geoffroy, P.E.
22 Northgate Drive
Albany, New York 12203
Phone/Fax 518-464-9551

If you have any questions, please call at the above number
A response by________ would be appreciated

APPENDIX B

Summary of Responses to the Questionnaire

TABLE B-1

AGENCIES USING THIN-SURFACED PAVEMENTS

Federal Level Agencies-10	State/Province
Bureau of Indian Affairs-Great Lakes Agency	WI
Forest Service-Georgia	GA
Forest Service-Nat. Forests & Grasslands	TX
Forest Service-Onachita National Forest	AR
Forest Service-Nevada	NV
Forest Service-Stanislaus National Forest	CA
Forest Service-Portland, Oregon	OR
Forest-Service-Tonto National Forest	AZ
Forest Service-Milwaukee	WI
Canada Public Works & Government Services	Ont

State/Province Level Agencies-20

Arkansas DOT	South Carolina DOT
Arizona DOT	Texas DOT
Colorado DOT	Utah DOT
Georgia DOT	Virginia DOT
Michigan DOT	Washington State DOT
Mississippi DOT	British Columbia DOT
North Carolina DOT	Manitoba DOT
Pennsylvania DOT	New Brunswick DOT
Ontario MOT	Saskatchewan MOT
Quebec MOT	Yukon MOT

County Level Agencies-97

County	State	County	State
Calhoun	AL	Trinity	CA
Cullman	AL	Ventura	CA
Elmore	AL	Collier	FL
Houston	AL	Hillsborough	FL
Limestone	AL	Sarasota	FL
Mobile	AL	Marshall	IA
Alameda	CA	McDonough	IL
Colusa	CA	Adams	IN
Contra Costa	CA	Allen	IN
Glenn	CA	Boone	IN
Humboldt	CA	Daviess	IN
Imperial	CA	Fulton	IN
Los Angeles	CA	Hamilton	IN
Madera	CA	Hendricks	IN
Marin	CA	Henry	IN
Merced	CA	Jay	IN
San Joaquin	CA	Morgan	IN
Santa Cruz	CA	Warrick	IN

TABLE B-1 (Continued)

Washington	IN	Becker	MN
Butler	KS	Crow Wing	MN
Douglas	KS	Dakota	MN
Finney	KS	Olmsted	MN
Linn	KS	Hall	NE
Lyon	KS	Warren	NJ
Pottawatomie	KS	Madison	NY
Saline	KS	Monroe	NY
Boone	KY	Steuben	NY
Boyle	KY	Ulster	NY
Kenton	KY	Wayne	NY
Shelby	KY	Defiance	OH
Quachita	LA	Richland	OH
Terrebonne	LA	Benton	OR
Allegany	MD	Marion	OR
Anne Arundel	MD	Bell	TX
Baltimore	MD	Chambers	TX
Caroline	MD	Ector	TX
Charles	MD	Fort Bend	TX
Dorchester	MD	Montgomery	TX
Frederick	MD	Nueces	TX
Hartford	MD	Randall	TX
Queen Anne's	MD	Smith	TX
Somerset	MD	Williamson	TX
St Mary's	MD	Jefferson	WA
Talbot	MD	King	WA
Aroostook	ME	Spokane	WA
Ionia	MI	Thurston	WA
Kent	MI	Yakima	WA
Lake	MI	Dane	WI
Luce	MI		

City Level Agencies-19

City	State	City	State
South Gate	CA	Beaverton	OR
Vista	CA	Corvallis	OR
Garden City	KS	Medford	OR
Manhattan	KS	Brownwood	TX
Columbus	NE	Converse	TX
North Platte	NE	Dallas	TX
Hobbs	NM	Missouri City	TX
Las Cruces	NM	Montpelier	VT
Las Vegas	NM	Madison	WI
Santa Fe	NM		

Town Level Agencies-13

Town	State	Town	State
Kernerville	NC	East Otto	NY
Charleston	NH	Charleston	RI
Colebrook	NH	Barre	VT
Hopkinton	NH	Bennington	VT
Loudon	NH	Essex	VT
Wolfeboro	NH	Middlebury	VT
Caroline	NY		

Metro Level Agency-1 (Included in the City Level for analysis and presentation)	
Metropolitan Area	State
Lexington Fayette	KY

TABLE B-2

AGENCIES NOT USING THIN-SURFACED PAVEMENTS

Federal Level Agencies-3	State/Province
Bureau of Indian Affairs-Choctaw Agency	MS
Bureau of Indian Affairs-Cherokee Agency	NC
Bureau of Indian Affairs-Shawano Field Office	WI

State/Province Level Agencies-32	
Alabama DOT	New Jersey DOT
California DOT	New Mexico DOT
Connecticut DOT	Nevada DOT
Florida DOT	New York State DOT
Iowa DOT	New Foundland DOT
Illinois DOT	Northwest Territories
Indiana DOT	North Dakota DOT
Kentucky DOT	Nova Scotia DOT
Massachusetts DOT	Ohio DOT
Maryland DOT	Oklahoma DOT
Maine DOT	Oregon DOT
Minnesota DOT	Puerto Rico DOT
Missouri DOT	Rhode Island DOT
Montana DOT	Vermont DOT
Nebraska DOT	Wisconsin DOT
New Hampshire DOT	Wyoming DOT

County Level Agencies-62

County	State	County	State
Amador	CA	Menominee	MI
Fresno	CA	Oakland	MI
Sacramento	CA	Saginaw	MI
Charlotte	FL	Carver	MN
Dade	FL	Kandiyohi	MN
Hendry	FL	Lake of the Woods	MN
Highlands	FL	Martin	MN
Lee	FL	St. Louis	MN
Orage	FL	Steele	MN
Henry	GA	Tunica	MS
Bannock	IA	Scotts Bluff	NE
Ascension	LA	Atlantic	NJ
Calcasieu	LA	Bergen	NJ
Franklin	LA	Burlington	NJ
Cecil	MD	Camden	NJ
Montgomery	MD	Cumberland	NJ
Washington	MD	Essex	NJ
Wicomico	MD	Gloucester	NJ
Alcona	MI	Hudson	NJ

County Level Agencies-62

County	State	County	State
Mercer	NJ	Saratoga	NY
Middlesex	NJ	Tompkins	NY
Monmouth	NJ	Warren	NY
Morris	NJ	Wyoming	NY
Ocean	NJ	Geauga	OH
Passaic	NJ	Multnomah	OR
Somerset	NJ	Panola	TX
Union	NJ	Whitman	WA
Chautauqua	NY	Brown	WI
Chenango	NY	Dodge	WI
Orange	NY	Eau Claire	WI

City Level Agencies-21

City	State	City	State
Anaheim	CA	Raleigh	NC
Murrieta	CA	Winston-Salem	NC
Porterville	CA	Lincoln	NE
District of Columbia	DC	Gresham	OR
Hays	KS	Providence	RI
Lawrence	KS	Bryan	TX
Lenexa	KS	Burlington	VT
McPherson	KS	Leavenworth	WA
Topeka	KS	Janesville	WI
Lewiston	ME	Montreal	Que
Old Town	ME		

Town Level Agencies-7

Town	State	Town	State
Falmouth	ME	Colerain	OH
Wiscasset	ME	Sycamore	OH
Southern Pines	NC	Glocester	RI
Anderson	OH		

Village Level Agency-1

Village	State
Hales Corners	WI

TABLE B-3

BACKGROUND OF THE PERSON(S) SELECTING PAVEMENT PROJECTS IN THE AGENCY

Level of Government	Total Number	Answer Selected in Question 5B					
		(1)	(2)	(3)	(4)	(5)	Blank
Federal	10	2	0	1	0	7	0
State	20	3	0	1	0	16	0

TABLE B-3 (Continued)

County	97	9	6	19	8	52	3
City	20	3	0	5	1	10	1
Town	13	0	2	4	2	5	0
Total	160	17	8	30	11	90	4

Column Headings:

(1) Elected or appointed official(s) without a background or experience in highways, (could be one individual or a board).
(2) Highway construction or maintenance experience, but no formal technical training.
(3) Highway construction or maintenance experience, supplemented by workshops and seminars.
(4) Two years formal education in highway, construction or engineering technology.
(5) Graduate or professional engineer with highway design, construction or maintenance experience.

TABLE B-4

BACKGROUND OF THE PERSON(S) DESIGNING PAVEMENT PROJECTS IN THE AGENCY

Level of Government	Total Number	Answer Selected in Question 5C							
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	Blank
Federal	10	0	0	0	0	1	0	9	0
State[1]	20	2	0	0	0	1	0	18	0
County[2]	97	5	3	2	5	15	10	54	4
City[3]	20	3	1	0	0	1	1	12	3
Town[4]	13	1	0	1	2	4	1	5	0
Total	160	11	4	3	7	22	12	98	7

Notes:
1. Ontario MOT indicated they use consultants and prepare their own designs.
2. Jay IN indicated they use both recommendations from vendors and prepare their own designs.
3. Santa Fe NM indicated they use consultants and prepare their own designs.
4. Charleston RI indicated they use consultants and prepare their own designs.

Column Headings:
(1) Designs are prepared by consultants hired by the agency.
(2) Recommendations are made by a local contractor or vendor.
(3) Elected or appointed official without a background or experience in highways.
(4) Highway construction or maintenance experience, but no formal technical training.
(5) Highway construction or maintenance experience, supplemented by workshops and seminars.
(6) Two years formal education in highway, construction or engineering technology.
(7) Graduate or professional engineer with highway design, construction or maintenance experience.

TABLE B-5

FIELD AND LABORATORY TESTING DONE BY THE AGENCY

Level of Government	Total Number	Answer Selected in Question 5 D							
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Federal	10	3	6	6	2	1	7	5	4
State	20	0	7	4	1	3	11	11	20
County	97	30	25	6	9	3	36	37	27
City	20	3	6	3	3	0	8	12	11
Town	13	5	7	1	1	0	3	3	0
Total	160	41	51	20	16	7	65	68	62

Column Headings:
(1) None.
(2) Digs test pits and take samples.
(3) Performs CBR tests on the subgrade.
(4) Performs CBR tests on the base.
(5) Performs resilient modulus testing.
(6) Does sieve analysis and determines moisture contents.
(7) Performs compaction tests.
(8) Performs all the basic testing required for pavementdesign and construction.

TABLE B-6

AGENCIES WITH A PAVEMENT MANAGEMENT SYSTEM, MAINTENANCE MANAGEMENT SYSTEM OR PREVENTIVE MAINTENANCE PROGRAM

Level of Government	Total Number	Number of Agencies with				
		PMS	MMS	PMP	All 3	None
Federal	10	7	7	4	4	1
State	20	16	15	13	11	3
County	97	59	42	68	29	11
City	20	15	7	12	4	2
Town	13	7	9	8	6	3
Total	160	104	80	105	54	20

PMS) Pavement Management System. MMS) Maintenance Management System. PMP) Preventive Maintenance Program.

TABLE B-7

THIN-SURFACED PAVEMENT PROJECT SELECTION CONSIDERATIONS: RANKING OF TRAFFIC VOLUME

Level of Government	Total Number	Number of Agencies Ranking Factor							
		1st	2nd	3rd	4th	5th	6th	7th	Blank
Federal	10	3	1	3	1	1	0	0	1
State	20	10	3	4	1	1	0	0	1
County	97	37	21	12	7	5	0	0	15
City	20	5	3	4	2	0	0	0	6
Town	13	5	3	2	1	0	0	0	2
Total	160	60	31	25	12	7	0	0	25

TABLE B-8

THIN-SURFACED PAVEMENT PROJECT SELECTION CONSIDERATIONS: RANKING OF VOLUME OF TRUCKS

Level of Government	Total Number	Number of Agencies Ranking Factor							
		1st	2nd	3rd	4th	5th	6th	7th	Blank
Federal	10	1	1	1	1	1	1	0	4
State	20	4	6	1	1	0	0	0	8
County	97	11	19	12	8	8	3	1	35
City	20	6	3	1	0	1	1	0	8
Town	13	2	2	2	3	0	0	0	4
Total	160	24	31	17	13	10	5	1	59

TABLE B-9

THIN-SURFACED PAVEMENT PROJECT SELECTION CONSIDERATIONS: RANKING OF ROAD CLASSIFICATION

Level of Government	Total Number	Number of Agencies Ranking Factor							
		1st	2nd	3rd	4th	5th	6th	7th	Blank
Federal	10	1	4	1	1	0	0	0	3
State	20	2	3	4	7	0	0	0	4
County	97	23	18	12	20	3	2	1	18
City	20	6	1	2	3	2	1	0	5
Town	13	5	0	4	1	0	0	0	3
Total	160	37	26	23	32	5	3	1	33

TABLE B-10

THIN-SURFACED PAVEMENT PROJECT SELECTION CONSIDERATIONS: RANKING OF COSTS

Level of Government	Total Number	Number of Agencies Ranking Factor							
		1st	2nd	3rd	4th	5th	6th	7th	Blank
Federal	10	7	2	0	1	0	0	0	0
State	20	6	2	4	3	1	0	0	4
County	97	38	19	8	12	3	2	0	15
City	20	7	2	1	1	2	0	0	7
Town	13	6	1	1	3	0	0	0	2
Total	160	64	26	14	20	6	2	0	28

TABLE B-11

THIN-SURFACED PAVEMENT PROJECT SELECTION CONSIDERATIONS: RANKING OF PUBLIC POLICY

Level of Government	Total Number	Number of Agencies Ranking Factor							
		1st	2nd	3rd	4th	5th	6th	7th	Blank
Federal	10	2	0	0	2	1	1	0	4
State	20	1	4	1	0	2	1	0	11
County	97	13	5	8	7	9	2	2	51
City	20	1	1	1	2	1	1	0	13
Town	13	2	1	0	0	1	0	0	9
Total	160	19	11	10	11	14	5	2	88

TABLE B-12

THIN-SURFACED PAVEMENT PROJECT SELECTION CONSIDERATIONS: RANKING OF EASE OF IMPLEMENTATION

Level of Government	Total Number	Number of Agencies Ranking Factor							
		1st	2nd	3rd	4th	5th	6th	7th	Blank
Federal	10	0	0	1	0	2	1	1	5
State	20	0	1	1	1	0	1	0	16
County	97	12	8	8	13	13	8	0	35
City	20	3	1	3	0	0	1	0	12
Town	13	3	1	0	0	0	1	0	8
Total	160	18	11	13	14	15	12	1	76

TABLE B-13

THIN-SURFACED PAVEMENT PROJECT SELECTION CONSIDERATIONS: TRAFFIC LEVELS

Level of Government	Number of Agencies Responding	Number of Agencies who would use thin-surfaced pavements for ADT indicated					
		<100	100-199	200-399	400-999	1000-2000	>2000
Federal	7	6	6	4	3	0	0
State	19	16	17	15	11	8	7
County	76	65	64	63	55	31	13
City	12	12	12	12	12	8	6
Town	10	9	8	5	4	1	1
Total	124	108	107	99	85	48	27

TABLE B-14

THIN-SURFACED PAVEMENT PROJECT SELECTION CONSIDERATIONS: VOLUME OF TRUCKS

Level of Government	Number of Agencies Responding	Number of Agencies who would use thin-surfaced pavements for a truck volume up to the percentage indicated				
		5 or less	6-10	11-15	16-20	>20
Federal	5	5	5	4	3	3
State	12	12	10	7	2	1
County	61	61	48	29	10	5
City	12	12	8	4	4	1
Town	7	7	6	2	1	1
Total	97	97	77	46	20	11

TABLE B-15

ROAD CLASSIFICATIONS WHERE THIN-SURFACED PAVEMENTS WOULD BE USED

Level of Government	Number of Responses	Answer Selected in Question 7 C								
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Federal	7	1	0	0	7	3	2	2	1	1
State	16	10	10	5	10	12	14	13	3	4
County	79	61	48	20	45	48	60	54	28	23
City	15	14	2	5	3	8	13	9	5	7
Town	10	10	6	3	5	5	7	5	2	0
Total	127	96	66	33	70	76	96	83	39	35

(1) Residential access; (2) Farm access; (3) Resource/industrial access; (4) Agricultural land access; (5) Recreational land access; (6) Local collector; (7) Minor collector; (8) Major collector; and (9) Minor arterial.

TABLE B-16

ECONOMIC REASONS WHY THIN-SURFACED PAVEMENTS ARE USED

Level of Government	Number of Agencies Responding	Answers Selected in Question 7 D			
		(1)	(2)	(3)	(4)
Federal	10	5	4	1	4
State	16	13	4	2	8
County	82	52	24	28	42
City	13	7	4	4	7
Town	11	4	0	1	10
Total	132	81	36	36	71

(1) They have the lowest first cost for a hard-surfaced pavement.
(2) We have found that they provide the lowest life-cycle cost.
(3) They are inexpensive to maintain.
(4) It is all we can afford on our limited budget.

TABLE B-17

PUBLIC POLICY REASONS GIVEN WHY THIN-SURFACED PAVEMENTS ARE USED

Level of Government	Number of Agencies Responding	Answers Selected in Question 7E		
		(1)	(2)	(3)
Federal	5	0	0	5
State	5	1	0	4
County	41	26	16	8
City	7	2	3	2
Town	3	0	1	2
Total	61	29	20	21

(1) To eliminate dust and provide a smooth surface, the legislative or executive body, (town board, county legislature, county manager, etc.) has decided that all our roads will have a hard surface consisting of a thin-surfaced pavement.
(2) The legislative or executive body has decided that all the roads with permanent residents or businesses will have a hard surface.
(3) Other reasons provided:

Federal: Reduce erosion, control dust and eliminate need for blading, provide smooth, quiet, dust-free surface, based on demonstrating life-cycle cost effectiveness, used on roads for recreational purposes.
State: Eliminate dust, avoid chip seal in urban areas, political decision cited twice.
County: Reduce complaints, when ADT>100 and funding is available, part of program to convert aggregate-surfaced roads to bituminous-surfaced roads, political decision cited 6 times, number of houses and use of road, when pavement markings are necessary, when funds are available.
Town: Ease of maintenance and political decision.

TABLE B-18

REASONS GIVEN WHY EASE OF IMPLEMENTATION OF THIN-SURFACED PAVEMENTS WAS SELECTED

Level of Government	Number of Agencies Responding	Answers Selected in Question 7F		
		(1)	(2)	(3)
Federal	4	2	2	2
State	4	2	3	1
County	58	30	49	18
City	7	3	5	4
Town	6	1	6	2
Total	79	38	65	27

(1) Our personnel are capable of designing thin-surfaced pavements.
(2) Thin-surfaced pavements can be constructed by our own crews.
(3) The specifications or purchase order for vendor-in-place paving or construction contracts are simple to prepare.

TABLE B-19

AGENCIES USING A BITUMINOUS SURFACE TREATMENT AS THE WEARING SURFACE: TRAFFIC LEVELS

Level of Government	Number of Agencies Responding	Number of Agencies who would use a bituminous surface treatment as the wearing surface the for ADT indicated					
		<100	100-199	200-399	400-999	1000-2000	>2000
Federal	6	2	2	2	1	0	0
State	16	15	14	13	9	6	1
County	70	65	64	55	28	9	2
City	9	9	9	9	8	4	2
Town	9	9	8	5	0	0	0
Total	110	100	97	84	46	19	5

TABLE B-20

AGENCIES USING A BITUMINOUS SURFACE TREATMENT AS THE WEARING SURFACE: VOLUME OF TRUCKS

Level of Government	Number of Agencies Responding	Number of Agencies who would use a bituminous surface treatment as the wearing surface for a truck volume up to the percentage indicated				
		5 or less	6-10	11-15	16-20	>20
Federal	5	5	4	2	2	2
State	9	9	8	5	2	1
County	51	51	32	14	5	4

TABLE B-20 (Continued)

City	8	8	5	2	2	1
Town	7	7	6	1	0	0
Total	80	80	55	24	11	8

TABLE B-21

ROAD CLASSIFICATIONS WHERE BITUMINOUS SURFACE TREATMENTS WOULD BE USED

Level of Government	Number of Responses	Answer Selected in Question 8 C								
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Federal	6	1	0	0	0	6	2	2	4	2
State	14	8	9	6	11	11	10	11	4	3
County	68	45	30	14	28	28	41	39	21	15
City	13	11	1	1	1	6	10	10	4	5
Town	10	9	5	4	4	4	9	6	2	1
Total	111	74	45	25	44	55	72	68	35	26

Column Headings:

(1) Residential access; (2) Farm access; (3) Resource/industrial access; (4) Agricultural land access; (5) Recreational land access; (6) Local collector; (7) Minor collector; (8) Major collector; and (9) Minor arterial

TABLE B-22

ECONOMIC REASONS WHY BITUMINOUS SURFACE TREATMENTS ARE USED

Level of Government	Number of Agencies Responding	Answers Selected in Question 8 D			
		(1)	(2)	(3)	(4)
Federal	9	3	5	0	3
State	13	9	3	2	9
County	73	41	24	20	35
City	12	5	4	2	8
Town	10	4	3	1	6
Total	117	62	39	25	61

(1) They have the lowest first cost for a hard-surfaced pavement.
(2) We have found that they provide the lowest life-cycle cost.
(3) They are inexpensive to maintain.
(4) It is all we can afford on our limited budget.

TABLE B-23

OTHER REASONS FOR CONSIDERING BITUMINOUS SURFACE TREATMENTS

Level of Government	Number of Agencies Responding	Number of Agencies Selecting					
		8E	8F	8G	8H	8I	8J
Federal	10	7	5	1	3	2	1
State	16	12	9	8	8	5	0
County	70	52	30	44	37	19	2
City	13	6	2	5	7	5	2
Town	10	5	8	4	3	2	0
Total	119	82	54	62	58	33	5

Column headings:

8E. Performance experience for similar conditions.
8F. Type of base course being used.
8G. Ability to apply bituminous surface treatments with in-house forces.
8H. Availability of materials.
8I. Availability of contractors to do the work.
8J. Other:
Federal: Type of subgrade soil
County: Whether roadway has curb and gutter section
Don't use bituminous surface treatment
City: Pavement age and long term plans, pavement age and condition

TABLE B-24

THIN-SURFACED PAVEMENT THICKNESS DESIGN PROCEDURE USED

Level of Government	Number of Agencies Responding	Total Number (1)	Answer Selected in Question 9								
			A	B	C	D	E	F	G	H	I
Federal	7	10	1	1	1	0	3	0	3	0	1
State	17	21	9	4	1	0	0	0	6	1	0
County	87	100	56	7	5	0	0	1	30	1	0
City	14	17	8	2	3	1	0	0	3	0	0
Town	11	18	7	1	1	2	1	0	6	0	0
Total	136	166	81	15	11	3	4	1	48	2	1

(1) Some agencies indicated that they used more than one method.

Column Headings:

A) Thickness and structural design based on experience. B) AASHTO Guide for the Design of Pavement Structures. C) Asphalt Institute Method. D) U.S. Army Corps of Engineers Method. E) U.S. Forest Service Method. F) National Stone Association Method. G) State DOT Method. H) Agency Pavement Design Procedure. I) Other.

TABLE B-25

AGENCIES RESPONDING TO THE CASES AND WEARING SURFACES USED FOR EACH CASE

Abbreviations:
SST = Single Bituminous Surface Treatment   DST = Double Bituminous Surface Treatment
TST = Triple Bituminous Surface Treatment   HMA = Hot-mix asphalt

Agency Name	State	Case 1	Case 2	Case 3	Case 4
Federal Agencies					
Forest Service-Onachita NF	AR	DST	–	–	Aggregate
Forest Service-Tonto NF	AZ	DST	DST	–	DST
Forest Service-Stanislaus NF	CA	DST	1.5 in HMA	–	DST
US Forest Service-Georgia	GA	DST	–	–	DST
Forest Service-Nevada	NV	DST	2 in HMA	2 in HMA	DST
Forest Service-Portland	OR	2 in HMA	3 in HMA	–	DST
Forest Service-Nat. Forests & Grasslands	TX	2 in HMA	2 in HMA	2 in HMA	DST
Forest Service-Milwaukee	WI	DST	–	–	–
Bureau of Indian Affairs Great Lakes Agency	WI	2 in HMA	2 in HMA	–	Aggregate
Canada Public Works	Ont	SST	SST	2 in HMA	2 in HMA
State/Province Agencies					
Arkansas DOT	AR	DST	DST	1.5 in HMA	2 in HMA
Arizonia DOT	AZ	1.5 in HMA	1.5 in HMA	2 in HMA	2 in HMA
Colorado DOT	CO	2 in HMA	2 in HMA	4 in HMA	4 in HMA
Georgia DOT	GA	TST	TST	3.5 in HMA	1.5 in HMA
Michigan DOT	MI	–	–	–	–
Mississippi DOT	MS	DST	DST	DST	DST
North Carolina DOT	NC	DST	1.5 in HMA	2 in HMA	2 in HMA
Pennsylvania DOT	PA	2 in HMA	1.5 in HMA	2 in HMA	2 in HMA
South Carolina DOT	SC	DST	2 in HMA	2 in HMA	2 in HMA
Texas DOT	TX	DST	DST	DST	DST
Utah DOT	UT	–	SST	1.5 in HMA	2 in HMA
Virginia DOT	VA	DST	1.5 in HMA	1.5 in HMA	DST
Washington State DOT	WA	DST	DST	DST	DST
British Columbia MOT	BC	DST	2 in HMA	>2 in HMA	3 in HMA
Manitoba DOT	Man	DST	3 in HMA	3 in HMA	DST
New Brunswick DOT	NB	DST	DST	2 in HMA	DST
Ontario MOT	Ont	DST	DST	2 in HMA	DST
Quebec MOT	Que	1.75 in HMA	2 in HMA	2 in HMA	2 in HMA
Saskatchewan MOT	Sas	1.5 in HMA	1.5 in HMA	DST	DST
Yukon MOT	Yuk	SST	SST	SST	SST
County Agencies					
Calhoun	AL	DST	DST	2 in HMA	2 in HMA
Cullman	AL	DST	DST	2 in HMA	2 in HMA
Elmore	AL	DST	1.25 in HMA	1.75 in HMA	1.5 in HMA
Houston	AL	1.5 in HMA	1.5 in HMA	–	–
Limestone	AL	DST	DST	–	Aggregate
Mobile	AL	1.25 in HMA	–	–	1.5 in HMA
Alameda	CA	–	2 in HMA	2+ in HMA	–
Colusa	CA	SST	SST	3 in HMA	3 in HMA
Contra Costa	CA	TST	1.75 in HMA	2 in HMA	–
Glenn	CA	SST	SST	2 in HMA	SST
Humboldt	CA	DST	DST	2 in HMA	DST
Imperial	CA	1.5 in HMA	1.5 in HMA	1.75 in HMA	–
Los Angeles	CA	2 in HMA	2 in HMA	2 in HMA	2 in HMA
Madera	CA	DST	2 in HMA	2 in HMA	2 in HMA
Marin	CA	DST	DST	2 in HMA	–
Merced	CA	2 in HMA	2 in HMA	2 in HMA	2 in HMA
San Joaquin	CA	2 in HMA	2 in HMA	2 in HMA	2 in HMA
Santa Cruz	CA	–	–	–	–
Trinity	CA	DST	DST	2+ in HMA	DST
Ventura	CA	2 in HMA	2 in HMA	2 in HMA	2 in HMA
Collier	FL	1 in HMA	1 in HMA	1 in HMA	1.5 in HMA
Hillsborough	FL	2 in HMA	2 in HMA	2+ in HMA	2 in HMA

Agency Name	State	Case 1	Case 2	Case 3	Case 4
Sarasota	FL	–	1.5 in HMA	1.5 in HMA	–
Marshall	IA	DST	2 in HMA	2 in HMA	2 in HMA
McDonough	IL	DST	DST	2 in HMA	DST
Adams	IN	DST	1.5 in HMA	1.75 in HMA	DST
Allen	IN	2 in HMA	2 in HMA	2 in HMA	2 in HMA
Boone	IN	1.5 in HMA	1.5 in HMA	2 in HMA	2 in HMA
Daviess	IN	DST	2 in HMA	2 in HMA	DST
Fulton	IN	DST	2 in HMA	2 in HMA	2 in HMA
Hamilton	IN	DST	SST	1 in HMA	–
Hendricks	IN	DST	2 in HMA	1.5 in HMA	–
Henry	IN	DST	Cold Mix	1.5 in HMA	2 in HMA
Jay	IN	–	2 in HMA	2 in HMA	2 in HMA
Morgan	IN	DST	DST	DST	DST
Warrick	IN	DST	2 in HMA	2 in HMA	2 in HMA
Washington	IN	DST	DST	2 in HMA	3 in HMA
Butler	KS	SST	DST	DST	–
Douglas	KS	DST	2 in HMA	DST	–
Finney	KS	DST	DST	2 in HMA	2+ in HMA
Linn	KS	DST	DST	DST	–
Lyon	KS	Aggregate	DST	DST	–
Pottawatomie	KS	DST	DST	6 in PCC	Aggregate
Saline	KS	DST	DST	2 in HMA	Aggregate
Boone	KY	DST	2 in HMA	2 in HMA	DST
Boyle	KY	2 in HMA	2 in HMA	2 in HMA	2 in HMA
Kenton	KY	2 in HMA	4 in HMA	2+ in HMA	Aggregate
Shelby	KY	1.5 in HMA	1.5 in HMA	2 in HMA	2 in HMA
Quachita	LA	SST	2 in HMA	2 in Hma	2 in HMA
Terrebonne	LA	2 in HMA	2 in HMA	2 in HMA	2 in HMA
Allegany	MD	TST	DST	2 in HMA	TST
Anne Arundel	MD	DST	>2 in HMA	>2 in HMA	>2 in HMA
Baltimore	MD	DST	DST	2 in HMA	DST
Caroline	MD	TST	TST	2 in HMA	4 in HMA
Charles	MD	1.5 in HMA	1.5 in HMA	2 in HMA	2 in HMA
Dorchester	MD	DST	DST	2 in HMA	DST
Frederick	MD	DST	–	>2 in HMA	–
Harford	MD	TST	TST	2 in HMA	2 in HMA
Queen Anne's	MD	TST	TST	3 in HMA	TST
Somerset	MD	TST	2 in HMA	2 in HMA	2 in HMA
St Mary's	MD	–	DST	2 in HMA	–
Talbot	MD	TST	TST	TST	TST
Aroostook	ME	DST	DST	DST	DST
Ionia	MI	DST	DST	2 in HMA	3 in HMA
Kent	MI	1.5 in HMA	1.5 in HMA	1.75 in HMA	–
Lake	MI	DST	TST	2 in HMA	2 in HMA
Luce	MI	2 in HMA	2 in HMA	3 in HMA	Aggregate
Becker	MN	2 in HMA	3.5 in HMA	4 in HMA	Aggregate
Crow Wing	MN	1.5 in Cold Mix Asphalt	1.5 in HMA	2 in HMA	2 in HMA
Dakota	MN	–	–	2 in HMA	–
Olmsted	MN	2 in HMA	2 in HMA	PCC	PCC
Hall	NE	5.5 in HMA	5.5 in HMA	2.5 in HMA	–
Warren	NJ	–	–	–	–
Madison	NY	2 in HMA	2 in HMA	2 in HMA	2 in HMA
Monroe	NY	SST	1.5 in HMA	1.5 in HMA	–
Steuben	NY	3 in HMA	DST	3 in HMA	3 in HMA
Ulster	NY	–	–	3 in Cold Mix w/ Chip Seal	2 in HMA
Wayne	NY	Cold Mix	Cold Mix	Cold Mix	Cold Mix
Defiance	OH	2 in HMA	2 in HMA	2 in HMA	–
Richland	OH	DST	2 in HMA	2 in HMA	2 in HMA
Benton	OR	Macadam Oil Mat	Macadam Oil Mat	2 in HMA	Macadam Oil Mat
Marion	OR	2 in HMA	2.5 in HMA	3 in HMA	4 in HMA
Bell	TX	DST	DST	DST	–
Chambers	TX	DST	DST	DST	DST
Ector	TX	DST	DST	DST	DST
Fort Bend	TX	SST	2 in HMA	2 in HMA	2in HMA

Agency Name	State	Case 1	Case 2	Case 3	Case 4
Montgomery	TX	1.5 in HMA	2 in HMA	1.5 in HMA	1.5 in HMA
Nueces	TX	DST	1.5 in HMA	1.5 in HMA	2 in HMA
Randall	TX	DST	DST	1.5 in HMA	–
Smith	TX	3 Cold Mix	Slurry seal	DST	DST
Williamson	TX	DST	DST	1.5 in HMA	DST
Jefferson	WA	DST	DST	2 in HMA	Aggregate
King	WA	2 in HMA	1.5 in HMA	2 in HMA	2 in HMA
Spokane	WA	TST	2 in HMA	2 in HMA	2 in HMA
Thurston	WA	DST	DST	2+ in HMA	2+in HMA
Yakima	WA	DST	DST	–	DST
Dane	WI	2 in HMA	2 in HMA	2 in HMA	2 in HMA
City Agencies					
South Gate	CA	–	1.5 in HMA	2 in HMA	–
Vista	CA	–	2 in HMA	2 in HMA	2 in HMA
Garden City	KS	Cold Mix Asphalt	Cold Mix Asphalt	2 in HMA	–
Manhattan	KS	–	–	–	–
Columbus	NE	–	2 in HMA	2 in HMA	–
North Platte	NE	6 in PCC	2+ in HMA	2+ in HMA	2+in HMA
Hobbs	NM	DST	DST	–	2 in HMA
Las Cruces	NM	1.5 in HMA	2 in HMA	2 in HMA	DST
Las Vegas	NM	2 in HMA	2 in HMA	OGFC	2 in HMA
Sante Fe	NM	RAP	2 in HMA	2 in HMA	–
Beaverton	OR	–	2 in HMA	–	2 in HMA
Corvallis	OR	–	–	–	–
Medford	OR	2 in HMA	2 in HMA	3.5 in HMA	5 in HMA
Brownwood	TX	DST	1.5 in HMA	2 in HMA	2 in HMA
Converse	TX	DST	1.5 in HMA	2 in HMA	2in HMA
Dallas	TX	–	–	2 in HMA	2 in HMA
Missouri City	TX	2 in HMA	2 in HMA	2 in HMA	2 in HMA
Montpelier	VT	–	2 in HMA	2 in HMA	2 in HMA
Madison	WI	2 in HMA	2 in HMA	2 in HMA	–
Town Agencies					
Kernersville	NC	2 in HMA	1.5 in HMA	2 in HMA	2 in HMA
Charlestown	NH	1.25 in HMA	2 in HMA	2+ in HMA	2+ in HMA
Colebrook	NH	2 in HMA	3 in HMA	3 in HMA	–
Hopkinton	NH	2 in HMA	1 in HMA	1 in HMA	–
Loudon	NH	2 in HMA	2 in HMA	–	Aggregate
Wolfeboro	NH	2 in HMA	2 in HMA	2 in HMA	2 in HMA
Caroline	NY	DST	2 in HMA	2 in HMA	2 in HMA
East Otto	NY	DST	DST	DST	DST
Charlestown	RI	SST	2 in HMA	2 in HMA	–
Barre	VT	DST	2 in HMA	2 in HMA	DST
Bennington	VT	1.5 in HMA	Cold Mix w/ Chip Seal	2 in HMA	2 in HMA
Essex	VT	2 in HMA	–	2 in HMA	2 in HMA
Middlebury	VT	DST	2 in HMA	2 in HMA	2 in HMA
Metro Agency					
Lexington Fayette	KY	–	1.5 in HMA	2 in HMA	–

TABLE B-26

CASE 1 SUMMARY OF WEARING SURFACES

Climatic Region (Figure 3)	Number of Responses	Number of Agencies Using Wearing Surface Indicated											
				BST			Hot Mix Asphalt Thickness (in.)						
		Agg	RAP	Single	Double	Triple	1.0	1.25	1.50	1.75	2.0	<2.0	Other
I	18			1	7	1	1	1	2		5		
II	53	1		3	32	7			3		5		2
III	38			1	15			1	2		15	2	2
IV	11			2	5	1			1		2		
V	22		1		13				2		5		1
VI	9			1	4				1		2		1
Totals	151	1	1	8	76	9	1	2	11	0	34	2	6
Percent of Total		1	1	5	50	6	1	1	7	0	23	1	4

TABLE B-26a

CASE 1: CLIMATIC REGION I—WEARING SURFACES

Level of Government	Number of Responses	Number of Agencies Using Wearing Surface Indicated											
				BST			Hot Mix Asphalt Thickness (in.)						
		Agg	RAP	Single	Double	Triple	1.0	1.25	1.50	1.75	2.0	<2.0	Other
Federal	2										2		
State	4				4								
County	11			1	3	1	1	1	2		2		
City	1										1		
Town	0												
All Levels	18	0	0	1	7	1	1	1	2	0	5	0	0
Percent of All Levels	102	0	0	6	39	6	6	6	11	0	28	0	0

TABLE B-26b

CASE 1: CLIMATIC REGION II—WEARING SURFACES

Level of Government	Number of Responses	Number of Agencies Using Wearing Surface Indicated											
				BST			Hot Mix Asphalt Thickness (in.)						
		Agg	RAP	Single	Double	Triple	1.0	1.25	1.50	1.75	2.0	<2.0	Other
Federal	3				2						1		
State	8				7	1							
County	40	1		2	23	6			3		3		2
City	0												
Town	2			1							1		
All Levels	53	1	0	3	32	7	0	0	3	0	5	0	2
Percent of All Levels	100	2	0	6	60	13	0	0	6	0	9	0	4

TABLE B-26c

CASE 1: CLIMATIC REGION III—WEARING SURFACES

Level of Government	Number of Responses	Number of Agencies Using Wearing Surface Indicated											
				BST			Hot Mix Asphalt Thickness (in.)						
		Agg	RAP	Single	Double	Triple	1.0	1.25	1.50	1.75	2.0	<2.0	Other
Federal	2				1						1		
State	4				3						1		
County	20			1	7				1		7	2	2
City	1										1		
Town	11				4			1	1		5		
All Levels	38	0	0	1	15	0	0	1	2	0	15	2	2
Percent of All Levels	99	0	0	3	39	0	0	3	5	0	39	5	5

TABLE B-26d

CASE 1: CLIMATIC REGION IV—WEARING SURFACES

Level of Government	Number of Responses	Number of Agencies Using Wearing Surface Indicated											
				BST			Hot Mix Asphalt Thickness (in.)						
		Agg	RAP	Single	Double	Triple	1.0	1.25	1.50	1.75	2.0	<2.0	Other
Federal	0												
State	1				1								
County	9			2	3	1			1		2		
City	1				1								
Town	0												
All Levels	11	0	0	2	5	1	0	0	1	0	2	0	0
Percent of All Levels	99	0	0	18	45	9	0	0	9	0	18	0	0

TABLE B-26e

CASE 1: CLIMATIC REGION V—WEARING SURFACES

Level of Government	Number of Responses	Number of Agencies Using Wearing Surface Indicated											
				BST			Hot Mix Asphalt Thickness (in.)						
		Agg	RAP	Single	Double	Triple	1.0	1.25	1.50	1.75	2.0	<2.0	Other
Federal	3				2						1		
State	4				3				1				
County	8				6						2		
City	7		1		2				1		2		1
Town	0												
All Levels	22	0	1	0	13	0	0	0	2	0	5	0	1
Percent of All Levels	101	0	5	0	59	0	0	0	9	0	23	0	5

TABLE B-26f

CASE 1: CLIMATIC REGION VI—WEARING SURFACES

		Number of Agencies Using Wearing Surface Indicated											
	Number of			BST			Hot Mix Asphalt Thickness (in.)						
Level of Government	Responses	Agg	RAP	Single	Double	Triple	1.0	1.25	1.50	1.75	2.0	<2.0	Other
Federal	3			1	1						1		
State	5				3				1		1		
County	0												
City	1												1
Town	0												
All Levels	9	0	0	1	4	0	0	0	1	0	2	0	1
Percent of All Levels	99	0	0	11	44	0	0	0	11	0	22	0	11

TABLE B-27a

CASE 1: CLIMATIC REGION I—AGENCY RESPONSES TO THIN-SURFACED PAVEMENT DESIGNS

					Base			Subbase			Performance (yrs)	
Agency	State	Subgrade Soils	Drainage	Wearing Surface	Material	Stabil. Agent	Thick (inch)	Material	Stabil. Agent	Thick (inch)	w/Prev. Maint.	w/o Prev. Maint.
Mississippi DOT	MS	Fine	Higher Crown Ditches Drainable	DST	Local	PC	6	Local	–	9	7–8	2–4
South Carolina DOT	SC	Fine & Coarse	Crown Ditches	DST	Local	PC	8				>10	9–10
Texas DOT	TX	Fine & Coarse	Higher Crown Ditches	DST	Crushed		10	Local	Lime	8	–	>10
British Columbia MOT	BC	Fine & Coarse	Crown Ditches	DST	Crushed		6				7–10	5–6
Houston	AL	Fine & Coarse	Higher Crown Ditches	1–1/2 in HMA	Native soil		6				>10	9–10
Mobile	AL	Fine	Crown Ditches Cross drains	1–1/4 in HMA	Crushed		6	Local	–	8	>10	7–8
Contra Costa	CA	Fine	Ditches	TST	Regrade existing						–	–
Humboldt	CA	Swelling clays	Higher Crown Ditches	DST	Crushed		6–8	ROB		4–6	7–8	5–6
Marin	CA	Swelling clays	Crown Ditches	DST	Crushed		12	Crushed	Lime	10	9 –10	5–6
Collier	FL	Stabilized limerock	Higher Crown Ditches	1 in HMA	Crushed		6–8	Crushed		12	>10	5–6

TABLE B-27a (Continued)

Agency	State	Subgrade Soils	Drainage	Wearing Surface	Base Material	Base Stabil. Agent	Base Thick (inch)	Subbase Material	Subbase Stabil. Agent	Subbase Thick (inch)	Performance (yrs) w/Prev. Maint.	Performance (yrs) w/o Prev. Maint.
Chambers	TX	Swelling	Higher Crown Ditches	DST	Crushed		8	Local	Lime	4	>10	5–6
Fort Bend	TX	Swelling	Higher Crown Ditches	SST	Crushed		6	Crushed		8	5–6	2–4
Montgomery	TX	Coarse	Higher Crown Ditches Drainable	1–1/2 in HMA	Crushed		8				9–10	7–8

TABLE B-27b

CASE 1: CLIMATIC REGION II—AGENCY RESPONSES TO THIN-SURFACED PAVEMENT DESIGNS

Agency	State	Subgrade Soils	Drainage	Wearing Surface	Base Material	Base Stabil. Agent	Base Thick (inch)	Subbase Material	Subbase Stabil. Agent	Subbase Thick (inch)	Performance (yrs) w/Prev. Maint.	Performance (yrs) w/o Prev. Maint.
Forest Service Onachita	AR	Fine & Coarse	Higher Crown Ditches Under	DST	Crushed		6				> 10	9–10
Forest Service Georgia	GA	Fine	Higher Crown Ditches Drainable	DST	Crushed		4	ROB	Lime fly-ash	8	7–8	7–8
Arkansas DOT	AR	Fine	Higher Crown Ditches	DST	Crushed		9				> 10	7–8
Georgia DOT	GA	Fine	Crown Ditches	TST	Full depth reclam		6				7–8	5–6
Mississippi DOT	MS	Fine	Higher Crown Ditches Drainable	DST	Local	PC	6	Local	–	9	7–8	2–4
North Carolina DOT	NC	Fine	Higher Crown Ditches	DST	Crushed		8				9–10	7–8
Texas DOT	TX	Fine & Coarse	Higher Crown Ditches	DST	Crushed		10	Local	Lime	8	–	>10
Virginia DOT	VA	Fine	Higher Crown Ditches	DST	Crushed		10				9–10	5–6
Washington State DOT	WA	Fine & Coarse	Higher Crown Ditches	DST	Crushed		8				9–10	7–8

TABLE B- 27b (Continued)

Agency	State	Subgrade Soils	Drainage	Wearing Surface	Base			Subbase			Performance (yrs)	
					Material	Stabil. Agent	Thick (inch)	Material	Stabil. Agent	Thick (inch)	w/Prev. Maint.	w/o Prev. Maint.
British Columbia MOT	BC	Fine & Coarse	Crown Ditches	DST	Crushed or Local	Lime	6				7–10	5–6
Calhoun	AL	Fine & Coarse	Higher Crown Ditches	DST	Crushed or RAP		8	ROB		8	9–10	5–6
Cullman	AL	Fine	Higher Crown Ditches	DST	Crushed		6				9-10	5-6
Trinity	CA	Fine & Coarse	Higher Crown Ditches Geotextile	DST	Crushed		6	ROB		6-12	7-8	5-6
McDonough	IL	Fine	Ditches	DST	Full depth reclamation		12			>10	7–8	
Elmore	AL	Fine	Crown Ditches	DST	Native soil		6				5-6	2-4
Hamilton	IN	Fine	Crown Ditches	DST	Crushed		6				2–4	<2
Hendricks	IN	Fine & Coarse	Higher Crown Ditches	DST	Crushed		6	Local	Lime	12	5–6	2–4
Henry	IN	Fine	Crown Ditches	DST	Crushed		8				5–6	2–4
Morgan	IN	Fine & Coarse	Higher Crown Ditches	DST	RAP		8–10	Crushed		8–10	5–6	2–4
Warrick	IN	Swelling	Higher Crown Ditches Drainable	DST	Crushed		4	Local	Lime	4–6	2–4	<2
Washington	IN	Swelling	Higher Crown Ditches	DST	Crushed		6				2–4	<2
Butler	KS	Swelling	Crown Ditches	SST	Crushed		6				>10	7–8
Douglas	KS	Fine	Crown Ditches Underdrain Drainable	DST	Crushed		6	Native		10	7–8	2–4
Linn	KS	Fine	Crown Ditches	DST	Crushed		6				>10	7–8
Pottawatomie	KS	Fine & Coarse	Higher Crown Ditches	DST	Crushed		6	Local	CaCl Lime fly-ash	8	5–6	2–4
Boone	KY	Fine	Higher Crown Ditches	DST	Crushed		6	Full depth reclamation		6	5–6	2–4

TABLE B-27b (Continued)

Agency	State	Subgrade Soils	Drainage	Wearing Surface	Base: Material	Base: Stabil. Agent	Base: Thick (inch)	Subbase: Material	Subbase: Stabil. Agent	Subbase: Thick (inch)	Performance (yrs): w/Prev. Maint.	Performance (yrs): w/o Prev. Maint.
Shelby	KY	Coarse	Higher Crown Ditches Drainable	1-1/2 in HMA	Crushed		8	Crushed		8	9–10	2–4
Quachita	LA	Fine, Coarse & Swelling	Higher Crown Ditches	SST	Local	PC	8	Crushed		12	>10	7–8
Allegany	MD	Fine	Crown Ditches	TST	Crushed		8				5–6	2–4
Anne Arundel	MD	Fine & Coarse	Higher Crown Ditches	DST	Crushed		12				>10	7–8
Baltimore	MD	Fine & Coarse	Crown Ditches Drainable	DST	Crushed		8				5–6	2–4
Caroline	MD	Fine	Crown Ditches Drainable	TST	ROB		8				>10	9–10
Charles	MD	Coarse	Higher Crown Ditches	1-1/2 in HMA	ROB		4				9–10	5–6
Dorchester	MD	Fine	Higher Ditches	DST	ROB		8	Full depth reclam		6	5–6	<2
Frederick	MD	Fine	Higher Ditches	DST	Crushed		6–8				2–4	2–4
Harford	MD	Fine	Crown Ditches Underdrain	TST	Crushed		8	Crushed		6	5–6	2–4
Queen Anne's	MD	Coarse	Higher Crown Ditches Underdrain Drainable	TST	Full depth reclam w/ ROB added		8				7–8	2–4
Somerset	MD	Fine	Higher Ditches	TST	ROB		8				5–6	2–4
Talbot	MD	Fine	Ditches	TST	Crushed		9				5–6	2–4
Benton	OR	Fine	Crown Ditches Drainable	Macadam Oil Mat	Crushed		6	Crushed		6	>10	7–8
Smith	TX	Coarse	Crown Ditches	3 in Road Oil (AC 1.5 mixed w/ native sand)	Native soil		6				9–10	2–4

TABLE B-27b (Continued)

Agency	State	Subgrade Soils	Drainage	Wearing Surface	Base Material	Base Stabil. Agent	Base Thick (inch)	Subbase Material	Subbase Stabil. Agent	Subbase Thick (inch)	Performance (yrs) w/Prev. Maint.	Performance (yrs) w/o Prev. Maint.
Jefferson	WA	Coarse	Crown Ditches Drainable	DST	Crushed		4	ROB		12	>10	5–6
Thurston	WA	Fine & Coarse	Crown Ditches Drainable	DST	Crushed		4	ROB		6	>10	5–6
Charlestown	RI	Coarse	Higher Crown Ditches 1:4 swales	SST	ROB		18	Full depth reclam		18	>10	7–8

TABLE B-27c

CASE 1: CLIMATIC REGION III—AGENCY RESPONSES TO THIN-SURFACED PAVEMENT DESIGNS

Agency	State	Subgrade Soils	Drainage	Wearing Surface	Base Material	Base Stabil. Agent	Base Thick (inch)	Subbase Material	Subbase Stabil. Agent	Subbase Thick (inch)	Performance (yrs) w/Prev. Maint.	Performance (yrs) w/o Prev. Maint.
Forest Service Milwaukee	WI	Fine & Coarse	Higher Crown Ditches Drainable	DST	Crushed		4-6	ROB		6-8	>10	5-6
British Columbia MOT	BC	Fine & Coarse	Crown Ditches	DST	Crushed or Local	Lime	6				7-10	5-6
New Brunswick DOT	NB	Fine	Higher Crown Ditches Drainable	DST	Crushed		6	ROB		6	9–10	5–6
Ontario MOT	Ont	Fine	Higher Crown Ditches	DST	Crushed		6	ROB		18	9–10	5–6
Quebec	Que	Fine & Coarse	Higher Crown Ditches	1-3/4 in HMA	Crushed		6	ROB		10	7–8	2–4
Marshall	IA	Fine	Higher Crown Ditches	DST	Local	CaCl	6				2–4	<2
Adams	IN	Fine	Crown Ditches Drainable	DST	Crushed		10				>10	7–8
Fulton	IN	Fine & Coarse	Higher Ditches	DST	Crushed	Asphalt Emulsion	10				9–10	5–6
Aroostook	ME	Fine	Higher Ditches	DST	ROB		12				5–6	2–4

TABLE B-27c (Continued)

Agency	State	Subgrade Soils	Drainage	Wearing Surface	Base: Material	Base: Stabil. Agent	Base: Thick (inch)	Subbase: Material	Subbase: Stabil. Agent	Subbase: Thick (inch)	Performance (yrs): w/Prev. Maint.	Performance (yrs): w/o Prev. Maint.
Ionia	MI	Fine	Higher Crown Ditches Drainable	DST	Crushed		6	ROB		12	9–10	5–6
Kent	MI	Coarse	Higher Crown Ditches Drainable	1-1/2 in HMA	Crushed		8	Full depth reclam		12	>10	>10
Lake	MI	Coarse	Crown Ditches Drainable	DST	Crushed	CaCl	6				>10	5–6
Crow Wing	MN	Fine & Coarse	Higher Crown Ditches	1-1/2 in Cold Mix Asphalt	Crushed		4				9–10	5–6
Monroe	NY	Coarse	Higher Crown Ditches Underdrain Drainable	SST	Crushed		12	Crushed		12	2–4	>2
Richland	OH	Fine	Ditches	DST	Crushed		8				5–6	2–4
Charlestown	NH	Coarse & Fine	Higher Crown Ditches Underdrains Drainable	1-1/4 in HMA	Crushed		6	ROB		Replace mat'l removed	9–10	5–6
Caroline	NY	Fine & Coarse	Higher Crown Ditches Drainable	DST	Crushed		10–12	ROB		6–8	9–10	2–4
East Otto	NY	Fine	Higher Crown Ditches	DST	Crushed		18	ROB		12	>10	2–4
Barre	VT	Fine & Coarse	Crown Ditches Drainable Geotextile	DST	Crushed		6	ROB		12	9–10	5–6
Bennington	VT	Coarse	Crown Ditches Drainable	1-1/2 in HMA	Crushed		24	ROB	CaCl	18	7-8	5-6
Middlebury	VT	Fine & Coarse	Crown Ditches	DST	Crushed		6	ROB		18-24	7-8	5-6

TABLE B-27d

CASE 1: CLIMATIC REGION IV—AGENCY RESPONSES TO THIN-SURFACED PAVEMENT DESIGNS

					Base			Subbase			Performance (yrs)	
Agency	State	Subgrade Soils	Drainage	Wearing Surface	Material	Stabil. Agent	Thick (inch)	Material	Stabil. Agent	Thick (inch)	w/Prev. Maint.	w/o Prev. Maint.
Texas DOT	TX	Fine & Coarse	Higher Crown Ditches	DST	Crushed		10	Local	Lime	8	-	>10
Colusa	CA	Fine	Higher Crown	SST	Crushed		8				7-8	5-6
Glenn	CA	Fine & Coarse	Higher Crown Ditches	SST	Local	Asphalt Emulsion	4	ROB		6	>10	>10
Imperial	CA	Fine	Higher Crown Ditches	1-1/2 in HMA	RAP		6	ROB	Lime	9	>10	5-6
Madera	CA	Fine	Higher Crown Ditches	DST	Crushed		8				7-8	5-6
Nueces	TX	Fine	Higher Crown Ditches	DST	Crushed		6	Full depth reclam	Lime	12	9-10	2-4
Williamson	TX	Fine	Crown Ditches	DST	Crushed		8-10				7-8	5-6
Spokane	WA	Fine & Coarse	Higher Crown Ditches	TST	RAP		4	Crushed		12	>10	7-8
Converse	TX	Swelling	Crown Ditches	DST	Crushed		10				9-10	5-6

TABLE B-27e

CASE 1: CLIMATIC REGION V—AGENCY RESPONSES TO THIN-SURFACED PAVEMENT DESIGNS

					Base			Subbase			Performance (yrs)	
Agency	State	Subgrade Soils	Drainage	Wearing Surface	Material	Stabil. Agent	Thick (inch)	Material	Stabil. Agent	Thick (inch)	w/Prev. Maint.	w/o Prev. Maint.
Forest Service Tonto NF	AZ	Fine & Coarse	Higher Crown Ditches Drainable	DST	Crushed		8	Crushed		8	9–10	2–4
Forest Service Stanislaus NF	CA	Coarse	Ditches	DST	Crushed		4				7–8	5–6
Arizona DOT	AZ	Fine & Coarse	Higher Crown Ditches	1–1/2 in HMA	Crushed		4				>10	5–6

TABLE B-27e (Continued)

Agency	State	Subgrade Soils	Drainage	Wearing Surface	Base: Material	Base: Stabil. Agent	Base: Thick (inch)	Subbase: Material	Subbase: Stabil. Agent	Subbase: Thick (inch)	Performance (yrs): w/Prev. Maint.	Performance (yrs): w/o Prev. Maint.
Texas DOT	TX	Fine & Coarse	Higher Crown Ditches	DST	Crushed		10	Local	Lime	8	–	>10
Washington State DOT	WA	Fine & Coarse	Higher Crown Ditches	DST	Crushed		8				9–10	7–8
British Columbia MOT	BC	Fine & Coarse	Crown Ditches	DST	Crushed or Local	Lime	6				7–10	5–6
Finney	KS	Fine & Coarse	Higher Crown Ditches	DST	ROB		6	Native		6	7–8	5–6
Saline	KS	Swelling	Higher Ditches	DST	Native		6				7–8	2–4
Bell	TX	Fine & Coarse	Ditches	DST	Crushed		6	Local	Lime	6	>10	7–8
Ector	TX	Coarse	Higher Crown Ditches	DST	Limestone caliche		6	Full depth reclam		6	>10	7–8
Randall	TX	Fine	Crown Ditches	DST	Crushed		6				>10	5–6
Yakima	WA	Fine & Coarse	Higher Crown Ditches Culverts	DST	Crushed		12				>10	9–10
Hobbs	NM	Coarse	Higher Crown Ditches Cuverts	DST	Limestone caliche		6				>10	9–10
Las Cruces	NM	Fine	Higher Crown Ditches Drainable	1–1/2 in HMA	RAP		8	ROB		6	>10	5–6
Brownwood	TX	Fine	Crown	DST	Crushed		8	Local	Lime	6	>10	5–6

TABLE B-27f

CASE 1: CLIMATIC REGION VI—AGENCY RESPONSES TO THIN-SURFACED PAVEMENT DESIGNS

Agency	State	Subgrade Soils	Drainage	Wearing Surface	Base Material	Base Stabil. Agent	Base Thick (inch)	Subbase Material	Subbase Stabil. Agent	Subbase Thick (inch)	Performance (yrs) w/Prev. Maint.	Performance (yrs) w/o Prev. Maint.
Forest Service Nevada	NV	Fine & Coarse	Crown Ditches	DST	Local	PC	6				>10	9–10
Canada Public Works	Ont	Fine & Coarse	Higher Crown Ditches Drainable	SST	Crushed		6	ROB		6	5–6	2–4
Washington State DOT	WA	Fine & Coarse	Higher Crown Ditches	DST	Crushed		8				9–10	7–8
British Columbia MOT	BC	Fine & Coarse	Crown Ditches	DST	Crushed or Local	Lime	6				7–10	5–6
Manitoba DOT	Man	Fine & Coarse	Higher Crown Ditches	DST	Crushed		4-8	Crushed		4–8	>10	5–6
Saskatchewan MOT	Sas	Fine & Coarse	Higher Crown Ditches	1-1/2 in HMA	Crushed		6	Native		6	>10	5–6
Yukon	Yuk	Fine & Coarse	Crown Ditches	SST	Native		–				2–4	2–4

TABLE B-28

CASE 2 SUMMARY OF WEARING SURFACES

Climatic Region (Figure 3)	Number of Responses	Agg	RAP	BST Single	BST Double	BST Triple	Hot Mix Asphalt Thickness (in.) 1.0	1.25	1.50	1.75	2.0	<2.0	Other
		Number of Agencies Using Wearing Surface Indicated											
I	18				5		1		1	1	9	1	
II	53			1	21	5		1	8		11	3	3
III	39				6	1	1		5		21	3	2
IV	13			2	2				4		5		
V	22				10				3		7		2
VI	10			2	1				1		3	3	
Totals	155	0	0	5	45	6	2	1	22	1	56	10	7
Percent of Total		0	0	3	29	4	1	1	14	1	36	6	5

TABLE B-28a

CASE 2: CLIMATIC REGION I—WEARING SURFACES

		Number of Agencies Using Wearing Surface Indicated											
	Number of			BST			Hot Mix Asphalt Thickness (in.)						
Level of Government	Responses	Agg	RAP	Single	Double	Triple	1.0	1.25	1.50	1.75	2.0	<2.0	Other
Federal	2										1	1	
State	4				2						2		
County	10				3		1		1	1	4		
City	2										2		
Town	0												
All Levels	18	0	0	0	5	0	1	0	1	1	9	1	0
Percent of All Levels	102				28		6		6	6	50	6	

TABLE B-28b

CASE 2: CLIMATIC REGION II—WEARING SURFACES

		Number of Agencies Using Wearing Surface Indicated											
	Number of			BST			Hot Mix Asphalt Thickness (in.)						
Level of Government	Responses	Agg	RAP	Single	Double	Triple	1.0	1.25	1.50	1.75	2.0	<2.0	Other
Federal	1											1	
State	8				4	1			2		1		
County	40			1	17	4		1	4		8	2	3
City	2								1		1		
Town	2								1		1		
All Levels	53	0	0	1	21	5	0	1	8	0	11	3	3
Percent of All Levels	101	0	0	2	40	9	0	2	15	0	21	6	6

TABLE B-28c

CASE 2: CLIMATIC REGION III—WEARING SURFACES

		Number of Agencies Using Wearing Surface Indicated											
	Number of			BST			Hot Mix Asphalt Thickness (in.)						
Level of Government	Responses	Agg	RAP	Single	Double	Triple	1.0	1.25	1.50	1.75	2.0	<2.0	Other
Federal	1										1		
State	4				2				1		1		
County	21				3	1			4		10	2	1
City	3										3		
Town	10				1		1				6	1	1
All Levels	39	0	0	0	6	1	1	0	5	0	21	3	2
Percent of All Levels	101	0	0	0	15	3	3	0	13	0	54	8	5

TABLE B-28d

CASE 2: CLIMATIC REGION I—WEARING SURFACES

		Number of Agencies Using Wearing Surface Indicated											
	Number of			BST			Hot Mix Asphalt Thickness (in.)						
Level of Government	Responses	Agg	RAP	Single	Double	Triple	1.0	1.25	1.50	1.75	2.0	<2.0	Other
Federal	0												
State	1				1								
County	11			2	1				3		5		
City	1								1				
Town	0												
All Levels	13	0	0	2	2	0	0	0	4	0	5	0	2
Percent of All Levels	99	0	0	15	15	0	0	0	31	0	38	0	0

TABLE B-28e

CASE 2: CLIMATIC REGION II—WEARING SURFACES

		Number of Agencies Using Wearing Surface Indicated											
	Number of			BST			Hot Mix Asphalt Thickness (in.)						
Level of Government	Responses	Agg	RAP	Single	Double	Triple	1.0	1.25	1.50	1.75	2.0	<2.0	Other
Federal	3				1				1		1		
State	4				2				1		1		
County	8				6						1		1
City	7				1				1		4		1
Town	0												
All Levels	22	0	0	0	10	0	0	0	3	0	7	0	2
Percent of All Levels	100	0	0	0	45	0	0	0	14	0	32	0	9

TABLE B-28f

CASE 2: CLIMATIC REGION III—WEARING SURFACES

		Number of Agencies Using Wearing Surface Indicated											
	Number of			BST			Hot Mix Asphalt Thickness (in.)						
Level of Government	Responses	Agg	RAP	Single	Double	Triple	1.0	1.25	1.50	1.75	2.0	<2.0	Other
Federal	3			1							1	1	
State	6			1	1				1		2	1	
County	0												
City	1											1	
Town	0												
All Levels	10	0	0	2	1	0	0	0	1	0	3	3	0
Percent of All Levels	100	0	0	20	10	0	0	0	10	0	30	30	0

TABLE B-29a

CASE 2: CLIMATIC REGION I—AGENCY RESPONSES TO THIN-SURFACED PAVEMENT DESIGNS

Agency	State	Subgrade Soils	Drainage	Wearing Surface	Base: Material	Base: Stabil. Agent	Base: Thick (inch)	Subbase: Material	Subbase: Stabil. Agent	Subbase: Thick (inch)	Performance (yrs): w/Prev. Maint.	Performance (yrs): w/o Prev. Maint.
Mississippi DOT		Fine	Higher Crown Ditches Drainable	DST	Local	PC	6	Local	–	14	7–8	2–4
Texas DOT		Fine & Coarse	Higher Crown Ditches	DST	Crushed	–	10	Local	Lime	8	> 10	7–8
Houston Co	AL	Fine & Coarse	Higher Crown Ditches	1-1/2 in HMA	Native soil		6				> 10	9–10
Contra Costa Co	CA	Fine	Crown Ditches	1-3/4 in HMA	Crushed		Compute	Crushed		Compute	> 10	7–8
Humboldt Co	CA	Swelling	Crown Ditches Under-drains Drainable	DST	Crushed		10–12	ROB		4–6	7–9	5–6
Marin Co	CA	Fine	Crown Ditches	DST	Crushed		12				7–8	5–6
Collier Co	FL	Stabilized lime-rock	Higher Crown Ditches	1 in HMA	Crushed		6	Crushed		12	> 10	5–6
Chambers Co	TX	Swelling	Crown Ditches	DST	Full depth reclam		8				> 10	5–6

TABLE B-29b

CASE 2: CLIMATIC REGION II—AGENCY RESPONSES TO THIN-SURFACED PAVEMENT DESIGNS

Agency	State	Subgrade Soils	Drainage	Wearing Surface	Base: Material	Base: Stabil. Agent	Base: Thick (inch)	Subbase: Material	Subbase: Stabil. Agent	Subbase: Thick (inch)	Performance (yrs): w/Prev. Maint.	Performance (yrs): w/o Prev. Maint.
Arkansas DOT	AR	Fine	Higher Crown Ditches	DST	Crushed		9				> 10	5–6
Georgia DOT	GA	Fine	Crown Ditches	TST	Full depth reclam		6				7–8	5–6
Mississippi DOT	MS	Fine	Higher Crown Ditches Drainable	DST	Local	PC	6	Local	–	14	7–8	2–4
North Carolina DOT	NC	Fine	Crown Ditches	1-1/2 in HMA	Crushed		8				> 10	7–8

TABLE B-29b (Continued)

Agency	State	Subgrade Soils	Drainage	Wearing Surface	Base			Subbase			Performance (yrs)	
					Material	Stabil. Agent	Thick (inch)	Material	Stabil. Agent	Thick (inch)	w/Prev. Maint.	w/o Prev. Maint.
Texas DOT	TX	Fine & Coarse	Higher Crown Ditches	DST	Crushed		10	Local	Lime	8	> 10	7–8
Virginia DOT	VA	Fine	Higher Crown Ditches	1-1/2 in HMA	Crushed		10	Full depth reclamation		6	7–8	5–6
Washington State DOT	WA	Fine & Coarse	Higher Crown Ditches	DST	Crushed		10				9–10	7–8
Calhoun	AL	Fine & Coarse	Higher Crown Ditches	DST	ROB		8	ROB		8	7–8	5–6
Cullman	AL	Fine	Higher Crown Ditches	DST	Full depth reclamation		6				9–10	5–6
Elmore	AL	Fine	Crown Ditches	1-1/4 in HMA	Native soil		6				7–8	5–6
Limestone	AL	Coarse	Crown Ditches	DST	Full depth reclamation		6				5–6	2–4
Trinity	CA	Fine & Coarse	Higher Crown Ditches Geotextile	DST	Crushed		6	ROB		6–12	7–8	5–6
McDonough	IL	Fine	Ditches	DST	Local	Asphalt Emulsion	12				> 10	7–8
Hamilton	IN	Fine	Crown Ditches	SST	HMA		2				2–4	2–4
Henry	IN	Fine	Crown Ditches	Cold Mix	Crushed		8	Crushed		4	9–10	5–6
Morgan	IN	Fine & Coarse	Higher Crown Ditches	DST	RAP		8–10	Crushed		8–10	5–6	2–4
Washington	IN	Swelling	Higher Crown Ditches	DST	Crushed		6				2–4	< 2
Butler	KS	Swelling	Crown Ditches	DST	Crushed		6				9–10	5–6
Linn	KS	Fine	Ditches	DST	Crushed		6				> 10	7–8
Lyon	KS	Fine	Crown Ditches	DST	Native soil		8				> 10	5–6
Pottawatomie	KS	Fine & Coarse	Higher Crown Ditches	DST	Crushed		6	Local	Lime fly–ash	8	5–6	2–4
Shelby	KY	Coarse	Higher Crown Ditches	1-1/2 in HMA	Crushed		8	Crushed		8	9–10	2–4

TABLE B-29b (Continued)

Agency	State	Subgrade Soils	Drainage	Wearing Surface	Base: Material	Base: Stabil. Agent	Base: Thick (inch)	Subbase: Material	Subbase: Stabil. Agent	Subbase: Thick (inch)	Performance (yrs): w/Prev. Maint.	Performance (yrs): w/o Prev. Maint.
Allegany	MD	Fine	Crown Ditches	DST	Crushed		8				5–6	2–4
Baltimore	MD	Fine & Coarse	Crown Ditches Drainable	DST	Crushed		8				5–6	2–4
Caroline	MD	Fine	Crown Ditches Drainable	TST	ROB		8				> 10	9–10
Charles	MD	Coarse	Higher Crown Ditches	1-1/2 in HMA	ROB		6				> 10	5–6
Dorchester	MD	Fine	Higher Ditches	DST	Crushed		6	Full depth reclam		8	5–6	< 2
Harford	MD	Fine	Crown Ditches Underdrain	TST	Crushed		8	Crushed		6	2–4	< 2
Queen Anne's	MD	Coarse	Higher Crown Ditches Drainable	TST	Full depth reclam w/ ROB added		8				5–6	2–4
St. Mary's	MD	Fine & Coarse	Crown Ditches	DST	ROB		8				2–4	2–4
Talbot	MD	Fine	Ditches	TST	Crushed		9				5–6	2–4
Benton	OR	Fine	Crown Ditches Drainable	Macadam Oil Mat	Crushed		6	Scarify old surface		8	> 10	7–8
Smith	TX	Coarse	Crown Ditches	Slurry seal	Native(iron ore gravel)		6				7–8	5–6
Jefferson	WA	Coarse	Crown Ditches Drainable	DST	Crushed		4	ROB		12	9–10	5–6
King	WA	Fine	Higher Crown Ditches	1-1/2 in HMA	Crushed		4				9–10	5–6
Thurston	WA	Fine & Coarse	Crown Ditches	DST	Local	PC	8				> 10	5–6
Kernersville	NC	Fine	Higher Crown Ditches	1-1/2 in HMA	Crushed		8	Native	Lime	18–24	> 10	7–8
Lexington Fayette	KY	Swelling	Crown Ditches	1-1/2 in HMA	Crushed		6	Crushed		6	> 10	9–10

TABLE B-29c
CASE 2: CLIMATIC REGION III—AGENCY RESPONSES TO THIN-SURFACED PAVEMENT DESIGNS

					Base			Subbase			Performance (yrs)	
Agency	State	Subgrade Soils	Drainage	Wearing Surface	Material	Stabil. Agent	Thick (inch)	Material	Stabil. Agent	Thick (inch)	w/Prev. Maint.	w/o Prev. Maint.
Pennsylvania DOT	PA	Fine	Crown Ditches Underdrain Drainable	1–1/2 in HMA	RAP		4	Crushed		6	7–8	5–6
New Brunswick DOT	NB	Fine	Higher Crown Ditches Drainable	DST	Crushed		6				9–10	5–6
Ontario MOT	Ont	Fine	Higher Crown Ditches	DST	Crushed		6	ROB		18	9–10	5–6
Adams	IN	Fine	Crown Ditches Drainable	1–1/2 in HMA	Crushed		10	Full depth reclam		6	> 10	5–6
Aroostook	ME	Fine	Crown Ditches	DST	ROB		18				7–8	5–6
Ionia	MI	Fine	Higher Crown Ditches Drainable	DST	Crushed		8	ROB		12	9–10	5–6
Kent	MI	Swelling	Higher Crown Ditches Drainable	1–1/2 in HMA	Crushed		8				7–8	5–6
Lake	MI	Coarse	Crown Ditches Drainable	TST	Crushed	CaCl	8				> 10	5–6
Crow Wing	MN	Fine & Coarse	Higher Crown Ditches	1–1/2 in HMA	Crushed		4	ROB		6	> 10	7–8
Monroe	NY	Coarse	Higher Crown Ditches Underdrains Drainable	1–1/2 in HMA	Crushed		12	Crushed		12	7–8	5–6
Steuben	NY	Fine	Higher Crown Dithches	DST	Crushed		12	ROB		12	5–6	2–4
Hopkinton	NH	Coarse	Higher Crown Ditches Drainable	1 in HMA	Crushed		6	ROB	CaCl	6	> 10	7–8
East Otto	NY	Fine	Ditches	DST	Crushed		12	Crushed		18	> 10	2–4

TABLE B-29d

CASE 2: CLIMATIC REGION IV—AGENCY RESPONSES TO THIN-SURFACED PAVEMENT DESIGNS

					Base			Subbase			Performance (yrs)	
Agency	State	Subgrade Soils	Drainage	Wearing Surface	Material	Stabil. Agent	Thick (inch)	Material	Stabil. Agent	Thick (inch)	w/Prev. Maint.	w/o Prev. Maint.
Texas DOT	TX	Fine & Coarse	Higher Crown Ditches	DST	Crushed	–	10	Local	Lime	8	> 10	7–8
Colusa	CA	Fine & Coarse	Crown Ditches	SST	Crushed		8				7–8	5–6
Glenn	CA	Fine & Coarse	Higher Crown Ditches	SST	Local	Asphalt Emulsion	4	ROB		6	> 10	> 10
Imperial	CA	Fine	Higher Crown Ditches	1–1/2 in HMA	RAP	Lime	6	Crushed	Lime	10	> 10	5–6
Sarasota	FL	Coarse	Higher Crown Ditches	1–1/2 in HMA	Local Native shell	PC	6				> 10	9–10
Nueces	TX	Swelling	Higher Crown Ditches	1–1/2 in HMA	Crushed		8	Local	Lime	12	> 10	2–4
Williamson	TX	Fine	Crown Ditches	DST	Crushed		8–10	Crushed		4	7–8	5–6
South Gate	CA	Fine	Crown Curb & Gutter	1–1/2 in HMA	Crushed		6				> 10	> 10
Converse	TX	Swelling	Crown Ditches	1–1/2 in HMA	Crushed		10				7–8	5–6

TABLE B-29e

CASE 2: CLIMATIC REGION V—AGENCY RESPONSES TO THIN-SURFACED PAVEMENT DESIGNS

					Base			Subbase			Performance (yrs)	
Agency	State	Subgrade Soils	Drainage	Wearing Surface	Material	Stabil. Agent	Thick (inch)	Material	Stabil. Agent	Thick (inch)	w/Prev. Maint.	w/o Prev. Maint.
Forest Service Tonto NF	AZ	Fine & Coarse	Higher Crown Ditches Drainable	DST	Crushed		8	Crushed		8	9–10	5–6
Forest Service Stanislaus NF	CA	Coarse	Ditches	1-1/2 in HMA	Crushed		4				. 10	7–8
Arizona DOT	AZ	Fine & Coarse	Higher Crown Ditches	1-1/2 in HMA	Crushed		4				. 10	5–6
Texas DOT		Fine & Coarse	Higher Crown Ditches	DST	Crushed	–	10	Local	Lime	8	. 10	7–8

TABLE B-29e (Continued)

					Base			Subbase			Performance (yrs)	
Agency	State	Subgrade Soils	Drainage	Wearing Surface	Material	Stabil. Agent	Thick (inch)	Material	Stabil. Agent	Thick (inch)	w/Prev. Maint.	w/o Prev. Maint.
Washington State DOT	WA	Fine & Coarse	Higher Crown Ditches	DST	Crushed		10				9–10	7–8
Finney	KS	Fine & Coarse	Higher Crown Ditches	DST	ROB		6	Native		6	7–8	5–6
Saline	KS	Swelling	Higher Ditches	DST	Crushed		6				5–6	2–4
Bell	TX	Fine & Coarse	Ditches	DST	Crushed		6	Local	Lime	6	. 10	5–6
Ector	TX	Coarse	Higher Crown Ditches	DST	Limestone caliche		6	Full depth reclam		6	. 10	7–8
Randall	TX	Fine	Crown Ditches	DST	Crushed		6				. 10	2–4
Yakima	WA	Fine & Coarse	Higher Crown Ditches Culverts	DST	Crushed		12				. 10	7–8
Hobbs	NM	Coarse	Higher Crown Ditches Culverts	DST	Limestone caliche		6				. 10	9–10
Brownwood	TX	Fine	Crown Curb & Gutter	1-1/2 in HMA	Crushed		8	Local	Lime	8	. 10	7–8

TABLE B-29f

CASE 2: CLIMATIC REGION VI—AGENCY RESPONSES TO THIN-SURFACED PAVEMENT DESIGNS

					Base			Subbase			Performance (yrs)	
Agency	State	Subgrade Soils	Drainage	Wearing Surface	Material	Stabil. Agent	Thick (inch)	Material	Stabil. Agent	Thick (inch)	w/Prev. Maint.	w/o Prev. Maint.
Canada Public Works	Ont	Fine & Coarse	Higher Crown Ditches Drainable	SST	Crushed		10	ROB		18–24	7–8	5–6
Utah DOT	UT	Coarse	Crown Underdrains	SST	Crushed	Lime	8				5–6	2–4
Washington State DOT	WA	Fine & Coarse	Higher Crown Ditches	DST	Crushed		10				9–10	7–8
Saskatchewan MOT	Sas	Fine & Coarse	Higher Crown Ditches	1-1/2 in HMA	Crushed		6	Native		6	> 10	5–6
Yukon	Yuk	Fine & Coarse	Higher Crown Ditches	SST	Crushed		4–6				5–6	2–4

TABLE B-30

CASE 3: SUMMARY OF WEARING SURFACES

Climatic Region (Figure 3)	Number of Responses	Number of Agencies Using Wearing Surface Indicated											
				BST			Hot Mix Asphalt Thickness (in.)						
		Agg	RAP	Single	Double	Triple	1.0	1.25	1.50	1.75	2.0	<2.0	Other
I	16				3		1		1		9	2	
II	51				9	1	1		4	1	27	7	1
III	40				2		1		1	2	24	7	3
IV	14				1				3	1	7	2	
V	18				4				1		9	3	1
VI	9				2				1		2	4	
Totals	148	0	0	0	21	1	3	0	11	4	78	25	5
Percent of Total		0	0	0	14	1	2	0	7	3	53	17	3

TABLE B-30a

CASE 3: CLIMATIC REGION I—WEARING SURFACES

Level of Government	Number of Responses	Number of Agencies Using Wearing Surface Indicated											
				BST			Hot Mix Asphalt Thickness (in.)						
		Agg	RAP	Single	Double	Triple	1.0	1.25	1.50	1.75	2.0	<2.0	Other
Federal	1										1		
State	4				2						1	1	
County	9				1		1		1		5	1	
City	2										2		
Town	0												
All Levels	16	0	0	0	3	0	1	0	1	0	9	2	0
Percent of All Levels	100	0	0	0	19	0	6	0	6	0	56	13	0

TABLE B-30b

CASE 3: CLIMATIC REGION II—WEARING SURFACES

Level of Government	Number of Responses	Number of Agencies Using Wearing Surface Indicated											
				BST			Hot Mix Asphalt Thickness (in.)						
		Agg	RAP	Single	Double	Triple	1.0	1.25	1.50	1.75	2.0	<2.0	Other
Federal	0												
State	8				3				2		1	2	
County	40				6	1	1		2	1	23	5	1
City	1										1		
Town	2										2		
All Levels	51	0	0	0	9	1	1	0	4	1	27	7	1
Percent of All Levels	101	0	0	0	18	2	2	0	8	2	53	14	2

TABLE B-30c

CASE 3: CLIMATIC REGION III—WEARING SURFACES

Level of Government	Number of Responses	Number of Agencies Using Wearing Surface Indicated											
				BST			Hot Mix Asphalt Thickness (in.)						
		Agg	RAP	Single	Double	Triple	1.0	1.25	1.50	1.75	2.0	<2.0	Other
Federal	0												
State	4										3	1	
County	23				1				1	2	12	4	3
City	3										3		
Town	10				1		1				6	2	
All Levels	40	0	0	0	2	0	1	0	1	2	24	7	3
Percent of All Levels	102	0	0	0	5	0	3	0	3	5	60	18	8

TABLE B-30d

CASE 3: CLIMATIC REGION IV—WEARING SURFACES

Level of Government	Number of Responses	Number of Agencies Using Wearing Surface Indicated											
				BST			Hot Mix Asphalt Thickness (in.)						
		Agg	RAP	Single	Double	Triple	1.0	1.25	1.50	1.75	2.0	<2.0	Other
Federal	0												
State	1				1								
County	11								3	1	5	2	
City	2										2		
Town	0												
All Levels	14	0	0	0	1	0	0	0	3	1	7	2	0
Percent of All Levels	99	0	0	0	7	0	0	0	21	7	50	14	0

TABLE B-30e

CASE 3: CLIMATIC REGION V—WEARING SURFACES

Level of Government	Number of Responses	Number of Agencies Using Wearing Surface Indicated											
				BST			Hot Mix Asphalt Thickness (in.)						
		Agg	RAP	Single	Double	Triple	1.0	1.25	1.50	1.75	2.0	<2.0	Other
Federal	0												
State	4				2						1	1	
County	7				2				1		3	1	
City	7										5	1	1
Town	0												
All Levels	18	0	0	0	4	0	0	0	1	0	9	3	1
Percent of All Levels	101	0	0	0	22	0	0	0	6	0	50	17	6

TABLE B-30f

CASE 3: CLIMATIC REGION VI—WEARING SURFACES

Level of Government	Number of Responses	Number of Agencies Using Wearing Surface Indicated: Agg	RAP	BST: Single	BST: Double	BST: Triple	Hot Mix Asphalt Thickness (in.): 1.0	1.25	1.50	1.75	2.0	<2.0	Other
Federal	2										2		
State	6				2				1			3	
County	0												
City	1											1	
Town	0												
All Levels	9	0	0	0	2	0	0	0	1	0	2	4	0
Percent of All Levels	99	0	0	0	22	0	0	0	11	0	22	44	0

TABLE B-31a

CASE 3: CLIMATIC REGION I—AGENCY RESPONSES TO THIN-SURFACED PAVEMENT DESIGNS

Agency	State	Subgrade Soils	Drainage	Wearing Surface	Base: Material	Base: Stabil. Agent	Base: Thick (inch)	Subbase: Material	Subbase: Stabil. Agent	Subbase: Thick (inch)	Performance (yrs): w/Prev. Maint.	Performance (yrs): w/o Prev. Maint.
Mississippi DOT	MS	Fine	Higher Crown Ditches Drainable	DST	Local	PC	8	Local	–	12	7–8	2–4
Texas DOT	TX	Fine & Coarse	Higher Crown Ditches	DST	Crushed	–	16	Local	Lime	8	>10	7–9
Collier Co	FL	Crushed limerock	Higher Crown Ditches	1 in HMA	Crushed		8	Crushed		12	9–10	5–6
Chambers Co	TX	Swelling	Crown Ditches	DST	Full depth reclam		8				>10	5–6
Montgomery Co	TX	Fine	Higher Crown Ditches Drainable	1-1/2 in HMA	Full depth reclam w/ mat'l added		10				>10	9–10

TABLE B-31b

CASE 3: CLIMATIC REGION II—AGENCY RESPONSES TO THIN-SURFACED PAVEMENT DESIGNS

					Base			Subbase			Performance (yrs)	
Agency	State	Subgrade Soils	Drainage	Wearing Surface	Material	Stabil. Agent	Thick (inch)	Material	Stabil. Agent	Thick (inch)	w/Prev. Maint.	w/o Prev. Maint.
Arkansas DOT	AR	Fine	Higher Crown Ditches	1-1/2 in HMA	Crushed		9				>10	>10
Mississippi DOT	MS	Fine	Higher Crown Ditches Drainable	DST	Local	PC	8	Local	–	12	7–8	2–4
Texas DOT	TX	Fine & Coarse	Higher Crown Ditches	DST	Crushed	–	16	Local	Lime	8	>10	7–9
Virginia DOT	VA	Fine	Higher Crown Ditches	1-1/2 in HMA	RAP		4				7–8	5–6
Washington State DOT	WA	Fine & Coarse	Higher Crown Ditches	DST	Crushed		12				9–10	7–8
Elmore	AL	Fine	Crown Ditches	1-3/4 in HMA	Native soil		6				5–6	5–6
Hamilton	IN	Fine	Higher Crown Ditches	1 in HMA	HMA		4				>10	7–8
Hendricks	IN	Fine & Coarse	Higher Crown Ditches Underdrains Drainable	1-1/2 in HMA	HMA		6	Crushed		6	5–6	2–4
Henry	IN	Fine	Higher Crown Ditches	1-1/2 in HMA	Crushed		8				>10	9–10
Morgan	IN	Fine & Coarse	Higher Crown Ditches	DST	RAP		8–10	Crushed		8–10	5–6	2–4
Butler	KS	Swelling	Higher Crown Ditches	DST	Crushed		8				9–10	5–6
Douglas	KS	Fine	Crown Ditches	DST	Crushed		10				5–6	2–4
Linn	KS	Fine	Ditches	DST	Crushed		8				9–10	5–6
Lyon	KS	Fine	Crown Ditches	DST	Crushed		10				>10	5–6
Talbot	MD	Fine	Ditches	TST	Crushed		9				5–6	2–4
Smith	TX	Coarse	Crown Ditches	DST	Native soil		8				9–10	5–6

TABLE B-31c

CASE 3: CLIMATIC REGION III—AGENCY RESPONSES TO THIN-SURFACED PAVEMENT DESIGNS

					Base			Subbase			Performance (yrs)	
Agency	State	Subgrade Soils	Drainage	Wearing Surface	Material	Stabil. Agent	Thick (inch)	Material	Stabil. Agent	Thick (inch)	w/Prev. Maint.	w/o Prev. Maint.
Adams	IN	Fine	Crown Ditches	1-3/4 in HMA	Crushed		10	Full depth reclam		6	>10	5–6
Aroostook	ME	Fine & Coarse	Higher Crown Ditches	DST	ROB		18				5–6	2–4
Ionia	MI	Swelling	Higher Crown Ditches Drainable	1-3/4 in HMA	Crushed		8				7–8	5–6
Monroe	NY	Coarse	Higher Crown Ditches Underdrains Drainable	1-1/2 in HMA	Crushed		12	Crushed		12	7–8	5–6
Hopkinton	NH	Fine	Higher Crown Ditches Drainable	1 in HMA	Crushed		6	ROB	CaCl	12	>10	7–8
East Otto	NY	Fine	Higher Ditches Drainable	DST	Full depth reclam	CaCl	18				>10	2–4

TABLE B-31d

CASE 3: CLIMATIC REGION IV—AGENCY RESPONSES TO THIN-SURFACED PAVEMENT DESIGNS

					Base			Subbase			Performance (yrs)	
Agency	State	Subgrade Soils	Drainage	Wearing Surface	Material	Stabil. Agent	Thick (inch)	Material	Stabil. Agent	Thick (inch)	w/Prev. Maint.	w/o Prev. Maint.
Texas DOT	TX	Fine & Coarse	Higher Crown Ditches	DST	Crushed	–	16	Local	Lime	8	>10	7–9
Imperial	CA	Fine	Higher Crown Ditches	1-3/4 in HMA	Crushed	Lime	6	Crushed	Lime	6	>10	5–6
Sarasota	FL	Coarse	Crown Ditches Underdrain Drainable	1-1/2 in HMA	Local Native shell	PC	8	Native shell		12	>10	>10
Nueces	TX	Swelling	Higher Crown Ditches	1-1/2 in HMA	Crushed	Lime	8	Local	Lime	12	>10	2–4
Williamson	TX	Fine	Crown Ditches	1-1/2 in HMA	Crushed		12	Local	Asphalt Emulsion	8	>10	7–8

TABLE B-31e

CASE 3: CLIMATIC REGION V—AGENCY RESPONSES TO THIN-SURFACED PAVEMENT DESIGNS

					Base			Subbase			Performance (yrs)	
Agency	State	Subgrade Soils	Drainage	Wearing Surface	Material	Stabil. Agent	Thick (inch)	Material	Stabil. Agent	Thick (inch)	w/Prev. Maint.	w/o Prev. Maint.
Texas DOT	TX	Fine & Coarse	Higher Crown Ditches	DST	Crushed		16	Local	Lime	8	>10	7–9
Washington State DOT	WA	Fine & Coarse	Higher Crown Ditches	DST	Crushed		12				9–10	7–8
Bell	TX	Fine & Coarse	Ditches	DST	Crushed		8	Local	Lime	6	>10	5–6
Ector	TX	Coarse	Higher Crown Ditches	DST	Crushed		8	Full depth reclam		6	>10	5–6
Randall	TX	Fine	Crown Ditches	1-1/2 in HMA	Crushed		6-8				>10	7–8

TABLE B-31f

CASE 3: CLIMATIC REGION VI—AGENCY RESPONSES TO THIN-SURFACED PAVEMENT DESIGNS

					Base			Subbase			Performance (yrs)	
Agency	State	Subgrade Soils	Drainage	Wearing Surface	Material	Stabil. Agent	Thick (inch)	Material	Stabil. Agent	Thick (inch)	w/Prev. Maint.	w/o Prev. Maint.
Utah DOT	UT	Coarse	Crown Ditches Underdrain	1-1/2 in HMA	RPA		12				7-8	2-4
Washington State DOT	WA	Fine & Coarse	Higher Crown Ditches	DST	Crushed		12				9-10	7-8
Saskatchewan MOT	Sas	Fine & Coarse	Higher Crown Ditches	DST	Crushed		6	ROB		12	>10	5-6
Yukon	Yuk	Fine & Coarse	Higher Crown Ditches	SST	Crushed		6	Crushed		6-18	7-8	2-4

TABLE B-32

CASE 4: SUMMARY OF WEARING SURFACES

Climatic Region (Figure 3)	Number of Responses	Number of Agencies Using Wearing Surface Indicated											
				BST			Hot Mix Asphalt Thickness (in.)						
		Agg	RAP	Single	Double	Triple	1.0	1.25	1.50	1.75	2.0	<2.0	Other
I	16				6				3		6	1	
II	46	5			14	3			2		16	5	1
III	33	4			6						17	4	2
IV	10			1	2						6	1	0
V	19	1			8						6	4	
VI	10				5						3	2	
Totals	134	10	0	1	41	3	0	0	5	0	54	17	3
Percent of Total		7	0	1	31	2	0	0	4	0	40	13	2

TABLE B-32a

CASE 4: CLIMATIC REGION I—WEARING SURFACES

Level of Government	Number of Responses	Number of Agencies Using Wearing Surface Indicated											
				BST			Hot Mix Asphalt Thickness (in.)						
		Agg	RAP	Single	Double	Triple	1.0	1.25	1.50	1.75	2.0	<2.0	Other
Federal	2				2								
State	4				2						1	1	
County	8				2				3		3		
City	2										2		
Town	0												
All Levels	16	0	0	0	6	0	0	0	3	0	6	1	0
Percent of All Levels	101	0	0	0	38	0	0	0	19	0	38	6	0

TABLE B-32b

CASE 4: CLIMATIC REGION II—WEARING SURFACES

Level of Government	Number of Responses	Number of Agencies Using Wearing Surface Indicated											
				BST			Hot Mix Asphalt Thickness (in.)						
		Agg	RAP	Single	Double	Triple	1.0	1.25	1.50	1.75	2.0	<2.0	Other
Federal	3	1			2								
State	8				4				1		2	1	
County	33	4			8	3			1		12	4	1
City	1										1		
Town	1										1		
All Levels	46	5	0	0	14	3	0	0	2	0	16	5	1
Percent of All Levels	100	11	0	0	30	7	0	0	4	0	35	11	2

TABLE B-32c

CASE 4: CLIMATIC REGION III—WEARING SURFACES

		Number of Agencies Using Wearing Surface Indicated											
	Number of			BST			Hot Mix Asphalt Thickness (in.)						
Level of Government	Responses	Agg	RAP	Single	Double	Triple	1.0	1.25	1.50	1.75	2.0	<2.0	Other
Federal	1	1											
State	4				2						1	1	
County	18	2			2						10	2	2
City	1										1		
Town	9	1			2						5	1	
All Levels	33	4	0	0	6	0	0	0	0	0	17	4	2
Percent of All Levels	100	12	0	0	18	0	0	0	0	0	52	12	6

TABLE B-32d

CASE 4: CLIMATIC REGION IV—WEARING SURFACES

		Number of Agencies Using Wearing Surface Indicated											
	Number of			BST			Hot Mix Asphalt Thickness (in.)						
Level of Government	Responses	Agg	RAP	Single	Double	Triple	1.0	1.25	1.50	1.75	2.0	<2.0	Other
Federal	0												
State	1				1								
County	8			1	1						5	1	
City	1										1		
Town	0												
All Levels	10	0	0	1	2	0	0	0	0	0	6	1	0
Percent of All Levels	100	0	0	10	20	0	0	0	0	0	60	10	0

TABLE B-32e

CASE 4: CLIMATIC REGION V—WEARING SURFACES

		Number of Agencies Using Wearing Surface Indicated											
	Number of			BST			Hot Mix Asphalt Thickness (in.)						
Level of Government	Responses	Agg	RAP	Single	Double	Triple	1.0	1.25	1.50	1.75	2.0	<2.0	Other
Federal	3				3								
State	4				2						1	1	
County	6	1			2						1	2	
City	6				1						4	1	
Town	0												
All Levels	19	1	0	0	8	0	0	0	0	0	6	4	0
Percent of All Levels	100	5	0	0	42	0	0	0	0	0	32	21	0

TABLE B-32f

CASE 4: CLIMATIC REGION VI—WEARING SURFACES

Level of Government	Number of Responses	Number of Agencies Using Wearing Surface Indicated											
				BST			Hot Mix Asphalt Thickness (in.)						
		Agg	RAP	Single	Double	Triple	1.0	1.25	1.50	1.75	2.0	<2.0	Other
Federal	3				2						1		
State	6				3						1	2	
County	0												
City	1										1		
Town	0												
All Levels	10	0	0	0	5	0	0	0	0	0	3	2	0
Percent of All Levels	100	0	0	0	50	0	0	0	0	0	30	20	0

TABLE B-33a

CASE 4: CLIMATIC REGION I—AGENCY RESPONSES TO THIN-SURFACED PAVEMENT DESIGNS

Agency	State	Season Limit	Subgrade Soils	Drainage	Wear Surface	Base Material	Base Stabil. Agent	Base Thick (inch)	Subbase Material	Subbase Stabil. Agent	Subbase Thick (inch)	Performance (yrs) w/PM	Performance (yrs) w/o PM
Forest Service Portland	OR	No	Fine & Coarse	Crown Ditches Drainable	DST	Crushed		10				9–10	5–6
Forest Service Nat Forest & Grassland	TX	No	Fine& Swelling	Crown Ditches Drainable	DST	Crushed		12	Local	Lime	12	>10	5–6
Mississippi DOT	MS	No	Fine	Higher Crown Ditches Drainable	DST	Local	PC	6	Local	–	12	7–8	2–4
Texas DOT	TX	No	Fine & Coarse	Higher Crown Ditches	DST	Crushed		12	Local	Lime	8	>10	5–6
Mobile Co	AL	No	Fine	Crown Ditches Cross drains	1-1/2 in HMA	Crushed		8	Local	CaCl	8	>10	7–8
Humboldt Co	CA	No	Swelling	Higher Crown Ditches	DST	Crushed		10-12	ROB		6–8	7–8	5–6
Collier Co	FL	No	Coarse	Higher Crown Ditches	1-1/2 in HMA	Crushed		8	Crushed		12	9–10	5–6
Chambers	TX	No	Swelling	Higher Crown Ditches	DST	Local	Lime fly-ash	8	Local	Lime	6	>10	5–6
Montgomery	TX	Weight	Fine	Higher Crown Ditches Drainable	1-1/2 in HMA	Crushed		12				>10	9–10

TABLE B-33b

CASE 4: CLIMATIC REGION II—AGENCY RESPONSES TO THIN-SURFACED PAVEMENT DESIGNS

						Base			Subbase			Performance (yrs)	
Agency	State	Season Limit	Subgrade Soils	Drainage	Wear Surface	Material	Stabil. Agent	Thick (inch)	Material	Stabil. Agent	Thick (inch)	w/PM	w/o PM
Forest Service Onachita	AR	No	Fine & Coarse	Higher Crown Ditches Geotextile	DST (but generally aggregate)	Crushed		6	ROB		12	>10	7–8
Forest Service Georgia	GA	Yes, weather closure	Fine	Higher Crown Ditches Drainable	DST	Crushed		8	ROB	Lime fly-ash	12	>10	9–10
Forest Service Portland	OR	Total closure deflection	Fine & Coarse	Crown Ditches Drainable	DST	Crushed		10				9–10	5–6
Georgia DOT	GA	No	Fine	Crown Ditches	1-1/2 in HMA	Crushed		6				2–4	2–4
Mississippi DOT	MS	No	Fine	Higher Crown Ditches Drainable	DST	Local	PC	6	Local	-	12	7–8	2–4
Texas DOT	TX	No	Fine & Coarse	Higher Crown Ditches	DST	Crushed		12	Local	Lime	8	>10	5–6
Virginia DOT	VA	No	Fine	Higher Crown Ditches	DST	Crushed		14	Local	PC	6	5–6	2–4
Washington State DOT	WA	Yes Weight	Fine & Coarse	Higher Crown Ditches	DST	Crushed		12				9–10	7–8
Elmore	AL	No	Fine	Crown Ditches	1-1/2 in HMA	Native soil		6				5–6	5–6
Trinity	CA	No	Fine & Coarse	Higher Crown Ditches	DST	Crushed		6–8	ROB		6–18	5–6	2–4
McDonough	IL	Yes Weight	Fine	Higher	DST	Crushed		14				>10	7–8
Daviess	IN	Yes Weight	Fine	Higher Crown Ditches	DST	Local	PC	12				5–6	2–4
Morgan	IN	Yes Weight	Fine & Coarse	Higher Crown Ditches	DST	RAP		8–10	Crushed		8–10	5–6	2–4
Boone	KY	No	Fine	Crown Ditches	DST	Crushed		4				5–6	<2
Allegany	MD	No	Fine	Crown Ditches	TST	Crushed		8				5–6	2–4
Baltimore	MD	No	Fine & Coarse	Crown Ditches Drainable	DST	ROB		12	Local	CaCl	12	5–6	5–6

TABLE B-33b (Continued)

						Base			Subbase			Performance (yrs)	
Agency	State	Season Limit	Subgrade Soils	Drainage	Wear Surface	Material	Stabil. Agent	Thick (inch)	Material	Stabil. Agent	Thick (inch)	w/PM	w/o PM
Dorchester	MD	No	Fine	Higher Crown Ditches	DST	ROB		8				2–4	<2
Queen Anne's	MD	No	Coarse	Higher Crown Ditches Drainable	TST	Full depth reclam w/ ROB added		12				5–6	2–4
Talbot	MD	No	Fine	Ditches	TST	Crushed		9				5–6	2–4
Benton	OR	Yes Tire pressure	Fine	Higher Crown Ditches	Macadam Oil Mat	Crushed		8	Crushed		10	>10	7–8
Smith	TX	No	Fine & Coarse	Crown Ditches	DST	Local	MgCl	8	Local	EN-1	6	9–10	2–4

TABLE B-33c

CASE 4: CLIMATIC REGION III—AGENCY RESPONSES TO THIN-SURFACED PAVEMENT DESIGNS

						Base			Subbase			Performance (yrs)	
Agency	State	Season Limit	Subgrade Soils	Drainage	Wear Surface	Material	Stabil. Agent	Thick (inch)	Material	Stabil. Agent	Thick (inch)	w/PM	w/o PM
New Brunswick DOT	NB	Yes Weight	Fine & Coarse	Higher Crown Ditches	DST	Crushed		6	ROB		6	9–10	5–6
Ontario MOT	Ont	No	Fine	Higher Crown Ditches	DST	Crushed		6	ROB		18	7–8	5–6
Adams	IN	No	Fine	Crown Ditches Drainable	DST	Crushed		6	Crushed		14	>10	7–8
Aroostook	ME	Yes Weight	Fine& Coarse	Crown Ditches	DST	ROB		12				7–8	2–4
East Otto	NY	Yes Weight	Fine	Ditches	DST	Crushed		24				>10	<2
Barre	VT	Yes Weight	Fine & Coarse	Higher Crown Ditches Drainable Geotextile	DST	RAP		6	ROB		12	9–10	5–6

TABLE B-33d

CASE 4: CLIMATIC REGION IV—AGENCY RESPONSES TO THIN-SURFACED PAVEMENT DESIGNS

						Base			Subbase			Performance (yrs)	
Agency	State	Season Limit	Subgrade Soils	Drainage	Wear Surface	Material	Stabil. Agent	Thick (inch)	Material	Stabil. Agent	Thick (inch)	w/PM	w/o PM
Texas DOT	TX	No	Fine & Coarse	Higher Crown Ditches	DST	Crushed		12	Local	Lime	8	>10	5–6
Glenn	CA	No	Fine & Coarse	Higher Crown Ditches	SST	Local	Asphalt Emusion	4	ROB		8	>10	>10
Williamson	TX	No	Fine	Crown Ditches	DST	Crushed		16	Local	Lime	8	7–8	5–6

TABLE B-33e

CASE 4: CLIMATIC REGION V—AGENCY RESPONSES TO THIN-SURFACED PAVEMENT DESIGNS

						Base			Subbase			Performance (yrs)	
Agency	State	Season Limit	Subgrade Soils	Drainage	Wear Surface	Material	Stabil. Agent	Thick (inch)	Material	Stabil. Agent	Thick (inch)	w/PM	w/o PM
Forest Service Tonto NF	AZ	Yes Weight	Fine & Coarse	Higher Crown Ditches Drainable	DST	Crushed		8	Crushed		8	9–10	2–4
Forest Service Stanislaus NF	CA	Yes Weight	Coarse	Ditches	DST	Crushed		4				7–8	5–6
Texas DOT		No	Fine & Coarse	Higher Crown Ditches	DST	Crushed		12	Local	Lime	8	>10	5–6
Washington State DOT	WA	Yes Weight	Fine & Coarse	Higher Crown Ditches	DST	Crushed		12				9–10	7–8
Ector	TX	No	Coarse	Higher Crown Ditches	DST	Limestone caliche		8	Full depth reclam		8	<10	5–6
Yakima	WA	No	Fine & Coarse	Higher Crown Ditches Culverts	DST	Crushed		12				>10	7–8
Las Cruces	NM	No	Fine & Coarse	Higher Drainable	DST	Crushed		12	ROB		10	5–6	2–4

TABLE B-33f

CASE 4: CLIMATIC REGION VI—AGENCY RESPONSES TO THIN-SURFACED PAVEMENT DESIGNS

						Base			Subbase			Performance (yrs)	
Agency	State	Season Limit	Subgrade Soils	Drainage	Wear Surface	Material	Stabil. Agent	Thick (inch)	Material	Stabil. Agent	Thick (inch)	w/PM	w/o PM
Washington State DOT	WA	Yes Weight	Fine & Coarse	Higher Crown Ditches	DST	Crushed		12				9–10	7–8
Manitoba DOT	Man	Yes Weight	Fine & Coarse	Higher Crown Ditches	DST	Crushed		4-6	Crushed		4–8	>10	5–6
Saskatchewan MOT	Sas	No	Fine & Coarse	Higher Crown Ditches	DST	Crushed		6	ROB		12	>10	5–6
Yukon	Yuk	Yes Weight	Fine & Coarse	Crown Ditches	SST	Crushed		3-4				<2	<2

APPENDIX C

Examples of Agency Policies

TABLE 1

SUMMARY OF DESIGN CRITERIA

CAROLINE COUNTY MANUAL OF SPECIFICATIONS AND DESIGN STANDARDS FOR COUNTY ROADS

Classification	R/W WIDTH	PAVEMENT WIDTH	DESIGN SPEED	MIN. RADIUS	MAX. GRADE REG.	MAX. GRADE ABSOLUTE	PAVEMENT TYPE	TYPICAL SECTION
LOCAL ROAD								
New Subdivision (25 lots or less)	50	22	30	150	8.0	10.0	P-2	TS-1
MINOR COLLECTOR								
New Subdivision (50 lots or less)	50	22	35	300	6.0	8.0	P-2	TS-1
MAJOR COLLECTOR								
Existing	50	22	40	500	6.0	8.0	P-1, P-2	TS-1
New Subdivision (51 lots or more)	60	24	40	500	6.0	8.0	P-2	TS-2
COMMERCIAL & INDUSTRIAL	60	24-36	35	300	6.0	8.0	P-2, P-3	TS-2/3
ARTERIAL ROAD	60	24	50	600	5.0	8.0	P-3	TS-3

Notes:

1. These are minimum design criteria. The Department may require higher design standards if deemed necessary.

TABLE 7

PAVEMENT DETAIL

CAROLINE COUNTY MANUAL OF SPECIFICATIONS AND DESIGN STANDARDS FOR COUNTY ROADS

SECTION NUMBER			ROAD CLASSIFICATION
P-1	8"	Bank Run Gravel Triple Surface Treatment	Existing County Roads Subdivisions (Local & Minor Collector Roads - 50 lots or less)
P-2	10" 2" 1"	Bank Run Gravel Bituminous Concrete Base Bituminous Concrete Surface	Parking Lots Subdivisions (Major Collector Roads - 51 or more lots) Commercial/Industrial
P-3	10" 2.5" 1.5"	Bank Run Gravel Bituminous Concrete Base Bituminous Concrete Surface	Major Collector Roads Arterial Roads Commercial/Industrial (Heavy Traffic)

Notes:

1. These are minimum pavement requirements. The Department may require a higher pavement specification if deemed necessary.
2. Equivalent pavement design can be submitted for approval to the Department.

APPENDIX D

Addresses to Obtain Foreign Pavement Design Manuals

Australia

The following manuals are available from:

ARRB Transport Research
500 Burwood Highway
Vermont South, Victoria
Australia 3133
Tel: 61– 3 9881 1555
Fax: 61– 3 9887 8104

- Austroads Pavement Design
- Sealed Local Roads Manual
- Unsealed Roads Manual

United Kingdom

The following manual is available from:

Transportation Research Laboratory
Old Wokingham Road, Crowthorne
Berkshire RG11 6AU
Tel: 0344 773131
Fax: 0344 770356

- Overseas Road Note 31: A Guide to the Structural Design of Bitumin-Surfaced Roads in Tropical and Sub-Tropical Countries

Republic of South Africa

The following manuals are available from:

Depart of Transport
P.O. Box 415
Pretoria
0001
Republic of South Africa

- TRH 4 Structural Design of Interurban and Rural Road Pavements
- TRH 14 Guidelines for Road Construction Materials

France

The following manual is available from:

le Laboratoire Central des Ponts et Chaussees
58 bd Lefebvre
75732 PARIS CEDEX 15
France

- Manuel de conception des chaussees neuves a faible trafic (Manual for the Creation of Low Traffic Roads) (In French).

THE TRANSPORTATION RESEARCH BOARD is a unit of the National Research Council, a private, nonprofit institution that provides independent advice on scientific and technical issues under a congressional charter. The Research Council is the principal operating arm of the National Academy of Sciences and the National Academy of Engineering.

The mission of the Transportation Research Board is to promote innovation and progress in transportation by stimulating and conducting research, facilitating the dissemination of information, and encouraging the implementation of research findings. The Board's varied activities annually draw on approximately 4,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation.

The National Academy of Sciences is a nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Bruce Alberts is president of the National Academy of Sciences.

The National Academy of Engineering was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encouraging education and research, and recognizes the superior achievements of engineers. Dr. William A. Wulf is president of the National Academy of Engineering.

The Institute of Medicine was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences, by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Kenneth I. Shine is president of the Institute of Medicine.

The National Research Council was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Bruce Alberts and Dr. William A. Wulf are chairman and vice chairman, respectively, of the National Research Council.

Transportation Research Board
National Research Council
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Washington, D.C. 20418

ADDRESS CORRECTION REQUESTED

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Los Angeles CA 90020-4630