Fall 2005

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The question remains: What makes our present problems serious challenges confront the world currently, and predictions of imminent disasters threaten our quality of life. Deterioration of the infrastructure, environmental pollution, global warming, exhaustion of natural resources, and a plethora of other problems paint a gloomy picture for our future. Fortunately, however, the future is not predetermined randomly, but is a consequence of strategic planning decisions. Civil engineers have a major role in providing the facts used to shape the policies of the world powers; those who educate civil engineers carry a major responsibility for educating their students so that they understand the impact of their future designs.

The ancient Greeks called the earth “aeiforos,” which literally means “perpetually giving.” This was the cornerstone of a philosophy that founded Western civilization and sustained the twentieth century’s Industrial Revolution. The earth, however, has a finite carrying capacity—requiring a certain stewardship on behalf of the engineer if the natural and built environment is to be maintained. The population can continue to increase and utilize the natural resources of the planet, so far as consumption does not irreparably damage these resources. While population growth is outside the control of engineers, limiting the stress on renewable resources is entirely a problem of engineering design optimization.

For more than a century, we have designed the infrastructure with the exclusive goal of maximizing the users’ convenience. When this practice appeared to stress the carrying capacity of a certain natural resource, we looked for alternative technological solutions that allowed continued growth. However, we have not yet attempted seriously to self-regulate consumption—mainly because the economic model of our society is based on a principle that requires continuous growth. The optimism for continuous growth stems from our primal instinct of self-preservation and the resilience of the human species. After all, pre-agricultural humans faced a severe threat for exhaustion of the available renewable resources, but innovation led to alternative resources, which sustained growth for several millennia.

The question remains: What makes our present problems different, and why should we devote our efforts to sustainable engineering instead of concentrating yet again on creating alternative renewable resources that will allow continued economic and population growth? Of course, it is difficult to imagine that the present stress on natural resources is having any significant impact on population growth. To the contrary, it appears that the load on the earth has continued to increase quickly, primarily because the highest population growth and resource exhaustion are not necessarily occurring at the same location. Therefore, one can argue both that the current stresses on the planet have reached a critical level, and that continuing to design based on the current engineering paradigm of user convenience will cause irreversible damage to the environment unless a new engineering paradigm is adopted.

In fact, the new engineering paradigm does not ask that a choice be made between creating alternative resources and reducing consumption. The principle of sustainable engineering simply tries to satisfy present needs—without undermining the ability of future generations to satisfy needs of their own. This principle sounds more like a legal premise than an engineering practice, i.e., to design a system in order that its current use does not limit the rights of its future owner. More important, this practice does not limit either economic growth or the development of alternative resources. It simply removes the focus of the design from the user’s convenience and places it on the integrity of the system—resulting in a system that is “perpetually giving.”

Educating a new generation of engineers based on the paradigm of engineering sustainability will not be easy. The questions are not well-defined, and unfortunately, the answers are few in number and often unsatisfactory. Any traditional engineering department is destined to face difficulties when faced with developing new basic courses, while at the same time working on fundamental research questions. This is where the Graham Environmental Sustainability Institute is expected to play a unique role. By bringing together engineering, science, business, policy, and public health, the Institute can transcend the obstacles presented by traditional thinking. By placing an equal emphasis on education and research, the Institute will ensure that new generations of engineers not only will grow with the sustainability paradigm, but also will base their decisions for design on the perpetual giving of the system—rather than promoting only user convenience.

The CEE Department at the University of Michigan is proud that Professor Semrau assumed a leadership role in the conception and formulation of the operational charter of GESI. We strongly believe that the Institute will lead to many contributions that will shape our understanding and practices of sustainable engineering; moreover, we are confident that Michigan engineers will be the pioneers of this new design paradigm.
**FROM THE CEEFA PRESIDENT**

Once again, football season is over, and it seems that winter is upon us for the foreseeable future. On the bright side, you hold in your hands the fifth issue of the Department newsletter in its new format, which far and away exceeds the previous format that we had become accustomed to over the years. On behalf of CEEFA, I’d like to thank Nik Katopodes, Janet Lineer (newsletter editor), Patti Mackmiller (newsletter editor), and Kimberly Bonner (newsletter assembler and editor) for their vision and hard work in producing this exemplary publication.

The annual fall football brunch was a rousing success with a huge demand for football game tickets. The legendary hospitality of the O’Neal Construction Company ensured that a great time was had by all who attended. We already have submitted our 2006 ticket request and hope to offer CEE alumni tickets to another Big Ten game this year.

The mentoring program is continuing, and several students are signed up. We hope to expand the numbers—of both mentors and students—as word spreads.

The spring meeting and technical session will soon be upon us, and the agenda is taking shape. If you have a favorite topic, please let us know, and we will give your suggestions every consideration. For now, please mark your calendar for Friday, March 31, 2006. See page 28 for more information.

As we all know, the annual dues to CEEFA increased from $15 to $20 last year. This, along with minor changes to the format of the spring meeting and technical session, has assisted us in our efforts to honor CEEFA’s original mission to “strengthen ties between alumni and the Department and to establish means for technical and financial support.” Our biggest opportunity to serve both our Department and our membership, however, is to significantly increase the number of members. Consider this: as alumni, we are both contributors to, and beneficiaries of, the Department’s reputation. An increase in the CEEFA membership rolls will further enhance that reputation. So, if you enjoy the newsletter; are proud of the accomplishments of your fellow alumni, the current students, and the faculty; and want to support current CEEFA efforts to maintain a leadership position; please become a member of CEEFA. If you are already a member of CEEFA, take the time to renew your membership, recruit new members, and share your enthusiasm for our association with alumni and friends alike! Who knows better how the Department and the University of Michigan have shaped our pasts, presents, and futures?

Later in this academic year, the voting ballot for the CEEFA Board of Directors (terms to begin in July 2006) will be provided to members. Current and past Board members who have volunteered their time to serve the alumni, friends, students and faculty of the Department often remark that they have found this service to be very rewarding. Please consider becoming a Board member and investing your time in the civil and environmental engineers of the future. Not only are we looking for volunteers to further the best interests of the Department, but we welcome new faces—those who can represent the many perspectives and ideas of CEE’s large constituency of alumni, students, and friends.

In closing, I wish to thank all who have supported the efforts of CEEFA and the Department over the years. If you have ideas that you wish to share, or if you want to add your name to either the potential mentor list or to the ballot for Board membership, please contact me at gar.hoplamazian@akahn.com. I look forward to hearing from you. Go Blue!!

Gar Hoplamazian, PE, CEEFA President

**DEPARTMENT NEWS**

**2005 Robert B. Harris Lecture in Construction Engineering and Management**

Professor James Garrett, Jr., Associate Dean for Academic Affairs in the College of Engineering at Carnegie Mellon University, delivered the 2005 Robert B. Harris Lecture. Garrett, also a professor of civil and environmental engineering, discussed the applications of sensors and sensor systems to civil infrastructure condition assessment. Specifically, Dr. Garrett discussed mobile hardware/software systems for field applications; representations and processing strategies to support the usage of engineering codes, standards, and specifications; knowledge-based decision support systems; neural networks for modeling; and interpretation problems in civil and environmental engineering.

The Harris Lecture, established in 1988, is named in honor of Robert B. Harris (1913-2003), U-M Professor Emeritus of Civil Engineering. Professor Harris served on the faculty of CEE for forty years and played a significant role in the development and advancement of the field of construction engineering and management—not only at U-M, but throughout the US and internationally as well.

*2005 Robert B. Harris Lecture (left to right): Assistant Professor Jerome P. Lynch, Dr. John Everett, Professor James Garrett, Jr., Assistant Professor Burcu Akinci, Professor Photos Ioannou, Assistant Professor Vineet Kamat, Assistant Professor Russell Green, Professor Nik Katopodes, Assistant Professor Ioannis Brilakis, Assistant Professor Hoon Sohn, and Associate Professor Lucio Soibelman*
The History of Chi Epsilon at the University of Michigan

By Professor Emeritus Eugene A. Glysson, PhD, PE, DEE

Chi Epsilon is the Civil Engineering profession’s national honorary society. It was organized to recognize the characteristics of the individual Civil Engineer fundamental to the successful pursuit of an engineering career and to aid in the development of those characteristics in the Civil Engineering student. Foremost among those characteristics are Scholarship, Character, Practicality and Social Ability.

—from The Story behind Chi Epsilon

History

Twenty-seven years after the first Chi Epsilon chapter was founded at the University of Illinois and became a national organization, the University of Michigan chapter of the honor society was installed—making it the 25th chapter in the US. Professor Jack A. Borchardt, a member of the Illinois Chi Epsilon chapter and, at the time, a new assistant professor in the Civil Engineering Department at Michigan, became the chapter’s first faculty advisor. Dr. Borchardt not only served in that capacity until 1965, but was responsible for much of the tradition and practices that have made Michigan’s Chi Epsilon chapter so unique and interesting. At the first installation of membership in 1949, the Michigan chapter initiated 35 members. The ranks of the organization now boast more than 1250 members—40 of whom have been recognized as Chapter Honor members.

Over the years, the Michigan Chapter has adopted practices and traditions that have shaped its character. Among the practices that have prevailed are such pledge activities as requiring that each initiate construct a signature book, to be signed by members of the chapter, by department faculty, and by deans of the College. Originally, each signer was offered a cigarette for his signature; that practice was changed, however, so that initiates now offer a stick of chewing gum. The signature books are judged for their originality and design, and the one judged “best” is recognized at the banquet held each term. The signatures gathered have proven to be of real sentimental value in later years.

One of the most interesting pledge projects required (now discontinued) was the casting of the brass Chi Epsilon keys, each measuring 7” x 3”. The scrap brass was melted in the Materials Engineering Department’s foundry—then located on the fourth floor of the East Engineering Building. (At that time the Civil Engineering Department was located on the University of Michigan Central Campus). In this project, the pledges made casting forms using sand packed around a key-shaped mold. Molten brass was then poured into the molds, and after cooling, the keys were polished—making a fine Chi Epsilon memento. With the relocation of the departments, and for other reasons, this project is no longer required. A red-and-white range pole with the pledge’s name on it was also required but is no longer requested.

Additional pledge activities included the updating of all the department’s faculty directories and bulletin boards—then located on the walls of the East Engineering and West Engineering Buildings. In one of the department classrooms, noon-hour movies were shown once a week.

Current pledge projects consist of such activities as assisting the Department during the College of Engineering Tech Day—an event where high school students and their parents learn about the various departments in the College and are encouraged to enroll at U-M; participation in Engineers Week activities; maintaining the Chi Epsilon website; and keeping Department display boards current.

Service activities are still required as well—for current membership, as well as for pledges. Recent activities include participation in Habitat for Humanity projects; collecting non-perishable food items for an area food bank; assisting at Chelsea’s St. Louis School for Boys and the Ann Arbor Hands-on Museum; removing invasive species from U-M campus woodlots and wild areas; volunteering at Nichols Arboretum; and assisting at an Ann Arbor teen-crisis center.

Social activities for the chapter have evolved since 1949 as well. Meetings, held five times each year, were the primary impetus for Chi Epsilon social gatherings, although occasionally, an after-meeting gathering would be held at a local pub. Now, members enjoy active participation in a variety of social events, including intramural sports, bowling competitions against other student groups, and visits to an area rock-climbing gym.

Fundraising activities to benefit Chi Epsilon have ranged from the sale of chocolate bars to assisting a local sanitary landfill operator in the cleanup of the landfill’s perimeter. Current support comes from several benefactors, including alumni donors, Department funds, and the U-M Engineering Council.

In the early days of the Michigan Chi Epsilon chapter, meetings were held at the Michigan Union; the East and West Conference rooms of the Horace H. Rackham Graduate School held later meetings—since graduate students were members of the chapter. Although the conference rooms were very elegant and were enjoyed for many years—as both meeting rooms and as sites for formal initiations—the rooms are no longer used due to the prohibitive cost of rental.

Organization

New pledges are inducted into the honor society each semester. To be invited, undergraduate students must have completed at least one-half of the coursework toward a bachelor’s degree in civil engineering and rank in the top one-third of his/her class; graduate students also must have completed at least one-half of the coursework toward a graduate degree and be recommended for membership by a graduate advisor.

Initiation includes two different rituals. The first, an informal gathering designed by Professor Borchardt and held at Island Park in Ann Arbor, allows for a shared outdoor experience. The second ritual is prescribed by the Chi Epsilon bylaws and constitution and is a more formalized initiation for pledges.

At the national level, Chi Epsilon is divided into ten districts—each of which is represented by a District Councilor.
charged with assisting the participant-universities in the district. Every two years, a National Conclave is held; all chapters are expected to send a voting delegate and any additional members who may wish to attend. At the Conclave, the voting delegates determine the decisions and policies that govern the chapters. Representation from all groups is considered critical.

The Michigan Chapter of Chi Epsilon (part of the Great Lakes District) has always been represented at the National Conclave. With the exception of the timeframe surrounding World War II, the Conclave has been held every two years since 1924. In 1970, the University of Michigan hosted the event at the Chrysler Center. The Michigan Union housed many of the guests. Professor E.A. Glysson was responsible for the overall effort in 1970. Professor James Wight organized an off-year conclave (which can be held at the discretion of districts) for the Great Lakes District in 1999.

Daily administration of the national Chi Epsilon organization is undertaken by the national office, currently located at the University of Texas at Arlington. Between scheduled conclaves, the National Council and Secretary-Treasurer administer Chi Epsilon business—as directed by the decisions and policies determined at the conclaves. The University of Michigan has been well-represented throughout the history of its Chi Epsilon chapter. CEE Professor Robert B. Harris served as a national council member for the U-M from 1964 to 1974. Professor E.A. Glysson has served as council member since 1982. Both faculty served as national presidents for the organization as well: Harris, from 1972 to 1974; Glysson from 1990 to 1992.

The University of Michigan Chapter of Chi Epsilon has been active in the installation of additional chapters throughout the Great Lakes District. Notre Dame established a chapter in 1966; Tri State University installed a Chi Epsilon chapter in 1973; the University of Toledo joined the ranks in 1992; and Lawrence Technological University established a Chi Epsilon chapter in 1994.

Only three faculty members (elected by the membership) have served as the advisors for the Michigan Chapter throughout its long history: Professor Jack A. Borchardt (1949-1965); Professor Eugene A. Glysson (1965-1995); and Professor Steven J. Wright (1995-present). Such longevity is unusual for chapters of the honor society, and this longevity attests to the dedication of the CEE Department and its faculty.

Scholarship

Since an important part of its mission is to encourage academic excellence, Chi Epsilon presents student scholarships and teaching awards at both the district and national levels each year. Each chapter nominates its own slate of individuals. U-M chapter members have received these scholarship awards on several occasions; Department faculty also have been awarded prizes at the national level.

Conclusion

Chi Epsilon, the national honor society for civil engineering, is a well-respected and special organization within the Department of Civil and Environmental Engineering. Supported and maintained by the Department, the organization continues its efforts to encourage academic performance and professional standards among upcoming graduates. Most important, it provides a linkage between the Department and its many outstanding students.

Faculty Appointments

The College of Engineering and the Regents of the University have approved a joint appointment for Dr. Stuart Batterman. Professor Batterman is Professor of Environmental Health Sciences at the School of Public Health and joins CEE through this appointment. Previously, he was in the Civil and Environmental Engineering Departments at Texas A&M and the International Institute for Applied Systems Analysis in Austria.
He earned a B.S. from Rutgers University and both his MS and PhD from the Massachusetts Institute of Technology. Professor Batterman’s current research and teaching focuses on air quality, hazardous waste management, exposure and risk assessment, air pollution epidemiology, and other topics in environmental science and engineering and sustainable development. In addition, he is involved in several domestic and international projects, including the sampling, analysis, and modeling of trace-level organic contaminants in air, water, and biological samples from North America and Africa.

Professor Jonathan Bulkley, Professor of Civil and Environmental Engineering, has been reappointed as the Peter M. Wege Endowed Professor of Sustainable Systems—a role he holds at the School of Natural Resources and Environment.

ABET Accreditation Review

The ABET review of the Department’s undergraduate program occurred on October 23-25, 2005. Professor William Highter from the University of Massachusetts served as the ABET team member conducting the review of the CEE Department. In general, CEE received a very strong rating from Professor Highter. He remarked that we had excellent undergraduate students, a very strong and diverse faculty, and outstanding classroom and laboratory facilities. In addition, Dr. Highter noted that our system for continuously assessing both courses and the overall CEE program was very good. Professor Highter listed three minor weaknesses and one concern to be addressed within the next six months. The Department faculty has undertaken the process of responding to these items, and we expect to receive a full six-year accreditation in July 2006. Thanks to Professor James Wight, the Department's ABET Coordinator and Department Chair Nik Katopodes for their work before and during the ABET visit. Thanks also to CEE staff member Jill Miller, who supported the Department efforts during the lengthy collection/preparation process and throughout the subsequent ABET visit.

Congratulations!

Professor Subhash Goel was honored on December 13, 2005, as he completed his final lecture in CEE 413: Design of Metal Structures. Faculty, students, and department staff came into the classroom to congratulate and celebrate with him as he concluded a thirty-nine year teaching career at the University of Michigan. Professor Goel has been long recognized as one of the top instructors in the CEE Department; his contributions to the teaching of structural analysis and undergraduate and graduate steel-design courses will be sorely missed. Dr. Goel will officially retire at the end of April, 2006, but he plans to maintain his activities in research and the code development process for steel structures. Congratulations to Professor Goel on a job well done.
Mark Your Calendar and Follow the Blue!

The 2006 ASCE North Central Regional Conference will be held at Ohio Northern University (Ada, OH) from Thursday, March 30, through Saturday, April 1, 2006. Once again CEE will be represented by student teams competing in the Steel Bridge Building and Concrete Canoe competitions. Alumni and friends in the area are invited to cheer on the Maize-n-Blue as it vies for its share of the regional titles. Follow the Blue!

CEE Department Food Drive

The faculty and staff of Civil and Environmental Engineering have reclaimed the coveted “Pork-and-Beans” Trophy in the eighth annual CEE Department holiday food drive competition. A total of 1861 pounds of non-perishable food was collected.

The competition, first initiated in 1998, resulted from a discussion between Environmental Engineering PhD student Martin Johnson and Professor Steve Wright. The purpose was to collect non-perishable food for the depleted coffers of an Ann Arbor-area food bank, Food Gatherers. To maximize the effectiveness of the collection, a healthy rivalry was created between CEE students (on one side of the balance) and CEE faculty and staff (on the other side of the balance). The balance, constructed by department technician Merrick Burch, provided a real-time snapshot of the competition progress and is still used today, although (happily) the volume of contributions often exceeds the ability to stack the items!

Through carefully constructed challenges, the spirit of competition has grown through the years—often resulting in good-hearted exchanges and emails designed to “spur on” the participation of all department groups. In 2000, a group of graduate students introduced the Pork-and-Beans Trophy, which is now engraved to record the competition’s annual winners. In 2004, more than 3000 pounds of food was collected for the area food bank.

The coveted “Pork-and-Beans” Trophy
Assistant Professor Gustavo Parra-Montesinos has received the 2005 American Concrete Institute (ACI) Young Member Award. At its fall meeting, the ACI Board of Directors cited Professor Parra-Montesino for his “pioneering work on earthquake applications for high-performance fiber-reinforced cement composites as well as research and design work for composite structural systems; his service to ACI technical committees; and his mentoring and guidance of students.” The award will be conferred at the ACI convention in March 2006.

The College of Engineering also has recognized Professor Parra-Montesinos for excellence by bestowing on him the prestigious 1938E Award for 2005-2006. The award, given to the most outstanding CoE assistant professor, is accompanied by a monetary award.

Two recent honors have been bestowed on Professor Victor Li. The first is election as Fellow to the World Innovation Foundation (WIF). In its letter of elected fellowship to Professor Li, the foundation states: “The WIF mission . . . bring[s] into a new world order that is based on equality, a sharing environment, human dignity, self-worth and the economic cooperation of nations… [Scientists] and engineers are the only ones who can provide the ‘tools’ for this future condition. . . . [WIF fellow] members will become involved with national and international decision-making.” Nobel Laureate Dr. Jerome Karle is WIF’s president.

The second honor comes from the Christopher Columbus Foundation. Professor Li is one of two finalists for the 2005 Frank Annunzio Award in the field of science and technology for his work in bendable concrete. In the recognition program, the Foundation notes that Professor Li has “invented bendable concrete that retains the benefits of normal concrete, but eliminates the commonly observed cracking and spalling associated with concrete brittleness.”

Associate Professor Avery Demond was awarded the 2005 GEM outstanding Alumni in Academia Award in recognition of her outstanding achievements in the field of education. GEM, the National Consortium for Graduate Degrees for Minorities in Engineering and Science, is a nonprofit organization whose mission is to enhance the
value of the nation’s human capital by increasing the participation of underrepresented minorities (Native Americans, African Americans, Mexican Americans, Puerto Ricans, and other Hispanic Americans) at the master’s and doctoral levels in engineering and science.

Congratulations to Assistant Professor Aline Cotel. She has been awarded the 2005-2006 CEE Departmental Award for her “exceptional contributions to the Civil and Environmental Engineering department at the University of Michigan.”

Associate Professor Sherif El-Tawil has received the 2004-2005 Chi Epsilon James M. Robbins Excellence in Teaching Award for his dedication to teaching in Civil Engineering.

CEE Professor Emeritus Richard Woods has been recognized as an Honorary Member of the American Society of Civil Engineers (ASCE) for distinguished service to Civil Engineering. The ASCE’s Michigan and Ann Arbor branches also named him Engineer of the Year.

Professor Walter J. Weber, Jr., Gordon M. Fair and Earnest Boyce Distinguished University Professor of Environmental Science and Engineering, was featured on the cover of the November 15, 2004, issue of Environmental Science & Technology.

FACULTY RESEARCH

New Trends in Research: Earthquake-Resistant Design at the University of Michigan

By Assistant Professor Gustavo Parra-Montesinos and Professor James K. Wight

Structural engineering faculty at the University of Michigan have gained worldwide recognition for their contributions to the design of earthquake-resistant structures during the past fifty years. Their impact, in fact, can be seen in seismic design documents for steel and reinforced concrete structures around the world. U-M research has led to new structural systems, such as the Special Truss Moment Frame, as well as to design provisions for critical members in earthquake-resistant structures, such as beam-column connections (reinforced concrete, steel and hybrid) and steel braces. Currently, five structural engineering faculty, Professors Subhash C. Goel, Antoine E. Naaman, James K. Wight, Sherif El-Tawil, and Gustavo Parra-Montesinos are involved in the development of design provisions for reinforced concrete, steel and composite structures. Professor Wight is the chair of the Building Code Committee 318 of the American Concrete Institute (ACI); Professor Goel is a member of the AISC Committee on Seismic Design Specifications; and Professor Parra-Montesinos is a member of the ACI Building Code Subcommittee 318-F on New Materials, Products and Ideas.

U-M’s tradition of its strong impact on design practice for earthquake motions will likely continue for the years to come. For the past five years, Professors Gustavo Parra-Montesinos and James K. Wight have evaluated the use of new high-performance fiber-reinforced cement composites to make structures safer and more damage tolerant during earthquakes. With the new trends in performance-based seismic design, the structural engineering community is not only looking at designing structures that resist earthquakes without collapsing, but also at developing new structural systems that can sustain large earthquakes with little damage—minimizing the risk of downtime and the need for post-earthquake repairs. This is particularly important for critical structures, such as hospitals, bridges, and government buildings.

High-performance fiber-reinforced cement composites (HPFRCCs) are attractive for use in earthquake-resistant structures because of their high tensile strength and strain capacity, as well as compression ductility. This makes HPFRCC materials excellent candidates for increasing the shear resistance and deformation capacity of concrete members during earthquakes, while allowing for significant reductions in the amount of reinforcing steel required.
to prevent undesirable failures. Figure 1 shows the damage in two structural models tested by Chompreda and Parra (2005) in the U-M Structural Engineering Laboratory after being subjected to earthquake-type loading associated with a major earthquake. One of the two structural models was designed according to the 2005 ACI Building Code (ACI 2005); the other specimen represented a new design developed at U-M, using HPFRCC materials. It is worth mentioning that the code-designed specimen was reinforced with closely spaced transverse hoops; no transverse reinforcement was provided in the HPFRCC specimen. The U-M designed specimen exhibited outstanding damage tolerance; the code-designed model, even though it was capable of sustaining the applied load up to large deformations, sustained severe damage that could be considered beyond repair.

Currently, U-M Structures faculty are leading two research projects funded by the National Science Foundation Network for Earthquake Engineering Simulation (NEES) program on the use of HPFRCC materials to develop structural systems with high damage tolerance under earthquake-induced loading. The first project, in collaboration with the University of Minnesota, began in October 2004, and focuses on the use of HPFRCC materials to enhance punching shear resistance and deformation capacity of slab-column connections. U-M faculty involved in this project are Gustavo Parra-Montesinos (Principal Investigator), Jerome P. Lynch, and Vineet Kamat; Professor Carol K. Shield is the University of Minnesota researcher. In addition to enhancing the seismic behavior of slab-column connections, the incorporation of wireless sensing technology to enable the system to self-evaluate its condition immediately after earthquakes will be investigated.

The safety of slab-column framed systems depends on the behavior of their connections, which are highly susceptible to punching shear failures under the action of high-gravity loads and/or earthquake-induced lateral displacements. With the increasing demands for longer spans, the use of shear reinforcement in the form of studs has gained popularity as a means to increase punching shear capacity of slab-column connections. This shear reinforcement is costly, it may interfere with slab longitudinal reinforcement (mild or prestressing reinforcement), and it does not ensure high damage tolerance during large displacement reversals. In the U-M proposed system, an HPFRCC material is used in the slab-column connection region. Given their large tensile strain capacity, HPFRCCs are expected to provide sufficient diagonal tension capacity to prevent a punching shear failure at levels of lateral displacement associated with a major earthquake. Results from tests of HPFRCC slabs under direct punching shear conducted by doctoral student Min-Yuan Cheng, are encouraging and have shown a significant increase in slab punching shear capacity. Figure 2 shows a picture of the test setup and the punching shear stress versus deflection behavior of two pairs of slabs—one made of regular concrete; the other with an HPFRCC material containing high-strength steel hooked fibers in a 1.5% volume fraction. The shear stress was normalized by the nominal punching shear strength assumed in the 2005 ACI Building Code. Two flexural reinforcement ratios (rho) for each direction were evaluated. Figure 2 shows that the use of an HPFRCC material led to superior response in terms of both strength and deformation capacity. Tests of large-scale slab-column connections will be conducted next, both at Michigan and at the NEES facility at the University of Minnesota, and will evaluate the proposed design under earthquake-type loading.
The other NSF-NEES research project on HPFRCC structures led by U-M faculty began in September 2005, and is aimed at developing a new coupled wall system using HPFRCC coupling beams. This four-year research study combines the expertise of various faculty at the University of Michigan, Stanford University, and the University of Illinois, and ranges from material development to highly sophisticated numerical modeling and hybrid testing of structures. U-M faculty involved in this project are James K. Wight (Principal Investigator), Sherif El-Tawil, Antoine E. Naaman, Gustavo Parra-Montesinos, and Thomas Finholt (School of Information). Professors Sarah Billington from Stanford University and U-M graduate Prof. James LaFave from the University of Illinois are also involved. This research will include the hybrid testing of coupled wall systems, in which the first few stories of the structure and an isolated upper floor will be physically tested, while the rest of the system is modeled analytically using state-of-the-art finite element simulation. Figure 3 shows a sketch of the hybrid coupled wall tests planned for this investigation.

Current design practice for coupling beams in wall systems includes the use of intricate reinforcement detailing to ensure adequate deformation capacity during earthquakes. This leads to substantial reinforcement congestion and construction difficulties (Figure 4a). Because of this, several alternatives to the use of diagonally reinforced coupling beams have been investigated, including the use of steel or hybrid steel-concrete coupling beams (see companion paper by El-Tawil and Hassan on page 17). In this investigation, however, a different approach is followed, which consists of the use of a “better” material as opposed to “more” material. The main goal of this research, then, is to develop a concrete coupled wall system with substantially simpler, highly damage-tolerant coupling beams through the use of HPFRCCs.

This research builds upon research conducted during the past six years by Professors Parra-Montesinos and Wight, and Dr. B. Afsin Canbolat (U-M Alumni), in which the idea of using precast HPFRCC coupling beams was first developed (Canbolat, Parra, and Wight 2005). Results from that investigation demonstrated the potential of the proposed coupling beam design for use in earthquake-resistant wall structures. As shown in Figures 4a and 4b, the proposed coupling beam requires much less reinforcement (particularly confinement reinforcement), and possesses larger shear strength and deformation capacity compared to well-detailed RC coupling beams. In addition, the proposed HPFRCC coupling beam resisted shear stress demands as large as 150%—the maximum stress allowed in the 2005 ACI Building Code. It is worth mentioning that the idea of using precast HPFRCC coupling beams in earthquake-resistant wall construction has been recently adopted in Japan, as described in a paper presented by Professor Li in this issue of the Newsletter on page 22.

Parallel to the NSF-NEES funded research, two other U-M research projects on structural applications of HPFRCC materials are currently funded by NSF: one on the use of HPFRCC materials in critical regions of earthquake-resistant structural walls (both slender and squat walls) led by Professor Parra-Montesinos (described in a companion paper on page 23); the other on the bond between steel reinforcement (bars and prestressing strands) and HPFRCC materials under gravity-type and earthquake-type loading, led by Professor Antoine E. Naaman. Also, research on fiber reinforced cement composites at Michigan has expanded to tunneling construction through collaboration with the fiber and construction industry.

In summary, the combination of expertise in structural materials and mechanics, as well as in the behavior, design, and
testing of large-scale structures, has allowed U-M structural engineering faculty to take a leading role in the development of highly damage-tolerant structures through the use of high-performance fiber reinforced cement composites (HPFRCCs)—particularly for earthquake-prone regions. Through two NSF-NEES projects, and through other NSF- and industry-funded projects on structural uses of fiber reinforced cement composites, findings from research conducted by U-M structures faculty will provide the civil engineering community with new design alternatives for structures located in regions of high seismicity.

Additional information and papers on HPFRCC-related research can be found at http://www-personal.engin.umich.edu/~gipm/

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Bridge Decks in Michigan Go Jointless

By PhD Candidate Michael Lepech and Professor Victor C. Li

Introduction
As one of the most expensive public works projects in history, the contribution of the interstate highway system to the development of the United States as an economic power is irrefutable. In 2002 alone, commercial freight transported over the interstate system accounted for 8.3 billion metric tons of shipments valued at over $6.6 trillion [USDOT, 2003]. Yet since its creation roughly 50 years ago, the expansion and maintenance of the interstate highway system has required massive allocations of federal, state, and local government budgets. Such commitment was most recently highlighted in the signing of the $286 billion 2005 Transportation Equity Act. Although work has continually progressed, the condition of the nation’s infrastructure has become exceedingly worse—mainly due to a persistent lack of funding, increasing traffic volumes, and heavier loads on roadways [ASCE, 2005]. To combat this trend, the State of Michigan alone invests more than $1 billion annually in transportation infrastructure [MDOT, 2002].

One of the main durability and maintenance problems confronting departments of transportation nationwide is the continual failure of mechanical expansion joints installed between adjacent, simple-span bridge decks. While these expansion joints are essential to accommodate the large thermal deformations of the nearby decks, their tendency to fail quickly into disrepair and eventually leak is an inevitable cause of deterioration of the entire superstructure. Water from the deck, saturated with de-icing salts during cold weather, leaks through deteriorated joints, and ultimately either corrodes the ends of steel girders or penetrates into precast concrete girders and corrodes the reinforcing steel. Solutions to this continuing problem have included the development of continuous bridge decks or integral abutment bridges which seek to eliminate mechanical expansion joints by using an uninterrupted deck surface over multiple spans. These solutions, however, are applicable only to new construction and present significant design complications within the superstructure or substructure when compared to simple bridge-span design.

Engineered Cementitious Composites
As seen recently in such media outlets as The Discovery Channel News and The History Channel’s “Modern Marvels”, a new class of composites has emerged to meet the seemingly contradictory requirements of both limiting cracking for durability, and achieving high ductility to meet the requirements of thermal expansion, drying shrinkage deformation, and structural safety. Called Engineered Cementitious Composites (ECC) [Li, 1993], this type of ultra-ductile, high-performance, fiber-reinforced cementitious composite (HPFRCC) developed by the Advanced Civil Engineering Materials Research Laboratory (ACE-MRL) at U-M exhibits nearly all of the characteristics sought by highway designers and structural engineers for a highly durable concrete rehabilitation material. [Professor Victor C. Li directs the ACE-MRL.] Developed through engineered tailoring of the components (i.e. cement, sand, fly ash, water, admixtures, and fibers), ECC exhibits mechanical properties far beyond concrete or fiber-reinforced concretes. Most distinctive is an ultimate tensile strain capacity of 3%-5%, depending on the specific ECC mixture. This strain capacity, over 300 times that of normal concrete, is realized through the formation of a large number of closely spaced micro cracks as the load increases, thus allowing the material to deform similar to ductile metals.

ECC “Link Slabs”
To allow designers both to maintain simple design and to allow for retrofitting of existing bridge structures, the use of ECC “link slabs”, rather than mechanical expansion joints between adjacent bridge spans, was proposed by U-M researchers. By removing the expansion joint and replacing a portion of the two adjacent decks with a section of ECC material on top of the joint, a continuous deck surface is constructed. The unique capability of ECC material to deform up to 4% strain in tension while maintaining low crack widths allows the ECC link slab to accommodate the deformations imposed by the adjacent decks (i.e. due to thermal expansion and contraction) while protecting the underlying superstructure and substructure from corrosives present on the deck surface.
To combat the continuing problem of deteriorating and leaking expansion joints, the Michigan Department of Transportation has recently completed construction of a demonstration ECC link slab within Michigan. This link slab, approximately 20 minutes from the Ann Arbor campus, is part of the Grove Street Bridge over I-94 in Ypsilanti, Michigan. Using design and construction guidelines developed by the U-M research team, an MDOT design team incorporated the design of an ECC link slab within a large multi-bridge rehabilitation project of I-94 between Detroit Metropolitan Airport and Ypsilanti. The construction was completed during the Summer/Fall of 2005. This unique project, vetted within the standard MDOT open bidding process, was awarded to Midwest Bridge Company in March, 2005. Field project engineering was contracted to HNTB; materials testing was conducted by CTL and NTH. Clawson Concrete was subcontracted as the project’s concrete material supplier.

Construction of Grove Street Bridge

The Grove Street Bridge is a four-lane bridge constructed originally in 1971 with a composite steel girder-concrete deck structure. The 9-inch thick concrete deck rests upon 10 built-up steel girder sections across the 66-foot width of the bridge. Traffic is carried over I-94 on four pin-and-hanger supported spans. Since its construction, the bridge has experienced significant deterioration. The most recent repair work performed on this structure was a thin overlay of bituminous asphalt placed in 2000 to extend the service life of the bridge for another 5 to 7 years.

The goal of the Grove Street Bridge construction project was to both return the bridge to fully operational conditions and improve the bridge through wider sidewalks and dedicated bike lanes. The MDOT plan called for painting of the steel girders and the replacement of the entire bridge deck. In addition, the ECC link slab was to be constructed at the bridge center. This work began on July 25, 2005, with the placement of traffic control devices; it proceeded in two phases ultimately completed on November 1, 2005. Placement of the ECC link slab for Phase One took place on Saturday, September 10, 2005. The two bridge spans adjacent to the ECC link slab had been poured overnight on September 9, 2005, to ensure that they were sufficiently cured to pour the neighboring ECC link slab. For the approximate twenty yards of ECC material needed for each phase of the construction, three trucks with seven yards of ECC material were batched and sent to the site. The placement and finishing of the ECC material for Phase One is shown in Figures 3 - 6.

Placement of the ECC link slab for Phase One took place on Saturday, September 10, 2005. The two bridge spans adjacent to the ECC link slab had been poured overnight on September 9, 2005, to ensure that they were sufficiently cured to pour the neighboring ECC link slab. For the approximate twenty yards of ECC material needed for each phase of the construction, three trucks with seven yards of ECC material were batched and sent to the site. The placement and finishing of the ECC material for Phase One is shown in Figures 3 - 6.
Phase Two of the Grove Street construction began on Friday, September 23, 2005, when traffic was shifted over to the newly constructed sections; work then progressed on the west half of Grove Street. Photographs of the construction process are shown in Figures 7-8.

Construction of the ECC link slab for Phase Two occurred on Tuesday, October 18, 2005. The two bridge spans adjacent to the ECC link slab had been poured overnight on October 15, 2005, to ensure that they were sufficiently cured to pour the neighboring ECC link slab. As in Phase One, approximately 20 yards of ECC material was needed for the link slab pour, so three trucks with seven yards of ECC material each were batched and sent to the site. The placement and finishing of the ECC material for Phase Two is shown in Figures 9-12.
Following each phase of link slab construction, a concrete sidewalk, concrete barrier wall, and metal railing were constructed over the full length of the bridge. Photographs of this construction are shown in Figures 13 and 14. Finally, the completed Grove Street Bridge and ECC link slab are shown in Figures 15 and 16, respectively.

### Load Testing

To validate the performance of the ECC link slab adopted upon the Grove Street Bridge, static load testing was conducted on the bridge immediately following its construction. This allowed the design team to both validate design assumptions and monitor the response of the ECC link slab under traffic loading. This work combined the research expertise of both the ACE-MRL and the Laboratory for Intelligent Structural Technology (LIST). [LIST is directed by CEE Professor Jerome Lynch.] Students from Dr. Szerszen’s research group also participated in this field study. In order to examine the performance of the ECC jointless bridge under its most severe design live load condition, an HS 25-44 truck was used to load the bridge during testing. This is shown in Figure 17.

For the collection of bridge response data, a wireless monitoring system assembled from wireless sensing units was
The wireless sensing units are not sensors per se, but rather are autonomous nodes of a wireless data acquisition system to which traditional sensors (e.g., accelerometers, strain gages, among others) were interfaced. The wireless sensors were assembled from off-the-shelf electrical components to offer true 16-bit data acquisition capabilities. The advantage of using a wireless monitoring system was its easy installation, which was orders of magnitude quicker than the installation time needed for wired systems. The wireless sensing units employed in this study were academic prototypes designed and fabricated at the University of Michigan. This is shown in Figure 18.

**Conclusion**

Within this demonstration project, a new cementitious composite was used on a bridge deck within Michigan to replace a conventional expansion joint within the deck. Through close collaboration between various U-M researchers, MDOT design and inspection personnel, general contractor crews, and field project engineering staff, this innovative material was successfully implemented on the Grove Street Bridge project. Based upon the results of this project, the use of ECC technologies is expected to increase throughout the State of Michigan and nationwide in upcoming years.

**Acknowledgements**

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**Additional Information**

Additional information about this or other projects can be found by visiting the Advanced Civil Engineering Material Research Laboratory (ACE-MRL) website at http://ace-mrl.engin.umich.edu.

**References**


Graham Environmental Sustainability Institute Launched at the University of Michigan

By Associate Professor Jeremy D. Semrau, Civil and Environmental Engineering and School of Natural Resources and Environment

On November 17, 2005, U-M announced the formation of the Graham Environmental Sustainability Institute (GESI) with $10.5M in expendable funds. GESI has as its general goal the creation of opportunities and encouragement of collaboration among science, policy, engineering, and business faculty to extend the knowledge of, and offer solutions to, complex environmental sustainability issues—while recognizing the necessity for balance between societal needs and social responsibilities.

Launched with $5.25M from the Graham Foundation and a matching $5.25M in support from the Office of the Provost, GESI will augment work at the University in the field of environmental sustainability. Collaboration between units will focus on five crucial areas of environmental sustainability: energy; freshwater systems; human health and its linkages to a changing environment; global change and biodiversity; and sustainable infrastructure and manufacturing.

A review of U-M activities found that more than 300 faculty members in seven schools (the College of Engineering; the School of Natural Resources and Environment; the School of Public Health; the Ross School of Business; the College of Literature, Science, and Arts; the Taubman College of Architecture & Urban Planning; and the Ford School of Public Policy) currently pursue studies in one or more of the five focal areas chosen for GESI. Within the College of Engineering, the Department of Civil and Environmental Engineering, in particular, has active and vibrant research in many of the identified areas—and it is expected that CEE will have significant role in the activities of GESI.

CEE has had a direct link to the development and direction of the Institute: Associate Professor Jeremy D. Semrau served, and continues to serve, as one of the two study-team leaders who developed the successful proposal. Professor Semrau, along with Special Counsel to the Provost Kenneth Kohrs proposed the formation of a campus-wide initiative that would provide financial support and other resources to leverage and integrate U-M academic and research activity in environmental sustainability.

With support from the Graham Foundation and the Provost’s Office, GESI funds will (1) award seed grants to faculty that will enable teams of researchers to compete more successfully for major external grants; (2) provide multi-year fellowships for graduate students pursuing studies in environmental sustainability; (3) provide internships to undergraduate students; (4) provide faculty with more resources to develop and/or revise courses to include discussion/analysis of environmental sustainability; (5) develop a new graduate program integrating studies in engineering with studies in policy, environmental science, and public health; and (6) develop a web portal that will serve to increase awareness of the University of Michigan's depth and breadth in the field of environmental sustainability.

Support from Don Graham, head of the Graham Foundation, is particularly appreciated. As a result of the tutelage of his father, Samuel Graham, a former professor in the U-M School of Forestry (now the School of Natural Resources and Environment), the younger Graham developed a long and significant interest in promoting environmental sustainability. The education Graham earned at U-M—first in engineering (BS, Industrial Engineering ’55; MS, Mechanical Engineering ’56), and then in business—culminated in the development of new methods of recycling plastics, effectively reducing landfill needs while saving on raw materials.

With the generous support of both Graham and the Provost's Office, U-M is positioned to optimize and integrate its numerous and substantial strengths to become a global leader in the critical area of environmental sustainability. GESI is expected to be operational by late 2006. The GESI web portal should be operational and available for review on the U-M home page (www.umich.edu) by mid-2006.

Seismic Modeling and Behavior of Hybrid Coupled Wall Systems

By Associate Professor Sherif El-Tawil, and Mohammad Hassan, Structural Research Engineer, The Englekirk Companies, Santa Ana, CA; also Assistant Professor Tanta University, Tanta, Egypt (on leave).

Introduction

Reinforced concrete (RC) coupling beams that couple adjacent RC shear walls can be subjected to severe distortional demands during an earthquake. These high demands have forced designers to provide special reinforcement detailing in the vicinity of RC coupling beams; this leads to difficulties for rebar contractors and increases in construction costs. In an attempt to mitigate these problems, some engineers have turned to structural steel coupling beams as an alternative to RC beams. The ends of the steel coupling beams are embedded in the wall boundary elements and the resulting structural system is called a hybrid coupled wall (HCW) system (Figure 1).
HCW systems have been studied, mostly experimentally, since the mid 1990s. Key conclusions from previous studies can be summarized as follows: 1) steel coupling beams can be designed to provide ductile behavior by yielding in shear, similar to the behavior of a shear link in eccentrically braced frames; 2) if sufficiently well detailed, the end-embedded connection between the steel beam and RC wall will perform well under reversed cyclic loading; and 3) structural performance is strongly influenced by the coupling ratio (CR), which represents the portion of system overturning moment resisted by the coupling action as shown in Figure 2.

This note summarizes research conducted to gain a better understanding of the system level response of hybrid coupled wall buildings subjected to various levels of seismic hazard. The goals of the research work were achieved through transient finite element simulations in which the most important sources of nonlinearity in structural response are taken into account.

**HCW Prototypes.**

The prototype structures considered are based on plans developed for the US-Japan cooperative research program on Composite and Hybrid Structures sponsored by the US National Science Foundation [US-Japan Planning Group, 1992]. The US-Japan theme structures have a regular floor plan and geometry and are intended to provide common focus for the various components of the US-Japan research program.

Seismic design loads are calculated in accordance with NEHRP’s Equivalent Lateral Force Procedure in FEMA-302 [1997]. Overall system design is conducted according to a method proposed by El-Tawil et al. (2002a), which ensures that a specified level of coupling is achieved. A coupling ratio of 30% is chosen for both systems, based on the pushover study by El-Tawil and Kuenzli (2002b), which showed that this level of coupling provided for good economy combined with satisfactory structural performance.

**Finite Element Modeling And Validation.**

The authors had previously developed detailed finite element models of hybrid coupled walls (Figure 3a). The models are described in El-Tawil et al. (2002a) and account for the effect of material inelasticity, concrete cracking, opening and closure of the gap between the embedded steel beams and the walls, and geometric nonlinearity. The models were thoroughly validated through comparisons with test data and were shown to be accurate for a wide range of conditions. It was not possible to use these detailed models for transient finite element analyses because of their large size. Instead, simplified models that were computationally tractable were developed and calibrated to the detailed models for use in the parametric study (Figure 3b).

**Parametric Study And Analysis Results.**

Extensive inelastic dynamic analyses were conducted to investigate a variety of parameters pertaining to hybrid coupled walls, including hazard level, earthquake record scaling, dynamic shear magnification, interstory drift, shear distortion, coupling beam rotation, and wall rotation. Performance measures calculated from the parametric analyses were compared to corresponding pushover results and examined for evidence of behavioral trends. The research confirms that moderately coupled hybrid wall systems are well suited for application in regions of high seismic risk. It was also shown that over-coupling can lead to problems, including widespread cracking; it also can induce large shear and compressive axial loads that are detrimental to behavior. At the other extreme, no coupling at all also could lead to poor behavior, manifested by high base wall rotations, story drifts, shear distortions, and deflections, as well as the potential for extensive concrete crushing in the plastic hing region at the base of the wall.

**Ongoing Work.**

The results produced by this research are currently being synthesized along with existing experimental information into recommended seismic design guidelines that will be published by the Structural Engineering Institute of the American Society of Civil Engineers (ASCE). The effort is being conducted through the Composite Construction Committee of ASCE, which is chaired by Associate Professor Sherif El-Tawil. The new document will propose performance-based design specifications suitable for use in regions of high seismic risk.

In another thrust, Professor El-Tawil is collaborating with Professors Naaman, Parra-Montesinos, and Wight of the Department of CEE to investigate the response of shear walls coupled via high performance fiber-reinforced cement composite (HPFRCC) beams. Like steel coupling beams, HPFRCC beams are a good alternative to the problematic reinforced concrete beam details currently in use. The work is funded through a NEES grant provided by the National Science Foundation and involves state-of-the-art hybrid testing of components and subassemblages. Hybrid testing requires the use of computational models and testing equipment networked together to provide realistic test conditions that are not feasible just through traditional testing techniques.
Visualization of Construction Activities in Outdoor Augmented Reality

By Assistant Professor Vineet R. Kamat and PhD Pre-Candidate Amir H. Behzadan

Introduction
The presented research investigates the application of outdoor Augmented Reality (AR) for 3D graphical simulation of construction activities. The objective of the research is an AR-based visualization platform that can be used with corresponding peripheral equipment (head-mounted display, GPS receiver, orientation tracker, and a portable computer) to generate both a mixed view of the real world (in background) and superimposed virtual construction graphics (e.g. CAD models) in an unprepared outdoor environment.

Background and Motivation
Visualization-based simulation has been the focus of interest for a number of previous works in this field. The main motive for such work has been the realization that by using visualization tools, all involved parties in a construction project can investigate and study the many potential issues and problems that may occur in the real project (such as resource utilization, physical constraints, operation conflicts, etc.) before committing real resources in the field.

As the basis for most of the above mentioned works (most of them in Virtual Reality), however, the CAD modeling approach requires that the entire project be modeled—including all the existing facilities, job site and temporary facilities, natural terrain, idle as well as operating equipments, etc. This, in fact, is a time-consuming, and in most of the cases impractical, method to animate and study a particular operation or portion of the whole project. By using the Augmented Reality (AR) approach, the real world can be conveniently used as the background; only virtual CAD models of those resources under study need to be created for being augmented over the real scenes of the surrounding environment.

There are a number of characteristics that distinguish the presented work from indoor AR applications. These include the extended use of advanced positioning tools (e.g. GPS); capability to produce real time output as the user moves around freely (i.e., by applying minimum constraints over the user's position and orientation); and the ability to operate independently of environmental factors (e.g. lighting conditions and terrain variations). These are mainly the factors that make the designed platform a powerful tool for several outdoor AR applications.

Technical Approach
The head-mounted display models the behavior of the user's eye where all the real objects in the surrounding space appear in a perspective view (i.e., the viewing area for the user consists of a truncated pyramid in which parallel lines coincide in the horizon). Using a set of C++ libraries called OpenGL, animated objects can be presented in a viewing frustum made by the platform with the user's eye located at the center. Appropriate alignment of these two views in real time leads to a realistic mixed view of both real and virtual objects which is viewable for the user within either the computer or head-mounted display. Figure 1 shows the technical approach by which virtual models are superimposed on a scene from the real world.

Acknowledgement
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References
In order to achieve this objective, a set of geometric transformation (translation and rotation) matrices are calculated at each instant during a simulation, and are applied to the current geometric state of the augmented virtual objects such that they are transformed to their correct location and pose appropriately relative to the user’s eye. By connecting an accurate GPS receiver and an inertial orientation tracker to a known point on the user (e.g. hard hat), the user’s global position and orientation (i.e. longitude, latitude, altitude, heading, pitch, and roll) are tracked continuously. These are used to compute relative translation and rotation matrices which are then applied to the augmented CAD objects in real time.

**Implementation and Validation**

To validate the results of the project, prototype software called UM-AR-GPS-ROVER has been developed and implemented. This software is capable of interactively placing three-dimensional CAD models at any desired location in an outdoor augmented space. The concept and the prototype have been tested successfully in several outdoor locations at the University of Michigan North Campus using various 3D construction models (such as buildings, frames, equipments). A Sony Camcorder was used to model the user’s eye input and a Delorme Earthmate GPS receiver together with an Intersense orientation tracker were the input devices for obtaining the user’s global position and head orientation. Figure 2 illustrates the peripheral equipments used in the field tests.

Figure 2: Hardware setup for UM-AR-GPS-ROVER field tests

In order to test the prototype’s ability to augment dynamically changing graphical information in the user’s view, the concept of 4D-CAD has been introduced and integrated into the platform. As an example of this concept, scheduled construction activities for the erection of a structural steel frame (columns erection and girders/ beams connections) have been animated with the passage of simulated project time. In the animated example, “time” is introduced as an extra dimension for each augmented virtual object; in other words an object (e.g. steel beam or column) is not shown in the augmented space unless the simulation clock passes its scheduled completion time.

Figure 3 shows some snapshots of the field tests in which various construction models have been used as virtual objects. The first snapshot in this figure is indeed a dynamic (i.e. 4D-CAD) model in which every element of the virtual building has a time tag. The time tag defines the elapsed time since the beginning of the simulation when that element should appear on the screen. This, in fact, is the main point of departure in UM-AR-GPS-ROVER platform, where time is being introduced as an extra dimension beside the three main physical dimensions of any virtual object.
Professor James Barber Completes Breakthrough Theory on Elasticity

In a seminal paper to appear soon in the proceedings of the Royal Society of London, Professor James Barber will present the first three-dimensional solution for determining the elastic stresses in a prismatic bar under fairly general loading. Before the completion of the new theory, only an approximate solution could be found using beam theory; exact solutions were restricted to cases where only the ends of the bar are loaded. In his paper, Professor Barber extends these exact methods to treat the case of fairly general lateral loading, using a recursive algorithm.

The method provides an exact solution for a wide range of beam problems and has the advantage of generality in comparison with widely-used numerical methods. It also can be used to investigate the effect of three-dimensional loading on stress concentrating features such as holes and cracks.

As shown in Figure 1, a general solution is given to the three-dimensional linear elastic problem of a prismatic bar subjected to arbitrary tractions on its lateral surfaces—subject only to the restriction that they can be expanded as finite power series in the axial coordinate z. The solution is obtained by repeated differentiation of the tractions with respect to z, establishing a set of sub-problems. A recursive procedure is then developed for generating the solution that involves three steps: (1) integration of the stress and displacement fields with respect to z, using an appropriate Papkovich-Neuber representation; (2) solution of two-dimensional in-plane and antiplane corrective problems for the tractions that are independent of z; and (3) expression of these corrective solutions in P-N form.

The method can easily be extended to include body forces, provided that these can be described by a body-force potential.

The Class of 2025?

It’s never too early to recruit a future CEE Engineer: 3-year-old Hugh Green pictured
U-M Developed ECC is First High-Performance, Fiber-Reinforced Cementitious Composite Material Used in a High Rise

By Professor Victor C. Li

On September 29, 2005, Kajima Corporation, the world’s largest construction company, announced that two high rises in the Tokyo area utilize coupling beams built with a high-performance, fiber-reinforced cementitious composite, K/ECC. The K/ECC is a Kajima-adapted version of the Engineered Cementitious Composite (ECC) material originally invented at the University of Michigan by a group of researchers under the direction of Professor Victor Li. This marks the first structural use of high-performance cementitious composite material (HPFRCC) in a tall building worldwide.

The two buildings involved are the 27-story Glorio Roppongi High Rise in Central Tokyo and the 41-story Nabeaure Tower in Yokohama. In each case, K/ECC coupling beams are used to connect the core walls of the building at every story for the purpose of enhancing energy absorption of the building under seismic loading. The significant improvement in damage tolerance is expected to lead to reduced repair cost after a major seismic event. In addition, the installation of these ECC coupling beams allows for more efficient building design and reduction in construction cost. Construction for the Glorio Roppongi High Rise began in 2003 and is expected to be completed by mid-2006; construction on the Nabeaure Tower began in 2004 and has a target completion date of early 2007.

ECC is an ultra-ductile, cement-based composite with carefully tailored ingredients based on micromechanics theory developed by Professor Li and his students. Under excessive tensile or shear loading, the composite “yields” rather than fractures as would most other concrete materials. This metal-like characteristic of ECC makes the material particularly suitable for structural elements subjected to large imposed deformation, as in the case of the coupling beams.

Dr. Tetsushi Kanda, who received a PhD from the CEE department at U-M in 1998, leads the R&D of ECC structural applications at Kajima Corporation. He was a former student of Professor Li. Over fifty research groups world-wide are currently engaged in ECC technology research and application studies.
Development of Lightly Reinforced, Highly Damage-Tolerant Structural Walls through the Use of High-Performance Fiber Reinforced Cement Composites (HPFRCCs)

By Assistant Professor Gustavo J. Parra-Montesinos, B. Afsin Canbolat, PhD, CE '04, and Ganesh R. Jayaraman, MSECE '04

Structural walls are often used in medium- and high-rise earthquake-resistant construction to provide the necessary lateral strength and stiffness to withstand the displacement demands imposed by ground motions. In wall regions expected to undergo large inelastic deformation reversals (typically the wall lower portion), special reinforcement detailing is required to ensure adequate wall deformation capacity as well as strength and stiffness retention. In particular, closely spaced confinement reinforcement is required at the wall edges or boundary regions to increase concrete ductility and provide lateral support to the wall main longitudinal reinforcement. Further, sufficient distributed web reinforcement must be provided to avoid a shear failure prior to the wall reaching its expected flexural capacity. The seismic provisions of the 2005 ACI Building Code (2005) require that wall boundary regions be designed as columns, with large amounts of confinement reinforcement spaced at a distance not to exceed ¼ of the minimum wall dimension (thickness). Thus, for a wall 30 cm thick, the transverse reinforcement spacing at the wall edges cannot exceed 7.5 cm. Even though these requirements have been shown to lead to satisfactory behavior during strong ground shakings, their structural efficiency is often overshadowed by the severe reinforcement congestion problems and construction difficulties created (Figure 1). Thus, there is need to develop new designs for structural walls that do not require large amounts of closely spaced transverse reinforcement while ensuring adequate seismic behavior.

During the past two years, researchers at the University of Michigan have investigated the use of high-performance fiber reinforced cement composites (HPFRCCs) to simplify the design and construction of structural walls in regions of high seismicity. The goal is to develop highly damage-tolerant structural walls that would require only the use of “non-seismic” reinforcement detailing, taking advantage of the tensile strain-hardening behavior of HPFRCCs, as well as their compression behavior that resembles that of well-confined concrete. Because special transverse reinforcement in the wall boundary regions is only required at the locations where large inelastic rotation demands are expected (typically at the wall lower portion), the HPFRCC material would only be used at the wall base over a height approximately equal to 1.5 times the wall length.

To evaluate the proposed design, four structural wall specimens were tested in the U-M Structural Engineering Laboratory under lateral displacement reversals. Figures 2a and b show a sketch of the test setup and a picture of one of the wall specimens ready for testing. Figures 3a and b show the reinforcement detailing used in two of the structural walls tested. The wall shown in Figure 3a was designed following the seismic provisions of the 2005 ACI Building Code, while the wall shown in Figure 3b was constructed with an HPFRCC material at its lower portion; it contained no special boundary reinforcement. The HPFRCC material contained steel hooked fibers (30 mm long and 0.55 mm in diameter) in a volume fraction equal to 2.0%. As can be seen, the wall constructed with an HPFRCC material contained substantially less transverse reinforcement compared to that required by the ACI Code. For example, the hoop spacing in the boundary zones of the HPFRCC wall was six times that of the reinforced concrete (RC) wall.
Figure 4 shows the lateral load versus displacement hysteresis response obtained for the two walls shown above. As can be seen, both specimens exhibited similar behavior, however, the HPFRCC wall being about 20% stronger. The HPFRCC wall exhibited excellent damage tolerance with negligible damage at 2.0% drift (lateral displacement ÷ wall height) (Figure 5a), a displacement that could be considered an upper bound in structural wall systems. Further, as shown in Figure 5b, no visible compression-related damage was observed in the HPFRCC wall boundary regions up to drifts as large as 3.0%. Failure of the HPFRCC wall occurred during a cycle at 3.5% drift due to fracture of the main longitudinal reinforcement at the wall boundary zone. At that displacement level, even though the RC wall was capable of maintaining its strength, it had sustained major damage characterized by wide diagonal cracks in the plastic hinge region.
In conclusion, it has been shown that the use of HPFRCC materials in structural walls is a viable option to relax transverse reinforcement requirements while increasing damage tolerance in earthquake-resistant structural walls, facilitating their construction and reducing the likelihood of requiring major repairs after a large earthquake.

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Acknowledgements
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STUDENT NEWS

Annual Career Fair to Be Held February 10

The annual Civil and Environmental Engineering Career Fair will be held on Friday, February 10, 2006, in the Duderstadt Center on the University of Michigan’s North Campus. The fair, hosted by the Student Chapter of the American Society of Civil Engineers (ASCE), is an exclusive event for civil and environmental engineering companies and students, and is designed to offer a venue within which both contingents can make contacts and discuss employment opportunities. CEE students are encouraged to take advantage of the opportunities to showcase their skills to a dedicated group of employers. More than thirty-five companies attended last year’s event; the goal for 2006 is that fifty companies will be represented.

To showcase your company and participate, download a registration form from www.engin.umich.edu/soc/asce/Response%202006.pdf. Direct questions to Shane Willis (swillis@umich.edu) or Nan Karczewski (nkarczew@umich.edu). Future career fair information can be found at the ASCE website: www.engin.umich.edu/soc/asce/.

Graduate Environmental Engineering Network of Professionals, Educators, and Students (GrEENPEAS)

By PhD Pre-Candidate Lisa Colosi

GrEENPEAS (Graduate Environmental Engineering Network of Professionals, Educators, and Students) continues to serve the environmental engineering program as outlined in its four-part mission: promoting relationships and networking, stimulating academic exchange, providing service opportunities, and advocating for the individual and collective needs of our graduate students. We’ve started off another academic year with a whirlwind series of events!

At our first external lecture of the year on September 7, we hosted Dr. Rene Schwarzenbach of the Federal Institute of Technology in Zurich, Switzerland. Dr. Schwarzenbach holds the title of 2005-2006 American Environmental Engineering & Science Professors’ Distinguished Lecturer, and spoke as part of the GrEENPEAS Environmental Science, Engineering and Policy in the 21st Century (ESEP-21) Seminar Series. His lecture, attended by over 40 individuals from the University community, coincided with the EWER program’s Welcome Party. The party, which was moved to the East Room of Pierpont Commons, provided a great opportunity for new and returning graduate students and faculty to interact.

GrEENPEAS’ second external lecture of the year followed close behind on September 29. On that date, we co-hosted the visit of Dennis Martenson, President-Elect of the American Association of Civil Engineers (ASCE). Martenson’s talk, entitled “ASCE—Current and Future” was also hosted by the U-M chapter of ASCE. In the tradition of ESEP-21 lectures, Mr. Martenson’s talk provided us the opportunity to consider the role of civil and environmental engineers as we look forward to our own professional careers.

EWRE program members had a chance to give something back to the community-at-large when we participated in the Huron River Watershed Council’s Fall River RoundUp. Five students spent a morning traversing two tributaries of the Huron River—the only river in southeast Michigan designated a “Country-Scenic Natural River”. By collecting an assortment of aquatic invertebrates, we assisted the HRWC in its biannual assessment of watershed health.

Other GrEENPEAS events for the semester include a variety of social happy hours, such as a trip to Arbor Brewing Company on Main Street, and a rock-climbing social event on campus as well. In addition, we look forward to the third-annual International Potluck, to be held at the end of the fall semester. Among the most popular of all GrEENPEAS social events, the potluck dinner allows graduate students the opportunity to both showcase their own cultural backgrounds and learn about those of their fellow graduate students.

Featured from left to right: Corrie Clark, Andy Turner, Lisa Colosi, Andrew Henderson and Hans Tritico
**STUDENT AWARDS**

**Rhodes Scholarship**

Carlos Sayao, a senior in civil engineering and environmental economics, will compete for a prestigious Rhodes Scholarship. A U-M swimmer who has represented Canada in various competitions around the world, Sayao is interested in studying environmental change and management at Oxford University, with a particular interest in the overlap between environmental and social policy.

**ASCE Award**

**Daniel W. Mead Prize for Younger Members**

Once again, a CEE graduate has received the Daniel W. Mead Prize for Younger Members. Ken R. Maschke was awarded the ASCE honor for his paper entitled, “Is It Ethical to Use an Engineering Software Program If You Cannot Complete the Calculations Manually?” Maschke earned both his bachelor’s and master’s degrees from the University of Michigan, where he was active in the ASCE student chapter; participated as a member of the 2003 CEE student steel bridge team; and served as captain of the concrete canoe team. Maschke currently works for the Thornton-Tomasetti Group, Inc., and is based in the firm’s Chicago office. He is an active participant in the ACE Mentor Program and serves on ACE’s national task committee that addresses precollege outreach efforts.

**Michigan Section Snags National Award**

The ASCE Michigan Section has been selected to receive the “2005 Certificate of Merit in State Government Relations” for its outstanding work in opposition to Governor Granholm’s proposed cuts to the dam safety program in Michigan. This award is presented annually based on proven examples of excellence in advocacy. The award will be presented during the ASCE 2005 Annual Meeting in Los Angeles.

**Rackham International Students Fellowship Award Winners**

Rita Awwad, a doctoral student working with Professor Photios Ioannou, and Min-Yuan Cheng, a doctoral student working with Assistant Professor Gustavo Parra-Montesinos, have been awarded the Rackham International Students Fellowship.

The fellowship assists outstanding international students who are in their second or third academic term and are actively pursuing a degree in any Rackham program. Students must have a strong academic record, be making good progress toward the degree, and demonstrate outstanding academic and professional promise. Of the twenty awards given for Winter 2006, five were given to CoE students.
The Civil and Environmental Engineering Friends Association 22nd Annual Tailgate Brunch, was held on Saturday, October 8, 2005 at O’Neal Construction, Argus Building.

Snapshots
**CIVIL AND ENVIRONMENTAL ENGINEERING FRIENDS ASSOCIATION**

**SPRING MEETING AND TECHNICAL SESSION**

**“SUSTAINABILITY”**

**FORD AUDITORIUM**

**1610 INDUSTRIAL OPERATIONS & ENGINEERING BUILDING**

**FRIDAY, MARCH 31, 2006**

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
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<tbody>
<tr>
<td>12:15 pm - 1:15 pm</td>
<td>CEEFA Board Business Meeting (2355 GG Brown, Conference Room)</td>
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<tr>
<td>1:15 pm – 1:30 pm</td>
<td>Registration (1610 IOE)</td>
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<tr>
<td>1:30 pm – 2:00 pm</td>
<td>“Sustaining and Operating Transportation Infrastructure” (Richard Beaubien)</td>
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<tr>
<td>2:00 pm - 2:30 pm</td>
<td>“Sustainability of Our Drinking Water” (James Cleland)</td>
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<tr>
<td>2:30 pm - 3:00 pm</td>
<td>“Graham Environmental Sustainability Institute” (Jeremy Semrau)</td>
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<tr>
<td>3:00 pm – 3:15 pm</td>
<td>Break</td>
</tr>
<tr>
<td>3:15 pm – 4:15 pm</td>
<td>THIRD ANNUAL FRANK E. RICHART DISTINGUISHED LECTURE</td>
</tr>
<tr>
<td></td>
<td>Dr. James K. Mitchell</td>
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<td></td>
<td>University Distinguished Professor, Emeritus</td>
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<td></td>
<td>Department of Civil and Environmental Engineering</td>
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<tr>
<td></td>
<td>Virginia Polytechnic Institute and State University</td>
</tr>
<tr>
<td>4:15 pm</td>
<td>Reception</td>
</tr>
</tbody>
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**Detach and Mail**

Please indicate the events you plan to attend and return this section with your check by **March 17, 2006**. Feel free to call Kimberly Bonner at 734-764-8495 or send e-mail to kabonner@umich.edu for reservations prior to mailing your registration form. You may also fax your reservation to 734-764-4292.

<table>
<thead>
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<th>Quantity</th>
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<tr>
<td>2006 CEEFA Dues @ $20.00</td>
<td>=$</td>
</tr>
<tr>
<td>Technical Session Registration (Includes Reception) @ $30.00</td>
<td>=$</td>
</tr>
<tr>
<td>TOTAL ENCLOSED</td>
<td>=$</td>
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</tbody>
</table>

Names of all attendees (for name tags):______________________________

Address:_________________________________________________________

E-mail:__________________________________________________________

Phone:___________________________________________________________

Do you need a parking permit? ___ Yes ___ No  (If Yes, please pick up your permit in the lobby of LEC upon arrival.)

Make check payable to: CEEFA. Send to: CEEFA, 2350 Hayward 2340 G.G. Brown Laboratory, Ann Arbor, MI 48109-2125
Frank E. Richart Distinguished Lecture
Friday, March 31, 2006  3:15 pm
Ford Auditorium
1610 Industrial Operations Engineering Bldg.
Reception Following

Hurricane Katrina:
Engineering and Institutional
Issues and Challenges

Dr. James K. Mitchell
Distinguished Professor, Emeritus
Civil and Environmental Engineering
Virginia Polytechnic Institute and
State University
ALUMNI NEWS

Civil and Environmental Engineering Alumni Society Merit Award Winner

Thomas Newhof (BSE CE ’60; MSE ’61), cofounder and president of Prein&Newhof, was awarded the Alumni Society Merit Award by the College of Engineering during the College’s annual Engineering Alumni Weekend. Newhof is cited for his expertise in the planning and design for water treatment and distribution; wastewater collection and treatment; storm water detention and flood control; airport and road improvements; and residential and commercial development.

A licensed professional engineer in the states of Michigan, Wisconsin, and Illinois, Newhof has won numerous professional awards, including the National Community Service Award (bestowed by the American Consulting Engineers Council) and the George Warren Fuller Award, from the Michigan Section of the American Waterworks Association. Mr. Newhof serves on the board of the U-M Civil and Environmental Engineering Friends Association; is a member of the department’s Civil and Environmental Alumni Advisory Council; and holds the title of adjunct professor in the engineering department at Calvin College, where he chairs the Engineering Advisory Council. He was recently appointed to the state’s Groundwater Conservation Advisory Council—a new initiative under the auspices of the Michigan Department of Environmental Quality.

Mr. Newhof and his wife recently established the Borchardt and Glysson Fund in the Department of Civil and Environmental Engineering, in honor of Professors Borchardt and Glysson, who were pioneers in the area of water and wastewater treatment at the University of Michigan.

ALUMNI EVENTS

Camp Davis Reunion

By Professor Emeritus Eugene A. Glysson, PhD, PE, DEE

On Friday, September 16, 2005, Professor Emeritus Eugene Glysson hosted the Camp Davis Reunion, which was held on North Campus, in the Blue Lounge of the G.G. Brown Building. Thirty-nine alumni—some from as far away as Utah and Oregon—participated.

The event afforded a comfortable gathering where the group shared remembrances and feelings about Camp Davis and the special experiences enjoyed there. A photo of the Class of 1937 (sent by a member of that class) was displayed with a photo of the Class of 1952—each inspired additional memories. The group reflected on the passing of Professor Donald Cortright. A former director and instructor for Camp Davis, Dr. Cortright was remembered by many.

Prior to dinner, reunion attendees had the opportunity to tour the department laboratories of Civil and Environmental Engineering. Dinner was followed by more socializing, reminiscing, and information sharing. Happy memories, enhanced by a pleasant evening, contributed to the success of yet another Camp Davis reunion gathering. Many thanks to the staff of the CEE department who assisted us with the planning and execution of a lovely—and memorable—eventing. We’ll do it all again in 2008!
OBITUARIES

Mr. Harold A. Schaill, MSCE 1941, January 19, 2005, at age 91.
Mr. Jack Buford Matson, BSEE 1954, September 20, 2005, at age 79.
Mr. Robert B. Gittins, BSEE 1945, September 22, 2005, at age 80.
Mr. Markham S. Cheever, BSEE 1941, October 8, 2005, at age 87.
Mr. John W. Brown, BSEE 1929 & MBA 1934, October 13, 2005, at age 101.
Mr. Malcolm D. Waring, MSEE 1953, November 22, 2005, at age 75.
Mr. David J. Dapprich, BSEE 1965, December 6, 2005, at age 63.

Camille Wilson (BSEE, ’04), former Vice-President of the University of Michigan Gospel Chorale, member of the National Society of Black Engineers and the American Society of Civil Engineers, passed away on Friday, January 6, 2006. Wilson battled lymphatic cancer, but walked with her class in May 2004, to accept her degree.

Send us your updates by mail, fax (734) 764-4292, or e-mail at kabonner@umich.edu. You may also send your contact information to Engin.Alumni.Relations@umich.edu

2006 CEEFA DUES FORM

Name:______________________________________
Address:_____________________________________
Phone:_______________________________________
E-Mail:_______________________________________

Please send this completed form with your $20.00 check or money order payable to CEEFA:

CEEFA
University of Michigan
Department of Civil & Environmental Engineering
2350 Hayward Street
2340 G.G. Brown Laboratory
Ann Arbor, MI  48109-2125

Thank you for your support!

Camille Wilson and her mother, Roberta, on graduation day
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*Includes discrimination based on gender identity and gender expression.

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