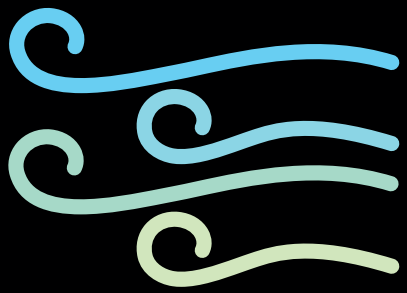
CIVIL

ENGINEERING IMPACT

PURDUE UNIVERSITY | FALL 2019

FIRE

FLOODS



HURRICANES

SPACE HAZARDS

ENGINEERING SOLUTIONS TO MITIGATE EFFECTS OF NATURAL HAZARDS

HEAD'S MESSAGE

Fall is always such an exciting time here at Purdue University — both in what it brings and what it symbolizes.

For most, this season represents the winding down of the year, the last flash of autumn colors before the cold winter takes over. However, for students and educators, fall represents a new beginning — a chance to make an impact, to make new friends, to reach greater heights, and to start off fresh in a new setting.

For me, personally, I fall somewhere in the middle — between proudly looking back on our school's accomplishments over the past year and enthusiastically looking forward to what the upcoming semesters will bring. Thankfully, magazines such as this fall edition of Civil Engineering Impact allow me both to reminisce about the past and anticipate future feats.

Of course, I cannot mention the idea of nostalgia without acknowledging Purdue's year-long sesquicentennial celebration, which will reach its climax this Homecoming. For the past 12 months or so, we here in the Lyles School — along with the rest of Purdue — have been celebrating the University's 150th anniversary, which officially was May 6, 2019.

For 132 of Purdue University's 150 years, the School of Civil Engineering, now the Lyles School of Civil Engineering, has proudly joined the University on its achievement-filled journey. As one of Purdue's oldest programs, we have been able to share and celebrate each other's successes. This sesquicentennial has been no different — and I look forward to celebrating our school's future successes in the years to come.

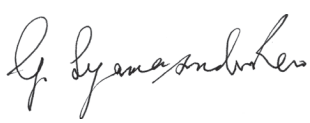
Speaking of successes and accomplishments, this edition of Civil Engineering Impact showcases several of them — particularly those of our faculty and graduate students.

In the following pages, you will be treated to stories on new and continuing research, such as the latest updates on the Resilient ExtraTerrestrial Habitats Institute, which NASA selected to lead a $15 million grant to develop resilient habitats for establishing human settlement on the moon and Mars.

You also will learn how our faculty and students are studying natural disasters from coast to coast, ranging from floods to wildfires, and how they are utilizing new technology and smart systems to prepare citizens and emergency professionals for future events. And you will learn about unique, full-scale assembly of steel components — used for developing and teaching the latest inspection methods.

Much of the research in the pages ahead would not be possible without tremendous, multidisciplinary cooperation between our school and multiple other entities, at Purdue and around the nation. I look forward to sharing even more of our successful, cooperative stories with you in the future. ■

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: Lyles School of Civil Engineering research mitigates effects of natural hazards: floods, hurricanes, wildfires and deep-space.

LYLES SCHOOL OF CIVIL ENGINEERING

Rao S. Govindaraju
Head

Garrett D. Jeong
Associate Head

Eric Putman
Chief Development Officer

Drew Stone
Director of Marketing and Communications

Sue Khalifah
Director of Student Experience

L. Scott Hinkel
Director of Development

Kathy Heath
Program Administration Manager

Moving?
Send change of address to:

Lyles School of Civil Engineering
Delon and Elizabeth Hampton Hall
550 Stadium Mall Drive
West Lafayette, IN 47907-2051

Or email: heathk@purdue.edu
Or call: 765-494-2166

EA/EOU ■ Produced in conjunction with Purdue Marketing and Media ■ ENGS-19-11648

NEWS AND EVENTS

Essam Sharaf, former Prime Minister of Egypt and Lyles School of Civil Engineering alumnus, discussed how his education and career in engineering served him in public office.

In spring 2019, the Lyles School was pleased to host Essam Sharaf, PhD, former prime minister of Egypt and Lyles School of Civil Engineering alumnus (BSCE '75, MSCE '80, PhD '84). Dr. Sharaf's lecture, "A Career Journey: From Engineering to Public Service," detailed his experience in engineering and academia and how it served him as leader of Egypt.

"Engineering thinking helped me a lot in my political duties," Sharaf says. "Actually, a lot of scholars now talk about engineers as the 'global citizen,' someone who can solve problems, see different aspects of them and look more wisely to the future."

Sharaf's talk is posted on the **Lyles School YouTube page: bit.ly/purdueCE-youtube**. ■

FROSCH SELECTED AS AMERICAN COUNCIL ON EDUCATION FELLOW

Congratulations to Robert J. Frosch, professor of civil engineering and senior associate dean of engineering for facilities and operations. Frosch was named ACE Fellow by the American Council on Education for academic year 2019-20.

Established in 1965, the ACE Fellows Program is designed to strengthen institutions and leadership in American higher education by identifying and preparing faculty and staff for senior positions in college and university administration.

Frosch has been at Purdue since 1997. His excellence in teaching, research and service has been recognized by his students and colleagues through numerous awards, including the Harold Munson Teaching Award, the Edmund M. Burke Outstanding Professor Award, the Roy E. and Myrna Wansik Civil Engineering Research Award, and the Ross Judson Buck Outstanding Counselor Award. His research, which focuses on the design and behavior of structural concrete, has resulted in changes in engineering practice and changes to the building codes for both buildings and bridges.

"I am extremely honored to have been selected to this class of Fellows," Frosch says. "I am confident that the ACE Fellowship program will help me become a stronger leader helping guide Purdue and higher education into the future." ■

2019 SPRING GRADUATION

This spring, about 150 undergraduate and graduate students earned degrees from the Lyles School of Civil Engineering.

ADVISORY COUNCIL

JIM ROWINGS, CHAIR BSCE '75, MSCE '79, PhD '82
Vice President
Peter Kiewit Sons Inc.

WILLIAM M. LYLES IV, VICE CHAIR BSCE '81
Vice President of Construction
Lyles Diversified Inc.

ROBERT L. BOWEN BSCE '62, HDR '07
Chairman and CEO
Bowen Engineering Corp.

CHRISTOPHER B. BURKE BSCE '77, MSCE '79, PhD '83, HDR '10
President
Christopher B. Burke Engineering Ltd.

RICK CONNER BSCE '76
President
American Structurepoint Inc.

JAMES CURE BSCE '75
President Emeritus
Advanced Technology Group

AL DAUSMAN MSCE '78
Engineer (Retired)
Bechtel Corp.

JAN EVERETT BSCE '76, MSCE '78
Vice President, Transportation, Florida
AECOM

STEVE FEHRIBACH BSCE '84
President and Owner
A&F Engineering Co. LLC

KEVIN FITZPATRICK BSCE '85
Executive Vice President
Great Lakes Regional Manager
Alfred Benesch & Co.

CLAUDIA GUNSCH BSCE '98
Associate Professor
Duke University

ROBERT HOLDEN BSCE '90, MSCE '92, PhD '99
Vice President
Wessler Engineering Inc.

VICKY KERAMIDA MSCE '76, PhD '79
CEO and Chief Technical Officer
Keramida Environmental Inc.

DOREEN MITCHELL BSCE '81
V.P., Facility Asset Management
Walt Disney World Co.

JOSH NIXON BSCE '01
Engineering Department Manager
The Schneider Corp.

STEVEN P. OSBORN BSCE '78
Founder, President and CEO
CE Solutions Inc.

ERSAL OZDEMIR BSCE '97
President and CEO
Keystone Construction Corp.

MARK PERNICONI BSCE '74, MSCE '76
Project Executive
Trinitas Ventures

GREG WORKMAN BSCE '84
Vice President Service Strategy
Union Pacific Railroad

HURRICANES

INTERACTIVE FLOOD VULNERABILITY MAPS

Lyles School research helps build

Interactive flood vulnerability maps aid citizens, first responders

Purdue civil engineers have developed a program that will allow the public to see exactly how vulnerable their homes are to floods, the world's most common and costly natural disasters.

Mohammad R. Jahanshahi, assistant professor in the Lyles School of Civil Engineering, says that with the expected climate changes for the next century, including sea-level rise, assessing flood risk is vitally important in order for coastal area residents and governments to make effective decisions about risk mitigation.

Assistant Professor Mohammad Jahanshahi and PhD candidate Fu-Chen Chen review the data, which includes thousands of structure images throughout coastal Louisiana.

"Floods are the deadliest natural disasters we face," Jahanshahi says. "So, we believe it's important for communities to better understand just how vulnerable their neighborhoods and their individual homes are."

As part of the vision for "smart cities," Jahanshahi's team has been developing a framework to provide citizens with interactive flood vulnerability maps through a website. The user can insert their address and learn about the flood risk in their region. To this end, the team has developed a framework to obtain information regarding buildings through measurements obtained from publicly available imagery that is from Google Street View, GIS imagery and satellite imagery. The framework includes data such as building type, foundation type and height, square footage and number of stories. The information is used to predict structural flood risk characteristics.

The result, Jahanshahi says, is a "heat map" for flooding that will allow people to see an accurate vulnerability assessment for their community. Additionally, the map could be a valuable tool for emergency-response teams to see which areas they should prioritize in a flood event.

Jahanshahi's team collaborated with an interdisciplinary team of Purdue researchers that included David R. Johnson, assistant professor of industrial engineering and political science, and Ed Delp, professor of electrical and computer engineering. They used the city of New Orleans as the basis for flood mapping research — a city that has historically seen some of the worst flood damage in America, most recently from the effects of Hurricane Katrina in 2005. The team worked with the Louisiana Coastal Protection and Restoration Authority and compiled thousands of publicly available images to complete its first report.

PhD candidate Fu-Chen Chen says the research has been grueling, but now that they have created a system based on their work, applying it to future cities will be far more streamlined.

"I believe we collected data from around 800,000 buildings in just five days — and some of them did not have current structure information," Chen says. "But, in the end, we managed to successfully collect all the necessary data."

Jahanshahi adds, "As you can imagine, this was a very time- and work-intensive project. We have shown how Big Data and advanced artificial intelligence techniques can help tackle grand challenges in engineering ."

The two-year project, which wrapped up in spring 2019, was funded by the Mellon Foundation. The findings will be published this year. ■

FLOODS

Lyles School researchers develop

MODEL FOR PREDICTING FLOODS

Lyles Researchers are developing new ways for simulating floods

As death rates and damage caused by floods continue to be among the highest of all types of natural disasters, Purdue University researchers are developing a system to give citizens and emergency teams as much time as possible to prepare and respond to them.

Lyles School of Civil Engineering Professor Venkatesh Merwade (right) and PhD candidate Siddharth Saksena review flood data collected from Hurricane Harvey.

Venkatesh Merwade, professor of civil engineering, leads a research team that is working on developing a new approach for simulating floods in hyper-resolution. Merwade says that this approach is applicable for any region in the United States to accurately predict the effects of future floods.

"In order to create an accurate model for simulating the effects of flooding, you need as much data as possible," Merwade says. "With flooding continuing to be one of the leading global causes of death and property damage among disasters, any amount of extra time we can offer communities to prepare will be lifesaving."

By creating a flood model for Hurricane Harvey — which most notably devastated Houston with floods — through gathering topography data, land-use, soil, climate and infrastructure data, Merwade's group has created an integrated simulation model for urban flooding. This model also requires road and stream network inputs to map the flood inundation from small streets to major rivers. Siddharth Saksena, PhD candidate, says he believes the work will certainly save lives.

"With such tools, people will know whether they need to evacuate sooner than they have before," Saksena says. "With the ability to predict flooding extent, from small- to large-scale, communities and community leaders will be able to act faster and more appropriately."

The predictive model also will arm city leaders with the information necessary to deliver more precise emergency warnings, Merwade adds.

"Not only will the tool allow governments to begin their emergency preparations sooner," Merwade explains, "but more importantly, they will know the best routes to take when evacuating. Knowing which routes to take when fleeing a flood is just as important as knowing when a flood event will happen ahead of time."

Merwade's research, funded through grants from the National Science Foundation, is in collaboration with multiple partners, including Information Technology at Purdue Research Computing, University of Minnesota and Streamline Technologies. The team is expected to publish its research this year. ■

NEW IDEAS FROM OLD STRUCTURES

ENGINEERS STUDY, TEACH STRUCTURAL HEALTH AT THE CENTER FOR AGING INFRASTRUCTURE

The Memorial Bridge connecting Washington, D.C., and Arlington, Virginia.

The Pensacola Bay Bridge in Florida.

New York's Brooklyn Bridge.

These are just three of more than 47,000 bridges across the nation that are classed as structurally deficient, according to a 2019 report from the American Road & Transportation Builders Association. The average age of these structures is 62 years. Fully four out of 10 U.S. bridges need to be replaced or repaired, the report states.

UNIQUE STEEL SPECIMENS

At Purdue University, transportation engineers learn to identify and prevent potential disasters caused by aging infrastructure — by educating students and practitioners and by developing cutting-edge inspection and monitoring techniques.

Purdue's Center for Aging Infrastructure (CAI), a 22-acre plot of ground nestled among farm fields south of campus, is home to dozens of steel infrastructure specimens that have been removed from their original locations and put on display. Visitors can walk around and examine numerous bridge components, including three full-scale bridges.

"No one else has assembled a set of specimens that can be used for training and research like this," says Robert Connor, center director and Jack and Kay Hockema Professor in Civil Engineering. "As far as we know, this is the only such place in the world."

In the coming months, Connor plans to install 600 feet of railroad track and working signals to further develop educational and research opportunities in support of the railway industry.

Unsurprisingly, the CAI is a magnet for civil engineering faculty and graduate students seeking to understand and prevent structural failure.

A HANDS-ON TEST BED

One regular researcher at the CAI is Ayman Habib, the Thomas A. Page Professor of Civil Engineering. Habib co-directs the Civil Engineering Center for Applications of UAS for a Sustainable Environment (CE-CAUSE). The site serves as a base camp for his remote sensing research as he aims to improve the reliability of infrastructure inspections.

Using unmanned aerial systems (UAS) and ground vehicles, Habib and his team collect high-resolution remote sensing data by means of LiDAR and other specialized imaging techniques.

By utilizing technology to perform inspections, Habib says we can examine structures more frequently and more accurately. Machine-driven inspections are safer, too, eliminating the need for workers to hang from cherry pickers or operate in high-speed traffic zones.

"This site is unique to Purdue," Habib says. "It is uncommon for students to have access to the infrastructure like we have here at the CAI — and to have access to the latest data acquisition systems. Our students get firsthand experience in the real-world process, from data acquisition to product delivery."

Habib's team employs remote sensing techniques that go beyond human vision. In addition to red-green-blue cameras and LiDAR imagery, he uses hyperspectral cameras to capture ultra-high resolution images of infrastructure components. "By looking over wavelengths invisible to the human eye, with very high spectral resolution, we can get much more information about corrosion, rust and fatigue," he says.

NEXT GENERATION'S RESEARCHERS

Graduate researchers like Radhika Ravi, a second-year PhD candidate in civil engineering, help in two ways: They assist with data acquisition and processing, and they develop software and algorithms to analyze the data.

PhD candidate Radhika Ravi

Ravi first experienced the CAI as a master's student. "It was a huge place," she says. "I had to ask around my research group to know what it was about."

As part of Professor Habib's geomatics research group, she uses UAV and vehicle-mounted LiDAR to discover deflections in the CAI infrastructure, including those that might reveal the possibility of collapse.

"We drive around the area, get LiDAR data and process it — which gives us the 3D point cloud," she says. "And from that, we can extract different features or different traits of the infrastructure."

Steel bridge components on display at the 22-acre Center for Aging Infrastructure.

Ravi's research focus is geomatics, working with LiDAR to extract information infrastructure along transportation corridors. "For people focused on structures, the CAI is a full-fledged place for getting a practical sense of what we study in theory."

A tenant of the CAI is the Steel Bridge Research, Inspection, Training and Engineering Center, known as S-BRITE. The group's mission is to ensure the nation's steel infrastructure remains safe and reliable.

After attending specialized S-BRITE training in bridge inspection, an individual from the Army Corps of Engineers commented that "you could spend 20 years inspecting bridges and never see all the details and forms of damage that you can examine firsthand when visiting the CAI."

Such sentiments gratify Connor, who understands that engineers learn by visual and tactile experience. "I could lecture all day, but when you can walk up to a specimen — see it and touch it — it just makes sense," he says. ■

NASA SELECTS PURDUE TO DEVELOP SMART AND RESILIENT DEEP SPACE HABITATS

Purdue Civil Engineering leads $15M effort to establish humans on the moon and Mars

The launchpad for humanity's next giant leap will very likely start at Purdue University.

Since well before Neil Armstrong made his — and humanity's — first step on the moon, a dream for many (and the basis for countless works of science fiction) has been to establish permanent settlements in space. And now, led by a research team from the Lyles School of Civil Engineering, humanity is closer to making that dream a reality.

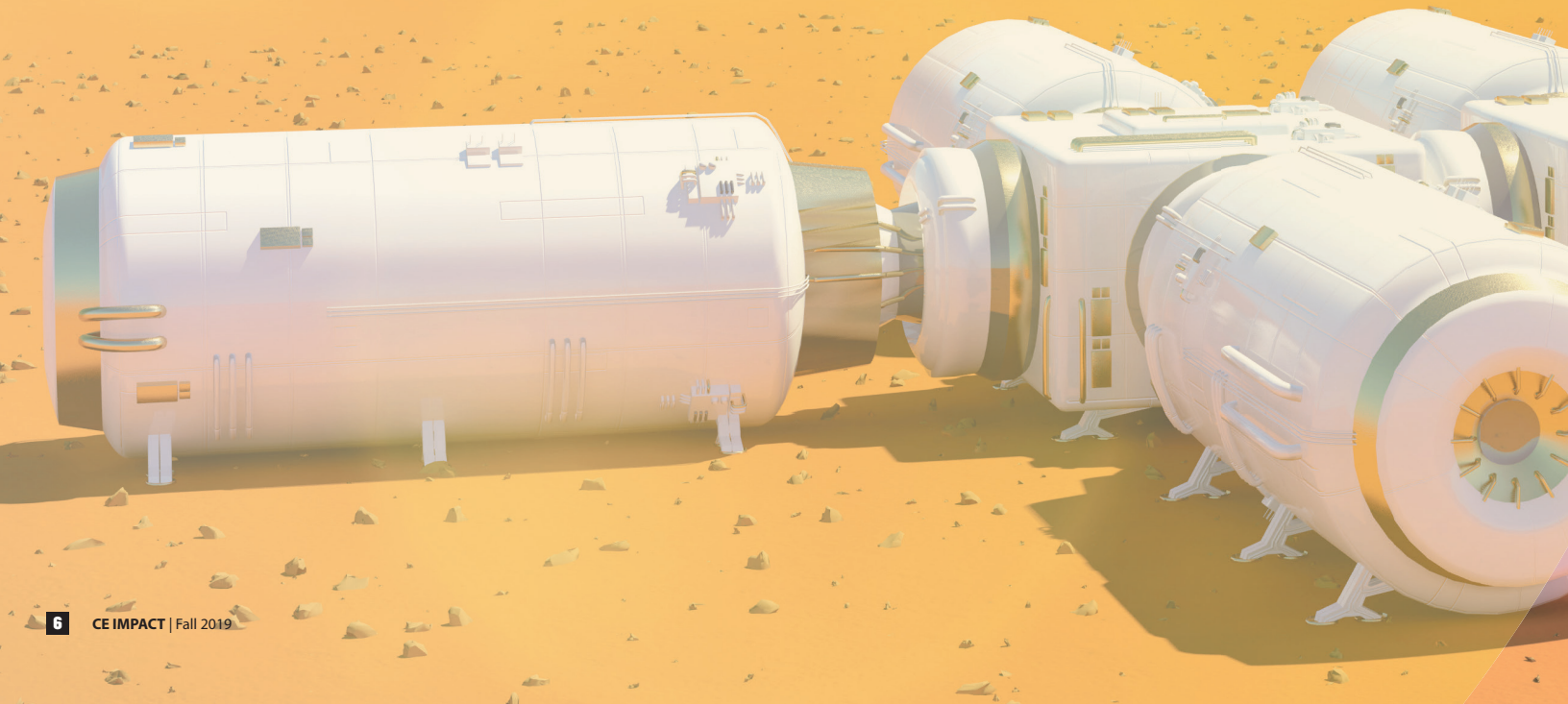
In the spring, NASA selected Purdue's Resilient ExtraTerrestrial Habitats Institute (RETHi) as one of its two multidisciplinary, university-led Space Technology Research Institutes (STRIs) charged with developing technologies critical to establishing a sustainable human presence on the moon and Mars. The grant is for $15 million over a five-year period.

The RETHi team will conduct research needed to develop resilient deep-space habitats that can adapt, absorb and rapidly recover from expected and unexpected disruptions. RETHi will leverage Purdue's world-class expertise in civil infrastructure responsive to catastrophic natural hazards and merge it with expertise from leaders in the fields of autonomous robotics, smart buildings, hybrid simulation, transformable architecture, and diagnostics and prognostics for intelligent structural-health management.

The project is led by principal investigator Shirley J. Dyke, professor of mechanical engineering and civil engineering, and she is joined, within civil engineering, by professors Antonio Bobet, Mohammad Jahanshahi and Julio Ramirez. The multidisciplinary partnership includes additional researchers from Purdue, the University of Connecticut, Harvard University and the University of Texas at San Antonio.

"Partnering with universities lets us tap into new expertise, foster innovative ideas, as well as expand the research and development talent base for both aerospace and broader applications," says Jim Reuter, acting associate administrator of NASA's Space Technology Mission Directorate. "We're excited to work with these two new STRIs to develop smart habitat technologies for exploratory missions on the moon and Mars."

Dyke says the team's research over the next five



years has three thrusts: building resilience into "Smarthabs," using sensors and data to monitor and manage the health of the habitat, and providing robots with the ability to handle automated repair and maintenance.

"Our focus is on developing smart deep-space habitats that are self-aware," Dyke says. "The idea is to establish the knowhow to build smart habitats that can monitor what's happening, respond, and take corrective actions — whether that is through humans, robots or automation."

Currently, the team is developing a cyber-physical test bed that combines mechanical and computational elements. It will allow for system-level studies — for experiments in ways intelligence can be integrated into complex systems, for assessing expected environmental challenges in creating and maintaining a settlement, and for establishing systems that can respond swiftly and accurately to problems.

Ramirez, the Karl H. Kettelhut Professor of Civil Engineering, says this is an exciting time to be a civil engineer.

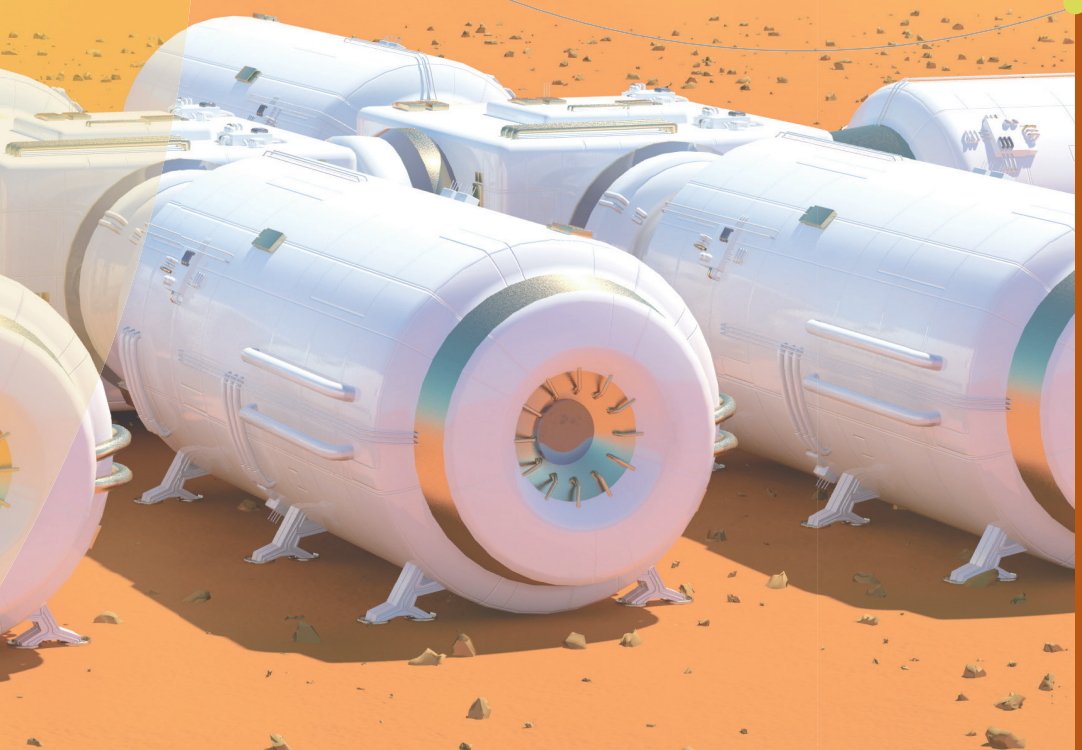
"This project is what civil engineering is all about," Ramirez says. "It's about setting new horizons and pushing the boundaries as humanity progresses forward by providing shelter and an environment to achieve its best. This is all deeply rooted in Purdue's space-related tradition as home to so many astronauts, like Neil Armstrong, and to train the next generation of leaders in the field."

Jahanshahi, assistant professor of civil engineering, says this project provides a unique opportunity for educating the next generation of civil engineers who will be collaborating with engineers from other disciplines to tackle challenging problems of the future.

"In addition, the lessons learned throughout this project will be used to further enhance the resilience of our civil infrastructure here on Earth," Jahanshahi says.

"This is a great opportunity for our students," adds Bobet, the Edgar B. and Hedwig M. Olson Professor of Civil Engineering, "as well as for the civil engineering community at large. We will use the expertise that we have accumulated here on Earth by addressing all the past challenges and hazards, to learn and tackle the enormous difficulties that a permanent habitat faces in space and, most importantly, to educate the civil engineers of the future — those who will build the infrastructure that will make it possible for humanity to thrive on the moon and Mars and beyond."

Much of this effort will be conducted at the Robert L. and Terry L. Bowen Laboratory for Large-Scale Civil Engineering Research and the Ray W. Herrick Laboratories, where the RETHi team plans to build scaled cyber-physical experiments to demonstrate the technologies. ■



Purdue researchers say that underground lava tubes are one of the most likely options for establishing settlements on the moon.

Lava tubes would shield inhabitants from radiation, temperature fluctuation and meteorite impacts.

About RETHi
the Resilient ExtraTerrestrial Habitats Institute

RETHi began in 2017 as a New Horizons seed grant awarded by the Purdue University Office of the Provost. A competitive program, New Horizons challenges established senior faculty to create new academic areas for the coming decades. Team members included Antonio Bobet, the Edgar B. and Hedwig M. Olson Professor of Civil Engineering; Shirley J. Dyke, professor of mechanical engineering and civil engineering; Julio Ramirez, the Karl H. Kettelhut Professor of Civil Engineering; and Jay Melosh, distinguished professor of earth and atmospheric sciences and physics.

Shirley J. Dyke, professor of mechanical engineering and civil engineering

In addition to conducting research, the team developed an honors class called "Life on Mars," where students studied the challenges facing future Mars settlers and discussed and debated approaches for combating them.

BEFORE

Anne Bigane Wilson: LEADER AND MENTOR

AFTER

NORTH AVE. BEFORE AND AFTER: One of Wilson's most memorable projects was for Chicago's North Avenue Bridge reconstruction project in 2005. Her company developed an asphalt mix for a temporary bridge during the reconstruction that withstood the Windy City's notoriously harsh winter weather. The bridge would be used for more than a year and withstood the traffic and weather throughout.

Anne Bigane Wilson credits much of her success to the female engineers who came before her. So naturally she feels it is only right to guide and inspire young women learning to be engineers today.

"It's very important to me that I pay it forward and make sure it's easier for those who follow me," says Wilson (BSCEM '79, MSCE '81). "I stand on the shoulders of the women who came before me. They led by example and showed me that I, too, must live and work as an example for the next generation of engineers."

Wilson also credits her father, Edward Bigane, with instilling in her the importance of integrity.

"Personal integrity is, above everything else, key to dealing with people both personally and professionally," she says. "I've found this to be the most important factor in my success over the years."

And she has achieved a great deal of success. Wilson has been an innovator in her family's fourth-generation business, Bigane Paving Co., diversifying it by acquiring two Chicago-area asphalt manufacturing operations, Reliable Ogden LLC and Ogden Avenue Materials. Both are now part of the Bigane portfolio.

In 2017, Wilson became the first person to receive a Construction Engineering and Management Outstanding Alumni Award at Purdue. Two years later, she won one of Purdue College of Engineering's highest honors, the Distinguished Engineering Alumni/Alumnae Award — given in honor of her outstanding professional career and service to the community.

"Honestly, I was in total disbelief when they told me I would be receiving the DEA," she says. "I've always seen this award as a really big deal, and for someone like me to have been selected — well, I was just blown away."

In addition to her professional successes, Wilson has, time and again, given back to her community in Chicago and to her alma mater. Throughout her career, she has been at the forefront of ethical construction practices, green initiatives and the promotion of women in STEM fields. For the latter endeavor, she regularly partners with Purdue's College of Engineering to ensure that the female engineers of tomorrow have every opportunity possible to succeed.

Wilson is a past president of both the American Subcontractors Association and the Federation of Women Contractors and is the co-founder of Purdue's Women in Construction program, which promotes the professional development of young women in construction and helps recruit and retain women in Purdue's CEM program. She is also a longtime member of CEM's Industrial Advisory Board and is often invited to be a guest lecturer at universities throughout the U.S.

To further encourage young women interested in engineering, Wilson is a registered mentor on MentorNet, an online program that pairs students with successful women in the STEM fields.

To Wilson, this is simply her way of "paying back" all the opportunities that were afforded to her.

"These young people, they're the next generation of engineers — they're the ones with the new ideas that will take our world further ahead," she says. "It's only natural we should help and encourage them. It is a benefit to everyone." ■

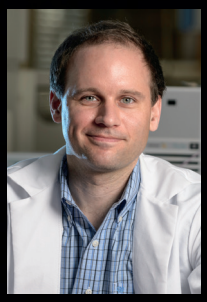
RETURNING SAFE WATER TO PARADISE

CIVIL ENGINEERING RESEARCHERS USE SCIENCE TO HELP THE FIRE-STRICKEN COMMUNITY

In November 2018, California's deadliest and most destructive wildfire burned nearly 240 square miles in the Sierra Nevada foothills. The "Camp Fire" raged through the town of Paradise, killing at least 86 people and destroying most buildings and infrastructure.

In particular, the firestorm ruined water pumps, hydrants — and miles of underground pipelines, which depressurized in the intense heat. Toxic chemicals from burnt materials and melted pipes seeped into the water system, where the liquid sat for weeks.

One year later, the biggest problem in Paradise? A contaminated water infrastructure.



Andrew Whelton, associate professor of civil engineering and environmental and ecological engineering

For help, officials in the Paradise Irrigation District turned to an authority on restoring water infrastructure post-disaster: Andrew Whelton, associate professor in Purdue's Lyles School of Civil Engineering and Environmental and Ecological Engineering.

Whelton and his team of students and faculty, which includes Caitlin Proctor, a Lillian Gilbreth postdoctoral fellow, set out to help the utility restore safe water to Paradise.

"Early on, we contributed directly," Whelton says. "We provided an understanding of chemistry, water testing, contamination, damage assessment and a number of other issues. It all boiled down to science."

Proctor's research interests include microbiology, drinking water quality and building plumbing.

She emphasizes that practicing engineers be able to recognize the limits of the data and the knowledge they have. "Even with a PhD, I am regularly asking questions. Luckily, at Purdue, it's easy to find the right expertise," she says.

During three visits to the Paradise area in 2019, Whelton's team surveyed the damage, met with officials, attended and held public meetings, and trained survivors about plumbing safety.

LONG, COMPLEX, EXPENSIVE

"City and utility officials know that characterization and recovery is a monumental effort," Whelton says. "We walked them through a process of removing and replacing assets, and we came up with a timeline of two or three years to restore the water network. And that's an expedited timeline."

To be surveyed and tested are more than 172 miles of buried lines, more than six miles of plastic pipes, 1,400 hydrants with gaskets and 10,000 service connections.

Local leaders estimate a $53 million cleanup cost, but Whelton and his colleagues believe that figure is low. Until officials obtain a sufficient number of water samples, it's impossible even to determine the extent of the damage.

Although most people have left Paradise (at least temporarily), remaining residents still view Whelton as a resource. People email and phone him, asking for technical advice about their water. "We've refocused our efforts to help the community directly," he says.

In April 2019, Whelton's team surveyed homes in the Camp Fire area. Results showed that six months after the fire, about half of respondents reported anxiety, stress and depression related to drinking water contamination. Most did not know if their plumbing was safe or how to test it. The Purdue team organized a community event in July to teach fire survivors about plumbing issues. On hand were colleagues from University of California, Berkeley; Chico State University; Butte College; and the Paradise community.

TRAINING FUTURE ENGINEERS

Whelton believes we need engineers trained to address situations where no scientific data is available. "When agencies and practicing engineers are faced with a scenario where there is no script, unfortunately, you see decisions that fail to protect public health," he says.

"At Purdue, we bring real-world issues into the classroom and student research so students can see for themselves how complex the issues are. From a scientific perspective, from a policy perspective, and from a human perspective." ■

BOOR RECEIVES NSF CAREER AWARD

Brandon Boor, assistant professor in the Lyles School of Civil Engineering, has been nationally recognized as a rising star in engineering research and education.

In February, Boor received a 2019 National Science Foundation CAREER award. The award supports junior faculty members who exemplify the role of teacher-scholars through research, education, and the integration of education and research within the context of the mission of their organization. The award comes with a five-year (2019-24), $500,000 grant for research and education activities.

"I was actually pretty shocked when I was informed that I had been selected for a CAREER award," Boor says. "Not only is there a lot of prestige attached to it, it also means others see great potential in the research we are doing here at Purdue."

Specifically, NSF cites Boor's research into the formation, growth and phase-state of organic nanoaerosols in indoor environments.

According to the NSF grant, air pollution from outdoor sources is well-recognized as a potential health risk, but it is also essential to improve air quality in homes and offices because Americans spend 90% of their time indoors.

"Human exposure to particles in air pollution is responsible for adverse health effects," the grant summary states. "An important class of indoor particles is nanoaerosols — particles smaller than 100 nanometers in size. New research is needed to better understand the fate and transport of nanoaerosols in buildings to better predict human exposure."

Boor says a major component of his research is dedicated to learning what exactly happens to these indoor particles: how they form and grow, where they deposit and how their properties change. He studies the life cycle of a particle, including where it ends up — be it on a surface, in a human body or vented outside.

"When it comes to indoor air quality there is so much we don't know," Boor says. "There are tremendous research opportunities when you consider that the vast majority of the air we breathe is indoor air."

As part of the NSF CAREER award, Boor will create an educational component to engage and excite undergraduate and graduate students at Purdue through a combination of service, experiential and team-based learning experiences.

The $500,000 CAREER grant will help fund Boor's research through 2024. ■

A NEW PROFESSIONAL MASTER'S IN THE BURKE GRADUATE PROGRAM

Fall 2019 kicks off the inaugural class of the school's professional master's degree program, based in the Burke Graduate Program.

With its focus on civil engineering leadership, entrepreneurship and management, the CE-LEM program provides opportunities for students to gain the best possible education and get prepared to make an immediate impact in the profession, whether they choose careers in industry or government.

"We couldn't be more excited to start the professional master's concentration," says Dulcy Abraham, professor of civil engineering and chair of the Christopher B. and Susan S. Burke Graduate Program. "Not only will our students gain a valuable, specialized education that will allow them to become leaders in their fields, but the world of civil engineering will greatly benefit from these highly trained professionals."

The CE-LEM option incorporates professional skills and managerial competencies. Instruction takes place primarily on campus. Up to 25% of the credits may be completed online. Additionally, students pursuing the concentration are eligible to apply to the recently approved concurrent MS-MBA program, offered jointly by Purdue's College of Engineering and Krannert School of Management. This program allows students to receive both their MSCE and an MBA in just two years.

For details, contact Jenny Ricksy, administrator of the Burke Graduate Program, by email at **jricksy@purdue.edu** or by phone at **765-494-2436**. ■

3D-PRINTED CEMENT GETS TOUGHER WHEN IT CRACKS, MIMICKING NATURE

Lyles School researchers develop cement paste as strong as arthropod shells

Taking a page from nature, Purdue Civil Engineering researchers have created materials that get stronger when they crack.

A team led by Lyles School professors has developed a new technique for 3D-printing cement. Pablo Zavattieri, professor of civil engineering; Jan Olek, the James H. and Carol H. Cure Professor of Civil Engineering; and Jeffrey Youngblood, professor of materials engineering, have developed a material that gets tougher under pressure — much like the shells of arthropods such as lobsters and beetles. The technique eventually could contribute to more resilient structures during natural disasters.

"We are looking at how nature deals with interfaces and weak spots. The material in arthropod shells is very robust; it does not shatter like cement," Zavattieri explains.

HOW EXOSKELETONS WORK

Arthropod exoskeletons have crack-propagation and toughening mechanisms that the team reproduces in 3D-printed cement. By incorporating designs from nature, the 3D-printed materials will give engineers more control over design and performance.

The team was inspired initially by the mantis shrimp, which conquers its prey with a "dactyl club" appendage that grows tougher on impact through twisting cracks that dissipate energy and prevent the club from falling apart.

The team uses micro-CT scans to understand the behavior of hardened 3D-printed, cement-based materials and therefore leverage their "weak" characteristics, such as pore regions found at the interfaces between the printed layers, which promote cracking. "We are studying the spatial arrangement of these interfaces to determine how these arrangements will influence crack propagation under load," says Olek. These findings were presented recently at the First RILEM International Conference on Concrete and Digital Fabrication in Zurich, Switzerland, and were published in the prestigious journal Advanced Materials.

The team's work was funded through a National Science Foundation grant. The acquisition of an X-ray microscope was supported by the 2017 Major Multi-User Equipment Program, offered by Purdue's Office of the Executive Vice President for Research and Partnerships.

FUTURE OF 3D-PRINTED CEMENT

"3D printing cement-based materials provides control over their structure, which can lead to the creation of more damage- and flaw-tolerant structural elements like beams or columns," says Mohamadreza "Reza" Moini, a PhD candidate in civil engineering and a member of the research team.

PhD candidate Mohamadreza "Reza" Moini demonstrates the latest 3D-printed model, created in Hampton Hall.

"The main applications for this, for now, are in structural research," Moini says. "We're still studying its characteristics and behaviors, but we see a lot of potential."

Zavattieri says, "There is still much to study, but what we have already been able to create and replicate has us very excited for the future. We hope to take what we have learned and expand it to many other applications." In particular, the team plans to explore ways that cement-based elements could be designed for building more resilient structures.

The research project is funded through spring of 2020. Additional publications are expected to be released by the end of this year. ■

LYLES SCHOOL RESEARCHERS DOCUMENT A VANISHING LAKE MICHIGAN SHORELINE

DRONES AND LiDAR SURVEYS REVEAL ALARMING CHANGES

The Purdue research team uses this drone fitted with a LiDAR device to measure coastal erosion at southern Lake Michigan.

Around Lake Michigan, coastal erosion is progressing so rapidly that beachfront properties soon could be located in the lake itself, Purdue Civil Engineering researchers say.

Since May 2018, Cary Troy, associate professor of civil engineering, and Ayman Habib, the Thomas A. Page Professor of Civil Engineering, have been using unmanned aerial vehicles (UAV) equipped with a Light Detection and Ranging (LiDAR) system, along with satellite images, to quantify coastal erosion around Lake Michigan. According to their findings, the lake's water levels are now at near-record highs, and the entire coastline is eroding at a very alarming rate.

"It's getting to the point where portions of beaches have completely washed away," Habib says. "And the erosion is not showing any signs of stopping."

In an effort to monitor the increasing erosion accurately and to keep city managers and affected residents informed, Habib and Troy's research team has set up a monitoring system that makes use of the UAVs equipped with LiDAR.

LiDAR is a remote sensing method that uses pulsed laser light to measure distances. Light pulses from the UAV — combined with trajectory data collected by a global navigation satellite/inertial navigation system — produce 3D point clouds with 2-3 centimeter position accuracy. The point clouds can be used to generate digital surface models, which provide precise descriptions of the Earth surface. Unlike satellite images and aerial photos, LiDAR provides 3D data that allows researchers to extract transects (a traditional metric of shoreline change) and quantify volume loss.

According to the study's findings, between May 2018 and May 2019, a 220-meter section of southern Lake Michigan showed a loss of 4,000 cubic meters of sand along the shoreline. That is roughly 7,700 metric tons of wet sand lost.

Meghdad Hashemin, PhD student and research team member, says it has been eye-opening to see the erosion progression.

"I didn't expect to see these kinds of changes in just a few months — I don't think anyone did," Hashemin says. "It's amazing to see — and very concerning."

The team has been monitoring multiple areas on the southern coast of Lake Michigan between Gary and Michigan City in Indiana.

"The rapidly rising water levels over the last few years appear to be the main reasons for the erosion," Habib says. "The higher water levels bring wave energy to parts of the shoreline that have not had time to adjust to the new lake levels."

The team is assembling a report for publication, detailing its findings. Habib says the team will publish the report by the end of this year. ■

RESEARCH OPPORTUNITIES

A STRATEGIC ADVANTAGE FOR LYLES SCHOOL GRAD STUDENTS

THE BURKE GRADUATE PROGRAM NURTURES FUTURE PROFESSIONALS IN CIVIL ENGINEERING

With world-renowned research faculty and some of the most technically advanced laboratories and tools available, the Lyles School of Civil Engineering is one of the world's premier destinations for a graduate degree.

These strengths provide students in the Christopher B. and Susan S. Burke Graduate Program in Civil Engineering with incredible research opportunities — and that is what sets the school apart, officials say. It is not surprising that Purdue's graduate program was ranked No. 6 in the nation by U.S. News & World Report in 2019.

Dulcy Abraham, professor of civil engineering and chair of the Christopher B. and Susan S. Burke Graduate Program, says a key to the school's long-standing success in educating and preparing some of the world's top civil engineering graduate students is through providing a multitude of research and networking opportunities.

"We don't simply want our graduate students to be strong academically," Abraham says. "We want them to be leaders and strong collaborators, so that they can push civil engineering forward and guide the next generation."

Amit Varma, the James H. and Karl H. Kettelhut Professor of Civil Engineering and director of the Robert L. and Terry L. Bowen Laboratory of Large-Scale Civil Engineering Research, echoes Abraham's thoughts. He adds that high-level research experience is a key reason why civil engineers with an advanced degree from Purdue are snapped up by industry and government recruiters.

> "Working with our top-flight faculty is perhaps the most important aspect about studying here at the Lyles School," says Varma.

Recently, Lyles School graduate students presented a paper at the North American Steel Structures Conference — an invitation-only event where guests and speakers are all considered to be at the forefront of innovative research.

"Attendees at this conference include the top civil engineering minds in the world, so it is not typical for graduate students to earn an invitation," Varma says. "This indicates that our students are very, very good. They are consistently recognized for their work and creative thinking."

Among them is Jessica Eisma, a PhD candidate focused on solving water-related problems. Eisma, who won the Fullbright U.S. Student Program grant for 2016-17, says she continues to be amazed by her research experiences, including many that go far beyond the lab.

Jessica Eisma, Lyles School of Civil Engineering PhD candidate, conducted research in Tanzania on sand dams.

Civil Engineering graduate student Nathan Shellhamer attended several conferences and lectures while working toward his master's degree, which he earned this past May.

"Purdue has provided me with innumerable opportunities that have enriched my education and enhanced my career prospects," Eisma says. "Not only have I been able to travel and learn from some of the leading researchers in the world, but top researchers regularly come to Purdue to share their experiences with us."

Among her endeavors, Eisma spent a year studying small-scale, water-harvesting structures in Tanzania, attended the Third International Conference on Global Food Security in Cape Town, South Africa, and met with Essam Sharaf (BSCE '75, MSCE '80, PhD '84), Purdue Civil Engineering alumnus and former prime minister of Egypt. ■

PURDUE UNIVERSITY | Lyles School of Civil Engineering

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