GW | Engineering

DEPARTMENT OF **CIVIL & ENVIRONMENTAL ENGINEERING**

Innovations for aesthetic, climate-neutral, resilient, and sustainable built environment

THE GEORGE WASHINGTON UNIVERSITY
WASHINGTON, DC

LETTER FROM THE DEPARTMENT CHAIR

DEAR COLLEAGUES, ALUMNI, FRIENDS, AND STUDENTS,

In today's world, advances in science and technology are providing unprecedented opportunities to address the challenges we are facing with the increasing demand and limited resources in many parts of the world exacerbated by emerging infectious diseases, climate-related disasters, and natural hazards. Civil and environmental (CEE) engineers play a key role in developing innovative solutions that lead to the creation of a safer, more pleasant, resilient, and sustainable world. I am very happy to report that the faculty and students in the CEE Department at GW continue to make outstanding contributions to the development of these innovative solutions. Motivated by the critical role played by the links between the exchange of heat, water and carbon in the earth's climate, CEE water resources engineering researchers are developing innovative data assimilation, optimization, and numerical modeling techniques to understand and predict the effects of climate change on the built environment. They have recently developed a novel observation-driven technology to capture these links from the information contained in land surface state observations. CEE environmental engineering faculty have also developed an innovative technology that enhances and uses naturally occurring bacteria to convert ammonia to nitrogen gas through a shortcut route that results in significant operational savings and lead to increased capacity in the existing wastewater plant configurations. To enable immediate occupancy and minimum economic losses following an extreme event, our structural engineering researchers have developed and tested a new system that can resist extreme hazards with minimum or no damage. Through an international collaboration, our geotechnical engineering researchers have demonstrated, for the first time, the role of material and geometric nonlinearities of pile foundations on the collapse of Showa bridge in the historic 1964 earthquake in Japan. In September, CEE faculty Xitong Liu and his PhD student won a $500,000 prize from the Department of Energy for their proposed chemical-free extraction of Lithium from Brines. This year, our transportation engineering researchers built the testbed of a smart city in the Nation's capital. In all these efforts, our main goal is to contribute to building a better world for everyone.

Sincerely,
Majid T. Manzari, Ph.D.
Professor and Chair,
Department of Civil and Environmental Engineering

PROFESSOR SAMER HAMDAR

Samer Hamdar is a professor of Civil and Environmental Engineering and the founding director of the George Washington University Transportation Engineering Program (GWTEP). As GWTEP director, Prof. Hamdar has established and maintained several laboratories, which focus on developing technologies, collecting data, and formulating models to improve the safety of our surface transportation systems. He also leads the GW Smart Cities Initiative and is a director of the newly established Health, Equity, And Transportation MOMENT Center. Prof. Hamdar obtained his Ph.D. in Civil and Environmental Engineering at Northwestern University and has been a visiting researcher/professor at multiple academic institutions around the globe.

Regarding research, Prof. Hamdar has 15 years of experience working with international collaborators from Germany, the Netherlands, Saudi Arabia, South Korea, and the US on projects surrounding driver behavior modeling, evacuation management, connected and automated vehicles, and vehicular and pedestrian traffic flow dynamics. He has received multiple prestigious awards, including a National Science Foundation CAREER Award and D.C.'s first Gigabit DCx competition. His research is funded through different US Department of Transportation and industry projects.

Prof. Hamdar serves as an Editor of the IEEE Transactions on Intelligent Transportation Systems, Associate Editor of the Journal of Intelligent Transportation Systems, and an Editorial Board Member of the Journal of the Transportation Research Record. Prof. Hamdar is also a member of the Transportation Research Board Committees on Traffic Simulation (ACP80) and Traffic Flow Theory and Characteristics (ACP50). Within ACP50, he is the secretary of the committee and the chair of the Sub-committee on Traffic Flow Modeling for Connected and Automated Vehicles. He has served on multiple panels, committees, and boards and was most recently selected to serve on the D.C. Quality Initiative Innovation Steering Committee.

DEMI LAPIDO-OBASA, PHD STUDENT

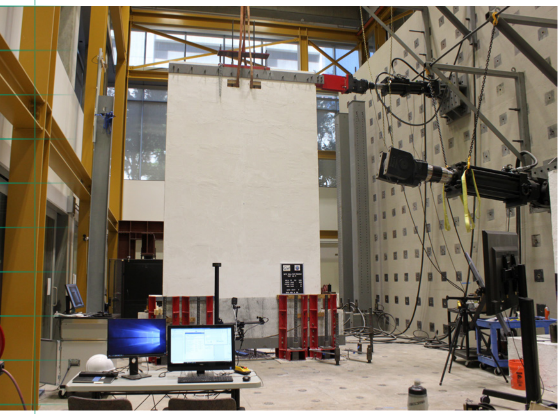
Mojolaoluwa (Demi) Ladipo-Obasa is an environmental engineering Ph.D. candidate under the supervision of Professor Rumana Riffat and Dr. Haydée De Clippeleir. She graduated from The George Washington University with a B.Sc. in Civil and Environmental Engineering in 2017. As an undergraduate, she tried her hands on transportation research and was actively involved in GW's chapter of the American Society of Civil Engineers (ASCE). She was the 2017 recipient of the Benjamin C. Cruickshanks and Martin Mahler Awards and the ASCE National Capital Section's Outstanding GW Senior Award.

Before GW, her experiences sojourning gave rise to her passion for the environment and desire to maintain harmony between Nature and humankind. Her doctoral research, in collaboration with DC Water, focuses on developing and implementing short-cut nitrogen removal processes, specifically partial denitrification-anammox (PdNA), for wastewater treatment. Demi has presented her work at several Water Environment Federation (WEF) and International Water Association (IWA) conferences, published at least two journal papers, and served as a member of the scientific committee for two WEF and IWA conferences. She was also an internal board member for GW's Center for Women in Engineering and a GW Engineering graduate student ambassador.

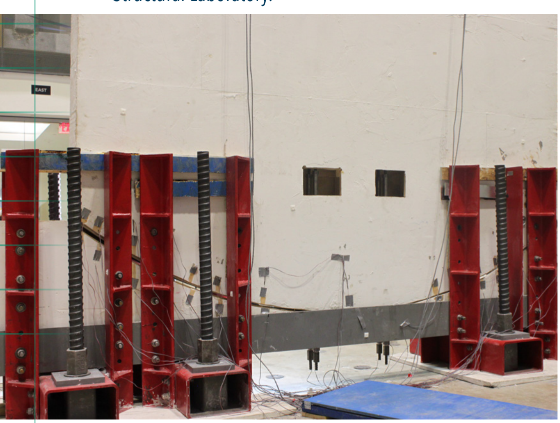
DAMAGE FREE STRUCTURAL SYSTEM TO RESIST LARGE MAGNITUDE NATURAL HAZARDS

A grand challenge in structural engineering is to develop structural systems that can resist extreme hazards, such as hurricanes or earthquakes, with minimum or no damage. Damage free structural systems are desirable in construction practice because their structural performance result in immediate occupancy and minimum economic losses following an extreme event. Progress has been made towards this goal with the development of new design schemes, yet limiting issues persist.

Professor Silva is leading a collaborative research project funded by the National Science Foundation. In this research, the team is developing an innovative construction concept that can result in systems performing damage free. This type of performance is desirable when buildings are subjected to earthquakes; because, immediate occupancy is restored in the post event phase. In addition, when buildings perform damage free, they do not require extensive repairs, resulting in minimum to no economic losses. The concept under investigation at GW has been designated in this research as a pendulum shear wall. This new type of structural system has been conceptualized for use in the design of new buildings with the main goal of performing damage free under large magnitude natural hazards.



Testing pendulum shear wall concept at GW High Bay Structural Laboratory.



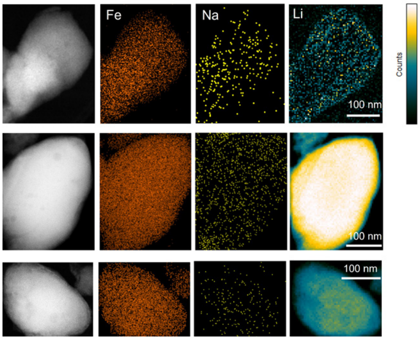
The concept consists of unbonded post-tensioned reinforced concrete walls that interact with the foundation via a curved surface. Lateral deformations are accommodated through a pendulum-type motion as the wall slides along the bottom curved surface. Lateral resistance is provided by friction along the curved surface and the vertical internal post-tensioned cables. This core idea has been validated by Professor Silva and the research team in the GW High Bay Laboratory. Experiments have verified that this new pendulum walls system can perform under large magnitude events without imposing limitations on material and overall system response. Numerical theories and methods of analysis related to damage-free structural systems, friction models, and energy dissipation design have also been advanced through this research.

REVOLUTIONIZING LITHIUM EXTRACTION FOR SUSTAINABLE AND RENEWABLE ENERGY STORAGE

Lithium, a crucial component in rechargeable batteries used in electric vehicles and energy storage systems, has become a vital resource in the transition to a greener, more sustainable future. However, traditional methods of lithium extraction have long been associated with slow processes, high water consumption, and heavy chemical usage. Prof. Liu's recent discovery offers a much-needed solution to these pressing concerns.

The new process leverages electricity-driven techniques to expedite the extraction process, making it remarkably selective and faster than conventional methods using solar evaporation. This accelerated timeline has the potential to revolutionize lithium production, meeting the rapidly growing demand for electric vehicles and renewable energy storage. By significantly reducing the extraction time from years to mere hours, Prof. Liu's team is poised to meet the ever-increasing demand for lithium more effectively.

Beyond the time reduction, the technology developed by Prof. Liu's team also brings about notable environmental benefits. Traditional lithium extraction methods are notorious for their excessive water consumption and reliance on various chemicals. However, Prof. Liu's innovation has the potential to reduce water consumption by 80% and chemical usage by 90%. This technology signifies a major step toward sustainable mining practices, mitigating the strain on water resources in arid regions, and minimizing the environmental impact associated with lithium extraction. Further, their technology enables the generation of battery-grade raw lithium materials ready for battery manufacturing.



Highly selective lithium extraction using electrode materials.

The Department of Energy has recognized the potential of Prof. Liu's team's technology and selected them as one of the five finalists in the Geothermal Lithium Extraction Prize Competition. This recognition further highlights the significance of their innovation and the transformative impact it can have on the energy industry.

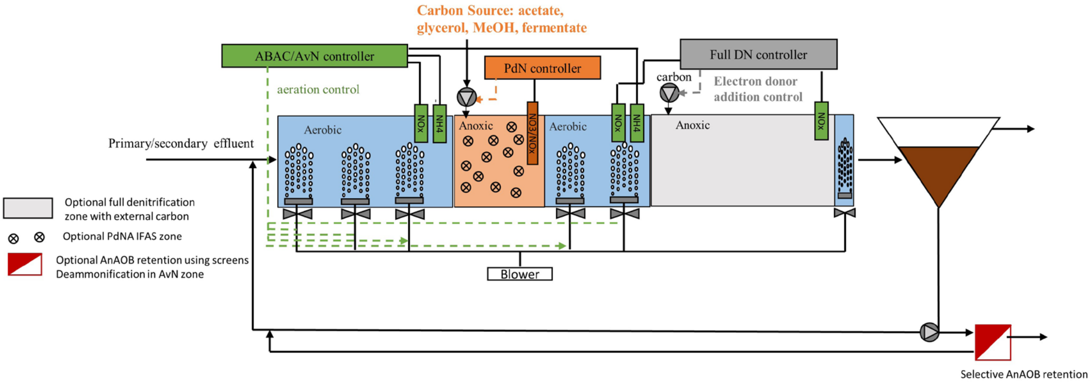
Speaking about their achievement, Prof. Liu expressed excitement and optimism about the future of lithium extraction. "Our team is thrilled to be recognized by the Department of Energy and to be named among the finalists in this competition. We believe that our electricity-driven, chemical-free direct lithium extraction technology can provide an environmentally friendly alternative to the industry and contribute to a more sustainable future."

As the world transitions toward renewable energy, the demand for lithium is expected to soar, making efficient and eco-friendly extraction methods critical. Prof. Liu's technology offers a faster, cleaner, and more sustainable approach to lithium extraction. With their continued efforts, Prof. Liu's team hopes to contribute to a more sustainable lithium supply chain and the clean energy revolution.

SHORT CUT NITROGEN REMOVAL USING A PDNA PROCESS

Nutrient pollution of our waterways due to anthropogenic activities has rippling effects on the ecosystem and human society, producing harmful algal blooms that eliminate oxygen content causing death of fish and other aquatic organisms, harm habitats, water quality, restrict recreational activities and impair plant growth. A top priority for wastewater treatment plants and water resource recovery facilities is to diminish nutrient loads (including nitrogen and phosphorus) that are discharged into water bodies. This is critical to maintain water purification and quality at a rate that matches our urban growth in this fast-paced world.

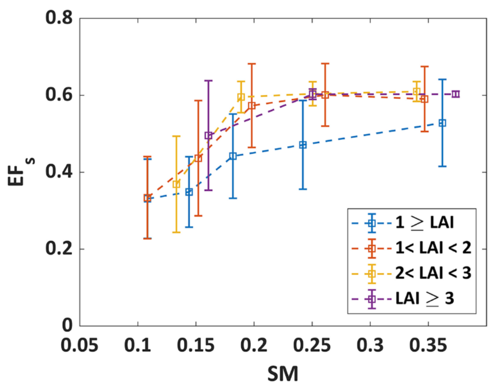
Prof. Rumana Riffat and her students are conducting research with a comprehensive group that includes DC Water, Hampton Roads Sanitation District, Water Research Foundation, Northwestern University, Columbia University and the Environmental Protection Agency to develop and implement alternative approaches to conventional nitrogen removal. They have developed a Partial denitrification-anammox (PdNA) process, which is an innovative technology that enhances and uses naturally occurring *anammox* bacteria to convert ammonia to nitrogen gas through a shortcut route, rather than the long conventional route. This shortcut nitrogen removal approach can result in operational savings of 70% in organic carbon chemical costs, 50% in aeration costs, and lead to increased capacity with existing plant configurations. Implementation of the PdNA process at Blue Plains Advanced Wastewater Treatment Plant operated by DC Water in Washington, DC has the potential to reduce carbon emissions by more than 11,000 tons of CO2, equivalent to a forest five times the size of the National Mall. Findings from this research will provide guidance for future nutrient removal operations at DC Water and other utilities across the globe.



Integrated PdNA process for nitrogen removal.

OBSERVATION-DRIVEN MAPPING OF LINKAGES BETWEEN TERRESTRIAL WATER, ENERGY, AND CARBON CYCLES

The exchange of heat (energy), water and carbon between the terrestrial (land) biosphere and atmosphere play a key role in the Earth's past and future climate. The rate of exchange of heat (energy), water and carbon in and out of the land surface, known as land surface fluxes, determine the local temperature, moisture states and carbon exchange with the atmosphere. The terrestrial or land component of water, energy and carbon cycles are strongly coupled and operate in a consistent manner. For example, an increase in atmospheric carbon dioxide will modify biomass, thus altering ecosystem photosynthesis and transpiration (hence, heat exchange) rates. All Land Surface Models (LSMs) used in hydrologic, ecological and climate models – directly or indirectly – account for the linkages between the terrestrial cycles. How various models perform is highly dependent on how these linkages are represented in the LSMs. Lack of proper representation of these linkages currently results in wide range of uncertainties and variations in regional simulated land surface fluxes, climate, and climate projections. There is a gap in real-world (true) representation of the linkages/coupling between the terrestrial water, energy, and carbon cycles at regional scale. The primary limitation is the lack of direct observation of key variables (land surface state and fluxes) that can quantify these linkages with the required spatial and temporal resolution and continuity. To fill this gap, Professor Farhadi research, focuses on quantifying the linkages between the terrestrial cycles, specifically the key linkage, which is the soil moisture control on evapotranspiration/EF. Novel observation-driven approaches are developed to indirectly capture/map these linkages from implicit information contained in land surface state observations (i.e., surface soil moisture, temperature and vegetation index) which are widely available from remote sensing across a range of spatial and temporal scales. Accurate characterization and understanding of the interplay between the terrestrial water cycle, energy cycle, and carbon cycle allows for more effective and sustainable water resource management. This knowledge aids in predicting changes in water availability, identifying vulnerable areas, and implementing appropriate water conservation measures. It also helps inform land-use decisions, such as protecting and restoring vegetation cover, which supports both the water cycle and carbon sequestration.



Prof. Farhadi's research shows that Soil Moisture (SM) dependence of evaporative fraction (*EF*, the fraction of available energy released as latent heat) is a function of vegetation density (LAI, leaf area index).

Professor Farhadi's relevant research endeavors are supported by the NSF (CAREER: Observation-Driven Mapping of the Linkages between the Terrestrial Water, Energy and Carbon Cycles) and NASA (Coupled Estimation of Evapotranspiration and Recharge from Remotely Sensed Land Surface Moisture and Temperature