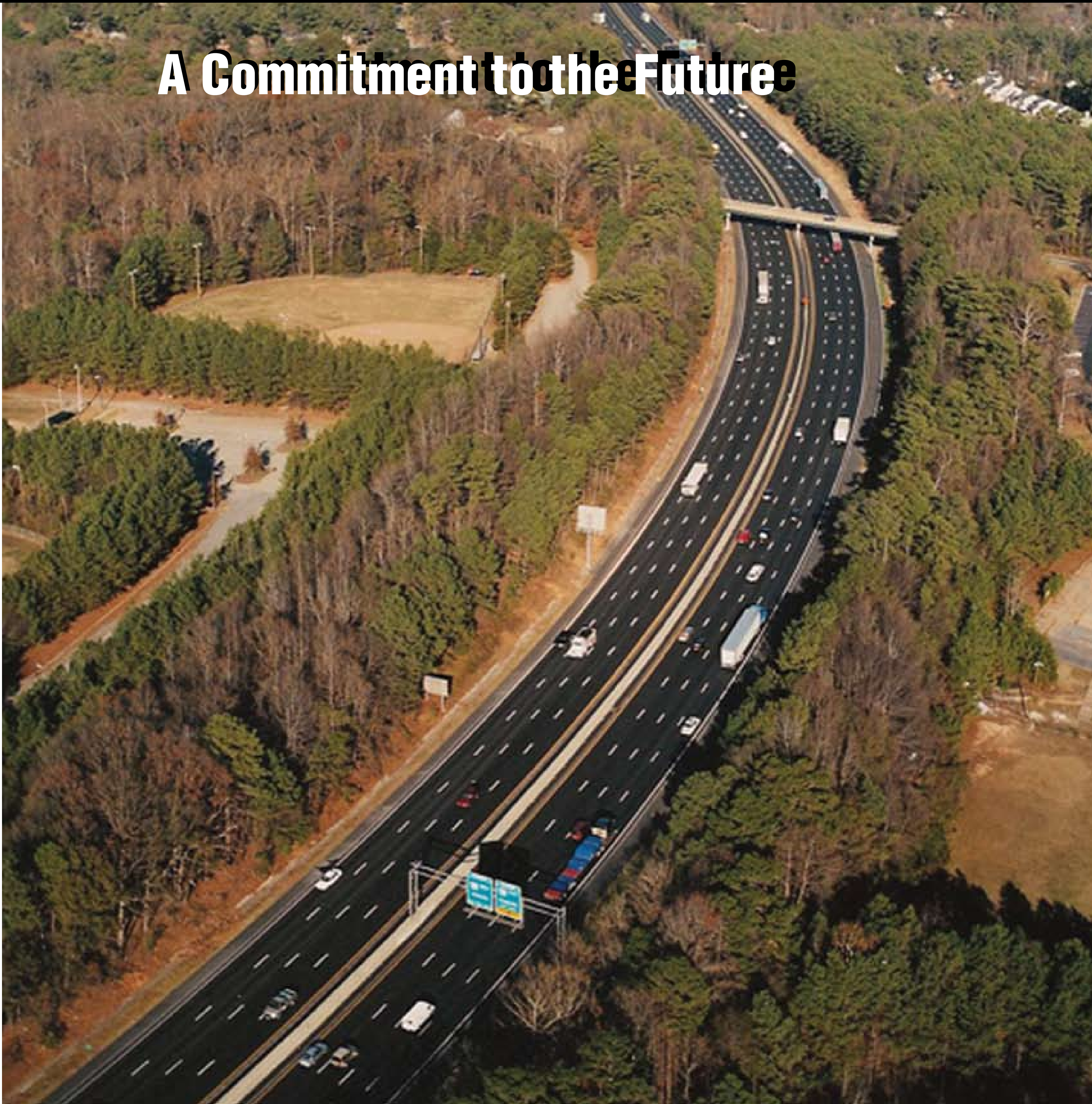
National Asphalt Roadmap

A Commitment to the Future



This publication is provided by the Members of the National Asphalt Pavement Association (NAPA), who are the nation's leading hot-mix asphalt (HMA) producer/contractor firms and those furnishing equipment and services for the construction of quality HMA pavements.

NAPA Members are dedicated to providing the highest quality HMA paving materials and pavements and to increasing the knowledge of quality HMA pavement design, construction, maintenance, and rehabilitation. NAPA also strongly supports the development and dissemination of research, engineering, and educational information that meets America's needs in transportation, recreational, and environmental pavements.

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National Asphalt Roadmap

A Commitment to the Future

EXECUTIVE SUMMARY

**Asphalt Pavement
Research and Technology**

A Special Report by

U.S. Department
of Transportation

Federal Highway Administration

**American
Association
of State Highway
and Transportation
Officials**

NAPA

National Asphalt Pavement Association

Asphalt Institute

NATIONAL STONE, SAND & GRAVEL ASSOCIATION

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NAPA Special Report 194

Acknowledgements

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CONTENTS

Vision and Purpose

This document is the result of public-private partnership and presents the shared vision of the asphalt community for research and technology in the field of asphalt pavement and material technologies. In addition to the contributing agencies and organizations recognized on the title sheet, many individuals and groups provided valuable input into the Roadmap. The roles of those who contributed varied from members of the working group, who were involved in the development of the report, to those who took time to provide review and comments. All of these contributions are valuable and are greatly appreciated. All of the organizations and individuals worked hard to make this report a valuable resource and are proud to call it our “commitment to the future.” It is our hope this report will be used often and will be useful in shaping the future of asphalt technology in the United States.

Vision

Develop improved asphalt pavement and material technologies to ensure the continued delivery of safe and economical pavements to satisfy our Nation’s needs.

Purpose

This Roadmap is a comprehensive report which addresses a full range of important challenges in asphalt technology. It serves as a guiding document for research and technology deployment organizations and for others involved in the identification and formulation of programs and projects. Individuals and groups are encouraged to draw upon and share this document.

It is our hope that the Roadmap will foster collaboration, partnership, and cooperation within the asphalt community to ensure the continued delivery of safe and economical pavements to satisfy our Nation’s needs.

Research Roadmap

The National Asphalt Roadmap is structured into programs and projects. Seven program areas are chosen to frame the major components of asphalt technology: Workforce Development, Long-Life Pavements and Pavement Performance, Improved Structural Design of Pavements, Materials Characterization and Mix Design, Construction Practices and Quality Management Systems, Innovative Contracting Approaches, and Surface Characteristics. Each program area has an introduction to provide insight into the current status of products, equipment and technology, and the major challenges in that area.

The National Asphalt Roadmap identifies a number of general research projects in each of the program areas. There are a total of 69 projects identified. The selection of projects is based on a consensus of experts from all segments of the asphalt community. The research projects discussed in the Roadmap are broad in scope. The description of each of the projects includes a brief problem statement that provides an introduction and background information related to the research needed in that project area. It should be remembered that the intent of the problem statement is to provide an overview of a research topic and not necessarily to completely define it. It is likely that a number of actual research projects with more specific scopes can be identified within each problem statement.

The tasks enumerated under each project are structured to result in clear and useful outcomes. The projects are presented in a format that includes: title, objective, introduction, background, expanded objective statement, and a work plan discussing the tasks that are anticipated. The detailed research problem statement for each project is available at www.hotmix.org.

Introduction

In the United States, transportation infrastructure investments account for approximately 7 percent of the Gross Domestic Product. As a vital part of this investment, over 550 million tons of hot-mix asphalt (HMA) are produced and placed each year. The total expenditure for asphalt pavement surfaces is in excess of $25 billion annually and over 300,000 men and women are employed in the asphalt industry.

Hot-mix asphalt is the predominant material in pavement construction, reconstruction, rehabilitation and maintenance projects. Of the 4 million miles of pavements in the U.S., 2.3 million miles are paved and approximately 94 percent of the paved miles are surfaced with asphalt. Today, many highways have exceeded their design lives and will require reconstruction, rehabilitation, and maintenance in order to continue serving the needs of the U.S. economy and traveling public.

The asphalt community, including government agencies, industry, and academia, understands how important HMA is to the nation's transportation system. Because of this enormous impact on the U.S. economy, there is a continuous effort to improve the quality and performance of asphalt pavements. These improvements would include the production and placement of HMA materials and research to discover innovations to enhance asphalt pavement-related products.

The asphalt industry provides products and services to public agencies and the private sector. The industry is comprised primarily of hot-mix asphalt producers, paving contractors, asphalt binder suppliers, aggregate suppliers, and equipment suppliers. It is committed to conducting and sponsoring research to improve the quality, economics, and versatility of asphalt mixtures, and to provide input into the development of research projects to ensure the industry's needs are addressed. Technology deployment is essential to achieve the overall goal of focusing research and development on improving the quality, economy and performance of asphalt pavements.

Joint discussions about research needs and objectives between agencies, industry, and researchers will focus the directions of innovations for asphalt pavements. Research accomplished in collaboration is more easily implemented and reaps far greater gains than research done by an individual group. With agencies and industry working together to identify, develop, and implement research programs, the potential for success of the work is greatly improved.

Background

In order to meet future technology needs, the asphalt community must take advantage of research efforts and must address the needs of both the private and public sectors. In 1994, the National Asphalt Pavement Association (NAPA) convened a forum to determine a course of action in the research and technology arena that would permit private sector input to research needs. Some key observations were made at the forum:

- Since research activities in the U.S. were highly decentralized, coordination of activities would be beneficial.
- Implementation of research results did not always occur in a systematic and timely fashion.
- Agencies were exploring ways to increase private sector participation in the research and technology (R&T) process.
- There was no structured mechanism for private sector input into the process for developing R&T needs.
- Opportunities existed for the private sector to partner in R&T issue identification and prioritization.
- The majority of highway funding for R&T came from either the individual States' Departments of Transportation, Federal Highway Administration (FHWA), or the American Association of State Highway and Transportation Officials (AASHTO), and The Transportation Research Board (TRB) which manages AASHTO's National Cooperative Highway Research Program (NCHRP) effort.

Also in 1994, TRB Special Report 244 Highway Research identified barriers to highway research. The barriers were:

- The highway industry was large.
- The economic impact of the industry was great.
- Administration of the highway system was decentralized.
- Dispersed private companies provided essential products and services.
- The highway industry provided few incentives for innovation.
- The highway industry had a "low-tech" image.
- Highway spending was substantial.
- The highway industry was now redefining its mission in the post-interstate construction era.

As a result of the NAPA forum efforts and understanding the TRB outcomes, NAPA established a major focus in the research and technology arena. A Committee for Asphalt Research and Technology (CART) was created to formulate private sector R&T concerns, working closely with FHWA and AASHTO member departments. The ultimate objective of the effort was to ensure practical implementation of research to improve the quality and performance of asphalt pavements.

CART has subsequently published two Special Reports (1996 and 1999) on asphalt industry technical needs. Collaboration between funding agencies and CART representatives has provided an excellent opportunity for partnership discussions on technical needs facing asphalt pavement performance. As expected, many of the CART-identified research projects were also on priority lists for state and federal research programs. Working collaboratively, significant progress has been made in accomplishing identified research projects.

In compiling information for this document, the writers have consulted with the National Center for Asphalt Technology, the Asphalt Institute, the National Stone, Sand, and Gravel Association, the FHWA Expert Task Groups on Asphalt and reviewed research initiatives from the International Center for Aggregate Research, the European Asphalt Pavement Association, the South African Bitumen Association, problem statements from TRB committee Web sites, and the NCHRP Web site.

This Roadmap presents the needs and state of the art of asphalt pavement technology.

Improving Asphalt Pavement Technology

Many changes have occurred in the technology associated with asphalt pavements over the last 50 years. These changes have resulted in new products, analytical tools, and testing procedures. The asphalt pavement community is committed to continuously improving the performance and economics of asphalt pavements. Thus, an on-going research and deployment program is vital to address unresolved technical issues in the industry.

Significant progress in asphalt pavement technology can only be achieved through a nationally coordinated effort to complete major projects. There is a need for large-scale efforts to solve the major challenges relating to asphalt pavements. An inclusive, well coordinated national effort is necessary to perpetuate asphalt pavement knowledge. Therefore, a focused program for asphalt research should be based on intellectual competition of substantial breadth and depth and directed by a consensus of stakeholders. Potential projects that would have a lasting impact might include: long-life pavements, safe pavements, rapid construction technologies, energy-efficient construction technologies, accelerated pavement performance evaluation approaches, and implementation of proven technology.

The Strategic Highway Research Program (SHRP) and the subsequent 15 years of follow-up research brought focus to asphalt pavement research and technology. The SHRP effort provided a new asphalt binder specification and an improved approach to dense-graded mixture design. SHRP's success demonstrates the effectiveness of a nationally coordinated program centered on discrete projects.

The U.S. Congress established the second Strategic Highway Research Program (or SHRP 2) in 2005. SHRP 2 is a targeted, short-term, results-oriented program of strategic highway research designed to advance highway performance and safety for U.S. highway users. SHRP 2 focused on applied research in four areas including efforts to address the aging infrastructure through rapid design and construction methods that cause minimal disruption to traffic and to produce long-lived facilities.

The asphalt research and technology focus must be to develop and deliver improved systems to ensure safe and economical pavements to satisfy our Nation's needs. Improvements and innovations that result from these efforts will advance the Nation's mobility and economic security while minimizing user inconvenience and environmental impacts.

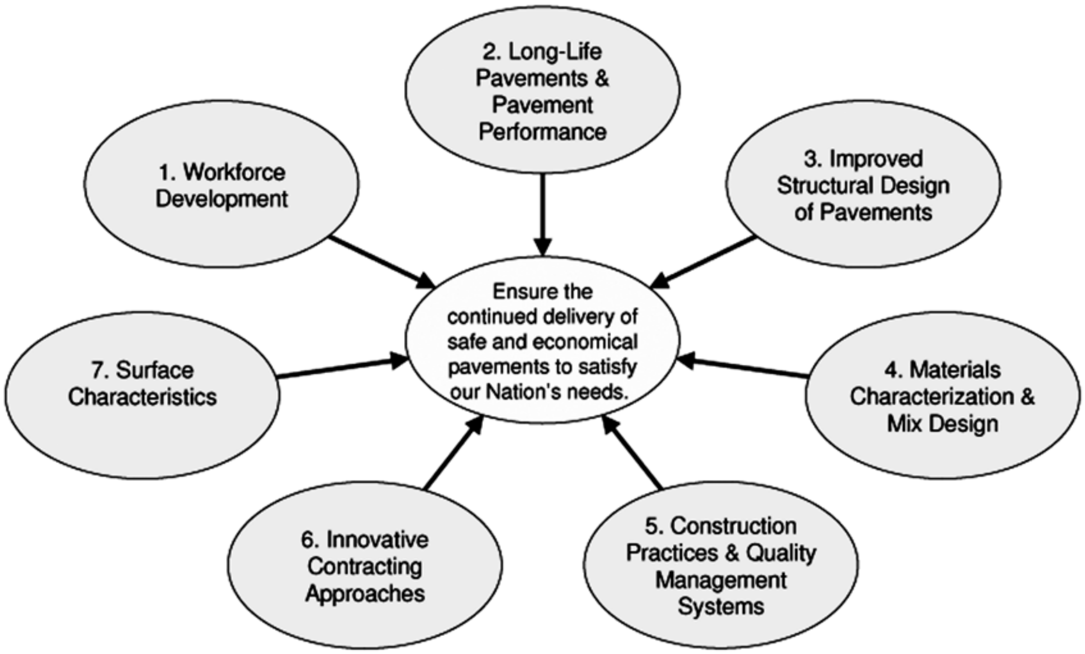
In order for the United States to remain economically competitive, its transportation infrastructure must operate at a high level of efficiency to move goods and services at the lowest possible cost. Major transportation issues of mobility, finance, safety, environmental awareness, resource availability, cost containment and workforce development need to be examined in a strategic approach to improvement. Pavements play a vital role in highway, air, and intermodal transfer operations. With over 2.1 million miles of asphalt paved roads in this country even relatively small but widely applicable advances in asphalt technology could save hundreds of millions of dollars

The over-arching goals of this Roadmap are the improvement of safety, performance, service life, and economics of asphalt pavements while safeguarding our environment. To accomplish this end, this document identifies improvements in asphalt technology that can be realized through a nationally coordinated course of action. Specific program areas and projects are identified and presented in a manner that allows interested parties an easy-to-use work plan to initiate any given project. The projects are available for downloading on-line from www.hotmix.org.

This Roadmap has been organized into the following program areas, which encompass the important components of asphalt technology:

Program Number and Title	
1.0	**Workforce Development**
2.0	**Long-Life Pavements and Pavement Performance**
3.0	**Improved Structural Design of Pavements**
4.0	**Materials Characterization and Mix Design**
5.0	**Construction Practices and Quality Management Systems**
6.0	**Innovative Contracting Approaches**
7.0	**Surface Characteristics**

FIGURE 1
Relationship between the overall vision and program areas



In each of these program areas, specific project needs are identified using both agency and contractor requirements. The project descriptions and problem statements are presented in the full report. The projects represent specific short- and long-term needs for the asphalt community. However, this is intended to be a "living" document, and the programs and projects are expected to change as research is completed and priorities change. Each project description is written as a stand-alone effort. It is also recognized that the list includes projects already under way and some projects may not be completed for several years. The project write-ups can be found at www.hotmix.org.

This report clearly demonstrates the need for strong partnerships between agencies and industry for the advancement of asphalt pavement technology. **This document is a cornerstone of the asphalt community's commitment to the future of research and technology.**

The Roadmap: Where to Start

The asphalt community understands that our future hinges on the ability to incorporate innovation in terms of product quality, performance, economics, and versatility. The deployment of technology in daily operations is the result of a process of research and development of new products and methods that show potential for improving pavement and materials technology. While any contribution to the state of the art or body of knowledge for asphalt technology stemming from the National Asphalt Roadmap will advance the general understanding of the material, construction, or pavement systems, the Working Group believes there are certain over-arching technology goals supported by multiple projects critical to the future of the Nation's pavement infrastructure. With this in mind, the Roadmap Working Group has identified high priority projects in the tables listed below under each of five over-arching goals. While all projects in the Roadmap are important and can be assigned to at least one of the goals, the listed projects are especially critical.

The five goals include: Long-life Pavements, Enhanced Mix Design, Performance Based Specifications, Enhanced Quality Management Systems, and Resource Availability and Cost Containment. To ensure the important issues regarding HMA pavement research are answered, the following priority projects in each of these goal areas should be accomplished.

Goal: Long-life Pavements

The most important goal of any research and deployment program is to improve the service life, or performance, of asphalt pavements. The programs and projects included in this Roadmap are all ultimately focused on that over-riding goal. Whether asphalt pavement applications are used in new construction, rehabilitation or maintenance, a satisfactory service life is expected. Many current asphalt pavements are performing exceptionally well and meet or exceed expected service life. However, in some cases, asphalt pavements do not have adequate service lives for a number of known and unknown reasons. In addition, there is a belief that the expectations for HMA service life are too low and that as an industry, we can do better. In order to achieve "long-life" asphalt pavements, best, and in some cases, improved practices must be used in component materials selection, mixture type selection, structural design, mix design, and the construction process. Therefore, the ability to consistently meet or exceed expected asphalt pavement service life will be enhanced with improvement in all aspects of asphalt pavement technology.

This report includes programs and projects that discuss specific approaches to pavement design and structural design methods. The terms "Long-life" pavement and "Perpetual Pavement" have specific meanings that refer to the structural design and mixture type selection that is used. It has been shown that long-life pavement design and construction can provide a number of economic, safety, and environmental benefits. Many of the high priority projects that relate to this goal include continued development of Mechanistic-Empirical (M-E) structural design and analysis systems and research related to Perpetual Pavement design methods.

A significant number of Perpetual Pavement projects have been successfully built around the country. These pavements have avoided distress mechanisms that originate deep within the structure and manifest themselves as rutting or bottom-up fatigue cracking on the surface. Because deep-rooted distresses do not occur in these pavements, there is no need to reconstruct them, and while their initial costs may be higher than a thinner flexible pavement, their life-cycle costs may be lower. Avoidance of major rehabilitation and reconstruction also conserves resources in the form of asphalt cement and aggregate. It has been estimated that a Perpetual Pavement may save as much as 20 percent asphalt binder and 25 percent aggregate over a 50-year period. Resurfacing a pavement through milling and filling is a rapid means of restoring the smoothness and removing surface defects since the operations can typically be done in "off-peak" periods. This minimizes traffic disruption and creates a safer condition for motorists. To ensure that the important questions surrounding Perpetual Pavements are answered and to enable other forms of long-life asphalt pavements, the following list of high priority projects must be completed:

TABLE 1
High priority projects supporting the over-arching goal of long-life pavements

Project No. and Title	
2.01	Improved Rehabilitation of Pavements to Achieve Long-Life Pavement Criteria
2.02	M-E Design of Perpetual Pavements
2.03	Document Performance to Date of Perpetual Pavements
2.07	Fatigue Endurance Limits of Perpetual Pavement Designs
2.09	Improve Aggregate Properties for Use in Long-Life Pavements
2.11	Remaining Service Life of In-Place Asphalt Pavements
3.01	Validate and Refine Proposed M-E Design Guide
3.04	Improved Characterization of In Situ Material Properties
3.05	Development of Next Generation of M-E Analysis Systems
3.08	Development of In Situ Structural Monitoring Systems
4.01	Full-Scale Accelerated Performance Testing
4.10	Accelerated Laboratory Performance Testing
7.01	High Friction Surfaces
7.03	Mix Types to Improve Friction and Mitigate Noise
7.06	Safety-Driven Pavement Surface Type Selection

Enhanced Mix Design

Advances in the selection of materials and design of hot-mix asphalt are essential to providing performance, economy, and versatility to the final product. This has been evident in the Superpave system resulting from the Strategic Highway Research Program, where five years of research and the subsequent 15 years of implementation have led to improved performance and producers gaining a better understanding of HMA.

Designing mixes to play specific roles within the pavement structure, specialty surface mixes for safety and performance, and the increased use of polymer-modified asphalts are only a few of the innovations that have occurred in the past 20 years. However, further critical work needs to be done to advance asphalt mixture design and improve economy. Completing the high priority projects listed below is essential in this effort:

TABLE 2
High priority projects supporting the over-arching goal of enhanced mix design

Project No. and Title	
4.05	Measurement of Interaction Between the Asphalt and Aggregate Surface
4.07	Warm Mix Asphalt
4.09	Develop High RAP Content Mix Design Procedure
4.11	Improved Equipment and Test Procedures
4.14	Field versus Laboratory Volumetric and Mechanical Properties
4.16	Validate/Refine Superpave Mix Design Procedure
4.17	Mix Designs to Utilize Locally Available Materials

Enhanced Quality Management Systems

Numerous improvements have been made in the production, quality control, and quality assurance of hot-mix asphalt. As construction processes have evolved, production and paving personnel have seen the benefit of receiving feedback concerning quality as material is manufactured and placed. Adjustments made on the basis of such information result in more consistent production, better efficiency, higher quality, and, in many cases, increased payment. Quality control has come to mean more than material sampling and testing, it includes communications, troubleshooting, and training so that all construction personnel are focused on the quality of the final product. Although great strides have been made within the industry in improving the quality of the final product, more training and technology must be brought to bear on the issue through the following set of high priority projects:

TABLE 3
High priority projects supporting the over-arching goal of enhanced quality management systems

Project No. and Title	
1.01-1.04	Workforce Development
5.04	Real-time Process Control for Asphalt Plant Operations
5.05	Real-time Process Control for Laydown and Compaction
5.06	Non-Destructive Evaluation (NDE) for Process Control and QC/QA
5.09	Improve Risk Assessment of QC/QA Statistical Specifications
5.11	Work Zone Safety
5.15	Improve the Quality of Night Construction

Performance Based Specifications

There are many factors that dictate the performance of asphalt pavements. Materials selection, thickness design, construction quality, traffic, and climate are all primary considerations in performance. In the past, asphalt mixtures have been manufactured and placed according to specifications that are assumed to be inherently related to pavement performance. However, the direct relationships between mixture characteristics and pavement behavior have been elusive. For instance, it is widely believed that pavement fatigue life, rutting, durability, and aging are strongly correlated with HMA density or void content. Yet differences in aggregate size (fine versus large), gradation (dense versus open versus gap), mix components (fiber or mineral filler), and binder grade prevent this relationship from being universal.

In the future, in order to ensure long-life pavements, a greater effort will need to be made in developing specifications that are based on specifying the quality characteristics of materials and construction that relate to long-term performance for specific applications. These specifications also provide HMA producers and paving contractors with the flexibility to incorporate innovations in their operations as they assume the risk for long-term performance. Thus, much will hinge on

the mechanical properties of the final mix and the relationships of these properties to the desired performance of the material. In order to make significant progress in this area, completion of the following high-priority projects is considered essential:

TABLE 4
High priority projects supporting the over-arching goal of performance based specifications

Project No. and Title	
2.06	Validate/Refine Pavement Performance Type Specifications
4.01	Full-Scale Accelerated Performance Testing
4.02	Improved Asphalt Binder Specification
4.04	Performance-Based and Related Aggregate Properties
4.10	Accelerated Laboratory Performance Testing
4.13	Develop Durability Test

Resource Availability/Cost Containment

Future uncertainty in the supply of materials for hot-mix asphalt, unpredictability in the cost of energy, and the need for economic stability in construction markets requires that private industry and public agencies maintain the greatest possible flexibility in the selection of materials, mixture design, production, and placement while preserving performance. A recent case in point was the 2005-2006 oil price increase which led to increased construction prices around the world. Another example is the inability of currently permitted aggregate resources to meet the increasing demand for construction and highway products in some key markets. Site permitting, zoning in metropolitan areas, and governmental regulatory barriers have made it difficult to open new aggregate operations to meet this demand and usable deposits are often covered up (or rendered unusable) because of land-use policies.

Maintaining the national infrastructure must be a high priority for this country to maintain its economic competitiveness. Reuse of materials, energy conservation, improved construction techniques, use of locally available materials, and use of viable alternative materials are strategies that may be employed to provide greater economy and improved sustainability. The following projects are a high priority in achieving these goals:

TABLE 5
High priority projects supporting the over-arching goal of resource availability/cost containment

Project No. and Title	
2.04	Advanced Understanding of Life Cycle Costs for Asphalt Pavements
2.05	Update User/Non-user Cost Data
4.03	Development of Alternative Binder Materials
4.08	Additional Recycled Materials (other than RAP)
4.17	Mix Designs to Utilize Locally Available Materials
5.01	Energy Efficiency
5.02	Recycling Technologies
5.03	Improved Construction Equipment and Procedures
6.01	Develop Rapid Construction Methods
6.02	Risk Assessment of Non-Traditional Contracting Techniques
7.04	Economics of Pavement Smoothness

The Challenge

The major challenge confronting the whole transportation community is maintaining the flow of people, goods, and services that allow the United States to remain economically competitive in a rapidly changing global marketplace. An essential component of this challenge is the continued improvement of the technology to design, build, and maintain roadways which are the fundamental arteries of the national economy. This challenge is even more difficult because it comes at a time when the asphalt community is struggling to maintain an aging infrastructure with increasing traffic and shrinking resources. For asphalt pavements, the challenge can be met using a nationally coordinated effort to conduct research focused on specific programs and projects.

The projects presented in the Roadmap represent the Working Group's top priority for research, development, and deployment. Some would more appropriately be addressed at a national level while others would be more pertinent to local conditions. In order to meet the future needs of the system of pavements in this country, all of these topics will require attention.

National Asphalt Roadmap

A Commitment to the Future

SUMMARY OF PROJECTS AND PROGRAMS

No.	*Project/Program*	*Objectives*
1	**Workforce Development**	**Develop strategies to recruit, retain, and develop the HMA workforce.**
1.01	**Workforce Growth**	Develop and implement possible avenues for increasing the workforce in asphalt community
1.02	**Workforce Training and Development**	Develop avenues for training existing workforce on current technologies
1.03	**Train the Trainers**	Develop a cadre of qualified experts to conduct technical/workforce training in the HMA industry
1.04	**Standardization of Workforce Competency**	Develop universal standards to establish levels of competency in technical and skilled labor
2	**Long-life Pavements and Pavement Performance**	**Verify and improve technology for long-life pavement structural design, materials optimization, life cycle cost analysis, and data collection techniques for pavement evaluation**
2.01	Improved Rehabilitation of Pavements to Achieve Long-life Pavement Criteria	Develop approaches for rehabilitating existing pavements to meet long-life pavement criteria
2.02	Mechanistic-Empirical Design of Perpetual Pavements	Validate design values and criteria used in Perpetual Pavement design
2.03	Document Performance of Perpetual Pavements	Review existing pavements meeting Perpetual Pavement criteria to evaluate performance
2.04	Advanced Understanding of Life Cycle Costs for Asphalt Pavements	Develop typical life cycle cost information and approaches for obtaining the information for asphalt pavements
2.05	Update User and Non-user Cost Data	Develop rational user/non-user cost information associated with HMA pavement applications
2.06	Validate and Refine Pavement Performance Type Specifications	Validate/refine performance type specifications for design and placement of asphalt pavements

No.	*Project/Program*	*Objectives*
2.07	Fatigue Endurance Limits of Perpetual Pavement Designs	Validate fatigue endurance levels with a field experiment
2.08	Improved Hot-Mix Asphalt Sample Preparation and Pavement Performance Prediction	Determine difference in properties among compacted HMA samples that are used in mix design, used for QC/QA purposes during production / construction and used for testing of in-place pavements
2.09	Improved Aggregate Properties for Use in Long-life Pavements	Develop aggregate treatments to alter properties and provide long-life performance
2.10	High-modulus Asphalt Base Courses in Perpetual Pavement	Develop/validate design and construction criteria and procedures for high-modulus base layers
3	**Improved Structural Design of Pavements**	**Develop improved design methods, which will optimize HMA pavements to accommodate future changes in traffic and materials while acounting for environmental effects.**
3.01	Validate and Refine Proposed Mechanistic-Empirical Design Guide	Validation and refinement of new Mechanistic-Empirical Design Guide being implemented under NCHRP 1-40
3.02	Develop Pavement Structural Design Guide for Low-Volume Roads	Develop simplified approach to structural design of low-volume roadways
3.03	Improved Structural Design for Special Vehicles on Heavy Duty Pavements	Develop improved structural methods for heavy duty loading situations
3.04	Improved Characterization of In-Situ Material Properties	Explore test equipment and methods for characterization of in-situ materials prior to an asphalt overlay, including cold and hot recycled AC and fractured PCC during pavement rehabilitation projects
3.05	Development of Next Generation of Mechanistic-Empirical Analysis Systems	Develop improved Mechanistic-Empirical design methods
3.06	Porous Pavement Design Guide	Develop improved design procedures for porous pavements for various applications including material guidelines and guide specifications
3.07	Laboratory Determination of Material Properties for Structural Design	Develop realistic testing procedures for material properties to be used in flexible pavement design
3.08	Development of In Situ Structural Monitoring Systems	Develop instrumentation and data systems capable of monitoring the long-term structural conditions of flexible pavements in-place

No.	Project/Program	Objectives
4	**Materials Characterization and Mix Design**	**To develop test methods, specifications, and performance relationships, which will lead to optimization of materials and mix design for asphalt pavements.**
4.01	Full-scale Accelerated Performance Testing	Develop guidelines and recommended practice for design, construction and operation of full-scale APTs
4.02	Improved Asphalt Binder Specification	Validate/refine the Superpave PG system for neat and modified asphalt binders
4.03	Development of Alternative Binder Materials	Identify and study alternative binder materials for use in flexible pavement mixtures
4.04	Performance-Based / Related Aggregate Properties	Develop and validate performance-based aggregate characterization techniques for inclusion in the mixture design system
4.05	Measurement of Interaction Between the Asphalt and Aggregate Surface	Identify laboratory equipment and test procedures to measure the strength of the interaction (bond) between the asphalt and aggregate surface
4.06	Moisture Damage Susceptibility of HMA Mixtures	Improve fundamental understanding of moisture susceptibility, including mix design and QC/QA tests and treatments/additives during production
4.07	Warm-Mix Asphalt	Investigate, validate, refine warm-mix asphalt technologies and analyze mix design, performance, and environmental data
4.08	Additional Recycled Materials (other than RAP)	Identify and develop procedures/guidance for the effective and economical recycling of reclaimed/reprocessed materials (other than RAP)
4.09	Develop High RAP Content Mix Design Procedure	Develop means to produce high quality, high RAP content HMA mixtures including RAP with polymers, asphalt-rubber, roofing shingles, etc.
4.10	Accelerated Laboratory Performance Testing	Develop improved laboratory tests/constitutive models to better predict pavement performance
4.11	Improved Equipment and Test Procedures	Identify laboratory equipment and test procedures to increase automation and reduced variability
4.12	Laboratory Workability Test	Develop a laboratory workability device to assess the ease of placement/compactability in the field
4.13	Laboratory Durability Test	Develop improved durability test for mixture aging/moisture sensitivity correlated to performance
4.14	Field Versus Laboratory Volumetric and Mechanical Properties	Define the causes of the differences between laboratory mixed-laboratory-compacted and field mixed-laboratory-compacted, and field mixed-field-compacted (QC/QA) volumetric and mechanical property test results
4.15	HMA for Low Traffic Roadways	Develop HMA mixture design approach with specific applicability to low traffic pavements where durability may be a more important characteristic than structural capability
4.16	Validate and Refine Superpave Mix Design Procedure	Investigate, validate, and refine new Superpave mix design procedure from NCHRP 9-33
4.17	Mix Designs to Utilize Locally Available Materials	Develop mixture design approaches to ensure the performance of HMA comprised of locally available materials
4.18	Resource Availability Study for Asphalt Binders and Aggregates	Forecast national supply and demand for asphalt binders and aggregates and develop approach for resource analysis at regional and local levels

No.	*Project/Program*	*Objectives*
5	**Construction Practices and Quality Management Systems**	**To develop construction practices to improve quality, increase productivity, improve safety, and extend pavement life.**
5.01	Energy Efficiency	Identify and develop equipment, innovations/improvements that will result in improved energy efficiency
5.02	Recycling Technologies	Improve equipment and best practices to facilitate the incorporation of reclaimed asphalt pavement (RAP) materials into recycled HMA
5.03	Improved Construction Equipment and Procedures	Identify innovative laydown/compaction equipment and procedures that will result in improved quality/efficiency in paving operations
5.04	Real-Time Process Control for Asphalt Plant Operations	Develop real-time test methods and processes for QC and QA purposes at HMA production plants
5.05	Real-Time Process Control for Laydown and Compaction	Develop real-time process control technologies for HMA laydown and compaction operations
5.06	Non-Destructive Evaluation (NDE) for Process Control and QC/QA	Identify and conduct research on NDE Process Control and QC/QA tools
5.07	Longitudinal Joints	Develop best practices for joint construction
5.08	Develop a Fundamental Model for Field Compaction	Develop models and advanced guidance to better understand the compaction process of HMA
5.9	Improve Risk Assessment of QC/QA Statistical Specifications	Standardize procedures and develop software to evaluate buyer/seller risk of a QC/QA statistical specification
5.10	Improved Techniques to Obtain and Measure HMA Smoothness	Evaluate new opportunities to improve HMA pavement smoothness and measuring equipment
5.11	Improved Work Zone Safety	Identify ways to improve work zone safety devices/ methods and develop guidelines for best practices
5.12	Asphalt Binder Content Measurement	Develop improved means of measuring the asphalt binder content of HMA mixtures
5.13	Segregation Control	Develop improved methods for measuring segregation longitudinally and transversely and develop guide specifications for segregation
5.14	In-Place Recycling	Evaluate ways to improve materials/equipment and develop guidelines for best practices of hot and cold in-place asphalt recycling techniques using bituminous materials
5.15	Improve the Quality of Night Construction	Develop methods to improve the construction of pavements during nighttime through better equipment, practices, and inspection techniques

No.	*Project/Program*	*Objectives*
6	**Innovative Contracting Approaches**	**Evaluate the advantages and disadvantages of innovative and non-traditional financing contracting approaches used for HMA projects.**
6.01	Develop Rapid Construction Methods	Develop and evaluate new opportunities to reduce construction time, improve safety, and improve economics while maintaining quality. Develop techniques to reduce lane occupancy time during placement of asphalt pavements
6.02	Risk Assessment of Non-Traditional Contracting Techniques	Evaluate the performance of projects built with innovative and/or non-traditional contracting to determine economic risks for owner/contractor
6.03	Critical Review of Pavement Projects Built Using Non-Traditional Contracts	Evaluate the pavement performance of existing warranty projects and the cost/benefit of non-traditional projects, including the appropriate length and conditions of the warranty
6.04	Best Practices for Innovative Contracting	Prepare a document describing the best practice for engaging in warranty, design-build, design-build-maintain, design-build-operate contracts
6.05	Education and Training for Design Consultants	Conduct workshops, seminars, and online training for consulting engineers to become familiar with pavement design standards in an innovative contracting environment
6.06	Best Practices for Maintenance Contracting and Facility Leasing	Develop a document that provides guidance to policy makers, administrators, agency personnel on contract content and performance standards for maintenance/facility leasing contracts
7	**Surface Characteristics**	**To develop materials selection, design methods, QC/QA guidelines, performance relationships, and mix type selection for mixes to improve surface characteristics (friction, smoothness, splash/spray, and noise) of HMA pavements.**
7.01	High Friction Surfaces	Develop improved materials selection, design methods, QC/QA for high friction surface mixes
7.02	Pavement Noise Reduction	Evaluate noise characteristics of materials/tests to measure noise
7.03	Mix Types to Improve Friction and Mitigate Noise	Develop a recommended practice for HMA mixtures that can be used to provide an acceptable level of friction and noise mitigation
7.04	Economics of Pavement Smoothness	Develop benefit/cost relationships for pavement smoothness considering both agency/user costs
7.05	Advanced Surface Characteristics Model	Developed advanced models relating 3-dimensional images to pavement surface characteristics, specifically: noise and spray
7.06	Safety-Driven Pavement Surface Type Selection	Develop surface HMA mix type selection guidance to enhance overall safety
7.07	Thin-Lift Surfaces	Develop improved mixtures and construction techniques for thin-lift surface construction

SI* (MODERN METRIC) CONVERSION FACTORS

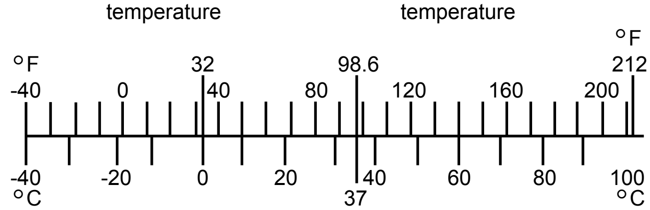
APPROXIMATE CONVERSION TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
inches	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
AREA				
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
TEMPERATURE (exact)				
°F	Fahrenheit temperature	5(F-32)/9	Celsius temperature	°C

NOTE: Volumes greater than 1000 L shall be shown in m^3.

APPROXIMATE CONVERSION FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
AREA				
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons(2000 lb)	T
TEMPERATURE (exact)				
°C	Celsius temperature	1.8C + 32	Fahrenheit temperature	°F



*SI is the symbol for the International System of Measurement.

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