FALL 2020

CE IMPACT

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POWERHOUSE

STUDENT-DESIGNED TINY HOME CREATES INNOVATIVE SPACE FOR ARCHITECTURAL ENGINEERING LAB

PURDUE UNIVERSITY

Lyles School of Civil Engineering

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MESSAGE FROM THE HEAD

I think I speak for just about everyone at the Lyles School of Civil Engineering when I say we have put more into preparation for the Fall 2020 semester than any previous semester in my recollection of nearly 30 years as a teacher.

After months of global uncertainty and cloistered living, we are desirous that the fall semester will bring a sense of stability to tens of thousands of Boilermakers. That said, we completely understand anyone's reluctance to return to campus and we have been working continuously to ensure the educational experience for those who wish to attend classes remotely is no less impactful. At its core, civil engineering has been a practice that moves with the changing times.

It is not an exaggeration to say that the worldwide COVID-19 pandemic altered our perspectives and approaches to daily life in a dramatic, and perhaps permanent fashion. This event has also influenced our way of thinking and approach to education moving forward. For years, we have known that a high-quality online education option was not just advisable — it was necessary.

This commitment also extends to our new and continued research. While our faculty, staff and student researchers had to make major adjustments over the months, their impactful research continued.

In this edition of IMPACT, you will learn about how our researchers are making cutting-edge advancements in monitoring bridges, research on tiny houses, rethinking how we can implement 3-D materials for renewable energy and, of course, how we can combat and better understand the effects of COVID-19.

This is an incredibly exciting time on campus and I am thrilled to see what this school year will bring in both educational advancement and groundbreaking research. As always, I encourage everyone to reach out to me anytime — either via email or when you are on campus. My doors — both physical and virtual — are always open.

All the best,

Rao S. Govindaraju
Bowen Engineering Head of Civil Engineering
and Christopher B. and Susan S. Burke Professor of Civil Engineering

IN THIS ISSUE:

ON THE COVER

Visiting Assistant Professor Nusrat Jung (at right) led a team of four students who designed the zEDGE (zero-Energy Design Guidance for Engineers) tiny house. The group worked on every aspect of the design, from modeling and materials to energy-use calculations and the electrical and plumbing systems — all with an eye on innovation, efficiency and sustainability.

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NEWS & EVENTS

#6

The Lyles School of Civil Engineering's Christopher B. and Susan S. Burke Graduate Program in Civil Engineering has been recognized — once again — as a top 10 graduate program in the country.

U.S. News & World Report has released its national rankings of graduate programs for 2021 with Purdue Civil Engineering ranked #6 in the nation. The graduate rankings are computed from the responses to a survey sent to deans, heads and selected senior faculty.

The Burke Graduate Program has been consistently ranked in the top 10 by *U.S. News & World Report* for over a decade. Overall, Purdue's College of Engineering graduate program was ranked seventh in the nation.

For more information about Purdue Engineering's 2021 graduate rankings, visit: http://bit.ly/COE-rankings.

NEW GRADUATE-LEVEL ONLINE STRUCTURES COURSE OFFERED

State-of-the-art methods in steel and concrete composite construction are the focus of a new series of online courses from the highly-ranked Lyles School of Civil Engineering. The courses are for working engineers and technical professionals looking to update their skills and log professional development hours, as well as for graduate students.

"Anybody who has completed an undergraduate degree in civil engineering would benefit from taking these courses," said Amit Varma, the Karl H. Kettelhut Professor of Civil Engineering and director of the Bowen Laboratory of Large-Scale Civil Engineering Research.

The courses, designed by Varma, each last eight weeks. Through hands-on learning grounded in case studies and experimental observations and analysis, the courses aim to prepare participants to apply the methods in their own practices.

Each of the one-credit-hour courses can be taken individually. Students who complete all three are eligible for a Purdue "Steel Designer" digital badge. The first course will be available in May 2021 with the second and third to follow in August and October. For more information, visit https://online.purdue.edu/programs/professional-development.

SPRING GRADS

Congratulations to the 150 graduate and undergraduate students who earned their civil engineering degrees in May!

Unfortunately, the campus shutdown prevented us from having our traditional post-commencement celebration but we could not be prouder of your achievements and what you overcame in the final months of the semester.

We cannot wait to see you all again when you come back to visit.

PURDUE UNIVERSITY | Lyles School of Civil Engineering

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BIOINSPIRED DESIGN

3D TECHNOLOGY SHOWS PROMISE FOR DURABLE, LIGHTWEIGHT STRUCTURAL MATERIALS

Whether it's drawing inspiration from a bone's microstructure or aiding in harnessing renewable energy, researchers at Purdue University are consistently seeking new ways to innovate with 3D-printed materials.

Pablo Zavattieri, the Jerry M. and Lynda T. Engelhardt Professor in Civil Engineering, has spent much of his research over the past several years on the innovation and application of 3D-printed materials. Just this past year alone, he and his teams have produced a pair of reports that could both push materials research forward and lead to a boom in offshore wind energy capturing.

BONE-INSPIRED MATERIALS

What do bones and 3D-printed buildings have in common? They both have columns and beams on the inside that determine how long they last.

Now, the discovery of how a "beam" in human bone material handles a lifetime's worth of wear and tear could translate to the development of 3D-printed lightweight materials that last long enough for more practical use in buildings, aircraft and other structures.

"Bone is a building," Zavattieri said. "It has these columns that carry most of the load and beams connecting the columns. We can learn from these materials to create more robust 3D-printed materials for buildings and other structures."

Zavattieri's team, along with researchers from Cornell University and Case Western Reserve University, found that when they mimicked this beam, an artificial material could last up to 100 times longer. The work was financially supported by the National Science Foundation.

Bones get their durability from a spongy structure called trabeculae, which is a network of interconnected vertical plate-like struts and horizontal rod-like struts acting as columns and beams. The denser the trabeculae, the more resilient the bone for everyday activities. But disease and age affect this density.

"When we ran simulations of the bone microstructure under cyclic loading, we were able to see that the strains would get concentrated in these horizontal struts, and by increasing the thickness of these horizontal struts, we were able to mitigate some of the observed strains," said Civil Engineering PhD student Adwait Trikanad.

Applying loads to the bone-inspired 3D-printed polymers confirmed this finding. The thicker the horizontal struts, the longer the polymer would last as it took on load. And, because thickening the struts did not significantly increase the mass of the polymer, researchers believe this design would be useful for creating more resilient lightweight materials.

"To create a stronger material without making it heavier would mean 3D-printed structures could be built in place and then transported," Zavattieri said. "These insights on human bone could be an enabler for bringing more architected materials into the construction industry."

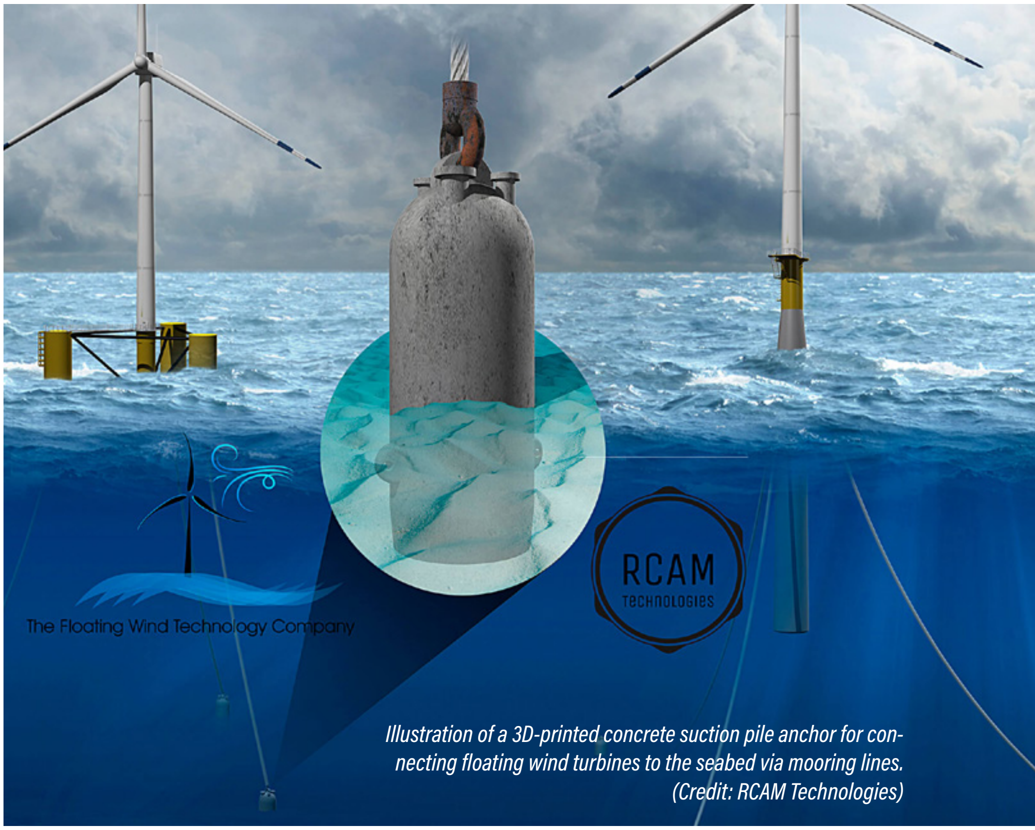


Illustration of a 3D-printed concrete suction pile anchor for connecting floating wind turbines to the seabed via mooring lines. (Credit: RCAM Technologies)

HARNESSING OFFSHORE WIND ENERGY

Wind off the coasts of the U.S. could be used to generate more than double the combined electricity capacity of all the nation's electric power plants, according to the U.S. Office of Energy Efficiency and Renewable Energy.

Unfortunately, building wind turbines offshore is expensive, requiring parts to be shipped at least 30 miles away from a coast. With that in mind, Zavattieri and fellow Purdue researchers Jan Olek, the James H. and Carol H. Cure Professor of Civil Engineering, and Materials Engineering Professor Jeffrey Youngblood, have been conducting research on a way to make these parts out of 3D-printed concrete, a less expensive material that would also allow parts to float to a site from an onshore plant.

"One of the current materials used to manufacture anchors for floating wind turbines is steel," Zavattieri said. "However, finished steel structures are much more expensive than concrete."

Conventional concrete manufacturing methods also require a mold to shape the concrete into the desired structure, which adds to costs and limits design possibilities. 3D-printing would eliminate the expenses of this mold.

Zavattieri's team is working in collaboration with RCAM Technologies, a start-up founded to develop concrete additive manufacturing for onshore and offshore wind energy technology, and the Floating Wind Technology Company (FWTC). RCAM Technologies and the FWTC have an interest in building 3D-printed concrete structures including wind turbine towers and anchors. The work also is funded by the National Science Foundation INTERN program.

The team is developing a method that would involve integrating a robot arm with a concrete pump to fabricate wind turbine substructures and anchors. The goal is to understand the feasibility and structural behavior of 3D-printed concrete produced on a larger scale than what the team has previously studied in the lab.

"The idea we have for this project is to scale up some of the bioinspired design concepts we have proven on a smaller scale with the 3D printing of cement paste and to examine them on a larger scale," said Mohamadreza "Reza" Moini (PhD CE '20).

The researchers will determine how gravity affects the durability of the larger-scale 3D-printed structure. The scaling up research could also be applied to optimizing and reinforcing structures in general.

"Printing geometric patterns within the structure and being able to arrange the filaments through it or playing around with distribution of the steel are both possibilities we have considered for optimizing and reinforcing the structures," said Olek.

Amit Varma, the Karl H. Kettelhut Professor of Civil Engineering and director of Bowen Laboratory, and Christopher Williams, an assistant professor of civil engineering, are assisting in deploying the robot as part of the internal project within the Lyles School of Civil Engineering and between the specialty groups of materials engineering and structural engineering.

Research is being conducted in the Robert L. and Terry L. Bowen Laboratory for Large-Scale Civil Engineering Research.

EXAMINING BRIDGES

SETTING NEW STANDARDS FOR BRIDGE INSPECTIONS

A LYLES SCHOOL OF CIVIL ENGINEERING PROFESSOR'S RESEARCH IS HELPING SHAPE HOW BRIDGES ARE INSPECTED ACROSS THE NATION

Robert Connor
Jack and Kay Hockema
Professor of Civil Engineering

Robert Connor, the Jack and Kay Hockema Professor in Civil Engineering, collaborated on research for the report "Proposed Guidelines for Reliability-Based Bridge Inspection Practices" under the National Cooperative Highway Research Program (NCHRP).

The research, which was completed six years ago, came up when the results were cited in the newly proposed National Bridge Inspection Standards (NBIS) under consideration by the U.S. Department of Transportation's Federal Highway Administration. The NBIS effectively governs how and when highway bridges are inspected in the United States.

"The results of the research will allow the intervals at which bridges are inspected to be established based on a risk-based approach," Connor said. "It's a compliment to see your work have a potentially major impact."

The NCHRP research cited in the proposed bridge inspection standards followed initial work Connor conducted for the Federal Highway Administration that developed risk-based inspection strategies for bridges that contain non-redundant steel tension members known as fracture critical members.

Connor said current bridge inspection standards are calendar-based, calling for on-site inspections every 24 months, whether it's a new bridge or 100-year-old bridge. There are no explicit adjustments for age or circumstances such as environmental conditions that can wear on a bridge faster.

Connor said the research report cited in the proposed inspection standards calls for a risk-based analysis that allows inspection efforts to focus on bridges and areas that are more likely to have problems or would have significant consequences should a problem arise.

"The research allows an owner to decide how to best manage the inspection needs of their diverse inventory of highway bridges," said Connor, director of the Steel Bridge Research, Inspection, Training and Engineering Center.

"Rather than over-inspecting newer, healthy bridges, the interval can be rationally extended to every 48 or 72 months for some," he said. "This will then allow an owner to spend more time on other bridges they are more concerned about and inspect those every 12 months, for example."

Connor was co-principal investigator in the research as part of a team of colleagues including Glenn Washer, a professor of civil and environmental engineering at the University of Missouri, who approached him for the project.

INVESTIGATING SEISMIC VULNERABILITY

WHICH INDIANA BRIDGES ARE THE MOST SUSCEPTIBLE TO EARTHQUAKES? PURDUE RESEARCHERS HAVE SET OUT TO FIND THE ANSWER.

The Indiana Department of Transportation (INDOT) is responding to the seismic risk presented by the Wabash and New Madrid faults with a multi-year effort, started in 2018, to enhance the seismic response and training of INDOT personnel. Over the last three years, the effort has focused on assessing the seismic vulnerability of the state's bridge network and empowering INDOT's maintenance database (BIAS) to conduct rapid seismic vulnerability assessment.

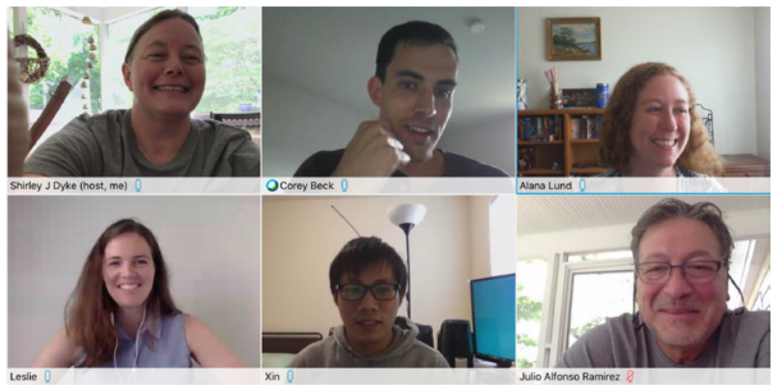
The work has been conducted through the Joint Transportation Research Program (JTRP), led by Purdue Civil Engineering and Mechanical Engineering Professor Shirley Dyke.

"Indiana needs powerful tools to determine which of its thousands of bridges are most vulnerable to earthquakes in regard to the seismic hazard in the state, and may be good choices to bring up to the latest standards," Dyke said. "This need is about to be addressed, thanks to the research at the Lyles School of Civil Engineering."

Dyke's team and collaborators from Purdue and Notre Dame universities have been developing an automated tool, INSAT, that can assess the seismic vulnerability of Indiana's bridge inventory. The program uses simple dynamic models, an understanding of typical bridge behavior and seismic hazard to rapidly assess bridge vulnerability. It color codes each bridge as either low, moderate or high vulnerability, with high meaning that particular bridge should be prioritized for attention.

INSAT is linked to BIAS and supplemented at this time with additional information from a detailed analysis and data from bridge drawings. One of the main recommendations from this study is in the form of additional data that if included in BIAS would empower INDOT to carry out a rapid seismic vulnerability assessment with INSAT.

Since January of 2018, Dyke's team has conducted a detailed analysis of 100 bridges of varying age, size and design. They created models to understand potential vulnerabilities across the inventory. Their focus was on bridges in the Wabash Valley Seismic Zone, located in the southwestern portion of Indiana.



"This project had a clear need and will serve as an invaluable asset to the Indiana Department of Transportation supporting their decisions as they ask which bridges need the most urgent attention," said Civil Engineering graduate student Alana Lund.

Around 4% of bridges the team examined ranked high priority for retrofitting to decrease their seismic vulnerability.

"In order for us to understand the criteria to use, we recreated these bridges and simulated them ourselves," said Civil Engineering graduate student Corey Beck. "From there, we've been able to identify specific vulnerability levels for different types of bridges along with strategies to improve them."

Civil Engineering graduate student Leslie Bonthron said their research determined that the greatest determining factor for a bridge's vulnerability was its substructure, no matter if it was reinforced concrete, pre-stressed concrete, or concrete and steel.

"The older the wall substructures, the more vulnerable they were to seismic activity," Bonthron said. "And, with this new tool, an engineer will be able to assess just how vulnerable a bridge is with a simple click of a button."

"The team is also making use of machine learning methods to populate the data fields that enable the tool to run robustly," said Civil Engineering graduate student Xin Zhang.

Dyke said the team expects to finalize and submit their work to INDOT before the end of 2020.

TINY HOUSE GIANT IMPACT

COMPACT RESEARCH SPACE GIVES STUDENTS zEDGE TO EVALUATE A ZERO-ENERGY STRUCTURE

At just 192 square feet, Purdue University's newest civil engineering laboratory is remarkably small for a research space. Yet, Lyles School of Civil Engineering Visiting Purdue Professor Nusrat Jung has big plans for it.

The architectural engineering laboratory comes in the form of a tiny house, called zEDGE (zero-Energy Design Guidance for Engineers), that Jung and a team of students designed and engineered for testing the energy efficiency of large structures on a small scale. Built on a trailer for easy mobility, zEDGE is stationed outside Hampton Hall.

"It's very small but it's a powerhouse," Jung said. "zEDGE is a great research lab for our students, because it's something very compact that still has all the energy efficiency parameters of a larger building, something very real that they can evaluate in real life."

NETTING ZERO

Increased energy efficiency and small homes are not new concepts, and the two have been closely tied since the small house movement emerged in the 1980s. The movement calls for a return to houses of less than 1,000 square feet, with tiny houses typically defined as those that measure less than 400 square feet. By comparison, the average size of a single-family home in America has grown to more than 2,600 square feet.

What makes the zEDGE project innovative is its mission: learning how to evaluate components of a truly zero-energy structure, which is the ultimate goal of many small-house and sustainability advocates. A net zero-energy building has zero net energy consumption over a 12-month period, meaning the amount of energy it uses in a year equals the amount of renewable energy created on the site.

"Energy efficiency and sustainability are things that have always resonated with engineers," Jung said. "Now, more and more people are realizing how important it is. What I found out is that there is a lot of interest in zero-energy buildings, which is my area of expertise, but not much knowledge of how to evaluate one."

FUN WITH FUNDAMENTALS

Jung recruited four students to join her design and engineering team, including civil engineering graduate students Motasem Qadan, Aditya Shivaji Mane and Chengbo Du — as well as undergraduate student Reno Lewis Sarussi. The four worked on every aspect of the design, from modeling and materials to energy-use calculations and the electrical and plumbing systems — all with an eye on innovation, efficiency and sustainability.

The final design featured many new energy technologies and components, including cutting-edge measuring instrumentation, high-efficiency lighting, two types high-efficiency insulation and unique Zip System sheathing that created a totally enclosed "building envelope." The house also has a solar energy system, pitched at the ideal angle for energy collection, and a water-collection system.

"The fact is that, with a tiny house, you can get away with some things that would take much more effort with a regular house — things like changing the direction of the house to reach the maximum solar energy potential. It is also easier to evaluate all the systems," said Qadan. "But you have to give a lot of attention to detail on a house on wheels, one that could be driving down the highway at 80 miles per hour. Nothing was done at random."

Finding the right builder for the project was one of the team's toughest challenges, Jung said. After an extensive search, they partnered with Colorado-based MitchCraft Tiny Homes. Construction began last December, and the final product was delivered to Purdue's campus in August.

MitchCraft owner Mitch Holmes, whose company has been building tiny homes since 2015, found the project both challenging and rewarding.

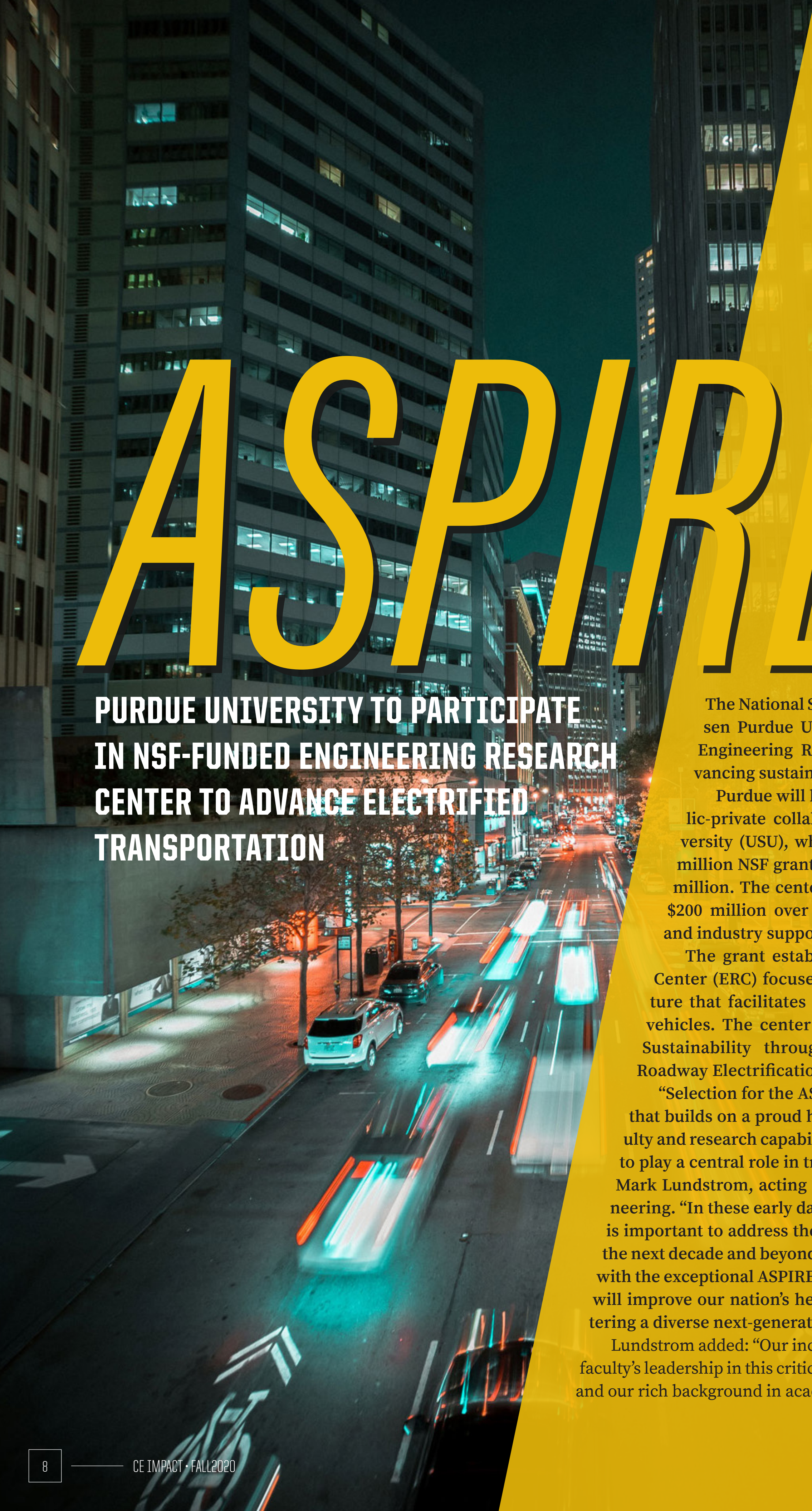
"Each home we build is a completely unique project with its own set of processes and challenges, so the Purdue project was no different in that regard," Holmes said. "But having Purdue engineers design the entire house, and having to build to such detailed specs, was definitely something new. It's certainly a nice project to add to our repertoire."

EYE ON THE FUTURE

In many ways, Jung sees both herself and zEDGE as part of a changing civil engineering landscape. Not only is she taking the lead as her field addresses the world's emerging sustainability issues, she is a female professor in a traditionally male-dominated area.

"Stereotypes exist, of course, but I think the gender dynamic is changing," Jung says. "One thing I really believe is that knowledge does not have a gender. I suppose I'm an example for young people of all genders that you can do amazing things if you simply have a passion. I think you can make your own story."

Jung recently received a Protect Purdue Innovations Faculty Grant and will carry out a research project in zEDGE to evaluate the chemical risk assessment of COVID-19 disinfection activities in buildings.



ASPIRE

PURDUE UNIVERSITY TO PARTICIPATE IN NSF-FUNDED ENGINEERING RESEARCH CENTER TO ADVANCE ELECTRIFIED TRANSPORTATION

The National Science Foundation (NSF) has chosen Purdue University to participate in a new Engineering Research Center dedicated to advancing sustainable, electrified transportation.

Purdue will be part of a multi-university, public-private collaboration, led by Utah State University (USU), which has received a five-year, $26 million NSF grant, renewable to 10 years and $50.6 million. The center is expected to raise more than $200 million over the next decade in government and industry support.

The grant establishes an Engineering Research Center (ERC) focused on developing new infrastructure that facilitates widespread adoption of electric vehicles. The center is named ASPIRE — Advancing Sustainability through Powered Infrastructure for Roadway Electrification.

“Selection for the ASPIRE team is a prestigious honor that builds on a proud heritage, speaks highly of our faculty and research capabilities and enables our researchers to play a central role in transforming transportation,” said Mark Lundstrom, acting dean of Purdue’s College of Engineering. “In these early days of electrified transportation, it is important to address the challenges and opportunities of the next decade and beyond. Purdue is pleased to collaborate with the exceptional ASPIRE team to develop innovations that will improve our nation’s health and quality of life while fostering a diverse next-generation engineering workforce.”

Lundstrom added: “Our inclusion in ASPIRE is a tribute to our faculty’s leadership in this critical area the new center will pioneer and our rich background in academic and industry collaboration.”

Purdue Engineering has a strong track record with ERCs. The College led one of the first centers, on Intelligent Manufacturing Systems, and the Center for Innovative and Strategic Transformation of Alkane Resources (CISTAR), launched in 2017.


Nadia Gkritza

Serving as Purdue campus director for ASPIRE and leader of the adoption research thrust will be Nadia Gkritza, professor of civil engineering and agricultural and biological engineering — a prominent expert and innovator in transportation energy and sustainability, including electrified vehicle infrastructure. In addition to teaching courses in transportation engineering, economic analysis of transportation investments and transportation data analysis, she is an associate editor of the *Journal of Transportation Engineering*. Gkritza also is a member of the Transportation Research Board (TRB) committees on Freight Transportation & Regulation and Agriculture & Transportation, and a former co-chair of the TRB Committee on Transportation & Economic Development.

Before joining the Purdue faculty, she was an Iowa State University faculty member, director of the Sustainable Transportation Systems Program at the Institute of Transportation and associate director of the U.S. Department of Transportation's Mid-American Transportation Center.

"The field of transportation is in the midst of a transformation not experienced since the invention of the automobile," Gkritza said. "Efforts are also underway to reduce emissions by improving vehicle and fuel technology and by promoting alternative, sustainable modes of transportation. Although the emergence of electric vehicles has shown capabilities of decreasing energy use and emissions levels, the electric vehicle market is developing slowly, due mainly to drivers' range anxiety and to charging time."

She continued: "ASPIRE researchers will convert the threats and weaknesses of this innovation ecosystem to opportunities and strengths through adoption of technologies across diverse users and stakeholders, vehicle classes and urban and rural areas. We also foresee opportunities to reduce emissions and near-road exposures to pollutants, coupled with other transportation innovations in shared mobility and automation that will shape data-driven policies encouraging advances."

Purdue faculty will be well-represented on the ASPIRE executive leadership team, as well as spanning the research, education and diversity and inclusion pillars. Donna Riley, the Kamyar Haghighi Head of the School of Engineering Education, will lead Engineering Workforce Development efforts; Rosie Clawson, professor of political science in the College of Liberal Arts, will head work toward Diversity & Culture Inclusion; and Steve Pekarek, the Dr. Edmund O. Schweitzer, III professor of electrical and computer engineering, will lead the Power Thrust area. Other Purdue faculty involved in ASPIRE include Dionysios Aliprantis, professor of electrical and computer engineering; Darcy Bullock, Lyles Family Professor of Civil Engineering; John Haddock and Samuel Labi, professors.

"We have a diverse and passionate set of researchers and educators working with other faculty and students across all campuses," Gkritza said. "The new ERC will benefit from Purdue's strong history on projects funded by the U.S. Departments of Transportation and Energy, NSF, and public policy forums."

The ASPIRE research will be linked with educational, mentoring and outreach initiatives for students at all levels. Purdue graduate students will have opportunities to engage in multi-institution collaborative research, to mentor undergraduate and K-12 students in research and to plan and participate in K-12 outreach events. Purdue undergraduate students will learn about the research through coursework and through educational training initiatives, such as Vertically Integrated Projects.

"The center launches at a critical moment in U.S. history," USU noted in announcing ASPIRE. "Nationwide, transportation and electric utility infrastructure are in need of extensive renovation. At the same time, vehicle emissions have serious impacts on public health and the environment, and fluctuating oil prices affect household budgets and economic stability. Electric vehicles play an important role in transforming the future of transportation, yet challenges remain to achieve sustainable and widespread adoption. Key to this new model of electric vehicle use is the development of charging technology that is built into roadways and parking facilities.

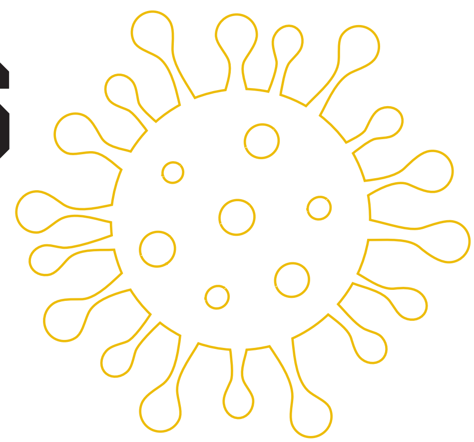
"ASPIRE researchers are developing holistic solutions that eliminate range and charging as obstacles to the broader electrification of all vehicles, including passenger cars and long-haul, heavy-duty trucks."

Regan Zane, USU professor and ASPIRE center director, said: "Now is the time to move past century-old mindsets and rethink how roadways and electric grid infrastructure can be co-designed to support low-cost, sustainable solutions for vehicle electrification and decarbonization of the electric grid."

In addition to Purdue, strategic university partners with USU in operating ASPIRE are University of Colorado Boulder, University of Texas at El Paso and the University of Auckland New Zealand. Other partners include researchers at Colorado State University, University of Colorado-Colorado Springs, Virginia Tech, Cornell University and four national laboratories. Global industry partnerships include more than 40 companies and organizations across the transportation and electric utility industries.

ASPIRE is designated as an Engineering Research Center, the National Science Foundation's flagship program for transformative multi-institutional research. It is one of four new Engineering Research Centers announced Aug. 4. It is the first in Utah in over 30 years and the only one dedicated to advancing sustainable transportation. After 10 years, ASPIRE will achieve graduated status and will continue as a self-sustaining research center. The related USU announcement is available **here**.

BIG? QUESTIONS



RESEARCHERS PIVOT TO EXAMINE ISSUES RELATED TO COVID-19 PANDEMIC

01

IS THE WATER SAFE TO DRINK?

The average person doesn't think twice before drinking from a water fountain. The public assumes the water is safe, that the building manager monitors the water quality. In reality, there are no standardized practices that govern plumbing safety. And water quality is easily compromised when buildings are underutilized and water in pipes remains stagnant for long periods of time. It's a problem exacerbated by the COVID-19 pandemic which led to salons, gyms, offices, municipal buildings, schools and sports venues standing empty for months.

Andrew Whelton, associate professor of civil engineering and environmental and ecological engineering faculty scholar, has researched the preservation and disinfection of water supplies for decades. Now, he and his team have fielded calls from around the world asking for advice on how to test water quality, flush and disinfect systems and ensure that building water is safe for occupants as facilities begin to reopen.

"It's not unusual that building managers don't know how to determine if plumbing is safe," Whelton said. "People have never really thought about it. Public health officials who oversee building occupancy and safety don't have extensive training in plumbing safety. And there are no federal, state, or county regulations to guide them on how to clean that water."

Whelton is developing a course in collaboration with Purdue Online to train public health officials about building water safety. He's also conducting research on buildings that have been sitting idle during the pandemic. This research will contribute significant gains in the area of plumbing safety which currently lacks evidence-based guidance on how to reinstate plumbing systems that sat idle for extended periods of time.

"Many building owners have never thought about plumbing safety because buildings are meant to be used," Whelton said. "When a building is in normal use, there is disinfectant and hot water running through the plumbing systems. When you have water sitting in plumbing for lengthy periods of time, all the chemical disinfectant is gone."

The longer water sits, the more lead and copper leaches into it. Consuming high concentrations of copper can lead to stomach cramps and nausea. Bacteria is also a concern, particularly *Legionella pneumophila* which causes Legionnaires' disease. The disease is contracted by breathing in droplets of water contaminated by the bacteria. But, Whelton cautions, just because major outbreaks associated with waterborne illness aren't reported, doesn't mean they don't happen.

The Centers for Disease Control issued water safety guidelines for schools as they reopen, encouraging staff and students to bring their own water to minimize use of water fountains. Although the guidelines were specific to schools, the same cautionary principles apply to any facility with significant periods of underuse.

"Circumstances surrounding the pandemic have led to a realization that what people thought they knew about water safety isn't necessarily true," Whelton said. "The assumption that water is safe at every tap is not based on science or evidence. We want to establish protocols for plumbing safety so when a building manager is asked, not only, 'Is the water safe to drink?' but 'What did you test it for? How did you test it?' They will be able to provide evidence-supported results based on established scientific testing procedures."

"CIRCUMSTANCES SURROUNDING THE PANDEMIC HAVE LED TO A REALIZATION THAT WHAT PEOPLE THOUGHT THEY KNEW ABOUT WATER SAFETY ISN'T NECESSARILY TRUE."

Andrew Whelton
Associate professor of civil engineering and environmental and ecological engineering faculty scholar

HOW HAVE PEOPLE RESPONDED TO STAY AT HOME ORDERS?

02

03 COULD UV RADIATION MAKE PUBLIC SPACES SAFE?

At the start of 2020, there were no data to describe how SARS-CoV-2, the virus that causes COVID-19, responds to UV radiation. Some preliminary research released in the months since indicates UV is likely to be effective for inactivating the virus. The consumer market has already responded with various devices that claim to eradicate the novel coronavirus from surfaces. The problem is, not only can UV radiation be damaging to human skin and eyes, there's also not enough scientific evidence to support its effectiveness against SARS-CoV-2 yet.

"There's a wide range of people from garage scientists to large corporations that believe UV is likely to be effective, but it hasn't been credibly proven yet," said Ernest "Chip" Blatchley, the Lee A. Rieth Professor in Environmental Engineering. "Should this hypothesis be validated, the possibility for UV technology to dramatically improve our ability to slow the spread of a pandemic or an epidemic has far-reaching implications."

Blatchley has proposed a set of experiments to quantify the effectiveness of UV radiation to inactivate SARS-Cov-2 and related viruses. In order to validate the performance of UV-based systems for control of SARS-CoV-2, it is likely that surrogate, nonpathogenic viruses will need to be released in settings where UV disinfection is planned.

While UV radiation has been used in disinfection practices for more than 100 years, it is dangerous to perform UV disinfection processes when human exposure is possible. But there is emerging research to suggest that far-UVC — a narrow range of wavelengths — may be safe for humans and lethal for viruses; however, the safety of far-UVC has not been conclusively demonstrated. Effective and efficient decontamination of high-use spaces such as classrooms, dining courts and athletic venues would greatly impact a university's ability to more safely operate with students in residence. More broadly, office buildings, public transportation, even aircraft carriers would benefit from such technologies.

"There's an urgent need to get the credible data we need to describe the kinetic behavior of SARS-Cov-2," Blatchley said. "There's an equally urgent need to develop UV applications that can be used for decontamination. We need to better position ourselves to respond to the next epidemic or pandemic."

Stay-home orders issued earlier in the year resulted in many Americans drastically reducing their time away from home. A study led by Jie Shan, professor of civil engineering, analyzed six months' worth of mobility data acquired through the Indiana Department of Transportation (INDOT) to examine traffic patterns and how they were affected by stay-home orders. While INDOT sensors recorded significant drops in vehicular traffic in March, there was almost no change for trucks.

"This tells us two things," Shan said. "First, Indiana citizens largely observed stay-home orders. Second, transportation of consumer goods was relatively unaffected. Supply chains didn't change much, which means the consumer market was still active and people still had access to goods."

Shan's team has been analyzing location-based big data to study mobility patterns to gain a better understanding of people's lifestyle and the urban setting for some time. With the methodology established, they were able to apply the same technology to understand people's mobility related to the pandemic.

But traffic patterns only tell part of the story. Shan's team also analyzed foot traffic data in Chicago, collected via the private sector, to understand how people's mobility changed during and after stay-home orders. By establishing the rate at which people resume trips to the grocery store, restaurants and other businesses, the researchers begin to establish predictive models that can help governmental authorities and policy makers understand what the economic impact has been and what's likely to happen when states reopen. These predictive models have far-reaching potential impact for navigating future outbreaks.

"We're collaborating with domain experts to illustrate how these mobility patterns relate to the number of cases, number of deaths and how that relates to available medical care resources," Shan said. "We want to try to make that link."

WHAT ROLE DOES ECONOMIC INEQUALITY PLAY IN A PANDEMIC?

04

Knowing that COVID-19 is spread by coming in contact with others, understanding where people are located and how they are moving about enables researchers to more accurately predict the spread of the disease. Analyzing the real-time location and mobility data of anonymized cell phone users in Japan and the United States, Satish Ukkusuri, professor of civil engineering, discovered trends in the relationship between mobility restrictions and the spread of COVID-19 and how different income groups were affected during the pandemic.

"Higher income people are able to reduce their social contacts at a much higher rate." Ukkusuri said. "Possibly because of the types of jobs they hold, flexibility of their workplaces and their ability to work from home."

Using the mobility data, Ukkusuri and his team build social contact networks and a social contact index that can be compared over time to determine how those contact networks have evolved. Although the researchers initially focused on Tokyo — the most populous metropolitan area in the world — the predictive models they created based on network science and machine learning can be applied to analyze data from any city to determine how well the population abides by precautions to reduce disease spread.

"One significant factor regarding Tokyo is that because of the cultural norms there, people already use face masks and practice social distancing," Ukkusuri said. "There was not a strict lockdown, but people instinctively restricted their mobility to limit contact with others. Contact with others was reduced by 60 to 70% without any emergency declaration from the city."

The drastic reduction in mobility levels among Tokyo's populace showed a correlation with a decrease of COVID-19 cases. But the data also showed dramatic differences in the ability for people of different income groups and from different locations to restrict mobility thereby reducing contacts. Lower income people may be more likely to hold essential jobs or provide services that cannot be carried out at home, such as retail, restaurant and grocery workers. Similar insights were obtained from the U.S. data.

"We were not expecting significant differences in terms of income inequalities," Ukkusuri said. "We need to understand what inequalities exist during a pandemic and how they relate to disease spread. Establishing those interdependencies and understanding the inequalities and their impact on people is the first step to understanding how to minimize those inequalities during a crisis and enable faster recovery."

ALUMNA SPOTLIGHT

AN INCREDIBLE JOURNEY

MEGAN ELBERTS CREDITS FIRM'S SUCCESS TO MEASURED PROGRESS

From following a family tradition, to forging her own path in the world of civil engineering, Megan Elberts has continually made great strides in her career — and she's poised to make her next giant leap.

In 2017, after nearly a decade working as a water resource engineer, Elberts (BSCE '06, MSCE '08) and her business partner, Lisa Gasperec, created Gasperec Elberts Consulting — a civil engineering, construction management and land surveying firm based near Chicago.

"It's an incredibly exciting time for us right now," Elberts said. "We have been slowly establishing ourselves and making measured progress over the past three years. We've managed to successfully move forward with our plans to run the business we want — and we're looking to grow even more in the future."

Elberts has her eyes set on building up her business to become a full-service consulting engineering and surveying firm. Another point of pride in her business, Elberts said, is that it is both a certified Disadvantaged Business Enterprise (DBE) and a Women-Owned Business Enterprise (WBE).

"As a growing firm, every day brings new challenges, and as engineers we strive to learn from them in order to continue our success." Elberts said. "We are very proud of our growth in our first three years, and look forward to building on our successes."

While much of Elberts' focus is on the future, she is certainly more than happy to reflect on her past. Growing up in a Boilermaker home as the daughter of Chris Burke (BSCE '77, MSCE '79, PhD '83, HDR '10), Elberts can recall attending many Homecoming breakfasts and Purdue Football games. Her mother, aunts, uncles and cousins also all attended Purdue.

"I try to come back as much as I can and catch the games and the omelets," She said. "It's always been a very fun tradition — for both my family and the school."

The family tradition continued as she enrolled at Purdue and pursued her degree in civil engineering. At Purdue, Elberts said she maintained a strong interest in civil engineering, but what really made the decision "click" for her, she said, was her urban hydraulics class.

"That class was definitely a big turning point for me," she said. "I started to really understand what I wanted to do and that I wanted to earn my master's degree."

Following graduation, Elberts worked as a water resources engineer for the Chicago Metropolitan Agency for Planning before moving on to work for Christopher B. Burke Engineering. Then, about three-and-a-half years ago, she partnered up with Gasperec to start their own company together.

"It's been such an incredible journey up to this point," Elberts said. "I've been fortunate to have great teachers and mentors along the way — and I hope to be one as I continue to move forward."

DID YOU KNOW?

CHECK US OUT ON YouTube

Did you know the Lyles School of Civil Engineering produces around 30 new videos every year? From guest lectures to student features, our YouTube page has a wide variety of civil engineering-related content.

Recently, we published a video series covering our nine specialty areas in civil engineering and what our incoming graduate students can expect when joining our program.

Many of these videos are also featured on our social media platforms — along with weekly updates on the school. If you want to keep up with the latest goings on with the Lyles School of Civil Engineering, this is the best way to do so!

You can connect with us on social media through our Facebook, Twitter, Instagram and LinkedIn pages. These platforms are also a great way to directly contact us if you have a story or photo to share.

Thanks, and we look forward to sharing more content with you!