Hot Mix Asphalt Surface Characteristics Related to Ride, Texture, Friction, Noise and Durability

***Work Plan***

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**Introduction**

Tire-pavement noise is the result of several generation mechanisms, including tire carcass vibration, adhesion, slip-stick, and air pumping. Each of these mechanisms is affected differently by changes in pavement parameters. The overall noise level depends on which of the several generation mechanisms is most prominent. A model of tire-pavement noise involving only overall noise levels is likely to give incorrect conclusions on the effects of the various pavement parameters, so reasonably accurate prediction of one-third band spectra is necessary.

This study will develop a model for tire-pavement noise using the mechanism decomposition method. The fundamental theory of this method is that a tire-pavement sound intensity spectrum can be decomposed into several constituent spectra, each representing the contribution from a generation mechanism. Since each mechanism is an independent noise source, the constituent spectra are added logarithmically to form the total tire-pavement noise spectrum. The magnitude of each constituent spectrum is a function of a subset of the pavement parameters.

**Objectives**

The objective of the proposed investigation is to develop a model to predict on-board sound intensity (OBSI) on hot mix asphalt pavements using on-site and laboratory data. Data measured on MnROAD test sections will be used to develop a nonlinear statistical model. The model will be able to predict one-third octave band and overall sound intensity on HMA pavements and will be used to identify the pavement parameters that most affect tire-pavement noise generation.

**Anticipated duration of project:** 24 Months

## Total Budget Direct & Indirect Cost: $50,000

Budget Details (Direct & Indirect Costs)

## Salaries, Wages, Fringe Benefits and Grad Fee Remission: $40,831

**Indirect Costs:** $9,169

**Budget by Task**

|  |  |  |
| --- | --- | --- |
| **Task** | **Salaries** | **Indirect Costs** |
| 1. Review of Literature
 | $5,544 | $1,241 |
| 1. Effect of Changing Seasons on HMA Surface Characteristics
 | $6,310 | $1,540 |
| 1. Physical Identification of Significant Variables
 | $5,856 | $1,322 |
| 1. Mathematical Model of Sound Intensity
 | $9,364 | $1,933 |
| 5. Draft Final Report | $9,353 | $2,088 |
| 6. Final Report | $4,403 | $1,045 |

## Work Plan

The following is a summary of the tasks and subtasks anticipated to be needed to meet the objectives of this study. The dates below are based on an assumed start date of July 1, 2011.

### Task 1: Review of Literature

A comprehensive review of all tire-pavement noise models will be undertaken, including national (e.g., Khazanovich and Izevbekhai, Ongel et al.) and international (e.g., SPERoN, TRIAS, PREDIT) literature. The primary goal is to determine which pavement characteristics are important in predicting noise on HMA pavements and to identify frequency ranges or mechanisms that are dominant for a broad collection of types of hot mix asphalt. In anticipation of a mechanism decomposition approach, the literature review will also include studies on the frequency ranges and pavement characteristics important to each of the tire-pavement noise generation mechanisms. These studies will provide the basis for determining the characteristic spectra to be used in the model. The subtasks involved in this effort include:

* 1. Collect data from MnROAD databases and enter into MATLAB. Identify and address missing or invalid data.
	2. Review national and international tire-pavement noise models.
	3. Review tire-pavement noise generation mechanisms and associated spectra.
	4. Review the effect of atmospheric conditions on tire-pavement noise.
	5. Prepare summary report.

Deliverable for Task 1: Report summarizing the literature review including identification of available data.

Duration of Task 1: 4 months (Months 1-4, July through October 2011)

### Task 2: Effect of Changing Seasons on HMA Surface Characteristics

Many asphalt pavement characteristics show seasonal variations; pavement friction is the most studied example. Since asphalt is a viscoelastic material, its properties vary with temperature. Pavement stiffness has an impact on noise generation, so as stiffness changes, the noise generation may also change. Moisture conditions may also impact noise generation and may vary seasonally. This task will explore the effects of seasonal changes in the environmental conditions on the HMA surface characteristics using the MnROAD database and mixture testing data. The change in properties will be related to the measured noise levels so that these effects can be incorporated in the noise model developed in task 4. The subtasks include:

* 1. Examine MnROAD data to establish relationship between seasonal variations in environmental conditions on HMA surface characteristics.
	2. Prepare report documenting the findings.

Deliverable for Task 2: Report documenting the findings related to seasonal variations in pavement characteristics.

Duration of Task 2: 6 months (Months 3-8, September 2011 through February 2012)

### Task 3: Physical Identification of Significant Variables

The goal of this task is to determine which pavement characteristics are related with on-board sound intensity levels and whether there is positive or negative correlation. As discussed above, it is likely that some variables only affect portions of the OBSI spectrum and that these variables are only important when a given mechanism is dominant. For each variable measured, the variation in the magnitude of each constituent spectrum will be identified. It will therefore be possible to determine the properties important to each mechanism and constituent spectrum. These results will be used to verify important parameters identified during Task 1 and to simplify the model as much as possible. The pavement characteristics important to each mechanism will be described in a Task Report. Subtasks include:

* 1. Identify pavement characteristics shown to correlate with overall noise levels.
	2. Identify pavement characteristics shown to correlate with each constituent spectrum.
	3. Prepare task report.

Deliverable for Task 3: Report identifying pavement characteristics related to overall noise levels and constituent spectra

Duration of Task 3: 7 months (Months 5-12, December 2011 through June 2012)

### Task 4: Mathematical Model of Sound Intensity

The research described above will culminate in a mathematical model for OBSI levels. Though the proposed statistical model is more complex than those proposed by other researchers, the model will be simple to use. The inputs to the model will be measured pavement characteristics, and the model will output one-third octave band and overall OBSI levels for any given HMA pavement. The model will be useful to both a pavement engineer wanting to determine if a given pavement would meet noise criteria and a tire-pavement noise researcher wanting to determine if a particular generation mechanism is significant. A sensitivity analysis will be performed to determine the effect of each pavement parameter on OBSI levels.

The limits and boundaries of the model will be thoroughly investigated. One goal is that the model should be applicable in as wide a range of conditions as possible, including seasonal temperature changes and aging pavement. The mechanism decomposition method can readily adapt to conditions where certain mechanisms become more dominant. However, it is likely that the model will not be applicable in situations where all of the mechanisms are likely to change dramatically, such as in icy-road conditions.

Subtasks include:

* 1. Develop model through mechanism decomposition method.
	2. Verify validity of model using other measurements or leave-one-out cross-validation.
	3. Identify limitations and boundaries of the model.
	4. Prepare task report.

Deliverable for Task 4: Report summarizing the noise model, validity of the model and limitations/boundaries.

Duration of Task 4: 7 months (Months 10-16, April 2012 through October 2012)

### Task 5: Draft Final Report

The culmination of the proposed project is a detailed report describing the model, its development, and the theories and assumptions involved. The report will incorporate detailed descriptions of the background and methods used in completing Tasks 1–4. The report will contain a thorough review of state-of-the-art modeling efforts and information on the mechanisms and variables important to tire-pavement noise. The description of the model and its development will be thorough enough so that the methods can be duplicated and adapted to pavements other than hot-mix asphalt, such as porous and textured portland cement concrete pavements. An executive summary will be provided so that the results and conclusions of the project can be understood quickly by a wide audience. The required subtasks include:

* 1. Compose draft final report, including a full description of all previous tasks.
	2. Submit draft final report through the Mn/DOT/University of Minnesota Center for Transportation Studies publication process.

Deliverable for Task 5: Draft final report, draft technical summary and draft executive summary.

Duration of Task 5: 6 months (Months 15-20, September 2012 through February 2013)

### Task 6: Final Report

The review comments will be incorporated into the final report, technical summary and executive summary.

* 1. Incorporate feedback and corrections from review process
	2. Submit final report, technical summary, and executive summary

Deliverables for Task 6: Final report, technical summary and executive summary revised according to review comments. The model for predicting on-board sound intensity levels measured with the Standard Reference Test Tire on HMA pavements, delivered as a Microsoft Excel, MATLAB, or other program as requested. And a brief user’s manual for the program with information on the limitations and applicability of the model, including pavement type and atmospheric conditions.

Duration of Task 6: 4 months (Months 21-24, March 2013 through June 2013)

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|  | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** |
|  | **2011** | **2012** | **2013** |
|  | **J** | **A** | **S** | **O** | **N** | **D** | **J** | **F** | **M** | **A** | **M** | **J** | **J** | **A** | **S** | **O** | **N** | **D** | **J** | **F** | **M** | **A** | **M** | **J** |
| **Task 1** |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| **1a** |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| **1b** |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| **1c** |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| **1d** |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| **1e** |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| **Task 2** |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| **2a** |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| **2b** |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| **Task 3** |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| **3a** |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| **3b** |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| **3c** |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| **Task 4** |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| **4a** |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| **4b** |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| **4c** |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| **4d** |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| **Task 5** |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| **5a** |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| **5b** |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| **Task 6** |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| **6a** |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| **6b** |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

\*Assuming a start date in July 2011.