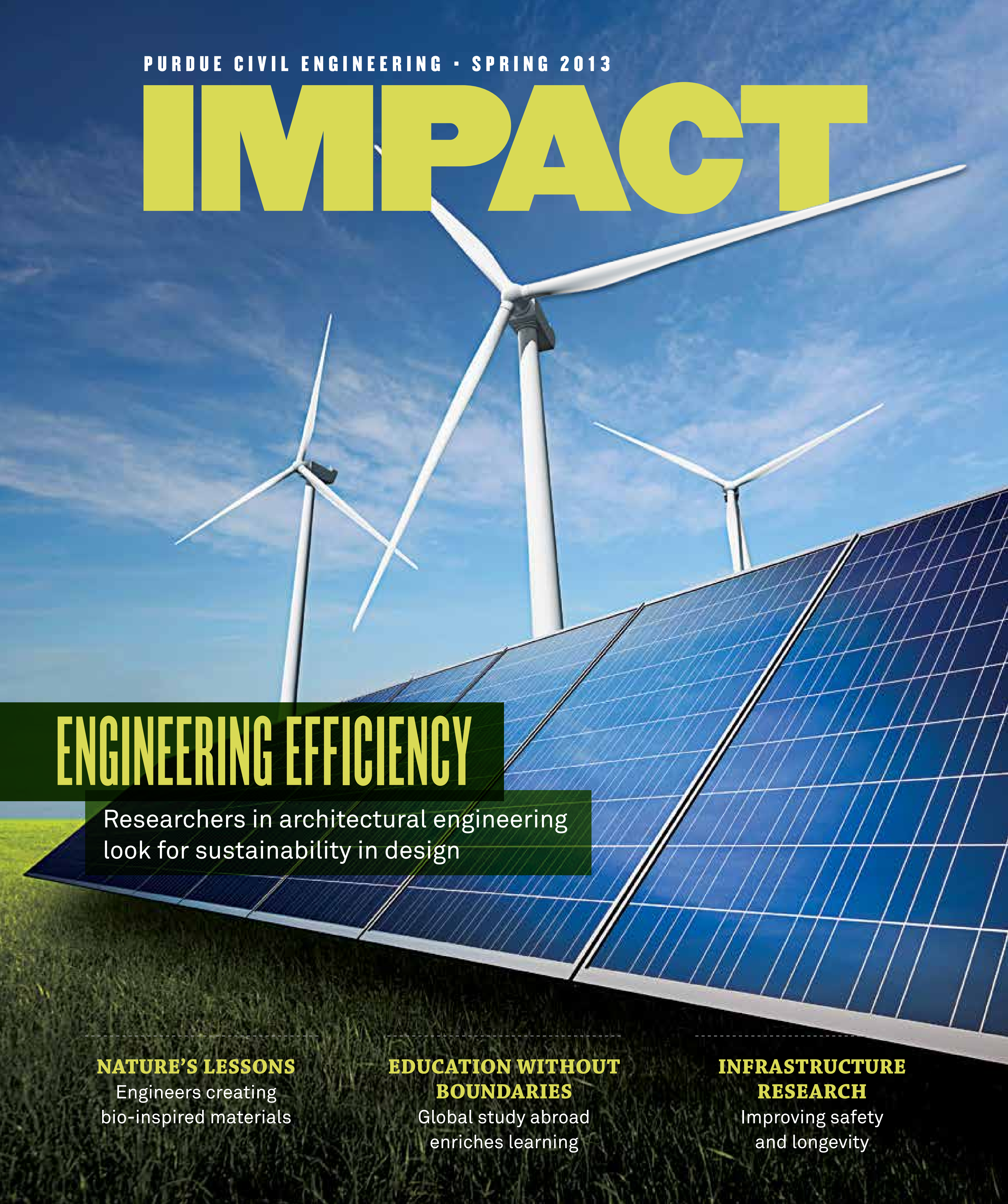


PURDUE CIVIL ENGINEERING · SPRING 2013

IMPACT

ENGINEERING EFFICIENCY

Researchers in architectural engineering look for sustainability in design

NATURE'S LESSONS
Engineers creating bio-inspired materials

EDUCATION WITHOUT BOUNDARIES
Global study abroad enriches learning

INFRASTRUCTURE RESEARCH
Improving safety and longevity

Photo by Steven Yang

GREETINGS CIVIL ENGINEERING FAMILY!

We have enjoyed commemorating with you 125 years of Civil Engineering at Purdue University and reminiscing about historical events and advances in education. Celebrating where we have come since that first fall of 1887 and recognizing that the road paved has brought us to where we are and will continue to propel us into the next 125 years.

Just in the past year, we have dedicated two new laboratory spaces, renamed our civil engineering building, published a memory book, and recognized the loyalty of our many alums, faculty, staff, students and friends.

The role that our alums play in providing advice and suggestions on our policies and thinking, together with their support that allows us to recruit and retain the best faculty, attract the best students, and bring recognition to our program cannot be overstated.

I've enjoyed meeting many of you and learning what memories of Purdue have stayed with you. We have proudly honored the accomplishments of alumni, faculty and students who have played major roles in the development or improvements of many major landmarks including the Panama Canal, the Golden Gate Bridge, the Leaning Tower of Pisa, the Hoover Dam and so many others. I am sure there are many more to come in the future.

We're pleased to present the latest issue of *CE Impact* magazine, which highlights the many activities and emerging research that helps us remain one of the top schools in the nation. Our faculty members continue to advance research that is internationally recognized.

Much of their research helps to protect people from major disasters such as earthquakes, landslides and bridge failures, making for a safer world.

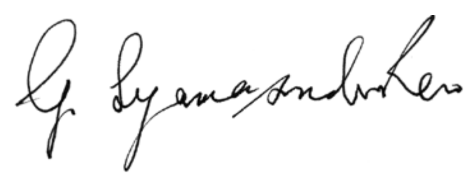
Whether it is creating stronger and lighter materials by learning from nature, utilizing computational power to understand complex behavior of natural and man-made systems, protecting our infrastructure, or thinking about "wicked problems," our faculty and students are continually in pursuit of innovative and efficient solutions.

Many faculty are engaged in interdisciplinary work and thrive on new challenges with new groups of people. Within and outside Civil Engineering, the disciplinary boundaries are now blurred but our basic driving principle remains the same: We strive for pre-eminence all across the board — in teaching, research and service.

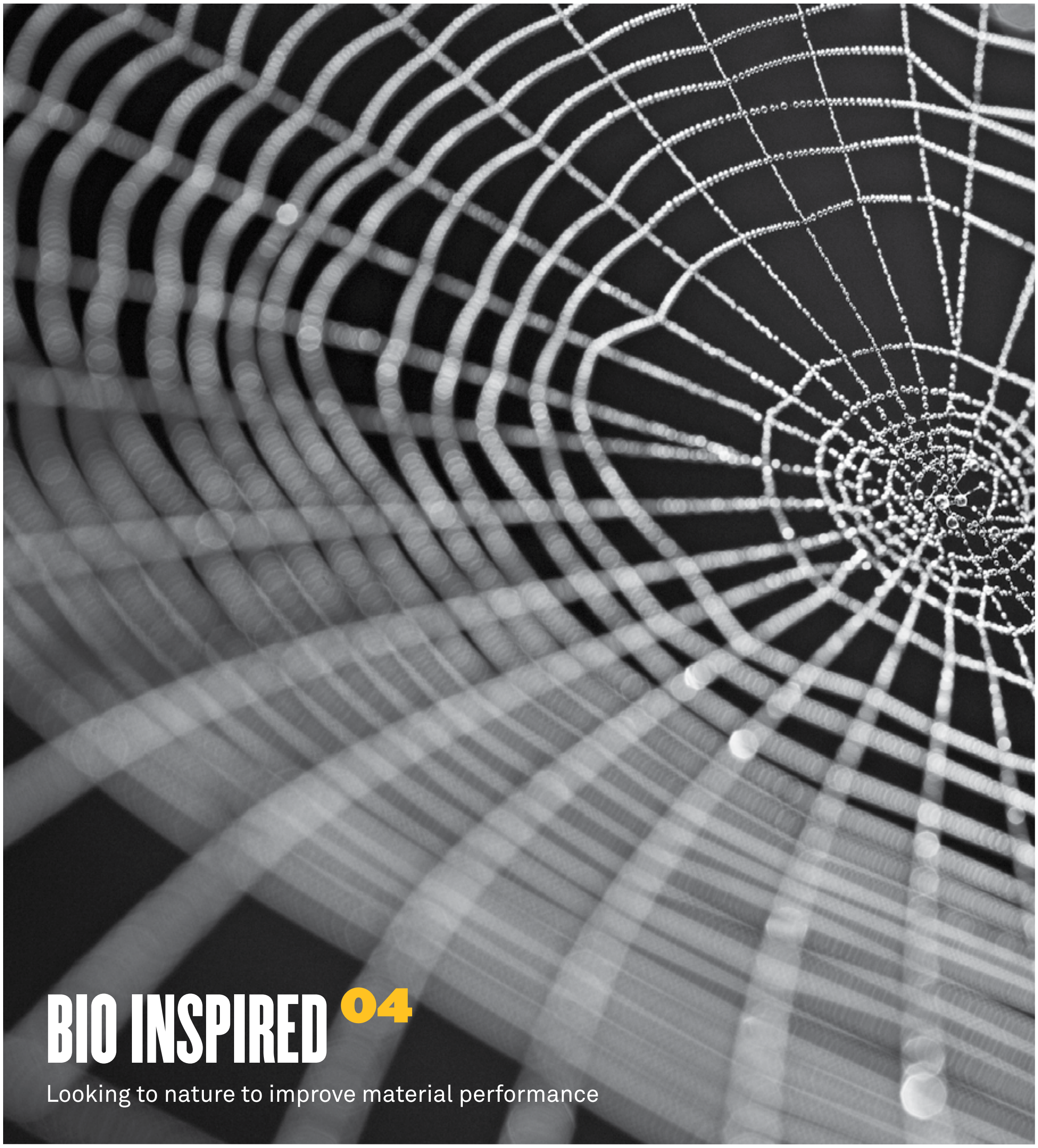
We continue our work to better prepare students for the challenges that lie ahead of them through experiential learning opportunities, enhanced global opportunities and advanced laboratory spaces. We are inventing new ways and methods to engage students, offering them more options, new and unique challenges, and varied experiences that contribute to a well-rounded development.

This year we gave scholarships and awards totaling more than a quarter of a million dollars, an amount that continues to increase each year. Our faculty and students mutually challenge each other, raising us to new heights, and we are proud of the role we play in creating tomorrow's global leaders.

As this spring semester draws to a close, I reflect over the past year with a great deal of pride. What an exciting time to take the helm of such a prestigious school. Thanks to each of you for the part you play in supporting your school. I look forward to the years to come.



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



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BIO-INSPIR

PURDUE CIVIL ENGINEERS INCREASINGLY LOOK TO NATURE TO IMPROVE MATERIAL PERFORMANCE

■ **BY WILLIAM MEINERS**

INVENTORS AND INNOVATORS HAVE LONG LOOKED TO NATURE FOR INSPIRATION. THOMAS EDISON LIKELY MARVELED AT A SUMMER EVENING'S FIREFLIES BEFORE THE LIGHT BULB WENT OFF IN HIS HEAD. SURELY THE WRIGHT BROTHERS LOOKED TO FLYING BIRDS IN KITTY HAWK BEFORE THEIR FIRST MANNED FLIGHT.

ED

Perhaps the most famous case of bio-inspired engineering comes from Georges de Mestral, the Swiss engineer who invented Velcro. In 1941, on return from a hunting trip with his dog in the Alps, Mestral examined the burrs, or seeds from burdock, stuck both to his coat and his dog's fur. Fast forward 15 years and those same hooks and loops he discovered under the microscope would be mimicked and patented to give zippers and shoestrings a run for the money in the marketplace.

It's not uncommon for civil engineers today, often pushing the boundaries of their own expertise, to look to nature for a better design. Two among our ranks include **JOHN HADDOCK**, associate professor of civil engineering and director of the Indiana Local Technical Assistance Program (IN-LTAP), and **PABLO ZAVATTIERI**, assistant professor of civil engineering with a courtesy appointment in mechanical engineering. Haddock is on a material search that could lead to better roads and surface pavement, consequently saving energy along the way. For his part, Zavattieri is looking to create stronger structural materials. Both researchers are mining nature's secrets for infrastructure solutions in civil engineering.

ADAPTIVE ENGINEERING

Natural products are used quite often in producing asphalt binder, says Haddock, who started looking into soy-based binders in 2009. The binder is refined from crude oil, a natural product itself.

Haddock continues on the road to produce better asphalt, in turn leading to energy savings, a critical challenge in road construction and maintenance. "Not only is asphalt binder refined from crude oil," he says, "but it also takes energy to produce asphalt mixtures and place them on the road."

Haddock says energy savings are achieved when new additives can help roads last longer. One breakthrough is the use of warm-mix asphalt over hot-mix asphalt, which saves energy by reducing production temperatures, thus saving fuel. Similarly, the use of recycled products like reclaimed asphalt pavement and reclaimed asphalt shingles is on the rise.

Pablo Zavattieri has studied how the nacreous layer of abalone shells gain toughness without sacrificing strength or stiffness. He recently received a National Science Foundation Career award to explore some of the bold and innovative ideas on biomimetics. Purdue University photo/Mark Simons.

Zavattieri had long been interested in nature's potential solutions to engineering problems, but he first brought his curiosity to his research about eight years ago. He began studying how shells, specifically the nacreous layer of abalone shells, gain their toughness without sacrificing strength or stiffness.

The long-term goal, Zavattieri says, is for his research group to understand how nature employs these strategies to further the knowledge necessary to design cost-effective and environmentally friendly multifunctional materials. The researchers focus on elucidating the microstructure and mechanisms behind the mechanical performances with an end goal of duplicating them in artificial materials.

"Materials in nature not only satisfy a structural function in many remarkable ways, but they also do more," Zavattieri says. "Materials can also sense, adapt and self-heal."

Zavattieri points to a biomimetic building in Zimbabwe that has no air conditioning, but stays cool through a termite-inspired ventilation system. "Architects are perhaps ahead of engineers in terms of ideas borrowed from nature as they are already thinking about green and sustainable solutions for heating and cooling by imagining special skins for buildings that can breathe, control light and exchange energy with the environment on demand," he says.

Still, the interdisciplinary nature of the research is sure to push the results. For Zavattieri, an atypical civil engineer who earned a bachelor's degree in nuclear engineering, obtained a PhD in aeronautics and astronautics and worked in the automotive industry for nine years, the research quest has never been about boundaries. "I continue to learn how to communicate with, and learn from, biologists, material scientists, chemists, physicists and other engineers working on other aspects of structural challenges," he says.

NATURAL INTELLIGENCE

"I don't believe the materials we are seeing nowadays for our infrastructure will look the same 20 years from now," Zavattieri says. "In fact, I think materials will have more functionality than just satisfying the structural purposes such as columns, beams and walls."

Zavattieri believes a bio-inspired push will continue to allow engineering materials to do more. Laptop or phone batteries could be designed as part of a protective case that is not only strong but also has great energy absorption capabilities to protect the electronics, he says. Walls and structural components of bridges, roads and buildings could also sense and adapt to environmental forces. Perhaps to save energy, but also to self-heal quickly in times of natural disasters.

"Imagine a structure in danger of collapsing after an earthquake," Zavattieri explains. "Intelligent materials and structures can sense damage and either adapt so that the load path of the structure changes, or self-heals, so lives can be saved. In those cases, only a few hours of structural integrity are needed until emergency responders can rescue people."

WHAT IS BIOMIMICRY?

Biomimicry (from *bios*, meaning life, and *mimesis*, meaning to imitate) is a design discipline that seeks sustainable solutions by emulating nature's time-tested patterns and strategies, e.g., a solar cell inspired by a leaf. The core idea is that nature, imaginative by necessity, has already solved many of the problems we are grappling with: energy, food production, climate control, nontoxic chemistry, transportation, packaging and a whole lot more.

Animals, plants, and microbes are the consummate engineers. They have found what works, what is appropriate, and most importantly, what lasts here on Earth. Instead of harvesting organisms, or domesticating them to accomplish a function for us, biomimicry differs from other "bio-approaches" by consulting organisms and ecosystems and applying the underlying design principles to our innovations.

■ **BIOMIMICRY 3.8 INSTITUTE**

John Haddock, right, is exploring soy-based binders for improved road construction. Purdue University photo/Mark Simons.

The very call to biomimicry seems to know few boundaries of possibility. Zavattieri points to solar cells inspired by plant leaves; high-strength fibers spawned from spider silk (one of the strongest materials known); multifrequency radars indebted to bats; smart materials fitted from dolphin skins or sea cucumbers; camouflage and morphing skins from squid, octopus and the like; fuel-economy flying devices linked to hummingbirds; and on and on.

RESEARCH RESTRUCTURED

Haddock's investigations into the soybean refining process that lead to soy-based products has not made him an expert in a new field, he says, but he's had to learn more about organic chemistry.

In his IN-LTAP role, Haddock can see how smarter approaches to improved roads can have rippling effects throughout local economies. Research, he says, indicates that smoother roads contribute to better vehicle fuel economy. Better-built roads require less reconstruction and overhaul. And energy savings from the asphalt bindings lighten the load of petroleum use.

Emerging technologies, such as microfabrication and nanotechnology, will further the development of biomimetic material designs. Fortunately, many of the cutting-edge facilities in Purdue's Discovery Park are providing interdisciplinary homes for such research. As the College of Engineering pushes forward on an unprecedented hiring campaign, these ever-curious faculty researchers and their students should find an inviting home at Purdue.

"As part of their training, this new generation of researchers will have to be exposed to a wide variety of state-of-the-art experimental equipment and computational techniques while becoming immersed in a true collaborative and multidisciplinary setting," Zavattieri says.

As such, Zavattieri always suggests that students embrace that training by taking courses not just within engineering, but also throughout the sciences at Purdue. "I also tell students to always be on the lookout for solutions in nature. You never know if the solution lies right in front of you."

The openness to collaboration, to take part in diverse teams working toward grand solutions, can put any young researcher on a creative course for great discoveries. Haddock encourages his students to maintain integrity in everything they do. "Beyond that," he says, "success is mostly a result of hard work."

LASER TECHNOLOGY
IMPROVES HIGHWAY CONSTRUCTION MODELS

Purdue civil engineers are working with the Indiana Department of Transportation on a "mobile mapping" system that uses lasers to create precise three-dimensional models of highway construction projects in progress.

The research is led by civil engineering associate professors Steve Johnson and James Bethel. It's a two-year project through the Joint Transportation Research Program (JTRP), a partnership between Purdue and INDOT.

The underlying laser technology is called LIDAR, for light detection and ranging, a "remote sensing" technology that works by measuring the precise distance to scanned surfaces. Pulses from a laser sweep over an object, and the backscatter of light is interpreted by a sensor to create the model.

The project focuses on learning how to use the technology in highway applications to monitor construction in progress, as a tool for management, planning and maintenance. Such a system is important because "as-built" construction often differs slightly from the blueprints.

Geomatics graduate students conduct a control survey in preparation for static laser scanning. Photos courtesy of the School of Civil Engineering.

"It's a growing area of research," Bethel says. "The more progressive construction companies and engineering design firms are getting interested."

The system collects thousands or millions of points of laser-scanning data, and these "point clouds" are then converted into detailed 3-D models of the scanned objects.

"You sample it many times per second and build a cloud of points," Bethel says. "The result is a photo-realistic model."

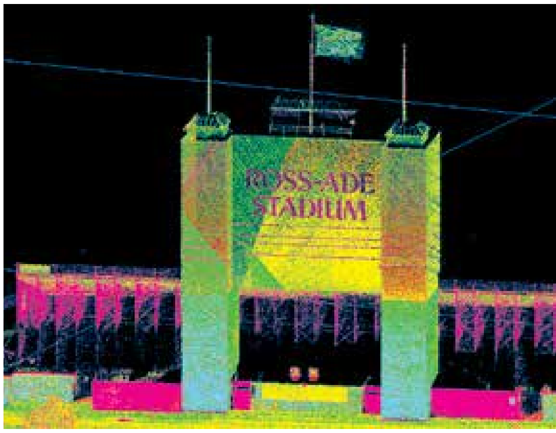
The researchers are developing software algorithms to extract features from the point-cloud data.

"There is still a lot of work to do in turning these dense point clouds into usable engineering data," Bethel says. "Nobody wants millions of points. They want their object described in a drawing or in a CAD model."

The researchers specialize in geomatics engineering, a discipline involved in the gathering and processing of geographic or spatial data traditionally derived from surveying.

Engineers began developing LIDAR decades ago, but recent advances in sensors, GPS and inertial navigation have ushered in mobile laser-scanning systems that can be mounted on a truck or operated from aircraft. Such systems can be used to make detailed models of a building or a city. GPS and miniature sensors called accelerometers allow the mobile system to accurately track its own changing position and orientation relative to the object being scanned.

"You can collect the point-cloud data while just driving around the object of interest, and this is made possible by advances in inertial navigation systems," Bethel says.



A "point-cloud" image of Purdue's Ross-Ade Stadium is part of civil engineering research on a "mobile mapping" system that uses lasers to create precise three-dimensional models of construction projects in progress.

The "intensity return" from an airborne laser-scanning mission gives a photo-like overview of the Interstate 70 corridor in Indianapolis.

Two doctoral students also are working on the project, which is a continuation of previous research with INDOT including the use of airborne laser scanning and static mapping of bridges. Partnerships with INDOT and private industry have boosted the research. Each project has involved about two students, adding up to about a dozen over the years.

"The students get experience that positions them to master this technology and to be able to understand the data," Bethel says.

Though not a focus of Purdue research, mobile mapping also could make possible a new approach for improving energy efficiency in buildings: detecting thermal leaks by creating a 3-D model that combines LIDAR measurements with data from a heat sensor, says civil engineering professor Jie Shan, who specializes in airborne LIDAR.

"The field is really exciting now," he says. "There are a lot of new things on the horizon."

■ **EMIL VENERE**

Purdue University photo/Andy Hancock.

LEE A. RIETH DISTINGUISHED PROFESSOR OF CIVIL ENGINEERING AND PROFESSOR OF ENVIRONMENTAL AND ECOLOGICAL ENGINEERING AND AGRONOMY

SURESH RAO

PRAGMATIC SUSTAINABILITY MAY BE THE ANSWER TO A HEALTHY FUTURE

Humanity's future well-being may very well depend on solving "wicked problems" plaguing the world's ecosystems — problems introduced by people — that might only be solved through "pragmatic sustainability."

Suresh Rao sat on a beach in Western Australia one day during a sabbatical leave in Perth, contemplating where to take his distinguished career next.

He'd risen to the top of his specialty area: hydrology and biogeochemistry. Things were becoming too comfortable, too boring. It was time to go in a new direction.

"Changing my research emphasis every five to seven years is the norm for me," says Rao. "I like the change. It allows me to interact with a whole new network of people, to get out of my comfort zone. It's a challenge to start at the ground floor and climb all the way up. No elevators, one step at a time!"

The previous decade he'd been concentrating on research into developing methods for cleaning contaminated soils, sediments, and groundwater, studying how urban, industrial and agricultural practices can be better managed to reduce their negative impacts.

His new direction would focus on an environmental paradox: How had humanity continued to thrive despite the consistent degradation of the environment? Was technology providing an edge to the people of the developed world, maintaining their well-being in the face of escalating air and water pollution, deforestation and loss of habitat and other ecosystem, services?

And how is this dynamic affecting the rest of the world?

"More than half of the world population is negatively impacted," he says. "Either people can't afford the technology because they live in poverty or they are living in environments that are being degraded to provide the resources for the technology."

But, when will mounting ecological degradation in the future begin to cause a decline in global human well-being?

"Many people in academia and policy making believe that the way we have done things in the past isn't going to cut it in the future," Rao says. "Fundamentally, the recognition is that we have to look at 'wicked problems.' Our attempt to solve them only educates us a little more about the problem. There are no silver bullets, because the problems are so complicated and multifaceted."

An example is the rising concentration of carbon dioxide in the Earth's atmosphere.

"Who put it there? We did, on this side of the world. Now that the other side wants to do the same thing, China, India and the others, we are saying you can't do that, and they are saying, you got it, we want it."

The only way to fix the problem is by using a pragmatic-sustainability approach.

"We are not tree-hugging puritans," says Rao, who teaches interdisciplinary graduate courses, including the Ecological Science and Engineering Colloquium. "We can't stop them from doing what they're doing, really, and we can't give up what we have, really. We all have to talk about it and find pragmatic solutions."

He encourages his students to seek compromises.

"We need to educate our engineers and scientists to think differently, to consider many kinds of ramifications in design and implementation. They have to walk outside of engineering and science spheres and talk to other people in other fields. We have to help broaden their intellectual horizons."

How else will the global community ever hope solve the world's most wicked problems?

ENGINEERING EFFICIENCY

Researchers in architectural engineering look for sustainability in design

BY WILLIAM MEINERS

Ming Qu (left), Thanos Tzempelikos and Panagiota Karava, all assistant professors of civil engineering, are researching sustainable energy solutions as part of Purdue's architectural engineering focus. Purdue University photo/Mark Simons.

Of all the global challenges staring down engineers, sustainable energy solutions may be the greatest. To somehow do more with less helps with depleting natural resources and improves sustainability efforts. Given the fact that buildings account for as much as 40 percent of the total energy use in the U.S. and Europe, it's not surprising then that the architectural engineering emphasis brings a decidedly integrated approach to lightening the load of energy consumption in residential and commercial buildings.

Announced in 2008, the architectural engineering emphasis has been one of the fastest growing areas in Purdue's School of Civil Engineering. That same year, four cluster hires — Travis Horton, Panagiota Karava, Ming Qu and Thanos Tzempelikos, all assistant professors of civil engineering — came to campus with cutting-edge ideas about how to turn the energy tide.

CAUSE FOR COLLABORATION

Through retrofits and smart construction practices, building energy consumption can be greatly reduced. As LEED-certified levels come into construction play, sustainability is becoming a driving business force. For Horton, who earned a Purdue PhD in mechanical engineering in 2001, the multidisciplinary approach will pay the most dividends. It's important, he says, that everyone from the different design processes are talking to each other.

"Sustainability is about meeting the needs we have today without compromising future generations," Horton says. "The production of renewable energy is important, but I don't think we'll be able to achieve full sustainability without addressing the demand side of things."

A renewed emphasis on constructing zero-energy homes and buildings, which exhibit a net-energy consumption of zero over a typical year, takes in matters of both supply and demand. Horton says the supply side can use solar and wind energies, or through the combustion of bio-fuels for small scale, distributed power generation. The demand side of the energy equation looks at new technologies that improve the energy efficiency of a facility.

Karava recently received the 2013 New Investigator Award from the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) for her work on model predictive control of high-performance buildings. The award will further her research that could enable net zero energy performance and market viability within the next decade.

Her innovative research considers energy balances with the smart grid of the future that could deliver optimal solutions, enabling consistent building performance. "This includes integration of key building-integrated solar energy systems and smart operation strategies that were not possible five or 10 years ago," Karava says. "The enabling technology simply did not exist, the computational power was limited and the weather forecasts were not as accurate."

Tzempelikos won the same New Investigator Award from ASHRAE in 2011. He wants to optimize perimeter-building zones for energy and human comfort. "I investigate the balance of natural light benefits versus the thermal requirements in nonresidential buildings through the use of an innovative building envelope and lighting technologies," he says.

Tzempelikos has often collaborated with mechanical engineers to achieve better designs. The new Herrick Center for High Performance Buildings, currently rising on Purdue's campus, will provide a state-of-the art living lab for technological breakthroughs in the area of indoor environmental and energy efficiency research. And the new full-scale architectural engineering facilities at the Robert L. and Terry L. Bowen Laboratory for Large-Scale Civil Engineering Research offer unique opportunities for experimental testing of new building technologies and concepts.

"The building envelope, lighting and comfort delivery systems have to operate in harmony in order to achieve improved energy performance and enhance occupant satisfaction," says Tzempelikos, who has also collaborated with mechanical and electrical engineers in the area of controls and optimization theory.

Bowen Lab has also provided a home for collaborative work between Karava and her industrial partners. The team can test and prototype innovative comfort and energy delivery systems along with methods and algorithms for smart building operations.

SMARTER BUILDINGS, OPTIMAL RESULTS

Along with the cross-disciplinary efforts is the need for integrated design components. For Qu's part, the research is a systematic approach to deliver a renewable HVAC system, which includes solar panels alongside absorption chillers, storages and controllers.

"We're developing an integrated solar cooling and heating system that takes into account the energy, economic and environmental performances," says Qu, whose research has been sponsored by the National Science Foundation and the U.S. Department of Energy (DOE).

In her work also at Bowen Lab, Qu and students designed, built and tested a state-of-the-art high-temperature solar cooling and heating system. Their findings helped establish a foundation for the development of a solar map of the U.S., which can be used by government agencies, builders, homeowners and manufacturers to support decisions about solar thermal systems.

The $1.5 million DOE grant came after Qu's yearlong study of green roofs. She and four faculty researchers from the University of Idaho and City College of New York are studying energy efficient integrated sandwich roof systems. "I'm in charge of the research activities related to energy performance testing, evaluation and modeling for the new roof system," she says. "This award allows us to explore innovative research projects related to building heat transfer through the building envelope."

Travis Horton, assistant professor, stresses a multidisciplinary approach to sustainable design.

Ming Qu, assistant professor, is researching advanced solar cooling and heating systems. Purdue University photo/Mark Simons.

As it is with most solar energy research, the biggest challenges for Qu are the high cost of solar panels and the demands of the highly technical operation.

"The breakthrough will be cost-effective, high-efficiency stationary high temperature solar panels constructed of high-performance coating and absorption material with an innovative heat transfer principle," she says. "This can significantly increase the market share of solar cooling and heating."

With his focus on employee comfort, the end users of building office spaces, Tzempelikos is developing new integrated models that take into account interactions between the different domains and dynamic systems. Essentially, he's matching heating, cooling, lighting and occupants with things like automated lighting and smart façade and thermal systems — all from an early design phase. An equally important challenge, he says, is to be able to "map" occupant comfort to indoor conditions and describe the human interaction with building systems for more realistic and comprehensive predictive models. The chance to collaborate with researchers from perception-based engineering in Herrick Labs is furthering these discovery efforts.

"A breakthrough on intelligent building controls and building materials with dynamic properties that respond to changing weather and internal conditions can help maximize energy savings while achieving human comfort," Tzempelikos says.

SOLAR HOMES AND STUDENT SUCCESS

For the increasing number of civil engineering students flocking to the architectural engineering emphasis area, the hands-on building opportunities have a way of bolstering classroom learning.

IN 2011, Purdue finished second at the Solar Decathlon in Washington D.C. Nineteen teams, including four international teams, designed and built affordable, energy-efficient, solar-powered homes for the competition. Horton served as an advisor to eight students working on the mechanical and electrical portions of the home. Within the constraints of relatively tight budgets, Horton says they built a very conventional-looking solar-powered home. "We approached it from an integrated design standpoint," he says.

Purdue's INhome was a true collaboration, involving the work of more than 200 students from six colleges and schools, including engineering, technology, liberal arts, health and human sciences, agriculture and business. The solar home had to be built, tested, deconstructed and rebuilt in West Lafayette twice prior to the competition. Then once again in the nation's capital. Ultimately, it was built and donated to the Lafayette community.

For the faculty researchers encouraging students, both undergraduates and graduates, to embrace cross-disciplinary challenges, competitions like the Solar Decathlon become literal and figurative building blocks for civil engineers on the brink of careers. "The essential message I try to deliver to students is about critical thinking and hard work," Qu says. "To be successful, people must do both of these well."

Tzempelikos wants his students to understand the limits of conventional energy resources and the absolute importance of reducing building energy use for the nation and the world. He also believes they can further the research. "There are a lot of innovative technologies that are not being used because we don't have a complete understanding of how they work," he says. "We also don't have integrated models to describe their performance and integration with other building systems. This has to change."

Q&A

ON THE BUSINESS OF SUSTAINABILITY

Sustainability is becoming big business. And whether it's the construction of a 120-tower wind farm in Brookston (2010) or a $57 million addition to the Lafayette Waste Water Treatment Plant, **BOB BOWEN** (BSCE '62, HDR '07), founder and chairman of Bowen Engineering, knows a thing or two about building big. Both of those projects earned AGC (Associated General Contractors) Build America Awards, considered the Oscar of the construction industry, bringing his company total to six such awards. A longtime sponsor of Purdue, Bowen is now donating his time in the classroom.

How important are sustainability issues in the construction industry?

Without question, it's very important. All owners are looking to the construction industry to improve the process and raise the bar on sustainability, and we're trying to lead the way. Our headquarters in Indianapolis is Gold LEED-certified. It has all the latest technology.

Bowen Engineering has hired a number of Purdue civil engineers over the years. In what ways are the graduates different now from when you graduated?

Most graduates are more family-oriented. They try to balance their lives better. However, the best of the best are still doing whatever it takes to be successful. My best project managers are the hardest workers.

You've had the opportunity to teach a leadership class as the first Donn E. Hancher Distinguished Fellow at Purdue. What's the main message you try to get across to students who want to be successful leaders?

I'm now teaching in my third year here. I focus on a positive attitude and leaders building leaders. People can naturally be negative, so it takes courage to break out of that shell and build others. Great leaders laugh three times more than average leaders. If you smile at people, they will smile back at you. You naturally give people back what they give you.

You're known for your fierce loyalty to your alma mater. Why is it important to you to stay connected to Purdue?

I went to work for a Purdue grad when I got out of Purdue (W.M. Lyles Construction Company), and I knew I had the greatest job in the world. All of my senior managers are Purdue grads. Purdue's program is considered the best in the world. I've been on about every committee I could at Purdue. Part of being a leader is giving back. Purdue just turns out great engineers who happen to have great values.

■ **WILLIAM MEINERS**

'INTELLIGENT' TECHNOLOGY REDUCES CONSTRUCTION, MAINTENANCE COSTS

■ BY EMIL VENERE

Purdue civil engineering researchers are working with the Indiana Department of Transportation to implement a new "intelligent compaction" technology that promises to make highway construction more efficient.

"The potential is to reduce the cost of infrastructure construction and maintenance and the burden on the taxpayer while speeding up the construction process," says Phillip Dunston, professor in the School of Civil Engineering and the Division of Construction Engineering and Management.

Highways are constructed layer by layer. The lowest stratum consists of compacted soil worked to the proper density using a machine called a roller-compactor. This foundation must be compacted properly or the road could fail prematurely, he says.

The inspectors with the Indiana Department of Transportation (INDOT) traditionally test these compacted layers with a dynamic cone penetrometer, or DCP: A pointed cone-shaped instrument is driven into the soil, revealing whether the compaction was done properly and uniformly.

HOW IT WORKS

Intelligent Compaction equipment are diesel-powered machines with heavy steel drums to compress soil, granular materials, or asphalt in the construction of roads and soil foundations. Intelligent compaction uses sensors, algorithms and an onboard computer to analyze vibrations from the roller during road construction, providing data about the compacted soil.

Dunston and Hubo Cai, assistant professor of civil engineering, are working with INDOT to perfect the use of intelligent compaction data to improve construction efficiency and consistency. The technique represents a potential new quality control and quality assurance tool that could save time and money.

The civil engineers have teamed up with Thomas Kuczek, professor of statistics, working through the Joint Transportation Research Program (JTRP), a partnership between Purdue and INDOT. Three doctoral students also are working on the research with INDOT project engineer Elsadig Ibrahim.

Commercial manufacturers equip some roller-compactors with instrumentation that provides the ability to map the soil layers in real time as they are being compacted. Sensors called accelerometers relay data to an onboard computer, revealing information about the compacted soil's stiffness and strength.

"As you are compacting the soil you make several passes, and as it becomes more dense it gets stronger or stiffer," Dunston says. "You want to ensure that each layer has the appropriate density."

A color-coded display provides information to the equipment operator.

"This is important for quality control purposes," he says.

The Federal Highway Administration is facilitating development of the technology, working with INDOT and other states.

"It would be a huge improvement if they can leverage the onboard instrumentation to reduce the inspector collected DCP data," Cai says. "First of all, you are able to see which areas are weak as you are riding over them in the roller-compactor. You know right then whether you should do more work in that area."

This real-time measurement capability offers significant advantages over DCP testing, which has to be performed after the compaction is done.

"Then, if it is under-compacted, you have to go back and redo a large area to be sure that you are thoroughly fixing the problem," Cai says. "If it's overcompacted, that means you've wasted time and money."

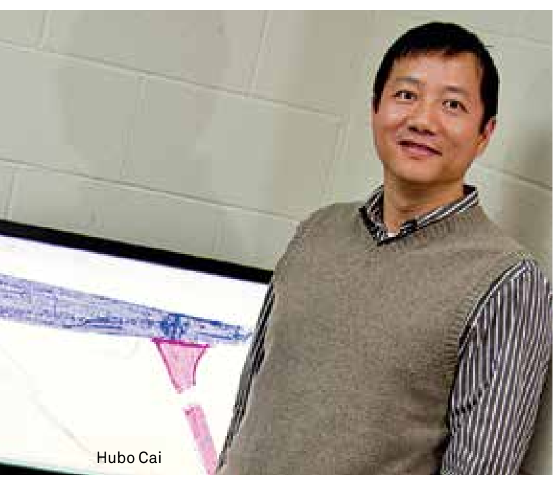
Whereas measurements are taken randomly at various points with DCP, intelligent compaction takes continuous measurements of the compacted soil stiffness. The method enables INDOT inspectors to pinpoint trouble spots.

Purdue's role is to determine how to compare the DCP data accurately with measurements taken with intelligent compaction.

"The state and contractors need to be confident that the output from an intelligent compaction system is reliable," Dunston says.

Complicating matters is that different brands of roller-compactors provide data differently. The Caterpillar machines used in the research transmit data in strips corresponding to a drum's progressive movement over the road. It is difficult to compare the point locations of DCP accurately with the strips of data from the intelligent compaction system.

Phillip Dunston



Hubo Cai

"THE POTENTIAL IS TO REDUCE THE COST OF INFRASTRUCTURE CONSTRUCTION AND MAINTENANCE AND THE BURDEN ON THE TAXPAYER WHILE SPEEDING UP THE CONSTRUCTION PROCESS."

— PHILLIP DUNSTON

The FHWA has co-sponsored work to develop Veda, software for viewing and analyzing geospatial data from various intelligent compaction machines. The Purdue researchers' findings may translate into changes in Veda.

"A big challenge is to visualize the comparison of DCP and intelligent compaction data," Cai says. "We have our own visualization platform."

The system uses GPS data to match the DCP points with the intelligent compaction strips, but often they do not align because gaps exist between the strips, he says. This requires that mathematical and statistical techniques be harnessed to match and compare the data and to create the mapping display.

"Statistical methods exist to do this work, but we need to properly apply them," Cai says. "First, we have to correctly comprehend the data we are getting, and then we have to visualize these data in a display for the equipment operator."

The researchers are studying the technique's reliability in work on U.S. 31 in Kokomo, Indiana, during the most recent construction season.

"We need to gauge how confident we can be in the comparisons between intelligent compaction measurements and DCP data," Dunston says.

The work will continue over another construction season.

Another issue in construction of infrastructure facilities is documenting the as-built plans for future uses in maintenance, repair and reconstruction.

Dunston and Cai also are working together on another interrelated project through the JTRP aimed at creating an "intelligent" method for making a precise record of underground drainage elements, utility lines and other buried infrastructure "assets" as they are being built. The information would be valuable to engineers, construction and maintenance workers in the future.

"This is needed because often the construction of infrastructure is not exactly the same as the design," Dunston says. "The reality is that sometimes things get adjusted in the field."

Uncertainty about the exact location of infrastructure leads to problems later when maintenance and other construction is required. Then, the assets have to be located in a time-consuming and expensive inventory.

"The best time to collect precise data on such assets is during their construction," Cai says.

GPS, among other technologies, can be used to fix the location of assets. The researchers are working with INDOT to determine what information should be collected, when it should be collected, what type of technology should be used to collect it and how to work the process into a broad range of construction activities.

Both of the projects are made possible by the widespread introduction of sensors such as accelerometers and GPS devices.

"We now have the ability to collect massive amounts of data with sensing technologies," Cai says. "The challenges are, how do we understand the data and then how do we respond to it?"

INNOVATIVE RESEARCH IMPROVES SAFETY WHILE SAVING MONEY

■ BY DELLA PACHECO

Strained budgets and aging infrastructure — a mix that can not only pose financial risk for communities but also compromise driver safety. Purdue Civil Engineering researchers are finding new ways to stretch limited dollars to maintain and extend the life of current roads and bridges while designing new cost-effective and safe structures.

INNOVATION LEADS TO COST SAVINGS, LESS TRAVEL DISRUPTIONS

Working with the Indiana Department of Transportation (INDOT), Robert J. Frosch, professor of civil engineering, and his research team at the Robert L. and Terry L. Bowen Civil Engineering Laboratory for Large Scale Research, have studied integral abutment bridges throughout the state. In this type of bridge, the joints and bearings are eliminated so that expansion and contraction occurs at the bridge ends. Removing the joints, Frosch says, saves costs, reduces maintenance, results in a smoother ride for drivers, and even reduces damage from snowplows. Frosch's research team instrumented a number of bridges to better understand how the structures behave or move over the span of years.

Robert J. Frosch

"Temperatures cycle between hot and cold over the course of a year, and the bridge expands and contracts with the weather," Frosch explains.

The key is to design the structure properly so it can sustain the types of loads it will encounter.

"Through instrumenting the structure, we determined how the bridge interacts with the soil," Frosch says. "We instrumented down the length of the piles that support the bridge to observe how the piles behave or deform. We also included displacement sensors that tell us how the bridge was physically moving. We compared this with our computer models in the lab to determine if the field findings correlate."

The data helps the team improve computer models for better design of these types of structures.

Frosch says the research has allowed INDOT to safely design bridges up to 1000 feet — five times the original limit of 200 feet. "All of the standards have been changed to reflect our findings and have been incorporated into the design standards for the State of Indiana, he says.

ACCELERATING KNOWLEDGE IN THE LAB

In a related study, Frosch's team built a 25-foot-long scale model integral abutment bridge in the back yard behind Bowen Lab to study skew angles and their impact on bridge behavior. The study bridge had a 45-degree skew — the angle at which a roadway or waterway passing under the bridge intersects.

"The problem with instrumenting field structures is sometimes INDOT isn't building a bridge that contains all of the variables that we would like to include in our study," Frosch explains. "We were looking at high skews, and a structure wasn't readily available at the time of the study. In addition, the model structure allows us to vary parameters that can't easily be done in the field."

Instead of waiting an entire year to get results in the field, the researchers imposed the deformations that bridges encounter over the course of a year in a matter of hours, instrumenting the test bridge as they would in the field.

The results will help inform new guidelines for bridge design and construction.

COATINGS STUDY LOOKS TO INCREASE LONGEVITY OF ROADS

Other research with INDOT is experimenting with coatings on rebar and bridge decks to extend the life and safety of the materials.

When bridge decks are poured, curing occurs and over time the material shrinks. As it shrinks cracks develop. The researchers are looking at ways to control the width of the cracks to keep de-icing salts from getting down into the reinforcement. Often these salts get into the deck and cause corrosion.

"The green bar you often see in road construction is an epoxy-coated reinforcing bar, Frosch says. "This technology has been around for a while but often the coating becomes compromised by cuts or damage to the coating allowing the salts to corrode the bar."

They have looked at reinforcing bars such as fiber-reinforced polymers made of glass and carbon fibers. Taking lab findings, a bridge deck was constructed by INDOT using glass fiber reinforced polymer bars. Sensors were installed inside the bridge deck that allow monitoring of behavior.

Frosch says that the team is currently looking at stainless steel, zinc-clad, and galvanized reinforcing steel bars as possible corrosion-resistant materials for reinforcing bridge decks.

"We have built mock-ups of bridge decks with full-depth concrete that we have embedded with the reinforcement materials as we would in the field," he says "We're subjecting these to cycles of salt water to understand which ones are corrosion resistant and which ones aren't as resistant but are better than uncoated steel."

Through the research they also hope to better understand price points. In an urban area like Indianapolis, using a more costly, high-corrosion resistant material might make sense because there's a "lifecycle cost," Frosch says.

"It's not just the physical cost of replacing a bridge but the cost of travel time, detours, inconvenience — the user cost — that is difficult to quantify but is very important to consider in many urban areas."

COMING FULL CIRCLE

Robert Connor, associate professor of civil engineering, was asked to visit San Francisco's Golden Gate Bridge recently to discuss a possible project to install monitoring sensors on the 75-year-old iconic suspension bridge. Charles A. Ellis, a Purdue Civil Engineering professor from 1934 to 1946, was the chief engineer responsible for the structural engineering and design of the nearly 9,000-foot bridge.

By extending the life of new and replacement structures, municipalities are saving dollars that can be used to bring current structures up to standards that will improve their use for decades.

"Through our research we can advise on how to better design structures to extend their life beyond what has currently been considered acceptable," Frosch says.

FIELD TEST YIELDS SURPRISING RESULTS

Robert Connor, associate professor of civil engineering, has led several projects using monitors to assess safety of high mast towers and bridges throughout the U.S. After doing this for more than 15 years, Connor says he has come to the conclusion that less is more when it comes to gathering important data.

Spending more for multiple sensing devices on a structure doesn't always make the best sense. "It's just more data to go through and more equipment to maintain," Connor says.

His team has worked with INDOT to monitor bridges that are considered fracture critical. These include trusses or two-beam bridges and are a special concern for owners such as INDOT as well as the Federal Highway Administration, and for good reason. The concern has been if one girder or a member in a truss line fails, the bridge will collapse.

Together they conducted a test on a 150-foot span truss bridge in southern Indiana putting approximately 75 tons of sand on the bridge deck. Then working with demolition experts, they installed shape charges and severed the lower chord to simulate a fracture. What the team found, though surprising to many, was what Connor and his team anticipated all along — the bridge barely "noticed" the damage.

"People believed that if you cut one truss the other isn't strong enough to support the bridge and it will collapse," Connor says. "In reality, it is a complex structural system capable of redistributing loads, allowing the bridge to remain stable, even under a considerable load of 75 tons."

From the monitoring images and analytical data, the team can apply their findings to other bridges of similar construction. "It's basically full scale testing," Connor says. "I don't know of anyone who has done this type of testing of a bridge in situ using shape charges to simulate a fracture."

All the more reason for creating low-cost and highly effective ways to monitor infrastructure, Connor says. "It's like healthcare. Let's figure out what your risk factors are and keep track of those. Usually it's the older structures where problems occur. You do a risk analysis to provide intelligent solutions."

"There's no such thing as a smart structure," Connor says. "There's just those that are intelligently instrumented."

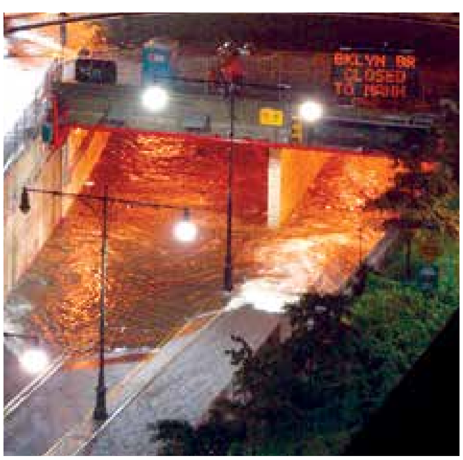
PATH OF LEAST RESISTANCE

NEW MODELS AID EVACUATION PLANNING

As Hurricane Sandy made landfall in New York City in October and turned into a "super storm," flooding city streets, freeway tunnels and subways, the importance of Purdue civil engineering professor Satish Ukkusuri's research became as clear as a blue sky.

Even with advance warning and prior disaster experience, effective evacuation planning can be the difference between life and death.

"During Hurricane Rita, for example, many people evacuated at the same time, due to overreaction for Hurricane Katrina three weeks earlier causing mass evacuations," he says. "Then everyone was stuck on the freeway for a very long time and ran out of gas which left vehicles stranded, further worsening the traffic congestion. The gas stations were depleted of fuel; people were out of food and water. But if we could stage the evacuation properly and we could understand how households react to evacuation warnings and communicate the warnings effectively in real time, we could build better evacuation strategies."



Rita hit Texas and Louisiana in 2005, killing seven people directly and 120 overall from other factors, including evacuation mishaps, and causing $12 billion in damage. By comparison, at least 125 deaths and $60 billion in damage are attributed to Sandy, making it is the second-costliest storm in U.S. history after Katrina, which caused more than $120 billion in damage and claimed more than 1,800 lives.

Using survey data collected from people in regions impacted by hurricanes, Ukkusuri is working with researchers at Florida International University and Virginia Tech to develop detailed models to predict how populations behave during hurricane evacuations. Public policymakers and emergency preparedness agencies will use the models to improve how evacuations are planned and carried out.

"The models will lead to a practical means of understanding specifically how people behave during disasters such as hurricanes, floods and tornados," Ukkusuri says. "Who will evacuate and who will stay? When will they evacuate, where will they go and which routes will be congested? Understanding these issues is important to make evacuations safer and more effective."

Funded with several grants from the National Science Foundation totaling about $1.25 million, the interdisciplinary work involves engineering, social sciences and policymaking.

"There are two major pieces to this work: behavioral research and computational modeling," Ukkusuri says. "The behavioral part is to learn how households in different demographic groups respond to hurricanes."

The engineering piece focuses on building transportation models for safe evacuation using the survey data. Different scenarios are analyzed with the computational models to improve the evacuation efficiency for future hurricanes. For Hurricane Sandy, Ukkusuri is analyzing data from new technologies such as social media to understand how individuals used these tools to share, respond and improvise during disasters.

"We are building a large-scale simulation model using computational techniques," Ukkusuri says. "There is a great need now to bridge varied disciplines and build tools from a holistic point of view, and that is what we are doing. These kinds of models are going to be more important in the future because of increasing frequency and severity of storms and rising population density in the coastal areas."

■ **ERIC NELSON**

IDEAS TO INNOVATION LAB ENABLES HIGH-TECH EXPERIENCES

The addition of a new laboratory space has professors and students enthusiastic about real-world engineering experience.

The Lyles Family Ideas to Innovation Laboratory in the School of Civil Engineering was created to provide students with a collaborative, high-tech workspace for lab projects relating directly to industry challenges.

Professor Monica Prezzi uses the lab for Geotechnical Engineering I, an introductory course to the field. Prezzi says the lab gives students experiences that are vital to career success. "We can plan course activities to be exactly like what students will be doing in the industry," Prezzi says. "Just watching and listening is simply not enough. Doing experiments and observing soil response when subjected to loading or to a hydraulic gradient is a totally different experience."

Labs in Prezzi's course require students to perform property tests on various soil types. These allow engineers to assess how strong, how deformable, how compressible or how permeable a soil is. Using properties of a given soil, engineers are able to calculate factors such as how much a soil may consolidate and how quickly it will do so. Knowledge of these properties is vital when designing structures, such as an embankment on soft, compressible soil.

The lab facility consists of several different rooms dedicated to the needs of specific classes, such as Prezzi's course. Additionally, the labs host laptops, large-scale testing and advanced geotechnical equipment, and digital image correlation setups and software. Resources are also available to help students design, prototype, build, and demonstrate different projects.

Pablo Zavattieri, assistant professor, teaches an introductory course in materials engineering. He uses a section of the lab to understand the fundamental behavior of materials under extreme conditions, including large deformations and fracture. Using a large universal testing machine, students are able to apply these extreme loading conditions to study how materials respond and to relate those measurements with the fundamental material properties learned in class.

Furthermore, laptops and imaging software in the labs allow students to run simulations of materials and tests, or to capture detailed footage of their own experiments.

"In my class, this is the first time that students are able to take a concept they learned on a chalkboard and then actually go and test it in the new labs with real materials," Zavattieri says. "We also challenge the students to figure out the best way to get the labs accomplished with the tools available, so that they'll be able to solve problems given to them when they're out in the industry or continue into research."

Chan Jeong, a junior who took Zavattieri's course in the fall, says he enjoyed using the equipment for destruction purposes.

"Even though there are safety restrictions, it was still exciting to try and destroy steel rods and other materials," Jeong says. "The lab is filled with equipment that helped me immensely to understand the course concepts and to expand my knowledge."

Jeong says the experiences have helped him prepare for research projects and graduate school.

■ RACHEL FLORMAN

Purdue University photos/Mark Simons

ALUMNUS PLAYING AN IMPORTANT ROLE IN

PANAMA CANAL EXPANSION

Global trade is set to change as the Panama Canal gains a third lane that will accommodate ships three times larger than any vessel that has sailed through its locks.

Since the SS Ancon became the first ship to navigate the canal locks on Aug. 15, 1914, the waterway has seen nearly 5 percent of all world trade move through the locks, saving ships from having to journey around Cape Horn and through the stormy Drake Passage at the tip of South America.

Civil engineering alumnus **LUIS ALFARO**, vice president of engineering for the Panama Canal, is an integral part of the project team, overseeing technical aspects responsible for the safety and reliability of all of the canal's vital structures. He shares details on the engineering work for the canal, including technical support for the expansion project and how Purdue Engineering prepared him for his career.

LUIS ALFARO *(MSCE '77, PhD CE '80), SECOND FROM RIGHT, LEADS THE ENGINEERING TEAM RESPONSIBLE FOR THE SAFETY AND RELIABILITY OF THE PANAMA CANAL'S STRUCTURES.*

Q&A

WHAT IS YOUR ROLE IN THE PANAMA CANAL EXPANSION?

As vice president of engineering for the Panama Canal, I manage the engineering division, which is part of the Engineering and Programs Management Department. The division is involved with technical work for the entire canal and is responsible for the safety and reliability of all of the canal's vital structures.

An important contribution to the Canal Expansion Program was to guide efforts to assess the seismic risk in the area, so the new locks and dams are built with design criteria consistent with best practices.

The division also lends technical consulting support on engineering matters to all other units in the Canal Authority and performs engineering designs for the canal as required. Our division designed all of the excavation and dredging projects as well as the large cofferdam structure that enabled the construction of a dam that will separate the new and old channels on a portion of the Pacific end. The new locks project involves a design-build delivery method.

HOW DID YOU COME TO THIS POSITION?

I started as a geotechnical engineer and progressed to manager of the geotechnical branch and then manager of the engineering division before being named to my current position.

AS A NATIVE OF PANAMA, HOW DO YOU VIEW THE IMPORTANCE OF THIS EXPANSION TO YOUR COUNTRY AND THE WORLD?

As excellent as the original design and construction of the canal were in 1904-1914 by the U.S. Corps of Engineers, the history of the canal is one of continuous improvements. Maintenance and improvements to the locks have been ongoing. The present Canal Expansion Program is a natural evolution to maintain the relevance of the canal in the growing maritime industry. This is a tremendous opportunity for the Republic of Panama, as the canal and its associated sectors of the economy — the ports, railroads, free zone and services — represent close to 30 percent of the country's gross national product.

HAVE YOU WORKED WITH ENGINEERS FROM OTHER COUNTRIES ON THE PROJECT?

Expertise has been greatly enhanced by lessons learned from the landslide control program that was recommended in the mid-1970s by the great geotechnical engineer Arthur Casagrande. The support of the Geotechnical Advisory Board that was formed in the mid-1980s was another essential ingredient. The board is composed of world-class consultants who provide invaluable guidance in making the canal's geotechnical group of engineers and geologists a very strong team. This expertise has been instrumental to improving the reliability of the navigation channels and increasing their capacity. It is one of our most important contributions in the growing relevance of the canal in the maritime industry.

I have worked closely with this board and we invited Professor Antonio Bobet, who is associate director of Purdue's Global Engineering Program, to join the group. His distinguished career and strong expertise in rock mechanics make him a valuable addition. Rock mechanics is a vital component of geotechnical engineering in the canal, where rockslides have been a consistent problem since its construction.

HOW HAS YOUR PURDUE ENGINEERING EDUCATION PREPARED YOU FOR YOUR CAREER?

The most important lessons my distinguished teachers imparted include appropriate management of uncertainty and risk, the ways to model problems in a practical and realistic manner and how to focus conservatism on the truly critical issues. They also taught me how to document my experience through lessons learned and how to recognize the various types of motivations colleagues may have when participating in a technical discussion.

Technical work in the canal has always been challenging and rewarding. In a certain sense the canal structures are like a giant laboratory observed over the course of a century. Many types of technical insights can be derived from this, including how much the engineering profession has advanced in this time frame. Problems that were not within reach of the profession when the canal was built are well understood and managed today. Risk-related issues can be better understood when infrastructure performance is examined over a long period.

WHAT CHALLENGES OR GOALS DO YOU HAVE LEFT TO CONQUER?

Some goals include the development of a tool for integral risk management of the canal's vital structures in order to achieve a balanced exposure to risk commensurate with international standards applicable to structures of similar importance. We specifically need to address the seismic capacity of the original locks and dams.

In addition, we hope to contribute to the identification and design of new water resources for future growth of the canal. And we want to leave a well-trained workforce to continue addressing the canal's technical needs in the future.

Education Without Boundaries

Global study abroad enriches learning

Purdue's Global Engineering Program and study abroad opportunities offer students valuable tools as they step into roles of international leadership, engaging and improving communities both at home and abroad.

Study abroad options through the School of Civil Engineering span the globe from Panama to London, China and beyond. The opportunity to consult with engineers and see firsthand a variety of engineering projects broadens students' education and helps them to develop a global view of engineering.

Geotechnical graduate students view Panama Canal project

Nine members of the Geo-Institute Graduate Student Organization (GI-GSO) accompanied Professor Antonio Bobet and Professor Emeritus Vincent P. Drnevich on a trip to study the Panama Canal in October.

Doctoral student Alain El Howayek, president of the organization, says the highlight of the trip was interacting with Purdue alumnus Luis Alfaro, vice president of engineering for the Panama Canal Authority.

"Technical presentations were given by more than 14 geotechnical engineers and geologists," El Howayek says. The presentations covered the canal expansion program, cofferdam design criteria, Borinquen dams, Panama Canal geology, landslide control and dam safety programs and other important engineering topics.

"The trip provided the students an opportunity to see large projects to develop insight into geotechnical project elements and execution," El Howayek says. "This is essential to complement the theoretical knowledge developed from research, laboratories and classrooms."

Similarities, differences viewed in Brazil

A group of civil engineering students traveled to Brazil in May 2012 to experience the country's thriving engineering projects.

Professors Rodrigo Salado and Monica Prezzi took two years to develop the program, "Brazil Energy and Transportation Infrastructure," in collaboration with colleagues in Brazil.

The goal was to develop an understanding of the wide range of engineering problems that are part of mega projects there and how specific engineering disciplines integrate with one another.

They paid a visit to the Alberto Luiz Coimbra Institute for Graduate Students and Research in Engineering (COPPE) at the Federal University at Rio de Janeiro. The majority of the labs are dedicated to materials research, but their focus was split between transportation and petroleum extraction applications.

COPPE is a world leader in energy and transportation research. Its graduate studies and engineering research programs rank number one in Latin America and are globally respected.

After hearing technical presentations, students toured multinational energy corporation Petrobras's $250,000 virtual laboratory. The lab allows users to experience firsthand what it feels like to be on an oil platform through a sophisticated 3-D visual display.

Green buildings and sustainability in China

World-class architectural engineers must be aware of the world and sensitive to the environment and international cultures, says Ming Qu, assistant professor of architectural engineering in the School of Civil Engineering.

In the summer of 2009, Qu led a group of 18 students to China to study green buildings and sustainability. The program aimed to teach students sustainable building technologies from both the theoretical and practical perspectives through lectures on campus and two-week field trips.

Qu addressed sustainable design in the classroom, and notable sustainable practices for built environment were explored during the field trips. Renowned professors in China in the field of sustainable design and technology presented lectures. Guided tours of sustainably built projects were led by designers, builders and owners.

Students also had the opportunity to experience China and its culture. In Beijing, students were hosted by Tsinghua University, and in Shanghai, hosts were from Tongji University.

The group had an opportunity to view the "Bird's Nest" and "Water Cube," built for the 2008 Olympics in Beijing, and the Shanghai World EXPO infrastructure and exhibition hall, among other locales.

Qu says many students commented that the study abroad course changed their lives.

■ **BY DELLA PACHECO**

Going for the Gold Leads to Career

As civil engineering student Emily Foote was looking toward graduation in 2010, there was one thing that she felt would make her college education complete: study abroad.

That opportunity has led to a career as a subcontract administrator for Bechtel Australia.

Foote learned of a 2010 Olympic Gold trip to London led by Dulcy Abraham, professor of civil engineering, and sponsored by Bechtel, Fugro and CH2MHill. Students studied engineering and construction issues related to the 2012 Summer Olympics. It also was an opportunity to examine many different aspects of construction in an international setting while earning credit for a technical elective.

"My experience in London was much different than I expected," Foote says. "While we were there only a short time, it was very well planned and we spent time on various project sites, focusing on the challenges involved with construction projects on an international level."

Before the trip, Foote says, she knew little about Bechtel. In London, she was impressed with Bechtel's representatives, who explained their experiences in the global firm. It was at one of the sponsored dinners that Foote happened to be seated next to a college-hire from Bechtel's London office. "He told me that he was a subcontract specialist and explained his day-to-day experiences," she says. "My eyes lit up and something clicked. I knew then that I wanted to work for Bechtel."

Foote started her career at Bechtel Oil, Gas & Chemicals as a subcontract specialist in Houston. After 11 months, Bechtel offered her a position as a subcontract administrator on Curtis Island, Gladstone, Australia, where she has been the past year. She manages subcontract packages ranging in value from $4 million to $65 million.

Her study abroad experience prepared her for some of the hurdles she faces working on an international construction project.

"My civil engineering degree has provided the technical expertise needed to give me credibility among thousands of experienced construction workers and offered insight behind the decisions that are made," Foote says. "I encourage current CE students to take advantage of whatever study abroad opportunity is a good fit. You never know what you'll learn about yourself or who you will meet along the way that could lead to the next chapter of your life."

■ **DELLA PACHECO**

RESEARCH BRIEFS

01

Cary Troy *: New buoy offers real-time Lake Michigan data in Indiana*

Boaters and beachgoers visiting the Indiana shoreline of Lake Michigan now can learn current conditions such as water temperature, wind speeds and other information provided by a new environmental sensing buoy.

Placed four miles off the coast of Michigan City on Sept. 4, the buoy is the first of its kind in the Indiana waters of Lake Michigan.

The buoy, jointly owned and operated by Illinois-Indiana Sea Grant and the Purdue University School of Civil Engineering, will advance the understanding of near-shore waters, alert the public to hazardous conditions, protect water quality and improve weather forecasts. From about April 1 to Nov. 1 each year, the TIDAS 900 buoy will relay real-time information on wind speed, air and water temperature, wave height and direction, and other environmental characteristics.

A new buoy four miles off the coast of Michigan City, Ind., in Lake Michigan will provide real-time information on lake conditions for boaters and others just off the shore. (Illinois-Indiana Sea Grant photo/Anjanette Riley.)

"This is an understudied area of Lake Michigan," says Cary Troy, assistant professor and principal investigator for the project. "It is an important improvement to now have coverage on this part of the lake where before we did not."

The buoy is important because conditions in the lake's center are much different from conditions closer to shore, says John Taylor, a National Weather Service meteorologist at the northern Indiana office.

"There are not many observations out on the lake itself, and for a long time we only had a single buoy that was 50 miles north of Michigan City," Taylor says. "The more information we have for near-shore areas the better."

Snapshots of lake conditions updated in 10-minute increments are available to swimmers, boaters and anglers on the Sea Grant website at http://iiseagrant.org/buoy. The site highlights conditions of particular interest to the lake's recreational users, such as wave height, wind speed and surface water temperature. A webcam provided by the National Oceanic and Atmospheric Administration's Great Lakes Environmental Research Laboratory will allow site visitors to see the area surrounding the buoy in real-time. Graphs showing trends over 24 hours help the buoy be a day-to-day tool for communities that rely on Lake Michigan for food, drinking water and recreation.

"This site allows people to easily access information and better understand the impact real-time data collection has on near-shore research and recreation," says Carolyn Foley, assistant research coordinator for Illinois-Indiana Sea Grant, based out of the Purdue University Department of Forestry and Natural Resources. "Over the years, we plan to include additional tools and applications that could be used to teach people about near-shore ecology. We're working with stakeholders to ensure that what we develop is useful in terms of what data we collect and display and how we choose to display it."

Information collected from the buoy also will be fed into the National Data Buoy Center operated by NOAA. The Michigan City buoy contributes to a worldwide network of buoys and coastal stations, all designed to observe and track marine environmental characteristics.

Data from the buoy will be used by forecasters at National Weather Service offices in northern Indiana and Chicago, the Indiana Department of Natural Resources, and researchers at Purdue to improve predictions of hazardous weather, help the fishing community better target particular species throughout the season and learn more about circulation patterns that affect Lake Michigan's biological activity. With real-time monitoring, researchers will be able to adapt weather, water quality and ecosystem models to the constantly changing lake conditions.

02

Amr Kandil *: Environmental policy impact on construction in Qatar*

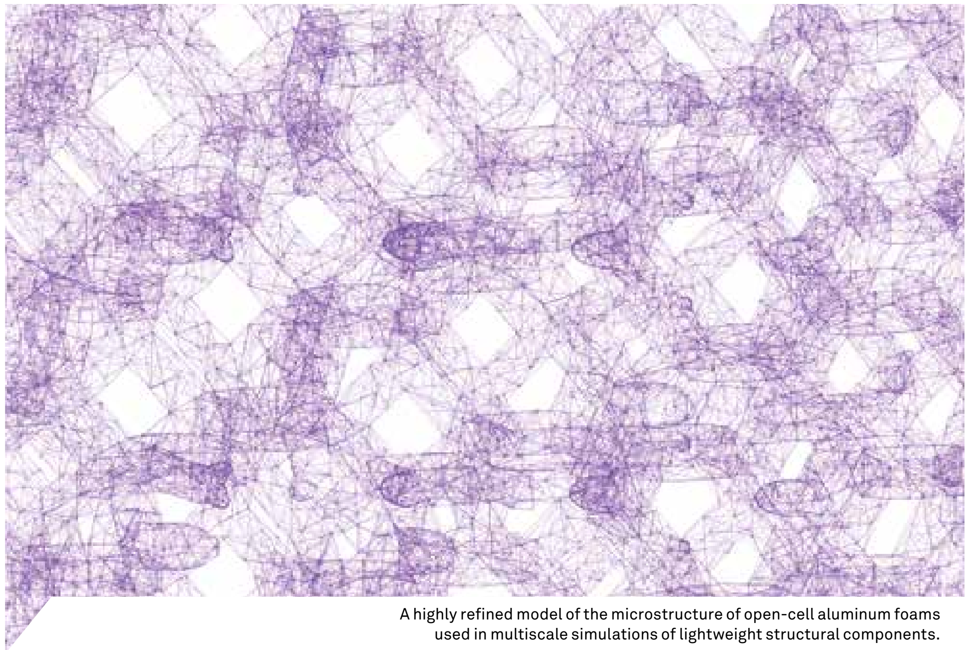
Amr Kandil, assistant professor of civil engineering, and his research team are looking at major environmental impacts of the construction industry that have led to policies that encourage environmentally conscious buildings and construction practices. These policies have received the attention of the Qatar government, and many owners there are starting to develop projects with an emphasis on the environment.

Kandil received a grant of over $200,000 from Qatar University to study the benefits and challenges facing construction in that country.

For example, environmental policies have a strong focus on the use of local resources and materials, which could decrease project procurement lead times and improve schedule performance of contractors.

These benefits, however, come with a few challenges that need to be analyzed such as the need to develop local expertise in Qatar.

Kandil's project aims to develop a simulation-based framework for evaluating the impact of environmental policies on the construction industry in Qatar. The research will evaluate the extent of the adoption of environmental policies, develop an agent-based simulation framework of the construction industry that gauges the benefits and challenges associated with different levels of environmental policy adoption, and evaluate the framework using analyses of construction projects in Qatar as well as the United States.



A highly refined model of the microstructure of open-cell aluminum foams used in multiscale simulations of lightweight structural components.

03

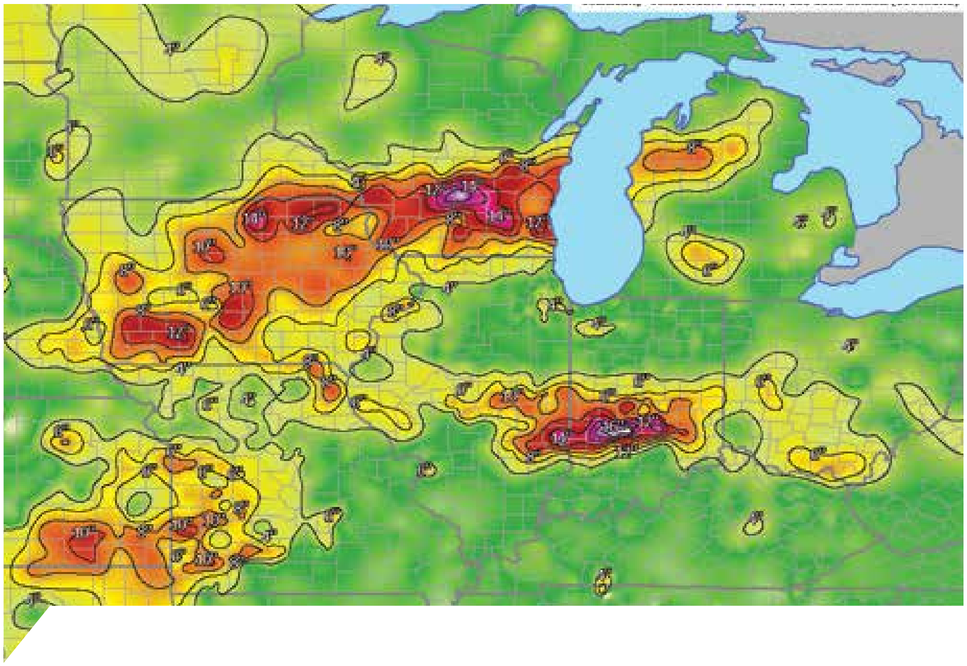
Arun Prakash *:* *Advanced modeling and simulation for structure design*

Computer simulation is playing an increasingly important role in the design of structures, says Arun Prakash, assistant professor of civil engineering. As computation continues to pervade almost every aspect of our society, the importance of simulation-based design, construction, monitoring and maintenance of structures will continue to grow as well.

Prakash's research is directed toward developing models of structures and systems that are capable of simulating a wide variety of structural behavior, such as multiscale models that can capture both global structural behavior and local material response. He is examining models that couple structural behavior with physical phenomena that can simulate thermal behavior, airflow within and outside the structure and energy characteristics.

He is also investigating the use of these models in hybrid testing and simulation that combines physical lab testing with models to allow system-level simulations of structures. Using hybrid simulation, physical testing of critical structure components can be conducted in a lab environment while still capturing their in situ behavior as if they were a part of a big structure. A key challenge with hybrid simulation is to be able to capture the dynamic behavior of a structural system in real time.

Advances in modeling and simulation capabilities are accompanied by the growth of computational resources from current peta-scale supercomputers to very large, highly parallel, heterogeneous exa-scale machines and beyond. Aside from sheer power and memory requirements, the challenges associated with running numerical simulation codes on these machines include fault-tolerance, interoperability, high degree of parallelism and software sustainability.



04

Venkatesh Merwade *:*
Tackling floods through hydrodynamics

Floods are the costliest and most frequent natural disasters in the world. According to data from the National Weather Service, over the last 30 years, the average economic loss in the U.S. from floods is nearly $8 billion, with 94 deaths per year.

Despite billions of dollars in investment in the form of dams, reservoirs and levees, the economic and human loss from floods continues to rise.

During the first half of June 2008, much of the Midwest received one storm system after another. Parts of Indiana, Illinois, Iowa and Wisconsin received more than a foot of rainfall, and widespread flooding was reported along the Mississippi River and its tributaries. Dams and levees were breached. Historical record-high streamflows occurred in some of the major regional rivers, and reported river crests exceeded 500-year levels in some locations.

Venkatesh Merwade, assistant professor of civil engineering, and his research group are working with the U.S. Geological Survey to develop a better understanding of river processes through an integrated approach that involves field instrumentation, computational modeling and education. An instrumentation network is being set up along the Wabash River north of the Purdue campus to conduct research in flood dynamics.

Merwade says there is a growing interest in addressing flood-related issues through nonstructural measures in the form of using floodplain storage or creating wetlands for attenuating flood peaks. The U.S. Army Corps of Engineers, which led the implementation of most structural measures in the U.S., is now focusing on implementation of more of these nonstructural measures.

This shift in focus from structural to nonstructural measures is driven by the goal to achieve environmental sustainability in flood damage reduction.

05

Ghadir Haikal *:*
Computational modeling of interfaces in complex structural systems

The design of large-scale structural systems such as high-rise buildings and long-span bridges against natural and man-made hazards often requires using the techniques of numerical simulation to predict their response under extreme loading events such as blasts and earthquakes, says Ghadir Haikal, assistant professor of civil engineering.

Haikal's research seeks to build an interdisciplinary program in computational mechanics that promotes the analysis and design of complex civil, mechanical and bio-mechanical systems characterized by the interaction of multiple components at different levels and scales.

To build the models, her team is piecing together simpler component models through interfaces. The presence of interfaces is a defining feature of complex systems. The bulk of the modeling process occurs at these interfaces where it is critical for the computational model to accurately reflect the nature of interaction between the components in the presence of large motions, material nonlinearity, dynamics effects, sliding and separation in unilateral contact problems such as seismic soil-structure interaction.

Haikal's work involves developing novel coupling techniques for a large class of complex systems that possess the ability to accommodate complicated interface behavior effectively to predict the response of large-scale coupled problems and structural systems to extreme events such as blasts, hurricanes and earthquakes.

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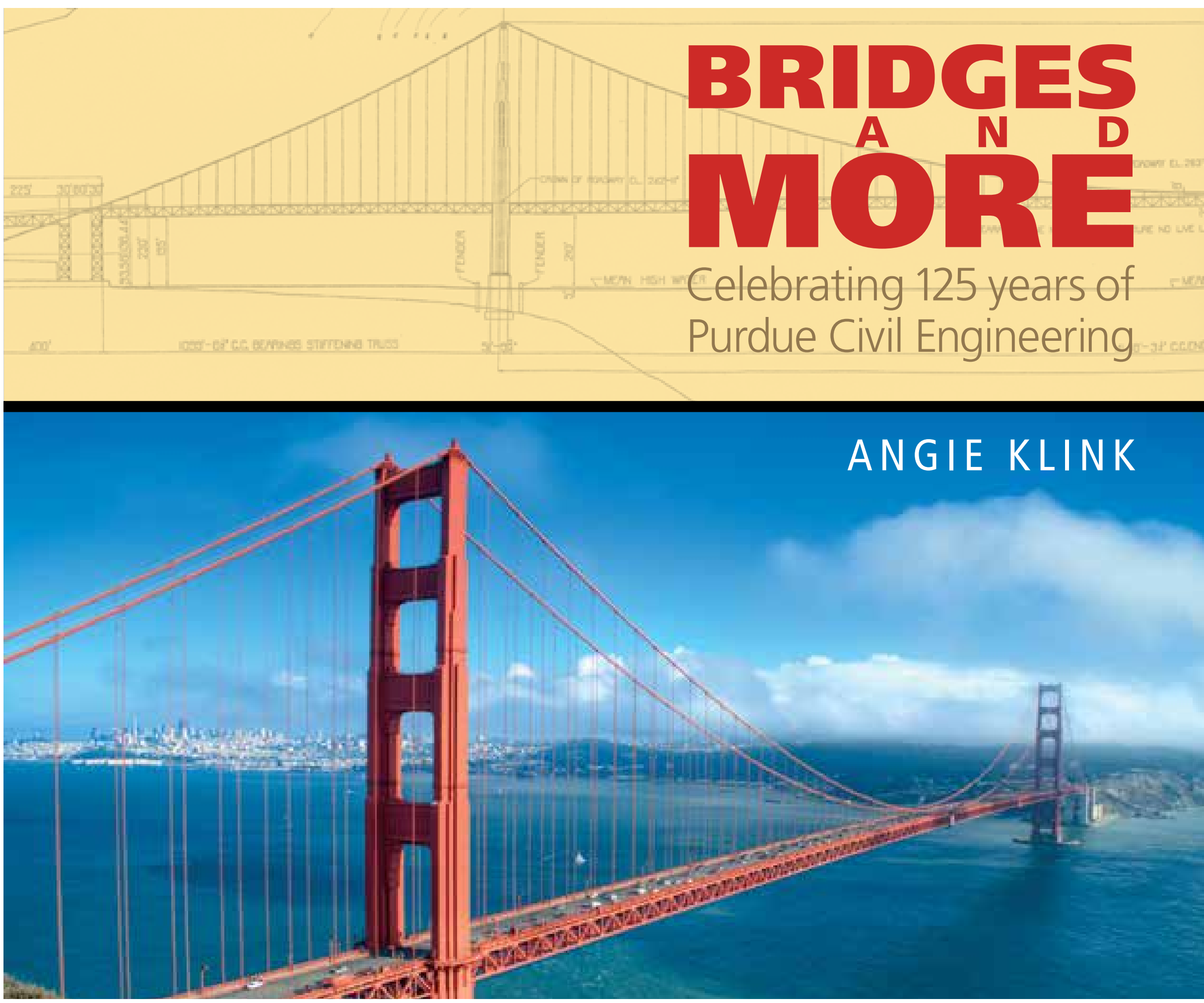

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