

# 21ST CENTURY EVOLUTION

**Innovative construction technologies  
to grow the industry**

**PURDUE CONSTRUCTION ENGINEERING AND MANAGEMENT**

# ENGINEERING IMPACT

SPRING 2010

**CEM Interns**  
Building on  
an education

**Professor Remembered**  
The Lloyd S. Jones  
Memorial Scholarship

**Big Mac Builder**  
McDonald's  
global developer

## On My Mind



**Welcome to the Spring 2010** issue of *CEM Impact* magazine.

Our focus this issue is risk taking and innovation. As institutions of higher education rush to address concerns of global importance, it is imperative that we, as a discipline, continue to reach out in new and unexplored directions.

In this issue you will read how CEM at Purdue is defining itself as a new interdisciplinary paradigm, one poised to tackle the needs of an ever-changing field. Through calculated and informed risk, we are realizing significant strides in research and innovation.

What an exciting time for CEM. From students taking on internships in burgeoning areas; to new faculty bringing diverse expertise into our already rich intellectual community; to alumni in industry who continue to achieve greater heights; and finally our many forward-thinking donors who support our upward trajectory in the future — all these are our sturdy partners in facing the challenges ahead.

Thank you for your continued enthusiasm and support.

Together we grow our legacy as a leader in this field as we reach even greater heights.



**Makarand "Mark" Hastak**  
Professor and Head

## Tell Us What You Think

Share your Purdue memories, react to a story, or let us know your thoughts about a particular issue. Write to us at [peimpact@purdue.edu](mailto:peimpact@purdue.edu). In doing so, you grant us permission to publish your letter in part or in whole in an upcoming issue. We reserve the right to edit letters for length and clarity.



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## COVER PHOTO

**About the Dinosaurs:** Messer Construction Company provided the cover photo and was the general on-site contractor for the Indianapolis Children's Museum. The world-class learning center includes more than a dozen galleries spanning the arts, sciences, and humanities. The museum completed phase one of its intermodal facility in 2004 and selected the Messer team to begin phase two in 2008. One of the CEM sponsor companies, Messer continues to push innovative technologies, such as integrated project delivery methods, to sustainably build the construction industry.



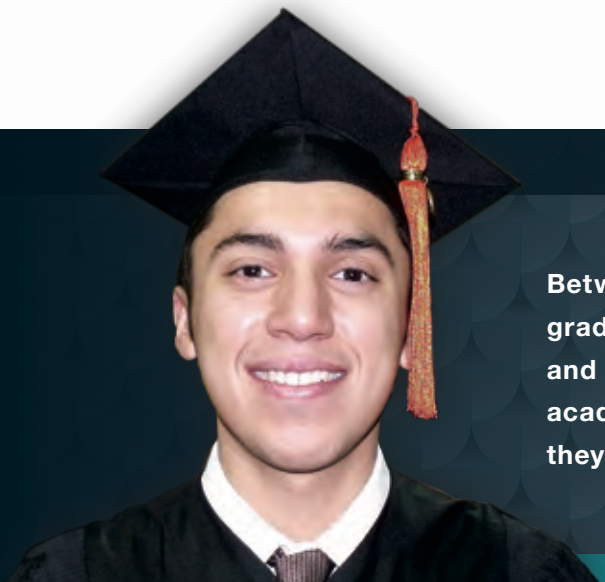
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10



## AROUND CEM

Between December and the forthcoming August graduates, the Division of Construction Engineering and Management is handing out 32 degrees in the 2009-10 academic year. We wish all CEM graduates the best as they begin their careers.

◀ Sergio Merino [BSCEM '09]



**SPRING COMMENCEMENT: MAY 15**



## International Success

A team from Purdue and Shanghai Jiao-Tong University, China, won a bronze medal at the biennial Mondialogo Engineering competition initiated by UNESCO and Daimler. The proposed project, “Building Rural Houses After Disaster in Dujiangyan Earthquake Areas of Sichuan Province, China,” targeted reconstruction of the affected region after the 2008 earthquake. The Purdue team was led by PhD student **Nader Naderpajouh**. **Saumyang Patel**, a CEM graduate student, attended the award symposium in Stuttgart, Germany, in November.

▲Nader Naderpajouh, Saumyang Patel, and Makarand Hastak with the bronze medal they won at the international competition. [Courtesy photo]

### Hastak Named Editor-in-Chief

We are pleased to announce that CEM Professor and Head **Makarand “Mark” Hastak** has been named editor-in-chief of the *Journal of Management in Engineering*. The journal, according to its Web site, “offers an avenue for researchers and practitioners to present contemporary issues associated with management and leadership for the civil engineer.”

#### A message from Dean Jamieson:

Colleagues,

I am very pleased to confirm formally Mark Hastak’s reappointment as head of the Division of Construction Engineering and Management, effective January 1, 2010 – December 31, 2012.

I’d like to express my appreciation for Mark’s leadership and contributions to CEM and to the College. I hope you’ll join me in congratulating him on this reappointment.

Best,

Leah

## Academic Crossroads

A practitioner and a researcher bring their perspectives to CEM



Panagjota Karava

**Two of the newer faces** among the faculty in the Division of Construction Engineering and Management (CEM) have come to Purdue from somewhat opposite directions. Panagjota Karava enters with dual assistant professorships in CEM and civil engineering. Victor Gervais brings three decades of industry experience to his continuing lecturer and advisor positions. Both, however, bring much passion to their teaching and research in the ever-changing world of construction engineering.

Purdue's strong engineering reputation, along with the opportunity to work with well-known researchers, helped to draw Karava to campus. "Here at Purdue, there is a critical mass of people doing research related to high-performance buildings," says Karava, a native of Greece. She received her bachelor's degree at the National Kapodistrian University of Athens in 2000 and her master's and PhD from Concordia University in Canada in 2002 and 2007, respectively.

The ability of a collective research effort to achieve more in the ways of sustainable building brought her to a university where she collaborates

with researchers in civil engineering, mechanical engineering, and beyond.

"We need to put the different disciplines together to achieve those goals," says Karava, who turned down an opportunity to take more of a leadership role in a civil and environmental engineering program at the University of Western Ontario.

As part of the new architectural engineering emphasis within the School of Civil Engineering, Karava spent much of her first semester on campus helping to develop the program and design new labs. Next year, she'll teach a CEM course titled "Sustainable Building Construction."



Victor Gervais

On the other side of the career coin is Gervais, who spent 31 years working as a civil engineer for the U.S. Army Corps of Engineers. From project manager to an eventual area engineer, Gervais had a staff of some 20 engineers, technicians, and construction inspectors. They worked mainly on heavy civil marine projects, often along the lakefront in Chicago and on locks and dams on the Mississippi and Illinois rivers.

When family circumstances brought him closer to Purdue, Gervais discovered the CEM program and thought it might be a perfect fit. So far it has been. Eager for true tales of what it's like to be a construction engineering manager, students in Gervais' classrooms get plenty of war stories. From California earthquakes to the Corps' response to other national emergencies like Hurricane Katrina, Gervais often brings that real world into his classes.

Gervais has taught CEM courses in estimating, scheduling, and human resources. The latter focuses on getting the students to look at things from a management perspective. "We try and see what it takes to lead," he says, "and what they can pull out of themselves to become leaders."

In this interactive course, Gervais had students mimic both sides of the table (management and union) as they participated in a collective bargaining simulation. On the leadership development front, he asked them to identify strong leaders they've known in their lifetimes. "I wanted to know who influenced them and what traits they brought," Gervais says. "About 90 percent of them picked someone from their internship position. Some of them picked a father or a coach, which was great, too."

For both the retired practitioner turned teacher and the eager researcher in search of innovative solutions for sustainable buildings, the CEM program represents another good starting point.

### ■ William Meiners

[ Karava photo by Andrew Hancock, + Gervais photo by Richard Myers-Walls ]

# CHANGES AND CHALLENGES

## Construction industry trends and technologies will influence **CEM** education

By **Gina Vozenilek**

**With the increasing availability** and use of computer simulation and building information modeling (BIM) software, the job of managing a construction project is literally taking on new dimensions. Nothing short of a revolution in the practice of CEM, these new tools promise to increase efficiency, speed work, and reduce waste by enabling an integrated project delivery (IPD) method. CEM students at Purdue and around the world no doubt will need to become well-versed in the new approaches offered by IPD. But new technologies do not render basic skills obsolete. Old-school construction engineers also advise that some seemingly simple things, like solid communication skills, will always be needed and are, in fact, more important than ever.



## Integration is key

Tim Steigerwald (BSCEM '87) is vice president for Messer Construction in the Indianapolis regional office. He started out at Messer as a construction engineering intern and is now in his 25th year with the company. He is also on the CEM advisory board for Purdue. "I really do think IPD is a trend-setting change in our industry," he says. "We are getting up to speed. It will be impactful."

Another member of Purdue's CEM advisory board, Tom Kudele (BSCEM '89, MSCE '90), agrees. He is a project execution advisor for ExxonMobil Research & Engineering based in Houston, Texas. "A current trend that is gaining momentum is the greater use of technology to integrate the large amounts of data and information on capital projects," he says.

Industrial projects employ databases containing vast quantities of information on engineered equipment, piping,

valves, instruments, and numerous other items. Large and usually complex 3D CADD models are built to represent these items, and the industry is moving toward their integration.

CEM is traditionally focused on procurement and construction. However, the life cycle of a project starts much earlier with conceptual design, basic design/engineering, and detailed design/engineering. "The question is, 'How do we link all of these independent islands >>

▲ Tom Kudele (BSCEM '89, MSCE '90), from ExxonMobil Research & Engineering, interviews Daniel Richards, a CEM senior, on campus in October. [ Photo/Mark Simons ]

► In November, ExxonMobil celebrated the full operation of China's first integrated refining and petrochemical facility with foreign participation. This facility, the Fujian Integrated Refining and Ethylene Joint Venture Project, will help meet the region's growing need for fuels and chemical products. [ Photo courtesy ExxonMobil ]



## “Managing project controls is **not** just accounting” Tom Kudele

of information, which often reside within different companies and in different countries?” asks Kudele.

With new construction simulation software, one can see in a colored 3D model what has been engineered, procured, fabricated, delivered, and installed. The project management team will be able to link this data with a schedule and track it over time. Other software tools and databases for inspection, testing, and certification also can be linked as well. “And,” Kudele adds, “once the facility is operational, these databases can then support operations and maintenance personnel during the operating life of the facility.”

Kudele believes that students need more exposure to this overall life cycle of capital projects, from conceptual design through completion. The next generation of CEM grads will need to be fluent in the new technologies that can power all these steps.

Steigerwald also stresses that IPD requires students to be able to build a team and function effectively together. It’s not all about software. “BIM is the technical component of IPD,” he says.

IPD also depends on things like new contract structures, whereby all entities on a project sign one unilateral agreement. This then requires the integration of more contractors earlier in the process, or as Steigerwald says, “more collaboration up and down the line.” And to drive this integrative team forward, IPD uses common sense incentives such as reward sharing. If the team beats a deadline or comes in under budget, all share in the gains.

### **Effective collaboration means good communication**

Jack Mollenkopf (BSCem '95) concurs with his colleagues that IPD is the future of CEM. Mollenkopf, a LEED® AP project executive for Pankow Builders, based in Pasadena, California, agrees that CEM graduates will need to master BIM software, but that is only one part of the picture. “Collaboration,” he adds, “can be taught to graduates to prepare them for projects that will be developed in an IPD format.”

To achieve effective collaboration, project teams need a clear understanding of the component disciplines — structural, mechanical, electrical, architectural — all working together to deliver a design for a project, Mollenkopf says.

Communication skills, too, are important to successful teamwork. “On the job site, a big part of the day is going to be communications,” Mollenkopf says. “When I was new on the job site some 15 years ago, communication would occur by phone and fax transmittals. Now, I get 50-75 e-mails a day. Everything is in real-time communication, and you are often expected to respond immediately.”

Good writing habits, which help CEM graduates communicate instructions clearly and record accurate documentation, are essential to the job. Poorly composed or unclear communications can lead to problems. “With e-mail and texting, people have really gone to their own shorthand. We need to get back to good writing skills,” says Mollenkopf, who believes more emphasis on technical writing will help CEM students. “There might be legal repercussions of sloppy direction that can be traced back to a hasty e-mail.”

Steigerwald knows working in CEM means, in part, being a good salesperson, something that does not necessarily come naturally for a technically minded engineer. He points out that “good communicators sell themselves” to the customer. Like Mollenkopf, Steigerwald would like to see more classroom-based communication education for CEM students. He also thinks that out in the field during internships is a good place to put communication skills into practice. “Interns benefit when they are in an environment where they have contact with clients and contractors,” he says.

### **Improving the forecast**

Kudele passionately advocates that CEM graduates have a solid understanding of project controls. “The best project managers have always been the ones who are good at both cost estimation and project control,” he says.

Successful management of all project controls (safety, quality, cost, and schedule) can be elusive. Oversimplifying the equation leads to cost and time overruns. “Managing project controls is not just accounting,” says Kudele, “especially when you are asked to forecast the cost of a project four to six years before its completion.”

“It used to be that a successful outcome was based on whether or not you met the end date and met the project budget,” says Steigerwald. “These are limited metrics. We need to be focused on all of the goals that are important to the customer.”

►The Annenberg Community Beach House at Santa Monica Beach is a 5-acre oceanfront California paradise. Originally developed during the Gold Coast era of the 1920s by William Randolph Hearst for actress Marion Davies, the property was rehabbed and rebuilt with new recreation and event spaces by Charles Pankow Builders. The building was awarded a Gold LEED rating from the U.S. Green Building Council. [ Photo courtesy Charles Pankow Builders ]



Steigerwald points out that IPD can be a tremendous fiscal help to the construction engineering manager because IPD measures progress every step of the way.

Kudele wants to see CEM educators continue to strengthen students' understanding of cost estimation, schedule development, and project controls. "That's going to go a long way for our industry," he says, "and a long way for our graduates in CEM."

### Building green

The topic of sustainable building practices features on the agenda when Mollenkopf meets with a client for the first time. Just two years ago, the same issues might have arisen, but they were usually an afterthought. "It always comes up in the first meeting now," he says. "It is common to use a LEED certification checklist to identify potential credits a project could obtain, and then set up goals for that from the outset of the design process."

Mollenkopf's firm has obtained gold and silver LEED certification on several construction projects. He stresses that with able planning, green doesn't have to mean more expensive any longer. "It doesn't cost a lot of additional money if it is implemented from day one," says Mollenkopf.

"Green building is quickly becoming a business imperative," agrees Steigerwald. He says 11 people in his Indianapolis office are accredited LEED "green associates" and are moving forward to becoming LEED AP accredited.

Over half of the people at Mollenkopf's company are LEED AP accredited, and everyone is encouraged to achieve this certification. Mollenkopf thinks it would be wise for students to be encouraged to get this certification, similar to the way they are urged to become OSHA certified, as they finish their schooling. He has recently seen job candidates come through the interview process already LEED AP accredited, a distinction he says helps set those candidates apart. Steigerwald concurs.

### Safety first

Kudele also advocates the advantages of additional accreditation for CEM students. "Safety is our number one priority for all our projects," he says.

He recognizes that there is safety risk in all construction work, but in his area of the industry — the design and construction of petrochemical facilities — that risk rises as one designs for and works among high-temperature and high-pressure fluids and gases.

Kudele encourages senior CEM students to take the newly available professional engineering licensure exam for construction management engineering. "It's how you differentiate yourself," says Kudele. "This is a very good step. I think it shows your commitment to the industry. It also shows you continue to study and learn and stay up to date on the latest techniques."

In their different areas of CEM practice, one thing Kudele, Steigerwald, and Mollenkopf all agree on is the value of the internship program at Purdue for preparing its graduates for whatever focus their careers might take. "What I love about Purdue is the combination of the theoretical education and the practical education in the summer internships," says Steigerwald.

"The strength of the program has always been the internship program. Bar none," says Kudele.

Although he recognizes that the current economy challenges it, he emphasizes the need to continue to support students with demanding internship projects. "We must keep the program going strong," he says. ■



LEED AP [ LEADERSHIP IN ENERGY EFFICIENCY AND DESIGN ASSOCIATE PROFESSIONAL ]





## Renaissance Engineers in the Making

### Two CEM students use summer experiences to prepare as Engineers of 2020

**Five years ago**, the National Association of Engineers released a report called “The Engineer of 2020,” detailing the abilities, proficiencies, and qualities the engineer of the future will need to develop, practice, and master. Purdue’s College of Engineering took that study to heart, and engaged in a multi-year process of review and adaptation to ensure that the University was preparing graduates to meet the demands of the next decade and beyond.

At least two CEM students spent their respective summers living up to that ideal.

For Ali Mostafavi, a PhD student who came to Purdue from his home in Iran, that meant coordinating a special project for undergraduate CEM majors who weren’t able to find internships. Mostafavi explains, “A big part of Purdue’s CEM program is helping undergraduate students find three consecutive years of summer internships. This year that wasn’t possible in every case due to the economy. So Dr. Deanna McMillan, our director of internships, worked out an alternative for seven students unable to place elsewhere. I was involved in supervising the project.”

The project took place at the Ebenezer Retreat and Camp Institute (ERCI) in Roachdale, Indiana, west of Indianapolis. ERCI’s primary goal is to serve low-income children by providing an overnight summer camp where they gain exposure to the outdoors and engage in nature-appreciation and leadership activities. Mostafavi explains, “The engineer of 2020 should be able to solve the problems of the community — and this is a community-based institute where we had the opportunity to propose actionable solutions to the limitations they faced.”

Those solutions sought to meet two goals: to increase the camp’s capacity from its current level of 25 to 70 and to increase revenue. To do that would require facility upgrades. “If they want to serve 70 children, they need to create one new building, renovate existing buildings, and create a larger-capacity septic tank,” Mostafavi says. “Our undergraduates worked and are working on proposals for each of those areas, which include detailed schedules, materials specifications, and cost estimates.”

▲ **Camp Builders:** From left, Daniel Bynam, Ebenezer Retreat and Camp Institute director Paula Rivera, Cameron McClay (Purdue shirt), Ali Mostafavi, Deanna McMillan, Hui Fan, Daniel Richards, and Jonathon Byrd at the Roachdale, Indiana, camp. [Courtesy photo]

To ensure follow-through on the project, Mostafavi also helped teach a senior design course where some 40 students took the recommendations of the summer interns and turned them into formal proposals. “We’re delivering all our recommendations to the camp so they can incorporate our findings into their future actions,” he says.

Sophomore Alexandria Henry sought to make a difference closer to home — right on Purdue’s campus. She landed her internship with Turner Construction. “I told them directly, I want to work inside, not out in the field,” Henry says. “I think they responded to that level of certainty, and offered me the position.”

Henry’s project involved renovating Mackey Arena. The adjoining space next to the basketball home will include two football practice fields and a parking lot to accommodate both sports. “It’s space we need as a residential university community,” she says. “I’m signed on next summer to keep moving the project forward to build more courts inside Mackey, as well as provide wider walkways, lounge areas, and expanding offices and locker rooms.”

Working inside, Henry collaborated with management and contractors, reviewing and evaluating submittals and then passing along recommendations to the owners. “I gained a much deeper understanding of how the business of construction sites work, how to manage employees, contractors, and management, and how to take a project from conception to completion,” she says.

Growing into the engineer of 2020 seems a daunting task. But these Purdue students prove to be uncommonly prepared to take on the challenge, and understand that embodying that ideal goes beyond personal achievement to also encompass societal improvement.

■ **Patrick Kelly**

# Legacy Learners

## Two CEM seniors benefit from memorial scholarship

**Logan Cook and David Fields,** both seniors in construction engineering management, enjoy a hard day's work. As young men who prefer outdoor construction projects to the confines of the cubical working world, they are the 13th and 14th recipients of the Lloyd S. Jones Memorial Scholarship. They also seem to be cut from the same mold as the late Professor Jones.



Logan Cook

A retired Navy man in his mid-40s who came to Purdue to earn a master's in civil engineering in 1975, Jones joined the faculty in the School of Technology before becoming an associate professor in the School of Civil Engineering in 1980. Believing that experience was the best teacher, Jones took eagerly to his director of internships position in the newly formed Division of Construction Engineering and Management (CEM).

Jones pioneered the concepts and policies by which every BSCEM graduate served three 12-week working internships in the construction field. Through his Navy personal contacts with executives from literally hundreds of construction firms, he pro-

vided each student with an internship assignment, ensuring a productive learning experience. His summers were spent monitoring the students and their sponsor firms and visiting their construction projects across the country, seeking to assure and improve the quality of the field experiences. Unique among U.S. universities, Purdue's CEM internship program grew to be a distinct product of Jones' insight, perseverance, and professionalism.

Jones retired on December 31, 1994, and succumbed to a brain tumor on October 10, 1995. In lieu of flowers, Marian Jones, his widow, requested that friends and family contribute to a memorial scholarship in her husband's name. "I was absolutely flabbergasted that, in 1995, \$24,000 came in," she says.

While Mrs. Jones laments that a couple thousand dollars a year may pale in comparison to some of the other endowments that help support students and programs, both of the current recipients are grateful for the financial relief that comes with the scholarship. Fields, a military veteran himself (a U.S. Marine formerly deployed in Iraq), says the scholarship eases his financial burden. "Because I am paying my own way through school, the scholarship has really helped keep my debt low by supplementing my veterans benefits," he says.

Though they never met Professor Jones, both Fields and Cook share his philosophy on experiential learning. "You gain the practical knowledge in summers and back it up with the theory from the classroom," says



David Fields

Cook, who interned at Duke Construction in the summers of 2007 and 2008 and for Wiss, Janney, Elstner in Chicago last summer.

Fields has worked an internship at Bowen Engineering in the summer of 2008 and ventured west to San Francisco to work for DPR Construction last summer.

Last year, Mrs. Jones supplemented the scholarship money, which is managed by the Purdue Foundation. She also met Cook and Fields at a spring banquet. Another pair of students her late husband is still helping to shepherd into careers in the construction engineering field.

■ William Meiners



## Lloyd Jones

The first director of CEM's renowned summer internship program, Lloyd Jones embodied the ideas and philosophies behind experiential learning. [ Photo courtesy Marian Jones ]



Plant  
maintenance

Up Close: Alumni

## Beyond Expectations

**How a construction engineering degree prepared one engineer to switch gears**

**Peggy Newquist had no idea that the job** she is doing now even existed when she graduated from Purdue's Construction Engineering and Management program nearly 25 years ago. Technically, it didn't exist. "I thought my career would be to work for a contractor, or the Corps of Engineers," Newquist (BSCNE '86) says. "They never told us there were jobs in the retail world." In the end, Newquist not only would land a job with a retail firm, but would pioneer her place in that world.

Newquist's story does start in the way she expected it would. Following her summer internships with Walsh Construction, she took a job there. Far from typical, however, this job was a company first in its own right: Newquist was the first woman Walsh ever hired. She was, in fact, one of only four women in her class of 31 graduates from the new division.

Newquist spent two years in a hard hat job at Walsh, working on construction of the I-355 Tollway in Illinois. It was while out in the field that her current career started to call to her. An infrastructure project brought her in proximity with the construction of a new McDonald's restaurant. She met the construction manager and became intrigued with the possibilities of working for a corporation with its own in-house construction management department. The potential for professional growth was enticing.

Newquist's first job at McDonald's was building local restaurants, but those famous golden arches straddle the globe. Something bigger beckoned. "We're in 118 countries with 31,000 restaurants," notes Newquist. "We employ 300 development professionals and construction project managers in the U.S. alone and there are 1,500 worldwide."

Newquist soon saw the need for consolidating and centralizing the training effort. "It was the right thing to do for the business," she says.

Today, Newquist is senior director of worldwide development for McDonald's Corporation in Oak Brook, Illinois. In this capacity Newquist and her team are responsible for the training of real estate and construction

professionals throughout the world, from new hires to executives. They are busy developing new tools and analytics to help associates decide where to build, where to remodel, and how to allocate resources.

Newquist is excited about injecting technological advances into the training process because, she admits, the huge corporation is "not very tech-forward at headquarters." She and her team recently completed a live online real estate training module with the participation of 22 professionals in seven countries.

"It's not only cost-effective," says Newquist. "It is also generating a lot of interest."

That's not really surprising. Newquist seems to have a proven record of getting others to look at a problem or a challenge from a new perspective. She's built a career on reimagining old things in new ways. ■ **Gina Vozenilek**



**ZENGZHONG WANG**  
visiting scholar

**HUBO CAI**  
assistant professor

**BONNIE SONDEGROTH**  
undergraduate secretary

**DONN HANCHER**  
visiting eminent scholar

**MELISSA GEIGER**  
secretary to the division head

**FENGYONG ZHAI**  
visiting scholar

# CEM Smiles

Faculty and staff gathered for a holiday outing in December.



**VICTOR GERVAIS**  
Continuing lecturer

**MICHELLE RYKER**  
CEM business office representative

**DEANNA MCMILLAN**  
internship director

**NETTIE HAAB**  
CEM area secretary

**ANDREA SILLS**  
CEM business office representative

**MAKARAND HASTAK**  
professor and division head

**AMY HAYDEN**  
CEM business office representative

**PANAGIOTA KARAVA**  
assistant professor

**BOBBY MCCULLOUGH**  
JTRP-IT & CEM IT

**DULCY ABRAHAM**  
professor

**JB KANG**  
JTRP-IT & CEM IT

**PHILIP DUNSTON**  
associate professor

**JULIO MARTINEZ**  
associate professor



A scanning electron microscope picture of nacre, also known as mother-of-pearl, a biomineralized composite that is known for its strength and resilience. The image is from civil engineering's Computational Multi-Scale Materials Modeling Group, led by Pablo Zavattieri. He has paired with David Kisailus, assistant professor of chemical and environmental engineering at the University of California, Riverside, to study the structure-mechanical property relationships of composites in order to develop new materials and structures that will offer a new combination of low weight, high strength/toughness and multifunctionality. The materials could have applications in the auto, energy, shipbuilding and defense industries, as well as widespread use in civil and aerospace engineering.

