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FIRST YEAR WORK PLANS

June 18 – December 25, 2007

ASPHALT RESEARCH CONSORTIUM

PROGRAM AREA:

VEHICLE-PAVEMENT INTERACTION

Prepared for
Federal Highway Administration
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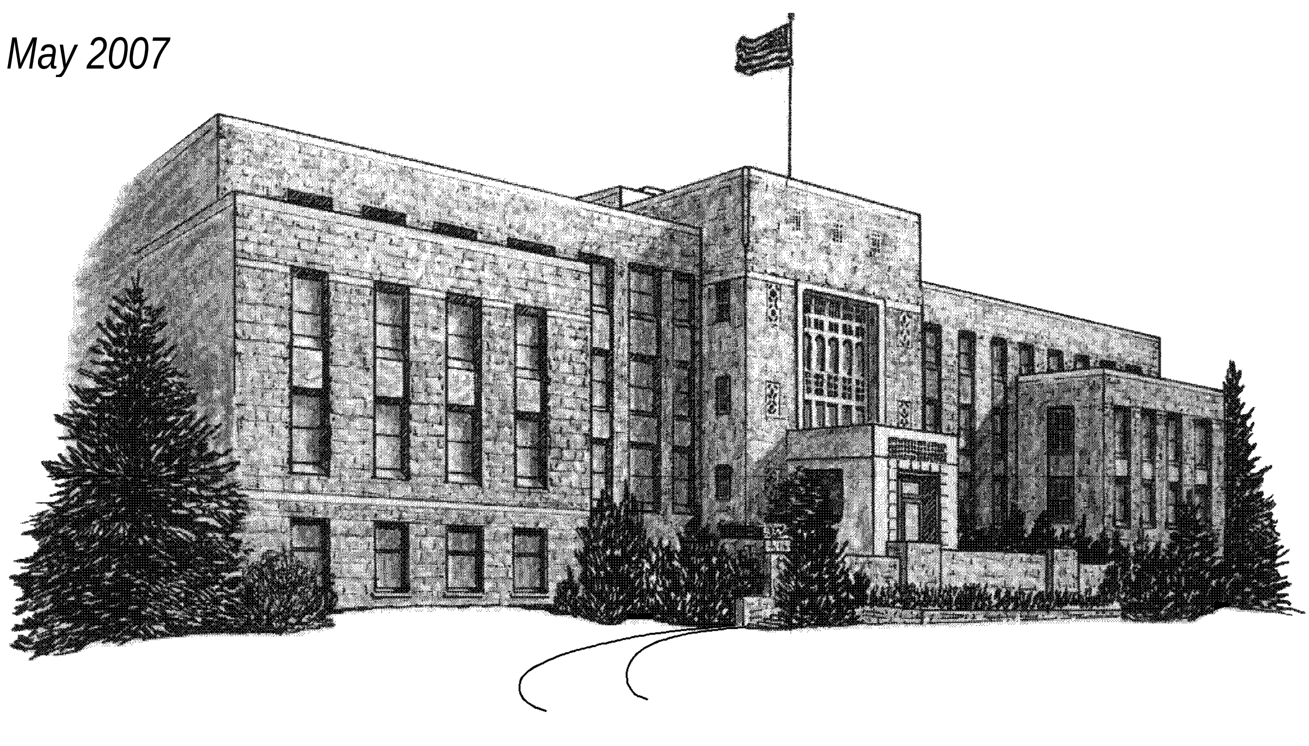

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RESEARCH PLAN FOR YEAR 1 OF FEDERAL HIGHWAY ADMINISTRATION CONTRACT DTFH61-07-H-00009 "ASPHALT RESEARCH CONSORTIUM"

FOREWORD

This document is the proposed Research Plan for Year 1 of the Federal Highway Administration (FHWA) Contract DTFH61-07-H-00009, the Asphalt Research Consortium. The Consortium is coordinated by Western Research Institute with partners Texas A&M University, the University of Wisconsin-Madison, the University of Nevada Reno, and Advanced Asphalt Technologies.

The Year 1 research plans are grouped into seven areas, Moisture Damage, Fatigue, Engineered Paving Materials, Vehicle-Pavement Interaction, Validation, Technology Development, and Technology Transfer. The format of the presentation of the work plans varies somewhat because of the different interactions of the work elements. The Moisture Damage and Fatigue areas contain work elements that are interrelated and thus will work together to advance the knowledge of mechanisms and models in these areas. In addition, there are some work elements that compliment one another by investigating a common principle using different methods. For example, in the Moisture Damage area, the principle of measuring surface energy of asphalts and aggregates is being pursued using the "macro" (or bulk) approach using the Wilhelmy plate and Universal Sorption Device for asphalts and aggregates, respectively. The surface energy of asphalts and aggregates is also being pursued using Atomic Force Microscopy at the nano scale. Using the two different methods provides a check on one another so that the true significance and importance of surface energy can be evaluated and related to performance properties. There are also examples of Modeling activities that compliment each other in a similar fashion. The Consortium members firmly believe that this approach make the research more robust.

The research areas of Engineered Paving Materials, Vehicle-Pavement Interaction, and Validation generally contain work elements that are more "stand-alone" in nature but this doesn't mean that these work elements will operate independently because in most cases, at least two Consortium partners are teaming to conduct the work. These work elements will also provide useful information to the other research activities in the Consortium.

Finally, the areas of Technology Development and Technology Transfer are the areas where the research deliverables will get transmitted to the user community. The Technology Development area will take promising research developments and refine them into useful tools for engineers and technologists involved in the design, construction, and maintenance of flexible pavement systems. The Technology Transfer area will also transfer Consortium research findings to the asphalt community using the Consortium website, presentations, publications, and workshops.

The Asphalt Research Consortium members strongly believe that the proposed research is responsive to the needs of asphalt engineers and technologists, state DOT's, and supports the FHWA Strategic Goals and the Asphalt Pavement Road Map.

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PROGRAM AREA: VEHICLE-PAVEMENT INTERACTION

The interaction between pavement surface and the loading vehicle plays a significant role in both the structural performance (i.e. resistance to fatigue, rutting, and moisture damage) and functional performance (i.e. resistance to skid, noise, and roughness) of pavements. The interaction at the tire-pavement interface represents the final link in the vehicle pavement interaction system, and it controls the distributions of both normal and shear stresses that are transferred to the pavement structure. The loads generated by the moving vehicle are dynamic in nature, and they invoke a dynamic response from the pavement structure which is greatly impacted by the inertia of the pavement structure and the viscoelastic behavior of the hot mix asphalt (HMA) layer.

The more accurate and more realistic predictions of the stresses at the tire-pavement interface and pavement responses under dynamic vehicle loads offer numerous advantages to the FHWA Strategic Roadmap and to the entire pavements/materials engineering community.

The Consortium will work on three elements of vehicle pavement interaction: a) Workshop on Super-Single Tires, b) Pavement Response Model Based on Dynamic Analyses, and c) Mix design to enhance safety. The Workshop on Super-Single Tires will be conducted in the first year while the other two elements will start in year 2.

Category VP1: Workshop

Work element VP1a: Workshop on Super-Single Tires

This effort will organize and hold a workshop on super-single tires usage and their impact on highway pavements. The University of Nevada will work with FHWA to organize the workshop. The following guidelines will be followed:

- The workshop will be held in October, 2007 in the U.S.A.
- The total number of workshop participants will be 12.
- FHWA will supply a list of potential participants.
- UNR and FHWA will identify the final list of participants.
- UNR will invite the workshop participants.
- Participants will make their own travel arrangements.
- UNR will cover travel expenses for the invited participants.
- UNR will prepare a summary of the workshop.

BUDGET

The cost for the workshop will be covered by the UNR budget and will be no more than $50,000.00.

Category VP2: Design Guidance

Work element VP2a: Mixture Design to Enhance Safety and Reduce Noise of HMA

BACKGROUND

One important emphasis of the new transportation bill is safety. Although safety, comfort, and noise control are known to be direct functions of macro and micro-texture, there are no significant efforts on integrating these design parameters into asphalt pavement mixtures (Bernhard and Wayson 2005; Guisik and Bahia 2006). It is also not well known if binders and mastics can change friction characteristics and pavement sound generation and absorption. University of Wisconsin-Madison researchers have been working with a number of DOTs in the mid-western region to look at new procedures for measuring macro and micro-texture and enhancing the methods for estimating micro-texture.

Micro-texture is the fine-scale (≤ 1 mm depth) grittiness on the surface of the coarse aggregates. The micro-texture makes direct tire-pavement contact and thus provides the resistance to skidding on the prevailing road surface. Macro-texture is the large-scale roughness that is present on the pavement surface due to aggregate arrangements and provides the drainage ability of the pavement. The combination of macro and micro-textures, and their changes with traffic and climate factors, make up the overall resistance to skidding. Furthermore, the proper macro-texture contributes to the reduction of roadway noise. Quiet pavement-tire systems have been implemented in Japan and many European countries because of the strong regulatory framework created by the European Community (EU). Several innovative techniques employed in Denmark, the Netherlands, France, Italy, and the United Kingdom have been able to reduced noise level in ranges that vary from 3 to 17 dB (Danish Road Institute 2005; Gibbs et al. 2007). Promising noise-reduction techniques include the use of porous elastic pavements (e.g., single and double layers porous asphalt, stone mastic asphalt, silent block pavements, etc.), recycled porous layers, emulsified asphalt concrete surfacing, use of a dense or semi-dense gradation in low-to-medium speed traffic roadways, and texturing of newly constructed concrete pavements for enhanced skid resistance and reduced pavement-tire noise.

This work element will focus on evaluating and modifying mixture design procedures to enhance safety and noise-reduction properties of asphalt mixtures for flexible pavements. In particular, this work element will develop a laboratory test procedure or a prediction model for the evaluation of macro and micro-textures of asphalt pavements. It will also focus on comparing these measurements with field measurements of skid resistance and pavement-tire noise. Results from this work will evolve into the development of pavement mixture design protocols that will not only include structural strength and durability, but also traffic safety, comfort and reduced pavement-tire noise.

HYPOTHESIS

The mixture design of asphalt mixtures (including binder types and aggregates) can be revised to include procedures to enhance driving safety and comfort while reducing noise generation. A holistic pavement mixture design protocol can incorporate mechanical strength, durability, safety, and improved roadway environment (noise) properties of asphalt mixtures.

OBJECTIVE

The overall objectives of this work element are:

- To study the state of the art on pavement-tire fiction coefficient and quiet pavement-tire design techniques.
- To develop a surrogate laboratory test to measure pavement macro and micro texture and predict safety and noise related properties.
- To establish criteria for the holistic mixture design protocol that optimizes mechanical properties, durability, skid resistance, and noise generation.

The final result of this work element will be the development of a mixture design protocol that will incorporate macro and micro-structure of mixtures that produce pavement surface layers with enhanced frictional response while reducing pavement-tire noise levels.

In order to achieve the objectives of this work plan, the following subtasks will be completed.

<u>Subtask VP2a-1: Evaluate common physical and mechanical properties of asphalt mixtures with enhanced frictional skid characteristics</u>

A literature review of the salient physical and mechanical characteristics of the pavement mixtures with improved skid characteristics will be collected to document the overall properties of asphalt pavements designs. Emphasis will be placed on aggregate properties and binder requirements for mixtures' types that improve not only frictional skid properties but also reduce cost and improve durability and comfort. Examples are Open Graded, Porous Asphalts, and Pavement Friction Courses. NCHRP most recent reports and the world wide literature will be covered.

<u>Subtask VP2a-2: Evaluate pavement macro and micro-textures and their relation to tire and pavement noise-generation mechanisms</u>

There are number of tire-pavement noise generation (e.g., thread vibration, air pumping, slip stick, and stick snap) and noise enhancement mechanisms (Bernhard and Wayson 2005). Quiet noise designs typically address these two issues and include surface textures of less than 10 mm, below surface textures, greater porosity (to reduce high frequency noise), and elastic surfaces. A complete literature review will be performed on both traffic noise generation mechanisms and noise reducing designs. Emphasis will be placed in technologies that reduce traffic noise in more than 5 dB and have a durability of more than 15 years. The results of this task will be compiled and evaluated along with the results from Task 1 to select best practices for pavement mixtures with enhanced skid friction behavior and reduced noise generation.

Subtask VP2a-3: Develop a laboratory testing protocol for the rapid evaluation of the macro and micro texture of pavements

Currently there is no system capable of measuring texture profiles for a laboratory prepared sample. Because of the difficulty in measuring micro-texture profiles, a surrogate for measuring micro-texture is required. The development of such a procedure would enable researchers and engineers to estimate macro and micro-texture of pavements in order to predict both the dry and wet frictional skid and/or noise reduction designs of pavements. The developed laboratory testing protocol will be correlated to traditional texture tests.

Subtask VP2a-4: Run parametric studies on tire-pavement noise and skid response

Using the data collected in tasks 1 and 2 and the laboratory testing protocol developed in Task 3, a set of parametric studies for different pavement mixtures will be performed to evaluate the correlation between measured macro and micro-textures and the skid resistance and pavement-tire noise levels. The pavement mixtures to be tested in this task will be selected in coordination with consortium research activities performed parallel to this work element. This will be done not only to evaluate noise-reducing pavement mixture design, but also to incorporate construction cost and durability in the pavement system design and help create a more holistic pavement mixture design protocol.

Subtask VP2a-5: Establish collaboration with established national laboratories specialized in transportation noise measurements. Gather expertise on measurements and analysis.

To complement the capabilities of the consortium with other expertise available in the country, the University of Wisconsin-Madison researchers will reach to nationally recognized laboratories and centers. A leading example is Purdue University's Institute for Safe, Quiet and Durable Highways. This institute's expertise on measurement and analysis will be leveraged to enhance the development of quiet pavement mixture designs. The University of Wisconsin-Madison researchers will establish collaboration initiatives to allow measuring the pavement-noise levels obtained with proposed holistic pavement mixture designs.

Subtask VP2a-6: Model and correlate acoustic response of tested tire-pavement systems

Results obtained in Tasks 4 and 5 will be correlated to pavement mixture design parameters (e.g., porosity, rugosity, granulometry, binder type, etc.). The obtained physical/engineering correlations will be used to constrain numerical models for the evaluation of frictional skid, noise generation mechanisms and pavement/tire noise-reduction designs. These results will be incorporated into a new asphalt mixture design protocol.

Subtask VP2a-7: Proposed optimal guideline for design to include noise reduction, durability, safety and costs

The parametric studies performed and the correlations and models obtained from previous tasks will be analyzed in combination with other work items in the consortium to maximize research resources and the use of the developed data and expertise. These parametric studies and designs will help in the development of improved frictional and noise-reducing mixture designs while maintaining/increasing comfort and reducing construction costs. State DOTs and nationally recognized laboratories and centers will be contacted to collect feedback about the practicality and the merits of the holistic pavement mixture designs.

YEAR 1 PROJECT DIRECTION

It is estimated that subtasks VP2a-1 though VP2a-3 will start during the first year.

SCHEDULE

Task	Year 1		Year 2		Year 3		Year 4		Year 5	
	Month									
	6	12	18	24	30	36	42	48	54	60
1	X	X								
2	X	X								
3		X	X	X	X					
4			X	X	X	X				
5				X	X	X				
6					X	X	X	X		
7							X	X		

RELATIONSHIP TO FHWA FOCUS AREA

This research effort fits under the flowing FHWA Focus Areas:

1. Advanced quality systems: Further development of test methods and design procedures that are more related to actual pavement performance.
2. Environmental Stewardship: Reduce noise of pavements is an environmental issue.

BUDGET

The anticipated budget is $325,000.

ARC Member	Year 1	Year 2	Year 3	Year 4	Year 5
UW-Madison	$75,000	$100,000	$100,000	$50,000	$0

REFERENCES

Bernhard, R. J. and R. L. Wayson (2005). "An Introduction to Tire/Pavement Noise". SQDH 2005-1 HL 2005-2. URL: http://meweb.ecn.purdue.edu/~sqdh/.

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Guisik, K., D. Noyce, and H. U. Bahia (2004). "Incorporating Road Safety into Pavement Management". MRUTC 04-04 Technical Report.

Category VP3: Modeling

Work element VP3a: Pavement Response Model to Dynamic Loads (Later start)

The researchers will develop a computer model to predict the responses of flexible pavements to dynamic loads generated by traffic moving at speeds ranging from stopping at intersections to highway cruising speed. The model is based on continuum-based "finite-layer" theory. The HMA layer is characterized as a viscoelastic material, while the base and subgrade layers are characterized as elastic materials. The normal and shear stresses at the tire-pavement interface can be modeled with any shape and any distribution. The vehicle loads are simulated as moving loads at a constant speed. The analytical model treats each pavement layer as a continuum and uses Fourier transform techniques to handle the complex normal and shear stresses at the tire-pavement interface.

Two major input components to the pavement response model are: magnitude of vehicle dynamic loads and stress distributions at the tire-pavement interface. The proposed model will incorporate results from existing state of the art technology in vehicle dynamics to predict the distribution of dynamic loads as a function of road roughness and vehicle speed. In the case of stress distributions at the tire-pavement interface, results of previous field and laboratory studies conducted by the UNR researchers and others will be incorporated. It is anticipated that the University of Nevada will conduct this task.