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Drexel Researchers Focus on New Tools to Manage Health Monitoring of Structures

by Dr. Ivan Bartoli

Despite the growing desire to invest in the rejuvenation of our civil infrastructure systems, promises of such investments often remain unfulfilled. Highways and bridges, particularly in the Northeast portion of the United States, clearly show signs of lack of intervention while they serve steady, if not, increasing traffic volumes.

Civil engineers are increasingly asked to manage structures such as bridges, that are approaching the end of their original life cycle with limited resources. Visual inspection remains the primary approach to assess bridge conditions but it can only provide qualitative rather than objective, quantitative evaluations. In this context, there is a growing need for reliable and practical approaches to quantitatively measure responses of bridges subject to traffic loads, and to quantify degradation of materials and structural components. These approaches, if properly used by infrastructure owners, would help maintain the safety of transportation infrastructures.

Researchers in the CAEE Department at Drexel, including myself and Dr. Emin Aktan, have been working the past few years to develop tools that would help increase the safety of such infrastructures. An example of our efforts is a research project sponsored by the Federal Highway Administration (FHWA) entitled "Multipurpose Wireless Sensors for Asset Management and Health Monitoring of Structures." This Exploratory Advanced Research (EAR) Program project started in 2013 and will be completed in 2018. The research has focused on the design, development, and validation of a suite of wireless multipurpose sensors suitable for rapid testing and health monitoring of bridges that could be used by bridge inspectors.

While sensing tools for infrastructure assessment are increasingly available, often the civil engineers and infrastructure owners are not completely familiar with their potential. Furthermore, improper use of this technology can result in misunderstandings and in improper assessment of infrastructure systems. Helping to educate infrastructure owners on the use of Non Destructive Evaluation (NDE) and Structural Health Monitoring (SHM) sensing systems for bridge assessment is one of the goals of the FHWA sponsored project entitled "Virtual Nondestructive Evaluation Laboratory for Highway Structures." This multiyear effort was granted to myself, Dr. Aktan and Dr. Kurt Sjoblom at Drexel with collaborators from Rutgers and Saint Joseph's Universities. This research intends to permit users from different backgrounds to explore NDE and SHM technologies using a website designed to work as a virtual laboratory. The website will not only allow users to comprehend how different sensors operate in the laboratory, but will also offer real case studies to expose users to scenarios requiring the selection and deployment of various NDE and SHM applications and the integration of their results for solving real-life bridge performance problems. If successful, the website will also provide a platform for the development of training for proper deployment of NDE and SHM technologies and serve as a virtual meeting place (FORUM) and library for the NDE and SHM community, bridge inspectors, and engineers.

Research on Urban Sustainability Metrics

by Dr. Simi Hoque

This past academic year, I have been very active with two research projects, the "Integrated Urban Metabolism Analytical Tool (IUMAT)" and "Climate Resilient Buildings."

Integrated Urban Metabolism Analytical Tool (IUMAT): Cities today contribute almost two-thirds of the world's primary energy demand. By 2030, this fraction is projected to increase to three-quarters, matching the urban sector's expected share of global energy-related carbon dioxide emissions. The current urban outlook demands a comprehensive understanding of urban sustainability policies to address climate change and energy security. Our research is aimed at developing an Integrated Urban Metabolism Analytical Tool (IUMAT) to measure, evaluate, and predict the impacts of energy and water use, land use, and transportation systems at an urban scale. IUMAT is designed to systematically quantify aggregate impacts in terms of performance metrics, such as GHG emissions and energy use.

This project is funded by an NSF CAREER grant (2016-2021). The research team consists of Dr. Nariman Mostafavi, Post-doctoral scholar and Shideh Shams Amiri, a Ph.D. student in Architectural Engineering.

Climate Resilient Buildings: Urban buildings are facing great risks due to regional climate impacts that affect their performance and resilience. Current simulations of building performance use weather input files based on the past thirty years of climate observations. These 20th century climate conditions may be inadequate when considering how buildings are meant to function in the 21st century. We will bootstrap future weather data files to anticipate future risks and vulnerabilities by simulating how these buildings will be impacted by variability in temperature, humidity, wind, and rainfall. Our models are used to study the performance of the building envelope under climate scenarios 10, 30, and 50 years into the future. We are also developing urban building models to quantify the risk of degradation and energy costs due to future weather conditions at the urban scale. This knowledge can be broadly applied towards understanding the risks and vulnerabilities against climate change and offering decision tools to evaluate the economic and environmental costs of managing the urban building stock.

The research team for this project includes Daniel Chung, Assistant Professor in Architecture and Ph.D. student in Architectural Engineering and Hamed Yassaghi, a Ph.D. student in Architectural Engineering.

Exploring Advanced and Sustainable Infrastructure Materials

by Dr. Yaghoob Farnam

While the focus of the 20th century in infrastructural materials research focused mainly on developing high strength materials for structures, 21st century challenges such as sustainability, low-carbon energy, advanced manufacturing, and environmental concerns have led the engineering focus in the 21st century to shift towards developing advanced materials strategies that can be used to improve the resilience and sustainability of infrastructure. This requires developing and exploring advanced, novel, and multi-functional construction materials for our infrastructure.

Our research in the Drexel Advanced and Sustainable Infrastructure Materials (ASIM) lab aims at fundamental multiscale understanding of the relation between chemical compositions and physical properties of materials and tailoring materials processing-composition-structure to create sustainable, novel, adaptive, and multi-functional construction materials. One example of our research efforts is exploring approaches to convert waste and unused coal combustion ash to structural lightweight aggregate (LWA)[1]. Each year in the United States, around 120 million tons of coal combustion products are generated of which 37% is reused. This has led to a large historical stock of unused coal ash stored in on-site surface impoundments, which constitute a risk to the environment and human health. In collaborations with Drs. Sabrina Spatari and Grace Hsuan from the CAEE and Dr. Pieter Billen from the University of Antwerp in Belgium, we seek a thermodynamically-based technology to convert waste coal ash to value-added products. Another example of our research is to take bio-inspired approaches to design multifunctional microbial self-healing concrete[2,3]. Concrete is a quasi-brittle material whose durability suffers from inevitable micro-crack formations that propagate with time, resulting in the formation of larger cracks or defects and thereby increasing rates of chemical ingress and deterioration. In collaboration with a microbiology expert, Dr. Chris Sales from the CAEE, and a fiber manufacturing expert, Dr. Caroline Schauer from Materials Science and Engineering at Drexel, we aim to establish a robust autonomic self-healing paradigm in concrete using microbial calcium carbonate precipitation (MCCP) and fiber reinforcement to improve its durability and resilience.

One of our recent challenges in the 21st century is providing green solutions for generating energy as needed in our buildings as infrastructure. The Drexel ASIM lab is currently working on using phase change materials (PCM) as a green approach of storing thermal energy in buildings or concrete transportation infrastructure[4]. PCM is an organic material that can be designed to store thermal energy from ambient, applied, or solar sources and to release the stored energy during cooling events for different types of applications such as saving energy in buildings or even enabling self-melting of snow in concrete pavement. Using experimental and numerical approaches, we aim to explore desirable PCM's that are suitable to produce thermal energy in different locations of the United States based on associated environmental and climatic conditions.

Developing durable and damage resistant cementitious materials is another line of the ASIM lab's research. A large portion of infrastructural systems are built using concrete; and yet concrete infrastructure suffers from excessive aging and low durability. We observe premature damage and deterioration in concrete infrastructure in a short service life span (~5 to 15 years) and we spend enormous amounts of money to rebuild and repair aging infrastructure. The ASIM lab's research in this area focuses on advanced understanding of damage mechanisms of cementitious materials due to thermal, mechanical, and/or chemical distresses using advanced materials characterization, monitoring, and nondestructive techniques. Collaborating with scientists from the Drexel Mechanical Engineering Department (Dr. Antonios Kontsos and Dr. Ying Sun), National Institute of Standards and Technology, University of Colorado at Boulder, Portland Cement Association, and Oregon State University, we aim to understand the physical and chemical sources of damage in concrete as they are exposed to several environmental conditions (e.g. freezing and thawing, deicing salt exposure) and explore suitable mitigation approaches to increase concrete durability and resilience[5-7].

The Drexel ASIM lab's ultimate goal is to enhance durability, resilience, and sustainability of civil engineering infrastructure through materials related research. Developing adaptive, responsive, sustainable, durable, and living construction materials for civil infrastructure is the core research area at the Drexel ASIM lab and we hope in the near future, our research results in significant impacts on addressing challenges that our society encounters in the 21st century.

For more information, please visit our web page at www.asim-lab.com.

1. Billen, P. et al. Coal ash as a well-studied feedstock for melt ceramics: Constitutive Product Design Using Thermal and Flow Properties. (2017).
2. Ksara, M. et al. Evaluating the Potential Use of Alginate to Enable Microbial Self- Healing in Concrete. in 6th International Conference on Self-Healing Materials 1-5 (2017).
3. Ksara, M., Newkirk, R., Langroodi, S. K., Sales, C. M. & Farnam, Y. Microbial Damage Mitigation Strategy in Cementitious Materials Exposed to Calcium Chloride Deicing Salts (Under Review).
4. Farnam, Y., Esmaeeli, H. S., Zavattieri, P. D., Haddock, J. & Weiss, J. Incorporating phase change materials in concrete pavement to melt snow and ice. Cem. Concr. Compos. 84, 134-145 (2017).
5. Farnam, Y., Geiker, M. R., Bentz, D. & Weiss, J. Acoustic Emission Waveform Characterization of Crack Origin and Mode in Fractured and ASR Damaged Concrete. Cem. Concr. Compos. 60, 135-145 (2015).
6. Althoey, F., Wisner, B., Kontsos, A. & Farnam, Y. Cementitious Materials Exposed to High Concentration of Sodium Chloride Solution: Formation of A Deleterious Chemical Phase Change (Under Review). Constr. Build. Mater.
7. Farnam, Y., Zhang, B. & Weiss, J. Evaluating the use of supplementary cementitious materials to mitigate damage in cementitious materials exposed to calcium chloride deicing salt. Cem. Concr. Compos. 81, 77-86 (2017).