College of Engineering
UNIVERSITY OF WISCONSIN–MADISON

SPRING 2024 NEWSLETTER

DEPARTMENT OF
CIVIL AND ENVIRONMENTAL ENGINEERING

Greetings from Madison!

As I reflect on eight months as department chair, I am proud of the efforts undertaken by our students, staff, faculty and alumni in the advancement of engineering for the public good. Communities and their citizens across the state, nation and globe greatly benefit from the achievements of our Badger engineers.

Our graduates are in high demand, and many are being hired for internships during their first year. Our students collaborate on community- and people-centered projects from their freshman design course to their senior capstone design course. Our community-based learning practices in senior capstone design have contributed to a 7th national education award from NCEES. You can read about one of our capstone design projects in this newsletter.

This newsletter also highlights achievements from several of our accomplished faculty members and alumni. We continue to engage in projects that benefit public and environmental health and safety, with an eye toward the societal, environmental and economic aspects of sustainability. I hope you enjoy reading about this work.

Our students are benefiting from a recent modernization of the engineering mechanics lab space. If you're in the area, please come by to say hello and see this new space.

On a much larger scale, our governor signed a bill to authorize the construction of a new $350M building for the College of Engineering. We expect this building to provide instructional and research lab space for environmental engineering and chemistry programs, as well as space for research in autonomous systems. The college can enroll 1,000 additional students when the building opens, and we expect many of them to be in one of our degree programs.

As you can see, we have much to be thankful for and much to look forward to.

Until next time, On Wisconsin!

Gregory W Harrington

Greg Harrington
Professor and Department Chair

On cover: Undergraduate student Ann McGrath-Flinn scoops water samples from Lake Mendota along with PhD student Jenna Swenson. Both students have worked together to research the impact of manganese oxides on contaminants in water. Photo: Joel Hallberg.

Get ready to golf!

Attend our 27th annual golf outing on Friday, Sep. 27, 2024, for a day of fun and fundraising with other alumni, industry colleagues, faculty, staff, and students. Your support helps elevate our students' educational experiences and better prepare them for their careers. Watch your email for an invitation to register or visit golf.cee.wisc.edu.

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Left: An aerial view of a sand trap dredging operation on the Eau Claire River. The river flows into Lake Altoona, carrying sediment that has caused challenging buildups for the community. Photo courtesy of Eau Claire County. *Below:* Civil and environmental engineering students Maya Pardanani, Kris Alvarado, Clara Zwolanek, Dylan Schindler and Rachael Heck (from left) worked together on a project to address sand buildup in Lake Altoona in Eau Claire County during the fall 2023 semester. Submitted photo.

Student team tackles deep challenge in northwestern Wisconsin lake

Day by day, sand piles up on Lake Altoona's lakebed.

It's a problem that builds over time and beneath the surface, making the 840-acre reservoir less suitable for fish and other aquatic life and impeding boating and other recreational activities. And it's been a challenge that Eau Claire County, in northwestern Wisconsin, has contended with for years.

Enter the Muddy Buddies, a five-member team of CEE students. They dug into the challenge in the fall 2023 semester as part of their senior capstone design course, in partnership with UW-Madison's UniverCity Alliance program.

Chad Berge, the land conservation manager with Eau Claire County's Land Conservation Division, says the Eau Claire River carries sediment from eroded banks upstream into Lake Altoona. A 30,000-cubic-yard sand trap catches some of the heavier sediments upstream, but that requires regular dredging. Finer silts and clays suspended higher in the water can slip past the trap and flow out into the middle of the lake.

Eau Claire County has partnered with the UniverCity Alliance, which connects communities throughout Wisconsin to faculty and student groups at UW-Madison through three-year partnership programs.

That's where the Muddy Buddies came in. The five students—Kris Alvarado, Rachel Heck, Maya Pardanani, Dylan Shindler and Clara Zwolanek—spent the semester designing a proposal to address the sediment problem in Lake Altoona.

The Muddy Buddies presented a bank stabilization project that built upon some of the work community stakeholders have already done to calculate the erosion rates of the Eau Claire River's upstream riverbanks.

"The channel meanders, so some of the banks were more severely eroded than others," Pardanani says. "We did a lot of hydraulic analysis, looking at how the water's velocity changes and how that impacts erosion. From there, we came up with the reasoning that because a lot of the erosion comes from a small number of banks, we could stabilize the sand there, before it gets into the river, instead of trying to chase it downstream."

The proposal primarily calls for gabion baskets and riprap to protect the toe of the riverbank against erosion. The students also proposed planting vegetation on the banks so the roots can help hold soil in place, with the option to add ground anchors for additional reinforcement where needed. Finally, the design includes berms that can direct rainfall into the river via pipes installed at the top of the banks.

The senior capstone course often puts civil and environmental students on projects that, like UniverCity's partnership program, draw on real-world needs. It gives them the chance to experience how their education has prepared them to enter the field as professionals.

"I really like how the entire project gave us the chance to apply everything we've learned over the last three to four years," Zwolanek says. "We've taken all of that and put it to use in a real-world project. It really shows how the things we learn in class are applied outside of class."

Upper Midwest water samples key in future industrial chemical breakdown

Sometimes it's best to embrace the complexities of environmental science.

That's one big takeaway from research that sheds light on how manganese oxides break down contaminants in water.

Fourth-year PhD student Jenna Swenson conducted the research under Professor Christy Remucal and Associate Professor Matthew Ginder-Vogel. Swenson is a student in our Environmental Chemistry and Technology program.

Manganese oxides are naturally occurring minerals that react with organic and inorganic materials, including chemicals that are contaminants in the natural environment. Swenson's research focused on six contaminants' reactions with manganese oxides, and how adjusting different variables in the environment—to emulate, for example, a natural water environment or a wastewater system—impacts those interactions.

The journal *Environmental Science & Technology* published her findings in January 2024.

Swenson tested bisphenol A (BPA), triclosan, phenol, 4-chlorophenol, 4-bromophenol, and 4-*tert*-octylphenol across experiments that emulated an array water samples collected from across Wisconsin and Minnesota.

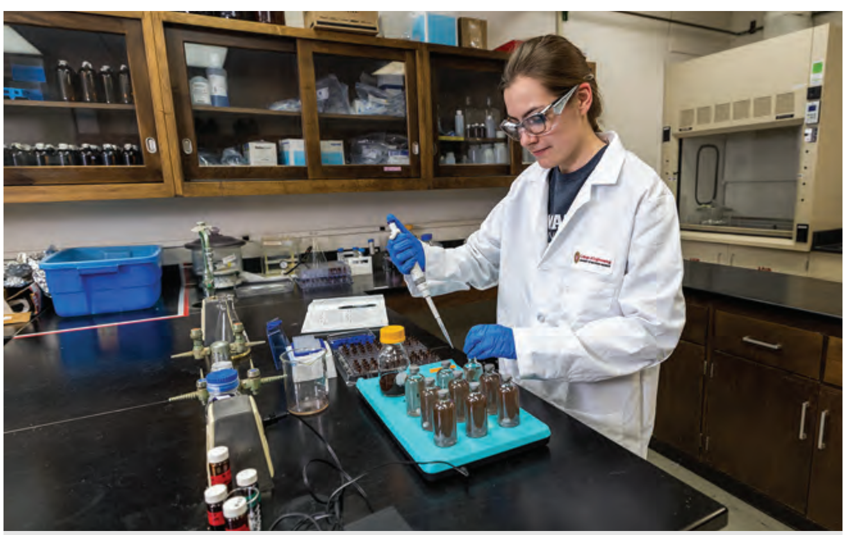
"The cool thing about our paper is that we're using real-life environmental samples, whereas a lot of research tends to use synthetic organic matter, model compounds, or things that have been tested but aren't realistic in terms of the environment," she says.

Chemicals with one aromatic ring—phenol, 4-chlorophenol, 4-bromophenol and 4-*tert*-octylephenol—took longer to degrade in the presence of manganese oxide in all tests. BPA and triclosan have two aromatic rings. They degraded faster in some tests and more slowly in others.

Across all tests, Swenson's experiments showed that wastewater dramatically reduced the rate at which manganese oxide broke down the contaminants; the researchers found those reactions slowed down due to the high presence of ions in wastewater.

However, the researchers have yet to discover what drives manganese oxide to break down contaminants more quickly.

"Ideally, we'd like to see these reactions happen faster," Swenson says. "If we could find a way to recreate those conditions in the experiments where they did speed up, then we could make our contaminant removal processes really efficient."



Environmental chemistry and technology PhD student Jenna Swenson checks bottles with samples of manganese oxide in them. Photo: Joel Hallberg.

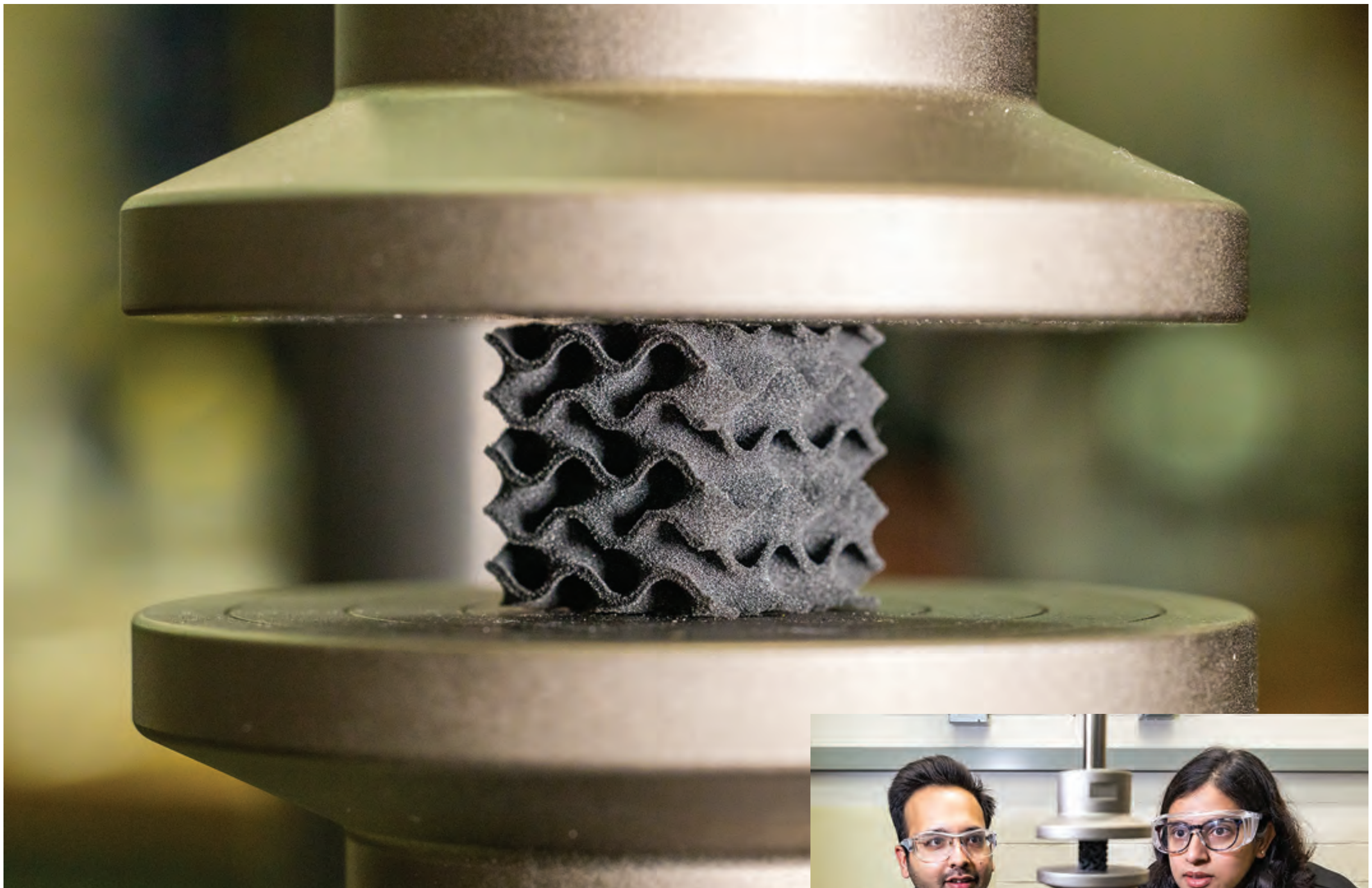
Pujara receives environmental protection fellowship

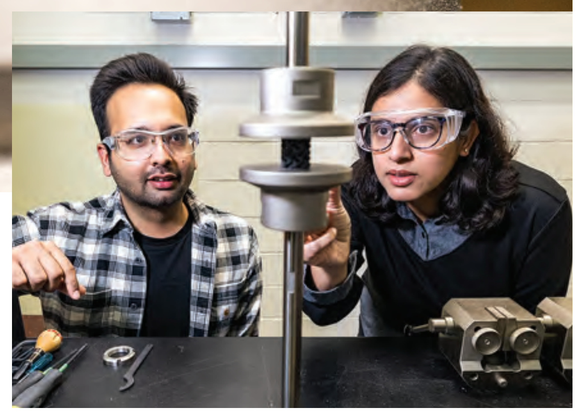
Assistant Professor Nimish Pujuara has been awarded the Early-Career Research Fellowship in Environmental Protection and Stewardship.

The Gulf Research Program of the National Academies of Sciences, Engineering and Medicine hosts the fellowship program. Pujara is one of seven fellows selected from institutions across the United States.

Fellows will research to predict and prepare for climate change-driven changes in coastal regions around the Gulf of Mexico. The program, which will run for two years, began in September 2023. Fellows receive $76,000 and mentoring support through the program, which encourages them to build new and unique collaborations while taking risks on untested research ideas.

Pujara leads a UW-Madison research group that studies fluid mechanics to understand the role of fluid motion in environmental processes. His research touches on how water can help shape our world and is tackling issues such as how waves erode beaches as they move along the shore.





New 'structures within structures' foam softens a blow and bounces right back

Top: A sample of the architected foam, which can take the force of a compression and return to its original shape thanks to multilevel embedded architectures. *Above:* Pavana Prabhakar, right, and Hridyesh Tewani have designed a foam built upon microscale level-architecture present within its solid regions. Photos: Joel Hallberg.

It might put an extra bounce in your step or add resilience to the hull of a ship: The unique internal structure of a lightweight 3D-printed syntactic foam created by UW-Madison engineers allows it to absorb a blow, then spring right back to its original shape.

Associate Professor Pavana Prabhakar and PhD student Hridyesh Tewani designed the new foam. Its key feature: "embedded multilevel architectures," which build upon the tiny structures already present within syntactic foams. Syntactic foams are composites made up of tiny hollow spheres called "microballoons." These microballoons, which can be made of different materials like polymer or glass, give syntactic foams high strength relative to their low density.

Then Prabhakar and Tewani tinkered with the structure even further, essentially creating an architecture around an architecture—using the microballoons as a guide to create larger, millimeter-scale gaps in the material. They described the new foam material in a paper published in the journal *Composites Part B: Engineering* in February 2024.

"We want to reduce weight, and a way to do that is to create higher-level hollow regions in the material," Prabhakar says.

Designing a material in this way could open opportunities for new lightweight, resilient materials with a wide range of potential applications. Tewani says the multilevel architecture creates a "bounce-back" foam, which means it can take the force of an impact and return to its original shape.

That ability to take repeated impacts and bounce back to form means that applications for these materials could include many ways to protect an object from repeated collisions—for example, a player's head inside an athletic helmet. The material can also be used between stiffer plates—say, in an airplane's hull.

Because the foams are created using 3D printing, they're incredibly customizable. That means they could have uses beyond highly specialized or intensive purposes.

"If you bring in different levels of architecture within the material, you can fine-tune the mechanical responses," Tewani says. "That gives you more freedom to design objects for different uses. So maybe one type of design in one material is good for a helmet liner, and another one is good for a ship, and an entirely different one might be good for shoe soles."

Tests inform how concrete building codes are set for structures nationwide

Professor Gustavo Parra-Montesinos has conducted a series of large-scale tests to determine how proposed changes to the American Concrete Institute (ACI) 318-19 *Building Code Requirements for Structural Concrete* (published in 2019) could impact structural integrity.

The changes revolve around required embedment lengths for headed rebar into concrete joints between beams and columns. Hooked bars that extend into a joint with a bend at the end for anchorage are typically used in beam-column joints. However, sometimes headed bars, which have rounded caps, are used instead of hooked bars. ACI building code committee members are reviewing proposed changes for the 2025 edition of *Building Code Requirements for Structural Concrete*, which may reduce how far headed reinforcing bars in beams have to be embedded into a building's exterior column.

Those changes, and the potential for breakout failure, prompted Parra-Montesinos to conduct tests. The ACI supported his work with fast-track test funding.

When a concrete floor is loaded, the headed bars embedded into the column will try to rip out a chunk of adjoining concrete, leading to what's called a breakout failure. Parra-Montesinos says that code-compliant connections with hooked bars have a long track record of adequate performance without breakout failures. While headed bars have also proven effective, there's less history behind them.

Parra-Montesinos conducted two tests in the Jun and Sandy Lee Wisconsin Structures and Materials Testing Laboratory at UW-Madison. The first test followed the 2019 code's requirements, with 1-inch diameter headed bars inserted 18 inches into the column. For the second test, his team inserted the bars 14 inches into the column, which is slightly deeper than proposed for the 2025 code update.

"The structure in the first test performed well, although the amount of damage at the end of the test was concerning," he says. "For the second test, we did have a breakout failure at the end. We saw even more damage in the joint of the second specimen prior to failure. Some of it was related to a breakout failure mechanism, but there was, to be honest, a lot more damage in the joint than I expected."

Professor Gustavo Parra-Montesinos looks at where a test column joins a beam during an experiment in the Jun and Sandy Lee Wisconsin Structures and Materials Testing Laboratory. Parra-Montesinos conducted the tests to study proposed code changes to headed rebar insertion depths where concrete columns and beams intersect. Photo: Alex Holloway.

Vacuum box enhances structures lab testing capacity

A new vacuum box in the Jun and Sandy Lee Wisconsin Structures and Materials Testing Laboratory will allow UW-Madison engineering researchers and students to test how steel deck roofing systems perform under realistic loading conditions.

Postdoctoral associate Hyeyoung Koh, undergraduate Lennart-Fredrik Schmitz and assistant professor Hannah Blum with the SEAhorse, a newly constructed vacuum box they'll use to test the performance of steel deck roofing systems. Photo: Hannah Blum.

Assistant Professor Hannah Blum and her students built the box, called the SEAhorse (Suction Experimental Apparatus) through the summer and fall 2023 semesters. The box is 8 feet by 16 feet, stands about 3 feet tall and is bolted to the floor to maintain structural integrity during tests. It's designed with modular 4-foot sections and can be made larger or smaller, as needed, for future tests. A steel deck can be set across the top, and during tests, vacuums siphon air out of the inside of the box to simulate realistic pressure loads. Valves throughout the box control pressure during tests.

Steel decks are sheets of corrugated metal that are often used as part of roofing structures. "They're very thin—about 1 to 2 millimeters. In conventional testing, if we want to apply load to test a deck's capacity, we have to apply load with a spreader beam," Blum says. "Even with a spreader beam, you're putting load on concentrated points, and something that thin with a load at a concentrated point might result in a localized failure. That's not always useful, because in a realistic setting, you'll have concrete uniformly spread on the deck, which applies load evenly across the deck."

Vacuum boxes circumvent this conundrum. When air is sucked out of the box, it pulls the deck down, simulating load uniformly across an entire surface. Blum says that approach provides better, more realistic data for how a steel deck might perform in real-world circumstances.

To that end, testing with the vacuum box will start with smaller pieces—for example, a steel deck—then ramp up to more complex systems, such as a steel deck with supporting joists that more closely resemble assemblies used in buildings. In those tests, researchers may study scenarios such as how a joist and deck system redistributes load in the event of one part failing.

The new vacuum box benefits undergraduate students because it's another avenue for them to get hands-on experience and see how the concepts they learn in the classroom can apply to real-world systems.

Capstone course wins 7th NCEES Award for renewable energy project

Collaboration, innovation and commitment to sustainability are key ingredients that earned our department its seventh Engineering Education Award from the National Council of Examiners for Engineering and Surveying (NCEES).

The award-winning project is an offshore wind turbine farm in Texas, which aims to improve and provide renewable energy sources to achieve carbon emission goals. With the award comes a $10,000 prize that will support the continued success of the capstone program.

A team of five senior CEE students, guided by practicing engineers and faculty, completed the project. Through the project, the students gained hands-on experience in construction management, structural engineering, geotechnical engineering, and environmental engineering.

Student to startup: Alumna Oliva Fritz finds career home in sustainability

An interest in sustainability, a passion for the environment, and the promise of a free Qdoba dinner sparked a unique and nontraditional career path for Olivia Fritz.

"Kohler Company was hosting a design for environment workshop on campus during my last semester," she says. "Being busy with capstone and preparing for the Fundamentals of Engineering exam, I was feeling pressured to study, but as I walked by the room and saw free dinner, I knew I couldn't pass up the opportunity. Looking back, I feel lucky since I didn't realize I would be attending an event that was the impetus to my career."

Fritz originally planned to study biomedical engineering at UW-Madison. However, experiences in college like joining Engineers Without Borders, learning to speak Mandarin, and studying abroad in China gave her a new perspective.

"Witnessing air pollution fluctuations, waste issues and speaking with locals in China about environmental concerns, such as the rise in single-use products, made me want to be part of the solution," she says.

A topics in sustainability course introduced Fritz to life cycle assessment, further opening her eyes to potential careers in sustainability, and a project in Professor Greg Harrington's water treatment lab helped her develop foundational research and presentation skills.

The Kohler workshop was a turning point in Fritz's college career. The event led to a co-op opportunity and introduced her to a colleague who helped co-found TrueNorth Collective seven years later, in 2021. TrueNorth helps clients make informed decisions with the full environmental impacts of products and services in mind, from raw material extraction through end of life.

Fritz's journey underscores the importance of lifelong learning, strategic networking and a strong commitment to personal passions. "Don't be afraid to try new things," Fritz says. "Be open to opportunities, raise your hand when they come up, and advocate for yourself along the way. You never know where you'll end up. We all start somewhere, and the experiences and connections we gain along the way are invaluable."

A web of fiber-optic cables will illuminate the condition of countless historic structures

In everything from tiny homes to massive skyscrapers, wear and tear can be imperceptible as it happens—a tiny crack here, a slight shift there. Over time, however, all those little changes can compound, adding up to expensive, or even dangerous, problems.

Now, UW-Madison engineers will use a unique integrated system to monitor damage propagation—particularly in many of the nation's landmark buildings—while blending structural and geological engineering with mixed reality.

Assistant Professors Hannah Blum and Jesse Hampton are collaborating with the U.S. Army Engineer Research and Development Center's (ERDC) Construction Engineering Research Laboratory (CERL). ERDC-CERL is supporting the project with a $3.4 million cooperative agreement.

The team will employ fiber-optic sensing networks capable of detecting subtle deformations in a structure. The system works by taking advantage of the physical nature of fiber-optic cables: they are long, narrow strands of glass or plastic that conduct light from one point to another. When light shined along the cable hits an imperfection, it's reflected. The researchers can use the reflections to interpret where and what type of deformation is occurring in a structure.

"If that cable stretches at any point, those little imperfections that reflect some of that light are going to move further away from each other," Hampton says. "If they compress, the response changes because those points are moving closer together. With that information, you can understand how a structure is deforming."

CEE students Gowshikan Arulananthan, Monamy Mustaq and Nate Opperman (from left) set up a fiber optic monitoring system for a test on the SEAhorse vacuum box. Photo: Hannah Blum.

Because we know how structural materials should perform under load, it may be possible to use initial readings from the fiber-optic network to infer what kind of damage a structure has accumulated. Additionally, the network can remain in place for long-term monitoring of the structures.

The team will create physics-based structural models of the infrastructure and then will feed data from the networks into the models to better estimate the performance of these structures subjected to anticipated future loading conditions. Blum's team has experience in creating detailed structural models to analyze behavior. Employing very detailed LIDAR scans to map out the historic structures, the team also will create detailed point cloud models of buildings.

"Mixed reality is becoming a lot more common for construction site inspections or post-disaster infrastructure inspections," Blum says. "This is now turning into a mainstream tool and students will benefit from exposure to this technology."

Department of Civil and Environmental Engineering
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Excitement is building

Our engineering campus is getting a facelift. With formal approval of state funding for a new 395,000-square-foot building, we're continuing our growth initiative.

The seven-story building will span parts of the existing Engineering Mall and the space currently occupied by 1410 Engineering Drive (which will be demolished), and feature refreshed green space and indoor and outdoor gathering spaces.

The $347 million facility, funded through $150 million in private giving and $197 million from the state of Wisconsin, will be a catalyst for research while allowing the college to educate many more exceptional students.

Explore more, follow along with the building's progress, and support the project at engineering.wisc.edu/new-building.

All images by Continuum Smithgroup. Artist's concepts of the new building.