NATIONAL ASPHALT ROADMAP

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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, and
National Stone, Sand, & Gravel Association.

INTRODUCTION

In the United States (U.S.), public agencies spend approximately $100 billion each year for highways. These costs are for planning, design, construction, rehabilitation, maintenance of our nation's highways. The total expenditures for asphalt pavement surfaces are in excess of $15 billion annually and over 300,000 men and women are employed in the asphalt industry.

Of the 4 million miles of pavements in the U.S., 2.3 million miles are paved and approximately 94 percent of the paved miles have an asphalt surface. Many of our highways have exceeded their design life and will require reconstruction, rehabilitation, and maintenance in order to continue serving the needs of the U.S. economy and the traveling public. Asphalt is the predominant material in any pavement construction, reconstruction, rehabilitation and maintenance project.

The asphalt community, (government agencies, industry, and academia), understands how important this product is to the nation's transportation system. Because of this enormous impact on the U.S. Economy, the asphalt community continually strives to improve the quality and performance of asphalt pavements. This includes the materials being produced and the research performed to solve problems relating to use of our products.

The asphalt community understands how important this product is to the nation's transportation system. Because of this enormous impact on the U.S. Economy, the asphalt community continually strives to improve the quality and performance of flexible pavements. This continuous quality improvement includes the materials being produced and the research performed to solve problems relating to the use of the product.

The asphalt industry is committed to ongoing involvement with the Research and Technology (R&T) community in order to stay abreast of developments in R&T and to have input into the research project development system to ensure asphalt industry needs are considered in the evaluation process. The overall goal is to focus research, development and implementation activities on improving the quality and performance of asphalt pavements. The step of implementation of research products has been sorely missing in many cases in the past. Research and development without appropriate implementation is futile.

Joint discussion of research needs and objectives will improve the performance of asphalt pavements. Research accomplished in a collaborative mode is more easily implemented and reaps far greater gains than research done by any individual group. With agency and industry working together to identify, develop, and implement research programs, the potential for success of the work is greatly improved. Implementation of the research products also becomes much more easily accomplished.

Background

In order to meet future technological needs, the asphalt community must be positioned to take advantage of research within the overall pavement community and to ensure that the needs of both private and public sector are addressed. Historically, agencies have had research departments which were charged with addressing specific technical issues for the agency. There has been a wide range of research performed using the State Planning and Research (SPR) funding mechanism. In general, the private sector has had little or no input into projects developed using this funding mechanism.

In 1994, the National Asphalt Pavement Association (NAPA) convened a Forum to determine a course of action in the research and technology arena that would permit private sector input to research needs. Some key observations were made at the Forum:

- Since research activities in the U.S. are highly decentralized, coordination of activities would be beneficial to the industry.
- Implementation of research results does not always occur in a systematic and timely fashion.
- All agencies are exploring ways to increase private sector participation in the R&T process, but few ideas have been identified and implemented.
- There is no structured mechanism for private sector input into the process for developing R&T needs.
- Opportunities exist for the private sector to partner in R&T issue identification and prioritization.
- The majority of highway funding for R&T comes from either the individual State Departments of Transportation, FHWA, or AASHTO (TRB manages AASHTO’s NCHRP effort.)

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

- The highway industry is large.
- The economic impact of the industry is great.
- Administration of the highway system is decentralized.
- Dispersed private companies provide essential products and services.
- The highway industry provides few incentives for innovation.
- The highway industry has a “low-tech” image.
- Highway spending is substantial.
- The highway industry is now redefining its mission in the post-interstate era.

As a result of the NAPA 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 that will 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 research projects identified.

Improving Flexible 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 community is committed to continuously improve the performance of asphalt pavements. An on-going research and technology implementation program is vital to address unresolved technical issues in the industry.

The Strategic Highway Research Program (SHRP) brought focus to the research and technology needs of the asphalt community. However, most of the SHRP effort centered on discrete, relatively small projects. Significant progress in asphalt pavements technology can only be achieved through a nationally coordinated effort to complete major projects. There is no current "mega" effort to solve the major issues relating to asphalt pavements. Such an effort is necessary to leave a strong legacy of technological advancement in asphalt pavement knowledge. Such a focused program for asphalt research should be based on broad intellectual competition, of substantial breadth and depth, and directed by a consensus of stakeholders. Potential "legacy" projects might include: long-life pavements, safe pavements, rapid construction technologies, accelerated pavement performance evaluation approaches, and implementation of proven technology.

The asphalt research and technology focus must be to develop and deliver improved asphalt pavement technologies that provide the public with safe, long-lasting, smooth pavements. These innovations will advance the nation's mobility and economic security while minimizing user inconvenience and environmental impacts.

The U.S. must address major transportation issues such as mobility, finance, safety, environmental awareness and workforce development. Moreover, there are many issues with which the asphalt community must contend. The purpose of this document is to identify improvements in the asphalt community which may be realized through advances in technology. In this document, specific program areas and projects will be identified and discussed. The following four themes are over-riding to all of the programs and projects. All research and technology activities within the industry should have these five themes as fundamental tenets.

- **Safety**
    - Safety is the number one criteria for the transportation system of our nation. People expect the roadways to provide a safe, comfortable traveling surface. This theme is and must be the first objective for all work done in the asphalt community.

- **Pavement Performance**
    - Asphalt pavements have been constructed for many years. Every effort must be made in the asphalt community to continually improve the quality, performance, and durability of pavements constructed. This includes material selection, design of both the mix and the pavement structure, proper construction of the pavement, and appropriate maintenance of the pavement. Quality is everyone's job!

- **Workforce Growth and Development**
    - The availability and knowledge of people to work in the asphalt community is a critical issue. Skilled workers are every agency's and organization's most valuable asset. Finding and retaining new workers has become extremely difficult. Most DOTs are downsizing and shifting responsibilities to the contractor. The transfer of responsibility from the public sector to the private sector will require contractors not only hire and retain employees with traditional construction management and trade skills, but also hire and retain employees with engineering skills for design, materials selection and operation and maintenance of transportation facilities.

- **Environmental Stewardship**
    - Everything the contractor does is subject to strict environmental scrutiny. Environmental issues today are inextricably linked with energy issues. The asphalt community has taken a proactive stance in environmental affairs, resulting in major accomplishments. Problem solving through partnerships has been and will continue to be the approach to handling upcoming challenges. The challenges on the horizon may be even more complex and more global in nature than those already completed.

- **Economics**
    - The cost of energy has heightened the consciousness on economic issues for the asphalt community. Without any question, this is the most critical issue facing the asphalt industry for the next many years. Agencies must determine how to construct and maintain their highway systems with dramatically increased material costs. Likewise the contractor must focus on how to produce at the lowest possible cost. All activities must be focused on producing a high-quality product at the lowest possible cost.

Based on the themes identified, the following program areas were identified:

- **Workforce Growth and 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**
- **Surface Characteristics**

In each of these program areas, specific project needs were identified using both agency and contractor requirements. The project descriptions are presented in the remainder of this report. The projects represent specific short- and long-term needs for the asphalt community. The programs and projects are expected to change as research is completed and industry priorities change. Each project description is written as a "stand-alone" effort. It is also recognized that this list will include projects already underway by others and that some projects may not be completed for several years.

This report clearly demonstrates the need for strong partnerships between agencies and private industry in order for asphalt pavement technology to advance. This document therefore provides a cornerstone in showing the asphalt community's ***commitment to the future in asphalt research and technology.***

SUMMARY OF PROGRAMS AND PROJECTS				
PROGRAM		**PROJECTS**		
NO.	OBJECTIVE	NO.	PROJECT NAME	OBJECTIVES
1	**Workforce Development**			
	Develop strategies to recruit, retain, and develop the HMA community workforce.	1.01	Workforce Growth	Develop and implement possible avenues for increasing the workforce in the asphalt community.
		1.02	Workforce Development	Develop venues for training existing workforce on current technologies
2	**Long-Life Pavements and Pavement Performance**			
	Verify and improve technology for long-life pavement structural design, materials optimization, life cycle cost analysis, and data collection techniques.	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	Document Performance to Date of Long-Life Pavements	Review existing pavements meeting Perpetual Pavement criteria to evaluate performance.
		2.03	Advance Understanding of Life Cycle Costs for Asphalt Pavements	Develop typical life cycle cost information and approaches for obtaining the information for asphalt pavements.
		2.04	Update User/Non-user Cost Data	Develop rational user and non-user cost information associated with HMA pavement applications.
		2.05	Refine and Validate Pavement Performance Type Specifications	Refine and validate performance type specifications for design and placement of asphalt pavements.
		2.06	M-E Design of Long-Life Pavements	Validate design values and criteria used in Perpetual Pavement design
		2.07	Fatigue Endurance Limits of Perpetual Pavement Designs	Validate fatigue endurance levels with a field experiment

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PROGRAM		**PROJECTS**		
NO.	**OBJECTIVE**	**NO.**	**PROJECT NAME**	**OBJECTIVES**
3	**Improved Structural Design of Pavements**			
	Develop improved design methods, which will optimize HMA mixtures to accommodate future changes in traffic and materials.	3.01	Validation and Refinement of Proposed M-E Design Guide	Validation and refinement of new mechanistic-empirical Design Guide currently being implemented under NCHRP 1-40
		3.02	Develop Pavement Structural Design Guide for Low-Volume Roads	Develop a simplified approach to structural design of low volume roadways
		3.03	Improved Structural Design for 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 on rubblized PCC during pavement rehabilitation projects.
		3.05	Development of Next Generation of M-E Design Systems	Develop improved M-E design methods.

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PROGRAM		**PROJECTS**		
NO.	**OBJECTIVE**	**NO.**	**PROJECT NAME**	**OBJECTIVES**
4	**Materials Characterization and Mix Design**			
	To develop test methods, specifications, and performance relationships, which will lead to optimization of materials and mix design for asphalt pavements.	4.01	Warm Mix Asphalt	Develop mix design method for Warm Mix Asphalt Technologies
		4.02	Accelerated Performance Testing	Develop improved laboratory tests and constitutive models to better predict pavement performance
		4.03	Full-scale Accelerated Performance Testing	Conduct full-scale APT to validate models and tests developed in Project 4.02.
		4.04	Improved Asphalt Binder Purchase Specification	Refine and validate the Superpave PG system for neat and modified asphalt binders
		4.05	Performance-Based / Related Aggregate Properties	Develop and validate performance-based aggregate characterization techniques for inclusion in the Superpave mixture design system.
		4.06	Recycled Materials	Identify and develop procedures and guidance for the effective and economical recycling of reclaimed/reprocessed materials (other than RAP)
		4.07	Improved Equipment & Test Procedures	Identify laboratory equipment & test procedures to increase automation and reduced variability
		4.08	Laboratory Workability Device	Develop a laboratory workability device to assess the compactability of the material in the roadway
		4.09	Field Versus Laboratory Volumetrics 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.
		4.10	HMA for Low Traffic Roadways	HMA mixture design approach with specific applicability to low traffic pavements where durability may be a more important characteristic than structural capability
		4.11	Development of Alternative Binder Materials	Identify and study alternative binder materials for use in flexible pavement mixtures

SUMMARY OF PROGRAMS AND PROJECTS				
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5	Construction Practices and Quality Management Systems			
	To develop construction practices to improve quality, increase productivity, improve safety, and extend pavement life.	5.01	Energy Efficiency	Identify and develop equipment, innovations/ improvements that will result in improved energy efficiency
		5.02	Recycling Technologies	Improve equipment and best practices to facilitate the incorporation of reclaimed asphalt pavement (RAP) materials into recycled HMA.
		5.03	Improved Construction Equipment & Procedures	Identify innovative laydown/compaction equipment and procedures that will result in improved quality and 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	Conduct research on real-time process control technologies for HMA laydown and compaction operations
		5.06	Non-Destructive Evaluation (NDE) for Process Control and QC/QA	Identify and conduct research on NDE Process Control and QC/QA tools
		5.07	Longitudinal Joints	Develop best construction practices for joint construction
		5.08	Develop a Fundamental Model for Field Compaction	Develop a model to better understand the compaction of HMA.
		5.09	Improve Risk Assessment of QC/QA Statistical Specifications	Standardize procedures and develop software to evaluate risk of a QC/QA statistical specification
		5.10	Smoothness Improvements	Evaluate new opportunities to reduce construction time, improve safety and improve project economics.

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	Develop Rapid Construction Methods	Develop and evaluate new opportunities to reduce construction time, improve safety, and improve economics while maintaining quality. Develop techniques to reduce lane occupancy time during placement of asphalt pavements.
		6.02	Risk Assessment of Non-Traditional Contracting Techniques	Evaluate the performance of projects built with innovative and/or non-traditional contracting to determine the economic risks to both the owner and contractor.
		6.03	Critical Review of Pavement Projects Built Using Non-Traditional Contracts	Evaluate the pavement performance of existing warranty projects and the cost/benefit of non-traditional projects, including the appropriate length and conditions of the warranty.
7	**Surface Characteristics**			
	To develop materials selection, design methods, quality control/quality assurance guidelines, performance relationships, and mix type selection for mixes to improve surface characteristics (friction, smoothness, splash/spray, noise) of HMA pavements.	7.01	Safety Driven-Pavement Surface Type Selection	Develop surface HMA mix selection guidance to enhance overall safety.
		7.02	Thin-Lift Surfaces	Develop improved mixtures and construction techniques for thin lift surface construction.
		7.03	High Friction Surfaces	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
		7.04	Economics of Pavement Smoothness	Develop benefit/cost relationships for pavement smoothness.
		7.05	Advanced Surface Characteristics Model	Developed advanced models relating 3-Dimensional images to pavement surface characteristics, specifically: noise and spray.
		7.06	Pavement Noise Reduction	Evaluate noise characteristics of materials/tests to measure noise.
		7.07	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 as well as noise mitigation

Program One

WORKFORCE DEVELOPMENT

<u>Projects in Program One</u>

Project 1.01   Workforce Growth

Project 1.02   Workforce Development

Program One
Workforce Development

Introduction

Government agencies and the asphalt pavement industry are 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 in private industry. The workforce issues include reductions in numbers, expertise and experience of people that are and want to work in career fields related to pavement. 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 well maintained and safe.

There are many reasons for the changes that are related to workforce, including major paradigm shifts in 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. In many cases, these issues coincide with increased funding for pavement related activities. This results in a smaller, less knowledgeable workforce trying to deal with an increased work load.

Background

The most obvious workforce problem can be seen at public agencies. 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 that can have immediate and long-term benefits are:

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

Government agencies are not the only member of the HMA community that is facing workforce issues. The private sector, including materials suppliers, paving contractors and the consultant community, 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.

One area of research should be geared specifically toward development and implementation of possible avenues for increasing the workforce in the asphalt community.

Scope / Objectives

The objective of this research program will be to study 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 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

Government agencies and the asphalt pavement industry are in the midst of unprecedented change from many directions.   Many of the most significant changes are related directly or indirectly to the workforce at both public agencies and in private industry. The workforce issues include reductions in numbers, expertise and experience of people that are and want to work in career fields related to pavement. 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 well maintained and safe.

There are many reasons for the changes that are related to workforce, including major paradigm shifts in 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. In many cases, these issues coincide with increased funding for pavement related activities. This results in a smaller, less knowledgeable workforce trying to deal with an increased work load.

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The same report goes on to recommend research efforts to study ways to deal with the 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 by the researcher in the NCHRP report that can have immediate and long-term benefits are:

(4) development of guidelines for and assistance to state DOTs in succession planning;
(5) an examination of programs for recruiting or developing information technology personnel; and
(6) an examination of programs for recruiting and retaining civil engineer and planning personnel.

Government agencies are not the only member of the HMA community that is facing workforce issues. The private sector, including materials suppliers, paving contractors and the consultant community, are also facing issues related to hiring and maintain 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.

One area of research should be geared specifically toward development and implementation of possible avenues for increasing the workforce in the asphalt community.

Scope / Objectives

The objective of this research project will be to study 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 in both public agencies and private industry. Specific strategies and venues to most effectively accomplish this workforce growth will be identified.

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

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

Task 2. Develop Strategies

Based on the findings of Task 1, identify and develop strategies for workforce growth.

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 grow the existing workforce in the asphalt community.

Program 1: WORKFORCE DEVELOPMENT

Project 1.02 Workforce Development

Objective: Develop venues for training existing workforce on current technologies

Introduction

Government agencies and the pavement building industry are in the midst of unprecedented change from many directions.   Many of the most significant changes are related directly or indirectly to the workforce at both public agencies and in private industry. The workforce issues include reductions in numbers, expertise and experience of people that are and want to work in career fields related to pavement. 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 well maintained and safe.

There are many reasons for the changes that are related to workforce, including major paradigm shifts in 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. In many cases, these issues coincide with increased funding for pavement related activities. This results in a smaller, less knowledgeable workforce trying to deal with an increased work load.

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The same report goes on to recommend research efforts to study ways to deal with the 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 by in the NCHRP report that can have immediate and long-term benefits are:

(7) development of guidelines for and assistance to state DOTs in succession planning;
(8) an examination of programs for recruiting or developing information technology personnel; and
(9) an examination of programs for recruiting and retaining civil engineer and planning personnel.

Government agencies are not the only member of the HMA community that is facing workforce issues. The private sector, including materials suppliers, paving contractors and the consultant community, are also facing issues related to hiring and maintain 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 development efforts should be focused on establishing and maintaining a well trained, professional workforce at all levels.

Ongoing training efforts are also necessary to develop and maintain a competent and knowledgeable workforce. One method of development and improvement of the workforce is through encouraging efforts to establish standards of professionalism, knowledge and practice. Well established mechanisms to accomplish this like professional registration, technician certification and laboratory accreditation are already in place in many government and industry organizations. These programs include extensive education and training efforts and require demonstrated understanding and competency in design, construction, inspection and acceptance procedures. Because these standards for professional knowledge, accomplishment and competence bring increased value to individuals and to the workforce in general, efforts to adopt them should be part of a strategy for workforce development.

In summary, research in this project area should be geared specifically toward development of the knowledge and expertise of the existing workforce in the asphalt pavement community. The focus of this research will to develop strategies for workforce development, including suggestions for development of effective venues for training and for increasing standards of professionalism in the existing workforce.

Scope / Objectives

The objective of this research project will be to develop the existing workforce. Specific strategies and venues to most effectively accomplish this training and development will be identified.

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

The state-of-the-practice related to addressing workforce issues will be evaluated. A specific focus of this project will be on development of the existing workforce.

Task 2. Develop Strategies

Based on the findings of Task 1, identify and develop strategies for workforce development.

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 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	**Document Performance to Date of Long-Life Pavements**
Project 2.03	**Advanced Understanding of Life Cycle Costs for Asphalt Pavements**
Project 2.05	**Refine and Validate Pavement Performance Type Specifications**
Project 2.06	**M-E Design of Long-Life Pavements**
Project 2.07	**Fatigue Endurance Limits of Perpetual Pavement Designs**

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 just 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 maintenance 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 are typically expecting 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 base 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 a large number or severity of 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 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 / Objective

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.

The concept of HMA mechanistic-empirical and mechanistic design methodology is being developed rapidly and these approaches are being adopted 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 empirical approaches are inadequate for design of rehabilitated pavements. Therefore, mechanistic methods need to be adapted and implemented by highway agencies to improve rehabilitation designs and, ultimately, to get better 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. 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 / Objective

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

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

State-of-the-practice related to Perpetual Pavement structural design for rehabilitation of existing rigid and flexible pavements will be evaluated.

Task 2. Laboratory and Field Tests

Identified design approaches and criteria will be evaluated using laboratory 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.

Task 3. Recommended Practice for Rehabilitation Structural Design

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 Document Performance to Date of Long-Life Pavements

Objective: Review existing pavements meeting Long-Life 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 was developed 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 / Objective

The objective of this project will be review existing pavements meeting Perpetual Pavement criteria to evaluate their performance.

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

The state-of-the-practice related to perpetual pavement design methods/criteria and performance of constructed perpetual pavements will be evaluated. A survey will be conducted of public agencies in the United States and other countries to identify perpetual pavement design procedure usage and performance of constructed perpetual pavements.

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. If practical, lab testing on pavement samples and/or non-destructive testing methods will be utilized to estimate stress / strain relationships in the pavement.

Task 3. Project Summary

A project summary document will be prepared based on the findings of this project. The document will include recommended practice for design and construction of pavements that meet the Perpetual Pavement criteria. The information will be in the presented in a format that will allow incorporation into specifications and standard test methods.

Program 2: LONG-LIFE PAVEMENTS / PAVEMENT PERFORMANCE

Project 2.03 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 in this theme) and life cycle cost analysis performed and summarized. User cost information needs to be better defined; however, this is not a task of this research project.

Scope / Objective

The objective of this project is to develop typical life cycle cost information for different types of pavements and different types of paving materials under different traffic volumes in different 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. Pavement life and cost information and user cost information will be summarized on a regional basis for inclusion in the life cycle analysis.

Task 2. Life Cycle Cost Determination

Determine both deterministic and probabilistic life cycle costs for different types of pavements and different types of paving materials under different traffic volumes in different environmental regions of the United States. Results will be presented to illustrate 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 calculations on a regional basis. Agency life cycle costs will be separated from user life cycle costs. 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 2.04 Update User/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 basic steps in most updated LCCAs. Since cost can vary considerably from one part of the country to the next, cost information that is appropriate and accurate for the traffic volume and materials used in the area of the country is essential. Therefore, cost data need to be obtained, analyzed and reported for different regions of the country and for different traffic volumes. Information for conventional dense-graded Hot Mix Asphalt (HMA) needs to be obtained as well as information on gap-graded, open -graded, Superpave and SMA mixtures. The cost of these mixes with both conventional and modified binders needs definition. Also, in order to be used most effectively, costs that are incurred by users of the roadway as well those that don't use the roadway but are affected by it must be developed and utilized.

Background

Cost information related to materials, production and placement activities can often be obtained from public agency construction and maintenance information management systems. Many agencies are now collecting and using this information since the use of LCCA is being encouraged and sometimes even mandated by funding agencies. These costs can differ dramatically depending on the type of construction activity that is performed. Therefore, costs associated with specific activities such as construction, rehabilitation or maintenance projects must be developed and historical records of costs for all construction activities must be collected and analyzed. In addition, these data will have to be reduced to a useful format to be included in the LCCA program. Detailed records of these costs must be kept that identify the specific materials and pavement types that were used on the project. Especially when different aggregate composition and binder grades are used, the cost of the pavement materials can vary considerably. For instance, the use of a polymer modified binder in a given HMA mixture can result in a significant increase in initial cost when compared to the same mixture where an unmodified binder is utilized but may result in extended life of the pavement.

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.

Scope/Objective

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

Work Plan
Task 1. Review Published Information

Information from national publications and internal public agency reports related to user and non-user cost estimation will be reviewed and summarized. It is anticipated that public agencies (state and local) will have to be contacted on an individual basis to obtain this information.

Task 2. Public Agency Visit

Public agencies will be identified and visited on a regional basis. 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.

Task 3. Summary Document

Prepare a summary document concerning estimation of cost information and sources to obtain developed information, including mean and variability information for cost of construction, rehabilitation and maintenance alternatives.

Program 2: LONG-LIFE PAVEMENTS / PAVEMENT PERFORMANCE

Project 2.05 Refine and Validate Pavement Performance Type Specifications

Objective: Refine and validate performance type specifications for design and placement of asphalt pavements.

Introduction

Currently, method specifications are the most commonly used specification approach used by highway agencies. Other specification types are being used more often, including warranty specifications, where pavement performance is measured after a predetermined time in service. However, there is a consensus that better approaches to specifications for design and construction of HMA pavements need to be developed and implemented. The most desirable specification type is performance-based or performance-related specifications that are based on performance predictions that can be made from tests and measurements made immediately after construction. These so called 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.

Background

Pavement engineers have long sought relationships between measurable material characteristics and pavement performance. If clear relationships can be determined, performance 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. Further research is needed to refine and validate the performance specifications based on these performance characteristics and to identify other performance characteristics.

Scope / Objective

The objective of this project will be to refine and validate performance specifications for design and placement of asphalt pavements.

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

State-of-the-practice related to materials performance characterization and the ability of these characteristics and their associated models to predict asphalt pavement performance will be evaluated. Existing performance specifications will be obtained and evaluated. Research efforts to refine and validate the performance specifications will be identified and studied.

Task 2. Conduct Laboratory Tests

The most promising laboratory tests identified in Task 1, 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. Based on the results of the testing, existing performance tests and criteria may be revised.

Task 3. Conduct Field Tests

The tests, measurements and criteria used in the performance specifications will be used on several projects. 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 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 2.06 Mechanistic-Empirical Design of Long-Life Pavements

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

Introduction

Experts in pavement design are generally of the opinion that empirical approaches are inadequate for design of 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 adapted 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-empirical and mechanistic design methods are being developed rapidly and these approaches are being adopted 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 that can be used for design of new pavement structures can also 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, 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. 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 sufficient 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

The objective of this research will be to validate design values and criteria used in Long-Life (Perpetual Pavement) structural design methods, including conducting field experiments to validate the recommended procedures.

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

State-of-the-practice related to M-E design protocol and the Long-Life concept of structural design and past and current research. 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 Experiment

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. 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 Long-Life structural design procedures.

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 and the design guide under development in NCHRP Project 1-37A, 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

The objective of this research will be to 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 Task 5. 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 Experiment

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, 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 Three

IMPROVED STRUCTURAL DESIGN OF PAVEMENTS

Projects in Program Three

Project 3.01 **Validation and Refinement of Proposed M-E Design Guide**

Project 3.02 **Develop Pavement Structural Design Guide for Low-Traffic Roadways**

Project 3.03 **Improved Structural Design for Heavy Duty Pavements**

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

Project 3.05 **Development of Next Generation of M-E Design Systems**

Program Three

IMPROVED STRUCTURAL DESIGN OF PAVEMENTS

Introduction

Hot Mix Asphalt (HMA) mixtures are expected to perform over 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 recognize this need and provide the tools to accomplish this objective for anticipated traffic loadings in the future. Pavement thickness design procedures must be able to accommodate the anticipated changes in traffic characteristics and the environment, mixture selection methods must provide the "tools" for the engineer to select the appropriate mix type to accommodate traffic and the environment for the application, and construction methods must provide for the preparation and placement of uniform mixtures that meet stringent specifications under varying 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 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. Few new roads will be located in environmental zones that presently do no contain pavements. Thus, the challenge of the next century is not to design HMA pavements for new or unusual environments, but to rehabilitate transportation facilities to carry different loading characteristics in vehicles that will be used in the future. In some cases, the pavements will be carrying extremely high volumes of heavy vehicle while, in other cases, pavements must be designed for low volume and rural areas.

To a great degree, the characteristics of heavy traffic loading on a given facility controls the pavement materials and thicknesses used. The characteristics of heavy traffic have significantly changed 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 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 of "super single" tire replacements for dual tire configuration on axles. These heavy vehicle changes are believed to be one of the significant causes of increased rutting on our nation's highways.

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.

The FHWA has a large research, development, and implementation effort devoted to Intelligent Transportation Systems. This effort is, in part, directed toward the development of intelligent vehicles which will be guided along a highway by electro-magnetic control systems. If this system is developed, the result will probably be more channelized traffic (less vehicle wander). The potential for channelized traffic create the need for pavement facilities and pavement mixtures that can withstand this type of traffic.

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 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 a consideration 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, 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 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 some of the changes in traffic characteristic expected over the next century.

Scope/Objectives

The objective of this program is to develop improved design methods, which will optimize HMA mixtures to accommodate future changes in traffic and materials.

Program 3: IMPROVED STRUCTURAL DESIGN OF PAVEMENTS

Project 3.01 Validation and Refinement of Proposed M-E Design Guide

Objective: Validation and refinement of 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 and which is based on mechanistic-empirical (M-E) principles was developed. The previous AASHTO Guide for Design of Pavement Structures was based primarily on empirical design procedures. Mechanistic-empirical 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) are planned to evaluate the design methodology and move it toward implementation. Several of the projects are currently underway.

Many pavement designers at state departments of transportation (DOT) 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 and ranges that have been verified with field data from different parts of the United States, and thus represents a nationally-valid analysis approach; these relationships could be refined to better reflect regional and 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 is an independent, third-party review to test the design guide's underlying assumptions, evaluate its engineering reasonableness and design reliability, and identify opportunities for its implementation 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 on the basis of 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 will be addressed in the NCHRP 1-40 A through J projects. Specifically, the 1-40 projects will accomplish some or all of the following tasks:

> *Task 1*. In coordination with FHWA, organize and convene workshops to acquaint state DOT personnel with the recommended guide and software.
> *Task 2*. Document error reports and user comments and suggestions from workshops and interactions with users of the guide and software that should be considered in their future enhancements.
> *Task 3*. Conduct a thorough, independent review of the guide and software to objectively assess the material contained in the guide, identify deficiencies, and recommend corrective measures, including short-term research activities (NCHRP Project 1-40A).
> *Task 4*. Develop step-by-step procedures for use by state DOTs to refine the performance models in the guide and software on the basis of local and regional conditions, materials, and practices (NCHRP Project 1-40B).
> *Task 5*. Provide technical support for installation and operation of the software by state DOT personnel and other users (NCHRP Project 1-40D).
> *Task 6*. Refine and upgrade the design software on a continuing basis (NCHRP Projects 1-40D and 1-40E).
> *Task 7*. Prepare a practical guide for mechanistic-empirical pavement design (NCHRP Project 1-40H).
> *Task 8*. Provide support for the Mechanistic Design Guide Lead States and related state DOT activities (NCHRP Project 1-40J).
> *Task 9*. Perform other tasks identified by the project panel and the AASHTO Joint Technical Committee on Pavements in support of the implementation and adoption of the guide and software.

After or during the completion of the tasks outlined in NCHRP 1-40 projects, there will be a need to validate and refine the structural design procedures and criteria based on the results of field testing of measured properties and performance of pavement structures designed with using the M-E concept.

Scope/Objective

The objective of this project will be the validation and refinement of new mechanistic-empirical Design Guide completed under NCHRP 1-37A and being refined and implemented under NCHRP 1-40 A-J projects. This project will follow up on the implementation effort with laboratory and field studies of pavements designed and constructed using the guide.

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

The state-of-the-practice of the routine use of 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 design/constructed using the guide methodology and criteria. The data gathered in this task will be used to validate the effectiveness of the procedure in designing long-lasting, cost effective pavement structures

Task 3- Provide Information

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

Task 4- Recommended Practice

A recommended practice document will be prepared that summarizes the findings of this project and recommends needed refinements in the design methodology and/or criteria.

Program 3: IMPROVED STRUCTURAL DESIGN OF PAVEMENTS

Project 3.02 Develop 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 designed to perform well and serve the needs of the traveling public as higher volume roadways.

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. These things are all basic parameters that are inputs into a structural design procedure. However, not all low volume roads have the same design parameters. Subgrade conditions, which are the foundation for the pavement, can vary significantly from one location to another. Traffic loading can also vary considerably with some low volume roadways. Some low volume roads carry a high percentage of heavy truck traffic. Since trucks are much more damaging to a pavement than a passenger vehicle, the percentage of trucks is an important consideration in structural design. Therefore, the first step in structural design is to quantify subgrade properties and estimate traffic loading over the anticipated design life of the pavement.

Unfortunately, currently used structural design methods do not lend themselves well to use for design of low volume roads. Therefore, a research project is needed to develop a structural design procedure for low volume roads.

Background

For a variety of reasons, adequate structural designs are often not conducted on low volume roads. This can result in pavement sections being constructed that are either too thick or too thin for the design parameters on a specific roadway. When pavements are too thin, they generally will not perform well over the expected service life. When constructed pavements are too thick, they are not cost effective.

Current structural design procedures are transitioning from empirical design methods to mechanistic-empirical design procedures. M-E design procedures are generally fairly complex and require a significant amount of input by the designer before the resulting pavement section can be obtained. Even though M-E procedures are better for design of higher volume roadways, the increased complexity makes them difficult to use on low volume roads where designers are looking for a simple approach.

One of the reasons that structural design are not performed on low volume roads is that current thickness design procedures are too complex for untrained personnel that are available at small public agencies. Conversely, detailed design parameters that are required in some design procedures may not be readily available to small public agencies. To address these problems with a lack of expertise and detailed design procedures, an option to utilize a simplified structural design procedure should be included in the design procedure developed under this project. The simplified procedure would allow the designer to select general categories of traffic volume and loading (low, medium and high) and subgrade support (poor, fair and good). The design procedure would then allow the designer to select from an illustrated selection of pavement sections.

A research effort is needed that will develop a structural design procedure for low volume roads. The design procedure should include an option for the designer to select a simplified approach that will allow the selection of a pavement section from a catalog of illustrated pavement sections that will meet the inputted design parameters.

Scope/Objective

The objective of this project will be to develop a simplified approach to structural design of 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 and innovative design methods and approaches will be identified that can offer a simplified approach.

Task 2. Development of Trial Design Approach

Based on the findings of Task 1, identify design methods and approaches that will be effective in obtaining adequate structural design 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” paper versions and in a software application using one of the widely available Microsoft applications.

Task 3. Validation of Design Outputs

The trial version of the simplified design procedure will be validated using other (more complex) design procedures to ensure that adequate structural designs are being produced. 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 design approach.

Program 3: IMPROVED STRUCTURAL DESIGN OF PAVEMENTS

Project 3.03 Improved Structural Design for Heavy Duty Pavements

Objective (6/7/06): Develop improved structural 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, 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 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 the environment in order to meet performance requirements.

Of special importance in this discussion is heavy duty loading situations. Heavy duty pavements are defined as roadway or parking lot pavements with a high number of very heavy loads anticipated over the design life or a relatively few repetitions of exceptionally heavy loading. Examples are pavements in ports, intermodal terminals, airports and heavy vehicle lanes. The current empirical design methods do not adequately produce acceptable thickness designs in 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 publication 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 any pavement structure that is subjected to heavy vehicle traffic, such as urban interstates, airports, container facilities, and logging yards. This publication is a valuable reference for pavement designers and specifiers, plant foremen and operators, and paving crews.

The structural design method used for flexible and rigid pavements is in need of improvement. The current AASHTO Guide is based on the AASHO road test that was completed in the 1960s. While it has served reasonably well for many years, the state-of-the-art has moved beyond the purely empirical approach used. Mechanistic design methods need to be incorporated into structural design procedures to account for changes in traffic and materials. New procedures are needed to guide pavement rehabilitation and reconstruction.

Mechanistic approaches to pavement structural design can more realistically account for the condition of existing pavements and improve the reliability of designs. Gaps in knowledge associated with mechanistic approaches will need to be addressed and/or empirical approaches used. This project will monitor the needs in the new mechanistic/empirical approach to pavement design and supply needed information as possible.

Background

The AASHTO Joint Task Force on Pavements is developing a new guide for the structural design of pavements. A 1996 workshop provided public input into the process, which has developed into an NCHRP research project. The NCHRP project is defining what existing information can be sued in the new guide and what subjects need additional information.

The HMA industry, and other associated paving materials industries, should be aware of the needs of this new effort and supply the information that will improve the structural design methods being developed. It is not envisioned at this time that extensive research effort will be conducted prior to development of the new AASHTO Guide.

Scope / Objectives

The objective of this project is to improve current structural design methodology for heavy duty pavements by monitoring the development of the new AASHTO structural design guide and by providing information needed for the development of the guide.

Work Plan

Task 1. Advisory Committee

Maintain an advisory committee to review the development of the new AASHTO structural design guide. Membership on this advisory committee from the HMA community is vital to gain an understanding of the needs of those developing the guide.

Task 2. Case Studies

Analyze designs of heavy duty HMA pavements to evaluate performance. Example conditions include, but are not limited to, port applications, intermodal terminal, airports and heavy vehicle lanes.

Task 3. Review LTPP database

The LTPP database should be used as appropriate to generate information for the analysis. The test sections may provide performance information which will be critical to the analysis process.

Task 4. Provide Information

Identified needs will be addressed by the working committee and limited research development and synthesis projects will be formulated and conducted. These industry funded efforts will address the information needs and supply reports with detailed technical information and references.

Task 5. Recommended Practice

A recommended practice document will be prepared that summarizes the findings of this project related to structural design of heavy duty pavements.

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 rubblized PCC during pavement rehabilitation projects.

Introduction

The majority of the tonnage of Hot Mix Asphalt (HMA) pavement that is placed each year is for existing pavement maintenance and rehabilitation applications. This is because our roadway system is maturing and there are relatively few new pavement construction projects 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 is a type of HMA application is commonplace throughout the country.

As should be done on all pavement projects, a design procedure of some type should be used to determine the appropriate materials selection, mix design procedure, HMA thickness and mix type for that specific loading and environmental situation. Another important design consideration is the ability of the underlying layer to support the new HMA overlay. In the case of pavement rehabilitation, the underlying material is the existing pavement. Therefore, ideally the in-situ properties of the existing pavement prior to HMA rehabilitation would be helpful to properly design the HMA overlay materials.

Background

Rehabilitation with HMA overlays can involve overlays of various thickness and also various types of preparation of the existing pavement. On existing asphalt pavements, rehabilitation projects may include removal of substantial portions of the pavement structure prior to placement of new HMA. On existing concrete pavements, rehabilitation projects may include procedures such as crack and seat or rubblization prior to the placement of a new HMA overlay.

As discussed above, a thickness design for rehabilitation projects should include an evaluation of the in-situ properties of the prepared existing pavement. 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 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 prior to rehabilitation and also during construction projects where extensive preparation of the existing pavement is being performed.

Scope / Objective

The objective of this project will be to explore test equipment and methods for characterization of in-situ materials prior to an asphalt overlay, including on rubblized PCC, 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 crack and seat and rubbilized concrete pavements.

Task 3. Ruggedness Testing

On selected test method(s), perform ruggedness testing to determine precision and bias of the test method and equipment. Based on findings, make modifications to improve.

Task 4. Implementation Manual

An implementation manual that will provide information about the findings of the project will be prepared. The information will be in suitable format for inclusion in both specifications and standard test methods.

Program 3: IMPROVED STRUCTURAL DESIGN OF PAVEMENTS

Project 3.05 Development of Next Generation of M-E Design 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 and which is 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 validated. As deficiencies are identified, the need for new research projects will be identified. 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

There is currently an effort to refine and implement the AASHTO Design Guide under NCHRP 1-40. As this project progresses and agencies start implementing the M-E structural design methods in the Guide, it is likely that the need for improvements and refinements in the procedures will be identified. There will also be a need to validate the structural design procedures with field projects where designed pavement sections are built to evaluate the structural capabilities and performance of the constructed pavement, possibly using full scale accelerated pavement performance methods. These field projects will provide researchers with critical information that will allow them to identify necessary improvements to design methods and criteria.

As discussed above, current M-E procedures now being introduced and tested are meant to be useful for structural design of both new and rehabilitated pavements. Because there are a high percentage of rehabilitation projects performed by agencies, it is very important that the structural design method work well for that application. Therefore, validation efforts must include work on rehabilitation projects where HMA is used on both existing rigid and flexible pavements.

As research efforts to improve the current methods are identified during implementation of the M-E design methods included in the AASHTO Design Guide, that research should be conducted promptly.

Scope / Objective

The objective of this project is to develop improved 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) to the design of new and rehabilitation using HMA pavements will be prepared. A survey will be conducted to identify pavements that were designed and constructed with the AASHTO M-E design procedure. Also, any research that has been conducted using field projects to validate the design procedure will be identified.

Task 2. Conduct Performance Review of Projects

Conduct distress surveys and Non-Destructive testing of identified pavement sections from Task 1 to measure and project probable pavement performance.

Task 3. Conduct Lab and Field Tests

Perform laboratory and field testing of pavement structures to validate pavement design methods and criteria.

Task 4. Recommended Practice

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

Program Four

MATERIALS CHARACTERIZATION AND MIX DESIGN

Projects in Program Four

Project 4.01 **Warm Mix Asphalt**

Project 4.02 **Accelerated Performance Testing**

Project 4.03 **Full-scale Accelerated Performance Testing**

Project 4.04 **Improved Asphalt Binder Purchase Specifications**

Project 4.05 **Performance-Based / Related Aggregate Consensus Properties**

Project 4.06 **Recycled Materials**

Project 4.07 **Improved Equipment & Test Procedures**

Project 4.08 **Laboratory Workability Device**

Project 4.09 **Field versus Laboratory Volumetrics and Mechanical Properties**

Project 4.10 **HMA for Low Traffic Roadways**

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 for HMA and the HMA mixture design methods must recognize this need and provide the materials and methods to accomplish this objective for anticipated traffic loading in the next century. Mixture design methods must provide the "tools" for the engineer to select materials and concentrations of materials to accommodate traffic and the environment for HMA.

In the United States, the majority of HMA will be used for pavement rehabilitation, reconstruction, widening and maintenance operations on existing highways and streets. New construction will primarily occur near existing urban areas. Few new roads will be located in environmental zones that presently do not contain pavements. Thus, the challenge of the next decade is not to design Hot Mix Asphalt pavements for new or unusual environments (rainfall, temperatures, sub grade moisture, etc.), but to design transportation facilities to carry large volumes of traffic in vehicles that will be used in the next fifty years.

The characteristics of the heavy traffic on a given facility controls to a large degree the type of HMA uses. The characteristics of heavy traffic have significantly changes 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. These heavy vehicle changes are believed to be one of the significant causes of increased rutting on our nation's highways.

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 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 channelized traffic coupled with the potential for heavier loads and the certain increase of the number of heavy loads will require changes in HMA design methods to ensure the successful use of HMA on these types of transportation facilities.

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 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 mixture that have been historically used, these design methods may remain adequate predictors of the pavement's ability to resist permanent deformation or rutting. Changes in traffic characteristics as previously described, and the desire to use a wider variety of asphalt binders and aggregate gradations have largely outdated these older design methods.

The SHRP developed the Superpave system of HMA mixture design. The Superpave system has test methods and prediction models that promise improvement compared to the existing Marshall and Hveem methods to handle changes in traffic characteristics. Projects are needed to revise software, models, and test techniques associated with the prediction models of the Superpave mix design system. The existing Superpave prediction models and/or the models may not be completely adequate to handle the changes in traffic characteristics, binders, and aggregate gradations expected in the upcoming years. In addition, research based on the revised Superpave approach and the use of accelerated pavement performance testing techniques will be need to adequately develop a mixture design method to satisfy the mixtures that will be required in the next century.

Scope/Objectives

The objective of this program is to develop procedures which will lead to optimization of materials and mix design for HMA.

Program 4: MATERIALS CHARACTERIZATION AND MIX DESIGN

Project 4.01 Warm Mix Asphalt

Objective: Develop mix design methods and accelerated pavement technologies for Warm Mix Asphalt Technologies.

Introduction

European countries are using technologies that appear to allow a reduction in the temperatures at which asphalt mixes are produced and placed. These technologies have been labeled Warm Mix Asphalt (WMA). The immediate benefit to producing WMA is the reduction in energy consumption required by burning fuels to heat traditional hot mix asphalt (HMA) to temperatures in excess of 300° F at the production plant. These high production temperatures are needed to allow the asphalt binder to become viscous enough to completely coat the aggregate in the HMA, have good workability during laying and compaction, and durability during traffic exposure. With the decreased production temperature, the additional benefit of reduced emissions from burning fuels, fumes, and odors generated at the plant and the paving site.

There are three technologies that have been observed in the European countries to produce WMA:

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.

In addition to the work done in Europe, a new Warm Mix Asphalt approach has been developed in the U.S. using advanced asphalt emulsion technology called Evotherm. This product is added to the mix production facility in replacement for the asphalt binder.

All four technologies appear to allow the production of WMA by reducing the viscosity of the asphalt binder at a given temperature. This reduced viscosity allows the aggregate to be fully 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 air quality restrictions. The reduction in fuel usage to produce the mix would also have a significant impact on the cost of transportation construction projects.

Background

WMA mixes are starting to be used in this country. The benefits of these technologies to the United States in terms of energy savings and air quality improvements are promising but these technologies need further investigation and research in order to validate their expected performance and added value. In addition, some of these technologies require significant equipment modifications and adjustments must be made in standard design, production and construction procedures to account for the significantly reduced temperatures used in WMA.

Technologies that allow reduced temperatures and increased workability and compactability are still under development. Therefore, material design methodology and associated accelerated pavement testing methods that are appropriate for low-production temperature and compaction aid technologies is 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.

Scope / Objective

The objective of this project will be to develop mix design methods for Warm Mix Asphalt technologies and accelerated performance tests that are applicable to low-production temperature mixes and compaction aid technologies.

Related Research

Anticipated Project: NCHRP Project 9-43 "Mix Design Practices for Warm Mix Asphalt Technologies" FY 2007

Work Plan

Task 1. State-of-the-Practice

State, federal and international practices for materials design methodology and associated accelerated performance test (APT) methods that are or can be applied to Warm Mix Asphalt Technologies will be reviewed and evaluated.

Task 2. Perform Laboratory and Field Tests

The most promising mix design methodologies and APT will be evaluated in both laboratory environments and field construction projects.

Task 3. Recommended Practice

An implementation manual will be prepared that describes the recommended practice for mixture design methods and APT for alternative mix technology. 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 4.02 Accelerated Performance Testing (APT)

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 able to be performed in both the lab during mix design and also in the field lab during HMA mix production. Test equipment and methods that fit this description can be called 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, especially 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. So, performance is considered adequate if the expected service life is obtained without excessive amounts of distress occurring in the pavement.

It would be desirable if laboratory tests were developed that could accurately predict the performance of a HMA material before it is constructed. These 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 older 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 / Objective

The objective of this project will be to 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. Report 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-Conduct 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-Conduct 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 AND MIX DESIGN

Project 4.03 Full-scale Accelerated Performance Testers

Objective: Conduct full-scale APT to validate models and tests developed in Project 4.02.

Introduction

Full scale, accelerated performance testing (APT) is conducted at facilities in which full-scale wheel loads are applied to full pavement structures by either 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 asphalt pavement. Therefore, there is no need to determine how data from small scale, laboratory testing applies to actual pavement performance.

The use of 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 has contributed greatly to researchers understanding of structural design, materials selection, mix design, construction practices, pavement response to vehicle loading and performance.

Background

A good example of the use of full depth 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, research is needed to identify and develop definitions of the data associated with the tests performed by APT facilities and to recommend guidelines for data collection, storage, and retrieval. This information will help to ensure proper interpretation of the data and facilitate their use by other agencies, thus 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. Research is needed to develop guidelines for the effective and appropriate use of full-scale APT in pavement studies. Guidelines should build on experience to date with these types of facilities both nationally and internationally. The guidelines should provide information related to planning, constructing, and setting up and performing research at full scale APT locations.

Scope / Objective

The objective of this project is to develop guidelines for the effective and appropriate use of full-scale APT.

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.

Task 2. Develop Draft Guidelines

Based on the findings from Task 1, draft guidelines will be developed. The draft guidelines will address full scale APTs 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. Guidelines

Guidelines for Full Scale Accelerated Performance Testers will be published.

Program 4: MATERIALS CHARACTERIZATION AND MIX DESIGN

Project 4.04 Improved Asphalt Binder Purchase Specification

Objective: Refine and validate the Superpave PG system for neat and modified asphalt binders

Introduction

Increased traffic volumes, higher axle loads, higher tire pressures and the use of single tire replacements among other factors have increased the demand for 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. Additional 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 binder, regardless of the presence of modifiers and/or additives. However, the system 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 widespread early deterioration of 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.

Scope / Objective

The objective of this project is to refine and validate 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.

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, ESALS 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

Evaluate 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. 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.

Program 4: MATERIALS CHARACTERIZATION AND MIX DESIGN

Project 4.05 Performance-Based / Related Aggregate Properties

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

Introduction

The properties of coarse and fine aggregates used in HMA mixtures significantly affect the performance of the highway pavements in which they are used. Despite their obvious importance, insufficient consideration is sometimes given to the testing of aggregates. Many currently used aggregate tests are empirical--they were developed without establishing a direct relation to pavement performance. For instance, the Superpave aggregate properties were developed by a panel of experts using a consensus process.

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

The second NCHRP project 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 on using these tests for evaluating and selecting aggregates for use in specific mixture applications. The final report will be 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 the journey to 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 / Objective

The objective of this project is to develop and validate performance-based aggregate characterization techniques for the inclusion in the Superpave mixture design system.

Work Plan

Task 1. State-of-the-Practice

State, federal and international practices relative to performance-based aggregate selection and mixture design of HMA mixtures will be reviewed. The relationship 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 laboratory tests in the lab 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 Task 1 and 2, a Superpave aggregate property specification will be developed that is the same format as the current consensus aggregate specification.

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 facilities, haul operations, lay down operations, 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 affect 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 4.06 Recycled Materials

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

Introduction

The amount of 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 is fairly well understood. HMA mixes containing RAP are generally of high quality and research has shown that they perform as well as virgin HMA pavements.

There are also many other types of reclaimed / reprocessed 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 a lot of pressure to incorporate these materials 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 PCC pavement material and host of other lesser quality materials. With the possible exception of reclaimed tire rubber, the equipment and process to incorporate this second group of reclaimed / reprocessed 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 and construction of the HMA pavements containing these materials.

Background

There are many questions that must be answered in order to effectively recycle these identified reclaimed / recycled materials into HMA pavement materials. The first questions involve the cost and availability of the material. Second, research must be done to 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 incorporating the recycled materials through the high temperature process of producing HMA materials. In order to receive serious consideration, it must be determined that the materials are readily available, can be cost-effectively incorporated into the HMA, that no serious health or safety issues are created and it must also be shown that the service life and performance of the recycled HMA pavement is not adversely affected by the addition of the reclaimed / reprocessed material.

Many other issues must also be addressed through laboratory testing and field projects before it is known whether it is practical to add recycled materials to the HMA. Some of these issues are related to the amount and type of processing that is required to prepare the materials for incorporation into the production process. Also, incorporation of reclaimed / reprocessed materials may require modifications to the standard materials selection, mix design, production and the laydown/compaction operation.

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 / Objective

The objective of this project is to identify and develop procedures and guidance for the effective and economical recycling of reclaimed/reprocessed materials (other than RAP) in HMA. The research should include efforts to develop improved mix design, plant production and construction evaluation techniques for the use of a wide variety of reclaimed/reprocessed materials in HMA mixtures, addressing 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.

Task 2. Status of Reclaimed / Reprocessed Materials

A list of reclaimed / reprocessed materials that should be considered during this research will be developed. Develop evaluation protocols for each of the identified reclaimed/reprocess materials for use in HMA. 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. 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 to AASHTO for approval.

Program 4: MATERIALS CHARACTERIZATION AND MIX DESIGN

Project 4.07 Improved Equipment & Test Procedures

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

Introduction

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. Thus, there is always a process to decrease the variability that is solely the function of the test itself as much as possible. The more that variability can be reduced or eliminated, the more useful the test method will be. One way to improve variability is by removing the human element from test specimen preparation, conditioning and testing. The only way to decrease the chance of variability due to human error is to find ways to include machine automation into the process.

Background

Typically, the development of a new test procedure is accomplished in several phases. The first step, which can involve a significant amount of research in itself, 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. Then, the second generation equipment and procedures are developed that includes improvements identified in the second phase. There are generally a very limited number of second generation equipment that is produced and distributed to various entities that will 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.

Scope/Objective

The objective of this project will be to identify laboratory equipment & test procedures to increase automation and reduce variability.

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. Lab and Field Testing

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 further improvements in test procedures or equipment.

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 4: MATERIALS CHARACTERIZATION AND MIX DESIGN

Project 4.08 Laboratory Workability Device

Objective: Develop a laboratory workability device 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 he 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 and any potential additives and the effect of that interaction on the workability of the mixture. A method to evaluate the workability and compact ability 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 / Objective

The objective of this project is to develop equipment and test procedures for the laboratory evaluation of workability and compact ability 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. Laboratory Evaluation

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 one device which holds the greatest promise for success at a reasonable cost. Precision of the selected test method will be defined.

Task 3. Field Validation of Device

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 that is designed to direct the researcher or contractor through a series of standard procedures to measure workability. This will provide for a standard procedure that each evaluator will use on each mix to make a non-subjective evaluation of workability / compactability. The form will include a scoring mechanism where the researcher or contractor will assign a numerical "workability score" to the HMA mixture being evaluated.

Task 4. Develop 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 AND MIX DESIGN

Project 4.09 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 also require testing of mechanical properties of the produced HMA, such as moisture susceptibility tests, rut tests and stability tests. These mechanical tests are also conducted on compacted specimens of the HMA. Generally, the same sampling and compaction equipment and procedures that are used to generate the compacted specimens for volumetric testing are 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. Generally, there are efforts made to ensure that the samples being tested for QC and QA purposes are as similar as possible. However, because different operators that are using different testing equipment are performing the tests, there will inevitably be variability because of these differences. 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 can be present if the location and makeup of the sample are not the same (laboratory produced versus plant/field produced) and/or the location of compaction are not the same (laboratory compacted versus field compacted). However, many specifications require the comparison of volumetric properties that are from different locations and that use different compaction methods. Because this happens routinely, one of the major barriers to conducting a legitimate, defensible QC/QA program is quantifying the variability that can be expected when comparing volumetric properties being produced on different materials produced in different circumstances (laboratory blended/mixed versus plant blended/mixed) being compacted in different locations, with different equipment and in different manners.

Specifically, the three different scenarios for production of test samples for volumetric and mechanical properties that exist on some 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 that the differences (or variability) between the expected results from each of these scenarios be better understood and quantified. It is also important to understand the causes of the differences in volumetric or mechanical results. Therefore, 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 outlined above. Also, guidance is needed about recommended practice for QC/QA programs that include testing of compacted HMA specimens.

Scope/Objective

The objective of this project is to 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. Conduct Lab and Field Studies

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 single 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. Recommended Practice Manual

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 AND MIX DESIGN

Project 4.10 HMA 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 / Objective

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. Perform Case Studies

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

Task 3. Develop 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 AND MIX DESIGN

Project 4.11 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. Asphalt cements are petroleum-based materials that are a by-product of the crude oil refining process. Prior to that, naturally occurring asphalt were used as binder material. The most well known source of natural asphalt material is from Trinidad Lake Asphalt (TLA). In fact, some of the earliest recorded flexible pavement projects in the U.S. were constructed with TLA in the early 1990s. Other sources of natural asphalt are other lake asphalts and also 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 at least one viable alternative binder material and the technology to produce it in sufficient quantities to make it a viable alternative to asphalt cements.

Background

At this time, there is no legitimate alternative to petroleum-based asphalt cement as a binder material. Although there are many asphalt additives and modifiers on the market that can be blended with asphalt cement to improve its properties, a material that can totally replace asphalt cement is not available.

There are a number of problems and potential problems with the use of asphalt cement as the only available binder material. The biggest problems are related to concerns with the future supply and costs of petroleum-based, asphalt cement binders. Recent world events and increasing environmental concerns may have a profound affect on the availability of crude oil and refining capabilities in the not-so-distant future. There has been a recent, significant increase in prices of all petroleum products, including asphalt binders. In fact, it has been estimated that asphalt cement has roughly doubled in price over the last three years. 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 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 must be less expensive than asphalt binders without reducing the quality of the produced flexible pavement material.

There are many possible components of alternative binder materials 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 materials or organic materials from non-petroleum sources.

As has been addressed elsewhere in this document, one focus to address the above concerns could be on extending the binders we currently use. This can be accomplished by improving existing flexible pavement reclamation and recycling technologies. 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 is speculation that technologies that will allow HMA materials containing 100% RAP will eventually be developed. 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.

Scope/Objective

The objective of this project will be to identify and develop alternative binders 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 used in the past and present. The review will include identification of non-petroleum based material that has potential as an alternative binder, 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 will be evaluated as an effective binder material 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 projects. The report will also make recommendations about ways to encourage the growth in production of the alternative binder materials and implementation of the technology

Program Five

CONSTRUCTION PRACTICES & QUALITY MANAGEMENT SYSTEMS

<u>Project in Program Five</u>

Project 5.01	**Energy Efficiency**
Project 5.02	**Recycling Technologies**
Project 5.03	**Improved Construction Equipment & 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 (NDE) for Process Control and QC/QA**
Project 5.07	**Longitudinal Joints**
Project 5.08	**Improve the Fundamental Model for Field Compaction**
Project 5.09	**Improve Risk Assessment of QC/QA Statistical Specifications**
Project 5.10	**Smoothness Improvements**

Program 5

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 can result from reduced need to perform maintenance and rehabilitation activities and from developing technologies to reduce the time needed to perform those activities under traffic.

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. Another factor is the ability of the project workforce (public agency and contractor) to produce a quality project that meets or exceeds the specification and that provides a pavement that will perform for the public over a long period of time.

Construction practices that improve quality, increase pavement life and reduce lane occupancy time will significantly reduce user (and non-user) costs and the need for more frequent and costly rehabilitation and maintenance operations. Reduced pavement life not only increases rehabilitation and maintenance costs but user costs (due to delays, roughness, etc) are also significantly increased. 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 also 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 the QMS area 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 road closures have become more popular in urban areas to reduce traffic congestion. This type of construction will become more popular in the future, and improved techniques are needed to increase production and to improve quality. Since traffic control and lane occupancy time is an integral part of rehabilitation and maintenance operations, new and improved equipment, technologies and techniques are required in that work segment of the project as well.

Construction Quality Control (process control) and Quality Assurance sampling and testing have become an integral part of construction in most situations. 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. Real time testing and data collection equipment and techniques are now available and appears to have quite a bit of promise to dramatically improve the information needed to effectively control the construction process.

The desire to provide HMA of uniform properties on a project is based on an assumed relationship between performance and uniformity (low variability). 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? Low variability construction materials may have a higher initial cost than construction materials of high variability and the testing frequency required to obtain low variability may be more costly.

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 to increase production, improve quality of HMA, and extend pavement life, and thereby reduce traffic congestion.

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) require the use of a significant amount of energy. The energy consumption comes in the form of fuel for hauling units, 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. While the current state of production and paving has been shown to be environmentally sound and not harmful to workers, improving energy efficiency at the plant is both an environmental and an economic issue.

The question is how to reduce energy consumption. Because HMA production and construction is a fairly complex issue with many steps, the problem must be attacked in each of these steps.

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 as high as 500 tons per hour or even higher. 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. Therefore, when heating this large mass of material to these high temperatures very quickly, it is apparent that this process will require a huge amount of burner fuel. The amount and type of burner fuel is dependent on the plant type and capabilities and also on the fuel efficiency of the plant. There could be a number of opportunities 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 are 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. Reduced production and paving temperatures would have beneficial environmental effects. There would be a decrease in the energy required to make HMA. This is especially important since projections suggest that the recent increases in petroleum prices will persist well into the future. Reduced temperatures could also have a profound influence in reducing emissions and odors from plants, thereby further improving environmental benefits and public opinion. 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 / Objective

Identify and develop equipment, innovative HMA mixtures and production plant improvements that will result in improved energy efficiency

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. Conduct Laboratory Tests

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

Task 3. Conduct 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 exploit. 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 as the price of asphalt and aggregate increase.

Background

The HMA Industry has for many years used RAP as a component in HMA composition. RAP is now routinely used in HMA base, intermediate and surface mixes in many states. Extensive research has 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 / Objective

The objective of this research will be to improve equipment and best practices to facilitate the incorporation of reclaimed asphalt pavement (RAP) materials into HMA. 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.

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 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. Conduct Field Projects

In order to validate the revised procedures and methods identified in previous tasks, field projects should be conducted to validate their effectiveness. Lessons learned in these field projects 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 / more 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.

It is anticipated that the expectations for quality and control of HMA laydown and compaction operations will continue to increase over the coming years. There are many factors that will affect 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 begin to make their way into mainstream 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 already a reality 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 / Objective

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

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 Testing

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 800 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 (real time if possible), that have good precision and no bias and that 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 mixture meets 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 adjust the HMA production. Current test methods of determining the above properties take hours, not minutes. Rapid, near "real time" test methods need to be developed for these determinations. Also, the development and incorporation of automated processes during plant production is another 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 (sublots per lots) as the buyer and seller risks are reduced.

Scope / Objective

The objective of this project is to develop real-time test methods and processes for quality control (process control) and quality assurance purposes 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 - Conduct 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 develop in this task. The precision and bias of these test methods as well as needed equipment, operator requirements, etc. will be defined through a controlled laboratory experiment.

Task 3 - Conduct 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: Conduct research on 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.

Determining in-place air voids, thickness and smoothness during the construction is either time consuming or lacks good precision and/or bias. Most current test methods are not "real time", that is their results can not be used to control the laydown and compaction operation. Improvement in techniques for measuring (or estimating) density, thickness and smoothness in a short period of time (continuously if possible) are needed so that tests can be made and reported and utilized quickly to adjust the laydown operation and compaction operations to optimize quality.

Background

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 available to measure pavement smoothness. The equipment is typically used on the pavement after the mat has been placed and cooled. (sometimes 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 operations to be adjusted based on these data.

For field operations, innovations in pavers and compaction rollers equipment that will 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 under development and require research efforts to help move them rapidly into mainstream production operations.

Scope / Objective

The objective of this project is to develop "real-time" test methods for quality control (process control) for laydown and compaction operations (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 needs to be developed. The information should be obtained from not only pavements literature but also from related industries. Nuclear and elector-magnetic technology should be included.

Task 2 - Conduct laboratory Tests

Select the most promising test methods from the state-of-the-practice review for inclusion in laboratory testing programs. 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 a controlled laboratory experiment. Preliminary test methods will be developed from the most promising techniques.

Task 3 - Conduct 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 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. 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 (NDE) 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 are nuclear density tests. Testing using nuclear gauges have 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.

Furthermore, the new 2002 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, an activity that is not at present a typical component in the acceptance 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 developed.

Recently, nondestructive testing (NDT) methods, including 3-dimensional imaging, lasers, ground-penetrating radar, falling weight deflectometers, penetrometers, and infrared and seismic technologies, 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 promising NDT technologies were accessed 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 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

Scope / Objective

This objective of this project will be to identify and conduct research on NDE Process Control and QC/QA tools. The research effort should focus on 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. Non-destructive density testing procedures are a particular concern and should be included in the research.

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 3-dimensional imaging, lasers, 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 Bias of Test Method

The precision and bias 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 bias 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 construction practices for 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 specification than five years ago. Typically, required joint density is lower than the specified density in the HMA mat.

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 can improve joint construction. The most effective improvements in equipment and techniques should be identified and implemented.

It is anticipated that there will be a trend among highway agencies to improve longitudinal joint performance over the coming years. The proposed research should 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 in specifications, equipment and techniques that will result in better joint performance.

Scope / Objective

Develop a recommended longitudinal joint specification (including geometric configuration, density and segregation requirement (if needed) and a recommended equipment and construction practices that will allow the construction community to meet the specification.

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 or other characteristic. Construction practices and equipment associated will also be defined as part of this state-of-the-practice evaluation.

Task 2. Determine Density of Field Projects

The determination of longitudinal joint density should be determined on several field projects using various construction practices. The various 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 Develop a Fundamental Model for Field Compaction

Objective: Develop a model to better understand the compaction of HMA.

Introduction

Compaction is the final step in Hot Mix Asphalt (HMA) laydown operations. There is a consensus that 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 smaller, denser volume to obtain target in-place air void content. Compaction is accomplished by static and dynamic forces being placed into the hot material by the paver screed during 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 methodology.

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 / Objective

Recommend models that identify the factors that affect the HMA compaction process. The models shall reflect current 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. Develop 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. Conduct Lab and Field Tests

Conduct both lab on HMA materials and field testing of compaction operations to answer key questions.

Task 4. Final Report and Recommended Practice

Prepare a report that documents the research effort and recommends new compaction model. 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 Improve Risk Assessment of QC/QA Statistical Specifications

Objective: Standardize procedures and develop software to evaluate 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 mostly in quality control/quality assurance types of specifications by over 35 states, FHWA, FAA and several local governments. Some of the reasons to utilized statistically based specifications include the fact that variability exists in quality control and quality assurance test results due to sampling, testing and materials and construction operations. In addition, the use of statistical specifications allow for the risk to be shared by the public agency as well as the contractor.

The development of a statistically based specification requires considerable time and effort. Statistics for quality control and quality assurance tests need to be developed for specific test methods, specific sampling locations, specific numbers of samples (sublot and lot considerations), and specific ranges of materials, specific construction equipment and operations among other factors. The database upon which these types of specifications are based should be regional in nature.

Often public 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 efforts often result in specifications with unbalanced risk for the public agency or the contractor.

Background

Since the first statistical based specifications in the 1960’s, over 35 states have developed these types of specifications. In some instances the developed specifications have based on little local or regional information upon which to define the basic statistics upon which the specifications are based.

Some statistical specifications are developed on multivariate parameters that create high risk for either the public agency or contractor. The risk for these types of parameters such as air void content) is seldom determined.

Statistical specification that is fair to both the public agencies and contractors need to be developed and the basis for their development understood by all parties.

Scope/Objective

Develop a recommended practice for the development of a statistically based quality control/quality assurance type of specification. Develop a recommended statistically based quality control/quality assurance specification for hot mix asphalt.

Related Research

Task Order Proposal Request # 2 - "Analysis of Risks in Percent Within Limits and Percent Defective Acceptance Plans and Specifications"

Work Plan
Task 1-State of the Practice

Few reports exist that define the methodology that should be used to develop these types of specifications. State DOT, FHWA, FAA and local government reports should be obtained and reviewed. Visits to state DOT personnel responsible for development of the specification should be scheduled.

Task 2-Data Base

A data base should be developed based on Task 1. This data base should define typically variability associated with the various parameters used in statistical specifications. This nation wide data base needs to define the test method and sample location as well as the number of samples in sublots and lots as a minimum. These variability values can be used to determine the reasonableness of current specifications.

Task 3-Recommended Practice for Development of Statistical Specifications

The methodology needed to develop a statistical specification needs to developed. This methodology will include the organization structure, skill sets, data collection, data sets, statistical analysis, implementation program and other activities needed to develop a quality statistical specification.

Task 4-Recommended Statistical Specification for Hot Mix Asphalt

A recommended statistical based specification for hot mix asphalt will be provided.

Program 5: CONSTRUCTION PRACTICES & QUALITY MANAGEMENT SYSTEMS

Project 5.10 Smoothness Improvements

Objective: Evaluate new opportunities to improve HMA pavement smoothness and 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 utilize International Roughness Index (IRI) in high speed profilers are 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 still expensive and lower priced options must be found that will allow contractors to own their own high speed profilers for QC purposes.

Improvements and innovations in paving equipment to aid in construction of smoother pavements are also being accomplished. These equipment improvements include advancements in grade control, material transfer equipment and remixing capabilities. There are also efforts underway by both FHWA and state DOTs to educate the highway industry about improving paving operations and equipment to obtain optimum smoothness in HMA pavements. However, more equipment improvements and educational efforts are needed to obtain the growing need for the construction of smoother pavements.

Research projects are needed to explore equipment improvements in both measuring and paving equipment as well as procedures/methods of their use.

Scope/Objective

The objective of this project is to evaluate new opportunities to improve HMA pavement smoothness and measuring equipment. Training to educate the highway industry on equipment and best practices for construction of smooth HMA pavements will be developed.

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.

Task 2. Development of Preliminary Recommendations

Based on the findings of Task 1, the most promising technologies will be identified in a preliminary report.

Task 3. Field Trials

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.

Program Six

INNOVATIVE CONTRACTING APPROACHES

Projects in Program Six

Project 6.01 **Develop Rapid Construction Methods**

Project 6.02 **Risk Assessment of Non-Traditional Contracting Techniques**

Project 6.03 **Critical Review of Pavement Projects Using Non-Traditional Contracts**

Program Six

Innovative Contracting Approaches

Introduction

Public agencies have used traditional contracting approaches in the United States to award HMA pavement contracts to contractors for a long time. In traditional highway construction contracting, cost is generally the one criterion that determines a winning bid. Traditional highway projects are designed, bid and built with the contract awarded 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: 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 factors. The term innovative contracting is now used regularly to describe any of a number of non-traditional contracting practices being used today. Innovative contracting is becoming more and more popular because it allows for consideration of other factors such as time, quality, and innovation to be considered, 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 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 non-traditional (or innovative) contracting 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.

As discussed, there are 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 theme will generally be limited to one or more of these four types. The four types of innovative contracting that may be evaluated in the recommended research problem statements in this theme my deal with cost-plus-time, lane rental, warranty contracts and design-build contracts.

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.

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. There are several different types of warranties including materials and workmanship warranties, short term warranties and long term warranties.

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.

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

The objective of this program is to evaluate a number of different 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.

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 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 asphalt 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 to improve safely, reduce delay and minimize disruption in highway construction, rehabilitation and maintenance work zones. Reducing lane occupancy time and providing a safe work zone are the key elements that are needed.

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 that is passed on to the agency.

Background

Rapid construction to be less disruptive to the roadway user, to improve work zone safety and to save money can be addressed in a number of ways. 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 / Objective

The objective of this project will be to evaluate new opportunities to reduce construction time, improve safety and improve project economics.

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. Conduct Lab 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.

Program 6: INNOVATIVE CONTRACTING APPROACHES

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 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 are used by many of the state DOTs. These so called “A+B” contracts have been used widely. 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 in the evaluation process.

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 contractor require the construction contractor to guarantee the post-construction performance of the pavement for a certain 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 is 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 / Objective

The objective of this project will be to 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. Evaluate Pavement Performance and Cost Effectiveness

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

Task 3. Develop 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.

Program 6: INNOVATIVE CONTRACTING APPROACHES

Project 6.03 Critical Review of Pavement Projects Built Using Non-Traditional Contracts

Objective: Evaluate the pavement performance of existing warranty projects and the cost/benefit of non-traditional projects, including the appropriate length and conditions of the warranty.

Introduction

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.

Warranties are one of a number of non-traditional contracting procedures being used by agencies. Other types of non-traditional contracting procedures are design-build contracts and cost and time contracts. Each of these contracting procedures has been used on pavement construction, rehabilitation and maintenance projects throughout the country.

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 of from one 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, and durability are used on material and workmanship warranties.

The second basic type of warranty is a Performance Warranty that is either short term lasting 5-7 years or longer term lasting longer than 19 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. 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 tern warranties as discussed above.

There is a need to conduct research studies to evaluate the performance of existing pavements that were constructed under warranty or other types of non-traditional contracting procedures and to determine cost/benefit of the use of this type of contracting procedures, and to recommend the appropriate length and conditions of the warranty portion of the contracts.

Scope / Objective

The objective of this project will be to conduct research to evaluate the pavement performance of existing warranty and non-traditional projects and evaluate 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 and other non-traditional contracting practices will be determined. State DOTs that are using non-traditional 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 warranties and other non-traditional contracting practices and determine cost/benefit of both materials and workmanship, short and long term performance warranties, cost and time and design-build contracting procedures.

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 non-traditional contracting procedures that include warranties including appropriate project type (overlay, rehabilitation, and new construction), length of project and conditions of warranty.

Program Seven

SURFACE CHARACTERISTICS

Projects in Program Seven

Project 7.01 **Safety Driven-Pavement Surface Type Selection**

Project 7.02 **Thin-Lift Material Performance**

Project 7.03 **High Fiction Surfaces**

Project 7.04 **Economics of Pavement Smoothness**

Project 7.05 **Advanced Surface Characteristics Model**

Project 7.06 **Pavement Noise Reduction**

Project 7.07 **Mix Types to Improve Friction and Mitigate Noise**

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 specification has 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 will focus only on friction issues although related safety issues of visibility/surface spray are also of great importance to the driver.

The increased emphasis on safety during the 1980s created awareness among public agencies to provide pavements with initial high friction and friction values that will remain high during the life of the pavement. High friction values on dry and wet pavements have thus become and important design consideration.

Technology exists which allows the design of pavement of high friction. The surface mixtures used on pavements to ensure high and lasting friction are often expensive and difficult to place and control. HMT mixtures for friction courses must be economical, capable of being placed in this lifts (if desired), designed with good prediction tests for friction and mixture constituent concentrations, and placed under QC/QA types of specifications that ensure a quality product.

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 I a new awareness for the need for improved HMA mixtures that will satisfy surface demand for the next century.

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

The objective of this program is to 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 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 and 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 be stable enough to provide enough strength for support of the subsequent layers. They must also be durable enough to resist premature aging, moisture damage and cracking. Surface mixes, however, 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 also must provide a safe pavement surface. A safe driving surface is one that has at least 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 / Objective

The objective of this project will be to 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.

Task 2. Perform Case Study Analysis

Identify sites in which specific surface mixes were selected based on existing guidelines and evaluate pavement safety-related performance of the HMA surface mixes. The purpose of the case study analysis is to determine if current guidelines properly balance safety related properties for safety mixes.

Task 3. Field Studies

Based on the results of Task 1 and 2, develop revised surface mix selection guidelines. 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 7.02 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 was placed, the traffic volume, the environment and the construction practices (among other factors).

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 / Objective

The objective of the project is to 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

Program 7: SURFACE CHARACTERISTICS

Project 7.03 High Fiction 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 this friction must be 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 QCD/QA practices are need to produce mixtures that are economical, that can be placed in relatively thin lifts and that maintain 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. Materials selection criteria, the laboratory mixture design methods, and QC/QA procedures for these mixtures (open graded, gap graded, coarse aggregate and Stone Matrix Asphalt) are based on limited research and the consequently performance problems have resulted. 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 / Objective

The objective of this project is to 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. Superpave technology will be used.

Task 4. Field Evaluation

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 7.04   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 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 roughness on vehicle operating and maintenance costs will create larger markets for those reconstruction, rehabilitation and maintenance techniques that provide initially smooth pavements and that retain this level of smoothness over long periods of time. Data is needed to relate pavement roughness with user vehicle operating costs and agency maintenance costs.

Background

The AASHO Road Test provided a relationship between pavement roughness 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 / Objective

The objective of this project is to 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 measurements in State DOT records as well as pavement performance 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 have a basic understanding that surface texture and the void structure of HMA pavements are important considerations in developing pavements that will meet surface characteristic requirements.

HMA pavements that provide sufficient stability to support expected vehicle loadings, are durable enough to provide long life and also have adequate surface texture to provide desired friction, noise and splash and spray characteristics are the goal of pavement engineers. These expectations are obtainable with standard dense-graded and gap-graded HMA mixes and design and construction methodology to get adequate surface characteristics with these surface mixes are well understood. However, sometimes designers want mixes that can provide outstanding 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. This research should include modeling to understand the relationship of materials (binder and aggregate) 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. This technology 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. Also, 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 / Objective

The objective of this project will be to 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 prepared. The relationship of materials selection, mix type selection, mix design and construction practices and surface characteristics and performance will be evaluated. Existing and proposed test methods for measurement of surface features and characteristics will be studied. The state-of-the-practice of advanced modeling and 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. Lab and Field Studies

Based on the findings of Task 1, 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 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 tow 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 interest 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 / Objective

The objective of this project is to evaluate noise characteristics of pavement materials and tests to measure noise. This will include 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. Conduct 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. Conduct 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. Conduct 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 7.07 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. A Federal Highway Administration/industry scanning tour was conducted in 2005 to capture the European technology. 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 both provide friction and reduce noise both initially and over a performance life of several years.

Scope/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. 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.

Task 2-Visits

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 3-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 4-Mixture Design

A materials selection and mixture design systems for hot mix asphalt surfacing materials that are capable of providing long lasting friction and noise reduction should be developed. This development will require both laboratory and field research to be completed. The field research should verify the laboratory studies relative to friction and noise mitigation as well as performance (stability, durability, etc.).

Task 5-Construction and Maintenance Practices

A construction and maintenance practices document should be prepared based on the best technology currently available. Trial field construction projects will be necessary to verify the literature review information on these subjects.

Task 6-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.