SPRING 2018

CIVIL AND ENVIRONMENTAL ENGINEERING

UNIVERSITY OF WISCONSIN-MADISON

MAKING MADISON'S STREETS A VEHICLE FOR INNOVATION

Photo: Jeff Miller

CHAIR'S MESSAGE

David Noyce

Greetings from Madison!

As the chair of our department, I am continually impressed by the sheer breadth of research conducted by CEE faculty.

From studying new ways to make concrete to unearthing novel approaches to assessing flood risk, our faculty vigorously pursue projects on an astonishing variety of relevant and influential topics. In fact, you can read about two of our promising assistant professors working on those very issues in this newsletter: Bu Wang (page 4) and Daniel Wright (7).

Our department includes experts on construction, hydrology, microbial ecology, soil mechanics, environmental chemistry, advanced materials and many more areas that bridge the built and natural worlds. We're eager to add more up-and-coming scholars who will further broaden our diversity of thought and bring ambitious research agendas in the coming months.

As a department, we have consistently ranked among the nation's elite when it comes to research expenditures per tenured faculty member. That kind of financial support allows us to embark on work that stretches across the globe and leaves a worldwide impact. CEE faculty currently have ongoing research efforts on five of Earth's seven continents!

Right here in Madison, we are at the forefront of autonomous vehicle (AV) research that holds the potential to transform transportation. Of the 10 federally designated AV proving grounds across the country, Wisconsin's is the only one primarily based at a university. Our department—specifically our transportation engineering faculty and researchers in the Traffic Operations and Safety Laboratory, which you can read more about on page 3—is thrilled to lead such important and forward-thinking work.

Be sure to stay connected with CEE on Facebook (@UWMadisonCEE) and Twitter (@UWMadisonCEE). And, should you find yourself on campus, stop by to say hello!

ON, WISCONSIN!

David A. Noyce, PhD, P.E., FASCE
Dr. Arthur F. Hawnn Professor and Chair
danoyce@wisc.edu • (608) 265-1882

A DIPLOMA ... 36 YEARS LATER

Stein Olaussen (MS '81) keeps a reminder of his time at UW-Madison in his office in Tananger, Norway, a small village on the country's southwest coast. Instead of his diploma, though, it's the textbook from his favorite class, *Statistics for Experimenters*.

"In one of the first chapters was a reference to someone who had published an article listing the number of stork nests versus number of births in a village," Olaussen recalls. "Found a fantastic correlation! It's a great example that causation and correlation don't always match."

But Olaussen will now need to find a spot for that diploma—one he's receiving 36 years after leaving campus, thanks to a little assistance from the CEE department.

Olaussen had completed all of the required coursework and had minor corrections to make on his thesis when he and his compatriot Svein Riibe left Madison in a customized Dodge Sportsman van for a road trip to the West Coast. Then it was time to return to his native Norway, where he soon landed a job as a trainee engineer at Halliburton, the company for which he's worked ever since.

"The fact that I needed to complete everything fully then receded further and further back into my memory bank," he says.

Until a spring 2017 cleaning spree led him to the loft above his garage, where he found a cardboard box containing red three-ring binders filled with notes, papers, lab projects, tests ... and his thesis on the anaerobic treatment of dairy waste from a cheese factory.

A flood of fond memories prompted him to email Professor Emeritus Paul "Mac" Berthouex, with whom Olaussen had reconnected at the department's environmental engineering conference for alumni, to explore belatedly getting a proper diploma.

Berthouex and Professor and CEE Department Chair David Noyce brought Olaussen's case to the Graduate School, which retroactively awarded him his master's degree in December 2017.

Not that he necessarily needs it after a successful career that's seen him rise to managerial positions in operations, business development and now safety and service quality.

"In practical terms it doesn't mean so much now," he says. "But of course the diploma will look nice on the wall."

TURNING MADISON INTO A CONNECTED VEHICLE TESTBED

An intoxicated driver loses control of his speeding vehicle. It jumps the curb and collides with a trio of pedestrians.

Had a nearby traffic signal and the vehicle itself been equipped with connected vehicle technology capable of transmitting a warning to the pedestrians, perhaps a loud cell phone alert, they might have had time to move to safety.

Such technology, which allows vehicles, pedestrians and even our transportation infrastructure to "talk" to each other, is an incremental step on the path to a future that includes fully autonomous vehicles.

And, with researchers from CEE's Traffic Operations and Safety (TOPS) Laboratory, the city of Madison is now turning heavily traveled Park Street into a testbed for connected vehicle technology—one of only a handful in the United States.

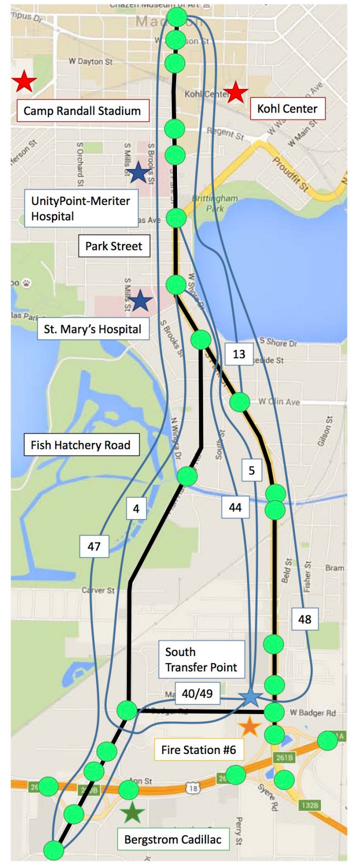
Along the busy 3-mile street, which links Madison's Beltline Highway with the UW-Madison campus, the researchers have installed five radio units on traffic signals and in a handful of city-owned vehicles that frequently travel the area, with plans to expand the testbed to a larger 6.2-mile loop—the Madison connected vehicle corridor—soon.

The corridor is part of the U.S. Department of Transportation-designated Wisconsin Automated Vehicle (WiscAV) Proving Grounds, which was established last year.

"Connected vehicles and autonomous vehicles are separate right now, but half of the nation's 10 proving grounds are currently pursuing connected vehicle projects because all autonomous vehicles will eventually be connected as well," says Jon Riehl, a researcher in the TOPS Laboratory, which is leading the WiscAV effort.

The backbone of Madison's corridor—already installed by city engineers in anticipation of future needs—consists of a high-speed fiber network that connects traffic signals and advanced traffic controllers with each other. The new radio units use dedicated short-range communication (DSRC), an open-source wireless communication protocol that allows only the messages of interest to be transmitted among traffic entities.

City staff and UW-Madison engineering and computer sciences researchers are extensively testing the technology and will then develop tools, such as the early-warning system for pedestrians, that will initially focus on safety. In parallel, UW-Madison mechanical engineers will simulate the corridor in a virtual reality environment.



The eventual 6.2-mile corridor will connect the campus with the Beltline Highway. It serves emergency vehicles for two hospitals and a fire station and frequently handles heavy event and bus traffic. *Image courtesy of Jon Riehl.*

For Professor David Noyce, who studies transportation engineering and directs the TOPS Laboratory, the connected vehicle corridor is part of a larger portfolio of WiscAV initiatives that is cementing UW-Madison's leadership in the field.

"The ability to experiment with connected vehicle systems in a live traffic stream really enhances our research," he says.

Noyce also serves on Gov. Scott Walker's recently convened steering committee on connected and autonomous vehicle testing and deployment.

"Wisconsin is quickly becoming a national leader in connected and autonomous vehicle research," Noyce says. "With a recently established collaboration with Southeast University in Nanjing, China, which houses that country's top-ranked transportation engineering program, we'll be able to lead connected and autonomous vehicle research on an international scale."

Photo: Renee Meiller

"Wisconsin is quickly becoming a national leader in connected and autonomous vehicle research ... we'll be able to lead connected and autonomous vehicle research on an international scale."

CONCRETE PLANS FOR SUSTAINABLE MATERIALS

Bu Wang has always been drawn to engineering. Whether it was building model planes as a child or roasting his own coffee beans after he moved from China to the United States for graduate school, he would spend hours tinkering with parts and pieces and figuring out the perfect conditions for a process of interest.

"I initially roasted coffee beans with a popcorn popper that I modified for better temperature control," recalls Wang, who joined CEE in January as an assistant professor and a Grainger Institute for Engineering fellow. "But it didn't end up working very well, so I eventually purchased a dedicated coffee roaster."

Now, Wang is thrilled to have the resources for building something much bigger: a research program that revolves around materials, from glass and concrete to next-generation batteries and ceramics for fuel cells.

His longstanding interest in materials can perhaps be traced to his dad's job as a construction company manager, while his mom—a college-level Chinese literature instructor—may have passed on teaching skills. But he found his true calling at Alfred University in New York, where he completed his PhD in ceramic engineering in 2015.

"I began to focus on researching materials that generate energy or make commonly used production processes more sustainable," Wang says. "One example of that is concrete."

Traditionally, concrete—the developed world's primary building material—is made by gluing together various rocks and minerals with cement paste. Making the cement paste consumes a lot of energy, since it requires temperatures up to 1,500 degrees Celsius, and generates carbon emissions galore.

One way to make the process more environmentally friendly is to replace a fraction of the cement—the higher, the better—with already existing fly ash, a waste material generated by coal-fired power plants.

Most of this fine-particle material is stored in landfills as ash ponds, but the concrete industry is already replacing up to 20 percent of cement with fly ash. The catch? Only fly ash below a carbon content threshold may be used, according to current industry specs.

Wang's research could help boost that percentage to at least 75, while also using ash that falls outside the specs. In a 2017 study, for example, he and his colleagues showed that a different type of reaction between fly ash and carbon dioxide yielded a product with the same strength as cement-based concrete, but without any cement at all.

While some of Wang's concrete research is in its early stages, he has also helped develop a low-carbon, low-energy concrete production process that could be implemented in a pilot plant soon, thanks to Carbon XPRIZE, an ongoing industry-sponsored international competition for new carbon capture and use technology.

In the process developed for Carbon XPRIZE, fly ash and lime react with the carbon dioxide produced by a coal- or natural gas-fired power plant to replace most of the cement paste in concrete. Wang's team has advanced into the final round of the competition.

Wang also studies the impact of radiation on a nuclear power plant's outer shell. That shell is typically made of the same concrete as other buildings, while a different material is used for the reactor shield itself. Using a recently published atomic-scale study of the damage radiation inflicts upon concrete as a starting point, Wang would like to eventually develop models that better predict the structure's lifetime and can become a part of regulatory monitoring plans.

RETHINKING RESURFACING: STUDENTS DIG INTO ALTERNATIVE APPROACH

Geological engineering undergraduates Morgan Sanger, Renee Olley and Tyler Klink are trying to make modern construction methods more sustainable and beneficial to the earth.

They conduct research through the Recycled Materials Resource Center and are focusing on the environmental benefits of cold-in-place recycling, a method of highway resurfacing.

"It's an alternative method that's been around for more than a decade and is used for its recognized economic benefits," Sanger explains. "Conventionally, the asphalt highway is reconstructed with a method called mill-and-overlay, where they mill the existing roadway, haul it to an asphalt plant, bring in new material and then lay that material down. Cold-in-place recycling does the milling, but instead of hauling it away, you mix it with something else at the site and lay it back down."

As a result, road builders use fewer new materials and spend less on transporting materials to a job site.

Although the method sounds like a win-win, its environmental benefit has not yet been quantified, says Sanger. In comparing the cold-in-place technique with the traditional mill-and-overlay process, the students

A NEW KIND OF GRADUATE COURSE


Photo: Renee Meller

Technology has changed our daily lives in countless ways—however, many university professors are still teaching their graduate-level classes exactly the same way they did 50 years ago.

"We're still getting in front of the room to lecture about the research that other people are doing, rather than use existing technology to actually connect these people directly with students across the country," says Associate Professor Steven Loheide.

So Loheide decided to change that, starting with his own field of hydrologic sciences, a broad discipline that includes engineers, geoscientists, limnologists and agronomists, just to name a few.

As a member of the board of directors of the Consortium of Universities for the Advancement of Hydrologic Science Inc. (CUAHSI)—an umbrella organization that builds community across more than 100 institutions nationwide—he worked to expand the nonprofit's educational mission by designing a new virtual graduate course.

The CUAHSI Virtual University's pilot course debuted last fall, with Loheide and five other professors teaching 45 graduate students from six institutions through live online lectures. The same format will be offered this fall.

By combining any three modules from the course menu, the students—from UW-Madison; Michigan State University; the University at Buffalo; the University of California, Santa Barbara; the University of Delaware; and the University of Nevada, Reno—earned three credits at their home institutions. Topics ranged from the use of drones for hydrologic applications to coastal hydrology and groundwater-dependent ecosystems.

"The unique feature of our program is the target audience of research-oriented graduate students, rather than the undergraduate and professional students for whom many forms of online education already exist," Loheide says. "The opportunity to learn directly from the people who are at the forefront of their highly specialized research areas is invaluable to these students, since a single campus could never dream of offering access to such a wide range of expertise."

MORE: www.engr.wisc.edu/testing-waters-new-kind-graduate-teaching/

Morgan Sanger explains her group's research to Wisconsin state Sen. Fred Risser during the 15th annual Research in the Rotunda event in April 2018 at the Wisconsin State Capitol. *Photo: Jeff Miller.*

found the former saves 20 percent in energy consumption, water consumption and carbon dioxide emissions.

"We compared the different stages of each method and found that the cold-in-place recycling was much more environmentally friendly, because even though you do use more energy to do the onsite mixing and crushing, this is only a small percentage of the energy you would use in mining and transporting and all this extra virgin aggregate," says Olley.

Cold-in-place recycling also cuts in half the cost of the mill-and-overlay process.

The student researchers worked with the Wisconsin Department of Transportation to collect data from 68 miles of roadwork. Their advisors, Grainger Institute for Engineering Assistant Director for New Technology Directions Angela Pakes and Professor Emeritus Tuncer Edil, presented the results in January 2018 at the annual Transportation Research Board Conference in Washington, D.C.

For more geological engineering stories, read the most recent program newsletter at go.wisc.edu/glewinter2018

ALUMNA PROFILE: A CAREER THAT HOLDS WATER


Photo courtesy of O'Brien & Gere

Laurie Parsons (MS '87) will do just about anything for water. If the goal is to reduce water pollution with better waste disposal systems, she'll even collect foul-smelling wastewater samples in a Wisconsin cheese factory.

But she didn't enjoy that experience enough to become a wastewater engineer. The path toward her true calling was guided by her passion for water and started with earning a bachelor's degree in environmental sciences at the University of Wisconsin-Green Bay. Next came a move to Madison for her first job with the Wisconsin Department of Natural Resources and then the idea of going back to school for a graduate degree—in either engineering or resource management.

To help make that decision, she sought out DNR projects that involved interactions with engineers.

"I found myself really enjoying those conversations, so I decided to become an environmental engineer, even though I didn't have a bachelor's degree in engineering and didn't always excel in math," Parsons says. "That's why I tell many students today, especially women, not to get stuck on math concerns early in life."

Since the Fond du Lac, Wisconsin, native had already fallen in love with Madison's lakes, the best place to pursue her graduate education was just a few miles away. In the civil and environmental engineering master's program, she designed her own curriculum by combining groundwater hydraulics and contaminant assessment, with a focus on water remediation.

In addition to Professor William Boyle, under whom she collected the smelly wastewater samples, Parsons credits Professors John Hoopes, Peter Monkmeyer and Kenneth Potter as being supportive and influential mentors, each in their own and unique ways. Before she even received her graduate degree, she accepted a job offer from Warzyn Engineering.

In 1994, just seven years out of graduate school, Parsons made her next career move: She left Warzyn, a large and solid company, to establish engineering services for then-startup company Natural Resource Technology Inc.

That ended up being an excellent decision. Thirteen years later, she became the president of NRT, growing the company from 40 to 70 employees and adding offices in Illinois and Michigan. It became so well recognized for its environmental services that it attracted the attention of the East Coast consulting company O'Brien & Gere (OBG). She and her partners sold NRT to OBG last year.

"I'm so glad I had the guts, at a second major crossroads in my career, to sell my baby to OBG in order to keep us on our 'best in class' trajectory for employment and professional development opportunities for our staff," says Parsons, who led OBG's environmental division for about a year before becoming its senior vice president in January with the charge of overseeing its continued growth in the Midwest.

She contributes to the growth of the firm's diverse services, such as advanced manufacturing, coastal resiliency, smart energy systems, wastewater treatment and forward-thinking techniques for environmental remediation.

> **"Challenge the status quo, don't be discouraged by an occasional poor grade, and pace yourself, since finishing your program as quickly as possible isn't always the best strategy."**

Parsons, who was honored by the American Society of Civil Engineers as the regional "STEM Forward Engineer of the Year" in 2015, regularly participates in events that expose young people to careers in science, technology, engineering and math.

She offers this advice to today's engineering students: "Challenge the status quo, don't be discouraged by an occasional poor grade, and pace yourself, since finishing your program as quickly as possible isn't always the best strategy."

"Most importantly, know that you've already made a great choice by getting a degree in engineering. Even if you don't stay in the specialty you trained in, there are many other ways to put your skills to work—so don't swim in a single lane."

NSF CAREER AWARD ENABLES WRIGHT TO DIVE DEEPER INTO FLOODING


Photo: Renee Meiller

Daniel Wright hopes to one day transform the way we analyze and estimate flood risk in the United States and around the world.

That's a lofty ambition that goes well beyond a single research proposal. But the assistant professor sees the work he'll undertake as the recipient of a National Science Foundation CAREER award as the next step on his longer quest.

Researchers have traditionally studied floods from two disparate perspectives: the physical point of view, which examines how rainfall interacts with the land and rivers that comprise watersheds; and the statistical approach, which attempts to define the relationship between flood severity and likelihood (known as flood frequency analysis).

"There's a lot of middle ground between those two approaches that hasn't really been very well explored," Wright says.

He hopes to bridge that gap through his NSF CAREER grant, which provides more than $500,000 over five years. To do so, he plans to use data analysis and modeling that starts, fundamentally, with what he calls the ingredients of floods: rainfall, land cover and use, and soil moisture.

"It's pretty ambiguous right now in terms of what the future holds for flood risk in a changing climate," he says. "The reason is that big floods are so rare that it's hard to infer directly from really infrequent observations how the world is changing, and specifically how flood risk is changing. I think we stand a much better chance of doing that if we focus on how the individual ingredients are changing."

To better understand the first and foremost ingredient—rainfall—Wright will analyze records of every rainstorm across the United States over the past 70 years, thanks to an algorithm created by collaborators at the University of California, Irvine. Wright says typical examinations of rainfall trends over time have relied upon data from rain gauges.

"We actually get to look at the size and shape and motion of these storms, as opposed to just looking at what the rain gauge is telling us," he says.

He'll also build upon work he did as a doctoral student at Princeton University and NASA's Goddard Space Flight Center, where he developed software called RainyDay. It allows users to develop thousands of hypothetical rainfall scenarios in order to run flood simulations for specific watersheds with different land use and soil moisture conditions. Wright will use RainyDay in combination with observations from the National Weather Service's NEXRAD network of weather radars.

"We've been showing that this approach can give us a richer picture of what this 'frequency versus severity of flooding' is than some of the more conventional statistical approaches can," he says. "And it's doing so because it's starting from really representing the physics."

The outreach components of Wright's CAREER project also lean heavily on technology, including using an "augmented reality sandbox" to illustrate concepts like topography and runoff for K-12 audiences; working with graduate students to develop web-based tutorial apps on key hydrology and statistics concepts; and creating educational modules based on the physics of the video game Minecraft.

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DIVING INTO DESIGN

First-year engineering students are designing portable laboratory incubators that could allow users to check for contaminants in their water supply—even in remote communities.

Two sections of *Interdisciplinary Engineering 170-Design Practicum*, taught by Professor Greg Harrington and Adjunct Professors Jack Cox and Kathryn Huibregtse, have taken up the challenge, which came from the UW-Madison chapter of Engineers Without Borders.

Half the students are creating the incubator, while the others are working on an independent power source.

Each project in the course comes from an outsider with a pressing need, a brainstorm or both, says course director Tracy Jane Puccinelli. She says the course's goals blend creativity, fun, cooperation and real-world applications.

"This is their first year of college and it's critical to show some context," she says. "They have been working really hard with math and science but may not realize how that applies. They don't necessarily know what an engineer does, and this class is an opportunity to see what they can do with those skills."