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The John A. Blume Earthquake Engineering Center

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2001 BLUME CENTER AFFILIATES MEETING

The 2001 Blume Center Affiliates Meeting was held on May 4, 2001. Blume Center Affiliate Members, donors and invited guests attended presentations by several Ph.D. students on their research: **Jun Peng**, **Dimitris Pachakis**, **Fatemeh Jalayer**, **Timothy Y. Lai**, **Paul Cordova**, **Jerome P. Lynch**, **Tina Kashef**, and **Ricardo Medina**; and a special presentation on the Jan. 26th India Earthquake by **Professors Chuck Menun** and **Eduardo Miranda**.

Following the presentations was an Open Forum on *Disaster Resistant Campuses*. **Prof. Mary Comerio** (UC-Berkeley), **Langston Trigg** (Asst. Vice Provost, University Facilities Project), **Dr. Nesrin Basöz**, and **Craig Comartin** (Comartin-Reis Engineers) discussed issues unique to large institutions with high concentration of facilities in earthquake prone regions and shared their experiences in developing and implementing prudent policies for reducing the potential losses.

The day concluded with a reception at the Blume Center and a dinner for the Affiliates at Tressider.

SEG SPRING GRADUATES

Congratulations to all of the Structural Engineering and Geomechanics Spring 2001 Graduates (all M.S. degrees): **John Castagnoli**, **Wai Yip Chan** (DCI) , **Ho-Yan Cheung**, **Christina Cho** (DCI), **Brian Crowell**, **Martha Delcampo**, **Sara Diegnan**, **Eliza Dubroff**, **Norman Faris**, **Kris Groteleuschen** (DCI), **Sangil Han**, **Lisa Hardin**, **Calvin Kam** (DCI), **Velvet Li, Douglas McCan**, **David Murray** (DCI), **Craig Quadrato**, **Jeanne Sum**, **Joel Vilamil** (DCI), **Geoffrey Weien**, and **Jeong-Mo Yang.**

ALUMNI NEWS

A team from the ASCE Student Chapter at the U.S. Military Academy, advised by **Cpts. Victor Nakano** (MS '00) and **Reid VanderSchaaf** (MS '00) won the most money in the 9th National Timber Bridge Design Competition, placing first in deck performance and practical design and second in structural performance and overall design.

BLUME CENTER NEWS

Profs. Greg Deierlein, Helmut Krawinkler, and **Allin Cornell** participated in the 4th year site visit and review of the PEER Center on April 30-May 1. Prof. Deierlein presented an overview of the PEER Research Program, while Profs. Krawinkler and Cornell gave presentations on the performance-based earthquake engineering methodology under development by PEER.

Prof. Anne Kiremidjian participated in the Committee of Visitors for the NSF Civil and Mechanical Systems Directorate, Washington D.C. Phase I Review on April 25-26, and the Phase II Review on June 17-19.

Prof. Eduardo Miranda was invited by SEAOCC to give a talk in May on the structural aspects of the Jan. 26th Gujarat India Earthquake in Sacramento.

Prof. Ronnie Borja spent the months on May and June on sabbatical at the Polytechnic University of Catalunya in Barcelona with the finite element group of CIMNE. During this time, he also gave talks on material instability at the University of Castilla La Mancha in Cuidad Real, at the Polytechnic University of Madrid, and at the Center for Public Works Studies and Experimentation in Madrid.

During May, June and July, **Dr. Renate Fruchter** was a guest and organized half day workshop presentations on "A/E/C Global Teamwork" offered by the PBL Lab at the University of Ljubljana, Slovenia; Technical University Prague, Czech Republic; Obayashi Corporation, Tokyo, Japan; and Hochtief Company, Essen, Germany.

Dr. Renate Fruchter was a guest speaker at the Japan Society of AI (JSAI) 2001 International Workshop on Social Intelligence Design, and gave a talk on "Brick, Bits and Interaction" in Matsue, Japan.

Dr. Renate Fruchter gave a talk at the ASEE National Convention in Albuquerque in June on "*Mentoring Models in an AEC Global Teamwork e-Learning Environment*".

In June, **Dr. Renate Fruchter** gave a talk entitled *"Playful on Internet 2"* at the International Workshop of the European Group for Structural Engineering Applications of Artificial Intelligence (EG-SEA-AI), in Loughborough, UK.

On June 19-21, **Prof. Anne Kiremidjian** presented a paper and chaired a session at the International Conference on Structural Safety and Reliability in Newport Beach, CA.

RESEARCH SPOTLIGHT

The January 2001 Gujarat Earthquake

By Charles Menun and Ravi Mistry

At 8:46 AM on January 26, 2001, a major earthquake measuring 7.6 on the moment magnitude scale shook the state of Gujarat in western India. It was felt in most parts of India. The earthquake caused substantial loss of life and property. According to the latest estimates available from government sources, 18,253 people lost their lives and another 166,836 suffered injuries of various degrees. The earthquake affected 7,904 villages in Gujarat, destroying 332,188 homes and damaging another 725,802.

Approximately one month after the earthquake, a reconnaissance survey organized by Professor-Emeritus Haresh Shah was conducted by a team of 21 professionals that included representatives from the fields of engineering, disaster management, public administration, political science, social geography and seismology. The survey spanned a period of eight days beginning February 25, 2001 and ending on March 4, 2001, and included affected regions of the Districts of Ahmedabad, Kachchh, Rajkot, and Surendranagar. The team visited the cities of Ahmedabad, Anjar, Bhachau, Bhuj, Gandhidham, Kandala, Limbdi, Morvi, Navlakhi, Rajkot, and Surendranagar.

The reconnaissance team represented a number of countries including Bangladesh, Germany, India, Indonesia, Iran, Japan, Kyrgyz Republic, Malaysia, Nepal, The Philippines, Uganda, United Kingdom, and United States. The individuals were sponsored by numerous organizations, including the World Seismic Safety Initiative (WSSI), Earthquakes and Megacities Initiative (EMI), OYO Corporation, and National Science Foundation. Professor Charles Menun participated in the reconnaissance survey with support provided by the John A. Blume Earthquake Engineering Center. Among the members of the reconnaissance team were Stanford University alumni Ravi Mistry, Weimin Dong and Laura Dwelley Sampat.

The objective of the reconnaissance survey was to investigate the Gujarat earthquake catastrophe from several angles including, but not limited to, engineering, rebuilding and reconstruction, social, economic, political, organizational, and disaster management perspectives, and to identify: (1) factors leading to the catastrophe, and (2) ways to mitigate it. The investigation addressed technical, disaster management, and social issues. A summary of the reconnaissance team's findings follows. A complete account of the reconnaissance survey is documented in the WSSI-EMI report *Interdisciplinary Observations on the January 2001 Gujarat Earthquake*, which can be obtained from the John A. Blume Engineering Center web site http://blume.stanford.edu.

Technical Issues

The majority of structures examined by the reconnaissance team were residential and commercial buildings. In general, these buildings can be classified as "non-engineered" (e.g., traditional masonry construction) or "engineered" (e.g., recently constructed reinforced concrete structures).

It was observed that buildings constructed inadequately for seismic safety, even at remote distances from the fault, were severely damaged. For example, the reconnaissance team visited several engineered buildings in Ahmedabad (approximately 230 km away from the epicenter) that were damaged beyond repair and must be demolished. However, it was also observed that properly constructed buildings (engineered and non-engineered) located at the epicentral areas of Bhachau and Bhuj survived the earthquake without severe damage.

The primary causes of the damage sustained by the buildings visited by the reconnaissance team are summarized below. We note that none of the observed damage can be classified as unexpected or surprising. Similar damage has been seen in recent earthquakes such as Mexico City (1985), Kobe (1995), Turkey (1999) and Taiwan (1999).

Non-Engineered Buildings

Non-engineered masonry buildings, which are used mainly as housing units, suffered heavy damages and were responsible for a large proportion of the casualties. This type of construction is extremely vulnerable to earthquakes, as evidenced by the destruction of entire neighborhoods observed in Anjar, Bhachau and Bhuj. The following factors were identified as weaknesses of the masonry construction used in Gujarat that led to the damage and collapse of non-engineered buildings and the loss of life:

1. Most of the old buildings in the non-formal sector are constructed of poor quality materials that are not properly maintained. The deterioration of these materials, particularly mud mortar, contributed to many collapses in Anjar, Bhachau and Bhuj.
2. In many non-engineered buildings there is a lack of integrity between the walls and the roofs and foundations. The connections between these elements are inadequate to prevent the buildings from coming apart. Proper connections and detailing that respect the traditional style of construction must be developed to improve the structural integrity of the non-engineered masonry buildings found in Gujarat.
3. In some instances, the heavy weight of the roof exacerbated the damage that was incurred in non-engineered masonry buildings. Because these heavy roofs are necessary for protection against the cyclones that frequently occur in the region, it is impractical to eliminate them. Instead, builders must be made aware of the danger they pose and given proper instructions as to how to best construct the walls to provide adequate seismic restraint to these roofs.
4. The stone parapets and architectural facades on many buildings were inadequately reinforced or anchored and, consequently, sustained damage. While damage to these elements does not cause buildings to collapse or become uninhabitable, the rubble does pose a threat to life if it falls to the street or sidewalk below.
5. The narrow lanes that characterize many of the older neighborhoods pose a significant threat to life-safety, particularly when debris can be expected to fall off of the buildings. In the old section of Anjar, 250 school children were killed in a narrow lane when the non-engineered buildings on either side collapsed. The reconnaissance team learned that the narrow lanes also hindered relief and rescue efforts after the earthquake.

Engineered Buildings

The engineered buildings that were studied were primarily multistory reinforced concrete structures. Many of these buildings collapsed completely and caused hundreds of deaths. The failure of reinforced concrete buildings was mainly due to poor design and construction practices. In particular, we noted the following shortcomings in the reinforced concrete buildings that sustained damage:

1. The predominant collapse mode of the reinforced concrete buildings in Ahmedabad and Bhuj was due to the presence of a soft story at the ground floor level. Typically, this lateral weakness was caused by large openings provided for parking stalls and shops.
2. The lack of proper seismic detailing was evident in the debris of most collapsed buildings. In particular, the spacing of the column ties was large. Furthermore, the hooks at the ends of the column ties were often only 90°

rather than 135°. Consequently, the column ties are unable to provide sufficient confinement to the concrete core of the column. Inadequate lap splices and embedment lengths for the longitudinal bars were also observed in many damaged columns.

3. Many of the damaged buildings appeared to be constructed with low quality materials. Poor quality concrete was evident in many damaged columns. In one instance, the "concrete" in a damaged column did not contain any aggregate, only sand and cement. Additionally, there was ample evidence of insufficient consolidation ("honeycombing") of cast-in-place concrete, both in the damaged buildings visited by the reconnaissance team and in undamaged buildings currently under construction throughout the region. The quality of the reinforcement steel was also questionable. At several locations, smooth bars had been used for the longitudinal reinforcement in the beams and columns. At the site of a collapsed school in Limbdi, the remains of a reinforced concrete column had four longitudinal bars, but no two were the same. Clearly, a designer would never specify such an arrangement. If the builder had construction drawings, he did not follow them.

Taksila Apartments, Bhuj. Two recently constructed five-story buildings collapsed due to soft story effects.

Engineering and Construction Practices in India

The damage sustained during the Gujarat earthquake can be partially attributed to poor quality engineering and construction practices. This contention is supported by what the reconnaissance team learned from Prof. G. N. Gandhi (DD Institute of Technology) and the Collector of Ahmedabad, Mr. K. Srinivas, during our meetings with them in Ahmedabad on February 26 and March 3, 2001. In particular,

1. The Indian Standard Code IS 1893-1984 is quite advanced and similar to seismic design codes found in developed countries. However, the seismic design provisions are not mandatory, they are only recommended. Without any incentive for adopting the seismic provisions of the building code, it is unlikely that they are ever put into practice.

2. The Indian Standards Institute administers codes for all construction materials; however, compliance to these standards is not mandatory. Naturally, the absence of quality control leads to the use of substandard materials and construction procedures.

3. Currently, contractors inspect their own work. The owner and/or city building officials make only superficial checks, if any at all. Clearly, there is a potential conflict of interest in such an arrangement. This aspect of the construction process may account for some of the poor quality construction that was observed.

4. India does not have an established professional engineering association. A system of peer-review that leads to an accepted professional qualification, which is commonly employed in most countries, does not exist. Thus, there is no means by which either the government or the public can judge the competence of design professionals.

Disaster Management

The State of Gujarat began developing an emergency plan after the cyclone of 1998 that focused on cyclones, drought and floods. After the recent tremors in Bhavanagar, the State Government began developing an earthquake plan, but they did not expect an earthquake of such magnitude to strike so soon. When the earthquake struck, limited preparations inhibited timely emergency response. Communications were totally disabled; electrical power was down; water supplies were severely disrupted. Many government offices were damaged; government personnel were killed and injured, and many were tending to their families. Loss of lives and property, including business interruption losses or loss of employment for residents of the damaged communities, were catastrophic. The following aspects of disaster management were examined during our reconnaissance:

1. For the first 48 hours, ham radios and police wireless system were used to notify various district collector offices in the Kachchh region. Cell phone communications were also established in first 48 hours. Immediate rescue operations were initiated by the people, followed by military and other non-government organizations (NGOs).

2. As a result of damage to many medical facilities, medical treatment was provided temporary quarters or tents in Kachchh region. In Ahmedabad, the local hospitals were overwhelmed by the need to treat a very large number of injured people. There was an overwhelming response of doctors and other medical volunteers who arrived from all over India.

3. Although most roads were cleared of debris, there still remains debris from collapsed buildings on site.

4. 90% of all school buildings were severely affected by the earthquake. Classes were suspended for 30 days before being resumed in tents or temporary quarters.

5. A lack of planning to prepare for such a disaster resulted in poor response to the emergency. This may have resulted from priority given to the more frequent hazards such as drought and cyclones, and underestimation of the magnitude and occurrence of the earthquake phenomenon.

6. Public awareness and establishment of proper disaster management processes are a must if disaster mitigation is desired.

Social Issues

The Gujarat earthquake, occurring in an area with a rich culture and wide industry base, presents a complex range of social issues; some unique to the area and others common to earthquakes generally. The reconnaissance team addressed four dimensions of social issues: economic, political, cultural and psychological. Based on our observations we make the following remarks:

1. In terms of economic aspects, the most affected group of people is the one belonging to middle class and upper middle class who have lost their property. Relocating entire settlements could cause economic hardships, and disruption of local culture and social support networks. Distribution of rebuilding funds fairly and effectively will be a challenging task that, if not properly handled, could lead to social tensions. People's livelihood needs must be addressed in the widest sense.

2. On the political front, the government seems pressured to rebuild quickly. Our recommendation will be to construct sustainable communities using proper design and construction methods with proper accountability on part of the engineers, contractors, and responsible government agencies responsible for enforcing the codes.

3. Culturally, the Gujarati community has demonstrated their closeness by helping one another out in time of need. The determination of people to restart their lives and to not be brought down by this immense disaster is inspirational.

4. The psychological injuries of affected people should be taken as seriously as physical injuries. Rehabilitation of Gujarat will be improved by incorporating counseling for the heavily impacted communities, with an emphasis on vulnerable groups. The rebuilding of temples, schools and hospitals should be prioritized to promote community cohesiveness and psychological support.

Concluding Remarks

Our observations indicate that most buildings would have been able to withstand the earthquake forces with minimum loss of life and property had they been properly designed and constructed for earthquake loads. Although the knowledge about earthquake-resistant design does exist in top academic institutions in India, it has not been practiced professionally. In addition, Indian codes provide recommendations rather than requirements for earthquake-resistant design. This, coupled with lack of proper inspection during construction, adds to the vulnerability of structures to resist earthquakes.

In as much as technical aspects of building design and construction are responsible for many deaths and the severe destruction of hundreds of villages, it is as important to address these issues in the context of the social disruption they have brought and suggest ways to reduce vulnerability and promote social development. Multiple levels of government must ensure that hazards of a similar nature are mitigated. For example, while proper design and construction techniques to make a structure earthquake-tolerant may cost 5% - 20% more, it would substantially reduce loss of life and property damage. Such action would avoid the level of social crisis that has been experienced by the people of Gujarat.

Disaster management programs must be designed, practiced frequently, and implemented, to aid the reduction of societal risk and promote resiliency. Public awareness about the nature of earthquake hazards and ways to mitigate them, including preparations for disaster management, should be created through education of and participation by the community at large.

Effective recovery should go beyond returning to the pre-disaster state. Sustainable development that enhances the economic opportunity and community well being while respecting, protecting and restoring the natural environment upon which people and economies depend must take place as part of the rebuilding process. The government must focus on creating such sustainable communities through a collaborative effort of public agencies, the private sector, people of the community, and key community leaders.

Reconnaissance Team Members

Dr. Haresh Shah, Professor-Emeritus, Stanford University, founder and Chairman of the Board of Risk Management Solutions, Inc. (RMS), California, USA, and Chairman of the Board, World Seismic Safety Initiative (WSSI), organized an international team of engineers, geologists, seismologists, sociologists, and disaster management experts for an interdisciplinary reconnaissance of the January 26, 2001 Gujarat earthquake. The reconnaissance was sponsored in part by WSSI and the Earthquakes and Megacities Initiative (EMI). Partial funding was also provided by the Oyo Corporation of Japan, RMS, and RMSI.

The WSSI/EMI team members, who participated in the reconnaissance and contributed to the writing of the WSSI/EMI report that can be found at the Blume Center web site, are Mehedi Ahmed Ansary (Bangladesh University, Bangladesh), Michael Baur (University of Karlsruhe, Germany), Teddy Boen (Indonesia), Louise Comfort (University of Pittsburgh, USA), Amod Dixit (National Society for Earthquake Technology, Nepal), Weimin Dong (RMS, California, USA), Laura Dwelley Sampat (Geohazards International, Palo Alto, USA), Maureen Fordham (Anglia Polytechnic University, United Kingdom), Rohit Jigvasu (India), Badru Kiggundu (Makerere University, Uganda), Tetsu Masuda (Oyo Corporation, Japan), Charles Menun (Stanford University, USA), Ravi Mistry (Stanford '75, USA), Timothy Sabiiti Mutebile (Ministry of Defence, The Republic of Uganda), Ahmad Naderzadeh (Center for Earthquake & Environmental Studies of Tehran, Iran), Naresh Raheja (RMSI, India) Swaroop Reddy (India), Mohd Rosaidi Che Abas (Malaysian Meteorological Service, Malaysia) Violeta Seva (The Philippines), Svetlana Uranova (Kyrgyz-Russian Slavic University, Kyrgyz Republic) and Vikas Wadhera (RMSI, India).

The WSSI/EMI reconnaissance team.

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