CIVIL

ENGINEERING IMPACT

PURDUE UNIVERSITY | FALL 2018

ADVANCING THE WORLD WITH CIVIL ENGINEERING RESEARCH

Civil engineering is widely regarded as a foundation of human society. While I certainly believe this to be true, I do not think it accurately portrays our study and practice.

Just as it has influenced our past and present, civil engineering has guided humanity into the future. And here at the Lyles School of Civil Engineering, our students, faculty and staff are continually researching to find the next innovation, the next discovery that will drive our society, and our discipline, into the next century.

This attitude toward innovation is shared throughout Purdue University, so it is natural that we should make "Giant Leaps" the theme of our institution's 150th birthday. Established on May 6, 1869, Purdue has dedicated itself to the pursuit of knowledge and to preparing the next generation of professionals and leaders.

Of those 150 years, Purdue's School of Civil Engineering has been integral to the University for 132 of them. Over the past 13 decades, our school has shared in Purdue's proud tradition of consistently making giant leaps, both scholastically and societally.

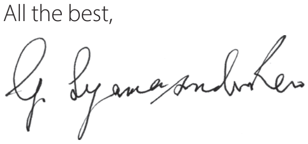
Purdue's first black engineering and female engineering graduates came from the School of Civil Engineering, and our alumni, staff, and faculty have made giant leaps around the globe with their involvement in key international landmarks such as the Panama Canal, the Leaning Tower of Pisa, the Hoover Dam, and the Golden Gate Bridge.

Today, our incredible students, faculty, staff and alumni continue to make strides in a huge variety of ways. From helping underdeveloped villages gain access to clean drinking water to researching how to colonize nearby planets, our studies and efforts ensure a brighter and better future for all of humanity.

In this edition of CE Impact magazine, you will learn about some of our latest leaps in research — and how our graduate students are a vital component to our faculty's and staff's findings. Stories this season include research into creating roads that charge electric vehicles while they are driven, gaining a greater understanding and responsiveness to natural disasters, harnessing energy from vibrations, and employing a robotic baby to measure microbes kicked up while crawling along carpets.

These stories represent merely a handful of the projects underway here at the Lyles School. I encourage you to contact me next time you are on campus to learn (and see for yourself) all that we are striving to achieve. ■

All the best,



RAO S. GOVINDARAJU
Bowen Engineering Head of Civil Engineering and The Christopher B. and Susan S. Burke Professor of Civil Engineering

TABLE OF CONTENTS

On the cover:
Over the entire spectrum, faculty and student researchers at the Lyles School of Civil Engineering continue to make giant leaps toward improving our natural and built environment.

LYLES SCHOOL OF CIVIL ENGINEERING

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NEWS AND EVENTS

BRUMUND HONORED WITH PRESTIGIOUS OPAL AWARD

In March 2018, Purdue Civil Engineering alum William F. Brumund (BSCE '64, MSCE '65, PhD '69) was honored with the Outstanding Projects and Leaders (OPAL) Award from the American Society of Civil Engineers.

The award recognizes a person's extraordinary contributions to the civil engineering industry throughout their career.

Brumund won in the management category, for senior managers whose primary responsibility is to oversee and direct operations of an engineering organization. Brumund's specialty is geotechnical engineering. After earning his PhD at Purdue, he went on to teach civil engineering at the Georgia Institute of Technology for five years before joining Golder Associates.

Brumund opened the Atlanta office for the firm and practiced geotechnical engineering while managing and directing various civil engineering projects. In 1985, he became president and global CEO. He served on the parent company's board of directors for 33 years until he officially retired in 2008.


William F. Brumund

As president and CEO, Brumund helped transform the specialty North American geotechnical consultancy into a global, multidisciplinary market leader and grew the company by 2,000 employees. He also oversaw the expansion of the firm's operations in the United Kingdom, started a company in Germany, acquired a firm in Sweden, acquired a firm in Italy, started a firm in Hungary, acquired all the stock in a partially owned affiliated company in Australia, and expanded Golder Associates' operations in Hong Kong.

In 1993, Brumund was honored by Purdue University with the Distinguished Engineering Alumnus Award. In 2000, he was recognized as the Chapter Honor Member of the Purdue Chapter of Chi Epsilon. He was also the recipient of the 2006 Heroes Award from the ASCE Geo-Institute. ■

CRUISE WITH THE LYLES SCHOOL

The Purdue University President's Council plans a Panama Canal and Costa Rica adventure for Jan. 18-26, 2019. This seven-night cruise will explore both natural and man-made wonders aboard a sailing yacht, the Wind Star.

Guest lecturer Antonio Bobet, Professor of Civil Engineering and member of the Panama Canal Geotechnical Advisory Board, will share his unique canal insight and expertise. Professor Bobet also is a founding member of Purdue's Resilient Extra-Terrestrial Habitats program, which is researching ways to establish human civilization on the moon and Mars.

To learn more or book a cabin, visit **purdue.edu/pc**. We hope you will consider joining your fellow Boilermakers on this bucket-list travel opportunity. ■

SPRING 2018 COMMENCEMENT

Congratulations to our graduating students, our newest alumni, who earned their degrees in the spring!

About 140 graduate and undergraduate students earned civil engineering degrees in May 2018. We were honored to have so many of them, along with their families and friends, join us at Delon and Elizabeth Hampton Hall to share in the celebration.

We at the Lyles School of Civil Engineering wish all of our graduates the very best in their professional and personal pursuits.

Purdue civil engineers are leading efforts all around the world, and our new crop of graduates are sure to join them. We eagerly look forward to hearing their stories of success in the years to come. ■


Nearly 40 Purdue Civil Engineering graduate and 100 undergraduate students earned their degrees in May.

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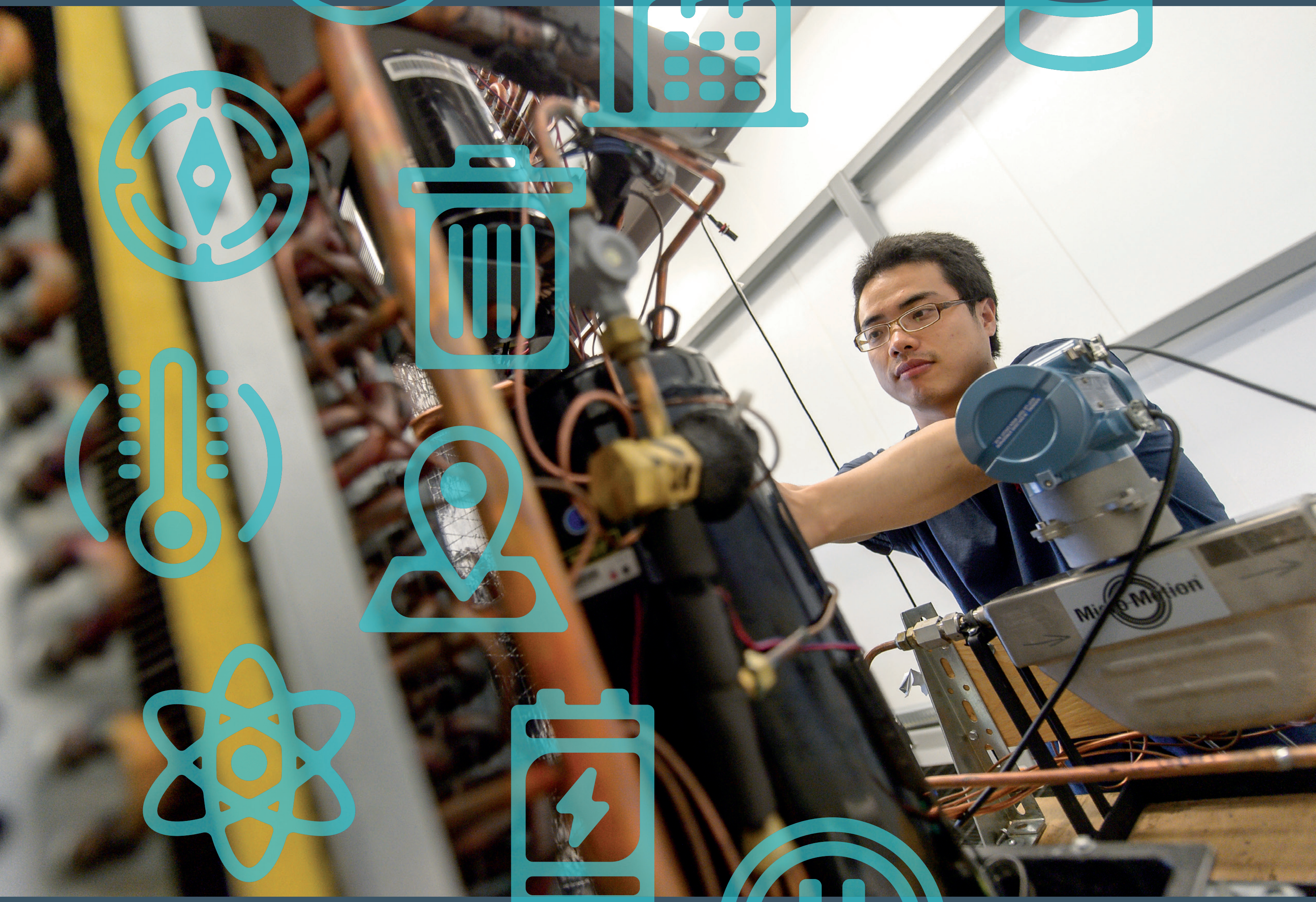


Civil Engineering students like Bin Yang (PhD 2017) perform research in the Herrick Laboratories.

SUSTAINABLE, HUMAN-CENTERED BUILDINGS

Lyles School leads multidisciplinary research to automate building environments

Somebody has turned up the conference room thermostat, again. And a co-worker wears a blanket at her desk.

Sound familiar?

It is more than annoying. In a recent survey of more than 1,000 office workers, 46 percent reported that their office was too hot or too cold. In fact, building occupants affect up to 30 percent of its energy usage. The building sector in the U.S. accounts for about 40 percent of primary energy usage, 71 percent of electricity usage and 38 percent of carbon dioxide emissions.

Panagiota Karava, Associate Professor of Civil Engineering

Panagiota Karava, Associate Professor of Civil Engineering, wants to help change that. With a $1.2 million National Science Foundation grant and private industry support, she and an interdisciplinary team at Purdue are developing practical solutions for reducing the energy consumption and environmental impact of buildings. And, most importantly, making people more comfortable at work.

Karava emphasizes the importance of having diverse researchers on the team. "We have civil engineers, experts on smart buildings and indoor environmental comfort, led by me and Thanos Tzempelikos, from Civil Engineering." Ilias Bilionis, Assistant Professor of Mechanical Engineering, is a mathematician working on predictive algorithms; Charlie Hu from Electrical and Computer Engineering studies control theory. Also on the team is Robert Procter, a psychologist from Psychological Sciences.

BUILDINGS THAT LEARN

The project goal is to develop an automatic system that connects the environmental control subsystems in a building with data from sensors and controllers and from human beings — and then automates the operation of the building.

In laboratory and field studies, the team has been using human test subjects to map indoor-environment conditions as well as thermal and visual perception and comfort.

"What we mean by thermal and visual perception is this: How do people perceive the thermal environment — is it warm or cold or neutral — and how comfortable are they with their sensation?" Karava says. Similarly, subjects report on their perception of the room's visual conditions — bright or dim or neutral — and how they like it.

With this and other data, the researchers do probabilistic classification of human perceptions and satisfaction and create algorithms for building systems to "learn" individual and group preferences. Results of the studies are being integrated into a cyber-enabled solution for self-tuning devices such as thermostats and actuators for lighting and shading. The team will quantify the resulting reduction in energy usage and the improvement in human satisfaction, which will help enable automated, personalized control systems.

"We get data from sensors, we account for the way different devices are controlled and their state of control, and then we get feedback from the occupant. From there you develop a probabilistic model that can predict what conditions different occupants prefer," Karava says.

A BUILDING FOR STUDYING BUILDINGS

Naturally, the building industry is highly interested in the work, which is taking place in Purdue's Center for High Performance Buildings, based in Herrick Laboratories.

"It is a building to do research on buildings," Karava says. The center has multiple industry partners that are helping to fund this research, including corporate giants such as Honeywell International Inc. and JLL Inc.

The project is unique in that it is funded by the federal government as well as private industry, which speaks to the eagerness of the public and private sector to rein in energy waste and improve occupant satisfaction.

"It is really beneficial to have research that is funded by NSF and industry for three consecutive years," Karava says.

The project is in its fourth year, and Karava is excited to be able to share the results of the team's efforts: "We have conducted really transformative research by collecting data from humans and their preferences, analyzing the data, and then developing technological solutions toward optimal control of the indoor environment. This year we're planning to work with an industry partner to demonstrate our concept outside the Purdue campus."

From left, Civil Engineering PhD students Joe Xiong and Seungjae Lee measure luminance levels at Herrick Laboratories. The data collected is then utilized to develop new algorithms for self-tuned indoor environments.

RESILIENT URBAN COMMUNITIES

By examining infrastructure failures, Purdue-led research aims to enhance urban community resilience

Suresh Rao studies failure. Specifically, he examines failures of the infrastructure networks that provide critical services to cities. By examining breakdowns and recoveries in urban infrastructure, he and his team are learning how to design and operate cities better — and help urban communities become more resilient.

Rao, Professor of Civil Engineering and the Lee A. Reith Distinguished Professor of Environmental Engineering, views cities as complex systems, a conglomeration of engineered networks (utilities, power grids, roads), the institutions that manage them, and the communities that expect their demands to be met reliably and affordably. These three elements — engineered networks, socio-economic institutions that manage them, and communities that receive the services — must work together to maintain the essential balance between security, resilience, and sustainability.

VITAL GRADUATE STUDENT RESEARCH

Over the past five years, Rao and his team of graduate students have developed strong international collaborations with colleagues in Asia, Europe and Australia as part of a National Science Foundation project. The PhD students work with a larger group to gather data from multiple global cities. They then analyze these data with three goals in mind: They create models for understanding the interdependence of urban networks, simulate their failure-recovery, and develop science-based guidance for better engineering design and operations.

Cities experience disruptions from inevitable and commonplace shocks, such as pipe bursts, road collapses and water supply contamination. They also suffer large-scale disasters, such as earthquakes, fires, tornadoes and floods. Modern cities in advanced countries recover quickly. This is not the case in developing countries, where the cumulative impacts of such common and infrequent shocks have serious repercussions, such as low service and no service to large portions of urban communities.

ADAPTIVE INFRASTRUCTURE

"The key word is adaptiveness," Rao says. Resilience of complex systems is a recursive process, and the adaptive cycle comprises four essential steps —sensing, with the aid of big data; learning, based on analysis of that data; anticipating, based on data modeling; and then adapting, which entails managing or transforming the urban system structures. Communities that work toward these steps can move from merely reacting to large events to anticipating them and recovering from natural hazards with minimal disruptions.

Rao says, "We need to have a paradigm shift in engineering design and engineering practice."

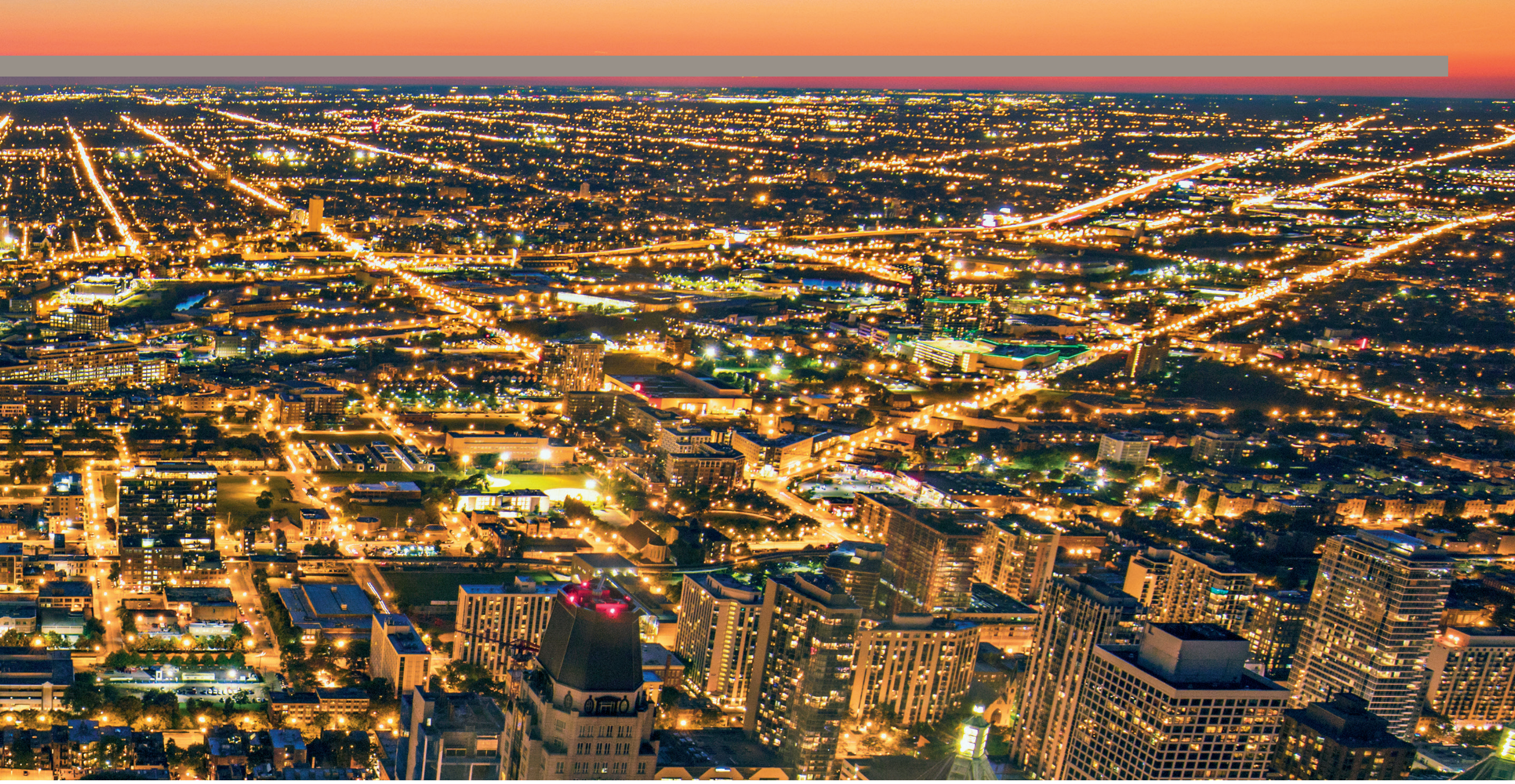
SURPRISING SIMILARITIES

"We are working with international colleagues, studying 50-70 cities around the world, with populations from a few thousand to a few million," Rao says. The team has gathered data on water and road

RAO LAB INVESTIGATIONS

At a recent conference on the interdependence of complex networks, graduate students on Professor Rao's team discussed their research.

"**Fractal Wetlandscapes**," Leonardo Bertassello
"**Humans and Point-Sources along River Networks**," Soohyun Yang
"**Fractal Urban Heat Islands and Health Impacts**," Anamika Sreevastava
"**Functional Topology of Infrastructure Networks**," Chris Klinkhamer
"**Urban Water (In) Security and Resilience**," Elisabeth Krueger
"**Tropical Storms: Regime Shifts**," Sai Balachandran



networks and on how the structure and functions of these engineered networks compare with natural networks like river networks, ecological networks and social networks. This data set incorporates 125 urban infrastructure networks in over 50 cities.

Rao and his team are focusing on road, water and drainage networks. They have seen, for example, that the larger the network, the more it resembles a natural network.

"My graduate students' work shows that in cities, everywhere in the world, the urban infrastructure functionally is the same — in spite of our engineering. The way it carries traffic, for example," Rao says. "It is an extraordinary thing to think about. Because they've all been designed by engineers over these hundreds of years. And why? Because we humans are part of nature."

Rao's team is analyzing these data in conjunction with international colleagues to learn and adopt global resilience principles. "We use complex network science to find the major differences and commonalities between these networks," he says.

"On the surface, cities look different, but the topology, their network structure, is the same. They evolve in surprisingly similar ways and function the same way." For example, all over the world, pipes and cables are laid near roads. Failure in one network can propagate to the co-located networks. Pipe bursts erode soil beneath roads and lead to potholes and even road collapse. Similarly, when roads are washed out during floods, pipes and cables are affected.

HOW URBAN COMMUNITIES COPE WITH FAILURES

Rao says it's also important to collaborate with social scientists when analyzing network failures and service losses. "How do people cope with network breakdowns?" he asks. "And how are people in New Orleans different from people in Houston — or Berlin or Amman or Cape Town? We want to know how different urban communities cope with inadequate services, especially in poorer or marginalized neighborhoods. And what coping and adapting strategies do urban communities deploy when there is a lack of services, both on a daily basis, and during failures from shocks?

"Cities are not only about roads and pipes and buildings; they're about people," he says. "Our work focuses on the resilience of urban communities, and in the long run developing sustainable uses of natural resources."

Rao says that improving urban resilience requires us to re-examine engineering design and operations and to develop better resource and infrastructure management strategies. "Isn't this our professional role in society: to use science and engineering to serve the public?"

At collaborative workshops, Professor Suresh Rao and his student team meet with researchers from around the world to forge solutions for resilient cities. Last spring, the team attended the Synthesis Workshop held at the University of Florida. (front row from left): Elisabeth Krueger (Purdue); Prof. Olaf Buettner (Germany), Soohyun Yang (Purdue); Prof. James Jawitz (Florida); Prof. Suresh Rao; Prof. DK Kim (South Korea); Katie McCurley (Florida); Amanda Desormeaux (Florida). (back row, from left): Prof. Dietrich Borchardt (Germany); Prof. Mike Annable (Florida); Prof. Gavan McGrath (Australia/Ireland); Sam Arden (Florida); Prof. Haki Klammler (Florida/Brazil); Nathan Reaver (Florida); Brady Evans (Florida); Anamika Shreevastava (Purdue); Chris Klinkhamer (Purdue).

Purdue Civil Engineering study influences INDIANA INFRASTRUCTURE FUNDING

Research finds that current funding cannot sustain the state's roads

A study completed in 2017 by the Lyles School of Civil Engineering was used by the Indiana General Assembly to realign the highway taxation structure that addressed the growing transportation-funding needs.

The study concluded that the existing (at that time) fuel tax was inadequate to ensure that the state's roadways were maintained properly. According to the report, federal and most state fuel tax rates have not changed for many years. That and the increased fuel efficiency of modern cars has created a serious funding gap that is rapidly growing.

The report authors are Kumares Sinha, the Edgar B. and Hedwig M. Olson Distinguished Professor of Civil Engineering; Samuel Labi, Professor of Civil Engineering; and Bismark Agbelie, post-doctoral researcher in civil engineering. Also providing support was the Joint Transportation Research Program.

"The fuel tax as it was, was not very equitable in terms of maintaining Indiana's roads and bridges," Sinha says. "It needed to be updated to keep up with modern vehicles and mass transportation."

Labi explained that the research was conducted by collecting data from state and federal agencies, such as the Bureau of Motor Vehicles and the Indiana Department of Transportation.

The research team cited three chief reasons that sole reliance on fuel tax revenue (in its pre-2017 form) fell short of maintaining and sustaining America's infrastructure:

- The revenue from tax depends on the amount of fuel consumed. Because the federal formula rewards highway agencies for higher miles of travel in their state, this mechanism does not promote travel reduction or fuel conservation.
- The increasing use of hybrid and electric vehicles makes the concept of fuel tax inconsistent with revenue-generation objectives.
- And although trucks consume more fuel per unit — thus, pay more in fuel taxes — their use results in more wear on roads compared to smaller vehicles. As a result, truck operators contribute relatively less in tax revenue per unit of damage they cause.

After the study was published, House Enrolled Act 1002 was signed in the spring of 2017, receiving a bipartisan vote from the state legislature. To address the issues outlined in the report, the new law aims to generate up to $1.2 billion for state and local roads and bridges, beginning in 2024.

Samuel Labi, Professor of Civil Engineering

Kumares Sinha, the Edgar B. and Hedwig M. Olson Distinguished Professor of Civil Engineering

Funding will come from a 10-cent-per-gallon increase on gasoline user fees, an annual $15 fee on all vehicles, an annual $50 fee on hybrid vehicles, and an annual $150 fee on electric vehicles. There also will be special fuel and motor carrier surcharge taxes indexed each year for seven years — capped at one cent per year.

Labi said he believes these updates will greatly benefit Indiana's aging infrastructure.

"The previous fuel tax simply was not sustainable," he says. "The overall condition of Indiana's infrastructure is continually deteriorating, and the funding needs to address this matter are increasing. This decision by the state will help bridge the gap to address Indiana's infrastructure needs." ■

ROADS THAT CHARGE ELECTRIC CARS

INDUCTIVE CHARGING IN THE ROADWAY COULD MAKE ELECTRIC VEHICLES MORE PRACTICAL

Electric cars that charge while driving? Purdue civil engineers want to make that leap.

Konstantina "Nadia" Gkritza, Associate Professor in the Lyles School of Civil Engineering, studies the practicality of a roadway where electric-powered vehicles are recharged as they drive along it.

Gkritza is leading a feasibility study on how to best "electrify" a roadway in Los Angeles County. The team includes researchers from Utah State University, Colorado State University and the engineering firm AECOM. The $500,000 project was awarded through the U. S. Department of Energy's Innovative Development in Energy-Related Applied Science (IDEAS) program.

Gkritza, along with Civil Engineering PhD students Christos Gkartzonikas and Theodora Konstantinou, studies inductive charging, which would entail installing charging pads into the pavement. The team is considering four Los Angeles-area corridors for potential field testing: I-710, I-210, Vermont Avenue and the Metro Orange Line.

Currently, there is nothing in the U.S. that resembles what Gkritza and her team are proposing. The closest thing to it is conductive charging, which relies on power lines above the road, used by vehicles such as San Francisco trolleys.

Gkritza says deployment of inductive charging into roads could yield significant benefits — both to the environment, with emissions reduction, and to the consumer, with greater product confidence.

"A common barrier for a lot of drivers — even those who own electric cars — is a concern that they'll run out of power and find themselves stranded in the middle of nowhere," she says. "Roads like we are proposing would encourage more people to take long drives in electric vehicles and consider them as reliable as standard vehicles."

There are still areas that require further study before physical testing can take place.

Lyles School of Civil Engineering PhD students Christos Gkartzonikas and Theodora Konstantinou work on estimating the environmental impact of inductive charging using California's Emissions Factor Model.

"Our main work focuses on identifying who will adopt this technology first and on assessing the willingness to pay for different scenarios of technology implementation," Gkartzonikas says. "And based on the market acceptance rates, we will quantify the environmental impact of inductive charging."

For now, Gkritza says her team's focus is on assessing market adoption and environmental impacts before creating a plan to bring their research out of the lab.

"This project is exciting, but there is a lot of work to do. There are only a few other countries that have done anything like this," she says. "We are all looking forward to making the next step."

If effective, Gkritza says the work may well be a giant leap for our mobile society.

Konstantina "Nadia" Gkritza, Associate Professor of Civil Engineering

ABOUT THE IDEAS PROGRAM

The IDEAS program provides a continuing opportunity for the rapid support of early-stage applied research to explore pioneering new concepts with the potential for transformational and disruptive changes in energy technology. IDEAS awards, which are restricted to maximums of one year in duration and $500,000 in funding, are intended to be flexible and may take the form of analyses or exploratory research that provides the agency with information useful for the subsequent development of focused technology programs.

IDEAS awards may also support proof-of-concept research to develop a unique technology concept, either in an area not currently supported by the agency or as a potential enhancement to an ongoing focused technology program. This program identifies potentially disruptive concepts in energy-related technologies that challenge the status quo and represent a leap beyond today's technology. That said, an innovative concept alone is not enough. IDEAS projects must also represent a fundamentally new paradigm in energy technology and have the potential to significantly affect the Department of Energy's Advanced Research Projects Agency-Energy mission areas.

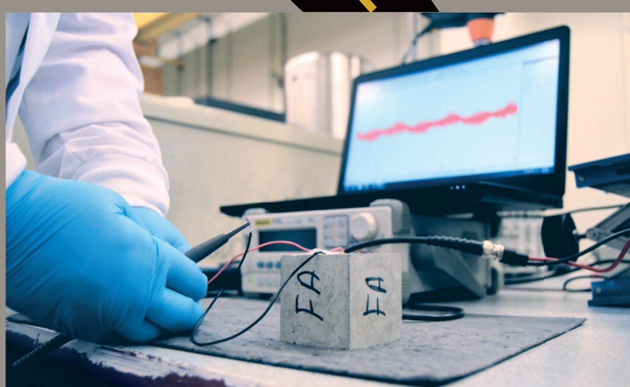
A NOVEL, NONDESTRUCTIVE TEST FOR ROAD READINESS

"Basically, we can estimate the strength of concrete by attaching sensors and using vibrations to measure," Lu says. "We hope to move our study out of the lab and test in the field next year."

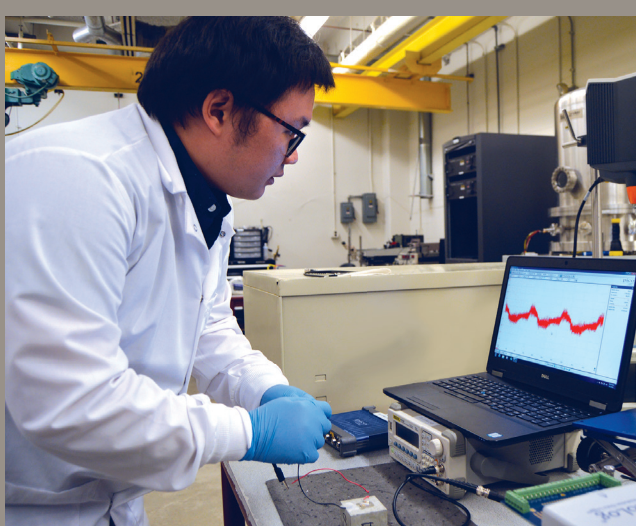
PIEZOELECTRIC RESEARCH MAY BE A GIANT LEAP IN THE FIELD OF MATERIALS TESTING

Sometimes big innovations are made through small steps. Civil engineering researchers at Purdue are developing a way to test the quality of newly laid concrete — through vibrations.

Currently, quality testing for laid concrete consists of retrieving a sample from the site, taking it back to a laboratory, and then testing its compression strength. Associate Professor Na "Luna" Lu of the Lyles School believes she and her graduate students have developed a better, faster method.



Associate Professor Na "Luna" Lu's team uses piezoelectric sensors coupled with electromechanical impedance to determine early-age properties of concrete.



Civil Engineering PhD student Yen-Fang Su uses vibrations to test the strength of a concrete sample. The team plans to take its research into the field within a year.

"The high-frequency detection and fast response of this method will provide an accurate and reliable data set of properties of concrete," Lu says. "This data will enable us to determine the optimal traffic opening time."

Luna Lu, Associate Professor of Civil Engineering

Lu's team is developing an in situ testing method. It employs piezoelectric sensors coupled with electromechanical impedance to determine early-age properties of concrete such as hydration and compressive strength. This novel technique addresses the deficiency of current testing methods for determining traffic opening. Current methods are unreliable, inefficient and expensive — often causing premature pavement failure, construction delays and cost overruns.

"Basically, we can estimate the strength of concrete by attaching sensors and using vibrations to measure," Lu says. "We hope to move our study out of the lab and test in the field next year."

Advantages of the new method include a reduction in premature failure of concrete pavement and a reduced need for patching and repairing other concrete structures. The technique could lead to significant construction cost and schedule savings because it reduces testing time and the number of testing samples. Further, it can eliminate construction worker safety issues on the jobsite and accident rates in opening zones.

Civil Engineering PhD student Yen-Fang Su says the team is onto something that could reshape the future of materials testing.

"We're finally taking technology and applying it to old testing methods," he says. "Not only could this make testing a lot faster, it's safer, and less disruptive and destructive to traffic and roads."

Once the lab testing phase is complete, the team intends to propose field testing with the Indiana Department of Transportation. Specifically, Lu's team would like to test Interstate 65 in Tippecanoe County. ■

ROBOTIC BABY KICKS UP DUST — FOR SCIENCE

When those adorable infants crawl across the carpet, they kick up a cloud of unsavory substances. Down there on their hands and knees, the babies are releasing — and inhaling — dirt, skin cells, bacteria, pollen and fungal spores.

But just how much unpleasant stuff is released into the air? And how much does the baby breathe in? Brandon Boor, Assistant Professor of Civil Engineering, decided to find out. Boor and his research team built a robotic baby that both kicks up particles and monitors how much it inhales.

"We used state-of-the-art aerosol instrumentation to track the biological particles floating in the air around the infant in real time, second by second," Boor says. "The instrument uses lasers to cause biological material to fluoresce. Most bacterial cells, fungal spores and pollen particles are fluorescent, so they can be reliably distinguished from nonbiological material in the air. We also worked with a microbiology group at Finland's National Institute for Health and Welfare, which conducted DNA-based analysis of the microbes we collected onto filters."

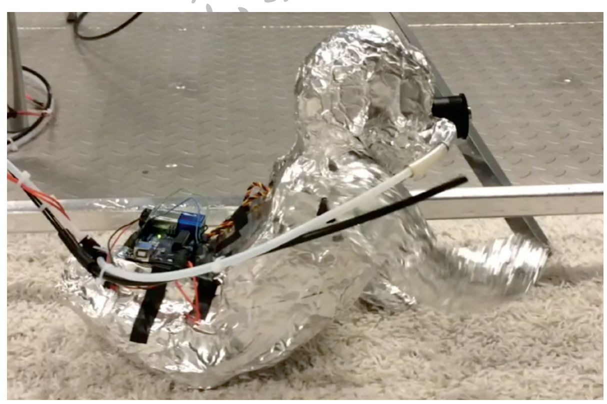
A CLOUD OF CRUD

The researchers found that a concentrated cloud of resuspended particles forms and that the concentrations around the baby can be as much as 20 times greater than the levels of material in the bulk air of the room. Moreover, infants' bodies are not good at blocking this dust storm, Boor says.

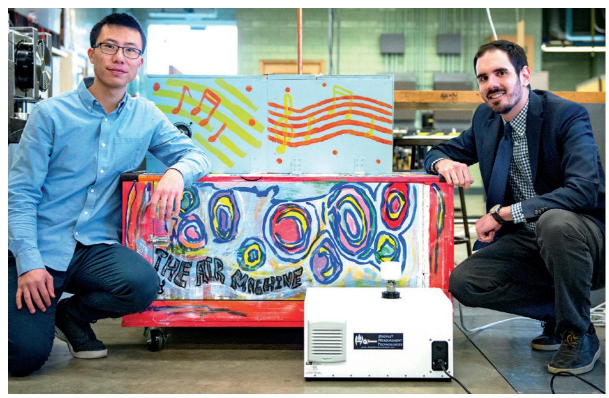
"For an adult, a significant portion of the biological particles are removed in the upper respiratory system, in the nostrils and throat," he says. "But very young children often breathe through their mouths, and a significant fraction is deposited in the lower airways — the tracheobronchial and pulmonary regions. The particles make it to the deepest regions of their lungs."

As alarming as this might all sound, Boor was quick to add that this is not necessarily a bad thing.

"Many studies have shown that inhalation exposure to microbes and allergen-carrying particles during infancy plays a significant role in both the development of, and protection from, asthma and allergic diseases," he says. "Studies have shown that being exposed to a high diversity and concentration of biological materials may reduce the prevalence of asthma and allergies later in life."



A robot baby was used to determine how much biological material crawling infants stir up from carpets. Researchers found that crawling children receive inhalation doses four times that of an adult walking across the same floor.



In the next phase of testing, Assistant Professor Brandon Boor (right) and PhD student Tianren Wu will use "The Air Machine" in a child care facility to study the amount of particles kicked up in a live, child-heavy environment.

THE NEXT (BABY) STEP

Through a new grant from the National Science Foundation, Boor will explore the factors that influence the adhesion and resuspension of biological particles in early-childhood indoor microenvironments. Boor is collaborating with the Infant Action Lab in the NYU Psychology Department to investigate how infant locomotion dynamics affect resuspension and exposure. Following this work, the team will study an active child care facility.

To do this, the researchers will use a bioaerosol sensor, a standalone device located in various rooms in a day care center. Dubbed "The Air Machine," the sensor will track the fluorescence properties of bacteria, fungi and pollen, so researchers can see how many bacteria are stirred up as a real child scoots or toddles by.

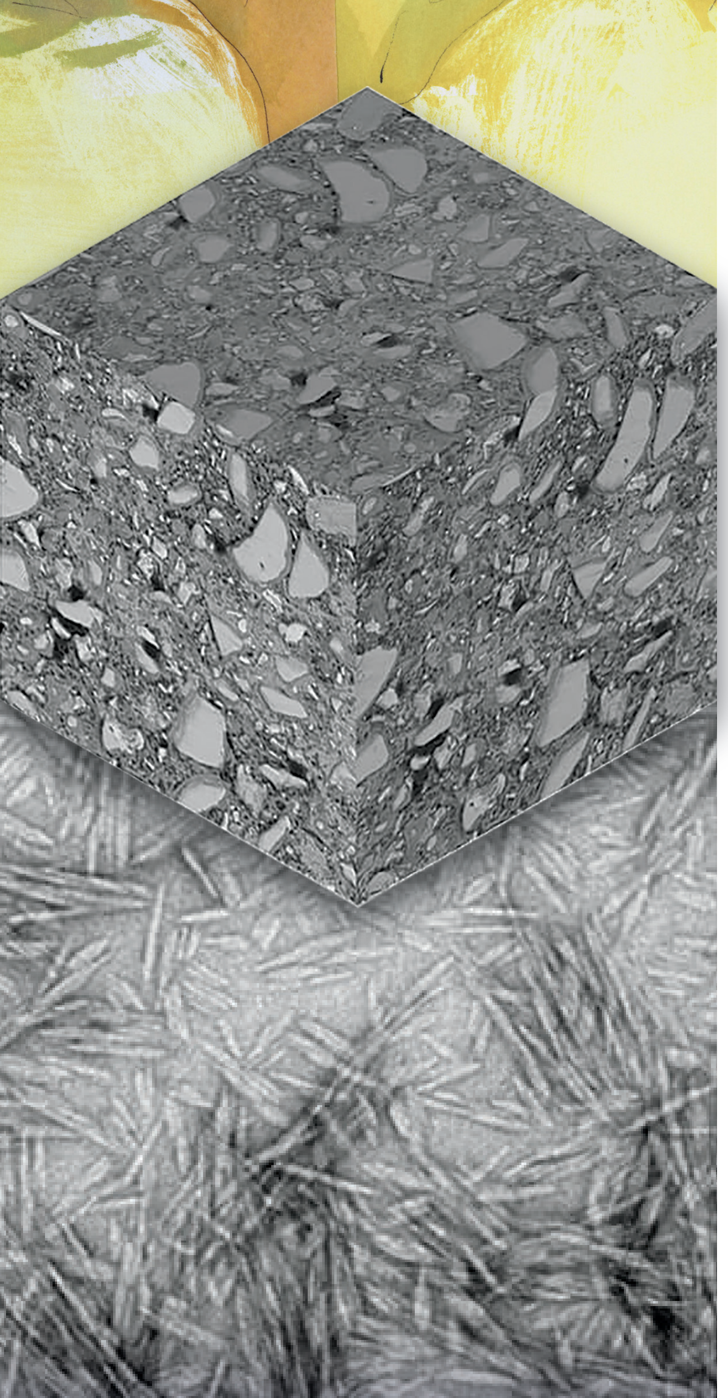
As with the previous phase, PhD student Tianren Wu, who builds the experimental devices, will dedicate much of his time to collecting data.

"This will be a fascinating part of the study — as with many other studies — because we are finally moving from a controlled setting to the real world," Wu says. "In this next phase, we will gain great insight into exactly how many particles are kicked into the air through crawling and walking."

The "live" phase of the air particle study is slated to begin in the fall of 2019. ■

WOOD NANOCRYSTALS STRENGTHEN CONCRETE, SUSTAINABLY

PURDUE CIVIL ENGINEERING RESEARCHERS ARE HOPING FOR A GIANTLEAP FORWARD IN SUSTAINABLE CONCRETE PRODUCTION



Purdue University researchers are ready to test whether they can make a stronger bridge by using concrete infused with microscopic nanocrystals from wood. The researchers have been working with cellulose nanocrystals, byproducts generated by the paper, bioenergy, agriculture and pulp industries.

By infusing concrete with microscopic crystals made from wood cellulose, Purdue Professor Pablo Zavattieri, along with researchers from Purdue's School of Materials Engineering and Oregon State University, have shown they can make concrete stronger. This project, which started in 2011 with a National Science Foundation grant, is now moving from the laboratory to the real world with a bridge under construction in northern California this year.

The researchers have been working with cellulose nanocrystals (CNCs), byproducts generated by the paper, bioenergy, agriculture and pulp industries, to find the best mixture to strengthen concrete, the most common man-made material in the world.

Zavattieri says strengthening concrete has other implications, such as making concrete items thinner and lighter. Another potential benefit is sustainable concrete production. Using less concrete means using less cement, which in turn means less carbon dioxide released into the atmosphere. Cement plants account for about 8 percent of global emissions of carbon dioxide, which is one of the main causes of climate change.

TINY AND UBIQUITOUS

The catalyst for this potentially transformative change is a cellulose nanocrystal about 100 nanometers long and 5 nanometers wide, so small that it can be seen only using an electron microscope. (For perspective, a human hair is about 100,000 nanometers wide.) Yet cellulose is the most common polymer in the world because it can be obtained from wood products, plants, bacteria and algae.

Zavattieri says that the cellulose nanocrystals provide an avenue for the water to be distributed in the mix. In traditional production, not all cement particles are hydrated when concrete is mixed, which hampers the strength and durability of the concrete.

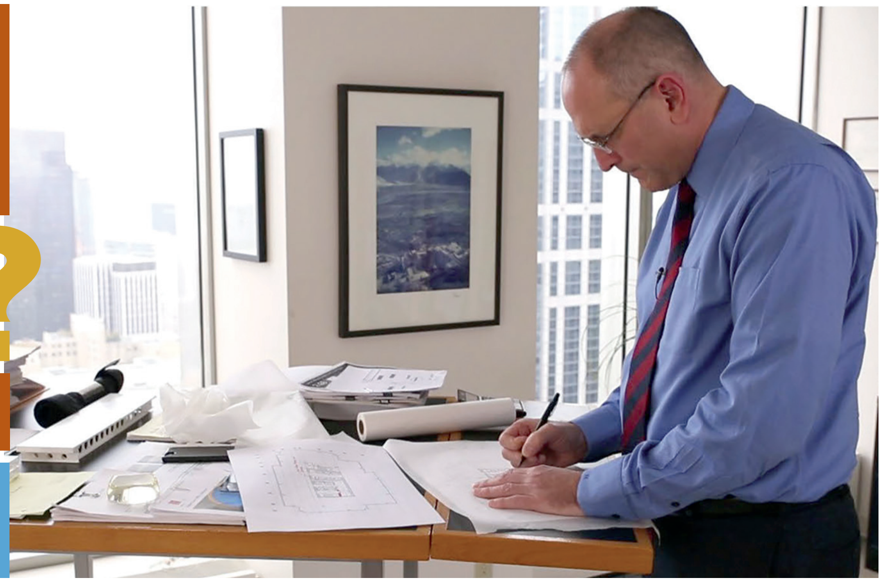
"The good thing about cellulose nanocrystals is that they create a kind of rail for the water to 'ride' into a particle," Zavattieri says.

Jason Weiss, the Miles Lowell and Margaret Watt Edwards Distinguished Chair in Engineering at Oregon State, who previously was a Purdue civil engineering professor, says the cellulose nanocrystals make concrete more sustainable and more efficient because less mass is needed to make something that is equally strong.

The research team reported that earlier NSF-funded work in CNCs led to the discovery that cellulose nanocrystals are not acting like conventional fibers but rather are altering the microstructure of the material.

The researchers say the cost of using the cellulose nanocrystals may be offset by being able to use less cement, although the exact cost of the new material hasn't been determined. Nevertheless, even if only a small percentage of all the concrete produced used cellulose nanocrystals, it would have a big impact just because concrete use is so ubiquitous.

WHERE DID CIVIL ENGINEERING TAKE YOU?



Leading the professional pack: Ron Klemencic

For Lyles School of Civil Engineering alumnus Ron Klemencic (BSCE '85), competition drives innovation, and he's not interested in losing his lead any time soon.

Through his project and technical experience, Klemencic stands at the forefront of the construction engineering industry, especially in the advancement of performance-based seismic design methodologies, development of innovative structural systems, execution of cutting-edge research undertakings, and involvement with code development and enhancements.

This past spring, Klemencic was recognized with the Engineering News-Record's Award of Excellence for championing public-domain research and development that advanced the design and construction of buildings.

Now serving as chairman and CEO of Magnusson Klemencic Associates, Klemencic has been the structural engineer-in-charge for more than 175 buildings over 27 stories high (the tallest being 112 stories) in 19 countries. Overall, his firm has completed projects in 47 states and 54 countries with an aggregate construction cost of $99 billion.

The firm — and Klemencic especially — continually seeks out new ways to design and construct buildings around the world. The motivation for all this, he says, is his strong desire to win.

"I'm an incredibly competitive person," he says. "And, to me, winning in engineering is coming up with 'the next big thing' — the next idea. I don't know why, but I've always had the competitive streak in me — and in business, you always need to stay ahead of your competition."

Asked how he feels the competition is going, he says: "The scorecard is certainly favoring us at the moment, but it's a game with no end."

A recent effort to expand his repertoire includes working with Purdue Civil Engineering faculty, graduate students and staff at the Robert L. and Terry L. Bowen Laboratory for Large-Scale Civil Engineering Research. Led by Professor Amit Varma, director of the Bowen Laboratory, a team of academics and industry professionals is developing a better method and guidelines for optimizing design — and speeding construction schedules — for high-rise buildings.

The three-year project aims to generate experimental data and numerical models using concrete-filled composite plate shear walls (CF-CPSW). In addition to speeding the construction process (and decreasing costs), the research could result in more creative options for skyscraper designs.

"Working with Purdue on this was not a difficult decision," Klemencic says. "In addition to it being my alma mater, I knew Professor Varma had been involved in similar research before. He and the rest of the civil engineering faculty are all among the world's best professors and researchers."

Recalling his own time as a student at Purdue, he says he could not have picked a better school to coach him up and prepare him for all that he has accomplished.

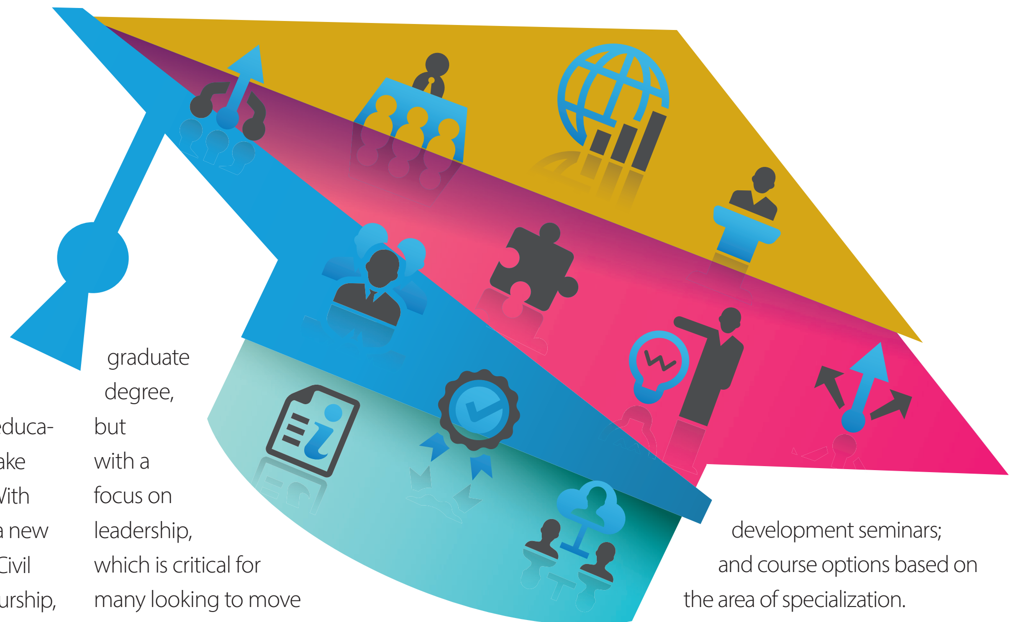
"Purdue offers an unparalleled education," he says. "I am unaware of anywhere else with the depth of faculty that Purdue Civil Engineering has."

He also does a bit of coaching of his own. For the past 25 years, Klemencic has been involved in lectures at Purdue and several other institutions around the world, including Cornell University's School of Architecture, Art and Planning; Georgia Tech; Illinois Institute of Technology; Universitat Stuttgart in Germany; Delft University in the Netherlands; and the University of Melbourne in Australia.

Klemencic says he is especially proud of the efforts made to educate and inspire the engineers of tomorrow and hopes one day to work either alongside them, or — perhaps — even compete against them.

"I come from a family of educators; it's in my blood," he says. "It's incredibly fun and satisfying to engage with students — and I look forward to seeing what they will accomplish one day in the future."

A NEW PROFESSIONAL MASTER'S CONCENTRATION, WITH A MANAGEMENT TWIST



The Lyles School of Civil Engineering strives to provide its students with opportunities to gain the best possible education and to ensure they're prepared to make an immediate impact in the profession. With that in mind, the school has announced a new professional master's degree option: the Civil Engineering with Leadership, Entrepreneurship, and Management (CE-LEM) concentration.

Designed for students who want to focus on a civil engineering career in industry or government, the professional master's concentration enables students to earn their graduate degrees in one year. Plus, students who earn the CE-LEM concentration will have the business knowledge to lead others in their field.

"We've developed this new concentration because we saw a growing need in both the public and private sectors for specialized, skilled civil engineers," says Dulcy Abraham, Professor of Civil Engineering and Chair of the Christopher B. and Susan S. Burke Graduate Program. "We also saw a need to serve students who want to further their education but also want to start their careers as soon as possible."

Jim Rowings, Peter Kiewit and Sons Inc. vice president and Purdue Civil Engineering Advisory Council member says the new concentration will propel the school further forward as a leader in civil engineering education.

"There are plenty of professional civil engineers out there who would love to pursue a graduate degree, but with a focus on leadership, which is critical for many looking to move up in their careers," Rowings says. "Time is also a factor — and with this concentration allowing students to earn their degree in as soon as one year — it also will be an attractive option for employers who would like their engineers to expand their skillsets."

The CE-LEM option incorporates professional skills and managerial competencies. Instruction is primarily residential. Up to 25 percent of the credits may be completed online. At present, students can earn the CE-LEM concentration in these civil engineering specialty areas:

- architectural engineering
- construction engineering
- environmental engineering
- geomatics engineering
- geotechnical engineering
- hydraulic and hydrologic engineering
- materials engineering
- transportation and infrastructure systems engineering

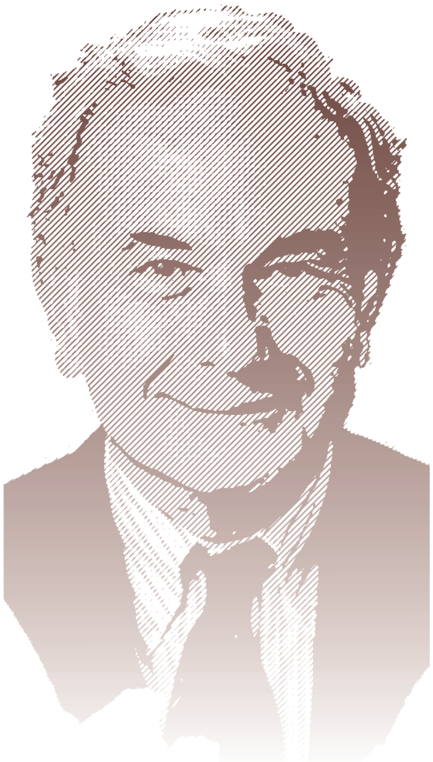
The CE-LEM concentration includes three components: core courses in management, entrepreneurship and leadership; professional development seminars; and course options based on the area of specialization.

Rao "G.S." Govindaraju, Bowen Engineering Head of Civil Engineering and Christopher B. and Susan S. Burke Professor of Civil Engineering, says the school's newest concentration is yet another example of how Purdue Civil Engineering continually strives to change and improve with the times.

"In addition to ensuring we provide the very best civil engineering education, we are cognizant that our students must be prepared to face the ever-changing professional landscape," he says. "As the world and civil engineering change, we must adapt as well."

Additionally, students pursuing this concentration are eligible to apply to the recently approved concurrent MS-MBA program, offered jointly by the College of Engineering and Krannert School of Management at Purdue. The program allows students to receive both their MSCE and an MBA in just two years.

For more information, contact Burke Graduate Program Administrator Jenny Ricksy at jricksy@purdue.edu or at 765-494-2436. ■



A loss for civil engineering: PROFESSOR METE SOZEN

Purdue Engineering mourns the loss of a beloved mentor, researcher and friend: Mete A. Sozen. He died on April 5, 2018, while visiting family in suburban London. He was 87 years old.

Sozen's research revolutionized the field of earthquake engineering. Over the course of his 60-year academic career, he consulted and lectured around the world, earned dozens of honors, and was revered as a teacher and mentor. He taught at the University of Illinois until 1994, and then at Purdue University, where he was the Karl H. Kettelhut Distinguished Professor of Civil Engineering. He advised 58 graduate students earning their PhDs — many of whom are now leaders in the field.

DRIFT, NOT FORCE

Perhaps Sozen's most famous invention was the earthquake simulator for structural applications, a tool that, in the early 1980s, led him to a watershed insight: The design of earthquake-resistant structures should not be based on force, the approach which had been prevailing for decades, but on drift — the degree to which the floors in a building move with respect to one another during an earthquake. This idea represented a radical change in a field that at the time was still operating on the basis of preconceptions established in the early 1900s. It opened the door to simpler and better ways to design and evaluate buildings and bridges.

AN ADVOCATE FOR SIMPLICITY

Sozen was an ardent advocate for simplicity in engineering. He was an unconditional supporter of "the heroes of the profession" as he called them, people like Talbot, Richart, Westergaard, Cross and Newmark — among others whom he often cited. Sozen was responsible for numerous innovations in design, analysis, and testing, in particular for reinforced, prestressed concrete and building systems. In 2006, the Applied Technology Council (ATC) added Sozen to its list of top seismic engineers of the 20th century. The nonprofit ATC helps transfer into practice research findings related to the effects of natural hazards.

MENTOR AND TEACHER

Sozen had a profound influence on his students. Santiago Pujol, Purdue Professor of Civil Engineering, studied under him as an undergraduate and graduate student. "He insisted we call him 'Mete,' not 'Dr. Sozen,' not 'Professor Sozen,'" Pujol says.

"What really made an impression on me was that he was quite kind and patient. He would find a smart way to tell me I was wrong, without exactly saying so," Pujol says, laughing. "He did that all the time."

As a researcher and thinker, Sozen was known for his remarkable focus. "When he was thinking about something, he wouldn't stop," Pujol says. "He would think about it day and night, every day. For weeks, if necessary." Invariably, he would find a solution. "You don't often encounter persistence like that."

Sozen loved research and teaching. "He never thought of retirement as something to be celebrated — because for him, work was a joy," Pujol says. ■

METE SOZEN SAID

- **Always guess before you calculate.**
- **If we're going to be wrong, we might as well be wrong the easy way.**
- **It is not what I do not know that worries me; it is what I think I know but ain't so.**
- **If an engineer can't guess calculation results within 15 percent, then there is either something wrong with the calculations or with the engineer, or both.**
- **The SDOF has two supreme advantages. It is easy to implement, and it is difficult to believe it is an accurate representation of the building.**
- **Engineers perform calculations to feel good. In the end, design decisions are based on a gut feeling.**
- **How many unbelievable things do you believe in?**
- **Analysis is done to compare competing systems, not to predict!**
- **Question calculation.**

HONORING METE

To honor Mete Sozen, the Lyles School is raising funds for a scholarship in his name. It will be used to support students interested in earthquake engineering. To make a contribution, contact Don Fry, chief development officer.
765-494-2236 ■ drfry@prf.org

PURDUE UNIVERSITY

College of Engineering

LYLES SCHOOL OF CIVIL ENGINEERING
Delon and Elizabeth Hampton Hall of Civil Engineering
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West Lafayette, IN 47907-2051

The Panama Canal, the Leaning Tower of Pisa, the Hoover Dam, the Golden Gate Bridge — GIANTLEAPS made possible with Purdue Civil Engineering know-how.

The Lyles School of Civil Engineering is celebrating Purdue's sesquicentennial year, 2019, with a series of "Giant Leaps" themed events:

- The Bridgebust, our annual student bridge-building competition with a Giant Leaps twist
- A talk in honor of alumnus David Robert Lewis, BSCE 1894, Purdue's first black engineer
- A special Giant Leaps themed alumni achievement award ceremony

Participate in the Purdue 150th festivities on Twitter: **#takegiantleaps**.

Show Boilermaker pride — and support Purdue scholarships — by purchasing commemorative merchandise at the Purdue Team Store: **purdueteamstore.com**.

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