CIVIL

ENGINEERING IMPACT

PURDUE UNIVERSITY | SPRING 2015

BRINGING CLEAN WATER TO THE WORLD

Exciting things are happening in our school. Our students are working progressively toward realizing one of the most important milestones of their careers: a Purdue University degree. Our faculty members are focusing their combined efforts, wisdom and experience toward imparting new knowledge to these students. Our faculty and staff are dedicated to providing experiences and programs to further all our efforts toward learning, discovery and engagement.

Together, we build a better world.

In this issue, the theme of *water* is evident. Professors and students are providing water filtration methods and resources to remote locales in Colombia, China and Africa. Our ASCE student chapter visited the Panama Canal, the expansion of which has led our senior design class to undertake deep experiential learning by partnering with industry to design oxygenation facilities to sustain aquatic life in the Savannah River. An undergraduate student is researching the astonishing properties of the dactyl club of a creature that lives below the ocean. Clearly, water has tremendous impact on our lives. And we are having an impact on how best to use this important resource.

We feature not only water in this issue though. Research into the makeup of the mantis shrimp club holds promise for the next generation of structural materials needed for society; our student team won first place in the 2014 International Bridge Contest; a noted alumnus in Virginia performs research into human behavior as it relates to transportation (and earned a ride with the President); and a group of students traveled to New Zealand to view the impacts of earthquake damage.

Closer to home, we have made great strides with our 2015-19 strategic plan. It is still in draft form, but we plan to finalize it by this summer. It articulates well our mission and our vision of leading the civil engineering profession and being the most sought-after and preeminent civil engineering program in the country.

Thank you for being a part of our school. Please stay connected, and plan on visiting us whenever the opportunity presents itself.

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

ON THE COVER: Sam Noel, a Purdue undergraduate student, rinses sand in the Barbosa Antioquia area of Colombia. Noel was part of a team working with Chad Jafvert, professor of civil engineering and professor of environmental and ecological engineering, that installed point-of-use filters to improve water quality in remote areas. Together, the sand and buckets comprised a slow-sand filter system the team installed in a nearby rural elementary school. Read more about this project in the story, "When a drop in the bucket is a very good thing," on page 2.

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

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ASCE STUDENT CHAPTER VISITS PANAMA CANAL

Purdue's chapter of the American Society of Civil Engineers traveled to Panama City, Panama, to attend the ASCE Global Engineering Conference in October 2014. Pictured in front of one of the new Panama Canal locks, from left: Mike Kelly, Kiewit Corporation's Paul Giroux, Jacob Bubalo, Ian Hogan, Patrick Toth and Kyle Konz. These new locks will allow extra-large "post-panamax" cargo ships through the canal. See the article on page 5 to learn more about a senior design project centered on the Savannah Harbor expansion project (SHEP) that is a direct result of the Panama Canal expansion.

TEAM WINS TOP PRIZE IN BRIDGE COMPETITION

A team of Purdue civil engineering students won first place in the 2014 International Bridge Contest, an annual event involving universities from Japan, the United States, Colombia, Mexico and Turkey. Students designed the structures and build them out of everyday materials such as wood sticks, rope and Styrofoam and test the models until they fail. Pictured, from left: Santiago Pujol, Chungwook Sim, Aishwarya Puranam, Nicholas Skok, Jacob Bubalo, Lucas Laughery, Yunlan Zhang, Derek Daluga and Samuel Magers. The students were advised by Pujol, an associate professor of civil engineering. Also providing guidance were associate professor Ayhan Irfanoglu and assistant professors Mohammad Jahanshahi and Arun Prakash. A YouTube video shows the team at work: **http://youtu.be/emwGk6F5lXE**

SLOW SAND FILTERS

When a drop in the bucket is a very good thing

Clean, safe drinking water is a given for many of us: It is as close as the nearest faucet or refrigerator. However, according to Water.org, more than 750 million people lack access to clean water and over 3.4 million people die each year from water-related diseases.

In 2010, an effort began in Purdue Civil Engineering sponsored by the Global Engineering Program, to address this issue in novel ways. Launched with a grant from Kimberly Clark to evaluate treatment options for improving drinking water in rural schools in the Barbosa Antioquia area of Colombia, Chad Jafvert, professor of civil engineering and professor of environmental and ecological engineering, and John Howarter, assistant professor of materials engineering and assistant professor of environmental and ecological engineering, explored slow-sand filtration (SSF) as a cost-effective, low-maintenance treatment technology to meet the needs of people living in rural villages.

SSF is the oldest type of municipal water filtration system, dating to its first documented use in 1804 in Scotland. The process can improve water quality significantly by removing particles and dissolved organic chemicals from the water, reducing turbidity and odor such that water meets even U.S. drinking water standards for turbidity.

To succeed, this project had to minimize capital costs, reduce construction time, and keep operation and maintenance requirements low.

In March 2011, Jafvert and several undergraduate students traveled to Barbosa, Colombia, to install point-of-use, slow-sand filters in three schools. These initial filters were constructed using 5-gallon pails, an innovative departure, as other projects have used larger, more expensive and harder-to-find drums or even poured concrete "boxes."

"The approach has been to 'design' the units using small, inexpensive, specialized components, which we check in our baggage — and which always receive curious looks from airport security people," Jafvert says.

The team's first filters used locally sourced gravel and sand layers, with each layer needing to be separately sieved. Over

the course of the next year, the team tested a replacement for the gravel layer — a commercially available plastic porous media plate.

In June 2012, Jafvert and Howarter visited Colombia again with another group of undergraduate students. This time they brought materials to install their improved filters in 15 schools. The team also conducted workshops, during which they taught local teachers how to assemble and operate the filters.

Each school was provided with materials for two units (each consisting of two 5-gallon buckets) that produce 60 liters of filtered water per day, which is approximately the daily amount needed for the 15 to 20 students at each school.

During the following year, the team evaluated ways of producing the plastic porous media plates themselves. In late 2013, this new plate design was successfully tested, bringing down the cost for each plate to just over $1.

About this same time, the team began working with Empresas Públicas de Medellín E.S.P. (EPM Foundation), a multi-utility group focusing on power generation, transmission and distribution, natural gas distribution, wastewater treatment, aqueducts and telecommunications. At EPM's invitation, Jafvert and Howarter, along with Purdue civil engineering graduate student Fernando Segovia, traveled to Medellín, Colombia, to further discuss, demonstrate and install the enhanced filter units.

TOP: Undergraduate students and PIs in the Barbosa area of Colombia in June 2012. From left: Erin Chichlowski, Professor John Howarter (EEE and MSE), Professor Chad Jafvert (CE and EEE), Fernando Segovia, Nicolas Guerra-Mondragon and Julia Wiener. **BELOW:** Students make a toast with their clean water at the elementary school (Centro Educativo Olaya Herrera) near Amaga, Antioquia. **LEFT:** Students sieving sand with the portable trammel. Using this equipment takes one-fifth the time and one-one-hundredth the energy.

During the 2014 visit, the team was able to check in on some of the filters they installed in 2011. They were delighted to learn they were still in use and operating at near-maximum capacity. One of the original units has treated more than 50,000 liters of water over the period of operation. Another unit even survived a vehicle accident, when a car crashed through an adjoining wall.

The team also delivered and demonstrated a portable trammel — a screened cylinder that members designed to sieve sand to the proper size. Sand can be sieved, rinsed and

LEFT: Water in Qinghai Province, China, in July 2014 shown before and after slow-sand filtering. **RIGHT:** Installing filters at Gongali Empower Community Center, Arusha, Tanzania.

bagged at a central location, and filters can be assembled in a very short period of time and in the same location where they will be used.

The project has further evolved into developing inexpensive slow-sand filter kits that cost less than $6 each and can be transported easily. Pails and sand cost between $3 and $6 and are obtained locally, so the system can be assembled by users or partners to improve local conditions.

"What happens to be a readily available necessity to some proves to be a tedious luxury to so many others," Jafvert says. "Purdue students have developed a successful filtration system for these developing rural areas, and 11 students have traveled to Colombia to deliver and construct the devices on site."

Over the past few years, this project has touched countless people in ways well beyond the original intent. New learning has taken place, new ideas put forth. Solutions to complex problems have been brought to bear — all culminating in one more example of Purdue civil engineers making a meaningful and lasting societal impact.

> "WHEN WATER COMES, EVERYTHING CHANGES: EDUCATION, HUNGER, HEALTH, AND POVERTY."
>
> – THEWATERPROJECT.ORG

EXPANSION TO CHINA AND AFRICA

Because of the great success of the slow-sand filter program in Colombia, the effort has expanded to East Africa and Western China.

In Africa, five slow-sand filters were constructed in March 2014 at the Nelson Mandela African Institute of Science and Technology (NMAIST) in Arusha, Tanzania, and at St. Christine School and Community Center in the Kibera area of Nairobi, Kenya, in cooperation with UN Habitat. In addition, materials for 50 more filters recently were sent to NMAIST.

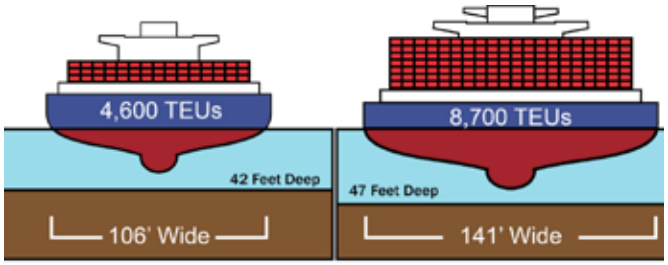
In China, Chad Jafvert and Tim Filley, professor of earth and atmospheric sciences and director of the Purdue-China Ecopartnership, arrived with materials for 16 slow-sand filters in summer 2014. In one day, all materials were prepared at Qinghai Normal University, and the next day filters were installed in homes in the rural Tu villages of Lian Da and Ji Jia Ling, north of Xining in Qinghai Province. After one more day, all systems were working, filtering turbid rainwater that had been collected and stored in underground cisterns.

In all three countries on all three continents, the slow-sand filters were successful in removing particles and dissolved organic chemicals, leaving clear water for people living in exceptionally remote areas.

Continuing partnerships exist in Colombia, Tanzania, and China. Over 50 Purdue undergraduate students have participated in research and implementation activities. Continued long-term cooperation in both regions is anticipated, with hopes of conducting a study abroad program in China in the coming years.

DIGGING DEEPER

Students help prepare conceptual designs for Savannah Harbor Oxygenation Facility



Comparison of Twenty-foot Equivalent Unit (TEU). The channel deepening project at Georgia's Port of Savannah will dredge 5 feet of mud and sand from a 30-mile stretch of river bottom to increase the depth of the Savannah River from 42 to 47 feet.

As part of their capstone design course (CE 49800), seniors in the Lyles School of Civil Engineering have a unique opportunity to work with an industry partner and help design an oxygenation facility that will be part of a $706 million project, contributing to America's second-busiest port and enhancing Georgia's export economy.

Plans to deepen the harbor in Savannah, Georgia, are more than a decade in the making. As part of a partnership, the U.S. Army Corps of Engineers, the Georgia Department of Transportation and the Georgia Ports Authority will dredge the now 42-foot-deep Savannah River to a depth of 47 feet and extend the entrance to the harbor by seven miles.

The catalyst for this project and other similar projects along the East Coast is the major expansion of the Panama Canal, estimated to be opened in April 2015. Not coincidentally, Luis Alfaro, the vice president of engineering for the Panama Canal Authority is also a Purdue Civil Engineering alumnus (MSCE '77 and PhD '80). Harbor expansion projects will allow larger cargo ships to traverse the harbor.

Dredging in the manner required, however, can deplete the Savannah River's dissolved oxygen levels, leading to potentially disastrous effects on aquatic life and creating negative ripple effects up and down the entire basin.

With a deeper channel, mean stream velocities are lower, reducing dissolved oxygen. Two oxygenation facilities will be constructed, one upriver and one downriver.

To address the challenges, 14 six-student teams will prepare conceptual designs for the Oxygenation Facilities. Designs will include geotechnical, structural, environmental, hydraulic and hydrological, architectural, and transportation considerations. Projects will also address preliminary construction schedules and costs.

"The main benefit to the students on a project such as this is learning to work in teams which, in addition to the technical issues, gives the students a taste of project management with its attendant scheduling and HR challenges," says Robert Jacko, professor of civil engineering. "Additionally, the availability of the engineering data and reports leading up to the decision to deepen the river provides the students with real-world information."

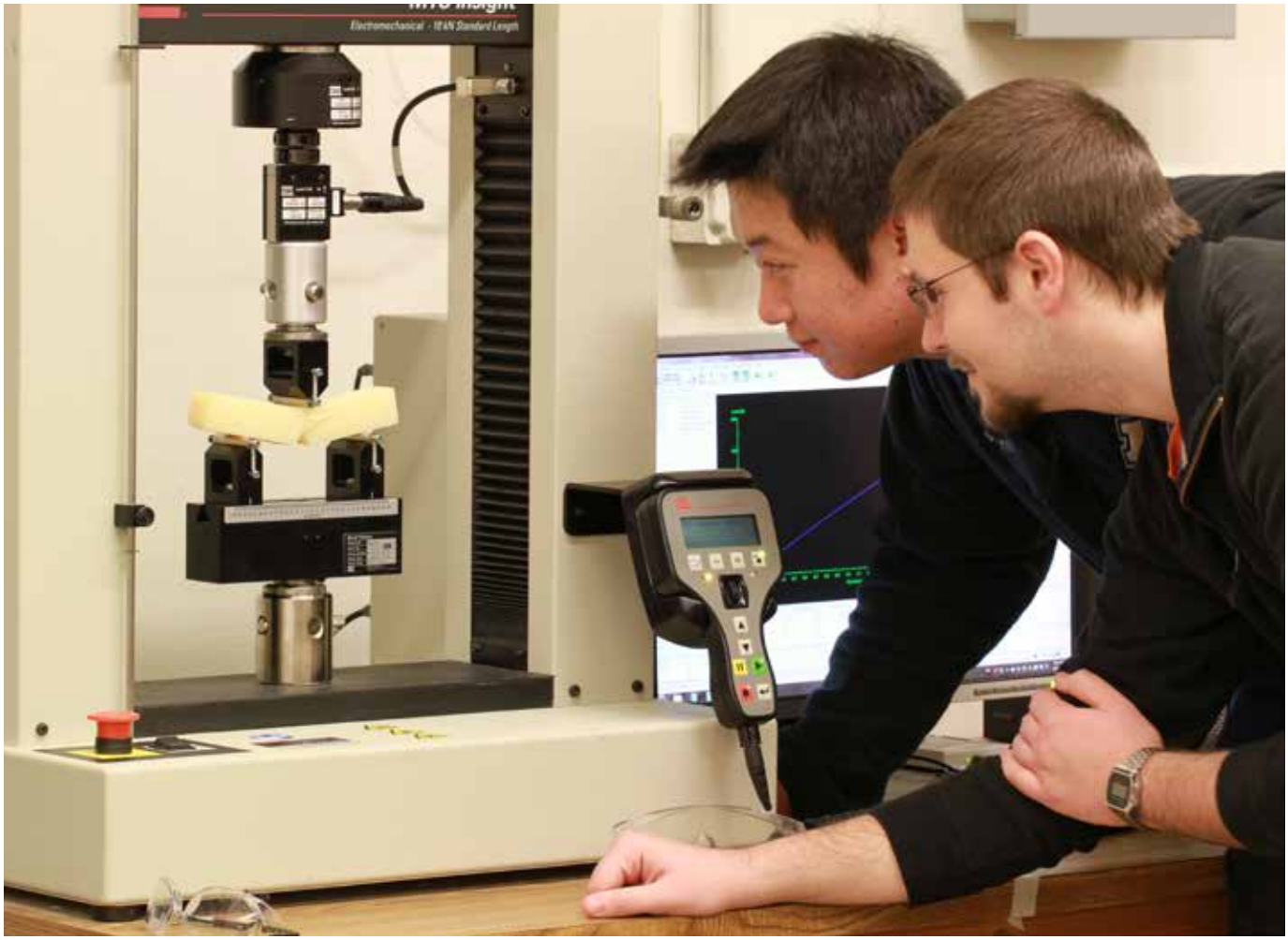
PARTNERSHIP BENEFITS STUDENTS

SuperOxygenation systems for water and wastewater treatment are designed and produced by ECO Oxygen Technologies, LLC (ECO2), an independent company headquartered in Indianapolis, Indiana. Founded in 2002, ECO2 provides eco-friendly alternatives to traditional chemical treatments for water and wastewater. David Clidence is president of ECO2 and a 2000 graduate of Purdue's civil engineering program. He is the lead person on this portion of the Savannah Harbor Expansion Project (SHEP) and is working closely with faculty and students in CE 49800.

"Partnering with ECO Technologies brings their people and expertise into the classroom to the advantage of our students," says Jacko.

CATCH A RESEARCH 'WAVE'

Summer Undergraduate Research Fellowships (SURF) program strengthens experiential learning



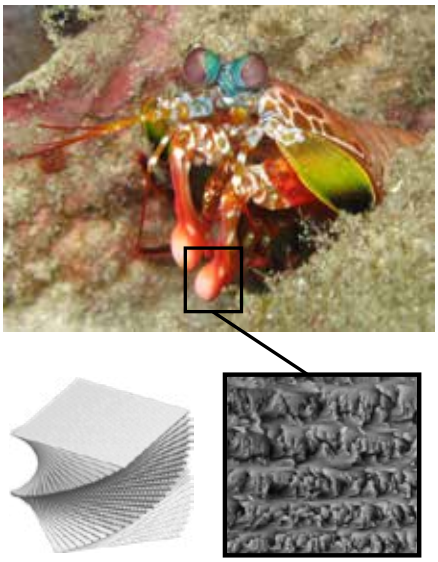
Nobphadon Suksangpanya (left) and Michael Jones supervising a fracture test being performed on a 3-D printed bioinspired helicoidal composite.

Purdue's College of Engineering launched the Student Undergraduate Research Fellowship (SURF) program in 2003 to meet the ever-increasing research demands of academia and industry by providing student experiences strengthening integrated, hands-on learning through discovery.

SURF brings undergraduate students into the modern research laboratories at Purdue, teams them with a faculty and graduate student mentor and introduces them to the research tools used on the cutting edges of science, engineering and technology.

Participants receive pay while conducting their research. During the program they also attend professional development and research seminars, present research discoveries at the SURF Symposium, enjoy social activities with other SURF students and celebrate during the end-of-summer banquet.

SURF provides an excellent way to get involved in academic research and to work alongside professors and graduate students on cutting-edge research and to make a substantial impact.



Odontodactylys Scyllarus (or "Smasher" Mantis Shrimp). Scanning Electron Micrograph of the interior of the dactyl club showing the helicoidal (or Bouligand) arrangement. "OdontodactylusScyllarus" by Silke Baron. Originally posted to Flickr as Mantis Shrimp. Licensed under CC BY 2.0 via Wikimedia Commons.

MICHAEL JONES

BIO-INSPIRED HELICOIDAL COMPOSITES: 3D PRINTING AND EXPERIMENTS

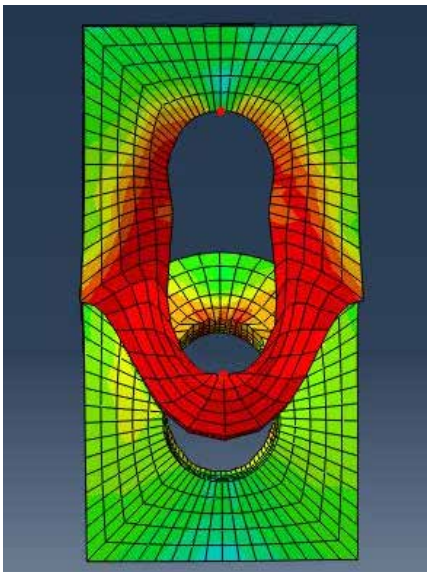
GRADUATE MENTOR: Nobphadon Suksangpanya

FACULTY MENTOR: Pablo Zavattieri, assistant professor of civil engineering

THE PROJECT: Nature often provides the inspiration for novel materials that are lightweight, strong, tough and impact-tolerant. The dactyl club of the stomatopod, or mantis shrimp, for instance, has high impact resistance and can inflict tremendous damage due to its helicoidal (spiral or helical shape) reinforcement. Jones used computer-aided design to generate models and a multimaterial 3-D printer to fabricate them. Using a series of experiments, he tested them to failure.

THE RESULTS: Analyzing similar composites of different pitch angles has provided insights into the fracture mechanisms of the structure and how they affect the macroscopic properties of the material. Jones' results confirmed that crack twisting contributes to the toughening and strengthening behavior. The experimental results identified the ideal pitch angles at which the composite was stiffest and best maintained its shape. Future work will continue to explore the influence of pitch angles on failure modes. These experiments, in combination with Suksangpanya's modeling work, will reveal design guidelines for the next generation of materials that will dominate not only building and civil infrastructure materials but also other critical areas of societal needs.

"The work done in Professor Zavattieri's lab is a significant first step toward my career goal of continuing materials research," Jones says.



The bearing deformation used in testing.

KE LIU

FINITE ELEMENT ANALYSIS ON STRUCTURAL BEHAVIOR OF SINGLE-BOLTED CONNECTIONS UNDER ELEVATED TEMPERATURES

GRADUATE MENTOR: Qiaqia Zhu

FACULTY MENTOR: Amit H. Varma, professor of civil engineering

THE PROJECT: Throughout human history, fire has been a major cause of lost lives and property. To help ensure building safety against fire, civil engineers seek to understand the behavior of structures at high temperatures. Bolted connections, specifically, are very important in steel structures. Liu helped to perform research to experimentally verify a plate-bearing computational model put forth by M. Sarraj (2007). Using experimental data from previous tests at Bowen Lab and Chiba University in Japan, Liu helped to conduct a parametric study to identify other parameters that could affect the plate-bearing behavior of bolted connections.

THE RESULTS: The finite element model is capable of predicting the behavior of bolted connections in fire with good accuracy. Also, the thickness of the plate, the end distance of the bolt hole, temperature, bolt size and loading angle can all affect the behavior of bolted connections in fire. Further studies are needed and future experiments will test bolted connections at other elevated temperature levels.

Q&A

David Yang joined Federal Highway Administration (FHWA) at the beginning of 2008. Currently, he is the Human Factors Team Leader in the Office of Safety Research and Development. He leads a multidisciplinary team at FHWA's Turner-Fairbank Highway Research Center to conduct transportation safety studies. He has co-authored more than forty journal articles, conference papers, and government reports. Yang chairs Transportation Research Board's User Information Systems Committee and serves on the editorial board of the *Journal of Intelligent Transportation Systems.*

Recently, we caught up with Yang and asked him to share his thoughts on his education from Purdue University and his professional career.

Q. WHAT LED YOU TO PURSUE ENGINEERING DEGREES AT PURDUE?

A. Primarily it was Purdue University's reputation as one of the top engineering schools. I am proud to have received all my degrees from Purdue. Also, Neil Armstrong was my childhood hero, so when I learned he graduated from Purdue that sealed the deal for me: I left my hometown of Honolulu, Hawaii, for West Lafayette, Indiana.

RIDING WITH POTUS: David Yang, human factors team leader with the Federal Highway Administration (FHWA), met President Barack Obama during a tour of the Turner-Fairbank Highway Research Center in July 2014. Yang accompanied the President as he "drove" FHWA's driving simulator and experienced how one aspect of connected vehicle technology might work. During the visit, the President quipped that it was the first time that he had driven a car, relatively speaking, in 6 years. White House photo/ Pete Souza.

Q. WHAT IS YOUR CURRENT ROLE AT FEDERAL HIGHWAY ADMINISTRATION (FHWA)?

A. FHWA is one of the modal agencies (representing multiple modes of transportation) within the U.S. Department of Transportation. We work closely with state and local governments with the goal of delivering the best transportation system in the world. In my role, I lead a team of engineers, experimental psychologists, statisticians and computer scientists to conduct research that enhances our understanding of how drivers and other road users perceive, process and respond to various driving scenarios and roadway environments. Our work improves transportation safety.

Q. CAN YOU DESCRIBE SOME OF YOUR CURRENT RESEARCH?

A. A majority of traffic incidents and crashes can be attributed to human errors. My team and I are conducting research to better understand the relationship between roadway and other transportation infrastructures on human behavior so we can improve transportation infrastructure designs and operations. Better designs will minimize human errors and ultimately save lives.

The field of transportation is especially exciting now with many new vehicle and transportation infrastructure technologies being examined. The intention of these new technologies is to assist travelers going from point A to point B safely and quickly. We are examining human factors and user behavior issues related to these transportation advancements.

Additionally, we are conducting human factors studies on topics related to intersections and interchanges, roadways, pedestrians, and traffic signs and markings. You can learn more about FHWA's Human Factors Program at www.fhwa.dot.gov/research/tfhrc/labs/humanfactors/.

Q. WHAT ARE SOME LESSONS YOU HAVE LEARNED IN YOUR CAREER THUS FAR?

A. Be courteous to others. Be consistent with your words and actions. Be prepared. Be innovative. Be thankful.

LEARNING BEYOND THE CLASSROOM

Study abroad programs provide real-life civil engineering experience

UNITED KINGDOM

Fourteen students from the Lyles School of Civil Engineering traveled to the United Kingdom in May 2014. The trip, led by Darcy Bullock, professor of civil engineering, blended experience-based learning about 18th and 19th century civil engineering infrastructure with field visits to modern 21st century engineering systems under construction.

The trip included field visits to Bechtel construction sites. Students saw the progress of the London Crossrail project, which is a new, 73-mile railway serving London and the surrounding areas. They visited a tunneling site near Canning Town, the downtown Bond Street Station and the suburban Reading Station outside of London.

Students also lived and worked together on two narrowboats. They manually operated over 100 locks in order to navigate 70-foot boats around the Stourport Ring.

NEW ZEALAND

Eighteen Purdue students traveled to New Zealand for the study abroad portion of a course on earthquake engineering. The team was led by Ayhan Irfanoglu, associate professor of civil engineering, and Jill Churchill from the Office of Global Engineering Programs (GEP) that supports engineering faculty-led study abroad programs. The University of Canterbury at Christchurch, New Zealand served as the host institute.

The group stayed in and toured the city of Christchurch and vicinity, still recovering from a series of earthquakes in 2010-11. Students saw the destruction and disruption earthquakes caused in urban life and how people coped with a large-scale disaster. Students toured historic and modern structures in various stages of retrofit, visited civil engineering labs at the University of Canterbury and listened to engaging lectures given by local experts in seismology, earthquake engineering, social sciences, emergency response and recovery planning.

ENGINEERING MAYMESTER — SWEDEN (MAY 16-27, 2015)

Purdue will partner with KTH, the Swedish Royal Institute of Technology, in Stockholm for a Maymester study abroad program. Students will participate in lectures by KTH faculty and visit full-scale sites, including tours of industry, water treatment and waste-to-energy facilities. Inez Hua, professor of civil engineering and professor of environmental and ecological engineering, will lead this 3 credit hour course (CE 497 or EEE 495). Scholarships are available.

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