APPENDIX: Past and Current Research

A- *Foam-Glass Light Weight Aggregate (FG-LWA) as fill materials*

In a recently completed project at the University of Waterloo I worked on different lightweight fill materials including an innovative recycled aggregate. In this project, an artificial aggregate from recycled glass of mixed sources was produced and investigated for pavement construction applications when poor subgrade soils with low bearing capacity is present. The environmental and chemical interaction of the recycled aggregates were investigated experimentally. Case studies of pavement structures from rural arterial roads in Ontario, where thick layers (approximately 2 meters) of expanded polystyrene (EPS) were used, to redesign new structures with the FG-LWA materials. A base Life Cycle Analysis (LCA) with focus on the environmental impacts of using this new material was conducted. A conference paper has been submitted and accepted for presentation at the upcoming Transportation Research Board annual meeting in 2020. I am also preparing a journal article based on the results of this research that will be submitted to the International Journal of Road Materials and Pavement Design. The material also has promising thermal insulating characteristics to be used in the granular base and subbase of pavement structures to protect the subgrade soil from detrimental effects of frost penetration in Ontario.

B- *Developing Biodegradable Asphalt Release Agents in Canada*

In a recently completed project I have worked with industry partners to develop a framework for evaluating the engineering properties and efficiency of biodegradable asphalt release agents (ARA) in Canada.

C- *Working as co-PI on Enhanced Moisture Sensitivity Study for WHRP:*

In an ongoing research sponsored by the Wisconsin Highway Research Program (WHRP) and the Wisconsin Department of Transportation, I am conducting a study on enhanced moisture sensitivity of asphalt concrete pavements. As a co-PI of this project I am working with our team at Penn State University, Bloom Companies LCC, and the Wisconsin Department of Transportation to identify a more reliable procedure to be used both in the mix design and the production stages in order to identify problematic mixtures with moisture sensitivity. Given the variability in climatic, geological, and traffic conditions in North America, a single conditioning protocol in the laboratory cannot represent the conditions that flexible pavements experience during their service life. Therefore, our design of experiment includes investigating four sets of moisture conditioning protocols and their evaluation through Hamburg Wheel Tracking Device (HWTD), Moisture Induced Stress Tester (MiST), indirect tensile dynamic modulus testing, traditional AASHTO T-283 tests, and a series of nondestructive Ultrasonic Pulse Velocity (UPV) tests. The former is one of the methods that the Ministry of Transportation Ontario is planning to study and considers including it in the materials specifications in the near future. During the course of this project, we have been looking into the state of the practice in the states surrounding Wisconsin as well as two Provinces in Canada, namely Ontario and Quebec. The outcome of our research would be in the form of standard specifications with the goal of mitigating premature damage of flexible pavements due to moisture-induced damage, especially in cold regions such as Wisconsin.

D- *Developing Specifications for the Use of Post-Consumer Recycled Asphalt Shingles for Pennsylvania Roadways:*

This project is sponsored by the Pennsylvania Department of Transportation. Recycled Asphalt Shingles, so-called RAS, are rich sources of asphalt binder and mineral fillers. In spite of their high asphalt content, typically in the range of 20 to 30% by mass, the high stiffness of the aged binder in RAS prevents using it at higher rates in the production of fresh asphalt concrete mixtures. Generally, a maximum allowable amount of 5% by the mass of total mix has been used by most of the agencies, while a few agencies allow manufacturer RAS usage up to 8%. However, post-consumer RAS, as opposed to manufacturer RAS, is a more complicated material and requires further processing and screening in order to be used in asphalt concrete production. I am overseeing experimental studies and data analysis for this project. The main goal is to develop specifications for using high amounts of post-consumer RAS in asphalt pavement construction without sacrificing the performance of pavements. In this capacity, I mentor graduate students at Larson Transportation Institute. The project involves asphalt concrete material characterization through a suite of conventional and advanced experiments. In a previous research, which was also a part of my Ph.D. research, simultaneous use of high amounts of Recycled Asphalt Pavements (RAP) and RAS was investigated. The result indicated that when a rational mix design is followed, this technique offers several advantages with respect to saving on landfill space, use of virgin asphalt binder, use of mineral aggregates, and reducing the cost of construction.

E- *Testing and Evaluation of Asphalt Binders and Asphalt Concrete Modified with Wacker Polymers:*

Use of polymer modifiers to improve the mechanical and rheological properties of asphalt binders/mixtures has become very essential during the past few decades. A more robust extraction process to separate the valuable elements from the bottom oil, especially during the past 15 years, has resulted in a lower quality of base asphalt cements and a growing demand to use polymer modifiers. In this study, sponsored by Wacker Chemical Inc., we have been investigating the possibility of using the well-known Styrene-Butadiene-Styrene (SBS) copolymer (an elastomer) in the presence of a plastomeric polymer to improve the high- and low-temperature performances of asphalt binders. I have developed microstructure image processing techniques to study the effect of duration, shear rate, and temperature of blending on achieving a homogenized and well cross-linked modified asphalt binder. To this end, I have used ultraviolet fluorescence microscopy in the Materials Research Institute (M.R.I.) of Penn State University. I have also studied the effect of base binder source and a sulfur-based crosslinking agent on rheology of the modified binders. Multiple SHRP binder tests including DSR, BBR, MSCR, and LAS tests were conducted on the blends to identify the optimum dosage of each of the elastomeric and plastomeric polymers. We have started the next and final phase of the project, which is studying the asphalt concrete mixtures produced using the proposed polymer modified binders. Figure 2 shows a view of the multiphase microstructure of a polymer modified binder during the initial stages of blending and prior to crosslinking that I captured using a UV-Fluorescence microscope at MRI.

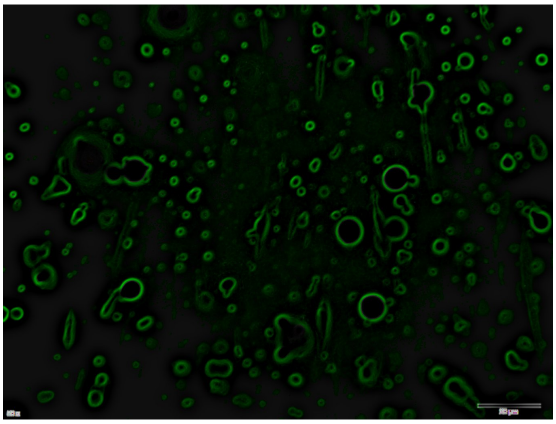

Figure 2- Incomplete blending of SBS into a PG 64-22 base binder in UV-fluorescence microscopy t 50x magnification level

Past Studies at Penn State University

During my *Ph.D. studies,* I developed a nondestructive test method to more accurately measure the complex shear and Young's moduli of asphaltic mixes. Loading frequencies and the attainable strain levels in this method are wider than those of conventional tests such as uniaxial dynamic modulus test. I successfully employed this method toward characterization of a variety of emerging asphalt concrete mixture technologies, especially Warm Mix Asphalt (WMA) mixes, high Recycled Asphalt Shingles (RAS), and high Reclaimed Asphalt Pavement (RAP) mixes for which the full spectrum of properties is not known very well yet. The method was also successfully used to correct the upper shelf of modulus master curve to provide an increased level of accuracy. The modulus master curve is a key input for mechanistic empirical (M-E) design of flexible pavements. Furthermore, during my doctoral research I have established a practical small-scale specimen geometry to characterize asphaltic mixes. Such geometry not only results in saving on costs, materials, and sample preparation efforts, but also makes it possible to perform mechanical tests on field-obtained cores, especially those from thin-lift asphalt concrete layers. The latter is not currently feasible due to the minimum required dimensions of conventional tests specimens. My main research was funded through two projects from the U.S. Department of Transportation.

During my course of studies at Penn State, I also had the great opportunity to work on *three projects* for the Pennsylvania Department of Transportation *(PennDOT)*. These experiences helped me to get a better understanding of the nature of demands from industry and public and private sectors:

A) **Developing Specifications for Midwest Soil Stabilizer Agent:** This project required a set of numerical modeling and experimental studies. I used ABAQUS finite element package to model structure of the pavement of interest. The objective was to identify the proper size to build a small-scale prototype of the pavement structure in the lab such that the boundary effects become negligible in regards to vertical, tangential, and shear stresses and strains under traffic loading. Based on the modeling results, I designed a cubic box that could accommodate the loading facility and pavement digital profile measurement devices. Pavement layers were constructed in the box and 1/3-scale model mobile load simulator (MMLS-3) was mounted on it using a crane to simulate traffic. I have used a series of destructive and nondestructive experiments to measure the mechanical properties of the prototypes such as light weight deflectometer (LWD), nuclear density gauge, and dynamic cone penetrometer (DCP).

Using LabVIEW™ I developed a closed-loop control-feedback and data acquisition code for conducting uniaxial tension-compression fatigue and dynamic modulus tests. The code has been used extensively towards conducting several industrial research projects since then. Distresses such as permanent deformation, modulus reduction, and material dislodging were monitored and quantified to compare the effect of stabilizer agents. The results were used for PennDOT publication 447 specifications.

B) **Polymer Modified Cold Recycled Asphalt Evaluation and Methodology:** Cold mixed emulsified asphalt is an environment-friendly pavement technology. During this project for PennDOT, I was mainly in charge of material characterization and performance evaluation. I used the developed LabVIEW code and a highly capable integrated MTS-Instron hydraulic testing system to perform uniaxial tension-compression fatigue tests on regular and polymer modified emulsified asphalt samples. I analyzed the experimental results using fracture mechanics theories and viscoelastic continuum damage (VECD) model to compare the fatigue lives of the cold mixed asphalt mixtures of interest.

C) Thin-Lift Asphalt Overlay: I conducted several uniaxial dynamic modulus tests on replicate specimens of three different hot mix asphalt (HMA) mixes. The tests included a series of cyclic frequency sweep tests performed at five testing temperatures. The complex modulus components (dynamic modulus and phase angle) were determined and modulus master curves were developed using the time-temperature superposition principle. I also used AASHTOWare Pavement M-E to model the performance of these mixes and compared the modeling results with the observed field performance in order to evaluate the performances of these rehabilitation strategies. The results of this study will help PennDOT with developing specifications and guidelines for design and construction of Thin Hot Mix Asphalt Overlays (THMAO) in Pennsylvania.

Past Experiences prior to Joining Penn State

Upon graduation from my bachelor's program of study, I pursued a master of science degree with the idea of bridging the gap between then available numerical models and experiments. I developed my code in FORTRAN to perform *discrete element modeling (DEM)* of asphalt concrete cylinders using a realistic geometric representation of microstructure of a given specimen. I used MATLAB to perform *image proces*sing and generated digital input for DEM. During my master's studies, I had the great opportunity of working on several research projects such as evaluating the effect of antistripping agents, developing a fatigue performance model and its calibration for the national highway pavement network.

Part Time Services: I got invited to serve as a *part time research engineer* at the Deputy for Research at traffic and transportation organization of Tehran municipality. In that capacity, I gained a better understanding about the nature of traffic loading in intrastate and urban highways and their inherent differences with rural highways. I noticed the interaction of traffic speed and pavement design and the fact that premature failures occurred in cases of the congested heavy traffic flow. I designed three Stone Mastic Asphalt (SMA) mixtures using the domestic materials and technologies – using cellulous fibers to control the draindown – to mitigate premature permanent deformation of the highway pavements.

Co-founding Research Center: Upon graduation from the M.Sc. program, my former advisor and I pursued founding the *National Transportation Infrastructure Research Center* (NTIRC) to foster the collaborative research in the area of transportation infrastructure.

NTIRC was a bridge among the Ministry of Transportation, Ministry of Science-Research and Education, and the transportation industrial partners. I served as a core-faculty member and *senior researcher* for two years prior to departing to Penn State to start my Ph.D. The goal of the research center was defined with respect to the existing gap between research and the state of the practice in Iran.