ABSTRACT

Neithalath, Narayanan. Ph.D., Purdue University, December 2003. Development and Characterization of Acoustically Efficient Cementitious Materials. Major Professors: Jan Olek and Jason Weiss.

Tire-pavement interaction noise is one of the significant environmental issues in highly populated urban areas situated near busy highways. Though the use of sound barriers, as well as texturing methods are adopted to minimize this problem, they have their own limitations. The understanding that methodologies to reduce the sound at the source itself is necessary, has led to the development of porous paving materials. This thesis outlines the systematic research effort conducted in order to develop and characterize two different types of sound absorbing cementitious materials – Enhanced Porosity Concrete (EPC), that incorporates porosity in the non-aggregate component of the mixture, and Cellulose-Cement Composites, where cellulose fibers are used as porous inclusions. The basic tenet of this research is that carefully introduced porosity of about 15% - 25% in the material structure of concrete will allow sound waves to pass through and dissipate its energy.

The physical, mechanical, and acoustic properties of EPC mixtures are discussed in detail. Methods are developed to determine the porosity of EPC. The tortuosity of the pore network, and the frictional losses in the pore walls are the main mechanisms that are responsible for energy loss. Using a shape-specific model, and incorporating the principle of acoustic wave propagation through semi-open cells, the acoustic absorption in EPC has been modeled. The pore structure and performance of EPC is characterized using Electrical Impedance Spectroscopy. Using a multi-phase conducting model, a pore connectivity factor has been developed, that correlates well with the acoustic absorption coefficient. A falling head permeameter has been designed to ascertain the water permeability of EPC mixtures. A hydraulic connectivity factor is proposed, which could be used to classify EPC mixtures based on their permeability. The intrinsic permeability also could be predicted using electrical conductivity. Electrical conductivity is shown to

be a single measurable parameter that defines the performance of EPC. Preliminary studies conducted on the freezing and thawing response of EPC are also reported.

From several porous, compliant materials, morphologically altered cellulose fibers are chosen to be used as inclusions. The "macronodule" (aggregate-like, 2-8 mm in size) fibers are shown to be the most effective among the various morphologically altered cellulose fibers considered. The physical and mechanical properties (porosity, flexural and compressive strengths, modulus of elasticity), acoustic absorption, and the energy dissipating capacity (specific damping capacity) are evaluated. The influence of fiber volume on these properties is dealt with in detail. Composite mixing relations have been used to model the loss modulus and loss tangent of these composites. The response of these composites to extreme exposure conditions has also been studied.