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TIRE/PAVEMENT INTERACTION NOISE RESEARCH ACTIVITIES OF THE INSTITUTE FOR SAFE, QUIET, AND DURABLE HIGHWAYS

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ABSTRACT
In the United States, tire/road interaction noise has been identified as the major source of highway sideline noise at highway speeds. The Institute for Safe, Quiet, and Durable Highways (SQDH) was established at Purdue University in 1999 to complement worldwide studies of tire/road interaction noise and to investigate the development of quiet highway and tire technology for U.S. applications. The activities of the Institute include education, research, and technology transfer. Initial research emphasis will be on investigations of the fundamental mechanisms of tire/road noise generation and control. Future work will involve consideration of the practical issues of quiet highway and tire construction and maintenance, material design, and traffic management. Application of quiet highway technology is also expected to reduce the need for roadway noise barriers in the U.S.

1 - INTRODUCTION

The Transportation Equity Act for the 21st Century (TEA-21) authorized funds to establish 33 University Transportation Centers (UTC) throughout the United States. TEA-21 was enacted on June 9, 1998 and specified funding for the UTCs during Fiscal Years 1998-2003. Ten Regional Centers and 23 UTCs were chosen to receive a share of the almost $195 million designated in TEA-21 for university transportation research and education. In Fiscal Year 2002, a competition will be held for the last two years of funding. Only 26 centers will receive FY 2002-2003 funding. All centers are required to match federal funds dollar for dollar.

Purdue University was one of the universities chosen to receive a grant to establish a University Transportation Center. The Strategic Plan for this UTC was officially approved in early 1999. Profs. Robert Bernhard (Mechanical Engineering) and Vincent Drnevich (Civil Engineering) are Co-Directors of Purdue University's Institute for Safe, Quiet, and Durable Highways (SQDH). The interdisciplinary nature of the SQDH Institute combines the acoustics, noise control, and tire behavior research expertise of the Purdue University School of Mechanical Engineering with the pavements, materials, and traffic management research expertise of the Purdue University School of Civil Engineering.

Tire/road interaction noise is the primary source of highway sideline noise at highway speeds. Increased traffic flows and population densities have caused a greater interest in this source of environmental noise in the United States. Development of quiet highways that are also safe, durable, and economical will reduce the effect of traffic noise near densely populated areas. In addition, this technology is expected to reduce the need for roadway noise barriers.

2 - INSTITUTE GOALS AND ACTIVITIES

The overall goals specified by the University Transportation Centers Program include:

1. Educational advancement (education, human resources, and diversity)
2. Research results (research selection and research performance), and
3. Technology Transfer to users.

The SQDH Institute Strategic Plan specifies particular activities to achieve each of these goals. Following is a description of activities relating to the UTC Program goals, with greatest emphasis on the Research activities.

2.1 - Education

The focus of the SQDH Institute Education activities will include new and revised classwork as well as programs designed to bring more students into the transportation field. Activities have thus far focused on a summer internship program for incoming engineering sophomores and facilities tours for pre-college and undergraduate students. Four undergraduate students were selected to be in the first class of SQDH Institute summer interns during the summer of 1999. Two interns worked in Mechanical Engineering and two interns worked in Civil Engineering. The interns worked on research projects with professors and graduate students while taking summer courses.

SQDH Institute research facilities tours were given for a wide variety of audiences. Elementary and secondary school students were given tours of the Ray W. Herrick Laboratories, a graduate research lab in Mechanical Engineering. Undergraduates and practicing engineers have toured the Herrick Laboratories in addition to several Civil Engineering labs (concrete lab, asphalt lab, and intelligent transportation systems lab), the North Central Superpave Center, and the Indiana Department of Transportation Research Facility (including the Accelerated Pavement Testing facility). These tours educate the visitors about the tire/road noise problem that they themselves experience each day, and hopefully will recruit young students into the transportation field.

2.2 - Research

The research program of the SQDH Institute is intended to be complementary to worldwide research activities on tire/road interaction noise. Initial emphasis is on fundamental investigations of the mechanisms of tire/road noise generation and control. Laboratory facilities will be constructed to facilitate acoustic and vibration measurements of tires rolling on realistic road surfaces. Future work will involve implementation of the understanding of tire/road noise generation mechanisms to the practical issues of quiet highway construction and maintenance, material design, and traffic management.

The SQDH Institute research selection process involves requesting Research Need Statements (RNS). The RNSs are one to two page documents describing the research problem. Submissions are welcome from any interested party. The 1999 solicitation of RNSs produced 30 submissions describing problems estimated to require over $5,000,000 in research. The 2000 RNS solicitation resulted in 20 RNSs for more than $3,000,000 worth of research.

The SQDH Institute Advisory Council reviews the RNSs and makes recommendations to the Executive Committee. Full proposals are solicited to address the top-ranked RNSs. The proposals are then peer-reviewed and, upon acceptable review, approved for funding. A requirement of each proposal is to procure one-for-one matching funds. Matching funds sources include industrial contracts, in-kind support, university cost sharing (research equipment, salaries, administration and facilities costs, etc.), and funds from the Joint Transportation Research Program (JTRP) within Purdue's School of Civil Engineering in association with the Indiana Department of Transportation. The research proposals funded from the 1999 RNS solicitation are described below.

Fundamentals of Tire/Road interaction noise (adapted from the proposal by J. Stuart Bolton, Jan Olek, and Nancy Franchek (Purdue University))

This investigation will build on worldwide research on tire/road interaction noise [1] and previous research at the Herrick Laboratories on tire vibration and noise. Measurement procedures and analytical models to predict noise generation of a rolling tire on various types of pavements will be improved and refined. A test apparatus, shown schematically in concept design form in Figure 1, will be constructed to measure sound radiation from a rolling tire on pavements with variable texture and composition. Analytical methods will involve wavenumber/frequency analysis of tire vibration and sound radiation. In addition, more extensive nearfield acoustic holography measurements, similar to those shown in Figure 2, will be made of sound radiation from a rolling tire.

Development of Quiet and Durable Porous Portland Cement Concrete Paving Materials (adapted from the proposal by Jan Olek and Jason Weiss (Purdue University))

Based on the results of European studies [2,3,4], the most promising noise-reduction technique for Portland Cement Concrete (PCC) pavements appears to be the use of a porous concrete surface layer. In

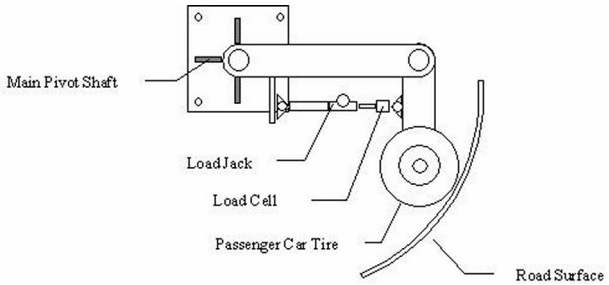

Figure 1: Schematic of tire/road interaction noise test apparatus.

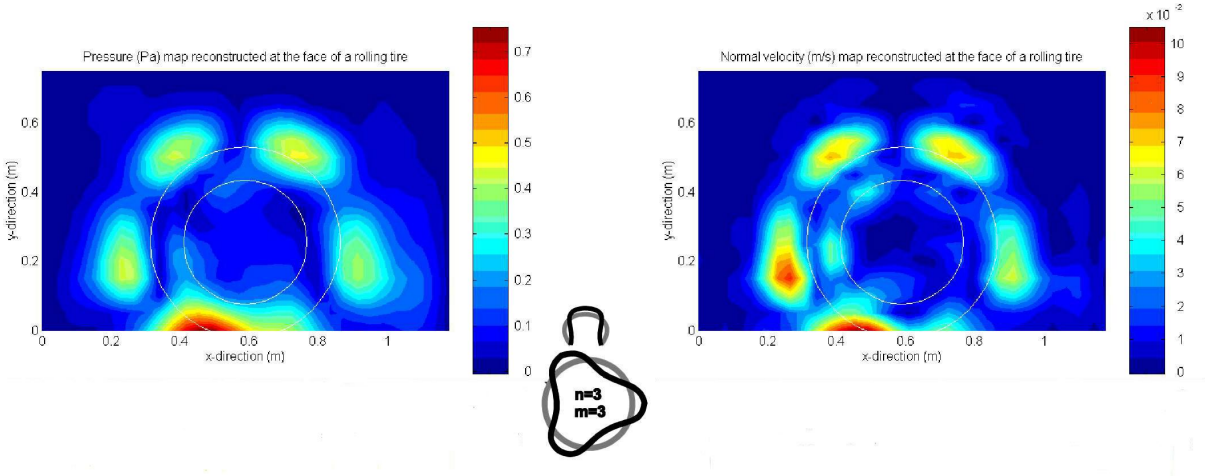

Figure 2: Nearfield acoustic holography measurements of a rolling tire [9].

order for such a layer to be effective with respect to noise reduction, its porosity must be approximately 25 percent. This high porosity requirement dictates that the surface mixture compositions be carefully optimized so that the noise-reduction modifications do not have a negative impact on durability, safety, and mechanical properties. The primary objective of this study is to develop porous portland cement concrete surface mixtures by optimizing their composition with respect to strength, safety, acoustic properties, and durability. A large matrix of potential mixtures will be initially developed and evaluated in the laboratory. The most promising mixtures will be considered for further testing and potential test-track or field installation.

Development of New Technologies for Texturing of PCC Pavements (adapted from the proposal by Jan Olek (Purdue University) and Dave Kuemmel (Marquette University))

This study involves the investigation of new and innovative texturing patterns for Portland Cement Concrete pavements. This investigation builds on previous studies at Marquette University [5]. Pavement texture applied to a concrete surface improves the friction properties, and thus the safety, of the surface. Transverse tining has been shown to increase tire/road interaction noise. Longitudinal tining generates less tire/road interaction noise, however, it may not be as safe. In this study, existing texturing patterns will be optimized using computer modeling, acoustical simulations, and lab testing. In addition, new texturing patterns will be developed and optimized for safety and noise characteristics. The best patterns for mechanical and acoustical properties will be tested in a laboratory setting and simulations will be developed for tire/pavement interactions. Finally, the most promising patterns will be field tested.

Development of Porous Modified Asphalt Mixes for Noise Control Applications (adapted from the proposal by Rebecca McDaniel, Jan Olek, and Magdy Abdelrahman (Purdue University))

Because of the high air voids and low density of porous asphalt mixes, there have been concerns regarding the performance and durability of these mixes. Literature indicates the success of optimizing the performance of porous mixes through the use of modified binders [6]. The main objective of this study is to optimize the noise control properties of modified porous asphalt concrete surface mixtures while considering mix performance criteria related to strength, safety, and durability. Different modified porous mixes will be compared, including the use of polymers, fibers, and crumb rubber modifiers. Surface texturing, porous surfaces, and surface mixture compositions will be evaluated to maximize noise

reduction.

Measurement and Evaluation of Roadside Noise Generated by Transit Buses (adapted from the proposal by Eric Mockensturm and Bohdan Kulakowski (The Pennsylvania State University))

Purdue University is collaborating with The Pennsylvania State University for multi-modal transportation studies. The Pennsylvania Transportation Institute (PTI) at Penn State has a test track facility for measuring noise generated by transit buses. A study will be conducted to identify the noise sources generated by buses traveling on various road surfaces at varying vehicle speeds. The focus of the study will be on tire/road interaction noise, engine noise, and exhaust noise. The engine and exhaust noises are particularly significant in urban environments where the bus speeds are lower and there are frequent times of acceleration and deceleration. Proper identification of these sources for transit buses can be applied to help improve the Federal Highways Administration (FHWA) Traffic Noise Model (TNM) [7].

Study of the Performance of Acoustic Barriers for Indiana Toll Roads (adapted from the proposal by Luc Mongeau and J. Stuart Bolton (Purdue University))

Acoustic barriers are needed in order to reduce the noise levels in some areas despite improvements in quiet highway materials and tires [8]. Considering the cost of barriers, it is important that optimal barrier designs be implemented. The aims of the proposed research are to study the influence of wind and temperature gradients on barrier performance, to investigate the effects of surface absorption treatments on barrier performance, and to investigate the effects of barrier-top geometry on barrier performance. Optimal sound barrier concepts will be proposed at the end of the study.

2.3 - Technology transfer

An important objective of the UTC Program is to transfer the new transportation technology developed by the centers and other results from the literature to practicing engineers and the community. The SQDH Institute has created a website (http://widget.ecn.purdue.edu/∼sqdh) and has mailed its first newsletter in order to facilitate this outreach. As more research results are obtained, journal papers will be written and conference presentations will be made to disseminate the latest information.

Another aspect of technology transfer was achieved by hosting a Traffic Noise Model (TNM) short course in association with the Federal Highway Administration, the U.S. Department of Transportation, and Harris Miller Miller & Hanson Inc. This short course was attended by practicing engineers from all over the midwestern section of the United States.

3 - FUTURE PLANS

Five research proposals have been invited based on the 2000 solicitation of Research Need Statements. These proposals include:

1. Sound Propagation Over Partially Absorbing Paved Surfaces in the Presence of Strong Thermal Gradients
2. Tire Noise Generation and Radiation Mechanisms
3. An Investigation into the Quality of Sounds Generated by Tire/Road Interactions: Vehicle Interiors
4. Identification of Far-Field Noise Sources on Heavy Trucks
5. Concrete Mixtures Incorporating Inclusions to Improve the Sound Absorbing Capacity of Pavements

Approximately half of these proposals are expected to be submitted and approved.

The initial objectives of the Institute involve understanding the fundamental mechanisms of tire/road noise generation and control. In the second phase, research on the implementation aspects of quiet highways will be pursued. The knowledge gained in the first phase will be applied to the practical issues of quiet highway construction and maintenance, material design, and traffic management. Application of quiet highways technology will hopefully reduce the need for roadway noise barriers which will save taxpayer dollars. Eventually, other aspects of highway noise and transportation noise problems will be studied.

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