UJNR Panel on Wind and Seismic Effects **Panel Update**

Volume 2, Number 1, June 2004

HIGHLIGHTS OF THE 36th JOINT MEETING OF THE PANEL ON WIND AND SEISMIC EFFECTS 17-22 MAY 2004

This Volume 2 Number 1 issue of ***Panel Update*** begins the second year of the Panel's eNewsletter that is aimed as sharing news about Panel activities. We value your readership and welcome your comments about content and format. The June issues of each eNewsletter deviates from its normal two page format by sharing greater highlights from the recently conducted annual Panel Joint Meeting.

Technical Meetings, 17-19 May

- 29 technical presentations
- Eight Sessions
  - Transportation Systems;
  - Next-Generation Building and Infrastructure Systems;
  - Wind Engineering;
  - Storm Surge and Tsunamis;
  - Geotechnical Engineering and Ground Motion;
  - Dams;
  - Advanced Information and Communication Technology for Disaster Prevention and Public Health Evaluation;
  - Progressive Collapse of Buildings.

Figure 1. Group Photograph of Panel Members at 36th Joint Panel Meeting.

- Technical presentations highlighted important work by the US and Japan Panel organizations.
- Panel Task Committees (T/C) activities grow in strength and are making good progress toward meeting the expectations set out in the Panel's Strategic Plan adopted at its 33rd Joint Panel Meeting. Three T/C Workshops will be conducted during the next 12-months. T/Cs are an effective vehicle to exchange in-depth advanced seismic and wind technologies being used by both countries. They increasingly seek partnering activities with other Panel T/Cs and other UJNR Panels. The T/C on Storm Surge and Tsunamis was reinstituted bring the number of T/Cs to seven.
- The Panel will explore the creation of a new Task Committee on the Fire Performance of Building and Transportation Structures in partnership with the U.S.-Japan Panel on Fire Research and Safety. Both Panels will to develop a proposed charter for the new Task Committee for consideration for approval at the Panel's 37th Joint Meeting, May 2005.

Technical Site Visits, 20-22 May

During the 36th Joint Panel Meeting the delegation visited three locations:

1. CHICAGO

Skidmore, Owings & Merrill (SOM).

Introduction. Skidmore, Owings & Merrill (SOM) founded in 1936 provides architectural, urban design, engineering, and interior architecture services. Its work ranges from architectural design and engineering of buildings to master planning and design of communities. SOM was involved in the design and construction of many well known buildings including the 100-story John Hancock Tower in

Chicago; 109-story Sears Tower, Chicago; the Lever House, New York City, the U.S. Air Force Academy; the Bank of America World Headquarters, San Francisco; and many others. SOM has completed projects in more than 50 countries.

Shane McCormick, SOM Associate and Lead Structural Designer of the Trump Tower, Christopher Rockey Associate, and Bradley Young hosted the delegation to technical overviews on SOM's involvement in designing the Burj Dubai Highrise Building, Trump Tower, the NSF Tall Building Wind Study, and the Gehry Band Shell followed by a visit to the construction site.

Burj Dubai Building. SOM is the architectural design consultants for the Burj Dubai skyscraper. The Burj Dubai building will be the world's tallest building at 610 m high. Its cost is estimated at between $1 billion and $2 billion. The design was selected as the winning entry of an invited design competition for the tower held by Emaar Properties PJSC of Dubai early 2003. Construction started in January 2004 and will be completed at the end of 2009.

Figure 2. Overview of SOM's buildings designed for Chicago.

The building will be the centerpiece of a large scale mixed-use development being developed by Emaar Properties PJSC of Dubai, which will combine residential, commercial, hotel, entertainment, shopping and leisure outlets with open green spaces, water features, pedestrian boulevards, a shopping mall and a tourist-oriented old town.

The design of Burj Dubai is derived from icons, six pedal rose, and the geometries of the desert flower, which is indigenous to the region, and the patterning systems embodied in Islamic architecture. It combines historical and cultural influences with cutting edge technology to achieve a high-performance building which will set the new standard for development in the Middle East and become the model for the future of the city. Burj Dubai (Burj is the Arabic word for tower or mountain) will be a 'city within a city', combining residential, commercial, hotel, entertainment, shopping and leisure outlets with open green spaces, water features, pedestrian boulevards, an old town and one of the world's largest shopping malls.

Figure 3. Burj Dubai Building (Image courtesy of Skidmore, Owings, & Merrill)

Wind tunnel tests were performed by RWDI Consulting Engineers, Ontario, Canada. The structure will be designed to withstand wind speeds of 36 m/s. Discussion addressed the computer and wind tunnel testing performed to design against vortex-induced vibration. Its tapered profile and notched levels will facilitate in "shredding" winds. The building's material selection is based on availability of indigenous materials -- poured concrete containing blast furnace slag and microsilicates. The piles are supported on mat foundations with reinforced concrete core wall system and steel braced frame. The structural design is stiff for torsion. A direct load path from the top of the building to its base provides for torsional stability. There is a continuous hexagonal core. Its aspect ratio is 8.2. The tower is composed of three elements arranged around a central core. As the tower rises from the flat desert base, setbacks occur at each element in an upward spiraling pattern, decreasing the mass of the tower as it reaches toward the sky. At the top, the central core emerges and is sculpted to form a finishing spire. A Y-shaped floor plan maximizes views of the Persian Gulf.

Trump Tower. Donald Trump along with the owner of the Chicago newspaper, *Sun Times* entered into a 50-50 partnership to build the $700 million mixed use structure. The Trump Towers will include condos, hotel rooms, office space, a restaurant, retail space, a health club and spa, and a riverfront park. The building will be the 4th-tallest in Chicago – Sears Tower at 442 m tall, the Aon Center at 346 m; John Hancock Building at 344 m tall.

Scheduled for completion in 2007 the Trump Tower will occupy the site of the current *Sun Times* building. Under its current schedule, Trump Tower Chicago marks the tallest building project in the United States since the Sears Tower was completed in 1974. The 92-floor 343 m highrise asymmetrically shaped structure will have a stainless steel façade with setbacks at three levels. The setbacks were selected to give the tower a visual continuity with its surroundings by matching the heights of surrounding buildings. Residential units on the 89th floor will break a 37-year world record held by the 344 m tall John Hancock Center for the world's highest homes off ground level.

The building is shaped to reflect its orientation along the riverfront, and its width is sensitive to its surroundings. The south side of the tower parallels the bank of the Chicago River, and this position enables the structure to connect with Chicago's north-south grid.

Figure 4. Trump Tower looking west down the Chicago River (Image courtesy of Skidmore, Owings, & Merrill)

The tower relates to its neighbors through a series of setbacks, the first of which occurs on the east side of the tower, at a height that is essentially the same as the cornice line of the Wrigley Building to the east. The next setback is on the west side of the tower and relates to both the height of the residential tower to the north and Marina City, to the west. The third and final setback is on the east side of the tower and relates to the height of the IBM Building immediately adjacent.

Materials include a stainless steel and clear anodized aluminum that reflects and refracts light from the sun. The tubes are set out from the glass surface to provide density and thickness and a metallic quality to the flush glass wall. This mullion system is vertical and horizontal and provides a delicate latticework to the facade. Wind tunnel testing was performed by RWDI Consulting Engineers, Canada.

NSF Tall Building Wind Study. Working with the University of Western Ontario and the University of Notre Dame under a National Science Foundation grant, SOM has instrumented three of four high-rise buildings (three in Chicago and one planned for Seoul, Korea) to validate in full scale the observed performance of tall buildings against wind tunnel and models used in their design. Buildings were instrumented with accelerometers, rooftop anemometers and high precision GPS systems.

The objectives of the work are to evaluate the performance of structural systems for tall buildings in full-scale wind environments to develop dynamic characteristics of high-rise buildings over a range of amplitudes. To facilitate unhindered access to real-time measurements an internet framework is under development to allow the project team, designers, consultants, and researchers, analysis capabilities from remote location. The subsequent analyses will provide insight into a variety of response characteristics for tall buildings and permit the systematic validation of existing design practice through the comparison of analytical and wind tunnel response estimates with full-scale observations.

Preliminary results suggest full-scale measurements collected appear to be consistent with the predictions from wind tunnel tests. Fundamental frequencies were accurately predicted by finite element modeling and damping values were slightly lower than levels assumed during design. The buildings will continue to be monitored for more analysis of damping over a range of amplitudes.

<u>Grant Park Amphitheatre Band Shell</u>. SOM is involved in project management of Chicago's $450 million 10 ha Grant Park Amphitheater designed by the architect, Frank Gehry. The Grant Park band shell contains a stage similar in size to The Symphony Center (Orchestra Hall) and accommodates an orchestra of 120 musicians and a chorus of 150 singers. The band shell is about 18 m high with steel ribbons that extend 11 m to 12 m high like the petals of a flower. The details of the band shell are:

- Stage opening is 27 m wide by 15 m tall. The proscenium doors contain 90 panes of glass.
- The Trellis is supported by 24 1.8 m diameter; 4.6 m tall concrete pylons set 18 m apart.
- The Trellis is made up of 120 pieces of 300 mm to 460 mm diameter pipes. Pieces range from 15 m to 32 m with the average of 24 m.

Under the trellis, there will be 4,000 self-rising seats and space for another 6,000 people on the lawn. The 190 m x 99 m trellis, 18 m at its highest point, will accommodate hanging of loudspeakers for a computer-controlled sound system. A 290 m long serpentine pedestrian bridge designed by Frank Gehry will be covered with a stainless steel skin. This approach alongside the lawn will double as a sound berm, containing the music and suppressing automobile traffic ambient noise.

Figure 5. Pedestrian Bridge from public garages, far right and photo, leading to the band shell shown as a trellis at upper left (Image courtesy of Public Building Commission of Chicago)

The steel pipe trellis is a bilaterally symmetrical, two-way intersecting arch form–a shell structure. The trellis consists of 24 flat arches, two each the same, made of 300 mm to 450 mm diameter pipes. The arches spring from parallel lines of twelve 1.8 m diameter concrete pylons, 4.6 m tall and 18 m apart. One flatter and one steeper arch spring from each pylon and land on different pylons along the opposite line. Nearly 700 aluminum panels make up the back of the Gehry ribbons. The panels were designed by Dassault Systems France. The panels, r length, are made from high-strength alumir Each plate has a unique position within its solid model surface of Gehry's design. The result is a series of shapes determined by the computer that are cut and assembled into frames on the shop floor, using computer numerically controlled equipment. The panels are held in place by 2,064 arms. 5,200 interlocking stainless steel sheets cover the Gehry ribbons.

The sculpted design of the band shell and pedestrian bridge is developed with CAD application and CATIA, a CAD/CAM software system produced by Dassault Systems France, to provide rapid prototyping capabilities which remove a number of intermediate steps in the process allowing new physical models to be validated. The system is then used to control the manufacturing process. Gehry and his team have radically altered the process and the way in which decisions are made to reduce risk and uncertainty and improve the predictability in design decision.

SOM imposed a two-way diagonal grid system on the architect's random arch configuration. Intersecting arches meet on the same surface but at different angles. For economy and constructability, SOM worked with Gehry to reduce the number of radii per arch to four. Radii change at the welded nodes. For economy in fabrication, SOM designed the arches to curve in one direction only. The four chord Pipe Truss is 0.5 m in diameter with 50 mm wall thickness. Box girders are in the center. Shoring towers supported the trellis at 48 node points. A braced top beam supported devices that suspended the trellis near the node point.

The structure will open in July 2004. The Band Shell cost $45 million and the serpentine bridge costs $15 million. The overall structure with parking is $450 million; the City of Chicago will pay 50 percent and the remainder is from private donations.

2. URBANA-CHAMPAIGN

University of Illinois, Civil and Environmental Engineering Department http://www.uiuc.edu and http://cee.ce.uiuc.edu

Dr. Nicholas Jones, Chair, Department of Civil and Environmental Engineering (CEED) and Dr. Amr Elnashai, Director, Mid-America Earthquake Center and PI of the NEES Project, Department of Civil and Environmental Engineering hosted the delegation. Reviews included the MAE, NEES and the work to upgrade the existing Multi-Axial Full-Scale Sub-Structuring Testing and Simulation Facility (MUST-SIM) site. CEED's research budget is $17 million/year that supports 50 faculty.

The National Science Foundation (NSF) Earthquake Engineering Centers were established in 1997 under a program that expanded the National Center for Earthquake Engineering Research, Buffalo to expand knowledge and technology for earthquake hazard mitigation. This decision was based on the original National Center for Earthquake Engineering Research (NCEER) that was funded in 1986 to conduct team-based earthquake engineering and multidisciplinary research and carry out information dissemination activities had been funded by NSF for 10-years (two five-year periods).

NSF funded three earthquake engineering research centers for up to $2 million each for a five-year period. The Centers can be funded for a subsequent and final five-year period. The centers emphasize cross-disciplinary team research, provide educational and training opportunities for undergraduate and graduate students, and establish outreach channels to industry, government agencies, and potential user groups. The centers formed a network to facilitate cooperation and sharing human and financial resources and facilities. The three Centers that were funded are: the Multidisciplinary Center for Earthquake Engineering Research (MCEER), the Pacific Earthquake Engineering Research Center (PEER), and the Mid-America Earthquake Center (MAE).

Mid-America Earthquake Center (MAE) http://mae.ce.uiuc.edu and http://mae.cee.uiuc.edu. Professor Amr Elnashai, Director of MAE reviewed the objectives of MAE and outlined its major focus in Consequence-Based Engineering (CBE). The University of Illinois is the lead MAE organization collaborating with the Massachusetts Institute of Technology, Georgia Institute of Technology, Washington University, University of Puerto Rico, and Texas A&M University in studying the response and behavior of the built environment that is translated to communities and national networks by researchers at these institutions in social science, economics and urban planning. Researchers at the University of Memphis and Saint Louis University provide the technical foundation for research in seismology and geophysics, which is complemented with talents in geotechnical engineering at Georgia Institute of Technology and the University of Illinois. MAE supports 37 research projects, 43 professors, and 60 students.

> MAE's mission is:
> "*to develop through research, and disseminate through education and outreach, new engineering approaches necessary to minimize consequences of future earthquakes across hazard-prone regions, including but not limited to, the eastern and central United States. Correlated interdisciplinary research synthesizing damage across regions, estimating seismic vulnerability across regional and national networks, and improving current engineering approaches, forms the core research needed to develop such consequence-based approaches, and to support stakeholder interests in risk assessment and seismic engineering.*"

MAE's core research focuses on addressing Consequence-Based Engineering (CBE) that includes three thrust areas. A program coordinator for each thrust area is responsible for planning and executing research and implementing projects. The thrust areas are:

- Damage Synthesis**.** An interdisciplinary thrust area focused on developing advanced tools to model damage and minimize consequences that have been previously assessed and to estimate economic impact. This work focuses on development of advanced visualization modules for easy-to-understand hypothetical consequences of scenario earthquake events. Using these models user-defined hazard mitigation scenarios can be examined easily and quickly.
- Consequence Minimization. This thrust studies ways that damage synthesis tools can best be used to reduce the consequences of future earthquakes. Central to this effort is research on probabilistic decision support that will provide the user with rational methods for judging which system interventions are the most appropriate.
- Hazard Definition. This work is directed towards development of synthetic earthquake hazards as needed for input to the damage synthesis module. Research findings from this thrust develops further fundamental earth science as it relates to better physical understandings of source, path and site effects, and ground failures.

MAE Visualization Tools are available at http://alg.ncsa.uiuc.edu/do/projects/visualization/mae

Figure 6. Dr. Amr Elnashai, Director, Mid-America Earthquake Center discussed MAE's activities and focus in Consequence-Based Engineering.

National Earthquake Engineering Simulation (NEES). NSF manages the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) a national resource with a shift of earthquake engineering research emphasis from current reliance on physical testing to integrated experimentation, computation, theory, databases, and model-based simulation. Eighteen awards have been made, to date, in areas of: shake table research equipment; geotechnical centrifuge research equipment; tsunami wave basin; large-scale laboratory experimentation systems; field experimentation and monitoring installations; system integration; consortium development. NEES will include 15 earthquake engineering experimental research equipment installations networked through the high performance Internet. Initially through 2004, NEES includes equipment sites funded through NSF program solicitations. NSF envisions that other globally significant earthquake engineering equipment sites will participate in NEES and bring unique experimental capabilities to NEES. NEES will become operational by September 30, 2004 and is expected to run through September 30, 2014. The program will provide for using advanced experimental and simulation capabilities to test and validate more complex and comprehensive analytical and computer numerical models. It will stress use of distributed experimental research equipment, including teleobservation and teleoperation, and to enable computation and distributed simulation for earthquake engineering experimentation. Researchers will be provided with remote access to a repository of databases, user-developed simulation software, and models for use in model-based simulation and visualization through access to a computational grid. Researchers will form an integrated network that facilitates interdisciplinary global collaboration among scientists and engineers. The program will enable participation from a broader earthquake engineering community, including educators, students, practitioners, and public sector organizations and individuals, who will have access to the equipment, data, models and software from NEES. The NEES Authorized Funding is $81.8 million.

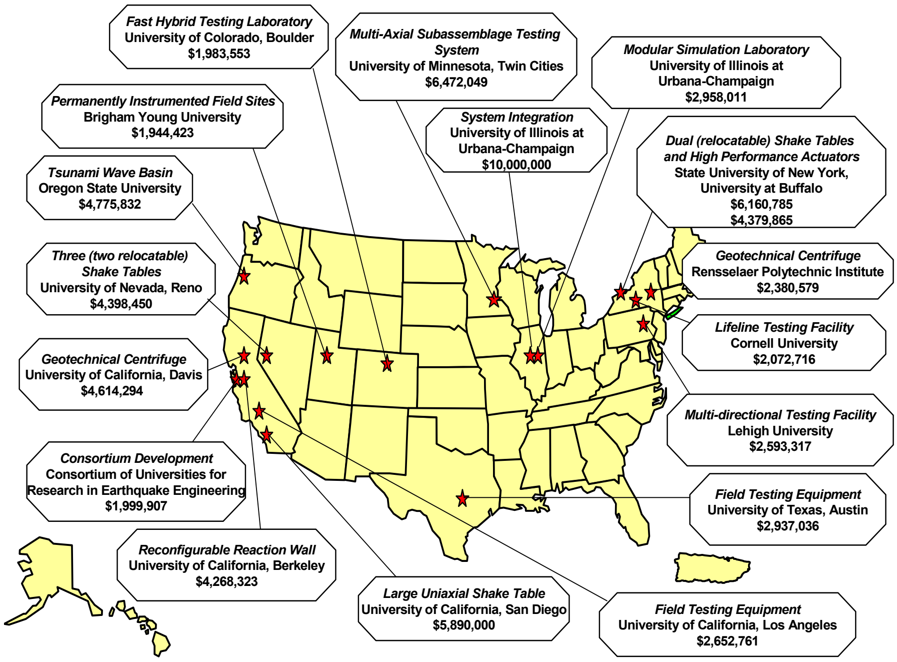

Figure 7. Locations of NEES Universities and Award Amounts. Figure provided by the National Science Foundation.

The University received four NEES awards:

- $2.96 million award for a Multi-Axial Full-Scale Sub-Structuring Testing and Simulation Facility (MUST-SIM),
- $10 million award to develop a "NEES grid: a distributed virtual laboratory for advanced earthquake experimentation and simulation",
- $0.3 million to design a national online network for sharing earthquake engineering data.
- $0.09 million to convene an Earthquake Engineering Research Community Workshop

Multi-Axial Full-Scale Sub-Structures Testing and Simulation (MUST-SIM). The $2.96 million award is to create a facility where a full-scale subassembly can be subjected to complex loading and imposed deformation states at multiple connection points on the subassembly, including the connection between the structure and its foundation. This NEES Multi-Axial Full-Scale Sub-Structures Testing and Simulation (MUST-SIM) facility consists of:

- 6-DOF load and position control at three connection points,
- system modularity to allow for easy expansion and low-cost maintenance/operation,
- multiple dense arrays of non-contact measurement devices,
- T-section strong wall creating two testing compartments each providing support in three loading planes and
- advanced visualization and data mining capabilities for integrated teleoperation and teleobservation.

The MUST-SIM facility achieves the first two features through the development of modular six-DOF "Loading and Boundary Condition Boxes" (LBCB) that allow for precise application of complex load and boundary conditions. The LBCBs, which are 4 m x 2 m x 2 m and house six actuators each, will be able to impose motions on the test structures that are determined from the results of concurrently running numerical models of the test specimen and the surrounding structure/foundation/soil system employing pseudo-dynamic testing methods. Dense arrays of state-of-the-art, non-contact instrumentation, will allow near real-time model updating for the model-based simulation.

MUST-SIM's Loading and Boundary Condition Boxes (LBCB) each use six actuators or 18 actuators for the three independent boxes. These six DOF boxes may be attached at the bottom (on the strong floor), on the side (on the reaction wall) or at the top (through an A-frame reacting onto the strong floor) of test specimens. Go to http://cee.ce.uiuc.edu/research/nees/lbcb.asp for a description of the LBCB and performance of the loading equipment.

A new reaction wall was constructed in CEED's Newmark Civil Engineering Laboratory as part of the NEES earthquake engineering testing facility. It is 25 m long and 9 m high. The facility will be deployed in testing complete soil-foundation-structure systems.

The MUST-SIM will allow researchers to combine computer simulation with laboratory testing to better understand what happens to structures and building materials during an earthquake.

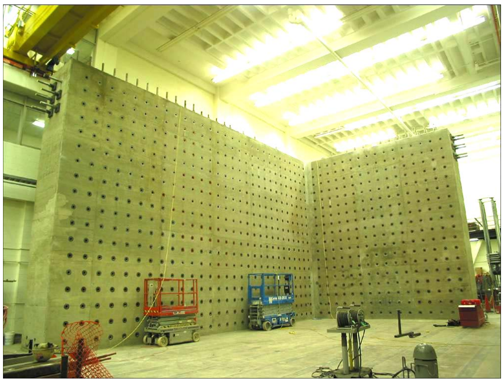

Figure 8. NEES MUST-SIM Reaction Wall (Image courtesy of University of Illinois)

The laboratory's testing floor is 15 m x 40 m based on a reinforced concrete box girder that is about 5 m deep. The girder was proportioned to accommodate tests to failure of full-scale bridge girders. The box girder's mass is over 106 kg making it an effective reaction structure for dynamic experiments. The box girder is in a bay equipped with an overhead crane of 200 kN capacity and has a clear height under the crane of over 9 m. The slab in the test area is perforated by 75 mm diameter holes at 914 mm spacing to facilitate the installation of modular loading equipment for a variety of tests with vertical and horizontal loads. The bottom slab and walls of the tunnels have attachments for installation of equipment for three-dimensional loading. A permanently installed piping system under the pressure of 21 MPa delivers hydraulic-ram fluid to all points on the test floor from a pair of pumps with a combined capacity of 5.7 L/sec.

To verify testing protocols, experiments are tested at 1/5th scale using a 1/5 reaction wall. These tests are integrated with other models and software for experimentation, analysis, and visualization and can be networked to the other 15 NEES users who have the authority to control the experiment. The same networking is available for full-scale testing. NEES and MAE and the Earthquake Engineering Centers are essentially one unit seeking answers to problems through shared capacities.

NEESgrid. The NEESgrid is a 39-month, $10,000,000 program to develop and operate a distributed virtual laboratory for advanced earthquake experimentation and simulation. The effort is led by the University of Illinois working in partnership with the Argon National Laboratory, Math and Computer Science Division; University of Michigan, Collaboratory for Research on Electronic Work; University of Southern California, Information Science Institute and the Civil Engineering Department; and Carnegie-Mellon University, National Laboratory for Applied Network Research. This multi-organizational team will make operational the Internet-based, national-scale high performance network system for NEES, called "NEESgrid". NEESgrid will connect, through a high performance Internet network, distributed major earthquake engineering research equipment that includes shake tables, geotechnical centrifuges, a tsunami wave basin, large-scale laboratory experimentation systems, and field experimentation and monitoring installations funded through separate NEES equipment awards made by the NSF NEES program. Teleobservation, teleoperation, and network monitoring will be performed among the NEES organizations. The NEESgrid will link computational resources and data storage facilities that will archive experimental and analytical earthquake engineering and related data. NEESgrid also will provide distributed physical and numerical simulation capabilities and resources for visualization of experimental and computed data. NEESgrid support nodes will maintain online knowledge bases that contain tutorials and operate help desks for using NEESgrid.

A $300,000 award is for implementing the NEES on-line network that will provide earthquake engineers remote access to testing and experimental facilities. The network will provide researchers across the U.S. access to advanced research equipment, databases, and computer modeling and simulation tools.

Its $90,000 Workshop award is to organize a national workshop that will define the information technology requirements of the earthquake engineering research community for NEES. This workshop will seek input from the earthquake engineering research community in six areas:

- access to shared use earthquake engineering research equipment,
- supporting telecollaboration and teleoperation of the shared use equipment,
- shared use of distributed heterogeneous data sets,
- definition of new data types and metadata schemes,
- use and sharing of simulation models, and
- use of advanced visualization technologies and tools.

The results of this workshop will be disseminated on the World Wide Web and in printed form.

National Center for Supercomputing Applications (NCSA) Visualization and Virtual Environments Group. Alan Craig of the Visualization and Virtual Reality, NCSA was one of two hosts providing demonstrations about NCSA’s Computer Aided Visualization Environment (CAVE) and the High Resolution Tiled Display Wall (HRTDW).

The CAVE is a virtual reality facility designed to explore and interact with spatially engaging environments. The CAVE allows stereoscopic viewing that enables the users to interact with their data such as "climb inside" a hurricane and visualize its complex and chaotic elements from any angle or visual perspective. A biological researcher can examine a tightly coiled strand of DNA and virtually "unravel" this strand and manipulate it in an environment that preserves the critical depth information of the data. Such technology allows innovation and facilitates cutting-edge research. The CAVE is a room about 3 m x 3 m with three walls and a floor. Projectors, situated behind the walls, projected computer-generated imagery onto the walls and floor. Two perspective-corrected images were drawn for each frame, one for the right eye and one for the left. Special glasses are worn to ensure that each eye sees only the image drawn for it. This created a stereoscopic effect where the depth information encoded in the virtual scene was restored and conveyed to the eyes of those using it. The CAVE has an advanced tracking system that enables it to constantly track the position and orientation of the special tracked glasses and the CAVE Wand. The tracked glasses have a wire attached to them that is attached to the Tracker Control Unit. The person wearing the tracked glasses controls the viewpoint of the CAVE. They can look around the corner of an object, step behind it, look underneath it, or anything else that they could do in real life. None of the other glasses have this capability. The CAVE Wand is also attached to the Tracker Control Unit by a wire and allows the operator to walk around (with the joystick in the middle) or interact with the virtual world through the push buttons.

The HRTDW uses eight by five grid of off-the-shelf Liquid Crystal Display (LCD) projectors powered by an equal number of side-by-side computers that creates a mosaic of imagery. The overall display is 2.6 m by 5.4 m that provides 31.5 million pixels. Each projector is aligned to minimize any visible gap between the edges of the projected image. The Tiled Display wall allows in-depth visualization to explore classes of problems that would be very difficult to analyze such as visualize the interior of a severe storm and examining the flow of particles through it. Analyzing prototype equipment and structural assembly techniques allows close up views to develop and test potential product design before building physical models and specifying assembly techniques that ultimately will reduce costs and speeds the time-to-market.

The delegation discussed advanced technologies permitting 3D visualization of hazard and vulnerability before and after intervention. The approach combines the system inventory, the various levels of vulnerability of the system under consideration and the hazard definition using advanced IT and GIS-based visualization in an interactive module that displays losses for given return periods, specific loss estimates for a scenario event or a real earthquake occurrence for a system relevant to a stakeholder. The project combines engineering seismologists, structural and geotechnical earthquake engineers, and computer scientists.

3. ST. LOUIS

Clark Cable-Stay Bridge, Alton, Il and New I-70 Cable-Stay Bridge. The delegation visited the Clark Bridge in Alton, Illinois to view its design and environmental setting. Thomas Havenar from Hanson Professional Services and Dr. Nicholas Marianos from Modjeski and Masters discussed the design and construction of the Clark Bridge, Alton, Illinois and the new I-70 Cable-stay Bridge respectively.

Clark Bridge.
The Clark Bridge links Illinois and Missouri. This $100 million bridge (costs includes demolition and renovations) accommodates four lanes of vehicle traffic and two bicycle lanes. It was named after the explorer William Clark who with Meriwether Lewis spent two-years during their 6,400 km expedition up the Mississippi River and to the Pacific Ocean during 1804-1806. The bridge replaced the former 6 m wide Clark Bridge constructed in the 1920s.

Construction of the new Clark Bridge started in 1989 and was completed in 1994. Its main span is 414 m. The bridge is constructed of a central pylon 18 m above the river and 30 m above its foundation. Piling tips are H-beams that served as a “stinger” to allow the piles to be driven 43 m below bedrock. The center span is supported by an innovative cable stay anchorage system. Its pylons are designed for cable stays with saddle pipe anchorage at the top. It is a single pylon and two planes of stays arrangement. The floor beams are 31 m spans, tapered 1.5 m to 1.8 m deep. The deck thickness is 260 mm tapered to 0.6 m thick at the pylon.

Cable stays vary from 19 to 46 strands that are epoxy coated within a polyethylene pipe with tedlar tape or inserted in a painted metal pipe.

DOT requested installation of cross ties in 1996 or 1997 to dampen rain-induced vibrations.

The bridge required 6 million kg of structural steel, 34,000 m^3 of concrete, and 260 km of cable (44 cables). The bridge design was based mostly on AASHTO standards. Wind loads were derived from the University of Western Ontario wind tunnel tests. The bridge design was honored with ten design awards and was the subject of a NOVA Special (documentary science television series).

Figure 9. Clark Bridge, Alton, Illinois

Proposed I-70 cable Stay Bridge.
The proposed $280 million I-70 Mississippi River cable-stay bridge is part of a $1.6 billion Illinois/Missouri transportation project that includes improving three major interstates that travel through and around St. Louis. The bridge will feature three planes of cables and two single-pylon towers 137 m above the deck each inclined nine degrees from the river. The bridge when completed will become the world’s widest cable-stayed structure at 68 m. Originally the bridge will be designed for eight lanes of traffic -- 22 m per side. Shoulders will allow an additional lane to be used for expansion at a later time. The 610 m main span will be the longest clear span across the river and the longest cable-stayed span in the Western Hemisphere and the fifth longest in the world. Construction was scheduled to start in 2004 but has been delayed due to the Congressional passage of the 2003

Transportation Reauthorization Bill; original completion is estimated at 2010. The bridge is designed for a 150-year life.

One of the main geotechnical issues is the existence of thick deposits of "low-density" sand below the water table. Limestone bedrock is 37 m below the surface on the Illinois side and between 9 m and 18 m below the surface on the Missouri side. The loose sand and the bridge's high seismic design requirements, results in the potential for liquefaction during an earthquake. To accommodate these conditions the foundations will feature 4 - 1.2 m to 3.7 m diameter, 37 m long drilled piers founded in rock to support the bridge superstructure. Also, possible areas of small voids in the rock under the Illinois tower will be filled before the Tower is constructed.

Figure 10. Proposed new I-70 Cable Stay Bridge St. Louis. (Image courtesy Hanson Professional Services)

The scour analyses led to special considerations about the bridge substructure. Excavation for the Illinois side pylon will be made using "a large, dredge well caisson." This method will incorporate a 34 m to 43 m concrete base containing open dredge wells with a perimeter steel cutting edge, which is sunk into the overburden. On the Missouri side, where bedrock is much shallower, a large concrete pedestal and footing foundation on rock will support the pylon.

Hydraulics analysis estimate the effect of the bridge on flood levels for the 100-year flood and for the 500-year flood indicated significant impacts on flood levels.

The Bridge's main span will consist of 1,600 km of 15 mm diameter stay-cable strand. The larger stands are 335 m long with 2,000 Kip tension over 100 stands per bundle. The design wind speed is 35 m/s with buffeting. The fundamental period is 0.23 HZ lateral and vertical is 0.25 Hz.

The bridge deck will be designed with a center joint so both halves of the bridge can operate independently. The center joint needs to accommodate various bridge deck rotations. The bridge will include dampers to reduce cable vibrations. Design provisions will include an option to install counter cable connectors at a later date should they be needed.

Melvin Price Lock and Dam.
http://www.mvs.usace.army.mil/dinfo/pa/NEWNAVIGATIONPAGE/melvinpricelocksanddam.htm
Dr. Gregory Hempen, Geophysicist/Geological Engineer, USACE St. Louis District hosted the delegation about the design and operation of and a visit to the Melvin Price Lock and Dam (MPLD). The Corps has been involved in the construction of the National Road, navigation improvements on the Ohio and Mississippi Rivers, dam construction, domestic inland waterway development, to name a few. In 1880 Congress mandated the USACE to create and maintain navigation channels and today they maintain over 19,000 km of US waterways. The USACE operates 36 district offices in the US; these districts follow watershed boundaries. The US Army Corps of Engineers (USACE) dates back to 1802 when Congress authorized the President to organize and establish a Corps of Engineers that was based in West Point, NY.

This new dam was build downstream of the older dam but upstream of the confluence of the Mississippi and Missouri Rivers. The Mississippi River has the third largest drainage basin in the world. The Missouri River is the longest river in the US and drains approximately one-sixth of the North American continent. The combined Missouri-Mississippi river system is the fourth longest river in the world.

The dam replaced Dam #26 constructed in the 1930s and became operational in 1938. It is located just upstream of the old and new Clark Bridge and about 3 km north of the new MPLD. Over time the dam's locking capacity became inadequate to accommodate the increased river traffic and the structure began to deteriorate with structural deficiencies. Scour holes developed in places below the dam and the scouring of the river bed led to the disintegration of the concrete and loss of foundation material which resulted in deflection and settlement of the lock walls and dam piers.

Construction on a new twin lock and dam began in 1979 and construction was partially completed and the dam and main lock began operation in 1991. Its main lock measures 365 m long by 34 m wide and the auxiliary lock measures 180 m long and 34 m wide. The dam dimensions are 488 m long with nine tainter gates (balanced by a counterweight as it is raised and lowered to keep the water level at the desired depth). The gates are each 34 m wide by 13 m high; they are not designed to control flooding. The pool length is 65 km.

Figure 11. Aerial view of the Melvin Price Lock and Dam. (Image courtesy of USACE)