College of Engineering
UNIVERSITY OF WISCONSIN–MADISON

FALL 2023 NEWSLETTER

CIVIL AND ENVIRONMENTAL ENGINEERING

FIRM FOUNDATION

Building on decades of research leadership

Introducing department chair Greg Harrington

Professor Greg Harrington brings a wealth of teaching and leadership experience to his new role as the 16th CEE department chair at UW-Madison.

A faculty member since 1996, Harrington has been a champion of growth in the CEE Department for nearly three decades. After guiding the launch of a new undergraduate degree in environmental engineering and a certificate program in architecture, he is ready for a new challenge and looks forward to the future of CEE at UW-Madison.

The fields of civil and environmental engineering face complicated challenges, driven by factors like climate change, prolonged lack of investment in civil infrastructure and increasingly-limited natural and financial resources. Harrington says these challenges, combined with significant rates of retiring engineers, are driving unprecedented demand for future engineers who will have to create unique, sustainable solutions.

"Our profession has the core purpose of engineering for public good," Harrington says. "We create solutions that value and sustain the health, safety, and welfare of civil society and the environment. It's a rewarding field with countless career opportunities for new civil and environmental engineers."

Harrington served as associate chair of CEE undergraduate programs for 15 years before taking his new role as department chair. During this time, he led the review and update of civil engineering undergraduate degree requirements with input from faculty and professional engineering community partners.

He also built partnerships with practicing engineers and alumni, as well as community-based partners like the UniverCity Alliance and the Morgridge Center for Public Service, that connect current students with the technical and professional aspects of real-world practice. Through these partnerships, CEE's senior capstone design course has become a model of its kind among peers with seven engineering education awards from the National Council for Engineering and Surveying.

"Building partnerships with professional practitioners and community-based organizations is among the most rewarding aspects of my career," Harrington says. "These partners help our students understand and appreciate that engineering goes beyond the application of math and science to solve problems. It's also about ethics, management, leadership, citizenship, communication, collaboration, and lifelong learning. As a Wisconsin native, I have long admired the Wisconsin Idea, and partnerships are one way we put that idea into practice."

Outside of class and away from his office, Harrington is active and engaged in service for the UW-campus and City of Madison.

Harrington's research focuses on the treatment, distribution, energy use and regulatory policy of drinking water systems. Three of his publications won national awards from the American Water Works Association. His dedication to teaching has been recognized with awards from students for outstanding instruction and from the College of Engineering for innovative teaching and learning practices.

Before coming to UW-Madison, Harrington worked for four years as a consulting engineer with Malcolm Pirnie (now part of Arcadis). During this time, he led the creation of a computer program used to develop federal regulations for the control of disinfectants and disinfection byproducts in drinking water systems.

On the cover: Junior Ella Thomas loads a 100-year-old concrete sample into a hydraulic press for testing. The concrete is wrapped in sensors that measure stresses while the sample is under load. Photo: Alex Holloway.

Master of Engineering registration open

The master of engineering option in the environmental engineering program is accepting registrations for spring 2024 until Wednesday, Nov. 15. The program is fully online and ideal for working professionals.

For more information, please visit: pdc.wisc.edu/degrees/environmental-engineering/

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Steven Cramer, a professor emeritus, carries a fractured concrete sample after testing it in a hydraulic press. Cramer oversaw testing the samples, which were first poured in 1923, to conclude a 100-year study. Photo: Alex Holloway.

Century-in-the-making tests conclude long-running concrete experiments

A series of concrete tests that began 113 years ago at UW-Madison concluded this summer, cementing a lasting legacy of research that has endured across generations.

During summer 2023, Professor Emeritus Steven Cramer and junior Ella Thomas cracked dozens of concrete cylinders that were first poured in 1923. In late July, they held open house demonstrations in the Jun and Sandy Lee Wisconsin Structures and Materials Testing Laboratory to see how the concrete withstood the test of time.

When Thomas and Cramer tested the samples with a hydraulic press, they found the century-old concrete held up well, with samples withstanding more than 8,000 pounds of pressure per square inch.

Concrete, perhaps counterintuitively, tends to get stronger as it ages. This is thanks to a process called curing, where concrete continues to draw strength from moisture in the environment. How much concrete strengthens—or if it does at all—can depend on its composition and long-term environment. When samples first poured in 1910 were crushed in 2010, Cramer said the cores left in water grew stronger, while those exposed to the air absorbed carbon dioxide and lost strength.

Some of the 1923 samples have been kept in water, while others were stored in the basement of Engineering Hall. Still others were left outside and exposed to wind and rain, baking heat and brutal cold. “Today, we have ways of simulating weather, but back then, they didn’t exist, so they’d just put them outside,” Cramer says. “So these poor cylinders have been subject to our severe winters and mild winters. There are times they’ve probably been close to a sidewalk and sprinkled with salt. It’s hard to generalize other than this: Despite what they’ve been through, they gained strength.”

What makes the tests unique is that, because the concrete was poured specifically for a long-range study, the researchers have specifications about it—details on its mix, the composition of the cement and aggregate used—that aren’t always available for similar tests. Though concrete mixing methods have changed and improved in the century since the study began, the tests may provide some insight into how older material behaves as it ages.

Thomas says she and Cramer tested 30 to 40 concrete cores by the time of the open house demonstration, with about 120 still to go. She joined the project after learning about it through her mechanics of materials class.

“Even though I have a smallish part here at the end, just finishing up the tests, it’s been really special to be a part of it,” Thomas says. “It’s been cool to learn about the history that this project has, for UW-Madison and for everyone who has worked on it.”

That the samples made it to the finish line 100 years later is, Cramer says, thanks to the collaborative relationships fostered within the College of Engineering.

“You can imagine two people who have a strong relationship,” he says. “But can you imagine those relationships building a chain among so many different people that lasts for 100 years? That’s pretty rich.”

Digging into decades of evidence, engineers find one big earthquake precipitates others

In a study led by Assistant Professor Jesse Hampton and then-postdoctoral researcher Qiquan Xiong, engineers have increased understanding of how one earthquake's seismic magnitude may influence another's. The researchers published their results in the journal *Nature Communications*.

The research demonstrates the existence of multiple earthquakes with similar seismic magnitudes, clustered in time and across various distances ranging from laboratory scales to spans of hundreds of miles. While previous studies have reported correlations in the magnitudes of sequential earthquakes, those findings have been questioned due to concerns about incomplete earthquake catalogs.

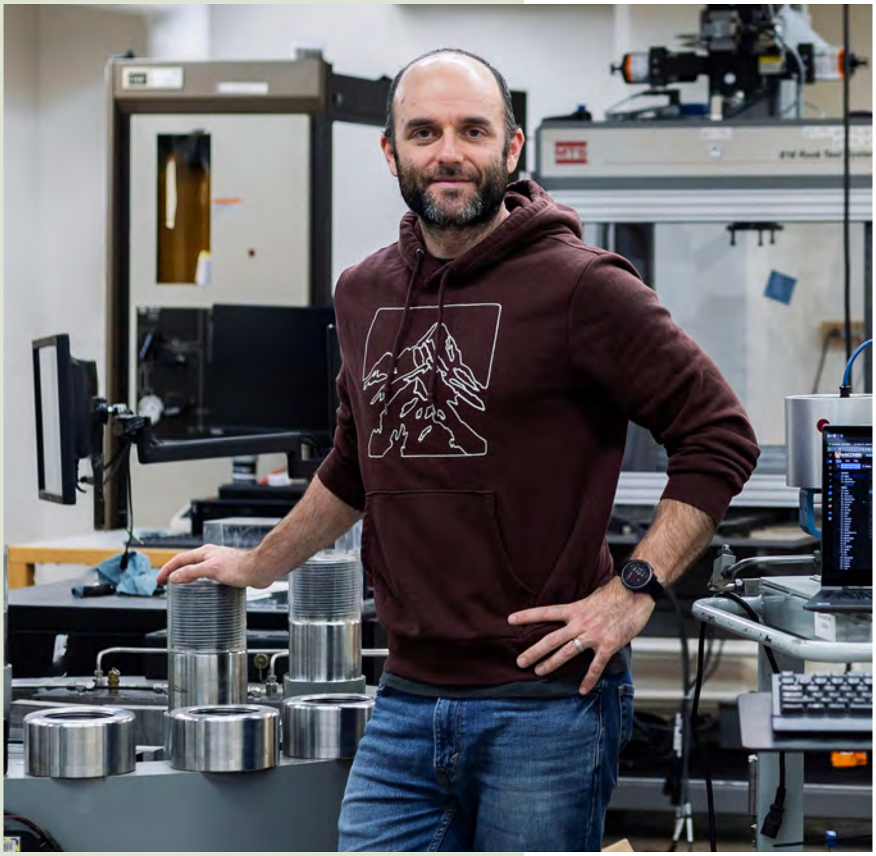
To conduct their study, Hampton and Xiong analyzed data from the Southern California Catalog, which encompasses information on more than 400,000 earthquakes recorded between 1985 and 2001. They also examined catalogs containing data on induced seismic events from hydraulic fracturing sites in Harrison County, Ohio, as well as wastewater disposal cases near Guthrie in central Oklahoma and in the Delaware Basin in west Texas.

Throughout their analysis of these catalogs and laboratory experiments, Hampton and Xiong discovered that clustering in earthquake magnitudes was more pronounced when earthquakes occurred within shorter time intervals and closer geographical proximity. They found that in order to recreate the same magnitude clustering signature seen in the field and laboratory catalogs, synthetic catalogs required up to 20% repeating events.

"There's been this debate for a really long time about whether magnitudes cluster," Hampton says. "We've been able to show in the laboratory and field catalogs that it does exist. Now that we can start to see that clustering of magnitudes is prevalent and we can begin to assign some physical meaning to that, we may one day be able to start including magnitudes in earthquake forecasting models that already account for space and time."

Such capabilities could be valuable in regions that are vulnerable to powerful earthquakes, especially if subsequent aftershocks are likely to be of similar strength. "After the main shock, you can have aftershocks, which can potentially cause more casualties than the initial earthquake" says Xiong, who now is a research scientist in Hampton's group. "That's because buildings may have collapsed and you can have search-and-rescue efforts underway. If we could predict an aftershock of similar magnitude, that could be crucial in reducing additional risks to human life."

Hampton is continuing research to build upon what he and Xiong have already laid out in this paper. He hopes their research will provide a foundation that other researchers can work from to continue deepening our understanding of earthquake magnitude, branching influences from one seismic event to the next and, ultimately, how earthquakes happen.



Assistant Professor Jesse Hampton's research into earthquake magnitude clustering may help shed light on how to predict the strength of earthquakes in the future. Submitted photo.

In Wisconsin, working with water grounds Wiersma

CEE PhD graduate Amy Wiersma has worked with communities in Wisconsin to understand how radium gets into groundwater. Submitted photo.

Amy Wiersma has long dreamed of an environmentally focused career.

Now she's getting to make that dream a reality. Wiersma, a PhD graduate of the Environmental Chemistry and Technology Program, has worked for years with a Wisconsin community to understand how radium is affecting its water supply.

Wiersma was a first-generation college student in Associate Professor Matthew Ginder-Vogel's research group. Her research focused on radium—a naturally occurring radioactive metal that can prove deadly if ingested regularly over long periods. She graduated in spring 2023 after accepting a position with the Wisconsin Geological and Natural History Survey as a scientist specializing in groundwater resources.

"My goal coming into graduate school was to really focus on groundwater quality and geochemistry," she says. "A lot of my work since then has focused on radium in Wisconsin's groundwater, which is a big challenge that a lot of Wisconsin communities are dealing with."

About 70 percent of Wisconsin's residents get their drinking water from groundwater sources. As groundwater moves through the aquifer, minerals and elements, including radium, can be dissolved out of the rock and into groundwater that is pumped by wells for drinking water. Prolonged exposure to radium can increase the risk of some types of cancer, including bone and lung, among other health concerns.

Wiersma has hands-on experience with this challenge: she's worked with the Fond du Lac, Wisconsin, water utility and residents to sample and analyze wells in the area.

"Through that project, we learned that, even seeing these conditions on the broad scale that may point to elevated radium, it can be really difficult to predict high radium levels at the local scale, because local conditions are so important," Wiersma says. "The radium is always going to be there in the rocks, but it depends on local geochemical conditions as to whether you're going to have elevated levels or not at a specific location."

Wiersma says Ginder-Vogel has been a great mentor and advisor. As she begins her next chapter post-graduation, Wiersma says she's ready to give back to Wisconsin, and to share her knowledge and expertise to make a difference for its communities.

"I'm really excited to keep working with local and county governments to help with whatever questions or issues they have with their groundwater," Wiersma says. "It's really satisfying to take what I've learned throughout my studies and apply it to something that's practical and matters to a lot of residents across Wisconsin."

Exosuits may ease strain on construction industry

The construction industry workforce is aging and facing major shortages to keep pace with demand across the United States. According to the Associated Builders and Contractors, almost a quarter of the construction workforce is older than 55—and the industry needs to hire more than half a million additional workers on top of normal hiring in 2023 to close the gap.

While meeting this massive construction worker shortfall will take a much broader effort, UW-Madison researchers are studying how wearing EXOs (a general term including both exosuits and exoskeletons) can help existing workers do more. "We can use EXOs to increase the ability of a single worker," says CEE graduate student Wei Han. "EXOs may help workers do more intensive work. We hope that they can also help all workers have a better experience and protect their health and safety while going about their jobs."

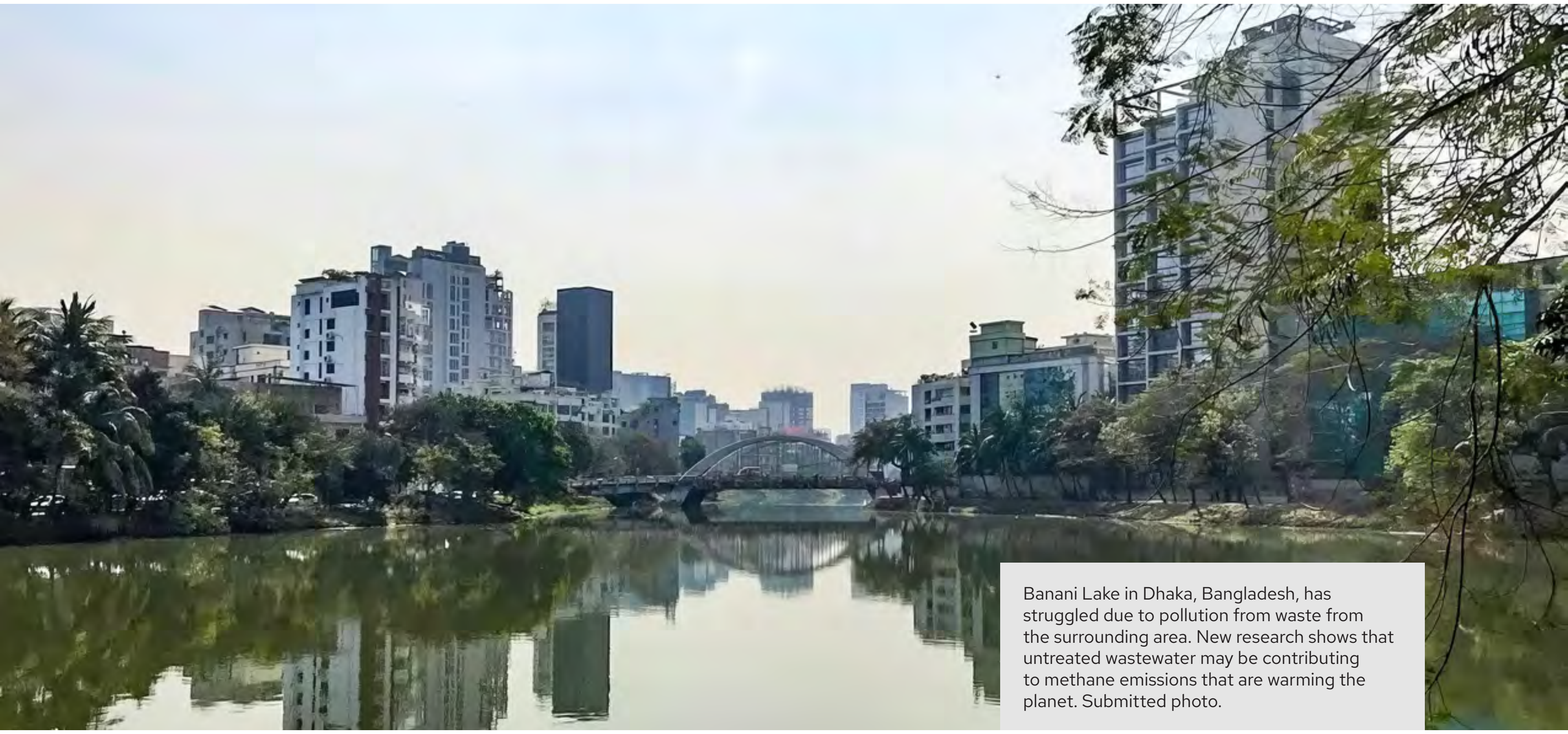
They're studying three passive EXOs: the HeroWear Apex, Hilti EXO-01, and Ekso Evo. Passive EXOs use springs and tension to support movement; the research team is focusing on suits that aid with back and shoulder support, says collaborator Tyler Bennett, a graduate student in mechanical engineering. Exosuits are made of soft, flexible fabric, while exoskeletons contain rigid supporting structures.

Bennett and Han have collaborated with employers from the national construction firm Mortenson since January 2022 to test the EXOs while workers perform various tasks like pushing a gondola or raising an object overhead. They collected data from those experiments to assess how EXOs impact construction workers; results so far show that EXOs helped reduce task completion time, though workers responded differently to them, and have mixed opinions about them.

Their testing so far has focused on workers performing prescribed tasks. Looking ahead, however, Bennett and Han hope to gather more data from laborers going about their normal work. They also plan to diversify the study's participants, especially including women workers, and hope to test on more active construction sites.

Tyler Bennet, left, and Wei Han are working together on research to study how exosuits and exoskeletons can support workers in the construction industry.

"EXOs aren't yet well-developed or prepared to be used in construction sites," Han says. "By doing these feasibility studies, we hope to assess which ways they can be helpful in construction sites, or what should be modified and improved to really get to the point where they can be viable tools."



Banani Lake in Dhaka, Bangladesh, has struggled due to pollution from waste from the surrounding area. New research shows that untreated wastewater may be contributing to methane emissions that are warming the planet. Submitted photo.

Untreated wastewater implicated in elevating world's methane emissions

James Schauer

Oil and gas systems, livestock and landfills top the global list of large methane emitters. However, new research has shown that urban areas release significantly more methane than previously thought—and untreated wastewater could be a major source of those additional emissions.

UW-Madison environmental engineers found that urban methane emissions are three to four times higher than previously estimated. The researchers studied methane emissions from 61 cities around the world, revealing that increased methane emissions correlates with the amount of untreated wastewater per person.

Scaled up to the 385 cities worldwide with more than 2 million citizens each, the research suggests these urban areas could account for up to 22% of global methane emissions.

Professor James Schauer says he and his collaborators noticed higher-than-expected methane levels while studying atmospheric plumes over the city of Dhaka in Bangladesh.

"We really started trying to understand, in the context of air quality, why the methane levels were so high," Schauer says. "Then we started connecting across cities in the region, and then around the world, trying to understand this observation."

Organic material in untreated wastewater breaks down anaerobically after it's discharged into water bodies, creating methane emissions that bubble up into the atmosphere. Methane emissions, along with carbon dioxide, are one of the main drivers of human-caused climate change. Though methane only remains in the atmosphere for about 12 years it's about 25 times more potent than carbon dioxide at trapping heat. That means methane is a significant driver of short-term climate change, and any efforts to reduce our impact on the environment should include methane emission reductions.

In their research, Schauer and his colleagues examined various sources to explain the variability of methane emissions in the 61 urban areas they studied. Within that group, 33 cities had medium to high levels of untreated water; reducing methane emissions in those cities, for example, to the mean level of emissions of cities with little or no untreated wastewater could reduce global methane emissions by 2%. Additionally, reducing all 61 cities to the emission level of the lowest city in the study could result in a reduction of almost 6% in worldwide methane emissions.

Reducing emissions in cities around the world to the level of those with complete wastewater treatment could lower global methane emissions by as much as 10%, according to Benjamin de Foy, the paper's lead author and a professor of earth and atmospheric sciences at Saint Louis University.

Schauer says that while leaks from natural gas use and landfills contribute to methane emissions, it became clear that these sources alone couldn't account for heightened methane concentrations in the atmosphere.

This research indicates that untreated wastewater may be a much larger methane contributor than expected and that knowledge may help communities focus on goals that can tangibly help in the fight against climate change, in addition to co-benefits for human and ecological health.

Researchers try to stop beaches from being washed away

A facility at Queen's University in Canada is allowing researchers, led by UW-Madison's Nimish Pujara, to study how waves move sand along shorelines. Submitted photo.

As they approach and recede from a beach, waves move water along the shoreline. But the phenomenon, called longshore drift, also drags sediment and eats away at beaches over time. It's a challenge for countries worldwide; for instance, the Netherlands has constructed a massive "sand motor" to mitigate shoreline loss caused by longshore drift.

"More locally in Wisconsin, some beaches have revetments built in," says Nimish Pujara. "Because of longshore drift, sediment can scour around these defenses and cause problems downstream because someone built a protection jetty or some other sort of structure."

Pujara, an assistant professor in CEE, says the mechanisms of longshore drift are not well understood. Now, he and colleagues from the University of Delaware, University of Puerto Rico and Queen's University in Canada are seeking a good way to quantify its impacts. With funding from the National Science Foundation, the team is taking a deep dive into the wave mechanics that drive these processes.

"We don't really understand why sediment moves in the way it does, or takes the trajectories that it follows or how fast it moves," Pujara says. "This project is really to uncover these dynamics that are happening everywhere, from the Dutch coastline to Wisconsin's coastline and lots of other places in between."

The research team will work at a facility that's being set up for the project at Queen's University. It will feature a swimming-pool-sized tank that's 25 meters along each side, with "beaches" made from gravel, concrete and sand mixtures. The tank will include paddles to create waves, along with velocity sensors, wave height scanners, overhead cameras, lidar sensors to track changes to the beach, and more. Researchers will also work with the SWASH and XBeach open-source models throughout the project.

Through the work, Pujara hopes to deepen understanding of how much sand moves along the shore due to coastal currents. Such knowledge could impact an array of coastal engineering and management areas, from improving green infrastructure efforts that employ natural barriers to protect the shore to dredging sand from the seafloor to replenish eroded beaches.

"A lot of beaches march, or move along the shore, and that's how they lose sand," Pujara says. "Dealing with this is one of the main tasks for the Army Corps of Engineers, and dredging companies that move sand toward the shore make up a huge industry. Anything we can do to help understand the rate at which you need to nourish—and why you need to nourish—these beaches will help more effectively manage those resources."

Devin Welch

Geological engineering degree sparks rewarding career for Devin Welch

"The earth is your office" is more than a catchy phrase coined by geological engineering program director James Tinjum. For Badger alum Devin Welch, it's reality.

As a geotechnical engineer at Westwood Professional Services, Welch spends a lot of his time working across the country. He's conducted geotechnical investigations in almost every state in America.

Through his work, Welch contributes to a more sustainable future. He began working at Westwood as a geotechnical intern in summer 2019 and has been an engineer full-time since graduating from UW-Madison in May 2021. He recalls his first month at Westwood as an "immersive, exciting, hands-on experience in the geotech industry."

Aided by a crew of geotechnical drillers, Welch was tasked with conducting and assisting in a large-scale geotechnical investigation near Amarillo, Texas, for a 700 to 800-megawatt solar energy project, which was one of the largest solar projects Westwood had worked on at the time.

While on geotechnical investigations, Welch leads a team in drilling soil borings and collecting soil samples for classification and lab testing. Occasionally, he conducts field tests, such as electrical resistivity testing and dynamic cone penetration testing. He also helps ensure safe drilling conditions and access to each boring, all while minimizing damage to the surrounding area.

"It's extremely rewarding to wake up and know that the technologies and infrastructure I aid in developing will be sustainable and continue to provide renewable energy to the world," he says. "Pursuing a career as a geological engineer has given me the platform and outlet to act on my passions and teach people how they can and should respect the earth."

Welch has been interested in earth science since he was young, and that later guided him toward geological engineering. He credits his experience at UW-Madison for giving him the tools to succeed as an aspiring engineer, while also deepening his appreciation for the natural world around him.

Now, Welch is pursuing his professional engineer license and plans to obtain a master's degree. He also hopes to establish youth STEM programs in his hometown of Boston, Massachusetts, and other communities to inspire young students to explore the field of engineering.

"There was always a lack of representation in the STEM field growing up, especially for people of color," he explains. "In my childhood, I never knew any Black engineers, but through the summer programs and youth programs I participated in, I was empowered by meeting other kids with the same ambitions and dreams as me. I'd like to continue to provide that opportunity to other young engineers and dreamers."

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Initiative aims to improve building safety

Hannah Blum is working with the Steel Deck Institute (SDI) to improve the safety and reliability of steel roofing and floor decks that are common in buildings. Blum is an assistant professor and the Alain H. Peyrot Fellow in structural engineering. "Through this collaboration, current students are training to be future leaders in structural engineering," she says.

Steel decks are corrugated metal sheets that can be used to support roof or flooring structures. They are typically supported by steel beams or joists.

Recently, two of Blum's SDI-funded research projects received additional funding by the American Iron and Steel Institute. In one, she will study roof diaphragms to better understand how the welds that connect the deck to the structure behave. A steel roof deck can be used as a diaphragm to distribute wind and seismic lateral forces across a building into structural elements that transmit them into the foundation.

In the second project, she hopes to better define roof safety and how it contributes to overall building safety. This project explores the steel roof deck dependability, including the benefits of the connections to the building and overlying rigid roofing material.

Both projects are part of a larger SDI research initiative focusing on the strength and safety of buildings that use steel deck products. "This ongoing partnership between the SDI and Dr. Blum will lead to safer and more economical steel structures that will serve the public for many years," says SDI Technical Director Thomas Sputo.

Undergraduate Lennart-Fredrick Schmitz and postdoc Hyeyoung Koh build a vacuum box in the Jun and Sandy Lee Wisconsin Structures and Materials Testing Laboratory. Assistant Professor Hannah Blum will use the vacuum box to test steel decks and other structures. Photo: Alex Holloway.