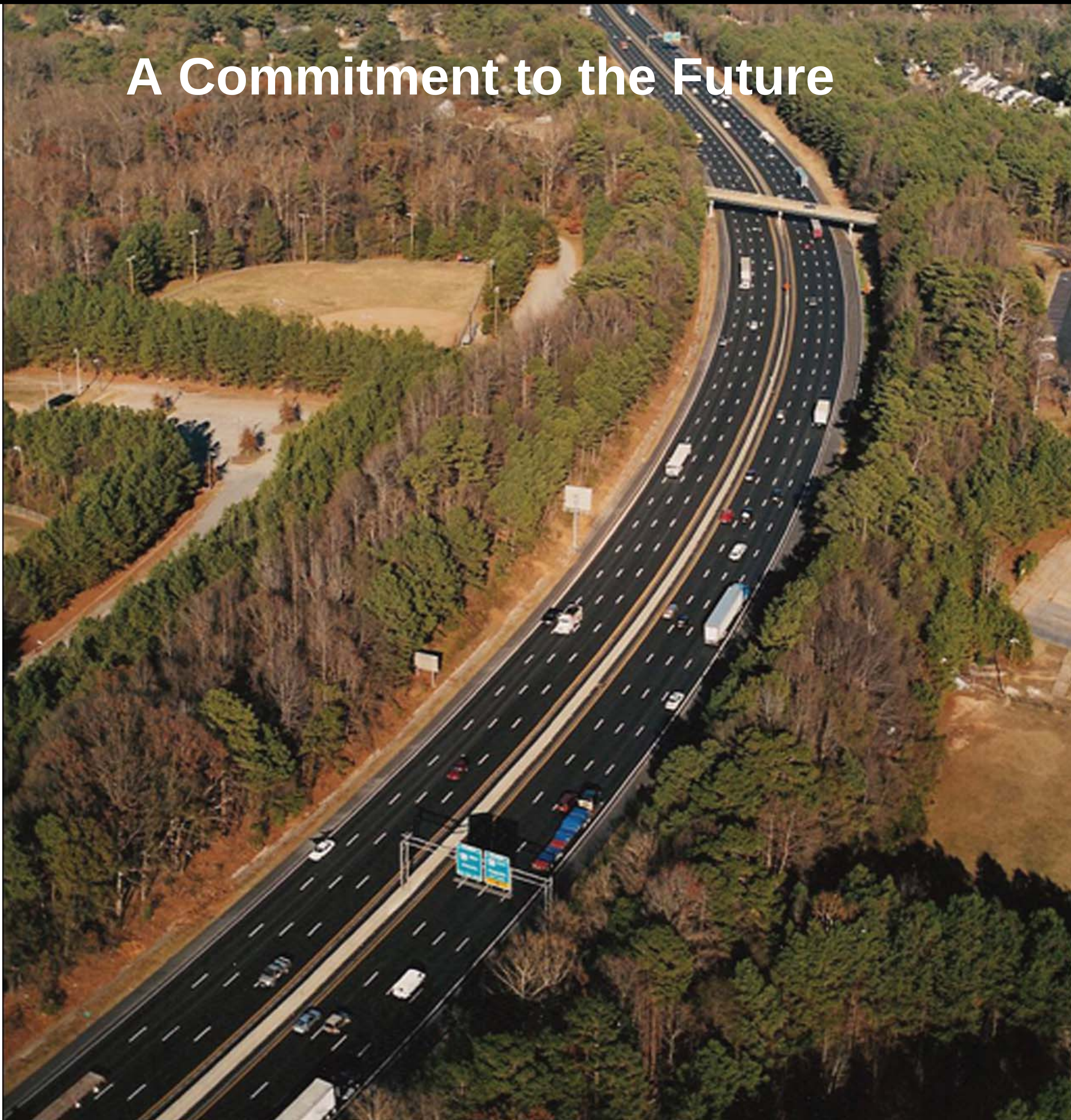
National Asphalt Roadmap

A Commitment to the Future



NATIONAL ASPHALT ROADMAP

A Commitment to the Future

Asphalt Pavement Research and Technology

A Special Report

by

Federal Highway Administration
American Association of State Highway and Transportation Officials
National Asphalt Pavement Association
Asphalt Institute
National Stone, Sand, & Gravel Association

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Acknowledgements

Many people have contributed greatly to making the National Asphalt Roadmap a reality. The Committee on Asphalt Research and Technology of the National Asphalt Pavement Association has spent many hours in deliberation on the outline of research projects and the review of this report. Special thanks go to the NAR Working Group members below.

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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 that 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.

Roadmap 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 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 (7) programs 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 sixty-nine (69) projects identified. The selection of projects is based on a consensus of experts from all segments of the Asphalt Community. The research projects contained in the Roadmap are broad in scope. 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 the intent of the problem statement is to provide an overview of a research topic and not necessarily to completely define a specific research project. It is likely 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 consisting of anticipated tasks. The detailed research problem statement for each project is available at www.hotmix.org

Introduction

In the United States (US), transportation infrastructure investments account for approximately seven-percent (7%) 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 US, 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 US 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 US economy, there is a continuous effort to improve the quality and performance of asphalt pavements, including the production and placement of HMA materials and research to discover new 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 US 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 research and 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 State Departments of Transportation, Federal Highway Administration (FHWA), or the American Association of State Highway and Transportation Officials (AASHTO), and The Transportation Research Board (TRB) 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 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 received consultation from 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 Asphalt Pavement Association, problem statements from TRB committee Websites and the NCHRP Website.

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 pavements 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 US 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 US 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 overarching 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

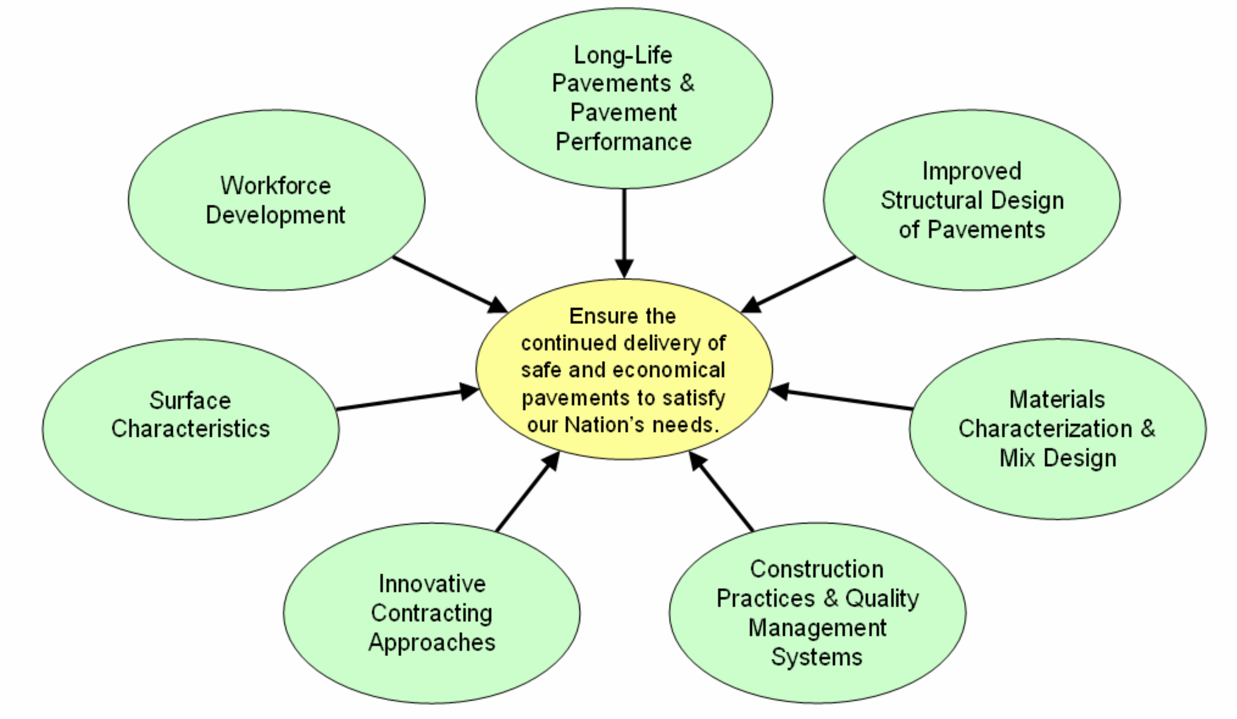

Figure 1. Relationship between the overall Vision and Program Areas.

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	**Program 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

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 underway by others and some projects may not be completed for several years. For those who only have the Executive Summary of the Roadmap, 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 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 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.

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 deeprooted 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:

Project No.	Title
2.01	Improved Rehab. of Pavements to Achieve Long-Life Pavement Criteria
2.02	Mechanistic-Empirical Design of Perpetual Pavements
2.03	Document Performance of Perpetual Pavements
2.07	Fatigue Endurance Limits of Perpetual Pavement Designs
2.09	Improved 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 fifteen 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 following high priority projects listed below is essential in this effort:

Project No.	Title
4.05	Measurement of Interaction Between the Asphalt and Aggregate Surface
4.07	Warm Mix Asphalt
4.09	Development of 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 and 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:

Project No.	Title
1.01	Workforce Growth
1.02	Workforce Training and Development
1.03	Train the Trainers
1.04	Standardization of Workforce Competency
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	Improved Risk Assessment of QC/QA Statistical Specifications
5.11	Improved Work Zone Safety
5.15	Improved 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:

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

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:

Project No.	Title
2.04	Advanced Understanding of Life Cycle Costs for Asphalt Pavements
2.05	Update User and 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	Development of 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.

SUMMARY OF PROGRAMS AND PROJECTS				
		PROJECTS		
NO.	OBJECTIVE	NO.	PROJECT NAME	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 & 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
		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 in compacted HMA samples 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 methods and treatments to improve aggregate properties 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
		2.11	Remaining Service Life of In-Place Asphalt Pavements	Develop a fundamental basis for assessing the remaining service life of existing pavements

SUMMARY OF PROGRAMS AND PROJECTS

NO.	OBJECTIVE	PROJECTS NO.	PROJECT NAME	OBJECTIVES
3	**Improved Structural Design of Pavements**			
	Develop improved design methods, which will optimize HMA pavements to accommodate future changes in traffic and materials while accounting for environmental effects.	3.01	Validate and Refine Proposed M-E Design Guide	Validation and refinement of new M-E Design Guide being implemented under NCHRP 1-40
		3.02	Development of 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 in-place recycled material and fractured PCC during pavement rehabilitation projects
		3.05	Development of Next Generation of M-E Analysis Systems	Develop improved M-E 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
4	**Materials Characterization & 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 rec. 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 & test procedures to measure the strength of the interaction (bond) between the asphalt and aggregate surface

SUMMARY OF PROGRAMS AND PROJECTS				
PROGRAM		PROJECTS		
NO.	OBJECTIVE	NO.	PROJECT NAME	OBJECTIVES
4	**Materials Characterization & Mix Design (continued)**			
	To develop test methods, specifications, and performance relationships, which will lead to optimization of materials and mix design for asphalt pavements.	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 matrls. (other than RAP)
		4.09	Development of 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 test 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

SUMMARY OF PROGRAMS AND PROJECTS

PROGRAM		PROJECTS		
NO.	OBJECTIVE	NO.	PROJECT NAME	OBJECTIVES
5	**Construction Practices & 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 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	Development of Fundamental Model for Field Compaction	Develop models and advanced guidance to better understand the compaction process of HMA
		5.09	Improved 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	Improved 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	Improved Quality of Night Construction	Develop methods to improve the construction of pavements during nighttime through better equipment, practices, and inspection techniques

SUMMARY OF PROGRAMS AND PROJECTS				
PROGRAM		**PROJECTS**		
NO.	OBJECTIVE	NO.	PROJECT NAME	OBJECTIVES
6	**Innovative Contracting Approaches**			
	Evaluate the advantages and disadvantages of innovative and non-traditional financing and contracting approaches used for HMA projects.	6.01	Development of 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 Warranty Contracts	Evaluate the pavement performance of existing warranty projects and the cost/benefit of warranty 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 on-line 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 hot mix asphalt 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

Program One: WORKFORCE DEVELOPMENT

<u>Projects in Program One</u>

Project 1.01	**Workforce Growth**
Project 1.02	**Workforce Training and Development**
Project 1.03	**Train the Trainers**
Project 1.04	**Standardization of Workforce Competence**

Program One
Workforce Development

Introduction

The HMA community comprised of government agencies and the asphalt pavement industry is in the midst of unprecedented change from many directions. Many of the most significant changes are related directly or indirectly to the workforce of both public agencies and private industry. The workforce issues include reductions in numbers, expertise and experience of people that already are and people that want to work in career fields related to pavement *design and construction*. How do these changes relate to pavement performance? These workforce issues can ultimately affect the ability of the HMA community to design, build and maintain pavements that are functionally sound and safe.

There are many reasons for the changes related to workforce, including major changes relating to the use of innovative contracting practices, the transfer of responsibility for pavement design, construction and maintenance from public to private entities, and dramatic reductions in experienced personnel at public agencies due to conscious efforts to reduce the size of government workforces. For some agencies, these issues coincide with increased funding for pavement construction and rehabilitation. This results in a smaller, less knowledgeable workforce trying to deal with an increased work load.

Background

According to the National Highway Institute's Transportation Workforce Technology Website (http://www.nhi.fhwa.dot.gov/transworkforce/new.html), the following are major issues related to transportation workforce development in the United States:

- Baby boom retirements. The Rockefeller Institute of Government estimates that 42 percent of the 15.7 million state and local government employees are between the ages of 45 and 64; and will soon be eligible to retire. There are similar projections for the private sector.
- The transportation industry will compete with other industries for a smaller labor pool of qualified workers.
- Rapid changes in transportation technology require on-going training for transportation workers.
- Changes in transportation management including downsizing of state staff and contracting out more activities and greater interaction with the public on more complex transportation issues requires new skill sets.
- A skilled, technically competent workforce is the single most effective tool the transportation community has to keep pace with increasing demand and to assure the efficient use of limited resources.

Issues relating to availability and training of personnel exist at both public agencies and private industry. NCHRP 20-24(14) "Managing Change in State Departments of Transportation" addressed the workforce issue. An excerpt from that report:

> "It appears that state Departments of Transportation (DOTs) have been hovering near crisis status regarding their workforces, and they will continue to be at the near crisis-level for some time to come.…Because of the problems faced by state DOTs – the exodus of retirees, the loss of productive employees to the private sector, the need to deal with bigger workloads in a time of losing FTEs – they have no choice but to change their mode of operation… the most important element in the execution of any statewide project is a well-trained workforce, ready to make things happen…"

The same report goes on to recommend research efforts to study ways to deal with workforce problems.

> "Workforce issue research, like many policy-related areas, has not received the attention of the research community that has other aspects of the state DOT operations. Sensible, applied research in these issues appears as necessary at this point in time as any other subject being addressed by the transportation community. The degree of importance of workforce issues to a state DOT is extreme. As one state DOT executive described it, the consequences of a high number of vacant positions or unskilled workers can truly compromise the transportation system as a whole and directly effect business and the traveling public. Yet, the workforce problems now faced can be viewed as an opportunity to develop and prepare the transportation workforce for the remainder of this century."

The specific workforce issues recommended in the NCHRP report can have immediate and long-term benefits to the asphalt community are:

(1) development of guidelines for and assistance to state DOTs in succession planning; and
(2) an examination of programs for recruiting and retaining civil engineer and planning personnel.

The private sector, including materials suppliers, paving contractors and consultants, are also facing issues related to hiring and maintaining a well trained workforce. Therefore, any research efforts undertaken to address workforce issues should include studies of private sector workforce issues in addition to studies that specifically address those issues in the public sector. Workforce needs are a reality at all levels within the pubic agencies and private industry.

One area of research should be geared specifically toward development and implementation of possible avenues for increasing the workforce in the asphalt community. Particular emphasis should be placed on addressing the perception that the asphalt industry is considered “low-tech” by many outside the industry.

Scope / Objectives

The objective of this program is to develop strategies to recruit, retain, and develop the HMA community workforce. Projects in this program will identify and address the specific workforce issues in both public agencies and private industry. Specific strategies and venues to most effectively accomplish this workforce growth will be identified

Program 1: WORKFORCE DEVELOPMENT

Project 1.01   Workforce Growth

Objective: Develop and implement possible avenues for increasing the workforce in the asphalt community

Introduction

The asphalt pavement community is made up primarily of members of the asphalt industry and government agencies. The asphalt industry is comprised of asphalt producers/ contractors as well as materials suppliers, equipment suppliers, trade organizations and consulting engineering firms. Government agencies are those that oversee and manage highway, street, airfield and parking lot pavements. In recent years, it has become apparent there are significant challenges related to workforce growth and development in virtually all aspects of the asphalt community.

The proposed workforce growth research is primarily related to the number of skilled and unskilled workers that are currently working in the asphalt community and those that would consider working in it. Many government agencies are reporting significant problems with having a sufficiently large work force. The same concerns are being reported in many areas of the asphalt industry. Although there are many theories about the reasons for this shortage of manpower, a study is needed to conclusively identify the causes. The same study can also recommend ways to address these causes and possible solutions to positively influence work force growth.

Background

When compared with other industries that potential employees can choose, jobs in the asphalt community are generally lower paying and working conditions are often less desirable. Many of the jobs in this industry require at least a portion of the worker's duties to be outside of an office environment, often in adverse weather conditions. Also, in this time where there is a major emphasis on the use of advanced technology by the workforce in other industries, the asphalt pavement community jobs are considered by many to be "low tech".

This research will be focused on ways to increase the number and quality of members of the workforce in the asphalt community. This study will identify and address the specific workforce issues at all levels in both public agencies and private industry. Specific strategies to most effectively address the reasons for the workforce problems and methods to accomplish this workforce growth will be identified.

Scope / Objectives

Develop and implement possible avenues for increasing the workforce in the asphalt community. Study ways to increase the number and quality of members of the workforce in the asphalt community. Identify the key workforce issues in both public agencies and private industry. Develop strategies to most effectively address these issues and accomplish the desired workforce growth.

Work Plan
Task 1. State-of-the-Practice

The state-of-the-practice related to addressing workforce growth issues will be evaluated. A specific focus of this project will be on growing and maintaining the growth in the size and quality of the available workforce.

Task 2. Strategies Development

Based on the findings of Task 1, identify and develop strategies for workforce growth. Recruiting techniques, career paths, educational assistance, and toolboxes for recruiters should be encompassed within these strategies.

Task 3. Implementation Manual

An implementation manual will be developed that summarizes the findings of the project. The manual will identify general strategies and make specific recommendations about avenues to recruit and retain the workforce for the asphalt community. Training on the materials found in the manual should be outlined and available upon request.

Program 1: WORKFORCE DEVELOPMENT

Project 1.02 Workforce Training and Development

Objective: Develop avenues for training existing workforce to allowing them to improve skills on current technologies

Introduction

The asphalt pavement community is made up primarily of members of the asphalt industry and government agencies. The asphalt industry is comprised of asphalt producers/ contractors as well as materials suppliers, equipment suppliers, trade organizations and consulting engineering firms. Government agencies are those that oversee and manage highway, street, airfield and parking lot pavements. In recent years, it has become apparent that there are significant challenges related to workforce growth and development in virtually all aspects of the asphalt community.

The workforce in the asphalt community is very diverse. It consists of a wide range of employees with varied education, profession requirements, experience and qualifications. The asphalt community employees vary from administrators, engineers, researchers and managers to technicians working on paving crews. In all aspects of the asphalt community, there are specific knowledge and skill sets that are required to accomplish the work. With this diverse workforce in mind, it is obvious the workforce development training programs must address employees with a broad range of education and professional needs.

One of the most important challenges is improving the knowledge level, skills and competency of employees in the asphalt community. This need can be addressed in a number of ways, including through education/training programs in a wide variety of topics that are tailored specifically for this workforce.

Background

There are currently a number of resources for training materials and courses with topics that are pertinent to the asphalt community. Some training is offered through mandatory technician certification and recertification courses at the state DOT level.

Other training opportunities include courses offered by National Highway Institute, Local Transportation Assistance Programs, the Asphalt Institute, NAPA, the Asphalt Pavement Alliance and others. The first challenge is to encourage members of the asphalt community to take advantage of these training opportunities. In addition, research in this project is to be focused on strategies for workforce development, including suggestions for effective venues and media for technical and skills training and for increasing standards of professionalism in the existing workforce in both public agencies and private industry.

Overall, it is perceived that the asphalt community must significantly improve the skills/technical training being offered to the workforce. A research effort to identify strategies to accomplish this objective is needed.

Scope / Objectives

Develop the existing workforce by first identifying the key issues related to workforce development. Identify specific strategies, media, and venues to most effectively address these issues and to accomplish this training and development.

Work Plan
Task 1. State-of-the-Practice

The state-of-the-practice related to addressing workforce development will be evaluated. Existing strategies, media, and venues available for development of the existing workforce will be identified and evaluated.

Task 2. Strategies Development

Based on the findings of Task 1, identify and develop multifaceted strategies for workforce development. The use of electronic media, traditional classroom training, college and technical school courses, hands-on training, and on-the-job training will all be incorporated in logical paths for different levels of training and expertise.

Task 3. Implementation Manual

An implementation manual will be developed that summarizes the findings of the project. The manual will identify general strategies and make specific recommendations about training or education to develop the existing workforce.

Program 1: WORKFORCE DEVELOPMENT

Project 1.03 Train the Trainers

Objective: Develop a cadre of qualified experts to conduct technical and workforce training for the HMA industry

Introduction

The asphalt industry has specific training needs at all levels that can most easily be addressed by other members of the asphalt community. Therefore, an effort should be undertaken to identify and develop subject matter experts with practical knowledge and experience that can provide training to employees in the workforce. One idea is to use individuals that are members of the regular workforce to train their co-workers. In order for this to be effective, the trainers must first be trained in technical and practical aspects of the specific job tasks. They must also be provided with training materials and instruction on effective training for employees at all levels. Therefore, there is a need to "train the trainers".

This training should be done in a wide variety of subjects, including technical areas and workforce training areas. The training should include both traditional classroom training and non-traditional, on-the-job training efforts.

Background

It is often not feasible to send all equipment operators and skilled laborers to formal training classes, and so the training must come on the job or as it becomes conveniently available. Training is many times provided by supervisors, foremen, plant managers, or co-workers who are well-versed in performing their jobs, but who may not understand the best methods of communicating with and teaching others. Thus, it is in the best interests of the industry to provide training tools so that these experts can effectively teach others the skills needed to develop an effective workforce.

The first step in developing a "train the trainer" program is to identify these second level trainers. These experts should be subject-matter experts and include those that specialize in adult education techniques. Then, needed training programs should be identified, standard training programs should be developed, including effective training materials that can be used by the instructors. Finally, a mechanism to schedule and present the training should be established.

Scope/Objectives

Teach those who are responsible for technical and workforce training effective teaching strategies appropriate for various levels of workers and skills. Trained supervisors and instructors will set levels of professionalism, standards, and competency in industry and agency personnel responsible for the production, placement, inspection, and testing of hot mix asphalt. Recognizing that people learn in different ways, supervisors and instructors will be taught multiple strategies for effective communication and knowledge assessment. Likewise, resources and aids necessary for effective teaching will be identified or developed.

Work Plan
Task 1. State-of-the-Practice

The state-of-the-practice related to train the trainer programs in the asphalt industry will be evaluated. Existing strategies, programs and tools in the transportation and other industries will be identified and evaluated. Also, determine job classifications in the HMA industry and evaluate the critical training needs.

Task 2. Levels of Training

The initial tasks will be to determine levels of training that are most important and to conduct an analysis to identify specific training efforts that are needed but not currently available. The training efforts will be at all levels and will include both technical and workforce topics. The number and type of trainers for each training topic will also be identified.

Task 3. Teaching Strategies

Trainers will be needed that use various teaching strategies, including in both traditional classroom and non-traditional, on-the-job training efforts.

Task 4. Training Resources and Identify "Training" Trainers

Based on the findings of Task 2 and 3, develop training resources and materials. Identify type and qualifications of employees at all levels that can serve as trainers.

Task 5. Pilot Training

The final step of the research will involve conducting pilot training. Based on critique of the pilot courses, improve the standard training materials and instruction skills of the trainers.

Program 1: WORKFORCE DEVELOPMENT

Project 1.04 Standardization of Workforce Competency

Objective: Develop universal standards to establish levels of competency in technical and skilled labor within the Hot Mix Asphalt industry

Introduction

An effective method to improve the credibility and success of the asphalt industry workforce is to establish standards of workforce competency. This approach is used effectively in other industries. Therefore, there is a need to establish a standard program of universal standards of competency for all of the various occupations in the asphalt industry workforce, including technicians, equipment operators, skilled laborers and laborers.

Typically, government agencies have a well developed employee evaluation program in place that can be used effectively in workforce development. However, in many parts of the asphalt industry, standards for professionalism and competency are often not available.

Background

Some helpful programs are already in place. For example, NAPA developed a tool for workforce development, which includes skills assessments in the areas of HMA production, QC/QA, HMA placement, and management. The purpose of these skill sets is to provide NAPA members with tools that may be used as part of an employee evaluation program. These skill sets can also be used as an employee improvement tool. The evaluation should be used to identify where additional training is needed, to show employees a career path and identify employees with superior skills who may be used to train other employees. These skill sets provide needed/vital information for career move assessment and is vital for training purposes.

Another approach to improving competency and credibility is to establish a standard program of employee professionalism, including accreditation and certification programs. Accreditation is a concept that is currently used for materials testing programs through the AASHTO Materials Reference Laboratory and many industry laboratories have accomplished accreditation. Certification programs for technicians in various aspects of HMA QC/QA procedures such as design, production and placement for individual employees are commonly used tools to ensure competency by state DOTs. The Asphalt Institute also offers binder testing training and certification for binder technicians.

These certification requirements have resulted in more competent employees and have also elevated the status of employees that have accomplished the certification procedure. More and more, employee compensation and value is enhanced by the certification program. This is an example of how similar professional programs can be adopted and can be of value for others in the asphalt community.

While progress is being made in developing tools to address workforce development issues in the asphalt industry, there is a need for more research to identify specific needs that are unmet and to develop standard programs that can improve competency and the level of professionalism among industry employees.

Scope/Objectives

Identify skill sets and the corresponding tasks for various levels of HMA related job functions including laborers, skilled laborers, equipment operators, truck drivers, plant operators, aggregate handlers, quality control technicians, inspectors, and supervisors. Identify levels of skills for given competence levels and the training and experience needed to attain these. Develop a systematic approach for identifying strengths and needed improvements in individuals and means for achieving these improvements.

Work Plan
Task 1. State-of-the-Practice

The state-of-the-practice related to standardization of workforce competency for employees in the asphalt industry will be evaluated. Existing strategies, programs and tools in the transportation and other industries will be identified and evaluated.

Task 2. Skill Sets and Levels of Skills Identification

Identify minimum education, experience and qualifications for various occupations and positions in the asphalt community. Identify specific skill sets and levels of skills for each position.

Task 3. Tasks within Skill Sets Identification

For each skill set identified in Task 2, identify specific tasks that are needed to accomplish the skill.

Task 4. Levels of Competency Based Upon Mastery of Tasks

For tasks identified in Task 3, define levels of competency from poor to exceptional.

Task 5. Systematic Approach to Ensuring Competency

With tools developed in previous tasks, develop and organize a systematic but practical approach to measuring competency of the workforce at all levels. The study will also recommend approaches to improving and ensuring the competency of work teams and individual employees, including consideration of establishing more certification opportunities for lower level and lower skilled employees.

Program Two: LONG-LIFE PAVEMENTS / PAVEMENT PERFORMANCE

Projects in Program Two

Project 2.01	**Improved Rehabilitation of Pavements to Achieve Long-Life Pavement Criteria**
Project 2.02	**Mechanistic-Empirical Design of Perpetual Pavements**
Project 2.03	**Document Performance of In-Place Perpetual Pavements**
Project 2.04	**Advanced Understanding of Life Cycle Costs for Asphalt Pavements**
Project 2.05	**Update User and Non-User Cost Data**
Project 2.06	**Validate and Refine Pavement Performance Type Specifications**
Project 2.07	**Fatigue Endurance Limits of Perpetual Pavement Designs**
Project 2.08	**Improved Hot Mix Asphalt Sample Preparation and Pavement Performance Prediction**
Project 2.09	**Improved Aggregate Properties for Use in Long-Life Pavements**
Project 2.10	**High-Modulus Asphalt Base Courses in Perpetual Pavement**
Project 2.11	**Remaining Service Life of In-place Asphalt Pavements**

Program Two
Long-Life Pavements & Pavement Performance

Introduction

The projects in this program will address research objectives that are related to improving HMA pavement performance and performance measurement, including the long-life pavement structural design, life cycle cost analysis, and related technologies.

Long-life or "perpetual pavements" are expected to last indefinitely with occasional replacement of the HMA surface layer. Perpetual Pavements are designed to avoid structural failure by minimizing the damage due to stresses or strains at critical points in the pavement. This assumes that there is a certain level of stress or strain in the pavement below which damage will not occur, called an endurance limit or limiting strain. Provided that this limit is defined, the computation of damage is not as critical a function as in typical M-E design.

Another topic that will be addressed in this theme will be Life Cycle Cost (LCC) analysis methodology and input variables. In the pavement type selection process, LCC analysis is used to help make the original decision about whether to use concrete or asphalt pavement. LCC is also used to make the appropriate decisions about maintenance and rehabilitation options. Since making the right decision in new and rehabilitation programs are critical from both pavement performance and cost effectiveness, it is important that LCC methodology and input information related to costs and life expectancy be accurate.

Background

Pavement performance can be measured in a variety of ways. It can be measured based on the overall service life before extensive maintenance or rehabilitation is necessary or it can be measured based on a specific pavement characteristic that the agency is using to judge pavement performance, such as smoothness, friction resistance or reduction in tire-pavement noise.

Pavement performance is most easily and most often measured based on the length of the service life of a newly constructed pavement. The goal is to produce pavements that routinely meet or exceed the expectations for long life. The expected service life of a HMA pavement application varies based on a number of factors. However, for new or rehabilitation projects, pavement designers typically expect 20 years of life from asphalt pavements before extensive rehabilitation is needed. In some cases, there are expectations for even longer service lives, especially for the underlying asphalt layers. HMA pavements are generally rehabilitated when the level of measured distress and /or deterioration in the pavement material exceeds a pre-determined serviceability level. Deep rutting or severe and extensive cracking are indications that the pavement needs to be rehabilitated.

Another way to measure pavement performance is the ability to provide a specific characteristic during the life of the pavement. For instance, characteristics like smoothness, friction resistance and reduction in tire-pavement noise are all functional quality measurements. When one or more of these desirable characteristics is present in a pavement during a specified service life, the pavement is thought to perform well.

Regardless of how performance is measured, there are many steps in the design and construction of a quality Hot Mix Asphalt (HMA) pavement that can affect performance. In order to obtain a long life asphalt pavement, it is important to ensure that life cycle cost analysis, structural design, materials selection, mix design, production and construction are all performed properly.   The technology has improved in each of these areas in recent years. The use of mechanistic based structural design methods, implementation of Superpave materials selection and mix design methodology, improvements and innovations in production, laydown and compaction equipment as well as improvements in quality control and acceptance procedures have all contributed to increase the likelihood that HMA pavements will perform for extended periods of time.

Research projects in this theme will help to obtain better performing pavements by searching for ways to improve asphalt pavement technology in performance measurement, life cycle cost analysis, structural design and mix design.

Scope / Objectives

The objective of the projects in this program will be to verify and improve technology for long-life pavement structural design, materials optimization, life cycle cost analysis, and data collection techniques.

Program 2: LONG-LIFE PAVEMENTS / PAVEMENT PERFORMANCE

Project 2.01 Improved Rehabilitation of Pavements to Achieve Long-Life Pavement Criteria

Objective: Develop approaches for rehabilitating existing pavements to meet long-life pavement criteria.

Introduction

As the highway system matures, there are relatively few new roadways being built. Instead the emphasis and the majority of the funding are dedicated to maintenance and rehabilitation of existing pavements. With the major focus of the highway community now on the design and construction of rehabilitated pavements, there is a need to improve the understanding of ways to ensure that rehabilitated design and construction processes will result in optimum performance.

HMA mechanistic-based design methodologies are being rapidly accepted and these approaches are incorporated into new AASHTO design procedures for structural design of new and rehabilitated pavements. There is also a specific mechanistic approach that is gaining attention as an improved model for improved pavement performance. This structural design method concept that can be used for design of new pavement structures can also be applied to rehabilitation design of existing rigid and flexible pavement structures.

Background

Experts in pavement design are generally of the opinion that past, purely empirical approaches are inadequate for design of modern-day rehabilitated pavements. Therefore, mechanistic methods need to be developed and implemented by highway agencies to improve rehabilitation designs and, ultimately, to improve pavement performance.

The long-life mechanistic design procedure is based on the concept of avoiding structural failure by minimizing the damage due to stresses or strains at critical points in the pavement. This assumes that there is a certain level of stress or strain (called limiting strain) in the pavement below which damage will not occur. If the structural design is adequate to ensure that limiting strain is not exceeded at these critical points, the pavement structure should have a very long life. The practical result of long-life mechanistic design is that only the top portion of the pavement structure will need to be replaced periodically to maintain the wearing surface. The structural design procedure has been effective for design of new pavement structures but more work must be done to adapt this design method to rehabilitation projects of both PCC and asphalt pavements, especially in addressing reflection cracking in the overlay. In addition, the structural design procedure must be validated with field projects where the designed pavement is constructed and then evaluated for performance.

Research is needed to develop and validate Perpetual Pavement methodology and criteria for use for design of rehabilitation projects.

Scope / Objectives

Develop approaches for rehabilitating existing pavements to meet perpetual pavement criteria.

Work Plan
Task 1. State-of-the-Practice and Experimental Plan

State-of-the-practice related to Perpetual Pavement structural design for rehabilitation of existing rigid and flexible pavements will be evaluated. During this task, existing long-life pavements that have had rehabilitation activities will be identified. The availability of information such as soils classification, design methods employed, input values, distress identification and quantities, etc. will be identified for the various pavement sections.

Task 2. Laboratory and Field Tests

Identified design approaches and criteria will be evaluated using laboratory and field testing. Field studies will be conducted on actual rehabilitation projects that were designed using Perpetual Pavement design approach. The focus of the testing will be validate the design methodology used and to project pavement performance. Information needed for this portion of the study includes, but is not limited to project design and construction records, material properties, structural evaluation, design inputs, and limiting strain values.

Task 3. Recommended Practice

Based on the findings of Task 1 and 2, a document that outlines recommended practice for using Perpetual Pavement mechanistic design procedures for rehabilitation projects on rigid and flexible pavements will be developed. This will include design software and a user's manual.

Program 2: LONG-LIFE PAVEMENTS / PAVEMENT PERFORMANCE

Project 2.02 Mechanistic-Empirical Design of Perpetual Pavements

Objective: Validate design values and criteria used in Perpetual Pavement design

Introduction

Experts in pavement design are generally of the opinion that past, purely empirical approaches are inadequate for design of modern-day pavements. Although empirical structural design procedures have resulted in pavements that perform well over their expected service life, these design methods often do not result in the most economical structural design especially on roadways with high traffic volumes. Therefore, mechanistic methods need to be developed and implemented by highway agencies to improve new and rehabilitation pavement designs and, ultimately, to ensure economical structural designs that result in better pavement performance. Mechanistic-based design methods are being rapidly accepted and these approaches are incorporated into new AASHTO design procedures for structural design of new and rehabilitated pavements. There is also a specific "long-life" mechanistic approach that is gaining attention as an advanced model for improved pavement performance. This long-life structural design method concept can be used for design of new pavement structures and be applied to rehabilitation design of HMA applications on existing rigid and flexible pavement structures.

The long-life mechanistic design procedure is based on the concept of avoiding structural failure by minimizing the damage due to stresses or strains at critical points in the pavement. This assumes that there is a certain level of stress or strain (called limiting strain) in the pavement below which damage will not occur. If the structural design is adequate to ensure that limiting strain is not exceeded at these critical points, the pavement structure should have a very long life.

Background

"Bottom-up" fatigue cracking of hot mix asphalt (HMA) pavements, has long been acknowledged as the most costly form of distress to correct through rehabilitation. Bottom-up fatigue cracking occurs when repeated wheel loads impose tensile strains of sufficient magnitude to initiate cracking at the interface of underlying aggregate base or subgrade material and the bottom of the asphalt pavement structure. This cracking eventually propagates all the way through the asphalt pavement structure up to the pavement surface. Factors contributing to this form of distress include inadequate pavement structure, weak underlying materials, and HMA mixtures with inadequate material properties. If the distress is widespread, rehabilitation to remove the entire asphalt pavement structure may be necessary.

Conversely, HMA pavements that exhibit good long-term performance have characteristics that prevent bottom-up fatigue cracking. First, they have a sufficient thickness of HMA to limit the tensile strain at the bottom of the HMA structure so that bottom-up fatigue cracking is not initiated. Next, they have a sound foundation to support the structure. Finally, the HMA mixture exhibits sufficient flexibility to counter the initiation of bottom-up cracking at low levels of tensile strain. The theoretical result of long-life mechanistic design is that only the top portion of the pavement structure will need to be replaced periodically to maintain the wearing surface.

Research is needed to continue to develop and implement "Long-Life" M-E structural design methods for new and rehabilitation projects on both existing rigid and flexible pavements.

Scope / Objectives

Validate design values and criteria used in Long-Life (Perpetual Pavement) structural design methods, including conducting field experiments to validate the recommended procedures. This project should be performed in conjunction with Project 2.03: Document Performance to Date of Perpetual Pavements.

Work Plan
Task 1. State-of-the-Practice

Document the state-of-the-practice related to M-E design and the Long-Life concept of structural design and past and current research. Review field projects to validate M-E methodology and criteria, the instrumentation of pavements to evaluate fatigue characteristics, including the use of full scale accelerated performance testing will be included. This should result in an usable synthesis for Long-Life pavement design development.

Task 2. Field Test

A field project will be conducted to collect data that can be used to validate the Long-Life M-E structural design method and any additions to current mechanistic pavement design procedures.

Task 3. Data Analysis and Recommendations

The database collected in Task 2 field evaluation will be submitted, along with the results of the analysis of the data. Recommendations for any further changes to the M-E design method or criteria and the need for further research will be developed and submitted.

Task 4. Design Procedure

A pavement design procedure for long-life asphalt pavement will be developed and presented along with a document that summarizes the findings of this project and discusses how M-E design methods and criteria should be used.

Program 2: LONG-LIFE PAVEMENTS / PAVEMENT PERFORMANCE

Project 2.03 Document Performance of Perpetual Pavements

Objective: Review existing pavements meeting Perpetual Pavement criteria to evaluate performance.

Introduction

In recent years, a specific type of long-life Hot Mix Asphalt (HMA) technology (called the perpetual pavement concept) has been introduced and studied on a number of projects around the country. The term is applied to a specific mechanistic design methodology that has been shown to result in a long life pavement structure. The perpetual pavement concept calls for a "bottom up" design philosophy that results in relatively thick, full depth asphalt pavement structures that are designed to limit the amount of damage to pavement structures that can occur under heavy loading.

It is anticipated that the perpetual pavement design concept will be implemented and used to design an increasing number of pavements, especially if it can be shown that constructed Perpetual Pavements are performing well. Research is needed to document performance of existing HMA pavement that meets the perpetual pavement design criteria.

Background

Perpetual pavements are designed to avoid structural failure by minimizing the damage due to stresses or strains at critical points in the pavement. This assumes that there is a certain level of stress or strain in the pavement below which damage will not occur, called an endurance limit or limiting strain. The theory behind limiting strain criteria is that bottom up fatigue cracking will be eliminated which will ensure long life of the asphalt base and intermediate layers. This will virtually eliminate the need for costly rehabilitation projects to replace underlying pavement courses. The only rehabilitation needed will be to replace the pavement wearing surface occasionally as surface related distress deteriorates the top pavement lift.

A large number of perpetual pavements have been constructed throughout the United States. There are also existing thick, full depth HMA pavements that were constructed prior to the perpetual pavement design concept that meet the design criteria. The proposed research project will identify perpetual pavements and conduct an evaluation of their performance and maintenance history to validate the design methodology and criteria.

Scope / Objectives

Review existing pavements meeting Perpetual Pavement criteria to evaluate their performance and to develop a systematic procedure to identify and categorize performance of Perpetual Pavements. This project should be performed in conjunction with Project 2.02: Mechanistic-Empirical Design of Long-Life Pavements.

Work Plan
Task 1. State-of-the-Practice

The documented performance of Long-Life asphalt pavements will be reviewed to assess the state-of-knowledge. Information contained in proceedings of long-life pavement conferences and symposiums as well as standard journal articles and reports will be summarized. From this, a plan to identify long-life pavements will be prepared and the data necessary to perform the study will be identified.

Task 2. Performance Evaluation of Perpetual Pavements

On pavements identified in Task 1, an evaluation of design methods/criteria used, the maintenance history, existing distress and anticipated performance will be conducted. Material properties, traffic, and climate data will play a critical role. If practical, lab testing on pavement samples and/or non-destructive testing methods will be utilized to estimate stress / strain relationships in the pavement. A mechanistic analysis of the various pavement sections will be conducted and the results will be compared to existing criteria.

Task 3. Project Summary

A project summary document will be prepared based on the findings in this project. The document will include performance data that may be used for design and construction of pavements that meet the Perpetual Pavement criteria.

Program 2: LONG-LIFE PAVEMENTS / PAVEMENT PERFORMANCE

Project 2.04 Advanced Understanding of Life Cycle Costs for Asphalt Pavements

Objective: Develop typical life cycle cost information and approaches for obtaining the information for asphalt pavements.

Introduction

Life cycle costs are increasingly being considered by public agencies as part of the decision making process for pavement type and pavement rehabilitation selection. Detailed life cycle cost techniques have the capability for including first costs, rehabilitation costs, maintenance costs, salvage value, user costs (delay, operating and accident), placement life and rate return on their calculations. Results of life cycle cost studies provide a valuable tool for the engineer.

Background

Historically, deterministic life cycle cost techniques have been used by engineers. Now FHWA software has allowed for a probabilistic approach which considers variability of cost and performance life in the calculations. Typical life cycle cost information needs to be developed for pavement, subjected to different levels of traffic in different regions of the country utilizing a variety of pavement type and paving materials.

Performance life and cost information needs to be obtained (See Project 2.03) and life cycle cost analysis performed and summarized. User cost information needs to be better defined and that will be accomplished in Project 2.05.

Scope / Objectives

Develop typical life cycle owner cost information for different types of pavements and paving materials under various traffic volumes and environmental regions of the United States.

Work Plan
Task 1. State-of-the-Practice

The state-of-the-practice relative to life cycle costing will be determined. It is likely that the FHWA probabilistic life cycle costing techniques will be selected for use in the study. Currently available pavement life, rehabilitation intervals for different treatments and cost data will be summarized for inclusion in the life cycle analysis.

Task 2. Life Cycle Cost Determination

Using both deterministic and probabilistic approaches, calculate the life cycle cost for different types of pavements and paving materials under a range of traffic volumes in different environmental regions of the United States. The LCCA calculations will evaluate the sensitivity of the calculations to rates of return, analysis period, life cycles, costs, etc.

Task 3. Implementation Manual

Prepare an implementation manual which presents the results of the results of the LCCA on a regional basis. Guidelines for conducting life cycle cost analysis will be given so that inputs to the process may be determined. A life cycle cost computer program together with operating instructions and typical input data will be included in the manual.

Program 2: LONG-LIFE PAVEMENTS / PAVEMENT PERFORMANCE

Project 2.05 Update User and Non-User Cost Data

Objective: Develop rational user and non-user cost information associated with HMA pavement applications.

Introduction

Agencies have historically used some form of life cycle cost analysis (LCCA) to assist in the evaluation of alternative pavement design strategies. Life Cycle Cost Analysis (LCCA) requires definitive information on construction, rehabilitation and maintenance costs in addition to other inputs such as the performance life of pavements and pavement materials. Estimating user and non-user costs is one of the more nebulous steps required in recent LCCAs. User costs may vary considerably according to the traffic volume, type and extent of rehabilitation, time of day, work zone strategies, lane closure policies, etc. Therefore, user cost data need to be obtained, analyzed and reported for different roadway conditions. Non-user costs are incurred by businesses and residents who are denied or allowed only restricted access due to road construction. These will vary according to the conditions listed above, as well as provisions for access, business lost due to diversions, and type of zoning.

Background

Cost information related to materials, production and placement activities can often be obtained from public agency construction and maintenance information management systems and are more readily available than user and non-user costs.
More advanced LCCA analysis requires the calculation of costs that are incurred by the highway user and also to the non-user. The user costs generally consist of vehicle operation costs and cost associated with delays as well as accidents. Increased user cost are generally the result of a deteriorating pavement that have increased distress levels, have decreasing smoothness that result in higher vehicle operating costs and more work zones that result in traffic delays. Non-user costs are more difficult to quantify. Procedures to estimate user and non-user costs at a given project location need to be improved.

Research is needed to develop improved procedures to estimate both user and non-user costs associated with HMA pavement for incorporation in Life Cycle Cost Analysis. This will help the agency/owner in the determination of the best rehabilitation strategy by focusing attention on those impacted by construction decisions.

Scope/Objectives

Develop rational user and non-user cost information associated with HMA pavement applications. This will encompass delay costs and vehicle operating costs for road users and a methodology for computing non-user costs for businesses and residents along routes that are in rehabilitation. Non-user costs may also include a methodology for computing damage to roads that are considered detours.

Work Plan
Task 1. State-of-the-Practice

Identify and review information from national publications and internal public agency reports related to user and non-user cost estimation. It is anticipated that public agencies (state and local) will have to be contacted on an individual basis to verify that this information is available. Research outside the usual realm of pavements such as the automobile and truck manufacturing industry and transportation planning will need to be consulted.

Task 2. Visits to Agencies and Industries

Public agencies and industries having the required user and non-user cost information will be identified and visited. Two to three day visits with follow-up contact will likely be required to obtain accurate cost information. Data from life cycle cost analysis and special studies will be of interest together with results from interviews with agency engineers and industry economists.

Task 3. Summary Document

A synthesis on existing sources of data, economic analyses, traffic flow, and construction productivity will be produced. From these sources, agency/owners should be able to find the inputs required to perform a Life Cycle Cost Analysis, considering user and non-user costs.

Program 2: LONG-LIFE PAVEMENTS / PAVEMENT PERFORMANCE

Project 2.06 Validate and Refine Pavement Performance Type Specifications

Objective: Validate and refine performance type specifications for design and placement of asphalt pavements.

Introduction

Currently, method or end-result specifications are those most commonly used by highway agencies. Other specification types are being used more often, including warranties, where pavement performance is measured after a predetermined time in service. There is a consensus that better approaches to specifications for design and construction of HMA pavements need to be developed and implemented. A desirable specification type is performance-based or performance-related that use performance predictions based upon tests and measurements made both before and immediately after construction. These performance specifications can eliminate the need to control the design and construction process and can base acceptance on measured characteristics that are linked to performance rather than recipes or volumetric requirements.

Background

Pavement engineers have long sought relationships between measurable material characteristics and pavement performance. If reasonable relationships can be determined, then mechanical and functional characteristics can be identified and performance specifications can be developed. Performance characteristics may include end-result elements such as product strength, bearing capacity, stability, visibility, and cracking, as well as more functional requirements such as smoothness, friction, noise reduction, chip retention, splash, and spray.

Research is currently being performed to identify performance characteristics, including fundamental performance tests and criteria. Performance specifications have been developed that use the identified characteristics, but have not yet been validated. Further research is needed to refine and validate the performance predictions based on these performance characteristics and to identify other performance characteristics.

Scope / Objectives

Refine and validate performance specifications for design and placement of asphalt pavements. This project is related to Projects 4.02, 4.04, and 4.09, and if possible it should be conducted concurrently with these efforts. If it is not, then the final product of this project should be designed to accommodate any future findings in the above Program Area 4 projects.

Work Plan

Task 1. State-of-the-Practice

The current state of materials performance characterization and the associated models to predict asphalt pavement performance will be reviewed and evaluated. Existing performance specifications will be obtained and evaluated. Research efforts to refine and validate the performance specifications will be identified and reviewed.

Task 2. Laboratory Tests

The most promising laboratory tests identified in Task 1 or in Projects 4.04 and 4.09, as well as other developed tests will be selected and evaluated by a laboratory testing program. The ability of the lab tests to predict field performance will be evaluated using the pavement sections identified for Task 3 below. Based on the results of the testing, existing performance tests and criteria may be revised.

Task 3. Field Tests

The tests, measurements, and criteria used in the performance specifications will be used on several projects, including full-scale accelerated performance testing. The specification will be evaluated for practicality, applicability, and accuracy of performance prediction. Actual pavement performance will be monitored and compared to predicted pavement performance. Based on the results of field testing, existing performance tests and criteria may be revised.

Task 4. Implementation Manual

An implementation manual describing the operation of the test equipment, including associated variability in the test results, the errors in performance prediction, and the use of the performance specification will be developed. The information will be in a format suitable for inclusion in specifications and test method standards.

Program 2: LONG-LIFE PAVEMENTS / PAVEMENT PERFORMANCE

Project 2.07 Fatigue Endurance Limits of Perpetual Pavement Designs

Objective: Validate fatigue endurance levels with a field experiment

Introduction

Fatigue cracking originating at the bottom of hot mix asphalt (HMA) structure has long been acknowledged as the most costly form of distress to correct through rehabilitation. If the distress is widespread, the rehabilitation may include complete removal of the HMA material. Bottom-up fatigue cracking occurs when repeated wheel loads impose tensile strains of sufficient magnitude to initiate cracking that eventually propagates up to the surface. Factors contributing to this form of distress include inadequate pavement structure, weak underlying materials, and HMA mixtures with inadequate material properties.

Conversely, HMA pavements that exhibit good long-term performance have characteristics that prevent bottom-up fatigue cracking. First, they have a sufficient thickness of HMA to limit the tensile strain at the bottom of the HMA structure so that bottom-up fatigue cracking is not initiated. Next, they have a sound foundation to support the structure. Finally, the HMA mixture exhibits sufficient flexibility to counter the initiation of bottom-up cracking at low levels of tensile strain.

Background

To date, fatigue studies of HMA mixtures have focused on establishing the fatigue curves that relate the tensile strain in the material to the number of load repetitions it can withstand before fracturing. These relationships have been invaluable in the development of mechanistic-empirical pavement design methods in that they serve as "transfer functions" relating the calculated mechanical response of the pavement to its performance. However, extrapolation of the equations to strains lower than those at which the tests have been performed dictates an increase in layer thickness with increasing load repetitions, regardless of the actual strain level. This may lead to over-design of the structure.

Performance data from well-constructed flexible pavements with a thick HMA structure, some of which have been in service for more than 40 years, show that bottom-up fatigue cracking does not occur in these pavements. This field experience suggests that an endurance limit, that is, a level of strain below which fatigue damage does not occur for any number of load repetitions, is a valid concept for HMA mixtures; its quantification could aid in the efficient design of long-life flexible pavements with a significantly reduced life cycle cost.

The idea of an endurance limit is widely recognized in other areas of material science, especially in ferrous metals. The endurance limit is usually determined from the relationship of strain to load repetitions to failure and is defined as the strain corresponding to the asymptote of the locus of points representing the fatigue life of a number of test specimens. Defining an endurance limit for HMA mixtures will result in more efficient structural design of pavements for mixtures of different characteristics. For instance, it is well known that mixtures with slightly higher binder contents have longer fatigue lives, and this would presumably translate to a higher strain level for the endurance limit of these mixtures. Other factors such as modifier type, aggregate type and gradation, binder grade, and mix volumetric properties also need to be examined in this light.

Previous research has suggested that the behavior of HMA pavements is consistent with the existence of an endurance limit for HMA, and it has suggested an approximate level of 70 microstrains. However, there are few laboratory studies to corroborate this value. Pavement design approaches, including the 1993 AASHTO pavement design guide, do not recognize an endurance limit. To date, research into the fatigue of HMA mixtures has been limited to strain levels well above the hypothesized 70-microstrain level. This proposed project will examine the hypothesis that there is an endurance limit for HMA and seek to measure it for selected HMA mixtures.

The objectives of NCHRP 9-38 study, which is currently underway, are to (1) test the hypothesis that there is an endurance limit in the fatigue behavior of HMA mixtures and measure its value for a representative range of HMA mixtures and (2) recommend a procedure to incorporate the effects of the endurance limit into mechanistic pavement design methods. Research is needed to validate the findings of 9-38 by conducting a field experiment. The field experiment will incorporate the use of instrumented test section(s), preferably on a full-scale, accelerated performance testing facility or test track.

Scope / Objectives

Conduct a field experiment to validate (1) the endurance limit as measured in the laboratory, (2) the relationship between laboratory results and field performance, and (3) the recommended changes to mechanistic pavement design procedures from Project 2.02. The work plan should incorporate the use of instrumented test sections, preferably within an accelerated pavement testing program.

Work Plan
Task 1. State-of-the-practice

State-of-the-practice related to M-E design protocol, the fatigue endurance limit concept and past and current research will be determined. A literature review of field projects to validate M-E methodology and criteria, the instrumentation of pavements to evaluate fatigue characteristics, including the use of full scale accelerated performance testing will be included.

Task 2. Field Tests

A field project will be conducted. The purpose of the field project will be collect data that can be used to validate fatigue endurance criteria developed in NCHRP 9-38 and any additions to the mechanistic pavement design procedures recommended in that study.

Task 3. Data Analysis and Recommendations

The database collected in Task 2 field evaluation will be submitted, along with the results of the analysis of the data. Conclusions will be made based on that data analysis related to validation of the 9-38 findings. Recommendations for any further changes to the M-E design method or criteria and the need for further research to validate the fatigue endurance limit will be developed and submitted.

Task 4. Recommended Practice

A recommended practice document will be developed that summarizes the findings of this project and discusses how M-E design methods and criteria should be used, including the fatigue endurance limit.

Program 2: LONG-LIFE PAVEMENTS / PAVEMENT PERFORMANCE

Project 2.08 Improved Hot Mix Asphalt Sample Preparation and Pavement Performance Prediction

Objective: Determine difference in properties among compacted HMA samples that are used in mix design, samples used for QC/QA purposes during production / construction and samples used for testing of in-place roadway materials

Introduction

Engineers perform asphalt mixture designs and pavement structural designs to provide pavements of specific life cycles to the driving public. The accuracy of the prediction models which relate mixture design and structural design to pavement performance is key to the engineer's ability to make these predictions. Improved models are needed if the industry is to significantly improve mixture design and structural design systems.

Historically, asphalt mixture design methods (Marshall, Hveem and Superpave) have been based on little information that relates mixture design measured properties (air voids, voids in mineral aggregate, voids filled with asphalt, stability, flow, etc.) to the pavement performance problems of rutting, fatigue, and thermal cracking as well as the impacts of asphalt binder aging and water sensitivity of the hot mix asphalt mixture. Pavement structural design systems are based on models developed from the AASHO Road Test of the late 1950's and early 1960's. The AASHO Road Test relationships were based on conditions that bear little resemblance to modern roadways.

Research to establish relationships between mixture characteristics and structural performance has been based largely on hot mix asphalt mixture samples prepared in the laboratory utilizing laboratory mixed-laboratory compacted (LMLC) samples. A few studies have utilized field mixed-laboratory compacted (FMLC) samples where the hot mix asphalt plants are utilized to produce the hot mix asphalt and laboratory compactors are utilized to compact the samples. On a few occasions field mixed-field compacted (FMFC) samples have been utilized.

Background

Traffic operates on and the environment alters field mixed-field compacted mixtures as these are produced by field plants and laid and compacted with field equipment. In general, the mix designers are attempting to duplicate field mixed-field compacted samples with lab mixed-lab compacted samples (typically used for the mixture design phase of the project) or field mixed-lab compacted samples (typically used for field quality control/quality assurance purposes).

The SHRP research program and other studies have shown that substantial differences exist among these three sample preparation methods. These differences are most pronounced when the more advanced mechanical characterization tests for hot mix asphalt stiffness, fatigue, and thermal cracking are utilized.

As the industry moves towards the integrated asphalt mixture and structural design approach to flexible pavements, the more important it becomes to establish robust relationships among mixture design, structural design, and pavement performance.

Before significant improvements can be made in asphalt mixture design methods and structural design methods, improved models need to be developed that relate mixture properties and structural design to pavement performance. Continuation of incremental research programs will not (by itself) significantly advance the ability to provide cost effective pavements to the country.

Scope / Objectives

Determine the differences among lab mixed-lab compacted samples (LMLC) (used for mixture design purposes), field mixed-lab compacted samples (FMLC) (used for quality control and quality assurance purposes) and field mixed-field compacted samples (FMFC) (actually placed in the field and subjected to traffic and the environment). The importance of these differences will be determined based on the ability of each of these sample preparation methods to accurately predict pavement performance (rutting, fatigue cracking and thermal cracking and the influence of aging and water sensitivity on these distress mechanisms). This work is closely tied to Projects 4.09 and 4.13.

Work Plan
Task 1. State-of-the-Practice

Perform a literature review to determine the magnitude of the differences in sample preparation on the mechanical properties of hot mix asphalt. Determine the relationships between mixture design methods, mechanical properties of asphalt mixtures, structural design, and pavement performance. This effort will include work in the last two decades associated with Accelerated Pavement Testing with devices such as the HVS, APT, MnRoad, WesTrack, NCAT Test Track, etc. as a minimum. In addition, the LTPP data should be carefully reviewed.

Task 2. Research Plan / Program

Develop a research program to improve the ability to predict pavement performance from asphalt mixture design and structural design. The testing program will focus on sample preparation using the methods described above (LMLC, FMLC and FMFC). Prepare an interim report describing the research program and experimental design and present it to the project panel.

Task 3. Lab and Field Tests

Conduct the research described in Task 2 on compacted HMA samples from both laboratory prepared samples and field mixtures to determine differences between LMLC, FMLC and FMFC samples. The data will be statistically analyzed and differences will be described as mechanistically as possible. In other words, merely noting statistical differences will only partially satisfy the analysis. The reasons behind those differences must be explained to the fullest extent possible.

Task 4. Report / Findings

Develop a final report which includes documentation of findings and recommendations to improve sample preparation / performance prediction. Provide a briefing of the findings to the project panel, AASHTO, the FHWA, and the industry through channels such as the NAPA Annual Meeting and World of Asphalt as a minimum.

Program 2: LONG-LIFE PAVEMENTS / PAVEMENT PERFORMANCE

Project 2.09 Improved Aggregate Properties for Use in Long-Life Pavements

Objective: Develop methods and treatments to improve aggregate properties to alter properties and provide long-life performance

Introduction

Some areas of the U.S. such as portions of the Gulf Coast and the North Central Plains have historically lacked locally available, high-quality aggregates. There have been numerous attempts made in the past to improve the performance of local materials in these areas by such methods as crushing gravel, minimizing the content of harmful materials such as shale, and adding sulfur to HMA containing beach sand. Gravel crushing has generally been very successful whereas the use of sand-asphalt-sulfur mixtures has not been viable to this point. However, the lack of locally available aggregates has become a problem beyond areas traditionally lacking in high quality aggregates.

Urban areas are now becoming increasingly problematic with respect to aggregate availability. Restrictions in zoning, barriers to expansion of existing sources, and local objections to mining and crushing operations have required that HMA producers turn to sources that are further away, which increases the cost of aggregates.

Background

Numerous attempts have been made to improve the quality of locally available aggregate sources in an attempt to make them viable for use in HMA. The blending of sulfur with HMA containing rounded sand was tried in Canada and Texas in the late 1970s. This process known as sand-asphalt-sulfur attempted to use a relatively stiff sulfur matrix to strengthen the mix and preclude rutting. Although laboratory and field trials were generally successful, concerns with odors and emissions as well as added expense prevented the process from being widely adopted. Other attempts at improving the strength of locally available aggregate treatments included heavy liquid separation which could be used by floating lighter mineral particles out of the desirable aggregate and combining lower quality aggregates with those of higher quality to improve the strength of the overall gradation. The use of coatings has also been tried to reduce the absorption of aggregates as well as improve the wear properties.

Scope / Objectives

Find ways to improve the durability, absorption, soundness, wear, reactivity with salts, strength, and adhesion of locally available or marginal aggregates through mechanical processing and chemical additives for use in HMA. The various means to be explored should include, but are not limited to combining marginal aggregates with high-quality aggregates, aggregate coating technology, and aggregate agglomeration through chemical binding.

Work Plan
Task 1. State of the Practice

Identify problems with locally available aggregates in a number of regions within the U.S. and describe the efforts to overcome these. Identify products for aggregate beneficiation and what they are intended to mitigate. Identify standard practices that have been developed to improve marginal aggregates in different regions. Identify promising techniques from other industries which may be applied to the improvement of aggregate characteristics. Present the findings in an interim report.

Task 2. Research Plan / Program

A research plan will be devised to investigate existing and promising methods of improving aggregates, targeting specific aggregate characteristics that are deemed to be most important. The research plan and an experimental design will be presented to the research panel for discussion and approval.

Task 3. Lab and Field Tests

The research plan will be executed using a combination of laboratory and field evaluations of the effectiveness of different aggregate treatments in improving certain characteristics. The economics of the treatments will be presented along with their performances in ranking the effectiveness.

Task 4. Report / Findings

Prepare a final report containing the findings and recommendations from the study. A plan to implement promising beneficiation techniques should be included in the report.

Program 2: LONG-LIFE PAVEMENTS / PAVEMENT PERFORMANCE

Project 2.10 High-Modulus Asphalt Base Courses in Perpetual Pavement

Objective: Develop / validate design and construction criteria and procedures for high-modulus base layers

Introduction

Perpetual Pavement sections typically consist of three to four asphalt layers constructed on a stable subbase. The standard section consists of a flexible but fatigue-resistant asphalt base course, an asphalt intermediate course that provides strength/support and a durable, rut-resistant surface course. In some designs, an initial course of "rich bottom" asphalt base material is placed which is designed to be highly impermeable and flexible for outstanding durability and resistance to fatigue cracking. A crucial factor in the function and performance of long-life asphalt pavements is the proper selection of mixture types for each of these layers. All layers should possess durability and constructability. However, demands for fatigue resistance, rutting resistance, safety and noise reduction will depend upon the individual layer being designed.

In most designs, a relatively thick, dense graded asphalt base course is used that contains un-modified asphalt binders and typical-quality aggregates. However, it is likely that the use of a "high modulus" HMA base mix can be used to design a thinner section for long-life asphalt pavements. Research is needed to evaluate the use of high modulus asphalt base materials in Perpetual Pavement design to ensure that adequate fatigue resistance and overall long-life performance is obtained.

Background

The asphalt surface and intermediate mixtures used in Perpetual Pavement designs are higher quality mixtures because of the component materials and mix design concepts used. Both layers generally use a high percentage of crushed, angular aggregate with stone-on -stone gradation and, possibly, modified asphalt binder. Since the two top courses are in the upper portion of the pavement structure, which is subject to high compressive stresses from heavy traffic loadings, their primary structural function is to provide exceptional rutting resistance. Therefore, surface and intermediate mixtures must have better modulus characteristics than pavement layers lower in the pavement structure.

Typically, the asphalt base course does not necessarily require high modulus materials or mix design. The main structural purpose of the HMA base course is to provide a flexible layer with excellent durability and fatigue resistance to prevent typical "bottom up" fatigue cracking. However, it is the total thickness of the pavement that controls fatigue cracking by limiting the tensile strain at the bottom of the pavement. Since standard thicknesses of intermediate and surface courses are used in Perpetual Pavement designs, it is the asphalt base layer that is increased when thicker pavement depth is needed. In the widely accepted mechanistic design theory currently used in the United States and elsewhere, fatigue resistance is mostly provided by the total thickness of all HMA layers. The tensile stress and strain at the bottom of the HMA, which is where bottom up cracking begins, decreases as a function of the cube of the thickness. So, as the total pavement thickness increases, the overall fatigue resistance also increases.

Increasing the modulus of the HMA produces a linear decrease in tensile strain. It has been found in France that a binder-rich base mixture made with a relatively hard asphalt binder results in a high modulus mixture that significantly reduces tensile strain at the bottom of the paved layers. The high binder content serves to increase the durability of the mixture. Studies in the United Kingdom have shown that the high binder content must be present along with the hard asphalt binder in order to make this concept viable.

The use of thinner, high modulus asphalt bas in Perpetual Pavement design show promise in providing the next generation of long-life pavements. While there is strong evidence that performance of Perpetual Pavement designs using thick, “low modulus” asphalt base courses provide long-life performance, there are many economical and practical reasons for experimenting with materials and design that will provide thinner pavement sections.

Scope/Objectives

Develop/validate design and construction criteria and procedures for high-modulus base layers.

Work Plan
Task 1. State-of-the-Practice

A literature study will be performed to determine the state-of-the-practice.

Task 2. Mix Design and Structural Design Procedures

Based on findings from Task 1, develop material selection and mix design procedures that will result in a high-modulus, high binder content HMA base course. Develop structural mechanistic-based design procedures to optimize the use of high modulus mixes while decreasing the required pavement thickness with the concept of fatigue endurance limits.

Task 3. Lab and Field Tests

Conduct lab studies to measure modulus and to estimate field fatigue characteristics of high modulus base layers. Develop and validate design and construction criteria through field trials applying the mix and structural design concepts from Task 2.

Task 4. Implementation

Develop implementation manual including new or modified AASHTO test methods/specifications, design and construction criteria and procedures for Perpetual Pavements using high-modulus base courses.

Program 2: LONG-LIFE PAVEMENTS / PAVEMENT PERFORMANCE

Project 2.11 Remaining Service Life of In-Place Asphalt Pavements

Objective: Develop a fundamental basis for assessing the remaining service life of existing pavements

Introduction

Asphalt pavements are designed to have expected service lives. The original design procedure includes a structural thickness procedure that may include a consideration of anticipated traffic loading during the expected service life, the subgrade support, modulus of all pavement/foundation materials and the terminal serviceability for the particular class of roadway being constructed. For new construction, a typical design service life is 20 years, which assumes that major rehabilitation may be needed at the end of that time period. For maintenance activities, the expected service life is

Most agencies perform periodic evaluations of the pavement condition at the network level, which typically includes an evaluation of surface distress and may also include other factors such as pavement smoothness. The result of the surface condition is a condition or serviceability rating, which can possibly be compared to the terminal serviceability and also to the condition rating of other pavements. At the project level, the condition evaluation may also include a structural analysis. The structural analysis can be accomplished in a number of ways, including using either deflection analysis or an assessment of the structural condition of the in-place pavement using AASHTO thickness design procedures. The structural analysis results can be used to determine if a pavement can carry the present and anticipated traffic loadings.

Whether from surface condition evaluations, structural evaluations or a combination of the two, there are various methods being used to express the evaluation results in a meaningful manner which will provide insight into the serviceability of the in-place pavement. Many agencies are using a concept called RSL (Remaining Service Life) to compare and prioritize pavements for use in their maintenance, rehabilitation and reconstruction programs.

The RSL concept has been in use, directly or indirectly, for many years. RSL is used by many different agencies and there are multiple definitions / methods for determination of RSL. There are also many different reasons for obtaining RSL, ranging from a network needs assessment to a project level determination as a part of a warranty or performance contract. Research is needed to establish a fundamental basis and best practice for most effectively measuring, calculating and utilizing RSL.

Background

Two of the most common definitions of RSL are ““the extent of the useful life remaining in a pavement section subjected to traffic and environmental forces, expressed in years/traffic or percentage of life left”. Another commonly understood definition is “the years until the next rehabilitation or overlay”.

Understanding and using the RSL concept has been complicated by the move from “worst-first” approach of rehabilitation to “lowest-life-cycle-cost” (LLCC) based preservation approach and the concepts of long lasting and perpetual pavements that assumes optimally timed preservation, maintenance and rehabilitation treatments. Because of the anticipated increase in the use of warranty-type contracting methods, there is a need to develop RSL methods that will include a more comprehensive determination of pavement condition and structural adequacy for use in defining risk. Therefore, the research study(s) undertaken in this area should include consideration of these recent trends.

It is anticipated that RSL will be useful to agencies in many different pavement management applications. Some applications will require RSL based on only on surface condition while others will require the RSL to include consideration of both surface condition and structural evaluations. Therefore, it is essential to develop RSL methods that meet all of the expected uses.

Scope/Objectives

Develop a fundamental basis for assessing the remaining service life of existing pavements. The study may include establishing a standard definition for RSL, determining the most effective methods for surface and structural condition evaluation, developing a recommended approach for using RSL in various pavement design applications and defining the use of RSL as a tool in warranty projects.

Work Plan
Task 1. State-of-the-Practice

A literature review and state-of-the practice will be accomplished, including surveys of federal, state and local highway agencies to evaluate the current use of the RSL concept and also what the ideal use of RSL would entail.

Task 2. Proposed Best Practice / Methods

Based on the findings of Task 1, a proposed definition of RSL, a proposed procedure for best practices for obtaining and utilizing RSL on various pavement applications will be developed.

Task 3. Implementation

The findings of the research will be published and presented to agency and industry groups for implementation. A Best Practices document will be developed.

Program Three: IMPROVED STRUCTURAL DESIGN OF PAVEMENTS

<u>Projects in Program Three</u>

Project 3.01 — **Validate and Refine Proposed Mechanistic-Empirical Design Guide**

Project 3.02 — **Development of Pavement Structural Design Guide for Low Volume Roadways**

Project 3.03 — **Improved Structural Design for Special Vehicles on Heavy Duty Pavements**

Project 3.04 — **Improved Characterization of In Situ Material Properties**

Project 3.05 — **Development of Next Generation of M-E Analysis Systems**

Project 3.06 — **Porous Pavement Design Guide**

Project 3.07 — **Laboratory Determination of Material Properties for Structural Design**

Project 3.08 — **Development of In Situ Structural Monitoring Systems**

Program Three
Improved Structural Design of Pavements

Introduction

Hot Mix Asphalt (HMA) mixtures are expected to perform over an extended period of time under a variety of traffic and environmental conditions. Pavement structural thickness design methods, HMA mixture selection methods, and pavement construction methods must provide the tools to ensure performance for the anticipated future traffic loadings. Pavement thickness design procedures must be able to accommodate the anticipated changes in traffic and the environment, mixture selection methods must provide the “tools” for the engineer to select the appropriate mix type for the expected service conditions, and construction methods must provide for the manufacturing and placement of high quality HMA under varying weather conditions during both day and night paving. This program area will focus on improving structural design procedures.

In the United States, the majority of HMA for roads will be used for pavement rehabilitation, reconstruction, widening and maintenance operations on existing highway and streets. New construction will primarily occur near existing urban areas. The biggest challenge for the future will not be to design HMA pavements for new or unusual conditions, but to rehabilitate pavements to accommodate the loading characteristics of future vehicles and to offer improved functional, structural, and environmental quality. In some cases, the pavements will be carrying extremely high volumes of heavy vehicles while, in other cases, pavements must be designed for low volume and/or rural areas.

To a great degree, the characteristics of heavy traffic loading on a given facility control the pavement structural design. The characteristics of heavy traffic are continuously changing. Tire pressures on heavy vehicles have increased from an average of about 70 psi to over 100 psi over the last 40 years. The tire pressure distribution on the pavements has also changed during this period as vehicle operators have changed from bias ply to radial tires. An increasing number of heavy vehicles are also using single tire or “super single” tire replacements for dual tire configuration on axles.

The trends of increased tire pressure and the use of single tire replacements are expected to continue in the future. Heavy vehicle manufacturers are making significant changes in vehicle dynamics (suspension systems) and vehicle aerodynamics. The impact of these types of vehicle changes on the performance of HMA pavement thickness and mixture design is not known at this time.

Changes in tire pressure, tire pressure distribution, number of single tire replacements, vehicle suspension systems, and possibly, channelized traffic due to guidance systems coupled with the potential for heavier loads and the increase in the number of heavy loads will require changes in structural design methods to ensure the successful use of HMA on these types of transportation facilities.

While high traffic volumes and heavy loads dominate the design of the 160,000 mile National Highway System, the majority of this nation’s 2+ million miles of paved roads carry low to medium traffic. Design methods and criteria for these facilities must also be considered in research efforts related to improved structural design.

Background

The American Association of State Highway Transportation Officials (AASHTO) has sponsored, through the National Cooperative Highway Research Program (NCHRP), a project to investigate the effects of “super single” tire replacement, tire pressure distribution and tire pressure on pavement performance. This research program used mechanistic pavement design methods and instrumented pavements to determine the impact on pavement life. AASHTO is also sponsoring a series of projects through NCHRP to revise the AASHTO Pavement Design Guide. The revised guide will be based on mechanistic design principles. This will be a major change from the currently used structural design procedures.

A resulting tool from these projects will be an improved pavement thickness design method for handling the changes in traffic characteristic expected in the coming decades.

Scope/Objectives

The objective of this program is to develop improved structural design methods to accommodate future changes in traffic, materials and environmental considerations.

Program 3: IMPROVED STRUCTURAL DESIGN OF PAVEMENTS

Project 3.01 Validate and Refine Proposed Mechanistic-Empirical Design Guide

Objective: Validate and refinement of the new mechanistic-empirical Design Guide currently being implemented under NCHRP 1-40.

Introduction

Based on a request of the AASHTO Joint Task Force on Pavements (JTFP), a pavement structural design methodology and guide for design of new and rehabilitated pavements based on mechanistic-empirical (M-E) principles was developed. The previous AASHTO Guide for Design of Pavement Structures was based upon empirical relationships established at the AASHO Road Test of the early 1960s. M-E design methods offer many attractive advantages due to their flexibility in modeling the behavior of the pavement. The new M-E design guide was originally developed under NCHRP Project 1-37A, which was complete in 2004. Subsequent to the development of the new design guide, another series of projects (NCHRP 1-40 A-J) evaluated the design methodology and moved it toward implementation. Several of the projects have been completed or are currently underway.

Many pavement designers at state departments of transportation (DOTs) may not be familiar with the concepts incorporated in the recommended M-E pavement design guide. Also, the recommended guide incorporates numerous relationships between traffic loading, climatic conditions, material characteristics, and distress modes that have been verified with field data from different parts of the United States in a so-called national calibration. This collection of relationships has limited applicability to pavements within a specific region; however, these relationships could be refined to better reflect local conditions, materials, and practices.

A key component of the JTFP's plan for implementation and adoption of the recommended M-E pavement design guide and software was an independent, third-party review to test the underlying assumptions, evaluate the engineering reasonableness and design reliability, and identify opportunities for implementation of the design guide in day-to-day design production work.

Beyond this immediate requirement, there is a need for a coordinated effort to acquaint state DOT pavement designers with the principles and concepts employed in the recommended guide, assist them with the interpretation and use of the guide and its software and technical documentation, develop step-by-step procedures to help state DOT engineers calibrate distress models based on their local and regional conditions for use in the recommended guide, and perform other activities to facilitate its acceptance and adoption.

Background

Many or all of these identified needs have been or will be addressed in the NCHRP 1-40 A through J projects. Specifically, the NCHRP 1-40 projects will accomplish some or all of the following tasks:

Task 1. Organize and convene workshops for state DOT personnel.
Task 2. Document error reports, comments and suggestions from users to be considered in future versions of the guide.
Task 3. Conduct an independent review of the guide and software (NCHRP Project 1-40A).
Task 4. Develop step-by-step procedures to refine the performance models for local conditions, materials, and practices (NCHRP Project 1-40B).
Task 5. Provide technical support to users (NCHRP Project 1-40D).
Task 6. Refine and upgrade the software (NCHRP Projects 1-40D and 1-40E).
Task 7. Prepare a practical design guide (NCHRP Project 1-40H).
Task 8. Provide support for the Lead States and other activities (NCHRP Project 1-40J).
Task 9. Perform other tasks to support of the implementation of the guide.

There will be an on-going need to verify, validate and refine the structural design procedures and criteria based on field testing of properties and performance of pavements designed with the M-E guide.

Scope/Objectives

Validate and refine the new mechanistic-empirical Design Guide completed under NCHRP 1-37A and being refined and implemented under NCHRP 1-40 A-J projects. Follow up on these implementation efforts with laboratory and field studies of pavements designed and constructed using the guide. Refine the methodology to improve the models, increase the scope of design scenarios and enhance the user-friendliness.

Work Plan
Task 1. State-of-the-Practice

The state-of-the-practice in using the M-E based AASHTO design guide will be evaluated. The evaluation will include a literature review, interviews with users, and identification of pavement projects designed/constructed using the guide methodology and criteria.

Task 2. Lab and Field Tests

Based on the findings in Task 1, laboratory and field evaluations will be performed on pavement structures using the draft guide methodology and criteria. The data gathered will be used to evaluate the effectiveness of the procedure in designing pavement structures.

Task 3. Communication of Findings

During and at the completion of this project, report (s) will be prepared that document the significant information and findings to the AASHTO JTFP and other researchers.

Task 4. Recommended Practice

A recommended practice document will be prepared to summarize the findings of this project and to recommend further refinements in the methodology and/or criteria to improve the applicability to various design situations.

Program 3: IMPROVED STRUCTURAL DESIGN OF PAVEMENTS

Project 3.02 Development of Pavement Structural Design Guide for Low Volume Roads

Objective: Develop a simplified approach to structural design of low volume roadways.

Introduction

Low volume roadways are a significant part of the transportation system in this country. Low volume roads are defined as those roads and streets that carry relatively few vehicles in a given time period compared to high volume roads that carry significant amounts of traffic on a daily basis. There are many more miles of low volume roads and streets than there are high volume roads in virtually every city, county and state highway system. Therefore, it is as important that these low volume roads be cost-effectively designed to perform well and serve the needs of the traveling public.

An essential part of roadway design is the structural thickness design of the pavement, even on low volume roads. A structural design will ensure that an economical and cost effective pavement section is constructed that is appropriate for the traffic volume, traffic loadings, subgrade conditions and expected service life of the pavement. Unfortunately, many of the current structural design methods are better suited for higher volume facilities, and they are not easily and efficiently applied to the design of low volume roads. Therefore, a research project is needed to develop improved structural design procedures for low volume roads.

Background

For a variety of reasons, structural design for new or rehabilitation purposes is often a secondary consideration on low volume roads. This may result in pavement sections that are either too thick or too thin for the design parameters on a specific roadway. Pavements built too thin do not perform well over the expected service life. When pavements are too thick, they are not cost effective. Another consideration is that current structural design procedures are transitioning from empirical design methods to mechanistic-empirical design procedures. M-E design procedures can be complex and require a significant amount of input and iteration by the designer before the resulting pavement section can be obtained. This increased complexity makes them difficult to use on low volume roads where designers need a simple approach based on a limited amount of information.

One reason structural designs are not performed on low volume roads is that current thickness design procedures are too cumbersome for small public agencies. Detailed information that is required in some design procedures may not be readily available to small public agencies. To address these issues, an optional simplified structural design procedure, developed under this project, should be included in the overall design package. This simplified procedure would allow the designer to select general categories of traffic volume (low, medium and high) and commercial truck percentage, and subgrade support by either quality (poor, fair, and good) or classification (unified, AASHTO, or USDA). The design procedure would then allow the designer to select from an illustrated selection of pavement sections. This is similar to the results of NCHRP

Project 1-32 in which a simplified design procedure was presented in the form of a catalog.
A research effort is needed to develop this low volume road structural design procedure. It should include an option to select a simplified approach that will allow a catalog of pavement sections that will meet the estimated design parameters.

Scope/Objectives

Develop a simplified structural design procedure for low volume roadways.

Work Plan
Task 1. State-of-the-Practice

The state-of-the-practice for structural design procedures will be conducted with an emphasis on procedures that are applicable to low volume roads. Existing concepts and innovative design methods and approaches will be identified that can offer a template for a simplified M-E approach. State asphalt pavement associations, the Asphalt Institute, state DOTs and local agencies will be canvassed to obtain such procedures. A review of the results of NCHRP 1-32 will conducted to ascertain whether the approach taken in that project might be refined for use.

Task 2. Trial Design Approach

Based on the findings of Task 1, identify an approach that will be effective in designing pavements for low volume roads. A trial version of a simplified design procedure will be developed for testing and validation. The design procedure will be produced in both “hard-copy” paper versions and in a software application.

Task 3. Validation of Design Outputs

The trial version of the design procedure will be validated using pavement performance data from low volume roads to ensure that adequate structural result from the limited design information available for low traffic volume roads. Any necessary revisions to the trial version will be performed.

Task 4. Implementation Manual

An implementation manual will be developed which will include the software and user manual for the simplified Low Volume Roads design approach.

Program 3: IMPROVED STRUCTURAL DESIGN OF PAVEMENTS

Project 3.03 Improved Structural Design for Special Vehicles on Heavy Duty Pavements

Objective: Develop improved structural design methods for heavy duty loading situations.

Introduction

Hot Mix Asphalt (HMA) mixtures are expected to perform over extended periods of time under a variety of traffic and environmental conditions. Changes in tire pressure, tire pressure distribution, super-single tire replacements, vehicle suspension systems and channelized traffic coupled with the potential for heavier loads and the certain increase of the number of heavy vehicles will require changes in pavement design methods to ensure the successful use of HMA in all traffic and environmental conditions. Pavement structural design procedures must accommodate the anticipated changes in traffic characteristics and a characterization of the local environment to meet performance requirements.

Heavy duty loading situations are of interest in this project. Heavy duty pavements are roadway, industrial, or parking lot pavements designed for very heavy loads. Examples include pavements in ports, intermodal transfer terminals, industrial facilities, airports, and heavy vehicle lanes. Most current pavement design methods do not adequately account for these situations.

Both the Asphalt Institute and the National Asphalt Pavement Association have developed publications on structural design of heavy duty pavements. The Asphalt Institute Manual, MS-23 “Thickness Design-Asphalt Pavements – Heavy Wheel Loads" presents a method for thickness design of asphalt pavements for heavy-duty vehicles such as log hauling trucks, dump-body haulers, fork-lift trucks, straddle carriers, rubber-tired hoists and other vehicles having as few as four to as many as twelve or more tires. The NAPA publication titled QIP-123, Design, Construction, and Performance of Heavy Duty Mixes was published in May, 2002. This publication consolidates and updates other NAPA publications dealing with large stone and heavy-duty mixes. These mixes are needed in pavement structures subject to heavy vehicle traffic, such as urban interstates, airports, container facilities, and logging yards. These publications are valuable references for pavement designers and specifiers, construction personnel, and inspectors.

The structural design methods used for heavy duty pavements are in need of improvement. The current AASHTO Guide is based on highway loading characteristics prevalent at the time of the AASHO road test in the early 1960s. While it has served reasonably well for many years for highway pavement design, it was never intended for large volumes of truck traffic or for very heavy loads. Mechanistic analysis methods offer an improved way account for heavy traffic in both new and rehabilitated pavements. Mechanistic pavement design can more realistically account for the condition of existing pavements and, in some cases, improve the reliability of designs. Gaps in complete understanding of pavement conditions will need to be addressed with empirical calibration. This project will develop a mechanistic empirical (M-E) approach to heavy duty pavement design.

Background

A new guide for the M-E structural design of highway pavements has been developed for AASHTO. Assuming a successful balloting through AASHTO, this design procedure will be implemented by various state DOTs. This M-E design procedure and others should be reviewed for applicability to heavy load situations. At this time, the proposed M-E design guide and others already in use have been primarily calibrated for typical highway loadings, and will need further modification for heavy loads.

The Asphalt Institute and NAPA publications on heavy loads contain useful and practical information on the design and construction of a number of facilities. Also, past research on large-stone mixes and performance are available through NCHRP, AAPT, and TRB publications.

Scope / Objectives

Develop or improve the M-E structural design methodology for heavy duty pavements by identifying the proper design parameters and assessing the capabilities of existing structural design practices. The proposed M-E design method, the Asphalt Institute's design method, and information from NAPA should be reviewed for their applicability in this effort. Other M-E design platforms should be reviewed for applicability. Design, construction, and performance reviews of heavily loaded pavements at various kinds of facilities should be used in the development of this design procedure.

Work Plan

Task 1. Review of Design Procedures for Heavy Duty Pavements

The new M-E design guide, the Asphalt Institute design procedure, NAPA guidelines on large-stone mixes, and other M-E design software will be reviewed for application in the design of heavy-duty HMA pavements. Model type (FEM, layered elastic, etc.), material considerations (non-linearity, viscoelasticity, etc.), user inputs, user friendliness, output interpretation, and comparisons with existing practices and performances should be included in the evaluation of the procedures. Select one or more design procedures to test against performance histories of actual pavements in Task 2.

Task 2. Performance Reviews

Review the design, construction, and performance of existing heavy duty HMA pavements. Analyze the performance of these facilities with the design procedures identified in Task 1 to evaluate and predict distresses. Example conditions include, but are not limited to, port applications, intermodal terminal, airports and heavy vehicle lanes. Critical shortcomings in design inputs and analysis parameters should be identified.

Any information in the LTPP database, applicable to the heavy duty applications, should be used as appropriate to obtain information for the comparative analyses. Available data from high volume test sections may provide design input and observed performance information, which could be useful in the evaluation.

Task 3. Communication of Findings

Identified needs will be documented for further research, deployment, and synthesis projects.

Task 4. Recommended Practice

A final report will be prepared that summarizes the findings of this project related to the recommended state-of-the-practice with regard to structural design of heavy duty pavements using the M-E design principles and the future research needs in this area.

Program 3: IMPROVED STRUCTURAL DESIGN OF PAVEMENTS

Project 3.04 Improved Characterization of In Situ Material Properties

Objective: Explore test equipment and methods for characterization of in situ materials prior to an asphalt overlay, including in-place recycled material and fractured PCC during pavement rehabilitation projects

Introduction

The majority of the tonnage of Hot Mix Asphalt (HMA) pavement that is placed each year is for pavement maintenance and rehabilitation. This is because the roadway system is maturing and there are relatively few new pavements built compared to the number of projects that are performed to maintain existing pavements. Since placing an HMA overlay on an existing pavement is a cost effective method of improving either existing concrete or asphalt pavement roadways, this type of application is commonplace throughout the country. In addition, various methods for recycling and rejuvenating the existing pavement material assets are offering cost-efficient ways of improving the existing foundation for these overlays to increase service life.

A design procedure should be used to determine the appropriate materials, HMA thickness and mix type for that specific loading and environment. Another important consideration is improving the capacity and integrity of the underlying layers to support the new HMA overlay. In the case of pavement rehabilitation, the underlying material is the existing pavement. Characterizing the in-situ properties of the existing pavement or the improved/recycled existing pavement prior to HMA rehabilitation is essential to the proper design of the HMA overlay in order to extend the pavement service life.

Background

Depending upon whether a functional or structural rehabilitation is needed HMA overlays of various thicknesses and surface preparation can be used. On existing asphalt pavements, rehabilitation may include removal or recycling of substantial portions of the pavement structure to mitigate existing distresses prior to placement of new HMA overlay. On existing concrete pavements, rehabilitation may include procedures such as crack and seat or rubblization prior to the placement of a new HMA overlay.

As discussed above, thickness design for rehabilitation projects should include an evaluation of the in-situ properties of the final prepared existing pavement support condition. Unfortunately, existing testing equipment and methods to determine the in-situ materials properties of pavements prior to rehabilitation are inadequate, especially when the existing pavement is cold or hot recycled asphalt concrete or is fractured concrete, as in crack and seat and rubblization projects. Research is needed to identify, study, and implement improved methods of in-situ characterization of materials properties for design prior to rehabilitation and also during construction projects where extensive preparation of the existing pavement is being performed.

Scope / Objectives

Develop or refine test equipment and methods for characterizing in-situ materials prior to an asphalt overlay, including in-place recycled material and fractured PCC, both for design and during pavement rehabilitation projects.

Work Plan

Task 1. State-of-the-Practice

An evaluation of the state-of-the-practice related to in-situ characterization of pavement materials prior to rehabilitation will be performed. Existing and innovative test equipment and test methods will be considered.

Task 2. Lab and Field Tests

Based on the most promising findings from Task 1, conduct laboratory and field testing to determine the effectiveness and practicality of test methods. Special emphasis will be placed on identifying methods that are effective for hot and cold recycled asphalt concrete and crack and seat and rubbilized concrete pavements.

Task 3. Ruggedness Testing

On selected test method(s), perform ruggedness testing to evaluate the sensitivity of the results to various operational parameters. Based on these findings, make modifications to the test procedures to improve the repeatability of the methods.

Task 4. Utilization on Recycled AC and Fractured PCC

On a few actual field projects, use the promising test methods to characterize the necessary properties of cold recycled and hot recycled asphalt concrete and fractured PCC to establish typical default ranges for in-situ characterization of the final prepared existing pavement in the M-E design guide.

Task 5. Implementation Manual

Summarize the project findings in an implementation manual. The information will be in suitable format for inclusion in material specifications and standard test methods, as well as a user guide providing input design information for the M-E design guide.

Program 3: IMPROVED STRUCTURAL DESIGN OF PAVEMENTS

Project 3.05 Development of Next Generation of Mechanistic-Empirical Analysis Systems

Objective: Develop improved M-E design methods

Introduction

Based on a request of the AASHTO Joint Task Force on Pavements (JTFP), a pavement structural design method and guide for design of new and rehabilitated pavements based on mechanistic-empirical (M-E) principles was developed. Efforts to refine and implement the new AASHTO Design Guide are currently underway.

As the AASHTO Design Guide is implemented and used on a regular basis, the methodology and criteria used in the guide will be refined and validated. As deficiencies are identified, the need for new research projects will be identified. Many of these projects will focus on developing the underlying models that are more mechanistic rather than the models that are heavily related to empirical data. It is anticipated that there will be a need to conduct these identified research studies to move toward the development of the next generation of M-E structural design methods.

Background

An effort to refine and implement the AASHTO Design Guide has been initiated under NCHRP 1-40. As this project is completed and agencies start implementing the M-E Guide, the need for improvements and refinements in the procedures will be identified. The structural design procedures need to be validated with field projects where designed pavement sections are built to evaluate the structural capabilities and performance of the constructed pavement. These field projects will provide researchers with critical information that will allow them to identify necessary improvements to design methods and criteria.

The M-E procedures now being introduced and evaluated are to be used for structural design and analysis of both new and rehabilitated pavements. Because most roadway work is rehabilitation, it is very important that the analysis method works well for the many types of pavement rehabilitation. Therefore, validation efforts must address rehabilitation projects where HMA is used on both existing rigid and flexible pavements.

Research efforts to improve the M-E design methods should be conducted promptly to more accurately model the traffic, climate, soils, structural and fundamental material behavior of roadways to ensure greater accuracy in performance estimates.

Scope / Objectives

Develop more fundamentally-based M-E design methods, including new pavements and rehabilitation projects on both existing rigid and flexible pavements.

Work Plan

Task 1. State-of-the-Practice

The state-of-the-practice related to the applicability of mechanistic-empirical (M-E) pavement design guide to the design of new and rehabilitated pavements constructed with HMA will be prepared. A survey will be conducted to identify pavement sections that were designed or evaluated with the AASHTO M-E design procedure and constructed. Also, any research that has been conducted using field projects to validate the design procedure will be identified, including accelerated pavement testing.

Task 2. Performance Review and Testing of Projects

Conduct distress surveys and non-destructive testing (NDT) of identified pavement sections from Task 1 to measure the current behavior, existing condition, back-calculated properties, and project probable pavement performance. Perform laboratory and field testing of pavement structures to validate pavement design methods and criteria. Identify gaps where performance prediction models are lacking due to their reliance on imperialism.

Task 3. Data Analysis

From the needs identified in Task 2, develop more mechanistically-based analyses of the selected field projects. Compare actual and predicted behavior and distresses. Develop recommendations as to how the more fundamental models can be incorporated into the AASHTO M-E pavement design and analysis system.

Task 4. Recommended Practice

A recommended practice document will be prepared that summarizes the findings of this project.

Program 3: IMPROVED STRUCTURAL DESIGN OF PAVEMENTS

Project 3.06 Porous Pavement Design Guide

Objective: Develop improved design procedures for porous pavements for various applications including material guidelines and guide specifications.

Introduction

Storm water runoff management has become a primary consideration in the design and construction of many pavement structures. Runoff discharge from impermeable surfaces increases erosion, stream flow, and pollutant concentrations after rain events. This has been mitigated somewhat in recent years through the construction of detention ponds which hold the runoff to some extent and allow it to filter back into the ground. However, detention ponds are expensive to construct and, often times, occupy real estate that could be put to better use or they displace natural vegetation possible wildlife habitat. For the past thirty years, porous asphalt pavements have been used successfully in the eastern United States to minimize storm water runoff, especially in parking lots.

Porous pavements are completely permeable structures that allow water to flow from the surface into a stone reservoir and allow it to percolate back into the groundwater table. The design typically consists of a geotextile separation between the uncompacted soil and stone reservoir containing 2 to 3-inch (50 to 75 mm) aggregate and 40 percent voids, on top of which is placed a thin capping layer of 3/4 –inch (19 mm) aggregate for constructability of the paved surface, and the top is 2 to 4 inches (50 to 75 mm) of an open-graded asphalt mixture. Porous pavements have been successfully constructed and have performed well in a variety of environments.

Although this type of pavement is typically found in parking lots for passenger vehicles, they have also been used for roadways. As more developers and designers struggle with ways to mitigate storm water runoff, there will be an increasing demand for porous pavements in wider applications. There will be a need to perform a structural design to ensure the longevity of porous pavements in a variety of loading conditions.

Background

In the 1970s, the Franklin Institute put forth the idea that parking lots could be constructed to be completely permeable in order to manage runoff. This idea was used in some high-profile pavements such as the parking lot at Walden Pond in Massachusetts and in a number of sites around Pennsylvania. Porous asphalt pavements have since been employed in locations throughout the United States including Kentucky, Kansas, Minnesota, California, Colorado, New Jersey, and North Carolina. The National Asphalt Pavement Association has published design and construction guidelines for the use of Porous Pavements, primarily for use in passenger vehicle parking lots.

Scope / Objectives

Assess performance of existing porous pavements in both parking and roadway applications, Develop improved design procedures for porous pavements for various applications, including material guidelines and guide specifications.

Work Plan
Task 1. State-of-the-Practice

The state-of-the-practice for porous pavements will be reviewed, including the identification of design procedures, material specifications for all layer components, and successful and unsuccessful applications. A report will be prepared summarizing the information from this task.

Task 2. Performance Assessment

Well-documented porous pavements identified in Task 1 will be visited, and their performance to date will be documented along with any pertinent engineering information available from the jurisdictional agency and the contractor that built the project. Information concerning pavement design, material sources, quality, material and site test results, and traffic will be included.

Task 3. Analysis of Pavement Structures

Using the information from Task 2, the pavement structures will be analyzed according to mechanistic-empirical principles in terms of stresses, strains, and displacements. Cases will be run under a range of scenarios from low to high traffic, dry to wet climates, and weak to strong soils. The objective of this task is to find appropriate combinations of open-graded HMA thickness to combine with the thickness of the stone reservoir necessary to carry the assumed loads.

Task 4. Final Report

The final report will document the efforts to complete the tasks in this project. It will contain a structural design guide to be used for porous pavements.

Program 3: IMPROVED STRUCTURAL DESIGN OF PAVEMENTS

Project 3.07 Laboratory Determination of Material Properties for Structural Design

Objective: Develop realistic testing procedures for material properties to be used in flexible pavement design

Introduction

The design of a pavement structure depends upon the accuracy of the input values used for modeling the pavement system behavior and the performance models. In the past, material properties measured in the laboratory either were not or could not be used in the design of flexible pavements. Material properties such as volumetric measurements or stability values had only nebulous relationships to the performance of pavements or the behavior of pavement structures.

With the introduction of M-E design concepts, it became more practical to develop material tests that could be used as input to design and performance models. For instance, the resilient modulus test, introduced by Roger Schmidt in the 1970s, offered a way of measuring the stiffness of asphalt mixes in the laboratory. These resilient modulus values could be used as proxy input for the elastic modulus required in layered elastic design. Beam fatigue testing also offered a mechanistic approach to laboratory testing that could be correlated to field performance, if only in a relative fashion. These early attempts at laboratory characterization were laudable but there still existed a gap between the material properties and behavior measured in the laboratory and that observed in the field. Modulus values measured for lab-mixed, lab-compacted materials were often much higher than those observed through the back calculation of field deflection test results. Fatigue lives observed in the laboratory were orders of magnitude less than fatigue lives in actual pavements.

Now that M-E design procedures are in the process of being implemented by a number of agencies, it is important to introduce laboratory test methods or correlations that provide realistic design and performance parameters. For the soon-to-be-implemented AASHTO M-E Pavement Design Guide, the dynamic modulus and repeated-load permanent deformation tests are the suggested laboratory tests to obtain inputs. An alternate method of estimating the dynamic modulus involves a regression equation with mixture volumetric, aggregate gradation, and binder properties. Equipment and test methods have been developed to obtain these inputs, and the test methods are in the process of being balloted by AASHTO. Improvements in the user-friendliness, repeatability, reproducibility, speed, and interpretation of these and other laboratory tests will be needed.

Background

NCHRP Projects 1-40 (A-D), 1-42, 1-42A, 9-30, 9-30A, 9-33, 9-38, and 9-44 all contain elements that are relevant to this research project. In the end, it will be important to maintain a unified approach to ensure that laboratory material testing and structural design through the M-E process do not develop independently of each other.

In the 1950s, Seed and his colleagues at the University of California, Berkeley, proposed triaxial modulus testing for soils and granular materials. A similar type of testing was performed at the AASHO Road Test in the late 1950s for the asphalt mixtures, granular materials, and soils used in the test loops. About the same time, layered elastic analysis was beginning to be used as a research tool for pavement behavior. The resilient modulus test for HMA was introduced in the 1970s. The dynamic modulus test was developed in about the same timeframe. Tests for viscoelastic parameters were also in use for research purposes in the late 1970s. Over time, refinements to these tests were made to improve their accuracy. However, the integration of testing results into design remains a very nebulous practice.

Issues surrounding laboratory testing, analysis, and use of results in pavement design need to be addressed. The differences noted between laboratory and field results need to be explained and reconciled within the framework of the M-E design process. How mixture testing during mix design relates to the structural performance of the pavement system needs to be resolved in order to progress to performance specifications.

Scope / Objectives

Develop realistic testing procedures for material properties to be used in flexible pavement design. Compare the test results of lab-produced and field-produced HMA mixtures. Perform a mechanistic analysis of the properties by comparing the modeled performance of the pavement systems against the assumed parameters used in design. Develop a method for reconciling differences or changing the testing procedures and analysis will be proposed.

Work Plan

Task 1. State-of-the-Practice

Review current procedures for determining pavement design inputs from laboratory testing of laboratory-mixed materials. Review past work comparing material properties obtained from laboratory testing as compared to field testing and those values used in pavement design.

Task 2. Work Plan

A work plan will be devised to examine the relationship between pavement design parameters obtained in the HMA mix design phase and those of actual plant produced mixtures. In addition to examining the results from different loading times and temperatures, the plan will explain how the variability of the results will be captured.

Task 3. Laboratory Testing

The plan prepared in Task 2 will be executed and the data will be gathered. As the data become available, they will be reviewed for consistency and precision. It will be important to maintain quality control over both laboratory and field testing procedures in order to have a valid comparison.

Task 3. Mechanistic Analysis of Results

The information obtained in Task 3 will be subjected to a comparison of mechanistic predictions for laboratory and field testing. Comparisons of the expected performances will be made to ascertain the impact of the testing results on potential pavement designs.

Task 4. Final Report

The report will present the results of the comparisons made in Tasks 3 and 4. A recommended practice to reconcile lab, field, and design input material properties will be developed.

Program 3: IMPROVED STRUCTURAL DESIGN OF PAVEMENTS

Project 3.08 Development of In Situ Structural Monitoring Systems

Objective: Develop instrumentation and data systems capable of monitoring the long-term structural conditions of flexible pavements in-place.

Introduction

Infrastructure systems require constant monitoring to ensure optimal timing for maintenance and rehabilitation to efficiently allocate resources and maintain the performance and level of service required by the traveling public. This is especially critical for high-volume roadways where the timing of maintenance and rehabilitation impacts user costs and life-cycle costs.

Monitoring of pavement systems is typically performed within the context of a pavement management system. Distress surveys, ride quality, and skid resistance are among the functional measurements that are periodically made. Usually, structural evaluations are conducted once distress and ride quality values indicate the need for rehabilitation.

Structural evaluations are typically performed by deflection testing and measurements on pavement core samples. Interpretation of deflection results by back calculation for modulus values or by deflection parameters and a review of road geometric requirements form the basis for decisions concerning the degree of material removal, material type, and thickness for rehabilitation.

Background

There have been many research projects involving the instrumentation of dedicated research pavements or in-service pavements. The Corps of Engineers conducted many instrumented pavement tests in the 1950s through the present day. The AASHO Road Test and the Washington State Test Track both had a number of instruments to measure pavement responses to load. More recently, there have been a number of accelerated pavement tests (APT) on both small-scale and full-scale test tracks. Those involving dedicated APT equipment include the FHWA Accelerated Load Facility, Heavy Vehicle Simulator tests in California, Florida, and the Corps of Engineers facilities in Mississippi and New Hampshire, Louisiana, Kansas, Indiana as well as a number of others. Full-scale test facilities include the Minnesota Road Research Project, the National Center for Asphalt Technology at Auburn University, the Ohio Test Road, and the Kansas Perpetual Pavement Test Sections.

Enough has been learned from these instrumented facilities to investigate the use of instrumentation in continuous monitoring of pavements. It may be possible to observe the onset of structural distress through changes in pressures, strains, or displacements within the pavement layers. This could impact the timing of rehabilitation process in order to minimize future pavement expenditures and users costs. It may also be a way to monitor the impact of changes in legal load limits and forecast their impact on the pavement system.

Scope / Objectives

Develop instrumentation and data systems capable of monitoring the long-term structural conditions of flexible pavements in-place.

Work Plan
Task 1. State-of-the-Practice

Review the literature pertaining to instrumentation, visit existing instrumented pavement research sites, and review instrumentation from other industries and applications that may be used in pavement monitoring.

Task 2. Evaluation of Existing Instrumentation

Obtain longevity, accuracy, and precision data and analysis from existing APT sites to find the best combination of instruments, signal processing and data acquisition systems, and data storage systems. Successful installation techniques will be identified and documented as well. Data analysis strategies will be reviewed and a recommended procedure will be identified.

Task 3. Feasibility Study

Agencies with interest will be contacted. New construction or reconstruction of major highways will be the preferred test sites for the system. The ability to install instrumentation, signal processing and telemetry equipment, and data recording and storage facilities will be key considerations.

Task 4. Instrument of Test Sites

Work with agencies and contractors to install and test instrumentation and to monitor initial results. The agencies will be given a manual on the data acquisition, data storage, troubleshooting, and data interpretation for their use.

Task 5. Final Report

Develop a manual that can be used by agencies interested in pursuing the idea of continuous structural monitoring, including installation and testing, data monitoring, troubleshooting, interpretation, and operations.

Program Four: MATERIALS CHARACTERIZATION AND MIX DESIGN

Projects in Program Four

Project 4.01	**Full-Scale Accelerated Performance Testing**
Project 4.02	**Improved Asphalt Binder Specification**
Project 4.03	**Development of Alternative Binder Materials**
Project 4.04	**Performance-Based / Related Aggregate Properties**
Project 4.05	**Measurement of Interaction Between the Asphalt and Aggregate Surface**
Project 4.06	**Moisture Damage Susceptibility of HMA Mixtures**
Project 4.07	**Warm Mix Asphalt**
Project 4.08	**Additional Recycled Materials (other than RAP)**
Project 4.09	**Development High RAP Content Mix Design Procedure**
Project 4.10	**Accelerated Laboratory Performance Testing**
Project 4.11	**Improved Equipment & Test Procedures**
Project 4.12	**Laboratory Workability Test**
Project 4.13	**Laboratory Durability Test**
Project 4.14	**Field Vs. Lab Volumetrics and Mechanical Properties**
Project 4.15	**HMA for Low Traffic Roadways**
Project 4.16	**Validate/Refine Superpave Mix Design Procedure**
Project 4.17	**Mix Designs to Utilize Locally Available Materials**
Project 4.18	**Resource Availability Study for Binders and Aggregates**

Program Four
MATERIALS CHARACTERIZATION AND MIX DESIGN

Introduction

HMA mixtures are expected to perform over extended period of time under a variety of traffic and environmental conditions. The selection of materials and mix design methods for HMA must recognize these conditions and provide the materials to handle the anticipated traffic loading in the next century. Mixture design methods must provide the "tools" for the engineer to select and proportion materials to accommodate traffic and environmental conditions.

The characteristics of the heavy traffic and environment on a given facility and the local economics control to a large degree the type of HMA used. While the environment has not changed significantly, the characteristics of heavy traffic have changed significantly over the past 15 years and additional significant changes are expected in the near future. Tire pressures on heavy vehicles have increased from an average of about 70 psi to over 100 psi in the last 20 years. The tire pressure distribution on the pavement has also changed during this period as vehicle operators have changed form bias play to radial tires. An increasing number of heavy vehicles are also using single tire or super single tire replacements for dual tire configuration on axles.

The changes in heavy vehicle characteristics are expected to continue in the future. Heavy vehicle manufacturers are making significant changes in vehicle dynamics (suspension systems) and vehicle aerodynamics. The impact of these changes on the performance of HMA and mixture design is not known. Changes in tire pressure, tire pressure distribution, number of single tire replacements, vehicle suspension systems, and channelized traffic coupled with the potential for heavier loads and the certain increase of the number of heavy loads will require improvements in HMA design methods to ensure the successful use of HMA pavements.

Coupled with concerns about changing vehicles is the reality of material availability and cost. The United States is in competition with other countries' economies for construction materials. Additionally, there are declining numbers of aggregate sources in this country and increased energy prices. Such pressures require the development of new materials and binder extenders, and methods to increase the amount of recycling taking place in pavement construction. By judiciously using new materials and greater amounts of recycled materials, the industry can move forward in a competitive manner.

Background

Marshall and Hveem Hot Mix Asphalt mixture design methods were developed over 50 years ago to provide the engineer with a tool to select aggregate and asphalt binder combinations and concentrations for use as pavement surfacing material. These design methods were based on stability tests and mixture volumetrics. Acceptance criteria were based on a limited amount of research and, mostly, engineering judgment.
At the time of their development, these tests were believed to be predictors of pavement performance. For some traffic conditions and for some mixtures that have been historically used, these design methods may remain adequate to design pavements to resist permanent deformation or rutting.   Changes in traffic characteristics, as previously

described, and the availability of a wider variety of asphalt binders and aggregate gradations have largely outdated these older design methods. There is a need to develop test methods/procedures to determine fundamental properties of HMA component materials, and their interaction to develop performance prediction models.

The Superpave system of HMA mixture design was developed under the SHRP program. The Superpave system has test methods that promise improvement compared to the existing Marshall and Hveem methods to handle changes in traffic characteristics and environmental conditions. However, during implementation of Superpave across the country, engineers identified a number of shortcomings and research needed to further refine the system. Specifically, projects are needed to revise software, models, specifications, and test methods associated with the prediction models of the Superpave mix design system. The existing Superpave prediction models and/or the test methods may not be completely adequate to handle changes in traffic characteristics and materials expected in the coming years. In addition, research based on the revised Superpave approach and the use of accelerated pavement performance testing techniques will be needed to develop a mixture design method that will be required in the next century.

Scope/Objectives

The objective of this program is to develop materials, test methods, specifications, and performance relationships, leading to the optimization of materials and mix design for asphalt pavements.

Program 4: MATERIALS CHARACTERIZATION AND MIX DESIGN

Project 4.01 Full-Scale Accelerated Performance Testing

Objective: Develop guidelines and recommended practice for design, construction and operation of full-scale APTs.

Introduction

Full-scale, accelerated performance testing (APT) facilities have full-scale wheel loads that are applied to full-scale pavement structures by machines or vehicles in a test facility, test track, or in-service pavements. The purpose of full-scale APT is to determine pavement response and performance in a compressed time period. Data from full-scale testing has the advantage of being directly applicable to in-service pavement performance because the testing is done with full-scale tires on an in-place pavement. Therefore, there is no need to determine how data from small scale, laboratory testing applies to actual pavement performance.

The use of full-scale APT for determining pavement response and performance has increased in recent years, primarily because of its ability to apply wheel loads in a compressed time period, thus providing an expedited means of evaluating potential materials, designs, and features. There are a number of full-scale APT facilities in this country and around the world. The findings from research conducted at these facilities have contributed greatly to the understanding of structural design, materials selection, mix design, construction practices, and pavement response to vehicle loading and performance.

Background

A good example of the use of full-scale APT is in Project 9-44 “Fatigue Characteristics of Full-Scale Long-Life Asphalt Pavements” that is scheduled to be initiated soon. This project is needed to validate the concept of an endurance limit for flexible pavements that has been studied in previous laboratory research. NCHRP 9-44 will be used to test the validity of the recommendations provided in those small scale, laboratory study in "real life" conditions where full sized tires and vehicle loading is placed on an actual in-place HMA pavement section.

The data collected and reported by the various APT facilities have often varied in definition and format, making it difficult for others to interpret and use. Therefore, standardization is needed in the data collected from APT facilities and to recommend guidelines for data storage and retrieval. This will help to ensure proper interpretation of the data and facilitate their use by other agencies, enhancing the benefits of APT results. NCHRP Project 10-56 was conducted to address this need.

Data collection and reporting is only one aspect of the construction and operation of a full scale APT. Overall guidelines need to be developed for effective and appropriate use of full-scale APT in pavement studies. Guidelines should build on experience to date with these types of facilities. The guidelines should provide information related to planning, experiment design, construction, and performing research at full scale APT locations.

Scope / Objectives

Develop guidelines and recommended practice for design, construction and operation of full-scale APTs.

Work Plan
Task 1. State-of-the-Practice

The state-of-the-practice related to full-scale accelerated HMA pavement testing will be reviewed. A survey of the operators of full-scale APT in three different categories will be conducted, including those located at test facilities, test tracks, or on in-service pavements, to gather information about planning, designing, constructing and operating them. This work should build upon the results from NCHRP Study 10-56.

Task 2. Develop Draft Guidelines

Based on the findings from Task 1, draft guidelines will be developed. The draft guidelines will address full-scale APT of different types, including those at research facilities, test tracks and in-service pavements. The draft guidelines will be thoroughly reviewed by experts, including the managers and operators of existing full scale APTs.

Task 3. Develop Recommended Practices for Data Collection

Based on finding from Task 1, develop recommended practices for data collection and performance/failure classification. Consistency among the different facilities will help in analyzing the data and creating databases to be used in material and performance models and greatly expand the usefulness and applicability of findings.

Task 4. Guidelines and Recommended Practices

Guidelines and Recommended Practices for Full Scale Accelerated Performance Test facilities will be published.

Program 4: MATERIALS CHARACTERIZATION AND MIX DESIGN

Project 4.02 Improved Asphalt Binder Specification

Objective: Validate and refine the Superpave PG system for neat and modified asphalt binders

Introduction

Increased traffic volumes, higher axle loads, higher tire pressures and the replacement of dual tires with single tires are among the factors have changed in pavement service conditions. These require durable Hot Mix Asphalt (HMA) mixtures that are rut resistant, fatigue resistant, and resistant to thermal cracking. The grade of asphalt binder used in the mix can affect each of these properties. The use of modifiers and additives offer the promise of providing improved performance characteristics. Technical information is needed that defines the performance of Performance Graded (PG) binders (both neat and modified) under accelerated laboratory testing and under actual traffic over a number of years in a variety of climates. Additional research is also needed to improve the current PG binder grading system so that the enhanced properties of modified binder can be measured and quantified. The current PG grading system does not fully accomplish this desired outcome.

Background

The Strategic Highway Research Program developed a binder grading system which is focused on evaluating the performance of the binder. This PG system was intended to grade the binder, regardless of the presence of modifiers and/or additives. However, the system has been shown to have some serious shortcomings in evaluating modified binders.

HMA mixes containing modifiers and additives have been used in the U.S. for years. Increased demand on paving materials, the desire for longer life pavements, and the use of the Superpave mixture design and analysis system has renewed interest in modifiers and additives. Additional research and implementation is needed to ensure that the improved properties of modified binders are measured and are reflected in the PG grading system. Research should also include an evaluation of mixes containing modifiers and/or additives to ensure that they are used economically and to determine their impact on pavement performance.

The research also needs to be done with an awareness of the state of development for Warm Mix Asphalt, and the implications that lower production temperatures may have on the aging of binders as well as their absorption into aggregate.

Scope / Objectives

Validate and refine the Superpave PG system for neat and modified asphalt binders to satisfy changing traffic characteristics and to ensure appropriate economic and performance evaluations of the products. Include laboratory, accelerated pavement testing, and long-term performance monitoring to provide the data necessary to evolve binder specifications that reflect the expected performance of the material.

Work Plan
Task 1. State-of-the-Practice

State, federal and international practices and the relationship between test parameters and performance relative to binder selection, mixture design and the construction of HMA mixtures designed with Superpave PG binders will be reviewed**.**

Task 2. Perform Accelerated Laboratory and Accelerated Field Tests

Accelerated laboratory performance tests will be used to determine the relative performance of PG binder in HMA. This effort will be coordinated with the NCHRP project on modified binders (9-10) and the FHWA models project. Issues which need to be evaluated include: (1) selection of binder grades as function of pavement temperature, environmental conditions, traffic speed, traffic loading, and depth in pavement system; (2) storage stability of the binder; and (3) relationship of binder properties to pavement performance.

Task 3. Perform Field Tests

Obtain and evaluate information from contractors, materials suppliers and state DOT personnel to determine the impacts of using PG binders with modifiers and/or additives on construction, including production, hauling, lay down, compaction operations and specifications and specification enforcement. The overall economic impact of using modifiers and/or additives should also be evaluated.

Task 4. Implementation Manual

An implementation manual will be prepared describing the specification, design, construction and Quality Control/Quality Assurance operations associated with the PG binders, and describe the relationship between binder test parameters and pavement performance. Recommendations for changes to the specification will be identified.

Program 4. MATERIALS CHARACTERIZATION AND MIX DESIGN

Project 4.03 Development of Alternative Binder Materials

Objective: Identify and study alternative binder materials for use in flexible pavement mixtures

Introduction

Over the years, there have been various materials used for binder in flexible pavements. Currently, binder materials are almost entirely made up of asphalt cements. Most of these are petroleum-based materials that are by-products of the crude oil refining process. There are naturally occurring asphalts used as binders to a lesser extent. The most well known natural asphalt is from Trinidad Lake. In fact, some of the earliest recorded flexible pavement projects in the U.S. were constructed with this material in the early 1990s. Other sources of natural asphalt are other lake asphalts and rock asphalts from various sources around this country and the world. Prior to that, non-asphalt materials such as coal tar and water bound macadam were used.

Due to many factors, including concerns with recent trends in petroleum supply and prices and in potential problems with supply and prices in the future, there is a need to conduct research to develop alternatives to traditional petroleum-based binders. The focus of this research should be in developing viable alternative binders and asphalt extenders with the technology to produce them in quantity.

Background

There are alternatives to petroleum-based asphalt cement, primarily derived from vegetable by-products. There are also additives and modifiers can be blended with asphalt cement to act as extenders and improve its properties.

There are a number of problems and potential problems with the use of asphalt cement as the only available binder material. These are primarily related to concerns with the future supply and cost of petroleum-based, asphalt cement binders. Recent geopolitical events and increasing environmental concerns may have a profound affect on the availability of crude oil and refining capabilities in the near future. There has been a recent, significant increase in prices of all petroleum products, including asphalt binders. These trends in supply and costs are problematic for the flexible pavement industry and it is likely that they will continue well into the future.

Of particular concern to the industry and its customers is the dramatic increase in the asphalt binder costs. Until recently, the flexible pavement industry has enjoyed a major price advantage over the rigid pavement alternative due in large part to the availability of relatively inexpensive component material like aggregate and asphalt binder. Ideally, alternative binder material or the use of an extender must be less expensive than traditional asphalt binders without reducing the quality of the final mix.

There are many possible components of alternative binders or asphalt extenders that may be considered in this project. It is possible that the list of components being considered will include petroleum-based materials, especially those that are used in the petrochemical industry. They may also include synthetic, vegetable-based, or inorganic materials from non-petroleum sources.

One approach to the above concerns could be on extending the binders currently in use. Improved recycling technologies could offer a means to use the binder of the old pavement as more of a component in new HMA mixtures than present levels of recycling. Currently, HMA is the most recycled material in this country and reclaimed asphalt pavements (RAP) that contain asphalt binders can be reintroduced in virgin HMA at the plant in fairly high percentages (up to 50% by weight). This allows the asphalt binders that are present in reclaimed pavements to be recovered and reused. There may be technologies that will allow 100% RAP. However, recycling is only effective in decreasing the amount of binders that are used in HMA materials, not totally eliminating the need for new binder. Therefore, improved recycling technologies and techniques can not fully address the concerns associated with the total reliance on asphalt binders. Therefore, research is needed to develop alternative, non-petroleum based binder materials.

Non-petroleum based asphalt binder extenders have included the use of carbon black, elemental sulfur, and lignin. The use of these materials has been experimental for the most part. Problems with water solubility, emissions, and costs have hindered their use on a widespread scale.

Scope/Objectives

Identify and develop alternative binders and extenders that can replace currently-used asphalt cements for use in flexible pavements.

Work Plan
Task 1. Literature review

A literature review will be conducted on flexible pavement binders and binder extenders used in the past and present. The review will include the identification of non-petroleum based material that has potential as an alternative binder or extender, including the development of synthetic binder materials. This task will include involvement of manufacturers of synthetic materials that are alternatives to petroleum products for other applications. It may also include petroleum-based materials, especially those currently used in the petrochemical industry.

Task 2. Lab and Field Studies

Based on the findings of Task 1, the most promising alternative products will be identified for further research and development efforts.   These efforts will include both lab and field studies where alternative binders and extenders will be evaluated for use in flexible pavement mixtures.

Task 3. Report / Recommendation for Future Research.

A report will be written that summarizes the findings of this research and makes recommendations for needed future research. The report will also make recommendations about ways to encourage the growth in production of the alternative binder materials or extenders and the implementation of the technology

Program 4: MATERIALS CHARACTERIZATION AND MIX DESIGN

Project 4.04 Performance-Based / Related Aggregate Properties

Objective: Develop and validate performance-based aggregate characterization techniques for inclusion in the mixture design system.

Introduction

The properties of coarse and fine aggregates used in HMA mixtures contribute significantly to the performance of the highway pavements. They comprise approximately 95 percent of the mixture by weight, and their shape and texture often define the rut resistance and workability of the mixture. The interaction between aggregate and asphalt is key in ensuring the durability of the material. Despite their obvious importance, insufficient consideration is sometimes given to the testing of aggregates. Most aggregate tests and their interpretations are empirical and some are very subjective. For instance, the Superpave aggregate properties were developed by a panel of experts using a consensus process to determine their importance in pavement performance.

Ultimately, the goal is to develop performance based / related aggregate consensus properties that can be used in performance specifications. Two NCHRP Projects were conducted to identify and validate performance-based aggregate properties. These projects were NCHRP 4-19 - "Aggregate Tests Related to Asphalt Concrete Performance in Pavements" (NCAT; 1997) and 4-19 (2) - "Validation of Performance-Related Tests of Aggregates for Use in Hot-Mix Asphalt Pavements" (Purdue, 2005).

Background

NCHRP Project 4-19(2) evaluated previously recommended aggregate tests related to hot-mix asphalt (HMA) performance and, based on the results of laboratory tests and accelerated tests of full-scale pavement sections, developed recommendations for a set of eight performance-based aggregate tests and provided guidance for evaluating and selecting aggregates for use in specific applications. The final report was published as NCHRP Report 557. The recommended set of eight aggregate tests deals with particle shape, angularity, surface texture, durability, and soundness of the aggregates and with the characteristics of the fines in aggregates.

Identifying performance-based aggregate properties and corresponding test methods to measure those properties was the first step in using this information to predict HMA pavement performance. Research is needed to build on these studies and work toward phasing out the currently used aggregate consensus properties used in the Superpave materials selection and mix design procedure. The goal is to replace them by developing and validating performance-based aggregate characterization techniques for inclusion in the Superpave mixture design system.

Scope / Objectives

Develop and validate performance-based aggregate characterization techniques for the inclusion in the Superpave mixture design system. Include a review of current methods to test and specify aggregates, laboratory and field testing, a study of design and construction implications, and implementation.

Work Plan

Task 1. State-of-the-Practice

State, federal, and international practices relative to performance-based aggregate selection and design of HMA mixtures will be reviewed. The relationships between aggregate properties and pavement performance will be included in this review of the state-of-the-practice. NCHRP Report 405, "Aggregate Tests Related to Asphalt Concrete Performance in Pavements" and NCHRP Report 557 "Validation of Performance-Related Tests of Aggregates for Use in Hot-Mix Asphalt Pavements" will be included in the review. A list of aggregate properties and related test methods that are related to HMA pavement performance will be developed.

Task 2. Perform Accelerated Mixture Tests

Using the performance-based aggregate properties identified in Task 1, accelerated testing in laboratory and in field applications will be used to verify the aggregate properties that can be related to HMA pavement performance. This effort will be coordinated with existing research projects on aggregates. Issues which need to be evaluated include: (1) relationship of aggregate properties to pavement performance, (2) mix sensitivity to aggregate properties, (3) sensitivity of mix volumetrics to aggregate properties, and (4) consideration of appropriate use of available aggregate resources, especially on low volume roadways and in underlying HMA pavement layers.

Task 3. Develop Aggregate Properties for Superpave

Based on the findings of Tasks 1 and 2, a Superpave aggregate property specification will be developed.

Task 4. Perform Field Evaluation

The revised Superpave aggregate properties will be used in the design of HMA pavements that will be produced and constructed on actual projects. The properties will be validated based on the performance of the pavements in both accelerated and non-accelerated loading situations.

Task 5. Design and Construction Impacts

Where trial pavement sections are constructed, there will be an effort to determine the impact and practicality of the new consensus properties. These impacts include those on HMA production, haul, placement, and compaction operations, and specifications and specification enforcement. The overall economic impact of the new, performance-based aggregate specifications will be included in this evaluation.

Task 6. Implementation Manual

An implementation manual will be prepared describing the development and impact of adopting performance-based aggregate properties in the Superpave materials selection and design procedures. The effect that this implementation will have on design, construction and Quality Control / Quality Assurance procedures will be described. Specifications for aggregates in ASTM/AASHTO format will be included in the manual.

Program 4: MATERIALS CHARACTERIZATION AND MIX DESIGN

Project 4.05 Measurement of Interaction between the Asphalt and Aggregate Surface

Objective: Identify laboratory equipment & test procedures to measure the strength of the interaction (bond) between the asphalt and aggregate surface

Introduction

The strength of the asphalt/aggregate interaction that exists in the HMA mixture, especially in the presence of water, is a key factor in the long-term performance of an asphalt pavement. There are currently no standard laboratory test procedures that can quickly and accurately measure the strength of the interaction (bond) between the binder and aggregate, and there are no criteria for evaluating the impact of the interaction on performance.

During plant production, the hot asphalt binder is blended with hot aggregate so that a film of binder coats the aggregate surface. In order for this mixture to perform well in a pavement, there must be a strong bond between the aggregate surface and the asphalt binder. Some pavements have prematurely failed due to a weak bond at the aggregate/binder interface, especially with the presence of water, which can actually displace asphalt binder on the aggregate surface. "Moisture damage" is the term used to describe a wide variety of weakening mechanisms, one of which is the phenomenon of the loss of bond between the binder and aggregate. Moisture damage can have significant adverse affects on the performance and service life of HMA pavements and is known to contribute to a variety of distresses, including rutting, raveling, and cracking.

Some aggregates and binder combinations are more prone to moisture damage than others due to interfacial incompatibility between the two materials. There is evidence that moisture susceptibility is influenced by aggregate mineralogy, aggregate surface texture, asphalt binder chemistry, and the interaction between asphalt and aggregate. The great number of different aggregate mineralogy and the numerous types of unmodified and modified asphalt binders used across the United States, coupled with varied environmental conditions, mix design practices, traffic, and construction practices, have made testing to accurately predict HMA moisture susceptibility a difficult task. However, it is possible to prevent bonding problems by selecting aggregates and binders that are highly "compatible" with each other and / or by using an "anti-stripping" additive during production. Therefore, if a potential problem with a weak aggregate/binder bond or potential for moisture damage can be identified during laboratory testing, steps can be taken to correct the problem. The key to solving the problem is to develop a laboratory test that can measure the interaction or bond between the project asphalt binder and the project aggregate. This test must have the potential to accurately predict the potential for moisture damage (moisture susceptibility) of an HMA mixture in the field.

Background

There have been extensive research efforts to identify a laboratory procedure that will accurately predict moisture susceptibility of HMA mixtures in the field. AASHTO Standard Method of Test T 283, "Resistance of Compacted Bituminous Mixture to Moisture Induced Damage," has been the laboratory test most often used by highway agencies. It is based on a concept of indirect tensile strength ratios of unconditioned and moisture conditioned, compacted HMA specimens. It has been modified and incorporated in Superpave volumetric mix design to determine HMA moisture damage susceptibility. Despite the widespread adoption and use of T-283 as the moisture susceptibility test of choice by the majority of highway agencies, there is a widespread belief that the criteria can often lead to false positive and false negative outcomes. There is a consensus that research efforts are needed to identify an improved test method. Several studies that compared laboratory testing results to actual field performance have supported that conclusion. Other research is ongoing to develop a more accurate moisture susceptibility test. NCHRP Project 9-34 is investigating whether combining the field-validated Simple Performance Tests (SPT) with an improved Environmental Conditioning System (ECS) conditioning procedure offers an enhanced ability, compared to present methods, to predict HMA moisture susceptibility.

This proposed research project will be an effort to develop a test method that will help to (either on its own or in conjunction with other tests) provide an accurate measurement of moisture susceptibility of an HMA mixture in the field. It will include efforts to develop a laboratory test to measure the interaction or bond between the asphalt binder and the aggregate surface and also efforts to identify methods of treating aggregate to improve this measured asphalt binder-aggregate interaction. The research should focus on developing a laboratory test where equipment is affordable, that is practical in nature and will be usable by highway agencies in mix design and QC/QA testing in field labs.

Scope / Objectives

Identify and possibly develop laboratory equipment and test procedures to measure the strength of the interaction (bond) between asphalt binder and the aggregate surface in an HMA mixture. Relate this bond measurement to moisture susceptibility of the HMA mixture, if possible.

Work Plan
Task 1. State-of-the-Practice

Conduct a literature review to evaluate the current state-of-the-practice related to equipment and test procedures to measure asphalt binder-aggregate interaction (bond). Identify the most promising equipment/procedures to be included in the research effort. If necessary, expand the literature review into non-asphalt pavement industry testing methods that might be applicable. If needed, identify the need to develop new / innovative equipment and test methods for evaluation in this study. Also, evaluate binders, aggregates and anti-stripping additives that have been used in HMA production and have a history of moisture damage performance when used in combination with each other.

Task 2. Identify and/or Develop Test Equipment and Procedures

Based on the findings of Task 1, identify equipment and test procedures that will be evaluated in this study. If new equipment is needed, develop prototype equipment.

Task 3. Identify Materials to be Used

Based on the findings of Task 1, identify asphalt binders, aggregates and anti-stripping additives that will be used in the study. The research will include combinations of these materials where a wide range of measured bond between the binders and aggregates are expected and where variations in performance are evident. An experiment will be designed to investigate combinations of materials and ascertain the influence of the identified variables.

Task 4. Conduct Laboratory Studies

Conduct laboratory studies to evaluate the ability of the selected lab test equipment/procedures to accurately measure the interaction (bond). The research should also relate measured interaction to the corresponding measured moisture susceptibility for each aggregate/binder/ anti-strip combination.

Task 4. Report Findings / Recommendations

Develop a report to communicate the findings of the research. The recommendations of the research team related to equipment and test procedures will also be included in the report.

Task 5. Implementation

Develop a proposed plan for implementation of the findings/recommendations of the research study. If the test method is proposed for implementation, a plan will be developed to address repeatability, reproducibility, and the development of a standardized test method.

Program 4: MATERIALS CHARACTERIZATION & MIX DESIGN

Project 4.06 Moisture Damage Susceptibility of HMA Mixtures

Objective: Improve fundamental understanding of moisture susceptibility, including mix design and QC/QA tests and treatments/additives during production

Introduction

In-place asphalt pavements are subject to deterioration from both environmental and traffic related effects. The environmental factors include moisture intrusion into the pavement through a variety of avenues. The strength of the asphalt/aggregate bond that exists in the pavement, especially in the presence of moisture, is an important factor in the long-term performance of asphalt pavement. When that interfacial bond is broken, the asphalt binder may be “stripped” from the aggregate surface by water displacing asphalt. Moisture-induced damage results in a loss of either adhesion or cohesion in the asphalt pavement. Moisture damage can have significant adverse affects on the performance and service life of HMA pavements and is known to contribute to a variety of distresses, including rutting, raveling, and cracking. Although it is known that moisture susceptibility can be potentially devastating to an asphalt pavement, relatively little is understood concerning its basic mechanisms.

Agencies and the asphalt industry are aware of the importance of addressing moisture susceptibility issues. Many agencies have experienced major stripping issues in the past and have since adopted provisions to address the problem. These provisions typically include requirements for laboratory testing for moisture susceptibility during mix design and, occasionally in production. As a remedy, anti-stripping additives may be used during plant production or introduced into the liquid binder at the terminal. Hydrated lime is used in some states and it is added to the aggregate during plant production prior to the addition of the asphalt binder. Many agencies allow the use of liquid anti-strip additives, which are added to asphalt binder either at the plant or at the terminal.

There has been extensive research on various aspects of moisture susceptibility, including efforts to develop improved test procedures to accurately predict moisture-related performance of in-place pavements. Other research has focused on identifying effective anti-strip additives, on conditioning test specimens prior to testing and on design/construction of mixtures that are less prone to moisture damage. However, a more fundamental understanding may help the industry and agencies develop more innovative and definitive remedies.

Background

Much of the research efforts to date have been focused on identifying a laboratory procedure that will accurately predict moisture susceptibility of HMA mixtures in the field. AASHTO Standard Method of Test T 283, "Resistance of Compacted Bituminous Mixture to Moisture Induced Damage," has been the laboratory test most often used by highway agencies. It is based on the concept of indirect tensile strength ratios of unconditioned and moisture conditioned, compacted HMA specimens. It has been modified and incorporated in Superpave volumetric mix design to determine HMA moisture damage susceptibility. Despite the widespread adoption and use of T-283 as the moisture susceptibility test of choice by the majority of highway agencies, there is a widespread belief that the criteria can often lead to false positive and false negative outcomes. There is a consensus that research efforts are needed to identify an improved test method. Several studies that compared laboratory testing results to actual field performance have supported that conclusion. Other research is ongoing to develop a more accurate moisture susceptibility test. NCHRP Project 9-34 is investigating whether combining the field-validated Simple Performance Tests (SPT) with an improved Environmental Conditioning System (ECS) conditioning procedure offers an enhanced ability, compared to present methods, to predict HMA moisture susceptibility.

This proposed research project will be an effort to consolidate the results of studies related to moisture susceptibility of an HMA mixture to summarize the current state of knowledge and to assist in efforts to implement the most important findings to date. Furthermore, it will develop a number of theories concerning the effects of moisture on the cohesion and adhesion within the asphalt-aggregate matrix in HMA. The research should have a broad focus to include all aspects of the subject matter, including materials characterization and compatibility, improved moisture sensitivity conditioning and test procedures and the effective use of anti-strip additives. In addition, the study should identify gaps in the knowledge base of the topic of moisture damage and should identify research efforts that are needed to address those concerns.

Scope / Objectives

Improve the fundamental understanding of moisture susceptibility, including laboratory test equipment/procedures to measure potential for moisture damage and treatments/additives used to decrease moisture sensitivity during production. Develop and explore mechanical and chemical processes involved in the weakening of asphalt mixtures in the presence of water. Recommend needed research topics and propose a plan to implement the use of materials, conditioning/test procedures, mix design and production procedures that comprise best practices to avoid moisture damage.

Work Plan
Task 1. State-of-the-Practice

The state-of-the-practice of the entire body of knowledge related to moisture susceptibility including materials characterization, asphalt-aggregate compactibility tests, anti-strip additives, mix design, QC/QA procedures and HMA production will be developed. **G**aps in the current knowledge base and research to provide the needed information/data will be identified.

Task 2. Findings / Recommendations

Write a report to communicate the findings of the research. The recommendations of the research team related to equipment and test procedures will also be included in the report.

Task 3. Development of Moisture Susceptibility Damage Mechanisms

Summarize the various fundamental theories concerning moisture susceptibility and explain them in the context of asphalt materials characterization, mix design, production, placement, and performance.

Task 4. Implementation

Develop a proposed plan for implementation of the findings/recommendations of the research study.

Program 4: MATERIALS CHARACTERIZATION AND MIX DESIGN

Project 4.07 Warm Mix Asphalt

Objective: Investigate, validate, refine Warm Mix Asphalt technologies and analyze mix design, performance, and environmental data

Introduction

The United States and Canada and European countries are experimenting with technologies that allow a reduction in production and placement temperatures. These technologies have been labeled Warm Mix Asphalt (WMA). The immediate benefit of WMA is reducing the energy required by burning fuels to heat traditional hot mix asphalt (HMA) to temperatures in excess of 300° F during production. These high production temperatures are needed to drive moisture out of the aggregate, to allow the asphalt binder to completely coat the aggregate, to promote workability during placement and compaction, and to maintain durability during traffic exposure. With decreased production temperature, the additional benefits are reduced emissions from the plant and the paving site.

There are four WMA technologies that have been observed in the European countries:

1. The addition of a synthetic zeolite called Aspha-Min® during mixing at the plant to create a foaming effect in the binder.
2. A two-component binder system called WAM-Foam® (Warm Asphalt Mix Foam) that introduces a soft and hard foamed binder at different stages during plant production.
3. The use of organic additives such as Sasobit®, a Fischer-Tropsch paraffin wax and Asphaltan B®, a low molecular weight esterified wax.
4. A production process where hot coarse aggregate and asphalt are combined prior to the introduction of moist sand. The moisture in the sand is converted to steam which creates an asphalt foam. This process is called Low Energy Asphalt (LEA).

In addition to the work done in Europe, two new Warm Mix Asphalt approaches have been developed in the U.S.:

1. MeadWestvaco is marketing a system using advanced asphalt emulsion technology called Evotherm. This product is added to the mix production facility in the same way a conventional asphalt binder would be added.

2. Astec Industries has a prototype process where asphalt is foamed prior to introduction to the mix. The foaming is achieved by injecting one pound of water to each ton of hot mix asphalt.

All of the technologies allow the production of WMA by reducing the mass viscosity of the asphalt mix within a certain temperature range. This reduced viscosity allows the aggregate to be coated at a lower temperature than what is traditionally required in HMA production. Warm Mix Asphalt technology could have a significant impact on transportation construction projects in and around environmental non-attainment areas such as large metropolitan areas that have restrictions on hours of operation for HMA facilities. The reduction in fuel usage to produce the mix may have a significant impact on the cost of projects.

Background

The benefits of WMA to the United States in terms of energy savings and air quality improvements are promising but need further investigation in order to validate their expected performance and value. In some instances, the implementation of these technologies will require adjustments to standard mix design, specifications, and production and placement procedures to account for the reduced temperatures used in WMA.

Technologies that allow reduced temperatures and increased workability and compactability are still under development. Therefore, mixture design methodology and associated accelerated pavement and materials testing methods that are appropriate for low-production temperatures are needed. One major adjustment that must be made is in the mix design procedures. Research is needed to develop a mix design procedure that can be performed effectively at lower temperatures using the various WMA technologies. Assumptions of binder aging through the plant and the consequences on rutting and cracking performance must be studied.

Scope / Objectives

Investigate, validate, refine Warm Mix Asphalt technologies and analyze mix design, performance, and environmental data. Develop mix design methods for WMA technologies and accelerated performance tests that are applicable to low-production temperature mixes and compaction aid technologies. Include both laboratory and field studies and identify recommended changes to AASHTO standard procedures.

Related Research

NCHRP Project 9-43 "Mix Design Practices for Warm Mix Asphalt Technologies" started in 2007, and its objective is the development of a mix design procedure for WMA. NCHRP Project 9-47 “Engineering Properties/Field Performance of Warm Mix Asphalt Technologies” will start in 2008.

Work Plan
Task 1. State-of-the-Practice

Results from existing research efforts and field trials will be reviewed and summarized. Included will be the results of mix design, construction records, performance and volumetric testing as well as emissions and health testing. This document will be used to assess the state-of-the-art of warm mix asphalt and to identify research needs for further efforts. Best practices to this point in time will be highlighted.

Task 2. Perform Laboratory and Field Tests

Using the information collected in Task 1, the most promising mix design methodologies and APT will be evaluated in both laboratory environments and field construction projects. This research will address both performance and environmental testing approaches.

Task 3. Recommended Practice

Implementation guidelines will be prepared that describe the recommended practices for mixture design, specifications, construction and performance monitoring of warm mix technologies. The manual will include specifications and test methods that are in the proper format suitable for inclusion in AASHTO specifications and test method standards.

Program 4: MATERIALS CHARACTERIZATION AND MIX DESIGN

Project 4.08 Additional Recycled Materials (other than RAP)

Objective: Identify and develop procedures and guidance for the effective and economical recycling of reclaimed/reprocessed materials (other than RAP).

Introduction

HMA recycling using reclaimed asphalt pavement (RAP) in the USA has increased during the last 20 years and is now standard procedure in most states. Even though research projects are needed to refine RAP recycling procedures for HMA, the equipment and process of incorporating a limited percentage of RAP to produce a recycled HMA are fairly well understood. HMA mixes containing RAP are generally of high quality and research has shown that they can perform as well as virgin HMA pavements.

There are also many other types of previously-used materials that can and have been used in HMA pavements. Because of the cost and environmental issues associated with disposing of many of these reclaimed materials in landfills and because public funds are used in pavement construction, public agencies are under pressure to incorporate them into their HMA pavement materials. Some of the reclaimed / reprocessed materials that have been shown to be recyclable in HMA are reclaimed tire rubber, crushed glass, recovered sulfur, roofing shingles, recycled concrete and host of other materials. With the possible exceptions of reclaimed tire rubber and roofing shingles, the equipment and process to incorporate other materials are not as well understood as the use of RAP.

Therefore, research is needed in each or all of these materials to address key issues related to health, safety, environmental concerns, recyclability, mix design, construction, and performance of the HMA pavements containing these materials.

Background

There are many questions that must be answered in order to effectively recycle these reclaimed / recycled materials into HMA pavement materials. First, the cost and availability of the material needs to be addressed. Second, research must determine how the addition of the reclaimed / reprocessed material affects the performance of the HMA pavement. Finally, it must be established that there are no adverse health or safety problems that will be caused by subjecting the recycled materials to high production temperatures. The materials must be readily available, be cost-effective, pose no health or safety concerns, and they must also be shown to provide the same or better service life than conventional mixtures.

Other issues that should be addressed through laboratory testing and field projects include the amount and type of processing required to prepare the materials for incorporation into HMA. The incorporation of reclaimed / reprocessed materials may require modifications to the standard materials selection, mix design, production and the laydown/compaction operation, and these will need to be documented.

Some of the reclaimed / reprocessed materials mentioned above have been used routinely in HMA in certain parts of the country. Others have been used on a small number of projects. Therefore, a research effort to conduct a thorough review of the effect of using a wide variety of reclaimed/reprocessed materials on the performance of HMA pavements is needed.

Scope / Objectives

Identify and develop procedures and guidance for the effective and economical recycling of reclaimed/reprocessed materials (other than RAP) in HMA.   Recommend improved mix design, plant production and construction evaluation for the use of a wide variety of reclaimed/reprocessed materials in HMA mixtures. Address the key issues of health, safety, environmental concerns, cost and availability, mix design, plant production, construction and pavement performance.

Work Plan
Task 1. State-of-the-Practice

The state-of-the-practice relative to the design and construction of HMA pavements using a variety of reclaimed / reprocessed materials needs to be established. This review should include a literature review of projects and research conducted throughout the world. The review will not include recycling of reclaimed asphalt pavement which should be covered under a different effort.

Task 2. Status of Reclaimed / Reprocessed Materials

A list of reclaimed / reprocessed materials to be considered during this research will be developed. Evaluation protocols for reclaimed/reprocess materials for use in HMA will be drafted, reviewed, and finalized. Consideration of the engineering, environmental and economic benefits and consequences of using a material must be included in the evaluation.

Task 3. Laboratory and Field Studies

Laboratory testing of reclaimed / reprocessed materials and of HMA containing the recycled materials will be performed using volumetric and performance tests. Then, field studies will be performed on actual construction projects where reclaimed / reprocessed materials are used. The field studies will evaluate the use of the reclaimed / reprocessed materials from an economic, engineering and environmental perspective.

Task 4. Implementation Manual

Prepare recommendations and guidelines for the use of specific reclaimed/reprocessed materials in HMA in proper format for submission as recommended practices to AASHTO for approval.

Program 4: MATERIALS CHARACTERIZATION AND MIX DESIGN

Project 4.09 Development of High RAP Content Mix Design Procedures

Objective: Develop means to produce high quality, high RAP content HMA mixtures including RAP with polymers, asphalt-rubber, roofing shingles, etc.

Introduction

Reclaimed Asphalt Pavement (RAP) is produced in large quantities by pavement removal operations throughout the country. Much of the RAP generated is being reused in various roadway applications and/or recycled into new asphalt pavements; however, there are excess quantities of RAP in stockpiles at some contractor's production plants. With rising energy and material prices, and dwindling supplies of readily available aggregate in many places, there is a need to utilize higher percentages of RAP in asphalt pavement applications. The increased use of RAP also has many financial and environmental benefits.

The use of RAP in recycled asphalt pavement is well accepted practice by many federal, state, and local agencies. In many areas, almost all HMA contains at least some RAP. However, with a few exceptions, the amount of RAP that can be added in hot plant mix asphalt mixtures is limited to relatively low percentages and, in some areas, the use of RAP is prohibited in certain types of mixtures, such as surface courses. Typically, the maximum percentage of RAP allowed is anywhere from 15 to 30% by weight of HMA mixture.

Laboratory and field studies have been performed on HMA with much higher percentages of RAP. These investigations have concluded that HMA materials with percentages in excess of 50% can be produced to perform to the same as "virgin" mixes. It has been well established that agencies that are not currently allowing RAP into their HMA mixtures and those that are only allowing small percentages of RAP can safely increase the amount of RAP used without fear of shortening pavement life, provided that best practices are followed. The use of RAP in HMA mixtures has been proven to be economically and environmentally sound.

With the recent increase in the amount of "additives" being specified in HMA pavements, some of the RAP contains polymers used in modified binders, ground tire rubber, roofing shingles, reclaimed glass and other reclaimed materials. A research study is needed to develop mix design procedures that will effectively address the incorporation of a higher percentage of RAP into HMA pavements with no loss of serviceability. These procedures will also accommodate the use of RAP containing polymers, asphalt rubber, roofing shingles, glass, and other additives.

Background

Develop means to produce high quality, high RAP content HMA mixtures including RAP with polymers, asphalt-rubber, roofing shingles, etc. Include a state-of-the-practice review, development of a research work plan, laboratory and field studies to resolve any outstanding issues and develop a standard of practice.

Work Plan
Task 1. State-of-the-Practice

The state-of-the-practice relative to the mix design procedures using high RAP content mixes needs to be established. Issues related to the recycling of RAP containing binder and mixture additives such as polymer binder modifiers, asphalt-rubber, and roofing shingles will be studied. This review should include the efforts completed by the National Center for Asphalt Technology, the National Cooperative Highway Research Program and the Federal Highway Administration.

Task 2. Work Plan

Based on the findings of Task 1, the most important research objectives and issues with development of new and improved mix design procedures for the use of RAP in higher percentages (50% and higher) in HMA surface, intermediate and base mixtures will be identified. A work plan will be developed that will address these objectives through both laboratory studies and field projects where mix design is accomplished using recommended procedures. At least one laboratory and field study should include RAP that contains commonly used binder or mixture additives.

Task 3. Laboratory and Field Tests

In order to validate the revised procedures and methods identified in previous tasks, laboratory studies should be conducted on selected mix design procedures. Based on the findings of the lab study, develop mix designs for high RAP mixtures, including surface mixes. Field projects should be conducted to validate the effectiveness of the mix design procedures to provide well designed RAP mixes. Lessons learned in these field projects should be used to modify the mix design procedures and recommendations that come out of this study.

Task 4. Guidelines / Revised Mix Design and Test Procedures

Based on the findings of the report, prepare guidelines for mix design procedures in HMA in proper format for submission to AASHTO for approval. Develop an implementation manual that can be used by designers to optimize the mix design process for higher percentages of RAP.

Program 4: MATERIALS CHARACTERIZATION & MIX DESIGN

Project 4.10 Accelerated Laboratory Performance Testing

Objective: Develop improved laboratory tests and constitutive models to better predict pavement performance

Introduction

Performance of Hot Mix Asphalt (HMA) pavements can be defined in a number of ways. Currently, performance can only be evaluated by constructing the pavement and then observing how it performs over time. A better method would provide the capability to perform a rapid test or tests in the laboratory that can accurately measure the HMA mixture properties that relate to performance in the laboratory. Ideally, a test should be performed in both the lab during mix design and in the field lab during HMA mix production. Test equipment and methods that fit this description are usually referred to as accelerated performance tests (APT).

Currently, measurement of performance must be based on the observed performance of the pavement in place after construction. Performance measurement can be based on the service life of the pavement, the measured amount of a specific type of distress or measurements that combine all types of distress. Regardless of how performance is measured, poor pavement performance that results in a short service life due to excessive amounts of distress is obvious. Unfortunately, this situation occurs more often than it should.

The most obvious measurement of pavement performance is related to service life or how long the pavement lasts before maintenance or rehabilitation must be performed. Typically, public agencies have expectations of the service life of pavements that are constructed or rehabilitated. This life expectancy can vary significantly depending on a number of factors, including the type of construction (new or rehab), the mix type and thickness, traffic volume and loading, etc.

Other ways to measure performance are by measuring specific types of pavement distress (such as premature rutting) or all types of pavement distress as is typically done in pavement management systems. Maintenance and rehabilitation is generally performed when the pavement experiences a certain level of distress. Performance is considered adequate if the expected service life is obtained without excessive amounts of distress occurring in the pavement.

Laboratory tests to accurately predict the performance of a HMA material before it is constructed are desperately needed. Such performance prediction tests must be able to predict specific types of distress such as permanent deformation, fatigue cracking, thermal cracking, aging and moisture susceptibility. Ideally, the test procedures could be performed in a field laboratory on plant produced HMA.

Background

There is a need to develop, evaluate and implement accelerated laboratory test equipment and method(s) that can be related to performance. There are a number of research efforts that have been completed or are currently underway to accomplish this goal. NCHRP 9-29 "Simple Performance Tester for Superpave Mix Design" is a current project that is intended to develop simple performance tests for evaluating the resistance of Superpave-designed hot mix asphalt (HMA) to permanent deformation and fatigue cracking during mix design and possibly in field quality control. The objectives of this research are to (1) design, procure, and evaluate simple performance testers for use in Superpave mix design and in HMA materials characterization for pavement structural design and (2) evaluate and refine the indirect tensile test (IDT) procedures proposed for use as the simple performance test for low-temperature cracking and as the materials characterization test for low-temperature cracking in the Mechanistic-Empirical Pavement Design Guide developed in NCHRP Project 1-37A.

Marshall and Hveem HMA mixture design methods were developed over 50 years ago to provide the engineer with a tool to select aggregate and asphalt binder combinations and concentrations for use as pavement surfacing material. These design methods were based on stability tests and mixture volumetrics. Acceptance criteria were based on a limited amount of research and engineering judgment. At the time of their development, these tests were believed to be predictors of pavement performance. For some traffic conditions and for some mixtures that have been historically used, these design methods may remain adequate predictors of the pavement's ability to resist permanent deformation or rutting. However, changes in traffic characteristics and the desire to use a wider variety of asphalt binders and aggregate gradations have largely outdated these design methods.

The Strategic Highway Research Program (SHRP) developed the Superpave system of HMA mixture design. The Superpave system has test methods that promise improvement compared to the existing Marshall and Hveem methods to handle changes in traffic characteristics. The Superpave system has been in place for quite some time and there have been efforts to improve and revise software, models, and test techniques related to optimum mix design and prediction models. These efforts will continue in the future but it is unlikely that the Superpave procedures will be completely adequate to handle the changes in traffic characteristics, binders and aggregate gradations expected in upcoming years. Additional research based on the revised Superpave approach and the use of accelerated pavement performance testing techniques will be needed to adequately develop a mixture design method to satisfy the mixtures that will be required in the next century. NCHRP Project 9-19, "Superpave Support and Performance Models Management," is tasked with identifying these simple performance tests and developing appropriate models for accelerated test procedures to measure performance-related HMA mixture properties.

The research to develop Simple Performance Testers and associated equipment and specifications has provided valuable insight into many issues related to specimen fabrication, specimen conditioning and the testing protocol for accelerated lab testing. Further research is needed to improve modeling and refine and implement the test equipment, test protocols and specifications related to the Simple Performance Tester. In addition to identified simple performance test equipment and procedures, research is needed to develop and refine test methods that can accurately predict pavement performance related to specific distress types. Therefore, subtasks of this research project would be development and refinement of:

1. Accelerated Permanent Deformation (Rutting) Tests
2. Accelerated Fatigue Tests

3. Accelerated Thermal Cracking / Thermal Fatigue Tests
4. Accelerated Aging Tests
5. Accelerated Moisture Susceptibility Tests

Scope / Objectives

Develop improved laboratory tests and constitutive models to better predict asphalt pavement performance.

Work Plan
Task 1. State-of-the-Practice

The state-of-the-practice of development of improved accelerated laboratory tests and constitutive models to better predict asphalt pavement performance will be reviewed. Reports from recent NCHRP projects will be included in the literature review. Existing, theoretical and innovative test methods will be identified that have promise.

Task 2. Laboratory Tests

Select the most promising accelerated performance testers and perform laboratory tests with the devices. Use mixtures from the ALF research, NCAT test track, Mn/ROAD and/or field accelerated load facilities to establish relationships among test results and pavement performance.

Task 3. Field Tests

Select the most promising test methods from Task 2 and perform a field evaluation of the equipment on three Hot Mix Asphalt projects. The equipment will be used for process control purposes on these projects.

Task 4-Implementation Manual

Prepare an implementation manual describing the operation of the equipment and the relationships among test parameters and performance. This information will be in a format suitable for inclusion in specifications and test method standards.

Program 4: MATERIALS CHARACTERIZATION & MIX DESIGN

Project 4.11 Improved Equipment and Test Procedures

Objective: Identify laboratory equipment and test procedures to increase automation and reduce variability

Background

In recent years, there has been a surge in the development of new laboratory equipment. There are many reasons for this trend but one reason is the recent need to develop performance-related, performance-based and accelerated performance testing equipment and methods. Another driving force behind the development of new and innovative test procedures is the desire to increase automation in testing procedures and to reduce variability.

A laboratory test procedure is ultimately expected to provide accurate and precise test results that are a true representation of the actual characteristic of the material being tested. An on-going issue for every test procedure is to decrease as much as possible the variability inherent to the test. Minimizing variability greatly increases usefulness of the test method. One way to improve variability is by removing the human element from test specimen preparation, conditioning and testing. A method to include machine automation into the testing process is the only way to reduce human error. Automation of testing equipment, sample preparation and/or test methods can not be practically accomplished at the same level with all tests. Therefore some test methods will benefit more than others from automation. Clearly, automation should not be adopted that reduces the accuracy, precision or variability of the test procedure.

Typically, the development of a new test procedure is accomplished in several phases. The first step, which may involve a significant amount of research, is the development of prototype equipment. In most cases, there is only a single piece of prototype equipment that is developed. The second step is the process of developing the test procedure is to perform ruggedness testing on the equipment, which involves testing and refining the equipment and test procedure. The second generation equipment and procedures are developed that includes improvements identified in the second phase. A very limited number of second generation equipment is generally produced. These second generation devices are distributed to various entities to perform further evaluation of the equipment and test procedure. Extensive evaluation of the improved test equipment and procedure is then accomplished. Finally, the production equipment is developed.

As many new and innovative lab test equipment and procedures are developed, there is a need to conduct research that can identify ways to increase the use of automation and decrease the variability of the test results. However, it is essential that equal emphasis be given to both automation and variability. Automation should not be adopted that will adversely affect the variability of test results.

Scope/Objectives

Identify laboratory equipment & test procedures to increase automation and reduce variability. Some tests and procedures have more potential to benefit from automation than others so the research will include an initial process to identify test and equipment with the most potential to benefit from research efforts.

Work Plan
Task 1. State-of-the-Practice

State-of-the-practice related to test equipment and procedures to improve automation and decrease variability.

Task 2. Test Methods / Equipment

Based on the literature review and an initial evaluation process, identify equipment and procedures that are the best candidates for automation and reduction of variability.

Task 3. Lab and Field Tests

Using the most promising items identified in Task 2, conduct lab and field testing to evaluate the applicability and practicality of the equipment and/or technology. Results of the testing will be reported and along with recommendations for adoption or further improvements in test procedures or equipment.

Task 4. Implementation Manual

To encourage implementation of promising technologies or equipment innovations, an implementation manual will be developed. The manual will include recommended practice and draft specifications for optimum use of the technologies and /or equipment. The manual will be published in a user-friendly document in a format that can be used in specifications and standard test methods.

Program 4: MATERIALS CHARACTERIZATION & MIX DESIGN

Project 4.12 Laboratory Workability Test

Objective: Develop a laboratory workability device and test method to assess the compactability of the material on the roadway

Introduction

Hot Mix Asphalt (HMA) pavements serve in a multitude of traffic and environmental conditions, demanding that the materials and design meet specific engineering properties. Pavement construction methods must recognize this need and provide the tools for the contractor to properly place the HMA in order to achieve this objective. The challenge for the contractor is to produce and place uniform mixtures that meet stringent specifications under congested conditions during both day and night paving. Thus, it is critical that the contractor be able to understand mixture workability and compaction properties to ensure that the mix can be placed satisfactorily.

Background

Historically, mixing and compaction temperatures for Hot Mix Asphalt mixtures have been determined based on the viscosity of the asphalt binder. This approach does not account for the interaction of the aggregate and any potential additives or the effect of that interaction on the workability of the mixture. A method to evaluate the workability and compactability of the HMA mixture in the laboratory needs to be developed. The test method should be capable of being used during the mixture design process as well as in the field laboratory during plant mix production.

Scope / Objectives

Develop equipment and test procedures for the laboratory evaluation of workability and compactability properties of HMA.

Work Plan

Task 1. State-of-the-Practice

State, federal and international practices relative to workability and compactability of HMA mixtures will be reviewed. Equipment form other industries will be included in the review. If possible, several devices with potential applicability will be identified. If none can be identified, a plan will be developed to produce a device.

Task 2. Lab Test

The device(s) that are identified in Task 1 will be evaluated in a laboratory study. The intent of this Task will be to identify a device which holds the greatest potential for success at a reasonable cost. Precision of the selected test method will be defined.

Task 3. Field Tests

The device selected in Task 2 will be used in field laboratories to predict workability and compactability with validation of the prediction based on workability and compactability being experienced in the field by the contractor. A workability evaluation form will be developed to direct the researcher or contractor through a series of standard procedures to measure workability. This effort will provide for a standard procedure the evaluator will use on each mix to make a non-subjective evaluation of workability / compactability. The form will include a scoring mechanism where the evaluator will assign a numerical "workability score" to the HMA mixture being evaluated.

Task 4. Implementation Manual

Guidelines will be developed for the use of the selected and validated device. An implementation manual will be prepared describing use of the device as a tool to assist the contractor in proper placement of HMA.

Program 4: MATERIALS CHARACTERIZATION & MIX DESIGN

Project 4.13 Laboratory Durability Test

Objective: Develop improved laboratory durability equipment and test method for mixture aging and moisture sensitivity correlated to performance

Introduction

Hot Mix Asphalt (HMA) pavements serve in a multitude of traffic and environmental conditions, demanding that the materials and design meet specific engineering properties. Laboratory test methods must recognize this need and provide the tools for the pavement engineer to properly evaluate the HMA mixture in the laboratory in order to achieve this objective. The challenge for the HMA mix design engineer is to measure the ability of the HMA mixture to perform well as an asphalt pavement. A suite of tests are needed to measure the full range of mix properties in the lab that relate to all aspects of pavement distress.

One of the key properties of a long-life pavement is durability. Pavement durability is largely a function of mixture aging characteristics and resistance to moisture damage. No well accepted performance test or tests currently exist to accurately predict durability. A research study is needed to develop an improved laboratory durability test that can be used during the mix design process and in the field lab during mix production.

Background

Temperature and the presence of air and moisture in the pavement during its service life contribute to long-term, irreversible changes in the properties of the asphalt binder and mixtures. Such changes are usually classified under the general term "aging." These changes can significantly impact the durability of the HMA.

During the development of Superpave, improved HMA mixture conditioning and aging equipment/procedures were developed. Conditioning procedures in the Superpave mix design method simulate short- and long-term field aging of asphalt binder and HMA. These procedures must be validated and possibly improved to ensure that they relate well with aging and moisture conditions that are encountered in an in-service pavement. New and innovative laboratory test procedures need to be developed to accurately predict pavement performance from a durability perspective. A method to evaluate the durability of the HMA mixture in the mix design and field laboratory needs to be developed.

This research study should use the findings of other related ongoing or completed studies that study HMA aging and moisture susceptibility testing equipment and procedures. NCHRP 09-23 "Environmental Effects in Pavement Mix and Structural Design Systems" is an active project with the objectives of (1) validate the latest version of Integrated Climatic Model (ICM) developed in NCHRP Project 1-37A; (2) develop practical guidelines for selecting ICM input data sets; (3) verify the estimated period or rate of aging simulated by the current conditioning procedures (AASHTO provisional practices PP1 and PP2) with data from Long Term Pavement Performance Specific Pavement Studies and other relevant field experiments; and (4) revise the current conditioning procedures as necessary. These procedures are also planned for use in conditioning specimens for the materials characterization test under development in Task F of NCHRP Project 9-19, "Superpave Support and Performance Models Management." A key question is whether these conditioning procedures will consistently simulate the effects of aging with sufficient accuracy for performance prediction.

Scope / Objectives

Develop an improved laboratory durability test for mixture aging and moisture sensitivity which is correlated to asphalt pavement performance.

Work Plan
Task 1. State-of-the-Practice

State, federal and international test equipment, procedures and practices relative to laboratory testing of durability of HMA mixtures will be reviewed. Innovative equipment/procedures and equipment from other industries will be included in the review. Several devices and procedures with potential applicability should be identified. A plan will be developed to produce a performance related laboratory durability test.

Task 2. Laboratory and Field Tests

The durability tests that are identified in Task 1 will be evaluated in a laboratory study. The intent of this task will be to identify one or possibly two test procedures holding the greatest promise for success at a reasonable cost and level of practicality. Precision of the selected test method(s) will be defined. Using procedures identified, develop a laboratory evaluation program for predicting durability of HMA mixtures. Durability predictions should be confirmed using accelerated testing techniques. The HMA mixtures will be produced and placed on in-service pavements. During production, field laboratories will perform the durability test and verify that the produced mixtures exhibit the desired durability properties. Then the performance of the pavement will be evaluated with validation of the prediction based on in-service performance and/or accelerated performance testing.

Task 3. Implementation Manual

Guidelines will be developed for the use of the selected and validated test procedures. Test method(s) and specification(s) will be developed in AASHTO format for possibly inclusion as provisional and eventually standard test methods and equipment.

Program 4: MATERIALS CHARACTERIZATION & MIX DESIGN

Project 4.14 Field versus Laboratory Volumetrics and Mechanical Properties

Objective: 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.

Introduction

Most federal and state DOTs and many local agencies have adopted Quality Control / Quality Assurance (QC/QA) programs for use on HMA pavement projects. The QC/QA approach requires the contractor and the agency to share testing responsibilities. Typically, the contractor conducts the majority of the testing for QC and acceptance purposes and the agency conducts fewer QA tests to verify the contractor's test results.

Many specifications require the measurement of volumetric properties by both the contractor and agency as part of the QC/QA testing program. Typically, the volumetric properties that are measured include air voids, voids in mineral aggregate (VMA) and percent voids filled with asphalt (VFA). Volumetric testing is performed on compacted samples of HMA material.

Many projects require testing of mechanical properties of the produced HMA, such as moisture susceptibility tests, rut tests and stability tests. These mechanical tests are conducted on compacted specimens of the HMA. The same sampling and compaction equipment and procedures that are used to generate the compacted specimens for volumetric testing are generally used to produce specimens for mechanical testing.

As with other QC/QA test results, the results of the volumetric testing conducted by the contractor and agency are compared statistically to verify the accuracy of the QC test results. This comparison helps the agency make a judgment about whether their QA test results are from the same population as the contractors test results. Efforts are made to ensure that the samples being tested for QC and QA purposes are similar. However, because different operators using different testing equipment are performing the tests, variability of the test results is inevitable. Therefore, it is essential that the variability of the test results based strictly on sampling, splitting, equipment and operator bias be kept to a minimum.

Another potential source of variability occurs if the location and makeup of the samples are not the same (laboratory produced versus field produced) and/or the location of compaction are not the same (laboratory compacted versus field compacted). Unfortunately, many specifications require the comparison of volumetric mixture properties from different locations and with different compaction methods. One of the major barriers to conducting a legitimate, defensible QC/QA program is quantifying the variability expected when comparing volumetric properties for different materials produced in different circumstances (laboratory blended/mixed versus plant blended/mixed), compacted in different locations, compacted with different equipment and in with potentially different test procedures.

Specifically, the three different scenarios for production of test samples for volumetric and mechanical properties on HMA pavement QC/QA projects are 1) laboratory mixed-laboratory-compacted specimens, 2) field mixed-laboratory compacted and 3) field mixed-field compacted specimens. It is essential to fully understand and quantify the variability between the expected results from each of these scenarios. Further, it is important to understand the causes of the differences in volumetric or mechanical results. A research project is needed to identify the differences and causes of the differences between volumetric and mechanical properties obtained on samples from each of the three scenarios discussed. Recommended practices for QC/QA programs that include testing of compacted HMA specimens are also needed.

Scope/Objectives

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.

Work Plan
Task 1. State-of-the-Practice

The state-of-the-practice of QC/QA testing programs that include testing of volumetric or mechanical testing of compacted HMA specimens will be performed. Any previous, current or proposed studies that address this issue will be identified.

Task 2. Lab and Field Tests

Based on the results of Task 1, an experiment on actual HMA projects using different HMA types will be conducted to determine variability and causes of variability between laboratory mixed-laboratory-compacted and field mixed-laboratory compacted, and field mixed-field compacted (QC/QA) volumetric and mechanical property test results. This experiment will include mixing and compacting of both lab and field applications. The data from the experiment will be analyzed and preliminary findings will be reported. The preliminary report will present recommended practice for comparison of volumetric and mechanical properties including variability numbers to be used in statistical comparison software.

Task 3. Validation of Results

The preliminary results from Task 2 will be further evaluated in a number of actual projects to validate the findings related to amount and causes of variability between volumetric and mechanical test results from testing of compacted specimens from various scenarios.

Task 4. Manual of Recommended Practice

A manual that summarizes the findings of the project will be developed. The manual will identify the variability and causes of variability between various mixing/compaction scenarios. It will also include recommended practice for development of a QC/QA specification where volumetric and mechanical properties are included.

Program 4: MATERIALS CHARACTERIZATION & MIX DESIGN

Project 4.15 Hot Mix Asphalt for Low Traffic Roadways

Objective: Develop HMA mixture design approach with specific applicability to low traffic pavements where durability may be a more important characteristic than structural capability.

Introduction

Hot Mix Asphalt (HMA) pavements serve in a multitude of traffic and environmental conditions, demanding that the materials and design meet specific engineering properties. While a great deal of research and study has gone into the evaluation of pavements for high traffic and heavy load conditions, little effort has gone into development of HMA mixtures with specific applicability to low traffic pavements.

Background

HMA mixtures are expected to perform over extended periods of time under a variety of traffic and environmental conditions. Over the years, the HMA Industry has developed specialized mixes to meet specific needs. An excellent example of a specialized mix is the open-graded friction course which is designed to minimize splash and spray from the pavement while decreasing noise levels.

For pavements constructed in high traffic conditions, the pavement designer must be concerned with both durability of the pavement as well as with structural capacity. However, for low traffic conditions, durability of the pavement may be more important than structural capabilities. The design approach, therefore, must be appropriately adjusted to reflect the needs for low traffic pavements. The approach must include optimization of materials selection with appropriate correlation to performance of the pavement.

Scope / Objectives

Develop HMA mixture design approach with specific applicability to low traffic pavements where durability may be a more important characteristic than structural capability.

Work Plan

Task 1. State-of-the-Practice

The state-of-the-practice relative to the optimization of the mix type for low traffic applications needs to be developed. Included in the evaluation should be criteria such as materials selection, mixture design, environmental, and the performance of the pavement. This information should be obtained from a combination of literature review, interviews and surveys of both private and public concerns in the HMA Industry.

Task 2. Case Studies

Identify sites in which low traffic mixes have been placed both successfully and unsuccessfully and analyze performance.

Task 3. Implementation Manual

Based on the state-of-the-practice, develop an implementation manual to assist the pavement engineer in the selection of mixtures for low traffic conditions. Engage the pavement community in the evaluation of the guidelines. Publish the implementation manual in a user-friendly format to ensure that the document will be routinely used to select the type of HMA mix for a specific project.

Program 4: MATERIALS CHARACTERIZATION & MIX DESIGN

Project 4.16 Validate and Refine Superpave Mix Design Procedure

Objective: Investigate, validate, and refine new Superpave mix design procedure from NCHRP 9-33

Introduction

NCHRP 9-33 "A Mix Design Manual for Hot Mix Asphalt" is an on-going research project to develop an improved mix design procedure for HMA which will make use of the best-available materials testing and performance-prediction technology to produce durable, distress-resistant mix designs tailored to the requirements of specific pavement layers. The objective of the project is to build on and improve on the existing Superpave system in the form of a manual of practice for use by engineers and technicians in the public and private sectors. The completion date on this research is late 2007.

It is anticipated that the mix design procedure will bring together the findings, equipment, test procedures and products from a number of different research efforts that have been conducted in the area of mix design, materials characterization and performance testing. The design procedure will probably include (1) the volumetric design method in AASHTO MP 2 and PP 28, (2) the simple performance test(s) (SPT) and equipment recommended by NCHRP Projects 9-19 and 9-29, (3) the hot mix asphalt (HMA) materials characterization tests and performance models developed in NCHRP Project 1-37A, (4) any improved method for measuring moisture susceptibility developed through NCHRP Projects 9-34 and 9-37, and (5) any other sound, applicable research products from, for example, NCHRP Projects 1-42, 9-9(1), 9-16, 9-17, 9-22, 9-25, 9-27, 9-31, 9-36, and 9-38. The mix design manual will follow the general format of Asphalt Institute Manual SP-02, "Superpave Mix Design," and be prepared in the form of an interactive CD-ROM.

After the Mix Design Manual is published, research will be needed to investigate, validate, and refine various components of the equipment, test procedures and products included in the mix design procedures.

Background

The current research effort will evaluate and build on research from the original Superpave performance-based mix design system. The mix design system described in the Strategic Highway Research Program (SHRP) Report SHRP-A-407, "The Superpave Mix Design Manual for New Construction and Overlays," provides three levels of design.

Level 1 is a volumetric design procedure based on gyratory compaction; it is implemented as AASHTO Specification MP 2, "Superpave Volumetric Mix Design," and Practice PP 28, "Superpave Volumetric Design for Hot Mix Asphalt."

The Level 2 and Level 3 design procedures are intended to test and refine Level 1 designs for situations with high traffic volume and load or other severe service factors. Performance characteristics of hot mix asphalt (HMA) specimens prepared in accordance with the Level 1 procedure are evaluated with the Superpave shear test device and the indirect tensile test device methods (AASHTO Provisional Methods TP7 and TP9, respectively). These test results are then input, along with traffic, climate, and structural data, to a suite of performance models for materials characterization, pavement response, and distress prediction, and the predicted distress levels are used to determine an optimum mix design. The Level 2 and 3 design procedures were not implemented because of serious limitations in the original SHRP performance models.

The NCHRP 9-33 project is studying the possibility of integrating HMA mix design with pavement structural design. NCHRP Project 1-37A, "Development of the 2002 Guide for the Design of New and Rehabilitated Pavement Structures: Phase II" proposes to utilize material properties measured with the dynamic modulus and indirect tensile tests. The measurement of mixture properties in an advanced mix design system along with the availability of the performance models from the proposed structural design method offers the opportunity to integrate HMA mix design and pavement structural design.

Scope/Objectives

Investigate, validate, and refine components of the new Superpave mix design procedure from NCHRP 9-33.

Work Plan
Task 1. State of the Practice

The research report and Mix Design Manual will be evaluated to identify components that need to be further investigated, validated and refined. Conduct a literature review on each of these components, which will include the state-of-the-practice performed as part of NCHRP 9-33 and other research projects in all related topics.

Task 2. Research Plan / Program

Based on the findings of Task 1, develop a research plan / program that lists the components of the research and manual that need further study. Problem statements will be produced for each of the proposed research projects identified. After approval of the research plan and problem statements, proceed with the research.

Task 3. Lab and Field Tests

Conduct appropriate laboratory testing to further investigate, validate and refine the lab testing done in the NCHRP 9-33 project. Based on the results of the lab testing, perform actual field projects where the mix design is accomplished using the procedures outlined in the Mix Design Manual. These field projects will include pavements that have several different levels of traffic volumes and loading in order to include all aspects of the mix design procedure in the trial sections. An evaluation of the practicality and effectiveness of the mix design procedures and link to structural design will be accomplished as part of the field projects.

Task 4. Findings and Recommended Practice Document

Develop a final report which includes documentation of findings and develop a recommended practice document. Provide a briefing of the findings to the project panel, AASHTO, the FHWA, and the industry through channels such as the NAPA Annual Meeting, World of Asphalt and other industry functions.

Program 4: MATERIALS CHARACTERIZATION & MIX DESIGN

Project 4.17 Mix Designs to Utilize Locally Available Materials

Objective: Develop mixture design approaches to ensure the performance of HMA using locally available materials.

Introduction

Hot Mix Asphalt (HMA) is a blend of asphalt binder and aggregate stockpiles of various sizes. In order for the HMA to perform adequately as an asphalt pavement material, the proper blend of these component materials must be determined through a laboratory mix design procedure. If poorly designed, the mixture may not exhibit the characteristics and properties (like stability, durability, flexibility, etc) that are required for good performance of the pavement.

Characteristics of the component materials are measured as part of the mix design process. The owner's specification establishes minimum requirements for given materials properties that vary based on particular roadway and traffic conditions. For instance, a specific grade of asphalt binder will be specified on a given project. There will also be criteria established for the component aggregate materials, which can include criteria for toughness, shape, polish resistance, gradation, etc. These specifications for a specific binder grade and minimum aggregate properties are necessary to ensure that the blend of component materials will result in a HMA mixture which will perform well as a pavement material.

The economics of HMA paving mixtures is largely dependent on the cost of the component materials (asphalt binder and aggregate) that are used, although other costs such as equipment, hauling and fuel costs can also contribute. If lower cost component materials can be utilized, a more economical HMA mixture can be produced. Owners have only a limited amount of funding to accomplish their paving needs; therefore, mix designers are encouraged to cut costs and produce a less expensive HMA mix that still exhibits good performance for the intended application.

Since the length of haul to transport component materials to the HMA production site has a major impact on the cost of those materials, locally available materials tend to be far less expensive than materials that must be hauled for considerable distances. Therefore, research is needed to allow the use of locally available materials and to develop mixture design approaches to ensure the performance of HMA comprised of these materials.

Background

In recent years, there has been greater emphasis on mix design specifications that require the use of "higher quality" aggregates and asphalt binders, HMA producers are being forced to transport these component materials from outside of the local area more and more. While these improved mix design methods have generally resulted in better performance of HMA pavements (especially on high volume roadways), they have also driven up the cost of the HMA. In many cases, locally available (and therefore lower cost) materials are available but can not be utilized because they do not meet the minimum requirements specified by the owner. Therefore, it is prudent to carefully evaluate these restrictions on the use of locally available materials to ensure that the constraints are appropriate for a specific application.

It has been shown that lower quality, locally available materials can be used successfully to produce HMA mixtures that perform well especially on lower volume roadways, resulting in significant savings to the producer and the owner. Using locally available materials has environmental advantages, as high quality materials are conserved and reduction in hauling distance results in significant conservation of fuel.

The use of Performance Graded (PG) binders is now common place around the country at national, state and local levels. The use of the PG binder grading system has provided agencies and mix designers with many more binder grade options (both neat and modified binders) and therefore, the ability to "customize" the binder grade depending on climate, loading and traffic volume/loading. In many cases, agencies have elected to limit the number of binder grades that can be used in a given area. Unfortunately, this may preclude the use of a binder grade that is locally available but could perform well when used in a given situation.

New mix design methods tend to encourage the use coarse and fine aggregates that are crushed, cubical, clean and highly abrasion-resistant. Many of the mix designs being produced are coarse graded, which requires a higher proportion of coarse aggregate and a lower proportion of fine aggregates. These coarse graded mixtures have resulted in an excess of fine crushed aggregate at many locations around the country. The requirements for processed aggregates has the affect of severely limiting the use of natural, unprocessed gravel and sands that may be rounded and/or contain relatively high percentages of fine aggregate. Mix designers are becoming increasingly aware of the availability of the local surplus of crushed fine aggregates and the unprocessed, natural gravel and sand aggregates. These locally available materials are generally far more economical than highly processed aggregate that must be hauled for considerable distances to the production plants. For many applications, the use of locally available materials will produce a mix with excellent performance.

Due to all of these factors, considerable savings in pavement funding could be realized if locally available materials can be better utilized in the design of HMA pavements. In order to accomplish this, mix design procedures that are geared specifically for the use of locally available materials must be developed and refined.

A limited amount of past research has been geared toward mix design methods using locally available or less expensive aggregate materials. Much of this research has explored the effectiveness and feasibility of using modified binders in conjunction with lower quality aggregates or finer-than-normal aggregate gradations. Some success has been achieved in producing HMA mixtures using these lower-cost materials. Satisfactory characteristics in the lab and good performance on the roadway have been obtained. The major drawback to this approach is modified binders are costly so optimum cost savings are not realized with this approach.

Scope/Objectives

Develop new or modified mixture design approaches to ensure the performance of HMA comprised of locally available materials.

Work Plan
Task 1. State-of-the-Practice

The state-of-the-practice of development of improved mix design methods will be reviewed and evaluated for applicability to mix designs using locally available materials. Reports from recent NCHRP projects involving mix design and materials characterization will be included in the literature review. Existing, theoretical and innovative test methods will be identified that have promise. A study will be performed to identify and catalog the various types of locally-available aggregates and/or less expensive aggregates that have the most potential for use in successful mix designs.

Task 2. Laboratory Tests

Select the most promising mix design methods and perform laboratory tests using a variety of lesser quality aggregates and less-than optimum asphalt binders, that are representative of locally available materials. Aggregates will include unprocessed and partially processed natural gravels and sands, as well as crushed fines in fine graded mixtures. Identify three mix designs using different types of locally available or less expensive materials and/or mix design methods that perform well in laboratory studies that will be used in field projects.

Task 3. Field Tests

Select the most promising test methods from Task 2 and perform a field evaluation of the HMA mixes on three Hot Mix Asphalt projects using the mix designs identified in Task 2. The HMA pavement will then be evaluated for performance, possibly using accelerated performance testing equipment.

Task 4. Implementation Manual

Prepare an implementation manual describing the mix design methods and materials that were evaluated in the study. The report will include findings and recommendations from the study, as well as standard test procedures and criteria. A step-by-step evaluation protocol for local materials will be in the final report. This information will be in a format suitable for inclusion in specifications and test method standards.

Program 4: MATERIALS CHARACTERIZATION & MIX DESIGN

Project 4.18 Resource Availability Study for Binders and Aggregates

Objective: Forecast national supply and demand for asphalt binders and aggregates and develop approach for resource analysis at the regional and local level.

Introduction

The two major ingredients of Hot Mix Asphalt (HMA) are asphalt binders and aggregates. The availability and cost of these two materials are very important factors in the continued economical use of HMA throughout the United States. Uncertainty about the supply and demand of component materials to build HMA pavements has become a major concern among paving contractors and agencies. A great deal of effort is expended by individual private and public organizations to estimate the supply and demand of these materials both on a national basis and in any given region of the country.

Asphalt binders are petroleum-based materials; the availability and cost of binders is tied directly to the availability and cost of crude oil, much of which is imported from outside of the United States. In recent years, the quantity of available crude oils has remained adequate to supply the asphalt binder needs of asphalt pavement producers around the country. However, the cost of a barrel of crude oil has risen dramatically, which has translated into a corresponding increase in asphalt binder prices. Despite the recent spike in price, demand for binder materials for use in HMA pavements has remained high.

Aggregate availability and cost have also become an issue in many places. This is especially true in situations where the uses of "high quality" aggregates are specified in all or a significant percentage of the HMA mixtures being used by an agency. The desired aggregates may include aggregates that have certain desirable characteristics, such as abrasion resistance, cubical shape, polish resistance or other properties. Problems with availability and cost can result when the desired aggregate is not locally available and must be hauled from a long distance or if the supply is limited due to other factors.

A research effort is needed to investigate and report on the best approach to establish a program to forecast national supply and demand for asphalt binders and aggregates and also to develop an approach for resource analysis at the regional and local level.

Background

The forecasts should be focused specifically on binders and aggregates used as component materials in HMA. In addition, the forecasts should be developed for a number of different scopes including national, regional, state and local. At a minimum, the forecasts should be made on an annual basis.

There are a number of trade association reports that summarize usage of HMA, asphalt binders and aggregates that are generated annually at state and national levels. In addition, there are both public and private organizations that track the price of various materials, including asphalt binder and aggregate. From these summaries, it is possible to estimate supply and demand based on both recent end-use spending and historical trends in aggregates and binder usage. However, since funding levels and materials usage can change dramatically from one year to the next, an estimate made strictly on the basis of past history can be flawed. Therefore, a more complex analysis approach is needed that takes into account up-to-date information about funding levels, analysis of how that funding will be used in terms of HMA usage and trends in materials being specified at the state and local level. Publications that focus on broad usage of these materials in all areas of construction are not especially useful since the materials used in HMA pavement applications are not specifically identified. For example, the United States Geological Survey publishes an annual "Minerals Yearbook" that estimates total production, consumption and average price of both crushed stone and construction sand and gravel.

National, regional, state and local forecasting is necessary to provide information that will be especially useful to a variety of users of the information. While forecasting at a national and regional level has value for seeing overall trends, it is likely that understanding trends and availability at state and local levels will be most valuable to individual contractors and state and local governments. This is because the amount of HMA paving and thus the demand for component materials can vary considerably from one state or locality to another. Much of the demand for paving materials is driven by federal and state funding for highway and street construction and maintenance. Highways are funded by federal, state, and local governments from fuel and motor vehicle taxes and general appropriations. In 2005, the U.S. Census Bureau estimated funding for new highway construction at $67 billion and for highway maintenance at $38 billion. Demand for HMA paving is also driven by other factors, including the amount of development in the private sector for a given location.

At this time, there are no formal, comprehensive program to provide national, regional, state and local forecasts for supply and demand of the HMA component materials of binders and aggregates. If this type of program could be formalized and conducted on a routine basis, the forecasting generated would offer a valuable service to contractors and agencies. Developing these forecasts could eliminate or reduce the considerable amount of time and effort expended by individual organizations to generate this information.

Scope / Objectives

Develop procedures and a mechanism to forecast national supply and demand for asphalt binders and aggregates. An approach for resource analysis at the regional and local level will also be developed.

Work Plan
Task 1. Public-Private Technical Working Group

A TWG that is composed representatives from all elements of both private and public agencies will be organized to oversee and guide the research effort. This group will establish a framework and timeline for the research and participate in the implementation of any forecasting programs developed through the project. The first task of the TWG will be write clear goals and objectives of the subsequent research efforts.

Task 2. State-of-the-Practice

The state-of-the-practice for forecasting will be conducted with an emphasis on procedures that are applicable to materials resources. Existing concepts and innovative methods and approaches will be identified that can offer a template for effective forecasting models. A broad spectrum of organizations representing the entire industry will be canvassed to evaluate resources that may assist in forecasting. These entities will also be interviewed to determine their specific needs for forecasted supply and demand. Current publications that summarize or estimate supply/production, usage and price will be evaluated and cataloged as potential sources of input into the forecasting database.

Task 3. Trial Forecasting Program

Based on the findings of Task 2, identify a number of trial approaches and procedures that will possibly be effective in forecasting supply and demand of asphalt binder materials and aggregates. The procedure will be used to make initial forecasts for testing and validation purposes. The level of effort needed to gather input data, the validity of the data and the credibility of the produced forecasts will then be evaluated. Recommended improvements will be made in a report form.

Task 4. Findings and Recommendations

Based on the findings of Task 3, summarize findings and make recommendations concerning the timeframe for reporting forecasts, data collection, the forecasting methodology that is most appropriate. Also make recommendations concerning the type of organization(s) that should be charged with doing the forecasting (trade associations, public agencies, consulting firms, etc.) and also recommendations about whether separate forecasting should be done for binders and aggregate or whether a single organization should conduct the forecasting for both materials.

Task 5. Implementation

Based on the previous steps, the TWG will implement the forecasting program by writing clear guidelines, procedures and expectation into a proposal to select a "contractor" to perform the forecasting. Under the oversight of the TWG, the contractor will produce initial forecasts for both asphalt binder and component aggregate materials on a national level and also on selected regional, state and local levels. The usefulness and accuracy of the initial forecast will be evaluated by the TWG. If necessary, revisions will be made to the forecasting procedures and a mechanism will be created to require the forecasting at specified time periods.

Program Five: CONSTRUCTION PRACTICES & QUALITY MANAGEMENT SYSTEMS

Projects in Program Five

Project 5.01	**Energy Efficiency**
Project 5.02	**Recycling Technologies**
Project 5.03	**Improved Construction Equipment and Procedures**
Project 5.04	**Real-Time Process Control for Asphalt Plant Operations**
Project 5.05	**Real-Time Process Control for Laydown and Compaction Operations**
Project 5.06	**Non-Destructive Evaluation for Process Control and QC/QA**
Project 5.07	**Longitudinal Joints**
Project 5.08	**Development of Fundamental Model for Field Compaction**
Project 5.09	**Improved Risk Assessment of QC/QA Statistical Specifications**
Project 5.10	**Improved Techniques for Obtaining and Measuring HMA Smoothness**
Project 5.11	**Improved Work Zone Safety**
Project 5.12	**Improved Asphalt Binder Content Measurement**
Project 5.13	**Segregation Control**
Project 5.14	**In-Place Recycling**
Project 5.15	**Improved Quality of Night Construction**

Program Five
Construction Practices & Quality Management Systems

Introduction

The term construction practices can involve all of the steps in production, hauling, placing and compaction of HMA pavement materials. The need for improved HMA construction practices has never been greater. The specific needs are for increased production capabilities, improved quality of HMA and extended pavement life. A related need is reduction in traffic congestion, which may result from reduced maintenance and rehabilitation activities. In addition, developing technologies may reduce the time needed to perform maintenance and rehabilitation activities under traffic. Safety, night-time construction, risk assessment and risk management are additional research need topics.

The long-term performance of a HMA pavement is dependent upon many factors. Three of the most important factors controlling performance are adequacy of the structural design, appropriate mixture design processes, and quality of the construction practices. Construction quality is largely controlled by materials variability, effective use of Quality Control or process control tests to measure variability in "real" time (QC/QA tests) and construction workmanship. Project personnel must have the tools to produce a quality pavement that meets or exceeds the specification requirements and that provides long-term performance of the roadway.

Construction practices that improve quality, increase pavement life and reduce lane occupancy time will significantly reduce user and non-user costs and reduce the frequency and cost of rehabilitation and maintenance operations. Reduced pavement life increases rehabilitation and maintenance costs but user costs are significantly increases user costs. User costs are becoming more significant as a larger percentage of our urban roadways are at capacity, and a larger percentage is at or near capacity over a longer period of the day. Congestion caused by rehabilitation and maintenance operations therefore creates more traffic delays and user costs are significantly increased.

The development and implementation of improved quality management systems (QMS) can be effective in improving pavement quality. There are many different types of QMS procedures and technologies that can be used, including traditional approaches such as Quality Control/ Quality Assurance (QC/QA) programs and other emerging technologies, such as Intelligent Construction Systems (ICS) technologies. Research is needed to improve existing QMS procedures and to identify and develop innovative technologies and procedures. Specific areas of immediate interest in QMS are real time process control protocols, reduction of test procedure variability, understanding changes in volumetric properties, and processes that allow reduced lane occupancy time.

Background

Over the last 20 years, the construction industry has developed new tools that allow for more efficient pavement rehabilitation. Cold milling machines and pavement recycling techniques are examples. More developments are needed to increase energy efficiency and to address specific concerns that have been identified as areas where improvements are necessary. For instance, improvements in recycling technology, pavement joint construction and smoothness are important focus areas.

Night construction and total road closures during road construction have used in urban areas to reduce traffic congestion. These type of construction approaches will be used more in the future to increase production and to improve quality. Since traffic control and lane occupancy time are an integral element of rehabilitation and maintenance operations, new and improved equipment, technologies and techniques are required.

Construction Quality Control (process control) and Quality Assurance sampling and testing have become integral parts of construction. However, with a limited number of exceptions, few developments in QC/QA methods have accompanied the improvements made in construction equipment and construction production in recent years. New and/or improved tests need to be developed to satisfy the desire to provide non-destructive evaluation technologies, higher frequency testing and real time measurements for Quality Control and Quality Assurance purposes. Improved real time testing and data collection equipment are in developmental stages are now available and can dramatically improve the information needed to effectively control the construction process. This effort needs to be aggressively processed to facilitate improved construction process control.

The desire to provide HMA of uniform properties on a project is based on an assumed relationship between performance and uniformity. The relationship between performance and variability is not well established and needs further definition. For example, at what level should variability be controlled to obtain the most cost effective balance between performance and uniformity?

In summary, research is needed in a wide variety of areas related to construction practices and quality management systems.

Scope/Objectives

The objective of this program is to develop construction practices and quality management systems to improve the quality of HMA to extend pavement life through improved process control during construction.

Program 5: CONSTRUCTION PRACTICES & QUALITY MANAGEMENT SYSTEMS

Project 5.01 Energy Efficiency

Objective: Identify and develop equipment, innovations/ improvements that will result in improved energy efficiency

Introduction

The production, transport and laydown of Hot Mix Asphalt (HMA) consumes significant amount of energy. The energy consumption comes in the form of fuel for trucks, burner fuel and electricity in production plants and fuel for pavers, rollers and support equipment during placement and compaction. In order to reduce costs, conserve energy sources and be good stewards of the environment, promoting energy efficiency is vital. Therefore, it is important to both the HMA industry and user agencies to identify, study and implement methods to reduce the amount of energy that is used in all phases of HMA production, hauling and laydown. Improving energy efficiency at the plant is both an environmental and an economic issue.

Background

The phase of the production and placement procedures for HMA that has the most energy demand is undoubtedly the production process. Production actually has a number of phases including hauling and storage of component materials (aggregate and binder), blending of aggregate, heating/drying the aggregate, blending the aggregate and binder in the proper proportions and storage of the produced HMA. Improvements are needed in all of these phases to address energy usage and efficiency.

Rated production capabilities of modern HMA plants can be in excess of 500 tons per hour. Traditional HMA materials are typically produced at elevated temperatures (280° to 310° F). Even higher temperatures are often associated with the use of polymer modified binders. Heating such a large mass of material to these high temperatures requires a significantly amount of burner fuel. The quantity of burner fuel consumed is dependent on the plant type and the fuel efficiency of the plant. Many opportunities exist to address energy efficiency at the plant production, including improving fuel efficiency and the types of fuels that can be used. Improved combustion systems that is more fuel efficient, quieter and cleaner are now becoming available. Energy efficiency can be improved by identifying less expensive or more efficient burner fuel sources.

Reducing HMA production temperatures would result in substantial burner fuel savings. In addition, reduced production and paving temperatures would have beneficial environmental effects. Reduced temperatures could also have a reduce emissions and odors from plants, thereby further improving environmental benefits. Cooler temperatures would also improve the working conditions at the paving site.

There is also substantial energy usage in other phases of HMA production and laydown. This energy consumption is mainly in diesel fuel and gasoline used by haul trucks, pavers and rollers, along with other miscellaneous equipment used in typical hauling and HMA laydown operations. Energy efficiency can be improved by making these operations as efficient as possible as far as number of vehicle used and by improving fuel efficiency of the units.

Another approach to increase energy efficiency is through the creative use of component materials. The HMA industry has been studying ways to increase the amount of RAP that can be used to replace a high percentage of new (or virgin) aggregate and binder used in the mix for the past 30 years. By re-using recovered aggregate and asphalt binder, virgin materials are conserved and the energy needed to produce and haul virgin materials are reduced.

In summary, improvements in energy efficiency will have many benefits including lower production costs, conservation of resources and positive effects on the environment. Research is needed to explore ways to improve energy efficiency of HMA production and laydown operations.

Scope / Objectives

Identify and develop equipment, innovative HMA mixtures and production plant improvements that will result in improved energy efficiency without adversely impacting quality.

Work Plan
Task 1. State-of-the-Practice

Review the current state-of-the-practice of HMA and component materials selection, mix design and plant production to identify ways to improve energy efficiency. Literature review should include identification of practical, theoretical and proposed methods to improve energy efficiency in all phases of HMA production and laydown.

Task 2. Laboratory Tests

Select the most promising equipment and mix technologies and perform laboratory testing to evaluate their effectiveness.

Task 3. Field Tests

Select the most promising technologies from Task 2 and perform a field evaluation of the technology. The production plant will produce the mixture, the amount of energy that is saved will be estimated and the constructability and performance of the HMA will be evaluated.

Task 4. Implementation Manual

Prepare an implementation manual describing the equipment, fuel alternatives or material innovations that resulted in energy savings. This information will be in a format suitable for inclusion in specifications and test method standards.

Program 5: CONSTRUCTION PRACTICES & QUALITY MANAGEMENT SYSTEMS

Project 5.02 Recycling Technologies

Objective: Improve equipment and best practices to facilitate the incorporation of reclaimed asphalt pavement (RAP) materials into recycled HMA.

Introduction

The amount of recycling in the USA using reclaimed asphalt pavement has increased during the last 20 years and is now standard procedure in most states. There have been a number of changes in the last few years that affect some of the procedures used to design and construct Hot Mix Asphalt (HMA) mixtures using RAP materials. Research is needed to improve guidance for design and construction of recycled mixtures in light of changes in HMA mix design procedures and a desire to increase the percentages of RAP that are being incorporated in HMA by many agencies.

It is anticipated that the use of RAP will take on increased importance, as asphalt binder prices continue to increase and aggregate sources become more difficult to acquire. It is conceivable that processes could be developed that allow even higher percentages than the current maximum of 50 percent RAP. It is a good bet that the future will bring an increased use of RAP materials in HMA will continue as the price of asphalt and aggregate increase.

Background

The HMA Industry has for many years used RAP as a component in HMA production. RAP is now routinely used in HMA base, intermediate and surface mixes in many states. Extensive research has been done in the past related to the use of RAP. However, most of that work was done in the 1970s and early 1980s. Given the changes in plant equipment, mix design approaches, use of modifiers/additives, use of non-dense graded mixes and the ongoing difficulty in recovering recycled asphalt binder, a thorough review of the effect of using higher percentages of RAP materials on the performance of HMA pavements needs to be conducted. The research should include an evaluation of materials characterization, mix design, processing, production and construction procedures to identify needed improvements that could improve the ultimate quality of HMA mixtures using increased percentages of RAP.

Scope / Objectives

Improve equipment and best practices to facilitate the incorporation of reclaimed asphalt pavement (RAP) materials into HMA. Evaluate current materials characterization, mix design, processing, production and construction procedures to identify needed improvements with the goal of improving the quality of HMA mixtures using increased percentages of RAP.

Work Plan
Task 1. State-of-the-Practice

The state-of-the-practice relative to the design and construction of HMA pavements using RAP materials needs to be established. This review should include the efforts completed at National Center for Asphalt Technology, National Cooperative Highway Research Program and the Federal Highway Administration.

Task 2. RAP Issues

The following difficulties with the use of RAP need to be evaluated: understanding the appropriate Superpave binder to use for a RAP mix; guidelines for processing of RAP at various RAP percentages; use of RAP containing modifiers and/or additives; procedures for handling RAP fines; and improving production and construction techniques.

Task 3. Laboratory and Field Tests

In order to validate the revised procedures and methods identified in previous tasks, laboratory testing and field projects should be conducted to validate their effectiveness. Lessons learned in this testing should be used to modify the recommendations that come out of this study.

Task 4. Implementation Manual

Prepare recommendations for the use of reclaimed/reprocessed materials in HMA in proper format for submission to AASHTO for approval.

Program 5: CONSTRUCTION PRACTICES & QUALITY MANAGEMENT SYSTEMS

Project 5.03 Improved Construction Equipment & Procedures

Objective: Identify innovative laydown/compaction equipment and procedures that will result in improved quality / efficiency in paving operations.

Introduction

The final step in the process of design, production and construction of HMA pavements is the laydown and compaction process. Equipment and methodology used in the placement operation can have a major impact on the quality and serviceability of the pavement. Critical performance characteristics such as pavement smoothness, uniformity and density are direct results of the laydown and compaction operation.

Requirements expectations for improved HMA laydown and compaction operations will continue to increase over the coming years. There are many factors that drive the increased expectations including new contracting practices, the rapid development of innovative equipment and a market demand for longer lasting, more durable, smoother, quieter pavements. Therefore, research is needed to identify innovative laydown / compaction equipment and procedures that will result in improved quality and more efficient paving operations.

Background

Over the years, there has been a constant improvement in material handling equipment, pavers and compaction rollers used on paving projects. These improvements have increased production, enhanced efficiency and improved pavement quality. When improved equipment is used in conjunction with best construction practices, a very high quality HMA pavement can result. There are also improvements and innovations in QC/QA testing equipment designed to measure constructed pavement characteristics that can improve accuracy and speed of testing and that can offer real-time feedback during the laydown and compaction operation.

For field operations, some examples of equipment that will see steady increase in use include systems to allow data sharing from the design to site operations, control systems for positioning the paver and roller, compaction control systems that monitor and adjust roller operations to meet compaction requirements and documentation systems to verify compaction density in real time. All of these systems are currently under development and will be introduced into HMA production operations in the next decade.

Some of the most recent innovations in placement and testing equipment is the in the area of Intelligent Construction Systems (ICS). ICS is any of a number of emerging technologies that provides performance related, real time information to the contractor and to the acceptance agency. Some examples of ICS technologies that are in various stages of development and implementation are:

- intelligent compaction rollers,
- pavers with intelligent features
- GPS Nuclear Gauges for quality assurance
- IR Camera to detect segregation

- automated truck sampling systems
- Global IRI (across the mat smoothness)

There are also other ICS innovations that we will evolve in the years to come. The ultimate goal of the ICS concept is that contractors with have real time, self adjusting, equipment for process control that maximizes performance. Benefits to ICS innovations are improved construction operations; quicker adjustments to changing materials, soft foundations, and weather, time saving from having to do rework and reduced on-site inspection. In addition, ICS technologies on pavers and rollers are designed to provide 100 percent inspection of construction projects by using sophisticated locating and documentation systems.

Scope / Objectives

Identify innovative laydown/compaction equipment and procedures that will result in improved quality and more efficient paving operations.

Work Plan
Task 1. State-of-the-Practice

The state-of-the-practice related to improved laydown and compaction operations and technology will be evaluated. Included in the evaluation will be innovations in ICS technologies for pavers, rollers and testing equipment and methodology.

Task 2. Lab and Field Tests

Using the most promising items identified in Task 1, conduct lab and field testing to evaluate the applicability and practicality of implementation of the equipment and/or technology. Results of the testing will be reported and along with recommendations for adoption or improvements that should be made before adoption of the innovations.

Task 3. Implementation Manual

To encourage implementation of promising technologies or equipment innovations, an implementation manual will be developed. The manual will include recommended practice and draft specifications for optimum use of the technologies and /or equipment. The manual will be published in a user-friendly document in a format that can be used in specifications and standard test methods.

Program 5: CONSTRUCTION PRACTICES & QUALITY MANAGEMENT SYSTEMS

Project 5.04 Real-Time Process Control for Asphalt Plant Operations

Objective: Develop real-time test methods and processes for QC and QA purposes at HMA production plants

Introduction

Modern day Hot Mix Asphalt (HMA) production facilities are capable of producing in excess of 500 tons per hour. These large production facilities must have well controlled ingredients (asphalt binder, aggregates, modifiers, additives, etc.) and good quality control systems if they are to produce uniform HMA quality. The determination of the uniformity and quality of the produced HMA is based largely on technology that is over a half century old. The test methods associated with this technology are slow and personnel/equipment intensive. Improved methods need to be developed that can be performed quickly are both precise and accurate and can be utilized quickly to adjust production operations. The results from these tests need to be used to adjust plant operations to produce quality and uniform products.

Background

The current method typically used to ensure that a quality HMA mixture is being produced involves the determination of: 1) the asphalt binder content and aggregate gradation (to determine that the mixture meets the JMF) 2) the volumetrics of the compacted plant-produced mixture 3) the temperature of the HMA and 4) the moisture content in the HMA. Ideally, these determinations would be made on a frequent basis (within minutes), and the results of the tests would be used to quickly adjust the HMA production. Current test methods of determining the above properties require a significant time commitment. Rapid, near "real time" test methods need to be developed for these mixture properties. The development and incorporation of automated processes during plant production is an opportunity to move closer to real-time control.

The development of test methods and processes that provide real time data for plant control also offer the opportunity for using these same tests for quality assurance proposes. Statistically-based quality assurance programs will be improved by utilizing larger data sets, which should reduce the buyer and seller risks.

Scope / Objectives

Develop real-time test methods and processes for process control and acceptance testing at HMA production plants including control of asphalt binder content, aggregate gradation, mixture volumetrics, temperature and moisture content.

Work Plan

Task 1. State-of-the-Practice

A state-of-the-practice document needs to be developed relative to rapid measurement techniques for determination of asphalt binder content, aggregate gradation, mixture volumetrics, mixture temperature and mixture moisture content. The information should be obtained from literature relative to pavements as well as food processing, mining industry and other material handling intensive industries.

Task 2. Laboratory Tests

Select the most promising test methods from the state-of-the-practice review for inclusion in laboratory testing. New test methods will likely be developed in this task. The precision and bias of these test methods as well as needed equipment, operator requirements, etc. will be defined through controlled laboratory experiments.

Task 3. Field Tests

Conduct field test program with the most promising tests identified in Task 2 to evaluate the practical application of the tests. Sampling and testing techniques, precision and bias of the test methods, operator training needs and comparisons with conventional testing techniques will be further defined.

Task 4. Implementation Manual

An implementation manual containing the test methods, operator requirements, precision, bias and equipment availability will be prepared including the use of the test results in modern specifications. The format of the information will be suitable for inclusion in specifications and test method standards.

Program 5: CONSTRUCTION PRACTICES & QUALITY MANAGEMENT SYSTEMS

Project 5.05 Real-Time Process Control for Laydown and Compaction

Objective: Develop real-time process control technologies for HMA laydown and compaction operations

Introduction

Modern day Hot Mix Asphalt (HMA) production, laydown and compaction equipment is capable of producing and placing several miles of pavement per day. The laydown / compaction operation including control of the density (in-place air voids), thickness and smoothness are critical if a long-lasting pavement is to be obtained.

Current test methods for determining in-place air voids, thickness and smoothness during the construction are both time-consuming or lack good precision and/or accuracy. Most current test methods are not "real time". Because of the delay in obtaining the test results, it is not practical to use the data to control the laydown and compaction operation. Improvement in techniques for measuring or estimating density, thickness and smoothness in a short period of time, and continuously if possible, are needed so that tests can be performed and the test results utilized quickly to adjust the laydown operation and compaction operations for optimum quality.

Background

Density of the in-place HMA is a critical performance criterion. A non-destructive method for density measurement has been a goal for contractors for quite some time. Nuclear density gauges have been used for over two decades. These gauges can have precision and bias problems, are subject to intense regulatory scrutiny and the results are obtained after the compaction operation is complete. Therefore, the results are not often used by compactor operators to control roller patterns to achieve the desired air void content level. Accurate thickness measurements are not available. Methods are needed that can quickly and accurately measure mat thickness during laydown and compaction. This information needs to be in a form that the laydown machine operator can use to adjust the process.

Equipment is currently available to measure pavement smoothness. The equipment is typically used on the pavement after the mat has been placed and cooled. In some cases, the smoothness testing is performed as much as several days after placement. Equipment needs to be developed that will measure smoothness during construction. In addition, methods need to be developed which will allow laydown and compaction operations to be adjusted based on these data.

For field operations, innovations in pavers and compaction equipment that may see steady increase in use include Intelligent Construction Systems (ICS) that will include documentation systems for highly accurate positioning and control of the paver and roller, compaction control systems that monitor and adjust roller operations to meet compaction requirements and monitoring systems to verify compaction density in real time. All of these systems are currently in various stages of development and require research efforts to bring them into mainstream production operations.

Scope / Objectives

Develop "real-time" test methods for process control during laydown and compaction operations including mat temperature, density, thickness and smoothness.

Work Plan
Task 1. State-of-the-Practice

A state-of-the-practice document needs to be developed relative to rapid measurement techniques for determination of HMA density, lift thickness and pavement smoothness. The information should be obtained from not only pavements literature but also from related industries. Nuclear and electro-magnetic technologies should be included.

Task 2. Laboratory Tests

Select the most promising test methods from the state-of-the-practice review for inclusion in a laboratory testing program. New test methods will likely be developed in this task. The precision, accuracy and ruggedness of these test methods as well as needed equipment and personnel requirements will be defined through controlled laboratory experiments. Standard test methods will be developed for the most promising techniques.

Task 3. Field Tests

Conduct a field test program with the most promising tests identified in Task 2 to evaluate the practical application of the tests. Sampling and testing techniques, precision and accuracy of the test methods, operator training needs and comparisons with conventional testing techniques will be further defined and evaluated.

Task 4. Implementation Manual

An implementation manual containing the test methods, operator requirements, precision, accuracy and equipment availability will be prepared. The use of the test results in typical specifications will also be included. The format of the information will be suitable for inclusion in specifications and test method standards.

Program 5: CONSTRUCTION PRACTICES & QUALITY MANAGEMENT SYSTEMS

Project 5.06 Non-Destructive Evaluation for Process Control and QC/QA

Objective: Identify and conduct research on NDE Process Control and QC/QA tools

Introduction

Test methods used for process control testing during production as well as in-place quality control and acceptance of individual flexible pavement layers and of new and rehabilitated flexible pavement systems have changed little in past decades. Process control procedures are based primarily on aggregate stockpile testing using small samples that are tested for aggregate gradation and other properties in the lab. Quality control and acceptance procedures during placement operations typically rely on nuclear density measurements or the results of testing conducted on pavement cores. Roughness measurements are often used to confirm that the newly constructed pavement has an adequate initial smoothness.

There are specific issues related to nondestructive, in-situ density measurements of HMA materials. In–place density test results are utilized in most quality control/quality assurance specification for determination of mat and joint density/air voids and their associated pay factors. The most commonly accepted NDT test procedure for measuring in-place density is the nuclear density test. Testing using nuclear gauges has some perceived shortcomings including concerns with testing accuracy/variability and time-consuming calibration procedures as well as the need for extensive safety and regulatory oversight. Some non-nuclear, non-destructive density tests are being refined and implemented by agencies which eliminate some of the safety and regulatory concerns. However, some of the accuracy/variability concerns and the need for calibration remain for these non-nuclear devices. Therefore, research to identify non-destructive density testing procedures is needed.

The new Mechanistic-Empirical Pavement Design Guide will use pavement layer stiffness as a key material property. This will lead to increased measurement of layer moduli by owner agencies, which is presently not a typical component of the acceptance parameters of a completed project. Test equipment and methods to measure HMA material modulus in the lab and on the in-place asphalt pavement need to be identified or developed.

Recently, nondestructive testing (NDT) methods, including laser sensing technologies, 3-dimensional imaging, ground-penetrating radar, falling weight deflectometers, penetrometers, infrared and seismic technologies, and Intelligent Compaction (IC) have been significantly improved and have shown potential for use in the process control of production activities and quality control/acceptance during flexible pavement construction.

Background

NCHRP PROJECT 10-65 Nondestructive Testing Technology for Quality Control and Acceptance of Flexible Pavement Construction is currently investigating the application of existing NDT technologies for measuring the quality of flexible pavements. On that project is assessing promising NDT technologies on field projects for their ability to evaluate the quality of pavement layers during or immediately after placement or to accept the entire pavement at its completion. The anticipated report from that project will identify the NDT technologies that are ready and appropriate for implementation in routine, practical quality control and acceptance operations.

Further research is needed to refine and implement the NDT technologies identified in NCHRP 10-65. Research is also needed to identify and develop needed improvements in the non-destructive, in-place density measuring test equipment and procedures.

Intelligent Compaction is also a rapidly emerging technology that can play a major role in the move toward modulus-based QC/QA during the compaction process and in compaction acceptance procedures. IC technology allows the use of measurement systems to continuously determine material stiffness which may be relatable to density and in-situ moduli measurements. It also provides the capability to utilize color-coded mapping of density-related stiffness at all locations on the roadway. Transportation Pooled Fund 5(128) to study the use of IC technology on asphalt pavement materials is currently underway. Some specific concerns related to using IC on asphalt materials that must be addressed in the research include adapting the technology to ensure that measured stiffness are not influenced by underlying materials and/or binder viscosity. More research is needed to answer key questions about using IC as a non-destructive tool for process control and QC/QA of the compaction operation. Activities conducted under projects 5.04 and 5.05 of this Roadmap should be coordinated with this project.

Scope / Objectives

Identifying, developing/ refining and implementing selected Non-Destructive Evaluation tools to assist with process control during production, quality control and acceptance of in-place HMA pavements, including in-situ material characterization and non-destructive density testing procedures.

Work Plan
Task 1. State-of-the-Practice

State-of-the-Practice will include review of existing and innovative process control, quality control and acceptance tools, including non-destructive testing equipment and procedures. Recent developments in NDT including the use of laser sensing technologies, 3-dimensional imaging, ground-penetrating radar, falling weight deflectometers, penetrometers, and infrared and seismic technologies, among others should be investigated. Non-destructive test equipment and methods that offer promise as ways to measure in-situ density in asphalt pavements should be identified.

Task 2. Lab and Field Tests

The most promising technologies that are identified in Task 1 should be evaluated in the lab and field studies.

Task 3. Precision and Accuracy of Test Method

The precision and accuracy of the various non-destructive test methods included in the Task 2 evaluation will be developed and reported.

Task 4. Implementation Manual

The findings of this research will be summarized in an implementation manual that will identify promising NDT test methods and procedures. The report will include the recommended use of each NDT test as well as the precision and accuracy of the typical test result. The manual will be written in a format that can be easily incorporated into standard test procedures, specifications and QC/QA plans.

Program 5: CONSTRUCTION PRACTICES & QUALITY MANAGEMENT SYSTEMS

Project 5.07 Longitudinal Joints

Objective: Develop best practices and recommended specification standard for longitudinal joint construction

Introduction

Longitudinal joints in Hot Mix Asphalt (HMA) pavement are often the "weak areas" of the pavement. Aggregate segregation and low density at and near the longitudinal joint often result in premature pavement distress including raveling, cracking and pothole formation. Reduced pavement life and increased maintenance costs associated with pavement joint performance is wide spread. Longer life pavements will be obtained if the joint construction problem can be solved. Therefore, research is needed to identify equipment, construction practices and specification requirements that can be implemented to improve longitudinal joint performance.

HMA mixture type and construction weather conditions can be factors in poor joint construction. Some types of mixtures tend to have more longitudinal joint deficiencies than others. Those HMA mixtures that are prone to aggregate segregation typically experience more problems. SMA and open graded mixtures have also experienced joint raveling problems. Also, pavements placed in cool weather and at the end of the construction season are also prone to more joint performance problems.

The solution to the problem will likely involve a number of different aspects since so many factors can affect longitudinal joint performance.

Background

One approach to the problem of longitudinal joint performance is to add joint density testing to the acceptance procedures. The Federal Aviation Administration (FAA) was the first public agency to specify a longitudinal joint requirement. Longitudinal joint density requirements are more common now in state and local government specifications than five years ago. Typically, required joint density is lower than the specified density in the HMA mat. This specification recognizes that the density of the joint will generally not be as high as the density of the asphalt pavement away from the joint.

A major cause of poor longitudinal joints is poor construction practices. Previous field studies have identified best practices for joint construction, including specific methods of joint construction. In addition, equipment in the laydown process has been developed that reportedly can improve joint construction. The most effective improvements in equipment and techniques should be identified and implemented.

Many highway agencies are considering some type of specification to improve longitudinal joint performance. This proposed research will provide both the contractor and agency with the knowledge and tools to produce improved joint construction through improvement in knowledge and tools to accomplish that improvement/advancements in specifications, equipment and techniques that will result in better joint performance.

Scope / Objectives

Develop a recommended longitudinal joint specification (including geometric configuration, density and segregation requirements) and recommended equipment and construction practices that will provide tools to contractors to meet specification requirements.

Work Plan

Task 1. State-of-the-Practice

Evaluate state-of-the-practice of existing longitudinal joint density specifications, construction practices and equipment innovations that have been shown to improve performance. Review of specifications will include the language associated with density and segregation requirements as well as the incentive / disincentives related to joint density. Construction practices and associated equipment will also be defined as part of this state-of-the-practice evaluation.

Task 2. Field Tests

The determination of longitudinal joint density should be evaluated on several field projects using various construction practices. The construction practices should include various types, sequences and timing of compactors as well as equipment to minimize segregation. The density measurements should be made at various locations relative to the centerline of the joint.

Task 3. Recommended Joint Specifications

A recommended joint specification will be prepared in AASHTO/ASTM format. This specification will give consideration to geometric configuration, joint density and joint segregation as needed. The location of the density measurement and test to be used for the density measurement will be defined. Pay factors will be included and will be based on field measurements and filed performance information.

Task 4. Recommended Construction Practices

A recommended or best practice for obtaining longitudinal joint density will be developed.

Program 5: CONSTRUCTION PRACTICES & QUALITY MANAGEMENT SYSTEMS

Project 5.08 Development of Fundamental Model for Field Compaction

Objective: Develop models and advanced guidance to better understand the compaction process of HMA.

Introduction

Compaction is the final step in Hot Mix Asphalt (HMA) laydown operations. Proper compaction that results in optimum air void content in the mix is essential to obtain expected performance of the asphalt pavement. The purpose of compaction is to compress the freshly placed asphalt pavement into a denser volume to obtain target in-place air void content. Compaction is accomplished by static and dynamic forces being applied into the hot material by the paver screed during **n** placement and rollers immediately after placement. The benefits of compaction are increased stability and decreased permeability to air and water.

Background

Factors that can have a significant impact on the compaction process include HMA characteristics, compaction equipment and compaction procedures.

HMA characteristics that are know to affect compatibility are mat thickness, temperature, asphalt binder type and content and aggregate size and type. There are three basic types of compaction rollers used in HMA construction; static steel drum rollers, vibratory steel drum rollers and pneumatic tired rollers that are used in specific situations. Each roller type generates specific compactive forces (vibratory, shear and static) into the HMA. Current trends are an increase in the use of vibratory rollers and the emergence of intelligent compaction technology.

Inadequate models for estimating the effects of all of the variables that affect mix compatibility make it difficult to conduct a rational analysis of how to conduct research to improve the compaction process. Research is needed to review available information, to evaluate existing models and to develop improved models applicable to HMA compaction. Such models will provide highway agencies and researchers with the tools necessary for improving HMA compaction equipment and processes. During model development, consideration should be given to factors such as vibration, static force, shear force, mat temperature and thickness and mix characteristics and tangible inputs to predict the compactability of HMA mixtures.

Scope / Objectives

Recommend models that identify the factors that affect the HMA compaction process. The models should reflect currently available compaction technology in the United States, including intelligent compaction technology. Identify needed research to improve the compaction process.

Work Plan
Task 1. State-of-the-Practice

Evaluate existing compaction models and past, current and proposed research projects related to HMA compaction.

Task 2. Improved Compaction Model

Based on findings of Task 1, identify potential improvements in models and needed lab and field studies to verify the important factors in the compaction process.

Task 3. Lab and Field Tests

Conduct appropriate lab and field testing of compaction operations to answer key questions and to validate proposed models.

Task 4. Final Report and Recommended Practice

Prepare a report that documents the research effort and recommends new compaction models. The document will also provide guidance related to recommended practice for compaction equipment, compaction procedures and testing to measure pavement properties related to compaction.

Program 5: CONSTRUCTION PRACTICES & QUALITY MANAGEMENT SYSTEMS

Project 5.09 Improved Risk Assessment of QC/QA Statistical Specifications

Objective: Standardize procedures and develop software to evaluate buyer/seller risk of QC/QA statistical specifications.

Introduction

Statistical specifications were developed shortly after the AASHO Road Test by West Virginia and Virginia. These types of specification are now utilized in quality control/quality assurance (QC/QA) types of specifications by over 35 states, FHWA, FAA and several local governments. Some of the reasons to utilize statistically based specifications include the fact that variability exists in quality control and quality assurance test results due to sampling, testing, materials and construction operations. Therefore, the use of statistical specifications allow for the risk to be shared by the owner/ agency of the pavement as well as the contractor that is constructing it.

The development of a statistically based specification requires considerable time and effort. Statistical elements for quality control and quality assurance tests need to be developed for specific test methods, specific sampling locations, and specific numbers of samples (sublot and lot considerations). The component materials used and the specific construction equipment and operations used during production and construction are also factors that should be considered. Research has shown that the database upon which these types of specifications are based should be local or regional in nature.

Often owner/agencies “borrow” significant portions of their statistical based specification from other public agencies with little or no consideration for test methods, sampling location, specific numbers of samples, local materials, contractor’s capability, etc. This type of specification development often results in specifications with unbalanced or miscalculated risk for the public agency or the contractor.

Background

Some statistic-based QA specifications and acceptance procedures have been implemented without fully understanding the risks involved to both the owner/agency and the contractor. The two types of risks discussed when developing Quality Assurance (QA) specifications are the seller's (contractor) risk and the buyer's (owner/agency) risk. A properly developed QA acceptance plan takes these risks into consideration in a manner that is fair to both the department and contractor. It is estimated that only a few owner/agencies have developed and evaluated the risk levels associated with their acceptance plans.

In some instances, statistic-based specifications have been based on insufficient amounts of local or regional information to define the basis for the statistics used in the specification. Another common problem is that statistical specifications have been developed on multivariate parameters that create high risk for either the public agency or contractor. The risk for these types of parameters may not be well defined.

A well-designed statistical specification is one where the basis for its development is understood by all parties and also one that balances the risk equitably between the owner/agency and contractors. The development of a statistical specification should always include a risk assessment procedure that can clearly define the risk to both parties. Therefore, there is a need for the development of a framework for the components of a risk assessment procedure that can be used to evaluate risk of a given statistical specification. The framework should include user friendly computer software that can automate the risk assessment analysis and a user manual that describes the needed data input and software operation.

Scope/Objectives

Standardize procedures and develop software to evaluate buyer/seller risk of QC/QA statistical specifications. Develop recommended practice for the development of a statistically based quality control/quality assurance type of specification. Develop a statistically based QC/QA guide specification for hot mix asphalt.

Work Plan

Task 1. State of the Practice

The state-of-the-practice for the development and risk evaluation of a statistically based QC/QA specification should be developed. Evaluate existing specifications, risk assessment methods and best practices documents. Conduct a search for existing software that can be used to automate the risk assessment procedures. "Quality Assurance Software for the Personal Computer, Demonstration Project 89," Publication No. FHWA-SA-96-026, Federal Highway Administration, Washington, DC, May 1996 is a DOS based software program that should be included in the evaluation.

Task 2. Framework for Data Base and Software

A framework of a risk assessment procedure should be developed that can be used by non-experts to evaluate a given statistical specification. This procedure should consist of software that provides blank database tables with internal calculation capabilities that can simplify and automate the risk assessment procedure. The user of the framework software should be able to input specification components/criteria and typical as-produced mixture property test results into the software database and obtain a risk assessment easily and accurately.

Task 3. Recommended Practice for Risk Assessment

A manual should be published that establishes best practices for risk assessment.

Task 4. Statistical QC/QA Specification for Hot Mix Asphalt

A recommended statistical based guide specification for hot mix asphalt should be developed, which provides a framework for owner/agencies to build upon and modify based on local materials and test methods.

Program 5: CONSTRUCTION PRACTICES & QUALITY MANAGEMENT SYSTEMS

Project 5.10 Improved Techniques for Obtaining and Measuring HMA Smoothness

Objective: Evaluate new opportunities to improve HMA pavement smoothness and smoothness measuring equipment

Introduction

In recent years, there has been a great deal more emphasis on obtaining smooth asphalt pavements during construction and on maintaining that smoothness throughout the service life of the asphalt pavements. This trend is driven by a number of factors. One of the biggest driving forces is the increased use of incentive/disincentive smoothness specifications by public agencies. Increasingly, smoothness is being viewed as a measurement of quality of construction along with more traditional quality measurements like binder content, aggregate gradation and mixture volumetrics. As incentives can be very substantial, paving contractors are now more motivated than ever to build smooth pavements.

Pavement smoothness has long been known to be the single most important factor with the driving public. Therefore, it is not surprising that agencies are placing increased importance in obtaining smooth roadways. However, there are some obstacles to specifying smoothness as a quality measure in pavement construction. The biggest obstacle is limitations in measuring equipment and also the time restrictions for measuring smoothness. Other obstacles that must be overcome are in limitations of traditional paving and grade control equipment and poor practices used in production, hauling and paving operations.

Background

Major strides have recently been made to address many of the obstacles to pavement smoothness that are noted above. Testing equipment for measurement of smoothness that utilizes International Roughness Index (IRI) in high speed profilers is now available. The use of IRI as the measurement parameter has dramatically improved the ability to measure properties that can be related directly to roughness that is felt in a typical passenger vehicle. The use of high speed profilers allows testing to be performed in a timely manner and safely because testing can be performed under traffic at normal traffic speeds. However, measuring equipment is expensive and lower priced options that would allow contractors to own their own high speed profilers for QC purposes would be desirable.

Improvements and innovations in paving equipment to aid in construction of smoother pavements are needed. Among other things, desirable equipment improvements include advancements in automatic grade control, material transfer equipment and equipment that will allow on-site remixing capabilities. There is also a need for training materials and programs to educate agency and contractor personnel on best practices for constructing smooth HMA pavements and equipment/specifications for smoothness measurement. Both classroom instruction and on-site training would be helpful to train production, laydown and compaction personnel to eliminate poor paving practices that can adversely affect pavement smoothness.

Research efforts are needed to develop improved techniques for obtaining and measuring HMA smoothness.

Scope/Objectives

Evaluate new opportunities to improve HMA pavement smoothness and measuring equipment. Develop training to educate the highway community on specification development, measuring equipment and equipment and best practices for construction of smooth HMA pavements.

Work Plan
Task 1. State-of-the-Practice

State-of-the-practice will evaluate currently available equipment for production and paving that can aid in improving smoothness and smoothness measurement equipment. It will also identify innovations and ideas for equipment improvements. Existing training materials and programs will be identified and evaluated.

Task 2. Preliminary Recommendations

Based on the findings of Task 1, the most promising technologies will be identified in a preliminary report. Recommendations related to improvements in training for both agency and contractor personnel will be developed.

Task 3. Field Tests

Using equipment identified in earlier tasks, field trials will be conducted to determine the effectiveness of each of the pieces of measuring and paving equipment.

Task 4. Report and Recommended Practice

A final report will be developed that summarizes the findings of the project. The most promising equipment improvements and innovations that were identified will be discussed in detail. The report will also include a recommended practice document that will provide guidance on measuring and paving equipment that should be used during construction of HMA pavements and for measurement of roughness. Needed improvements in existing training materials and programs will be recommended.

Program 5: CONSTRUCTION PRACTICES & QUALITY MANAGEMENT SYSTEMS

Project 5.11 Improved Work Zone Safety

Objective: Identify ways to improve work zone safety devices/ methods and develop guidelines for best practices

Introduction

The safe and efficient flow of traffic through work zones is a major concern to transportation officials, industry, the public, businesses, and commercial motor carriers. As the nation's highway system matures, the emphasis has shifted from constructing new roadways to reconstructing, rehabilitating and maintaining existing pavements. New construction typically means that paving operations can be performed where there is no public traffic, which eliminates the safety concerns that can occur when the traveling public and highway workers are sharing the same roadways. With an increasing need to perform rehabilitation and reconstruction work on existing roads already carrying traffic, most work is now being done "under traffic". Work zones are defined as a section of pavement is temporarily closed to traffic while work is accomplished. The function of the work zone safety setup is to warn motorists that a work zone is ahead, to decrease their speed to the work zone speed limit and to direct them safely through/around the work zone. It is essential that these work zones are effective in providing a safe environment for both workers and motorists.

One relatively new consideration in recent years is the emphasis on maintaining the mobility of the traveling public, even in areas where work zones are established. Growing levels of congestion and the adoption of a customer service philosophy by many agencies when dealing with the traveling public has added the complexity of designing and implementing effective work zones during pavement work activity. A work zone must not only be safe but also is expected to minimize delay to motorists at the same time. These and other issues have lead to additional, more complex challenges to maintaining work zone safety and mobility in recent years.

Background

The national publication titled *Manual on Uniform Traffic Control Devices* (MUTCD) presents guidelines and sets minimum standards for work zones in almost every conceivable combination of highway category and configuration, speed limits and work activity. The work zone safety devices and procedures that are spelled out in MUTCD are the well accepted standard procedures for traffic control in the United States. However, work zone safety is like many other industries, in that there are constant changes in public policy as well as improvements and innovations in traffic control and work zone equipment. The FHWA has developed the National Highway Work Zone Safety Program (NHWZSP) to reduce the fatalities and injurious crashes in work zones, and to enhance traffic operation and safety within work zones. In addition, recent changes in FHWA work zone related rules and requirements are forcing federal, state and local agencies to update their policy and procedures related to work zones. For instance, agencies are encouraged to develop an agency-level work zone safety and mobility policy, to develop standard processes and procedures, including the use of work zone safety and operational data, work zone training, and work zone process reviews.

There is a need for research in work zone safety to modify policy and procedures, to test improved, new and innovative equipment and to measure and analyze the effectiveness of work zone activities.

Scope / Objectives

Identify ways to improve work zone safety devices/ methods and develop guidelines for best practices.

Work Plan
Task 1. State -of-the-Practice

A literature review will be performed to determine the current state-of-the-practice. Existing publications, policies and practices will be evaluated as well as equipment and traffic control devices currently in use. The review will also study proposals to improve work zone safety using a wide variety of approaches including development of new publications, guidelines, work zone practices/methods, training and equipment.

Task 2. Work Plan

Based on the findings of Task 1. identify and prioritize specific research tasks that should be accomplished that will provide valuable information and tools for improvement of work zone safety. Prepare a report that presents the proposed work plan to the panel for approval.

Task 3. Field Studies

Conduct studies on work zones according to the approved work plan. The research will include field studies on actual work zones that use best practice recommendations from this study to verify effectiveness.

Task 4. Report Findings/Recommendations

Develop a comprehensive report that describes the research, reports the findings and recommendations.

Task 5. Implementation

Develop a plan to communicate the findings of the research and implement selected components of the research.

Program 5: CONSTRUCTION PRACTICES & QUALITY MANAGEMENT SYSTEMS

Project 5.12 Improved Asphalt Binder Content Measurement

Objective: Develop improved means of measuring the asphalt binder content of HMA mixtures

Introduction

HMA is a blend of asphalt binder and aggregate stockpiles of various sizes. During the mix design process, the target binder content that will be used during plant production of the HMA is determined. Research and practical experience has shown that obtaining the target binder content in the produced HMA is critical for good performance. Therefore, accurate measurement of binder content is a critical step in quality control and quality assurance of plant produced HMA materials.

Binder contents are expressed in either percent of aggregate weight or, more often, in percent of total mix weight. Binder contents are checked both during mix design and during HMA production. Construction tolerances for binder content are typically range from ± 0.2% to 0.5%. Binder content testing is normally performed at frequent intervals during production by the contractor in the field lab in addition to testing done by the agency in their lab. Therefore, test methods must be applicable to both the mix design lab and the field labs.

There are a number of methods for determining asphalt binder content in both the lab and during production. Lab tests include using chemical extraction with solvents to extract the binder from the asphalt mixture, using ignition ovens to remove the binder by burning the asphalt from the aggregate and using nuclear binder content gauges. Each of these methods has advantages and disadvantages but all current methods have significant drawbacks that make them less than ideal.

A research study is needed to identify improved binder content measurement technologies that are accurate, practical and can be used both mix design labs and field labs during production. Issues such as test method precision, operator safety, retained aggregate degradation and environmental considerations should be addressed in the research.

Background

The ideal binder content test methods can be conducted rapidly and accurately with none of the negative issues associated with current test methods.

Chemical extraction using petroleum solvents was used extensively for determination of binder content for many years. However, concerns with operator exposure to the solvents and issues with disposal of waste materials forced the development of alternate test methods. In addition, there was a desire for a test that would provide faster test results.

Ignition oven testing is based on the concept of using combustion to burn binder from the aggregate surface. The National Center for Asphalt Technology (NCAT) conducted extensive testing of ignition oven technology and developed the widely accepted NCAT ignition test method, which involves igniting the binder in the mix, measuring the asphalt binder weight loss and automatically displaying the percent of asphalt binder in the mix. While this method addresses many of the concerns with solvent extraction methods and offers a more rapid measurement of binder content, there are issues with ignition testing. One of the largest issues is degradation of certain aggregate types during the ignition process, adversely affecting the binder content results. With some aggregate types, the aggregate gradation testing performed after the ignition test may also be affected. The ignition oven requires an extensive and time consuming calibration process for each individual oven prior to testing.

The use of nuclear binder content testing technology has been developed by several manufacturers and is used by a number of contractors and agencies. This use of nuclear technology offers advantages and disadvantages when compared to other test methods. Advantages include the elimination of solvents in the extraction process and a fairly rapid test procedure. Disadvantages include regulatory and safety concerns related to use of nuclear-based technology and the fact that a separate aggregate sample must be taken if gradation testing is performed. Some agencies desire to eliminate test equipment that is based on nuclear sources thereby reducing the extensive documentation of worker exposure and administration duties required with nuclear regulatory agencies. As a result of these factors, the nuclear gauge does not appear to be a viable, long term solution to the need for binder content testing.

Scope / Objectives

Develop improved means of measuring the asphalt binder content of HMA mixtures. Test equipment and methods should be practical, economical, accurate and repeatable.

Work Plan
Task 1. State-of-the-Practice

State, federal and international test equipment, procedures and practices relative to laboratory tests to determine binder content of asphalt mixtures will be reviewed. Innovative equipment/procedures and equipment from other industries will be included in the review. If possible, devices and/or procedures with potential as an improved method will be identified. A plan will be developed to produce a performance related laboratory durability test.

Task 2. Lab and Field Tests

The binder content tests that are identified in Task 1 will be evaluated in laboratory study and field studies. The intent of this task will be to identify one or possibly two test procedures which hold the greatest promise for success at a reasonable cost and practicality. The test method(s) selected and evaluated will be validated during extensive testing at both mix design labs and field labs during production. This testing will provide data from mixes with a full range of binder contents over a long enough time frame to adequately evaluate the effectiveness of each proposed test method / equipment. Equipment durability, cost and practicality will be evaluated in this step.

Task 3. Implementation Manual / AASHTO Test Methods / Specifications

Guidelines will be developed for the use of the selected and validated test procedures. Test method(s) and specification(s) will be developed in AASHTO format for possible inclusion as provisional and eventually standard test methods and equipment.

Program 5: CONSTRUCTION PRACTICES & QUALITY MANAGEMENT SYSTEMS

Project 5.13 Segregation Control

Objective: Develop improved methods for measuring segregation longitudinally and transversely and develop guide specifications for reducing segregation.

Introduction

Asphalt pavement segregation is a common and costly problem in the paving industry throughout the country. The goal of quality HMA pavement construction is to build a pavement that has uniform surface texture and materials properties throughout the mat, however, pavements with non-uniform (segregated) surface textures and areas of low density occur throughout the United States.

Segregation is defined as the presence of non-uniform materials in the asphalt pavement, and is especially noticeable at the pavement surface.   Segregation of hot-mix asphalt has resulted in poor performance and reduced service lives in many pavements. The solution to the problem is complicated because there are a number of different types of segregation with different causes and sources. Two general categories of HMA segregation are aggregate gradation segregation and HMA mixture temperature segregation. *Aggregate gradation segregation* is the non-uniform distribution of coarse and fine aggregate materials in the finished HMA mat. This segregation can be caused by problems at one or several points in the HMA production, hauling, and placement operations. The most common type of aggregate segregation is localized mat areas with high percentages of coarse aggregate. These coarse areas that are typically associated with high air voids and low asphalt contents. This condition can lead to moisture intrusion and subsequent damage as well as to durability-related pavement distresses such as fatigue cracking, pothole formation, and raveling. *Temperature segregation* occurs as the result of differential, non-uniform temperatures on the surface of the pavement behind the paver. The presence of the cooler spots in the pavement can result in areas of low density which can lead to durability problems in the mat. Temperature segregation is caused by uneven cooling of the asphalt mixture during hauling and placement.

A research effort is needed to develop improved methods for identifying and measuring both aggregate and temperature segregation and to develop guide specifications to address segregation both during the production and construction process and after construction on in-place pavements. This research should include methods to evaluate segregation both longitudinally and transversely in order to provide a way to accurately identify the location and limits of the segregated areas.

Background

There are currently no widely accepted identification methods to evaluate segregation. Many of the identification methods are based on subjective visual evaluations of the HMA pavement surface appearance. It is likely that most of the disagreements over segregation-related issues that occur among contracting parties could be resolved if there were established, non-subjective procedures for identifying, measuring, and evaluating the effects of segregation.

There have been numerous studies conducted to identify segregation's causes and also studies to evaluate the effect of segregation on HMA pavement properties and performance. The National Asphalt Pavement Association has developed a publication titled "Segregation: Causes and Cures" which is an excellent resource to help with the understanding of segregation and an in-depth discussion of its causes at the production plant, during mix transfer at the plant and paver and during the paving operations. It also includes a discussion of how to correct these causes and reduce/eliminate segregation. However, less research has been done to systematically develop definitions/guidelines, to develop procedures to identify segregation, to categorize its severity, to establish the limits of the segregated pavement or to recommend practical ways to eliminate segregation.

There have been some notable research projects performed to identify test methods that can be used to measure and categorize the presence, limits and severity of segregation. The findings of NCHRP 9-11, "Segregation in Hot-Mix Asphalt Pavements" was completed in the late 1990s are outlined in NCHRP Report 441. The objective of this research was to develop procedures for defining, locating, and measuring segregation and to evaluate segregation's effects on HMA pavement performance.

The project developed recommended test methods and example specifications to detect and measure segregation of hot-mix asphalt (HMA) using various test devices and approaches, including provisional standard test procedures and specifications for using infrared thermography to identify and measure segregation in HMA during paving operations for using ROSAN (ROad Surface ANalyzer) laser surface texture measurements to identify and measure segregation in HMA pavements after construction.

ROSAN is a non-contact portable profiler that is capable of measuring longitudinal texture and pavement profiles at highway speeds. The advantage of using ROSAN (or other high speed testing equipment) is that testing for segregation in an in-place pavement in a longitudinal direction can be accomplished quickly. Infrared thermography is a test method that uses infrared imaging to detect variation in temperature (temperature segregation) during paving operations. The advantage of using this method is that excessive temperature variation both longitudinally and transversely can be identified quickly and corrective actions to address the problem can be taken during the paving operation.

There has also been considerable work done at both state and national level to develop other test procedures to detect and categorize segregation, including test methods and specifications using sand patch and nuclear density gauge testing methods. The advantage of these test methods is that they establish non-subjective test methods for identifying and establishing the locations of segregated areas.

Various agencies have adopted one or more of the non-visual test procedures discussed above with varying levels of success in eliminating or at least reducing the occurrence of segregation. Other agencies continue to try to address segregation issues using strictly visual examination. These agencies are reporting limited success with visual methods. While considerable progress has been made in understanding and addressing segregation in HMA pavements, more work is needed to increase the understanding of test procedures to identify and quantify segregation both during the construction process and after construction on in-place pavements.

Scope/Objectives

Develop improved test methods for measuring segregation longitudinally and transversely. Develop guide specifications for segregation control. Any test methods must be non-subjective, must have the ability to be conducted rapidly and ideally can be applied to freshly placed HMA during the construction process as well as in-place pavements after construction.

Work Plan
Task 1. State-of-the-Practice

The state-of-the-practice related of test methods and guide specifications for use in identification and categorization of segregation in HMA pavements.

Task 2. Potential Test Methods

Based on the findings of Task 1, identify the test methods for further evaluation with the most potential to effectively address segregation issues both during the paving operation and on in-place pavements. For each test method selected for further evaluation, find or develop draft guidelines and specifications that describes in detail the way that test data will be used, acceptance criteria, etc.

Task 3 Field Tests

Conduct field trials of selected test methods and guidelines to evaluate their suitability and practicality for identification / categorization of various types of segregation. Test methods and guidelines should be evaluated for accuracy of test results, for effectiveness of measurements in both the longitudinal and transverse directions, applicability during the paving operation as well as an evaluation of time needed to perform the test and obtain the results.

Task 4 Recommended Practice / Test Methods / Specifications

Based on the findings of the study, develop a document that outlines the recommended practice for evaluation of segregation in HMA pavements. The document should include recommended equipment / test procedures and guide specifications and a detailed explanation of the advantages and disadvantages of each method. If necessary, submit test methods written in the proper format to AASHTO for consideration of making them provisional standard test methods.

Program 5: CONSTRUCTION PRACTICES & QUALITY MANAGEMENT SYSTEMS

Project 5.14 In-Place Recycling

Objective: Evaluate ways to improve materials / equipment and develop guidelines for best practices of hot and cold in-place asphalt recycling techniques using bituminous materials

Introduction

A recent FHWA study reported the state of the practice and usage of asphalt pavement recycling, technical and institutional barriers restraining its use, and recommendations for enhancing the use of asphalt recycling. FHWA's policy states "Recycling can offer engineering, economic and environmental benefits and recycled materials should get first consideration in overall materials selection." There are a number of ways to re-use reclaimed asphalt pavement (RAP) into a new asphalt pavement. Hot plant mix recycling using RAP taken from an existing pavement is the most common method but there are also other methods used, including cold mix recycling at a plant or in-place and hot recycling that is accomplished in-place. With plant recycling, there is substantial expense to first hauling the RAP to the plant and then hauling the new, recycled asphalt mixture to the project site. The advantage of in-place recycling is that a significant amount of trucking can be eliminated, which can have a significant impact on the economics of the project.

In-place recycling is an on-site, in-place rehabilitation method which consists of loosening, scarifying, mixing, re-placing and re-compacting of existing pavement materials. The purpose of the in-place recycling is to mitigate or eliminate distress in the existing pavement and to improve the characteristics and service life of the in-place material. There are a number of different in-place recycling techniques, including cold in-place recycling (CIR), hot in-place recycling (HIR) and Full Depth Reclamation (FDR).

Background

Cold In-Place Recycling (CIR)

In CIR, the existing asphalt pavement are milled and mixed with additives such as virgin aggregate, emulsified asphalt binder and recycling agents and then placed and compacted. Specialized equipment and paving trains are used to accomplish each of the subsequent steps in the CIR techniques. Either single or multiple unit paving trains are used to perform CIR.

Hot In-Place Recycling (HIR)

In HIR, heat is applied to soften the existing asphalt pavement which is then loosened and mixed with additives such as virgin aggregate, asphalt binder, recycling agents, and/or new HMA. There are three categories of HIR, defined by the construction process used, consisting of Surface Recycling, Remixing and Repaving. The steps and additives used in each of the HIR categories vary from one to another. Selection of the proper HIR category depends on the agency's expected design life, performance requirements during the design life and acceptable future maintenance requirements. Specialized equipment and paving trains are used to accomplish each of the subsequent steps in the specific categories of HIR. The research should be focused in each of the specific categories on improvement of bituminous binders and recycling agents, improvements/ innovations in equipment used in HIR and in identifying best practices in project selection, design and construction.

Full Depth Reclamation (FDR)

FDR is an in-place rehabilitation technique in which the full thickness of the asphalt pavement and a pre-determined portion of the underlying materials (base, subbase and/or subgrade) is uniformly pulverized and blended to provide an upgraded, homogeneous material. The blended material can then be stabilized with an additive, such as virgin aggregate, chemicals or bituminous material. Bituminous stabilization is accomplished with the use of liquid asphalt, asphalt emulsion or foamed (expanded) asphalt. The research should be focused on FDR design, equipment and mix design where stabilization is accomplished using bituminous materials. Other areas of research should be in identifying best practices in project selection and FDR construction.

In cooperation with the FHWA and NHI, The Asphalt Recycling and Reclamation Association (ARRA) published the Basic Asphalt Recycling Manual (BARM) in 2001. The BARM describes in-place recycling methods in detail, including sections on detailed project analysis, mix design, construction and specifications / inspection. The construction sections provide detail about best practice for equipment and construction methods. FHWA also recently published checklists for various pavement preservation techniques using bituminous applications, including CIR and HIR. Any research effort should reference the BARM and FHWA publications and utilize the resources and knowledge of both FHWA and ARRA to help with identification of needed research.

Scope / Objectives

Evaluate ways to improve materials / equipment and to develop guidelines for best practices of hot and cold in-place asphalt recycling techniques using bituminous materials. The research should be focused on improvement of bituminous binders and recycling agents, improvements/innovations in equipment used in CIR and in identifying best practices in project selection, design and construction.

Work Plan

Task 1. State of the Practice

Conduct a literature study to determine the current state-of-the-practice in selection criteria, design, equipment, construction and specifications/inspection of in-place recycling methods. Identify and survey agencies that are doing in-place recycling to determine economics, service life, performance, advantages and disadvantages of each of the methods, including HIR (Surface Recycling, Remixing and Repaving), CIR and FDR. Evaluate currently available "guidelines" and "best practice" publications.

Task 2. Needed Research Topics

Recommend needed research topics based on the findings of Task 1, prioritize the projects and write them up for review by the panel. Research topics should be identified in each of the categories of in-place recycling.

Task 3. Laboratory and Field Tests

Conduct experimental studies in both the laboratory and the field to address the selected research topics in each of the above categories of in-place recycling.

Task 4. Report Findings / Develop Best Practices Publication

Produce and publish the findings of the research. Develop a "Best Practices" in a form that is ready for distribution to highway agencies, equipment manufacturers, contractors and materials suppliers.

Program 5: CONSTRUCTION PRACTICES & QUALITY MANAGEMENT SYSTEMS

Project 5.15 Improved Quality of Night Construction

Objective: Develop methods to improve the construction of pavements during nighttime operations through better equipment, practices, and inspection techniques

Introduction

A significant amount of HMA paving is now being performed during off-peak hours or at night. This trend by highway agencies across the country is driven by a greater emphasis on customer service, reducing user delay and improving safety for both the traveling public and workers. In fact, it is safe to say that most mainline paving performed in high-traffic urban areas is performed during low-traffic periods, including nights and weekends. This construction approach minimizes the project's impact on motorists, residences and businesses.

While there are many advantages to night construction activities for the contractor, the owner-agency and the traveling public, there are also some significant disadvantages. One of the biggest disadvantages is the likelihood that it is more difficult to construct a quality paving project at night. There are a couple of reasons for this; poor visibility during the paving operation and cooler night time temperatures.

By its nature, night paving is performed in low light conditions. Even though paving crews are required to illuminate the paving operation from both a safety standpoint and to allow the paving crew and inspection personnel to see their work, the ability to visually evaluate the paving work is dramatically impaired at night. Therefore, using adequate lighting is a critical issue because vision plays a large role in workers ability to place a quality asphalt pavement and also for the inspection team to evaluate the appearance of the pavement. Paving deficiencies that would be easily seen during daytime paving are difficult to see in the poor lighting used during night paving operations.

The other major problem with night paving is related to the cooler ambient temperatures that occur at night. When these night time temperatures are too low, they can cause excessive and uneven cooling of the HMA during hauling and paving operations. This cooling can result in workmanship and quality issues in the completed mat.

In some cases, reduced quality of the asphalt pavement can be experienced during night time paving. A research study is needed to identify ways to improve the quality of HMA paving constructed at night. The study should result in guidelines and a "best practices" publication that identify specific equipment and/or inspection techniques that are effective for use on night paving operations.

Background

Typical workmanship problems that are reported during night construction include poor joint construction, segregation and poor mat appearance from handwork to name a few. The typical cause of these deficiencies is the inability to see the deficiencies when the paving operation is being done. Some of the typical mixture quality issues that are encountered in night paving operations are related to smoothness and density.

There have been a number of efforts to study ways to improve quality of night paving operations in recent years; however, a comprehensive national research effort is needed to address the specific problems associated with night construction of HMA. The research should identify all of the potential problems in night time paving, address specific issues in each of the phases of production and placement of HMA pavement, including issues at the production plant, hauling, paving and compacting the HMA materials.

Scope/Objectives

Develop methods to improve the construction of pavements during nighttime operations through better equipment, practices, and inspection techniques.

Work Plan
Task 1. State-of-the-Practice

Conduct a literature study to determine the current state-of-the-practice in improving the quality of night time paving HMA construction operations. Survey owner-agencies that do a significant amount of night paving to determine the techniques that are currently used. Evaluate currently available "guidelines" and "best practice" publications related to night construction of HMA pavements.

Task 2. Needed Research Topics

Recommend needed research topics based on the findings of Task 1, prioritize the projects and write them up for review by the panel. Research topics will be based on practical studies of actual night-time paving projects.

Task 3. Field Tests

Conduct experimental studies on actual projects to address each of the selected research topics identified in Task 2. Studies will be conducted in a variety of circumstances, including situations where long hauls during cool night-time temperatures are present and where remixing at the paving site is not being done.

Task 4. Report Findings / Develop Best Practices Publication

Produce and publish the findings of the research. Develop a "Best Practices" document that is in a form that is ready for distribution to highway agencies, equipment manufacturers, contractors and materials suppliers. Present findings and "Best Practices" at government and industry conferences.

Program Six: INNOVATIVE CONTRACTING APPROACHES

Projects in Program Six

Project 6.01	**Development of Rapid Construction Methods**
Project 6.02	**Risk Assessment of Non-Traditional Contracting Techniques**
Project 6.03	**Critical Review of Pavement Projects Built Using Warranty Contracts**
Project 6.04	**Best Practices for Innovative Contracting**
Project 6.05	**Education and Training for Design Consultants**
Project 6.06	**Best Practices for Maintenance Contracting and Facility Leasing**

Program Six
Innovative Contracting Approaches

Introduction

Public agencies have used traditional low-bid contracting approaches in the United States to award HMA pavement contracts to contractors for many years. In traditional highway construction contracting, cost is generally the one criterion that determines a winning bid. Historically, highway projects are designed, bid and built with the contract awarded by the public agency to the lowest bidder. This approach has worked fairly well over the years and many miles of quality HMA pavements have been produced using this type of contracting approach. However, owner agencies are becoming more aware of the limitations and disadvantages of traditional contracting approaches and of only using a single approach to contracting regardless of the circumstances.

In recent years, as State highway agencies strive to meet customer needs, factors other than cost have also emerged as important. These factors include quality, delivery time, social and economic impact, safety, public perceptions, life-cycle costs, and use of improved technologies. So-called "Innovative contracting techniques" can help to address these other factors. The term innovative contracting is now used regularly to describe any of a number of non-traditional contracting practices in use. Innovative contracting is becoming more and more popular because it allows for consideration of these other factors, in addition to low-bid.

Since the early 1990s, FHWA has been supporting the evaluation of non-traditional contracting techniques with the goal of accessing innovative contracting practices that might reduce the life cycle cost of projects while maintaining or improving product quality. Through these evaluations, four basic types of innovative contracting practices have been used with varying degrees of success. These four innovative practices are: cost-plus-time bidding, lane rental, warranty clauses and design-build contracting.

Since the concept of using non-traditional contracting approaches is still relatively new in the United States, research is needed to provide insight into the benefits and disadvantages of these practices.

Background

Projects that are suitable for innovative contracting techniques are those in which right-of-way, utility, environmental and other socio-political issues have been resolved. They are also applicable to projects where the potential exists for increasing quality, decreasing costs, decreasing time, reducing administration costs and reducing the possibility for legal claims and change orders.

Cost-plus-time bidding, lane rental, warranty clauses and design-build contracting are the four basic types of innovative contracting practices that have been endorsed by the FHWA for use on pavement construction, rehabilitation and maintenance projects. The research discussed in this program will generally be limited to one or more of these four types. Following is a brief description of each of the four basic types of innovative contracting:

Cost-Plus-Time Bidding

Sometimes referred to as A+B bidding, cost-plus-time bidding is a procedure that selects the low bidder based on a monetary combination of the contract bid items (A) and the time (B) needed to complete the critical portion of the project. This procedure is intended to provide a contractual incentive for the contractor to minimize delivery time for high priority and congested roadways by offering incentives for early completion and assessing disincentives for late completion. “A+B+Q” is a modification that has been used to include a pavement quality element to the evaluation process.

Lane Rental

Lane rental is the practice of charging the contractor a fee for occupying lanes or shoulders during construction. Charges are based on hourly or daily rates and can vary with time of day, amount of traffic, and other measures of user costs. Similar to cost-plus-time bidding, lane rental provides a contractual incentive for early completion.

Warranty Clauses

Warranties are intended to increase the quality of a product thereby giving the contractor responsibility for replacement or repair of deficiencies for a specified period of time. There are several different types of warranties including materials and workmanship warranties, short-term warranties and long-term warranties. In the warranty approach, the owner and contractor must agree on the warranty items and the evaluation process.

Design-Build

"Design-build" refers to contracting with a single firm for the design and construction of a project to decrease project delivery time and associated user costs. This technique allows the contractor greater flexibility for innovation in design, materials selection, and construction methods. In design-build contracting, the highway agency identifies the scope of work and establishes the design criteria. The proposers then develop technical proposals that optimize their abilities. Proposals may be rated on factors such as technical quality, timeliness, and management capability, as well as cost. Some design-build contracts also include provisions that require the contractor to be involved in maintenance or operation activities after construction, through design-build-maintain and design-build-operate contracts.

There are a number of specific questions that need to be addressed with research in the area of innovative contracting. The most important issues at this time are the amount of risk to the public owner agency and the contractor, the quality and performance of the HMA pavement obtained and the cost effectiveness of the innovative contracting compared to traditional contracting practices. Research should address these and other issues.

Scope / Objective

Evaluate all feasible contracting approaches that are or can be used for HMA projects to determine their advantages and disadvantages. Specific traditional and innovative contracting methods and philosophies will be compared in various ways, including an evaluation of projects constructed with each type of contracting approach. In addition, research projects to develop guidelines and best practice documents and to develop training programs will be conducted.

Program 6: INNOVATIVE CONTRACTING APPROACHES

Project 6.01 Develop Rapid Construction Methods

Objective: 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 hot mix asphalt pavements.

Introduction

Hot Mix Asphalt (HMA) is used for both new construction and resurfacing of existing roadways. In most states, the emphasis has shifted to widening, rehabilitating and maintaining existing pavements with fewer new highways being built. This trend has meant that the majority of HMA paving is being done "under traffic" which means that a portion of the roadway must be closed temporarily during paving operations. These types of reconstruction operations on already congested highways further increase congestion during reconstruction. Pavement rehabilitation and maintenance activities are also responsible for congestion. Methods and techniques need to be developed which will provide a customer focus and a balanced approach to improve safety, reduce delay and minimize disruption in highway construction, rehabilitation and maintenance work zones. Reducing lane occupancy time while providing a safe work zone is a necessity. However, sometimes rapid production and safety concerns can be in conflict with each other. With this in mind, the scope of this project should include assessing the balance between safety and rapid construction methods.

Recently, there are increased efforts to minimize traffic disruption related to the construction activities and an increasing awareness of safety concerns for both the driving public and workers in work zones. Therefore, there is a need to identify rapid construction methods that can result in reduced lane occupancy time where quality HMA pavement is produced in a shortened time frame.

Rapid construction techniques also have the potential to improve project economics in a number of ways. Shorter construction time can mean lower costs for labor, equipment, traffic control and lane rental. This can result in savings to the contractor and ultimately to the agency.

Background

Rapid construction can be addressed in a number of ways to be less disruptive to the roadway user, to improve work zone safety and to save money. The first approach is through better project scheduling and better project management of workforce, equipment, and materials. The most common method of minimizing the impact of work zones on users is performing the work during off-peak hours, such as nighttime, returning all the lanes back to the traveling public during peak times. The second approach is through improved HMA technology, including mixtures that are easier to place, less prone to segregation, and easier to compact while maintaining the needed quality. Future research efforts should be undertaken to develop materials handling, transportation, placement, and management techniques and equipment to provide for high-production, high-quality construction. The development of rapid construction techniques go hand-in hand with the desire for reduced lane occupancy time.

Scope / Objectives

Evaluate new opportunities to reduce construction time, improve safety and improve project economics while maintaining quality. Develop techniques to reduce lane occupancy time during placement of asphalt pavements.

Work Plan
Task 1. State-of-the-Practice

The state-of-the-practice related to rapid construction techniques will be evaluated. Currently available materials, techniques and equipment that can be utilized will be identified and implemented. New and innovative materials, techniques and equipment for future research will also be identified. Traditional and innovative methods to reduce lane occupancy time will also be identified.

Task 2. Laboratory and Field Tests

The most promising materials, techniques and equipment will be studied and validated with laboratory testing and field trials. The field trials will include a comparison of standard construction practices and rapid construction to quantify the reduction in lane occupancy that results from specific rapid construction methods.

Task 3. Implementation Manual

An implementation manual describing materials, techniques and equipment that have been identified to effectively speed up construction and reduce lane occupancy will be developed. The format will be suitable for inclusion in specifications and test method standards.

Project 6.02 Risk Assessment of Non-Traditional Contracting Techniques

Objective: Evaluate the performance of projects built with innovative and/or non-traditional contracting to determine the economic risks to both the owner and contractor.

Introduction

Many highway agencies are gradually transferring more responsibility for the design, construction, maintenance and overall pavement performance to the private sector. One way that this is done is through various "innovative or non-traditional contracting" methods. These methods are alternatives to the traditional low bid contracting system that has been prevalent in the United States for many years. Non-traditional contracting methods include lane rental, cost and time contracting, design-build contracting, warranty contracting among others.

Although it appears that low bid contracting will be the predominant method used in the foreseeable future, there will be an increase in non-traditional contracting practices in coming years. This shift toward innovative contracting methods is driven to a large degree by funding and manpower issues in government agencies. It is also a result of philosophical beliefs that the HMA industry should take on more responsibility and risk associated with cost effectiveness and pavement performance.

Background

Cost and Time contracting methods base the award of the contract to a given contractor on both cost and time required for roadway construction. These so called “A+B” contracts have been used widely by many state DOTs. This approach places a premium on productivity at the work site and the ability to quickly mobilize and de-mobilize. “A+B+Q” is a modification that has been used to include quality such as warranties in the evaluation process.

Lane Rental is the practice of charging the contractor a fee for occupying lanes or shoulders during construction. Charges are based on hourly or daily rates and can vary with time of day, amount of traffic, and other measures of user costs. Similar to cost-plus-time bidding, lane rental provides a contractual incentive for early completion, however it does not relate to quality of construction.

Design-Build contracting requires the contractor (or project team) to assume all or more responsibility for financing, designing, building, and operating a given project or transportation system. The scope of the individual projects can vary and include alternatives such as: 1) design/build, 2) design/build/operate or 3) design/build/finance/operate.

Warranty Contracting methods require the construction contractor to guarantee the post-construction performance of the pavement for a specified number of years. Under a pavement-warranty specification, quality is measured by the actual performance of the pavement as opposed to the properties of the pavement materials and methods of construction. Generally, minimum performance criteria are established and monitored during the warranty period. The contractor is responsible for performing maintenance on the pavement to meet those criteria during the warranty period.

Because these non-traditional contracting methods are forcing significant changes in responsibility for (and control over) pavement performance from agencies to the HMA industry, there is a need to study the actual pavement performance being achieved and cost effectiveness of the contracting method on projects where innovative contracting techniques were used. The expanded use of non-traditional contracting will also require further development of laboratory performance tests and performance prediction models. Finally, the degree of risk for both the industry and the owner agencies should be evaluated.

Scope / Objectives

Evaluate the performance of projects built with innovative and/or non-traditional contracting to determine the economic risks to both the owner and contractor.

Work Plan
Task 1. State-of-the-Practice

Determine the state-of-the-practice of innovative and/or non-traditional contracting practices. Conduct surveys of owner agencies to identify non-traditional contracting methods used and to obtain information on cost and performance data from existing projects.

Task 2. Pavement Performance and Cost Effectiveness

Visit identified projects using non-traditional contracting practices. Evaluate cost effectiveness and pavement performance on each project.

Task 3. Guideline and Criteria for Innovative Contracting Type Selection

Summarize and evaluate the data collected in Task 2. Develop guidelines which include performance criteria for each contracting practice.

Task 4. Implementation Manual

Prepare an implementation manual which presents the results and findings of the research. The information will be in a format suitable for inclusion in agency procedures manuals and non-traditional contracting documents.

Project 6.03 Critical Review of Pavement Projects Built Using Warranty Contracts

Objective: Evaluate the pavement performance and the cost/benefit of existing warranty projects , including the appropriate length and conditions of the warranty.

Introduction

Warranties are one type of non-traditional contracting procedures being used by agencies. Some state highway agencies have been using warranties for asphalt pavement construction and rehabilitation for many years. Approximately 35 states have varying degrees of experience with the use of some form of warranty provisions on Federal-aid highway projects. Under a pavement-warranty specification, quality is measured by the actual performance of the pavement as opposed to the properties of the pavement materials and methods of construction. Pavement warranties require the construction contractor to guarantee the post-construction performance of the pavement. The shifting of post-construction performance risk from the state highway agency to the contractor is perceived to reduce premature pavement failures, reduce costs, and increase pavement quality.

Background

There are two basic types of warranties on pavement projects. The first type of warranty addresses materials and workmanship issues on the original construction. These warranties are short-term and have warranty time periods generally from two to four years. This approach ensures that the contractor will build the pavement as specified by the owner and fix any defects resulting from the use of improper materials or inferior installation. Performance indicators including rutting, cracking, durability, etc. are used on material and workmanship warranties.

The second basic type of warranty is a performance based. This type of warranty can be either short-term lasting 5-10 years or long-term lasting 10 to 20 years. Performance warranties require the contractor to assume full responsibility for certain aspects of pavement performance during the warranty period. Generally, the contractor is given more freedom for materials selection, workmanship, equipment selection, traffic control, and possibly certain aspects of pavement structural design as the warranty period is extended. In performance warranties, the contractor is responsible for performing planned maintenance activities and also unplanned maintenance if pavement deficiencies occur during the warranty period.

Time and cost and design-build contracting procedures can contain warranty provisions that are similar in nature to short or long-term warranties as discussed above.

A research study is needed to 1) evaluate the performance of existing pavements that were constructed under warranty contracting procedures; 2) determine cost/benefit of this type contracting procedure; and 3) recommend the appropriate length and conditions of the warranty portion of the contracts.

Scope / Objectives

Evaluate the pavement performance and the cost/benefit of warranty projects along with the appropriate length and conditions of the warranty.

Work Plan
Task 1. State-of-the-Practice

The state-of-the-practice relative to warranties will be determined. State DOTs that are routinely using warranty contracting procedures will be identified along with details about individual projects.

Task 2. Pavement Performance Determination

Evaluate selected pavement history and performance to measure effectiveness of warranty contracting practices and determine cost/benefit of both materials and workmanship and short and long term performance warranties.

Task 3. Implementation Manual

Prepare an implementation manual which presents the results of Tasks 1 and 2. The manual will make specific recommendations on cost effective use of warranty contracting procedures for appropriate project type (overlay, rehabilitation, and new construction), project size and conditions of warranty.

Project 6.04 Best Practices for Innovative Contracting

Objective: Prepare a document describing the best practice for engaging in warranty, design-build, design-build-maintain, and design-build-operate contracts.

Introduction

With the growing interest in innovative contracting approaches among policy makers and pavement designers, there is reason to believe that a significant percentage of future projects will be let using non-traditional contracting. However, decision makers need effective guidance to make informed decisions about the applicability of these contracting methods including risks and benefits of each approach.

While a few transportation departments have aggressively incorporated the use of innovative contracting on a large number of projects, the majority of agencies are taking a slower approach to implementing these practices. There are several reasons for the caution of many agencies in implementing innovative contracting approaches but a major concern is a lack of understanding of the “best practices” of using these methods. Many agencies do not feel comfortable with their understanding of the right innovative approach to use in a given situation, in establishing criteria to be used and in understanding and balancing risk to themselves and the contractors.

Background

There are a number of research projects underway or pending to answer key questions and increase the knowledge of the use of innovative contracting practices. In addition, a fairly large number of projects that were contracted using a wide variety of innovative contracting approaches have been in service for a number of years. The agencies that have used non-traditional contracting are reporting their findings, successes and failures with these methods. A growing amount of data is becoming available to accurately assess the advantages/disadvantages and applicability of each specific approach to a given circumstance. A research study is needed to build on agency/contractor experience as well as completed research work to provide clear guidelines and best practices for selecting, designing and managing non-traditional contracting practices.

The major deliverable of this project will be the development of a “Best Practices” document that can provide practical information and recommendations about each of the viable innovative contracting approaches, including short and long term warranties, design-build, design-build-maintain, and design-build-operate contracts.

Scope/Objectives

Prepare a document describing the best practice for engaging in warranty, design-build, design-build-maintain, and design-build-operate contracts.

Work Plan

Task 1. State-of-the-Practice

Determine the state-of-the-practice in the United States and other countries of innovative contracting practices, findings of research studies, experience with contracting approaches and pavement performance on projects. Perform a survey of agencies that have used non-traditional contracting.

Task 2. "Best Practices" Document

Based on findings of Task 1, develop a comprehensive document that identifies best practices for proper selection and effective use of each specific innovative approach.

Task 3. Implementation

Promote the use and implementation of the "Best Practices" document through all possible avenues, including presentations, magazine articles and advertisements and training programs related to innovative contracting approaches.

Project 6.05 Education and Training for Design Consultants

Objective: Conduct workshops, seminars, and on-line training for consulting engineers to become familiar with pavement design standards in an innovative contracting environment.

Introduction

There is a nation-wide trend toward the use of innovative contracting methods for HMA projects. These new contracting practices are frequently being used for new roadway construction as well as pavement rehabilitation and maintenance overlay projects. At the same time, there has been a gradual philosophical change with many highway agencies to reduce workforce and to privatize many aspects of pavement engineering. This downsizing trend has evolved into a major paradigm shift from virtually all design work being done by agency personnel to a significant amount of project/pavement design work now being done by consulting engineers. The result of the two trends is that consultants are being asked to put together pavement designs using innovative contracting approaches.

When design work was performed by the agency, there was direct communication between policy makers and agency design personnel. Also, the experience with and knowledge of the agency's philosophies and procedures were well understood by a group of agency designers that work closely together. Therefore, preparing effective pavement designs that are compatible with innovative contracting methods could be done effectively when all work was done by agency personnel. However, many consulting engineers may not have the knowledge and experience with the use of innovative contracting methods and the agency's pavement design procedures in this area. Therefore, there is a need to educate and train consultants about the use of innovative contracting approaches.

Background

A broad strategy for education and training of consultants in innovative contracting is needed. In order to make these efforts effective and practical, a number of different resources need to be developed that can be used by agencies to conduct formal training efforts and by consultants to educate themselves. Educational materials should include both written publications and on-line resources, including on-line training courses. Formal training workshop and seminars should also be developed as part of this research study.

The workshop development should be in established National Highway Institute (NHI) format and should include a suggested program and agenda for one and two-day courses, PowerPoint presentations and a workshop manual containing presentation handouts and other resources. The project should include the delivery of the pilot training course for the project panel members and other selected individuals. The participants of this pilot course will critique the training course and suggested improvements. After the suggested revisions are made, the training will be submitted to NHI for award to a team of instructors for delivery upon request by agencies, consultants or others.

After approval by the project panel, on-line education and training materials will be submitted for posting on the internet.

Scope/Objectives

Develop education and training, conduct workshops, seminars, and on-line training for consulting engineers to become familiar with pavement design standards in an innovative contracting environment.

Work Plan
Task 1. State-of-the-Practice

Determine state-of-the-practice of the best ways to educate/train the consultant workforce, to determine education and training that is currently available in the field and in related fields.

Task 2. On-Line Resources/ Classroom Training

Develop and conduct initial evaluation of pilot on-line and classroom training tools.

Task 3. Pilot Workshops / Seminars

Refine the resources and training developed in Task 2 by conducting pilot training of both classroom and on-line programs for a panel of experts. Improve materials and programs based on suggested revisions.

Task 4. Implementation of Education and Training

Implement on-line resources and training on a Website and advertising its use. Implement classroom training through NHI format or other established program.

Program 6: INNOVATIVE CONTRACTING APPROACHES

Project 6.06 Best Practices for Maintenance Contracting and Facility Leasing

Objective: Develop a document that provides guidance to policy makers, administrators, and agency personnel on contract content and performance standards for maintenance and facility leasing contracts for HMA pavements.

Introduction

The use of innovative and non-traditional contracting approaches that are used for major pavement construction and rehabilitation projects can also be applied through maintenance contracting and facility leasing. Maintenance contracting is a non-traditional contracting approach where specific (or all) pavement maintenance on a section of pavement is the responsibility of a contractor for a given period of time. Facility leasing is a contracting approach whereby an owner agency leases the entire responsibility for a roadway, or system of roadways, to a concessionaire for a stated period of time.

Typically, maintenance activities (such as crack sealing, pothole patching, etc.) are handled either with agency forces or with traditional contracting practices where a contractor is hired to perform a specific maintenance activity on a given section of roadway. Agencies are learning that using their own infrastructure, equipment and personnel to accomplish needed maintenance may not be the most cost effective approach. Further, in traditional contracting practices, the contractor is not financially responsible for any negative impacts the work being performed has on traffic flow and user delay.

In facility leasing, a private entity would have total pavement responsibility during a specified time period which may span decades. This type of agreement includes minimum standards the owner expects of the facility during that time. Any maintenance, rehabilitation, or reconstruction during the concession agreement is funded by the lease holder and their funding comes from investors and tolls. This is a very different business dynamic in which construction contractors will be accountable to multinational firms and investment banks.

Maintenance contracting and facility leasing are innovative methods to remove pavement expense and responsibilities from the agency and assign them to the private sector. It has been shown that the use of these approaches can save time and money, reduce user costs and make agency personnel available for other activities.

Background

Agencies commonly perform pavement maintenance with their own workforce. This can be very time consuming as well as equipment/ labor intensive and may not be cost-effective. Other agencies award their maintenance activities using traditional contracting methods. This type of contract administration approach can be time consuming for the agency contracting personnel due to the significant number of maintenance contracts that must be let during the life of a typical pavement. Either of these approaches can be problematic for an agency, especially in an environment where both maintenance and contracting workforces are being downsized. Agencies may consider the option of using a maintenance contracting approach, where a contractor is given total responsibility for the maintenance of a section of pavement for a specific period of time (for example, five years). This allows agency resources and personnel to perform other functions and allows the contractor to use innovation to perform the activities more efficiently.

Agencies may also consider adoption of a facility leasing approach. In the short term, it is being advocated as a way for agencies to turn liabilities (infrastructure costs) into assets (concessionaire payments). This method of maintaining pavements could pose an impact on the asphalt construction industry, and a study to document these potential impacts is needed. Guidance is needed for best practices for setting up these agreements to protect the public interest.

For either maintenance contracting or facility leasing, it is critical to include specific content in the contract language. These types of innovative contracts are typically based on pavement and user cost performance standards that must be maintained throughout the project. A research study is needed to provide a best practices document with information and guidance for the use of maintenance contracting and facility leasing by agencies.

Scope/Objectives

Develop a document that provides guidance to policy makers, administrators, and agency personnel on contract content and performance standards for maintenance and facility leasing contracts. A "Best Practices" document should be developed and implemented.

Work Plan
Task 1. State-of-the-Practice

Determine the state-of-the-practice related to maintenance contracting and facility leasing for HMA pavements. Surveys will be conducted with agencies that have used these contracting methods will be done. Projects of this type that have been or are being used will be evaluated. Contract language and performance standards used will be analyzed for effectiveness. The cost effectiveness and advantages/disadvantages of these approaches will be summarized.

Task 2. "Best Practices" Document

Based on the findings of Task 1, determine the most effective contract content, performance standards and other critical components to be included when using either of these contracting approaches. Develop a document that describes best practices and offers guidance that is applicable to policy makers, administrators as well as contracting personnel. The document should also provide insight into the cost-benefit as well as positive and negative implications of adopting these contracting approaches.

Task 3. Implementation

The research study should include an extensive effort to implement the findings of the study and encourage use of the Best Practices document. Specific methods to accomplish implementation should be recommended as part of the research study but should include presentations at conferences for policy makers, administrators and agency contracting and construction/maintenance personnel. Also, education and training materials should be developed around the produced document.

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Program Seven: SURFACE CHARACTERISTICS

<u>Projects in Program Seven</u>

Project 7.01	**High Friction Surfaces**
Project 7.02	**Pavement Noise Reduction**
Project 7.03	**Mix Types to Improve Friction and Mitigate Noise**
Project 7.04	**Economics of Pavement Smoothness**
Project 7.05	**Advanced Surface Characteristics Model**
Project 7.06	**Safety-Driven Pavement Surface Type Selection**
Project 7.07	**Thin Lift Surfaces**

Program Seven
Surface Characteristics

Introduction

The driving public expects a roadway to be smooth and to have good friction characteristics (when needed) to stop or control a vehicle. Smoothness specifications have improved the ride quality of pavements as initially constructed. Adequate funding for rehabilitation and maintenance of pavements will ensure that satisfactory levels of smoothness will be maintained during the life of the pavement.

Friction between the tire and the pavement is required to ensure relatively short stopping distance and to maintain vehicle control. Since friction decreases dramatically when pavements become wet, it is important that wet pavement friction be considered as the primary item of concern to the designer of both the pavement structure and mixture and to the driving public. This program is focused on friction-related issues.

The increased emphasis on safety during the 1980s created awareness among public agencies to provide pavements with initial high friction and friction values that remain high during the life of the pavement. High friction values on dry and wet pavements have thus become an important design consideration.

Technology exists which allows the design of pavement with good friction characteristics. The surface mixtures used on pavements to ensure high and lasting friction are often expensive and difficult to place and control. HMA mixtures for friction courses must be economical, capable of being placed in thin lifts, designed with good prediction tests for friction and mixture properties, and placed under QC/QA specifications that ensure a quality product.

Other issues related to asphalt pavement surface characteristics that are of great importance to the driving public are increased visibility and reduced surface splash/spray when water is on the pavement, reduced tire-pavement noise and improved pavement smoothness. This program contains projects directed at improvements in those areas.

Background

A significant amount of research was performed in the 1970s and early 1980s to understand the physics of tire-pavement interaction, and to develop surface course mixtures that provided high initial and long lasting friction. Aggregate selection criteria were changed to avoid the use of polishing aggregates in surface courses. The importance of pavement micro texture (aggregate surface texture) and macro texture (pavement texture) was recognized. Aggregate selection criteria included the need for crushed aggregates and more open graded HMA mixtures were developed (open graded, gap graded, SMA, etc.) as a result of this research.

The technology developed in the 1970s and 1980s has served the driving public well. As traffic volumes increase, aggregate supplies decrease, and materials costs increase, there is a new awareness for the need for improved HMA mixtures that will satisfy surface demand for the future.

Research is needed to develop improved mixes and construction techniques for thin lift applications, for design and construction of high friction surfaces, to develop a relationship between smoothness and user costs, and to improve ways of measuring roughness.

Limited research exists which relates pavement smoothness or ride quality to user costs. Relationships that are presently used in life cycle costing programs are based on limited data and are not well defined relative to user costs incurred by the driving public and to business including trucks. Likewise, little research has been performed which attempts to relate pavement smoothness (both initial and long term) to pavement performance. The increased damage to pavements resulting from dynamic truck loads on rough roads may be significant in terms of pavement life. This relationship needs to be quantified and used as an input for determining pay adjustment factors for pavement construction including HMA surfaced pavements.

Scope/Objective

Develop design methods, Quality Control/Quality Assurance guidelines, and performance relationships for mixes to improve surface characteristics (friction and smoothness) of HMA pavements.

Program 7: SURFACE CHARACTERISTICS

Project 7.01 High Friction Surfaces

Objective: Develop improved materials selection, mixture design methods and QC/QA for high friction surface course mixtures. Validate findings of NCHRP 1-43 and 1-29 related to lab testing, mix design and QC/QA procedures

Introduction

Friction between the tire and the pavement is required to ensure relatively short stopping distance and to maintain vehicle control. Pavements need to be constructed with high initial friction and with adequate friction maintained over the life of the pavement. A variety of aggregate specifications and mixture specifications have been developed over the years to provide the desired levels of friction. Many of these mixtures and the aggregates have become expensive and are difficult to place and maintain in certain environments. Improvements in materials selection, mixture designs and QC/QA practices are needed to produce mixtures that are economical, that can be placed in relatively thin lifts and that maintain adequate friction over the life of the pavement.

Background

A significant amount of research was performed in the 1970s and the early 1980s that allowed for the fundamental understanding of tire-pavement interaction and the development of high friction mixtures. Examples of these high friction mixes are open graded, gap graded, coarse aggregate and Stone Matrix Asphalt mixtures. Materials selection criteria, laboratory mixture design methods, and QC/QA procedures for these mixtures are based on limited research. Improved materials selection, mixture design methods and QC/QA procedures are needed. The developed techniques should be based on Superpave technology and test methods.

Scope / Objectives

Develop improved materials selection, mixture design methods and QC/QA procedures for high friction surface course mixtures (SMA, OGFC, gap graded, etc.)

Work Plan
Task 1. State-of-the-Practice

The state-of-the-practice relative to high friction surface course mixtures will be reviewed together with Superpave technology and test methods.

Task 2. Improved Material Selection

The selection of the asphalt binder and aggregate for high friction surfaces must consider stability, durability and friction among other factors. Modified binders may improve stability and durability of the mixture. The use of highly crushed aggregates may improve stability and allow thicker films of asphalt binders that will improve durability. These and other considerations, including constructability, will be explored to provide improved material selection criteria for the ingredients in high friction surface HMA mixes.

Superpave technology will be used to define the material selection criteria. Improved test procedures for determining the friction characteristics of aggregates and mixtures may have to be developed as part of this task.

Task 3. Improved Mixture Design

Develop improved laboratory mixture design techniques for open-graded friction courses, gap-graded coarse aggregate mixtures and Stone Matrix Asphalt mixtures.

Task 4. Field Tests

Use the mixture design techniques developed in Task 3 on field projects. These projects will be selected to ensure a range of mixture types and project environments. The developed test methods will be used for mixture design and field QC/QA.

Task 5. Implementation Manual

Develop an implementation manual which contains the materials selection criteria, mixture design methods, the test methods and the QC/QA specifications necessary to design and construct high friction surface course mixes. The developed information will be suitable for use in public agency specifications.

Program 7: SURFACE CHARACTERISTICS

Project 7.02 Pavement Noise Reduction

Objective: Evaluate noise characteristics of materials and tests to measure noise.

Introduction

Noise originating from roadways is a problem that has received increased public attention during the last two decades. The two major sources of noise on highways are those associated with the vehicle (power generation and wind noise) and tire-pavement interface.

Public concern about noise has necessitated the installation of sound wall, plantings and other noise mitigation treatments near highways. The cost of these installations is high and alternative treatments that are more cost effective are needed. Noise originating from vehicles is being addressed truck manufacturers. An increased effort in vehicle sound mitigation is needed; however, this problem statement is only concerned with the noise generated form the tire-pavement interface.

The highway community needs to determine the noise levels associated with different types of pavement surfacing materials. Laboratory tests need to be developed that can be used to predict noise levels on installed pavements. The development of laboratory tests which simulate or predict actual pavement noise will allow for the development of pavement surfacing materials that will reduce tire-pavement noise.

Background

Noise generated on highways has been measured in Europe, Japan and the United States. The European and Japanese activities have been longer term and hence more measurements exist. Studies in the United States have been conducted in Oregon and California among other states and, in general, have been associated with the use of open graded friction courses and their ability to reduce noise.

Open graded friction courses with 20 percent and higher air void contents have the ability to reduce noise by 3 to 5 decibels (dBa). This amount of noise reduction is equivalent to a traffic reduction of 50 percent or a 100 percent increase in protective distance from the roadway for a given noise level. The retention of noise reducing characteristics under traffic also needs to be studied. Pavements that can retain these characteristics over an extended service life are needed.

The development of Hot Mix Asphalt (HMA) paving mixtures with the ability to attenuate noise will result in an economic savings. If quieter pavements can be developed and utilized, roadway sound walls and other types of treatments to reduce noise near highways may not be necessary.

Accurate determination of noise levels generated from the tire pavement interaction needs to be better defined for existing pavements. Also, laboratory testing techniques need to be developed which will allow the testing of HMA materials during design to determine their noise attenuation capability.

Scope / Objectives

Evaluate noise characteristics of pavement materials and tests to measure noise, including defining the levels of noise generated by the tire-pavement interface, developing HMA surface mixtures to reduce noise and developing laboratory test methods to predict noise levels of in-service pavements.

Work Plan
Task 1. State-of-the-Practice

The state-of-the-practice relative to field measurements of highway noise on different types of pavement surfaces needs definition. Measurements and measurement techniques in Europe, Japan and the United States need to be summarized. The literature search should also address the laboratory measurement of noise generated from different types of pavement surface materials. The existence of correlations among laboratory measurements of noise and actual field measurements is important.

Task 2. Field Measurements

Field measurements of highway noise and, in particular, tire-pavements noise will be made on a number of pavement surfacing materials including dense, open, gap graded and SMA Hot Mix Asphalt as well as joint-plain, jointed-reinforced and continuously reinforced Portland Cement Concrete pavements. These measurements should be made on pavements of different ages and different levels of surface texture and air void contents. Samples of the pavement surface materials will be obtained from these pavements and will be used in Task 3 of the research program.

Task 3. Laboratory Tests

The most promising laboratory tests identified in Task 1 and/or tests that will be developed in this task will be used to define tire-pavement noise levels. When adequate correlations among laboratory tests and field noise levels have been established, improved HMA mixtures capable of reducing noise levels will be developed.

Task 4. Field Tests

The most promising HMA mixtures that reduce noise will be placed and evaluated in the field. Constructability, durability and the ability of these new mixtures to reduce noise both initially and over the long term will be evaluated. Also, field noise measuring devices will be tested during field trials and the test results from various devices will be compared to lab testing results to validate the results.

Task 5. Implementation Manual

An implementation manual describing the design, construction and noise mitigation of HMA surface mixtures will be developed. The manual will also describe the laboratory and field measuring techniques associated with determining noise levels on highway surfacing materials. Cost savings associated with the use noise reducing surfacing materials will be described in the implementation manual.

Program 7: SURFACE CHARACTERISTICS

Project 7.03 Mix Types to Improve Friction and Mitigate Noise

Objective: Develop a recommended practice for hot mix asphalt mixtures that can be used to provide an acceptable level of friction as well as noise mitigation

Introduction

As traffic volumes increase on our nations highways, the demand to reduce accidents and reduce noise on the pavements becomes more important. Surface friction associated with pavements has been a topic of considerable study since the 1970's. The importance of aggregate properties as well as aggregate gradation and asphalt binder contents has been defined. Friction numbers as a function of speed and under wet conditions need to have lower limits to provide adequate safety for the driving public.

Increased traffic volumes and the expansion of our urban areas has created a conflict between highway transportation needs to move people, goods and services and the noise associated with this transportation and adjacent property owners. Both commercial business and private home owners are becoming increasingly aware of the noise caused by transportation vehicles on our roads, streets and highways.

Over the last several decades friction and noise mitigation have become highway design considerations. Typically highway designers require that pavement surfacing materials maintain a friction value above a selected value as measured by a standard friction measuring device. In addition, highway designers will utilize barriers (sound walls or earth berms) or design elevated or depressed roadway segments to reduce noise in commercial or private housing areas. These practices are expensive and alternative methods for reducing noise from our highways are needed. The use of pavement surfacing materials to provide friction and decrease the tire/pavement contact noise and vehicle noise (engine and air movement) has become common in selected European countries as well as some states in the United States

The design of hot mix asphalt pavement surfaces must include consideration for both friction and noise mitigation. These two requirements are intrinsically tied together from a materials selection and design standpoint.

Background

Hot mix asphalt surfacing materials have been developed in Europe and the United States to provide friction and reduce the noise associated with highway vehicles. The European technology appears to be more advanced than the current technology available in the United States in this field. A Federal Highway Administration/industry scanning tour was conducted in 2005 to better understand European technology and practices. In addition, research conducted at NCAT and by several states including Arizona has provided information relative to hot mix asphalt materials that can be used to provide both friction improvement and noise reduction initially and over a performance life of several years.

Scope/Objectives

Develop a recommended practice for hot mix asphalt mixtures that can be used to provide an acceptable level of friction as well as noise mitigation. This recommended practice should include materials selection criteria, mixture design methodologies, construction practices and maintenance practices for these materials.

Work Plan

Task 1. State of the Practice

The state of the practice should be determined from reports generated by the FHWA/industry scanning tour, the Purdue Conference on noise mitigation and measurement, NCAT and various state reports associated with friction and noise reduction. The FHWA position on noise mitigation should be reviewed and the technical basis for the position understood. Visits should be made to selected European countries as well as selected states. NCAT measuring technology as well as information collected at the test track and at various states should be reviewed.

Task 2. Friction and Noise Measuring Systems

Several techniques are available to measure friction and noise in close proximity to the tire/pavement interface as well as variable distances from the vehicle. These measuring systems and criteria for friction and noise levels should be summarized.

Task 3. Mixture Design

A materials selection and mixture design system for hot mix asphalt surfacing materials should be developed. The system must be capable of providing mixtures with long lasting friction and noise reduction using both laboratory and field research. The field research should verify the laboratory studies relative to friction and noise mitigation as well as performance.

Task 4. Construction and Maintenance Practices

A construction and maintenance practices document should be prepared based on the best technology currently available.

Task 5. Recommended Practice

A recommended practices document will be prepared based on the completed tasks. This recommended practice should contain all design details, mixture design methods, construction methods and maintenance methods and supporting test methods in AASHTO/ASTM formats.

Program 7: SURFACE CHARACTERISTICS

Project 7.04 Economics of Pavement Smoothness

Objective: Develop benefit/cost relationships for pavement smoothness.

Introduction

Pavement type selection and the selection of reconstruction, rehabilitation and maintenance alternatives are becoming more dependent upon the use of life cycle cost analysis (LCCA). LCCA often contain provisions for the inclusion of agency costs, user costs and non-user costs. Public agencies are interested in including user costs in these analyses but do not have good methods to rationally determine those costs. One of the significant user costs is associated with pavement smoothness and vehicle repair costs.

The Hot Mix Asphalt (HMA) industry offers public agencies reconstruction, rehabilitation and maintenance alternatives that can reduce user costs by constructing pavements that are initially smooth and that retain smoothness over a long period of time. Smooth pavements reduce vehicle operating and repair costs.

The development of good user cost models with rational determination of the effects of pavement smoothness on vehicle operating and maintenance costs will create larger markets for reconstruction, rehabilitation and maintenance techniques that provide initially smooth pavements and retain a high level of smoothness over long periods of time. Data is needed to relate varying degrees of pavement smoothness with user vehicle operating costs and agency maintenance costs.

Background

The AASHO Road Test provided a relationship between pavement smoothness and pavement performance that has been used since the early 1960s for pavement design purposes. The relationship between pavement smoothness and user costs has been defined by limited research. The literature, including NAPA Report IS-111, Pavement Smoothness, defines available information. These data suggest relationships between smoothness and the following: long-term pavement performance, time prior to rehabilitation, roadway safety, vehicle operating speed, braking friction, vehicle steering/control, driver's ability to collect information and perform motor skills, driver comfort and annual vehicle and pavement maintenance costs. There is also a cost associated with obtaining improved pavement smoothness.

Additional research needs to be performed to define relationships among initial pavement smoothness, long term smoothness and agency and user costs. Based on the findings of the research, a benefit/cost relationship for pavement smoothness should be developed.

Scope / Objectives

Develop benefit/cost relationships for pavement smoothness.

Work Plan

Task 1. State-of-the-Practice

The state-of-the-practice relative to pavement smoothness and costs as well as the relationship between initial pavement smoothness and long-term smoothness will be defined. Literature contained in NAPA Report IS-111 will be used as a starting point. Information will be collected worldwide.

Task 2. Initial and Long-Term Smoothness

Collect data related to both short and long term pavement smoothness for HMA pavements. Define the relationship between initial and long-term smoothness for a variety of HMA pavement types and initial pavement smoothness values. Collect data related to the cost and benefits of pavements with various initial smoothness values. This study will use roughness and pavement performance measurements in State DOT records as well as agency and user cost data available from the Long Term Pavement Performance study and appropriate test track data. Evaluate existing benefit/cost relationships that have been developed in previous research efforts.

Task 3. Roughness and User Costs

Existing relationships between pavement roughness and agency/user costs will be determined. User costs will be expanded to include different vehicle types and pavement roughness. Information from car, truck and tire test tracks will be obtained from cooperating industries.

Task 4. Summary Report /Implementation Manual

A summary report that includes the findings of this research will be developed. The report will include the results of the benefit/cost study and will define the relationships among initial and long term pavement smoothness and agency/user costs. In addition, a manual to provide guidelines that will assist with implementation of the findings will be developed.

Program 7: SURFACE CHARACTERISTICS

Project 7.05 Advanced Surface Characteristics Model

Objective: Develop advanced models relating 3-Dimensional images to pavement surface characteristics, specifically noise and spray.

Introduction

The driving public expects smooth and safe pavements. They also have other expectations, including pavements that are quiet and allow visibility during rainfall. Many of these pavement performance features are directly related to the surface characteristics of the pavement. Therefore, public agencies are putting more emphasis on designing and constructing pavements that provide at least adequate pavement surface characteristics and in many cases are interested in obtaining exceptional surface characteristics.

Some of the most important surface attributes are friction, splash and spray and tire-pavement noise levels. Studies have shown that Hot Mix Asphalt (HMA) pavements that are properly designed and constructed can provide outstanding performance in each of these areas. Pavement engineers understand that surface texture and the void structure of HMA pavements are important considerations in developing pavements that will meet surface characteristic requirements.

The goal of pavement engineers is to design and construct HMA pavements that provide sufficient stability to support expected vehicle loadings, are durable enough to provide long life and have adequate surface texture to provide desired friction, noise and splash and spray characteristics. These expectations are obtainable with standard dense-graded and gap-graded HMA mixes. Design and construction procedures to achieve adequate surface characteristics with these surface mixes are well understood. However, in some applications designers want mixes that can provide enhanced friction, noise and splash and spray characteristics. In these cases, specialty mixes can be used on the pavement surfaces that are specifically designed to provide the high levels of these surface characteristics. Open Graded Friction Courses (OGFC) and other porous friction courses that are designed to drain water from the roadway surface to reduce splash and spray, provide significant tire-pavement noise reduction and outstanding friction resistance are being used routinely by many public agencies. A greater understanding of how to evaluate the surface characteristics of both laboratory-produced and in-place pavements is needed. Research is needed to answer some key questions in this area.

Background

Research is needed to identify and measure pavement surface features that relate directly with friction, noise, and splash and spray performance. The research must include modeling to understand the relationship of materials selection, mix types, mix design and construction practices that affect surface texture. It should also include a study of the relationship between specific surface texture features and performance characteristics like friction resistance, reduction in splash and spray and reduction in tire-pavement noise levels. Test methods that can quickly and accurately measure surface texture features on lab specimens and on in-situ pavements are under development.

A technology that is being developed and used in many aspects of HMA pavement technology is 3-Dimensional imaging, which may be of special interest in the measurement of surface texture features and characteristics. The advanced modeling research to be conducted in this project should include an analysis of how 3-dimensional imaging technologies can be related to pavement surface characteristics, specifically noise and splash and spray. Field studies should be performed to verify the models and evaluate the use of 3-Dimensional imaging technology to measure surface texture and predict performance in these areas.

Scope / Objectives

Develop advanced models relating 3-Dimensional images to pavement surface characteristics, specifically noise and spray.

Work Plan
Task 1. State-of-the-Practice

The state-of-the-practice related to improved surface characteristics of HMA pavements will be evaluated. The relationship between materials selection, mix type selection, mix design, construction practices, surface characteristics and pavement performance will be evaluated. Existing and proposed test methods for measurement of surface features and characteristics will be studied. Advanced modeling of the relationship between test equipment / methodology and friction resistance, tire-pavement noise and splash and spray will be included. In particular, the use of 3 dimensional imaging technologies to measure surface characteristics will be reviewed.

Task 2. Laboratory and Field Tests

The most promising findings related to design and construction, as well as test equipment will be evaluated. Design and construction procedures will be evaluated to validate that desired surface characteristics are obtained. Test equipment, including 3-dimensional modeling equipment, will be evaluated in the lab and field to confirm relationships between test results and pavement surface characteristics and performance related to friction resistance, tire-pavement noise reduction and splash and spray reduction.

Task 3. Recommended Practice

A recommended practice document will be prepared based on the completed tasks. This recommended practice should contain all design details, mixture design methods, construction methods and maintenance methods and supporting test methods in AASHTO / ASTM format.

Program 7: SURFACE CHARACTERISTICS

Project 7.06 Safety- Driven Pavement Surface Type Selection

Objective: Develop surface HMA mix selection guidance to enhance overall safety.

Introduction

Many public agencies use written pavement selection guidelines to assist designers in selection of appropriate mix type, design criteria and construction specifications for a given situation. These guidelines are based on the assumption that specific engineering and functional properties are needed depending on environment, traffic loadings and whether the HMA mix will be used as a base, intermediate or surface application. Unfortunately, many of the current guidelines need to be improved to put more emphasis on safety considerations for HMA surface mixes. There is a growing concern that many guidelines do not properly balance engineering and functional properties related to safety with those related to stability and durability.

Background

Hot Mix Asphalt (HMA) pavements can be designed to serve in a multitude of traffic and environmental conditions, demanding that the materials and design meet specific engineering and functional properties that are appropriate for the intended use. HMA mixes can be used as base mixes, as intermediate mixes or as surface mixes. Because they are intended to provide a specific function in the pavement structure, each mix type requires different engineering and functional properties.

For instance, base and intermediate mixes must have adequate stability to provide strength for support of the subsequent layers. They must also be durable to resist premature aging, moisture damage and cracking. Surface mixes have additional functional property requirements because they must also provide the driving surface for the pavement structure. Not only do surface mixes need to be stable and durable but they must provide a safe pavement surface. A safe driving surface is one that has adequate friction resistance in either dry or wet roadway conditions. Another desirable surface mix characteristic that is related to safety is the ability to reduce the amount of splash and spray from vehicle tires during heavy rainstorms. Excessive water splash and spray can create visibility problems which compromises the roadway safety. Some surface mixes are designed to drain water from the roadway surface through an open void structure in the HMA layer.

This project is needed to create new HMA pavement selection guidelines that properly balance engineering and functional pavement properties related to safety (like friction resistance and splash and spray) with other necessary properties for surface mixes.

Scope / Objectives

Develop surface HMA mix selection guidance to enhance overall safety by balancing the functional property requirements of the pavement surface.

Work Plan
Task 1. State-of-the-Practice

The state-of-the-practice relative to the mix type selection guidelines for HMA surface mix applications needs to be developed. Specific attention should be given to the degree that safety-related properties such as pavement friction and splash and spray are considered for surface mixes as well as traffic, environment and performance life of the pavement. This information should be obtained from a combination of literature review, interviews and survey of both private and public organizations in the HMA Industry. Determine if current guidelines properly balance safety related properties for safety mixes.

Task 2. Draft Guidelines

Based on the findings of Task 1, develop revised surface mix selection guidelines.

Task 3. Field Tests

Evaluate the effectiveness of the guidelines based on the use of the revised guidelines for pavement selection on actual projects.

Task 4. Implementation Manual

An implementation manual will be prepared to assist the pavement engineer in selection of HMA surface mixes that put a balanced emphasis on safety-related pavement properties. The information will be presented in a user-friendly format to ensure that the document will be routinely used for pavement selection.

Program 7: SURFACE CHARACTERISTICS

Project 7.07 Thin Lift Surfaces

Objective: Develop improved mixtures and construction techniques for thin lift surface construction.

Introduction

Thin lifts of Hot Mix Asphalt (HMA) are often used for preventive maintenance operations as well as to rehabilitate pavements when budgets are limited or funds are not available to properly rehabilitate or reconstruct a roadway. The performance of these thin lifts varies considerably depending upon the type of pavement on which the overlay is placed, the traffic volume, the environment and the construction practices used.

Thin lifts of HMA would be more widely used by public agencies if some of the performance problems could be avoided. The risk of early performance problems with HMA thin lifts is lower than other types of preventive maintenance alternatives such as chip seals and slurry seals. In addition, thin lifts have the potential to improve ride quality of a pavement more so than other preventive maintenance alternatives and to add structural capacity to pavements.

Background

Public agencies have used thin lifts of HMA for years. Typically, these mixtures contain a smaller maximum aggregate size and have lower stability than conventional HMA. Construction quality is often below that desired and expected life cycles are lower than conventional HMA materials. One reason may be that contracts are often administered by maintenance personnel that have limited equipment and workforce for quality assurance purposes. Improved thin lift mixtures and construction techniques are needed to prolong the life of this type of construction and maintenance.

Scope / Objectives

Develop improved mixtures and construction techniques for thin lift construction and maintenance applications.

Work Plan

Task 1. State-of-the-Practice

The state-of-the-practice relative to thin lift mixture design and construction will be evaluated. Asphalt binder and aggregate selection and mixture design tests will be considered. Construction practices to achieve improved smoothness and density will also be reviewed.

Task 2. Materials Selection and Mixture Design

Thin lift surface mixtures must have both initial and long term friction as well as adequate stability and durability. Materials selection criteria for binders and aggregates may have to be different for these thin lifts as compared to conventional HMA materials. Stiff binders -including binder modification-and aggregates of reduced maximum size, rough surface texture and increased angularity are some of the factors that should be considered in developing improved thin lift mixtures. Superpave test methods should be used for the design of these mixtures.

Task 3. Construction Practices

The construction practices associated with thin lifts may have to be altered and/or specialized equipment developed. Thin lift construction problems including underlayer considerations, density and smoothness should be addressed in this task. Field projects will be placed using the improved materials selection and mixture design techniques and the construction guidelines.

Task 4. Implementation Manual

An implementation manual will be developed which contains the improved mixture design methodology and construction guidelines including Quality Control/Quality Assurance approaches. The developed information will be suitable for use in public agency specifications.