MCEER BULLETIN

The Quarterly Publication of MCEER   Volume 12, Number 2, Summer 1998

Screening Guide for Liquefaction Hazard at Highway Bridge Sites

by T. Leslie Youd

*This article summarizes procedures to conduct a preliminary assessment of the vulnerability of existing highway structures to damage as a consequence of liquefaction induced ground failure. The full procedure is detailed in **Screening Guide for Rapid Assessment of Liquefaction Hazard at Highway Bridge Sites**, MCEER-98-0005. Comments and questions should be directed to Professor T. L. Youd, Brigham Young University, Department of Civil and Environmental Engineering, 368 Clyde Building, Provo, UT 84602-4081; phone: (801) 378-6327; email: tyoud@byu.edu.*

Liquefaction does not occur randomly in natural deposits but is limited to a rather narrow range of seismic, geologic, hydrologic, and soil environments. Taking advantage of relationships between these environments and liquefaction susceptibility, this article introduces a screening guide that highway geotechnical engineers can use to perform rapid assessments of liquefaction hazard. The guide presents a systematic application of standard criteria for assessing liquefaction susceptibility, evaluating ground displacement potential, and assessing the vulnerability of bridges to liquefaction-induced damage. The screening proceeds from least complex, time-consuming, and data-intensive evaluations to the more complex, time-consuming, and rigorous analyses. Thus, many bridge sites can be evaluated and classified as low hazard with very little time and effort. Only bridges with significant hazard need to be evaluated with the more sophisticated and time-consuming procedures. At each level of screening, a conservative assessment of hazard is made. If there is clear evidence that liquefaction or damaging ground displacements are very unlikely, the site is classed as “low liquefaction hazard and low priority for further investigation,” and the evaluation is complete for that bridge. If the available information indicates a likely hazard, or if the data are inadequate or incomplete, the site is classed as having possible liquefaction hazard, and the screening proceeds to the next step. If the available site information is insufficient to complete a liquefaction hazard analysis, then simplified seismic, topographic, geologic, and hydrologic criteria are used to prioritize the site for further investigation.

The screening guide is conservative; that is, at each juncture in the screening process, uncertainty is weighed on the side that liquefaction and ground failure could occur. Thus a conclusion that liquefaction and detrimental ground displacement are very unlikely is a much more certain conclusion than the converse outcome—that liquefaction and detrimental ground displacements are possible. This conservatism leads to the corollary conclusion that additional investigation is more likely to reduce the estimated liquefaction hazard than increase it.

The principal steps and logic path for the screening procedure are listed in figure 1. In assessing liquefaction hazard, the recommended procedure is to start at the top of the logic path, perform the required analyses for each step, and proceed downward until the bridge is classified into one of four categories:

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Research Activities (Cont'd)

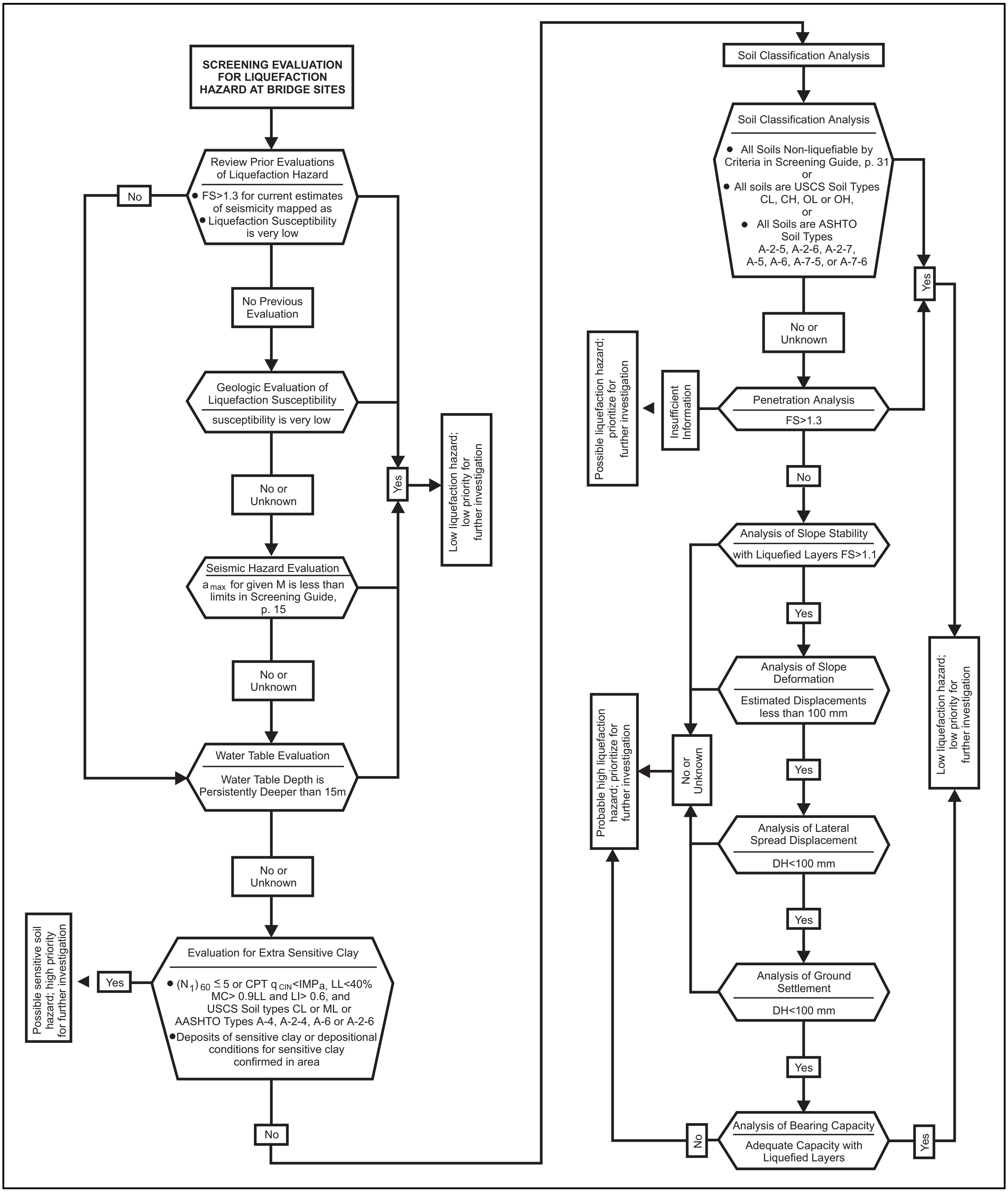

Figure 1: Flow Diagram Showing Steps and Criteria for Screening of Liquefaction Hazard for Highway Bridges

(continued from Page 1)

(1) confirmed high liquefaction and ground failure hazard—very high priority for further investigation and possible mitigation; (2) confirmed liquefaction susceptibility but unknown ground failure hazard—high priority for further investigation; (3) insufficient information to assess liquefaction susceptibility—prioritized for further investigation; or (4) low liquefaction hazard—low priority for further investigation. Based on these outcomes, the following procedures are recommended for setting priorities for further investigation or mitigation of liquefaction hazard.

Confirmed High Liquefaction Hazard

Sites with confirmed high liquefaction or sensitive soil hazard should be given very high priority for additional investigation and development of possible mitigative measures. Prioritization at this level should consider the following factors: A primary criterion should be the importance of the bridge. Essential bridges, as defined in Standard Specifications for Highway Bridges (AASHTO, 1992), should be given priority for further investigation and mitigation over other bridges. Bridges with higher traffic volumes generally would be given priority over bridges with lower traffic volumes. Older bridges or bridges with weaker or more brittle foundations and structural components should be given priority over stronger and more ductile structures. Bridges scheduled for major renovation or replacement might also be given high priority. These considerations are provided as general guidance; highway agencies should weigh these criteria along with local needs to set priorities for further investigations and hazard mitigation.

Confirmed Liquefaction Susceptibility, but Unknown Hazard

Sites with confirmed subsurface liquefiable, but with unknown ground failure hazard owing to insufficient site information, should be given high priority for further investigation. The further site investigation would usually include CPT and SPT soundings and laboratory testing to provide sufficient site information to conduct an analysis of the ground displacement hazard. Prioritization of sites for further investigation should proceed using the same general guidelines as suggested for the above category, with the following additional guideline. Most past bridge damage caused by liquefaction has occurred at river or other water-channel crossings. Thus bridge sites involving water crossings should be given priority for further investigation over non-water crossings, such as viaducts and overpasses.

Insufficient Information to Assess Liquefaction Resistance or Strength-Loss Potential

Where insufficient information is available, additional site investigations will be required to fully evaluate liquefaction and ground failure hazards. These investigations usually include additional drilling, SPT or CPT, and laboratory testing to identify and delineate liquefiable layers of liquefiable or sensitive soils, and analyses to define ground failure and bridge damage potential. Sites associated with water crossings should be given priority over sites at nonwater crossings. Sites with geologic conditions indicative of high liquefaction susceptibility should be given priority over sites assessed as having moderate or lesser susceptibility. The guidelines listed in the first category should also be considered in setting priorities for further hazard investigation.

Low Hazard and Low Priority for Further Investigation

Sites categorized as low hazard and low priority for further investigation need not be further analyzed or prioritized for further study, except for very critical structures where a high level of performance is mandated. Nevertheless, engineers should apply appropriate screening criteria for liquefaction hazard when new data is developed, such as for a new bridge or highway segment. Liquefiable sediment may exist beneath a small percentage of sites classed as low hazard by the criteria herein for reasons such as unusual local geologic conditions or inaccurately reported site information. Thus evaluations might be made as new information becomes available, but further specific investigations for liquefaction hazard are not required.

References

AASHTO, 1992, Standard Specifications for Highway Bridges, 15th ed., American Association of State Highway and Transportation Officials, Washington, DC.

Research Activities (Cont'd)

Seismic Behavior of Infilled Frames

by K. Mosalam

This article summarizes experimental and computational studies to evaluate the behavior of infilled frames subjected to earthquake loading. Complete research findings have been recently published as a series of three MCEER reports (see page 20 and Mosalam et al. 1997b, 1997c, and 1997d). Comments and questions should be directed to Professor Khalid M. Mosalam, 721 Davis Hall, University of California, Berkeley, CA 94720, phone: (510) 643-4805, or via email: mosalam@ce.berkeley.edu.

A common type of construction in urban centers is low-rise and mid-rise building frames with masonry infill walls. These walls are usually ignored when designing the bounding frames.

The effect of this practice is accentuated in highly seismic regions, where the frame / wall interaction causes a substantial increase of stiffness resulting in possible changes in the seismic demand. Lessons from recent damaging earthquakes illustrate the consequence of ignoring the contribution of infill walls. In general, the changes in the distribution of straining actions in the frame members due to frame / wall interaction render the structural detailing ineffective.

The problem of considering infill walls in the design process is partly attributed to incomplete knowledge of the behavior of *quasi-brittle* materials such as masonry and to the lack of conclusive experimental and analytical results to substantiate a reliable design procedure for infilled frames.

Quasi-static Experiments

Five experiments were carried out to investigate the performance of single-story reduced-scale infilled frames under earthquake-type loading. The frames were gravity load designed, i.e. frames with semirigidly connected steel members. The walls were constructed using unreinforced concrete block masonry. These experiments are described in table 1 and complete documentation can be found in Mosalam et al., 1997a and 1997b. In table 1, f_b is the block compressive strength based on the net area, f_c is the mortar cylinder compressive strength, and f_p is the masonry prism strength based on the face shell areas.

Specimen	Bays	Openings	f_b[MPa]	f_c[MPa]	f_b/f_c	f_p[MPa]
S1-N	1	None	13.1	10.0	1.31	12.4
S2-N-I	2	None	13.1	14.8	0.88	13.8
S2-N-II	2	None	19.3	11.7	1.65	16.5
S2-ASYM	2	Asymmetric[a]	19.3	11.7	1.65	1.65
S2-SYM	2	Symmetric[b]	27.6	21.4	1.29	22.8

[a] Window and door [b] Windows

Table 1: Experimental Program

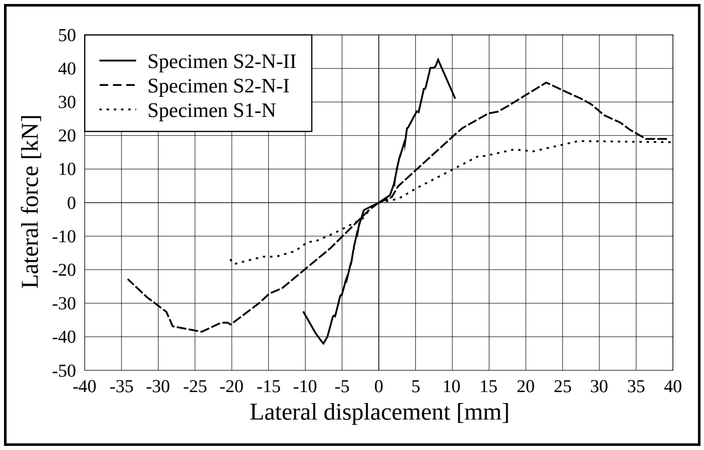

Figure 1: Effect of number of bays and materials of infills on the hysteresis envelopes

Specimen	P_u^+[kN]	P_u^-[kN]	Δ_u^+[mm]	Δ_u^-[mm]	Mode of failure
S2-N-II	42.7	42.3	8.1	7.6	Mortar cracking
S2-N-I	36.0	38.7	22.9	24.1	Corner crushing
S1-N	18.2	18.2	27.2	19.8	Corner crushing

Table 2: Effect of number of bays and materials of infills

The effect of the number of bays and the materials of infill walls is demonstrated by comparing the hysteresis envelops in figure 1. Table 2 summarizes key values from figure 1 and the corresponding modes of failure. In this table, the superscripts + and - refer to the positive and negative excursions, respectively, and P_u and Δ_u are the ultimate lateral force and the corresponding lateral displacement, respectively. The hysteresis envelopes shown in figure 2 illustrate the effect of openings on the global performance of the two-bay specimens.

Pseudo-dynamic Experiments

The pseudo-dynamic algorithm presented in Mosalam et al., 1998 was used to test a two-bay, two-story steel frame infilled with unreinforced concrete block masonry. Three earthquake records, Taft, El-Centro, and Nahanni, were selected as input ground motions (Mosalam et al., 1997c). The Taft earthquake was applied with increasing peak ground acceleration (PGA) until significant damage was observed in the walls. The mass properties of the prototype of the tested frame were selected based on frame spacing of 16 ft. (4877 mm), gravity loading from a 6 in. (152 mm) thick reinforced concrete slab, and design live load of 100 psf (4788 Pa). In the present pseudo-dynamic experiment, proportional damping was assumed (Mosalam et al., 1998).

Cracking in the infills started at the second story close to the corners of the windows. The larger inter-story drift in the first story led to cracking in the walls of this story as shown in figure 3. Under the Taft earthquake, the variations of the total energy terms (E_I for input energy and E_H for hysteretic energy) are shown in figure 4.

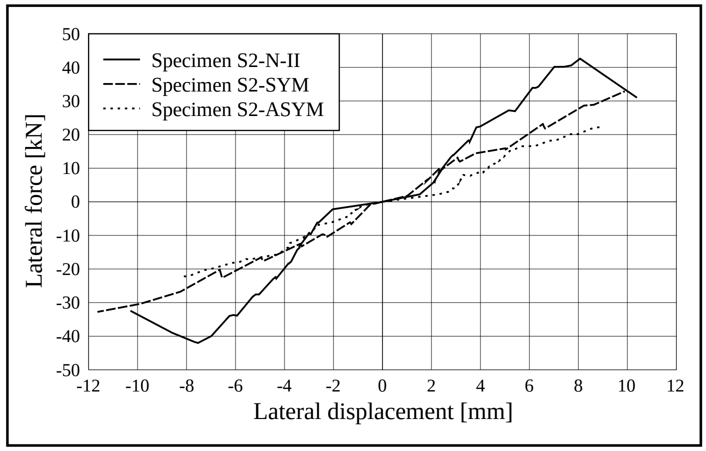

Figure 2: Effect of openings on global response

Computational Studies

Several computational strategies have been developed for the analysis of infilled frames. A complete documentation of this research effort can be found in Mosalam et al., 1997d. These strategies focused on different modeling techniques for masonry. The first model is based on a discrete approach where interface elements were considered to model the mortar joints between the concrete blocks. A new constitutive model was formulated and implemented in the

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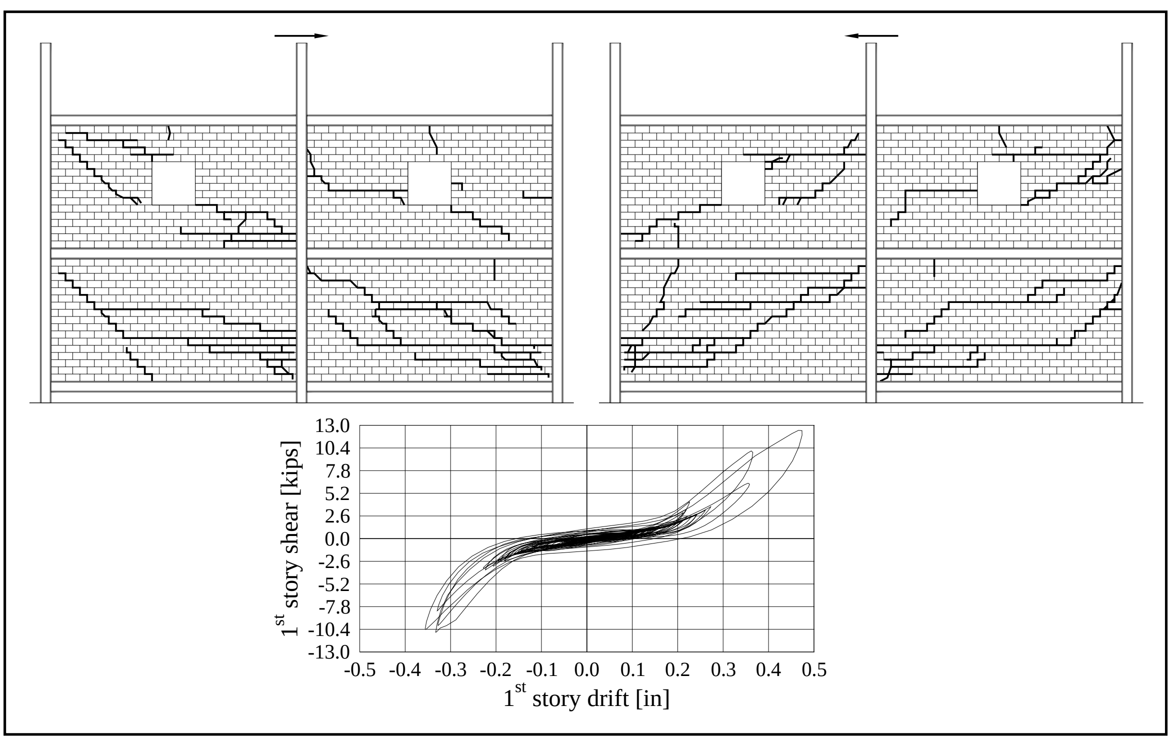

Figure 3: Crack patterns and hysteretic relation under Taft earthquake scaled to 0.6 g (1 in. = 25.4 mm, 1 kip = 4.448 kN)

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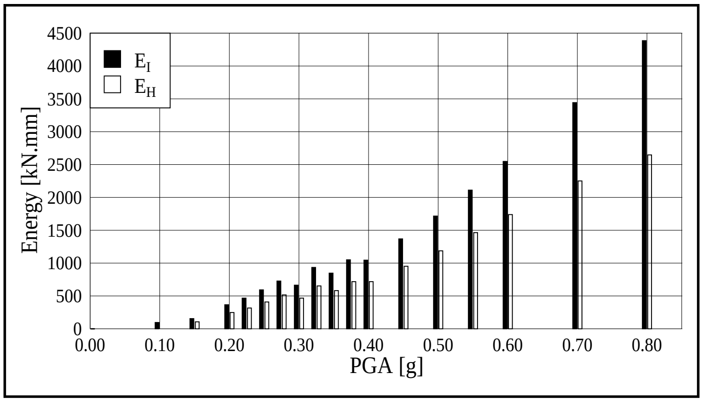

Figure 4: Variations of maximum values of energy terms with PGA

finite element program DIANA [1]. The model was verified using the standard diagonal tension test of masonry assemblages as shown in figures 5 and 6. This detailed finite element model was applied for the analysis of steel frame with infill panels including openings. Results of this analysis can be found in Mosalam, 1996.

The second model is less computationally intensive and is based on treating masonry as a homogeneous material where cracking is represented as damaged regions using the fixed smeared crack concept. A reformulation of this technique was performed utilizing a self-adaptive strategy at the constitutive level. This formulation focuses on continuous adaptation of the crack band width leading to the so-called evolutionary characteristic length method for smeared cracking (Mosalam and Paulino, 1997).

Analysis of the two-story structure tested pseudo-dynamically is presented in figure 7. In this figure, the incremental deformation and the corresponding smeared crack pattern are shown at applied total drift of 0.33%.

Finally, an approximate model for seismic fragility of gravity load designed concrete frames with and without infill walls was developed. This approximate model is based on the dynamic plastic hinge method, where the structure is reduced to a nonlinear single degree of freedom (Mosalam et al., 1997e). The method was validated by finite element analyses using the smeared representation of cracking. Detailed presentation of

[1] *DIANA: DISplacement ANAlyzer is the finite element code of TNO Building and Construction Research of The Netherlands.*

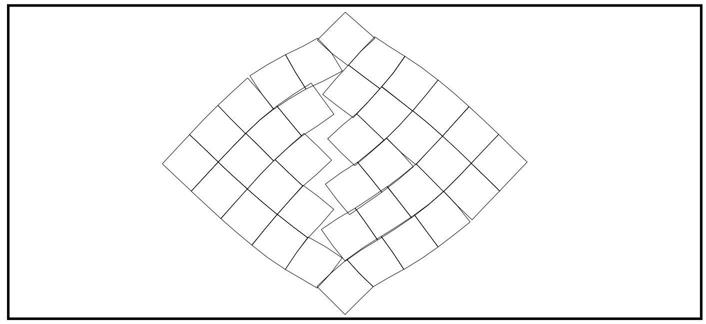

Figure 5: Deformed shape at full cracking of the masonry diagonal tension example

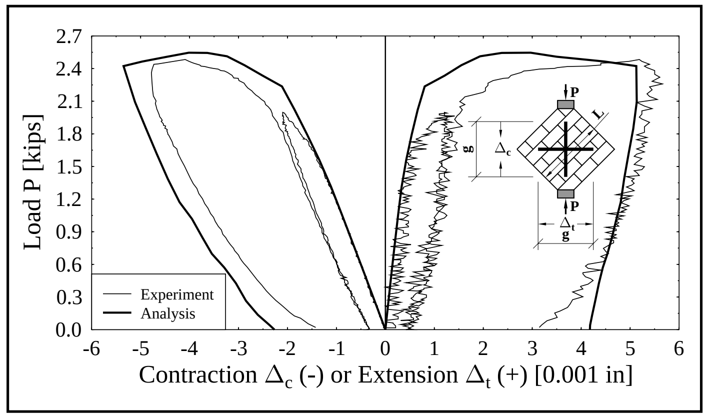

Figure 6: Comparison between FE results and experimental results for the masonry diagonal tension example (1 in. = 25.4 mm, 1 kip = 4.448 kN)

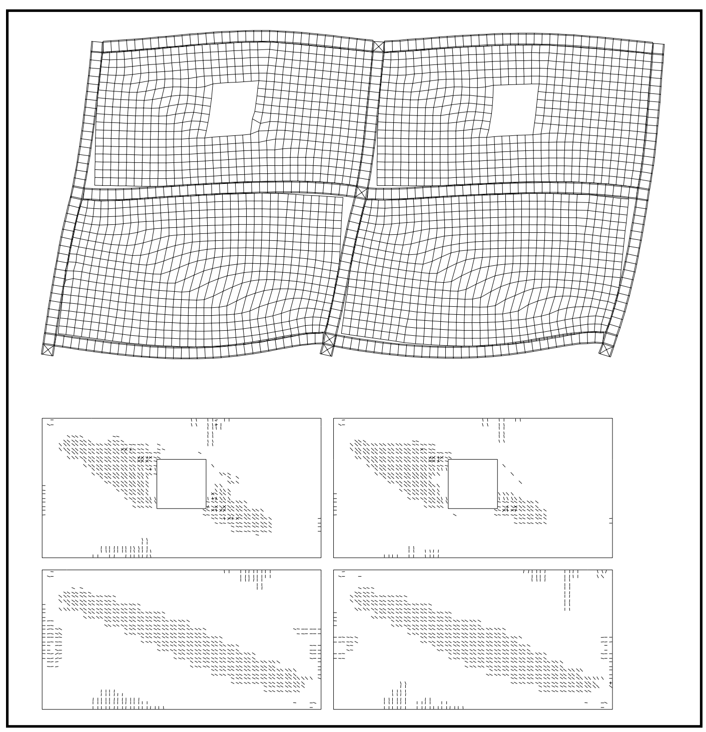

Figure 7: Finite element results of an infilled frame at the last converged loading increment; top: incremental deformation (amplification factor = 485); bottom: crack pattern in the infill walls

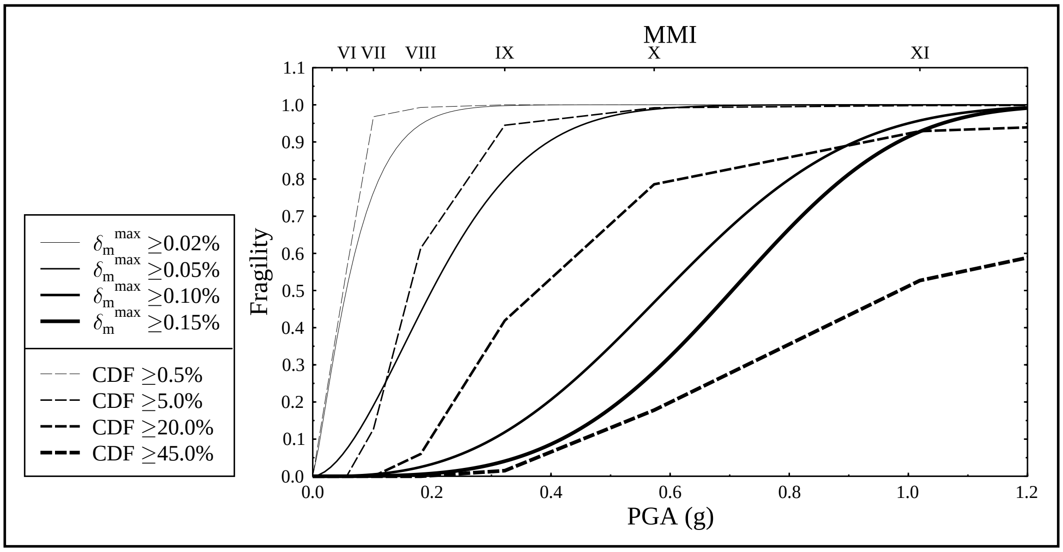

Figure 8: Fragility curves for infilled LRC frames and results from ATC-13

development of these fragility curves can be found in Mosalam at al., 1997e. Figure 8 shows comparisons between the fragility curves developed in this study for lightly reinforced concrete (LRC) frames with unreinforced masonry infill walls and those by ATC-13 for low-rise unreinforced masonry (with load bearing frame). In this figure, δ_m^{max} represents the maximum interstory drift and CDF is the central damage factor as defined by ATC-13.

Conclusion

In this study, experimental and computational strategies have been developed to provide an improved basis for the evaluation of frames with masonry infill walls. The study was conducted in three parts: quasi-static experimentation, pseudo-dynamic experimentation, and computational strategies. To a reasonable extent, the study provided insightful information into the problem of frame / wall interaction under seismic loading. The author is currently expanding the applicability of the developed nonlinear finite element methods to the design of hybrid systems such as frames with infill walls.

References

Mosalam, K. M., (1996), "Modeling of the Nonlinear Seismic Behavior of Gravity Load Designed Frames," Earthquake Spectra, Vol. 12, No. 3, pp. 479-492.

Mosalam, K. M. and Paulino, G. H., (1997), "Evolutionary Characteristic Length Method for Smeared Cracking Finite Element Models," Finite Elements in Analysis and Design, Vol. 27, No. 1, pp. 99-108.

Mosalam, K. M., White, R. N., and Ayala, G., (1998), "Response of Infilled Frames Using Pseudo-dynamic Experimentation," Earthquake Engineering Structural Dynamics, Vol. 27, pp. 589-608.

Mosalam, K. M., White, R. N., and Gergely, P., (1997a), "Static Response of Infilled Frames Using Quasi-static Experimentation," J. Structural Engineering, ASCE, Vol. 123, No. 11, pp. 1462-1469.

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Mosalam, K. M., White, R. N., and Gergely, P., (1997c), "Seismic Evaluation of Frames with Infill Walls Using Pseudo-dynamic Experiments," Technical Report NCEER-97-0020.

Mosalam, K. M., White, R. N., and Gergely, P., (1997d), "Computational Strategies for Frames with Infill Walls: Discrete and Smeared Crack Analyses and Seismic Fragility," Technical Report NCEER-97-0021.

Mosalam, K. M., Ayala, G., White, R. N., and Roth, C., (1997e), "Seismic Fragility of LRC Frames With and Without Masonry Infill Walls," J. Earthquake Engineering, Vol. 1, No. 4, pp. 693-720.

Center Activities

1998 Activities

ACT-29-1 Seminar on Seismic Design, Retrofit and Performance of Nonstructural Components
San Francisco, California
January 22-23, 1998
(Sponsors: Applied Technology Council, MCEER)

MCEER Implementation Advisory Committee Meeting
San Francisco, California
February 4, 1998

U.S.-Japan Workshop on Social Consensus and Acceptable Risk in Urban Earthquake Disasters
Los Angeles, California
March 16-17, 1998
(Sponsors: MCEER and the Ministry of Education of Japan)

MCEER Implementation Advisory Committee Meeting
Buffalo, New York
April 3-4, 1998

Workshop on Earthquake Performance Criteria for Communication Systems
Stanford University, California
April 16, 1998

ASCE Steel Bridge and Concrete Canoe Competition
University at Buffalo
Buffalo, New York
April 17-18, 1998
(Sponsors: University at Buffalo Department of Civil Engineering, MCEER)

U.S.-Italy Workshop on Seismic Protective Systems for Bridges
Columbia University, New York
April 26-28, 1998
(Sponsors: MCEER/FHWA, Columbia University)

PACE (Professional and Continuing Education) Pilot Course: Seismic Retrofit of Highway Bridges
Nashville, Tennessee
May 28-29, 1998
(Sponsors: MCEER /FHWA)

MCEER-INCEDE Center-to-Center Workshop on Transportation Systems
Tokyo, Japan
June 22-23, 1998
(Sponsors: International Center for Disaster Mitigation Engineering (INCEDE) of Japan, MCEER)

MCEER Scientific Advisory Committee Meeting
Buffalo, New York
July 10, 1998

MCEER-INCEDE Center-to-Center Workshop on Post-Earthquake Reconstruction Strategies
Newport Beach, California
August 24-25, 1998
(Sponsors: International Center for Disaster Mitigation Engineering (INCEDE) of Japan, MCEER)

Workshop on Advanced Materials, Non-Destructive Evaluation & Condition Assessment for Critical Facilities
Buffalo, New York
August 26-27, 1998

Honors and Awards

Research Committee Chairman Receives Honors

Masanobu Shinozuka, MCEER Research Committee Chairman and Fred Champion Professor of Civil Engineering at the University of Southern California, was recently the recipient of several prestigious awards. He was elected to the Russian Academy of Sciences (Natural) this past April. In 1997, the Society awarded Professor Shinozuka the Kapitsa Gold Medal for his noteworthy contributions to the field of earthquake engineering. Named for Peter L. Kapitsa, the Nobel Prize-winning Russian physicist and former head of the now-defunct Soviet Academy of Science, the medal honors scientists whose work holds international significance and also leaders of major research institutions or organizations who have done work of unusual distinction.

The faculty of the school of engineering of the University of Southern California awarded Professor Shinozuka the 1998 Senior Research Award in April. He received this honor for his research in Earthquake Engineering and Risk Reduction.

The Tongji University, a premier university in China, awarded Honorary Professorship to Professor Masanobu Shinozuka in 1997. This award has previously been awarded only 22 times to internationally distinguished people like Chancellor H. Kohl of Germany and the world renowned architect I. M. Pei of U.S.

He also received the Japan Society of Civil Engineers International Prize for his distinguished service and contribution to international exchange in civil engineering. This prize was awarded in the summer of 1998.

MCEER Appoints Deputy Director

Dr. Michel Bruneau, an authority on seismic evaluation and retrofit of steel bridges, buildings and masonry infrastructure, has been named deputy director of MCEER. He will assume responsibility for coordinating the center's nationwide research program in advanced technology applications. He previously served as director of the Ottawa-Carleton Earthquake Engineering Research Centre at the University of Ottawa, Ontario.

Dr. Bruneau replaces Dr. T.T. Soong, Samuel Capen Professor of Engineering Science at UB, who served as deputy director since last year's departure of Dr. Ian Buckle. Dr. Bruneau has also joined UB's department of civil, structural and environmental engineering as a tenured professor.

Dr. Bruneau is one of six founders of the Ottawa-Carleton Earthquake Engineering Research Centre, which he headed since its inception in 1994. He also served as director of the University of Ottawa structures laboratory, and as associate professor of engineering in the university's department of civil engineering.

Previously, Dr. Bruneau was a consulting engineer with Morrison Hershfield Limited, a prominent Canadian consulting firm specializing in structural and transportation engineering, and project management. He holds an undergraduate degree in civil engineering from the University of Laval, Quebec, and an M.S. and Ph.D. in structural engineering from the University of California, Berkeley.

Dr. Bruneau has served as a consultant on earthquake design and retrofit to engineering firms in the United States and Canada. Currently, he is taking part in the review of proposed changes to Canada's national building code. He also serves on the Seismic Committee of the Canadian Highway Bridge Design Code, the American Society of Civil Engineers (ASCE) Steel Bridge Committee, and the Canadian Association for Earthquake Engineering Standing Committee on Seismic Design.

He has taken part in numerous post-earthquake reconnaissance investigations in the U.S. and abroad, including those in Kobe, Japan (1995), Northridge, California (1994), Erzincan, Turkey (1992), San Francisco, California (1989), and Mexico City, Mexico (1985).

Dr. Bruneau is co-author of *Ductile Design of Steel Structures*, published by McGraw-Hill in 1997, and author of numerous book chapters and technical papers. He is a member of the Earthquake Engineering Research Institute (EERI), Canadian Association for Earthquake Engineering, American Society of Civil Engineers (ASCE) and the Canadian Society of Civil Engineering.

Obituary

Elaine Weiner, Longtime MCEER Staff Member

It is with great sadness that we report the death of our longtime Information Service Secretary and beloved friend, Elaine Weiner, on July 8, 1998, after a brief illness. Elaine had been employed in the Information Service since 1989 as a secretary to the manager and professional staff, with responsibilities for personnel matters. More recently she had assumed responsibility for formatting the **MCEER Information Service News** using desktop publishing software. Elaine's official duties, however, were but a small part of her contributions to the Information Service. In addition to her impressive secretarial skills, Elaine brought many years of experience in university protocol, as well as memorable cordiality and enthusiasm. Her knowledge and love of life was remarkable. Elaine will be sorely missed by all who knew her—staff members and students alike, many of whom she shepherded along life's paths. Before coming to the University, Elaine had worked in banking and in a family-owned business. She is survived by two sons: Mike of Birmingham, AL, and Stephen of Chapel Hill, NC; a daughter, Jill Mazzola of Buffalo; and three grandchildren.

Center Activities (Cont'd)

NYC Area Consortium for Earthquake Loss Mitigation to Form

Metropolitan New York is the largest city in the nation in terms of population, and contains significant percentages of certain key national economic sectors. It is also categorized as a moderate earthquake hazard area by the U.S. Geologic Survey (USGS). Considering its population density and building stock conditions, it is clear that even a moderate earthquake would have considerable consequences in terms of public safety and economic impact. In spite of this, earthquake awareness is low among key agencies and corporations. Similarly, little is known about the loss reduction measures that should or could be implemented to minimize unnecessary damage from an unanticipated moderate earthquake.

Through NIBS, FEMA has supported the development and implementation of HAZUS. FEMA Region II, which supports New York, New Jersey, Puerto Rico, and the U.S. Virgin Islands, has worked with other agencies over the past year to begin construction of a seismic hazard and accompanying damage profile for the area using HAZUS. HAZUS and similar loss and damage estimation products are viewed as valuable tools for promoting loss-reduction activities. In parallel, FEMA's Project Impact champions the elements essential to building a disaster resistant community. Many of these concepts, such as forging partnerships, assessing vulnerabilities, developing and prioritizing risk reduction measures, and sharing information, are at the foundation of an earthquake loss reduction consortium being established in the New York City metropolitan area to help address its seismic risks.

FEMA Region II is leading the effort to build the Consortium, which is being coordinated by MCEER with FEMA support. Interested organizations and stakeholders from such areas as academia, emergency management, public service agencies, the private sector, and financial and insurance arenas are invited to be active participants and contributors to the program. Members will work collectively toward the development of realistic regional seismic characteriztions and inventories of the built environment and supporting infrastructure. The model will then be used as a platform to foster earthquake awareness within the community, encouraging wider involvement of key groups for sharing of data to further refine the model. The overriding objective of the program will be to offer reasonable seismic vulnerability and loss estimation information to promote concerted adoption of appropriate mitigation strategies throughout the metropolitan region. It is anticipated that the core membership for the Consortium will be in place by the fall of 1998.

The project is led by a technical coordinator, Guy Nordenson of Princeton University, with technical advisement on seismic issues provided by Klaus Jacob and researchers at Lamont Doherty Earth Observatory of Columbia University. An Executive Committee for the project includes representatives of FEMA, MCEER, Princeton, Lamont Doherty, New York State Emergency Management Agency, New Jersey Office of Emergency Management and New York City Office of Emergency Management. An external technical advisory panel for the project is drawn from experts in the U.S. community and is co-chaired by Professor Thomas O'Rourke of Cornell University and Dr. Ramon Gilsanz, of Gilsanz, Murray and Steficek, Inc.

DOT Awards New Highway Contract

MCEER will receive $10.8 million over the next six years from the U.S. Department of Transportation to apply its expertise to improving the seismic performance of the nation's highway system.

The funds, allocated under the federal Transportation Equity Act for the 21st Century, which was signed into law June 9 by President Clinton, will extend work begun by MCEER in 1992 under two current Federal Highway Administration contracts that have focused on federal-aid highways, bridges and tunnels.

The new DOT contract will focus on the development of a seismic design and retrofit manual for long span bridges, loss estimation methods for highway systems, seismic protective systems for bridges, and foundations and geotechnical studies.

5th U.S. Conference on Lifeline Earthquake Engineering

The American Society of Civil Engineers (ASCE) is seeking papers for the *5th U.S. Conference on Lifeline Earthquake Engineering (5USCLEE)*, to be held August 12 - 14, 1999 in Seattle, Washington. Sponsored by ASCE's Technical Council on Lifeline Earthquake Engineering (TCLEE), the conference theme is "Optimizing Post-Earthquake Lifeline System Reliability." It is being coordinated for ASCE by MCEER.

5USCLEE will provide a forum for research, practice, investigation, and public policy in lifeline earthquake engineering. The 2½-day program will include sessions on traditional lifeline topics: water, sewage, transportation, ports and harbors, electric power and communications, gas and liquid fuels. Special emphasis will be placed on bridge hazards, analysis and retrofit. Earthquake seismic risk and socioeconomic issues will also be explored. Lessons learned from the Northridge, California, and Kobe, Japan earthquakes will be prominent in the program.

Authors wishing to make presentations at the conference should submit four copies of abstracts, 2 - 3 pages long, to the Proceedings Committee Chair: Mr. William Elliott, Portland Bureau of Water Works, 1120 SW 5th Avenue, Rm. 600, Portland, Oregon 97204-1926; phone: (503) 823-7486; fax: (503) 823-4500.

Abstracts must include title, full name of author(s) and the mailing address of the lead author, including work telephone and fax number. In the upper right hand corner of the title page, authors should indicate by code, their preference for the topical session for which their abstract should be considered, as well as the type of presentation preferred, traditional (t) or poster (p); (e.g., CS-t = a traditional presentation of a Case Study). Topical sessions include:

- Case Studies (CS)
- Communications (CM)
- Electric Power (EP)
- Emergency Planning (EmP)
- Gas and Liquid Fuels (GL)
- Implementation Issues (IM)
- Multi-Hazard Risk Assessment (MR)
- Performance Objectives (PO)
- Pipelines (PL)
- Post-Earthquake Investigations (IN)
- Seismic Hazards (SH)
- Seismic Risk (SR)
- Socioeconomic Considerations (SE)
- Transportation (TR)
  - Airports
  - Harbors
  - Highways
  - Rail
- Water and Wastewater (WW)

Abstracts will be reviewed for significance of technical content, originality, clarity, objectivity, organization, and freedom from commercialism. Authors of papers accepted for presentation will be notified by November 15, 1998. Papers will be limited to 10 pages in length and are due March 1, 1999.

Presentations of research findings from colleagues abroad, particularly from those in Pacific Rim nations who are involved in U.S. international collaborative research and technology exchange activities, are especially encouraged.

For information on the technical program, contact conference co-chairs: Donald Ballantyne, EQE International, 1411 4th Avenue Building, Suite 500, Seattle, WA 98101; phone: (206) 442-0695; fax: (206) 624-8268; email: *dbballan@eqe.com*; or Thomas O'Rourke, School of Civil and Environmental Engineering, Cornell University, 273 Hollister Hall, Ithaca, NY 14853-3501; phone: (607) 255-6470; fax: (607) 255-9004; email: *tdo1@cornell.edu*.

Abstracts will be accepted throughout the month of October. For a copy of the Call for Abstracts or information about conference registration, contact Andrea Dargush at MCEER, phone: (716) 645-3391; fax: (716) 645-3399; email: *dargush@acsu.buffalo.edu*.

Center Activities (Cont'd)

MCEER-INCEDE Center-to-Center Workshops

The third and fourth in a series of workshops organized under the MCEER-INCEDE Center-to-Center project have been held during the past few months. The Center-to-Center project is jointly funded by the U.S. National Science Foundation (NSF) and the Japan Society for the Promotion of Science (JSPS). The project focuses on collaboration between earthquake engineering researchers and practitioners in the U.S. and Japan to study and document the development or improvement of post-earthquake reconstruction strategies following the 1994 Northridge and 1995 Kobe earthquakes. The project is being jointly conducted by MCEER and the International Center for Disaster Mitigation Engineering (INCEDE) in Japan. A description of the project and previous workshops is provided in the **NCEER Bulletin**, Volume 12, Number 1, Spring 1998.

Earthquake Engineering Frontiers in Transportation Systems

The *MCEER-INCEDE Center-to-Center Workshop on Earthquake Engineering Frontiers in Transportation Systems* was held in Tokyo, Japan, on June 22 and 23, 1998. Dr. George Lee led a U.S. delegation of eight researchers, practitioners, and government officials, who met with 29 Japanese counterparts in this fourth workshop. Among the topics discussed by the workshop participants were the following:

- Economic impact resulting from transportation system damage
- Emergency management and control of transportation systems
- Risk assessment methodologies for transportation systems
- Reconstruction activities following the Kobe earthquake
- Transportation system retrofitting methods and procedures
- Earthquake impacts on port facilities

The two-day workshop included formal paper presentations, along with informal panel discussions and presentations. Among these were presentations by

Transportation system damage following the Kobe (left) and Northridge (right) earthquakes

agencies responsible for emergency management and police operations from the city of Kobe.

One of the products of the Center-to-Center project will be a digital sourcebook containing 2-page abstracts summarizing lessons that have been learned from reconstruction efforts following the Northridge and Kobe events. A presentation on the sourcebook was made by INCEDE during the workshop, demonstrating the interactive and visual nature of the technology and material contained within it. When completed, the sourcebook will be a searchable information resource residing on the INCEDE and MCEER websites.

INCEDE is currently in the process of publishing proceedings of the workshop. Copies will be available from MCEER in the fall of 1998.

Water Lifelines

The *NCEER-INCEDE Center-to-Center Workshop on Water Lifelines* was held December 8-9, 1997 in Newport Beach, California. Sixteen people attended the workshop, eight from the U.S. and eight from Japan.

Technical sessions focused on seismic damage and behavior of water lifeline facilities, socioeconomic impacts, damage estimation and restoration of water following earthquakes. Presentations focused on experiences observed and implemented following the Kobe and Northridge earthquakes.

Center Directors Dr. George Lee and Dr. Ken Sudo represented the two Centers. Mr. Donald Ballantyne, EQE International and Professor Shiro Takada, Kobe University, organized the workshop. For more information, contact Donald Ballantyne at EQE, Inc., email: *dbballan@eqe.com*.

U.S.–Italy Workshop on Seismic Protective Systems for Bridges

The *U.S.-Italy Workshop on Seismic Protective Systems for Bridges* was held at Columbia University in New York City on April 27 and 28, 1998. The workshop was attended by 12 Italian and 27 U.S. participants. The workshop was organized by MCEER under the MCEER Highway Project. Financial sponsorship on the U.S.-side was provided by the U.S. Federal Highway Administration; similar sponsorship for the Italian side was provided by the National Group for Defense Against Earthquakes (GNDT) of the Italian National Research Council (CNR). Columbia University was a co-sponsor of the workshop and provided important logistical and operational support.

The workshop consisted of brief presentations of 13 U.S. and 11 Italian papers which focused on research and the application of seismic protective systems for bridges, and the state-of-the-art and practice in bridge seismic isolation and energy dissipation in the two countries. Presentations were also made on the related subjects of application of active control systems and the use of advanced composites for bridge seismic retrofitting. The presentations were intended to provide an overview of recent developments in each country. Discussions were held on each major topic as well as on the comparison of and differences between design philosophies and practices in each country; and written guidelines and standards, and codes of practice currently in use in the two countries.

Workshop participants suggested that both Italy and the U.S. are at the forefront in international developments and the application of seismic protective systems for bridges. Participants, and particularly invited observers from State transportation agencies and the bridge engineering community, were pleased to learn of these developments and applications.

Due to rapid advancements currently being made in the development and application of seismic protective systems technologies, it was agreed that a continuing dialog and exchange of information between the U.S. and Italy on seismic protective systems for bridges should continue and that a second workshop should be organized in Italy in the near future. While this first workshop provided a common basis of comparison, the second workshop will concentrate on specific applications and topics of direct use to practitioners, including design philosophy and standardization of practice and codes.

The workshop was preceded by a tour of interesting bridge rehabilitation projects around the New York City area on April 26, 1998. The tour was arranged and hosted by Dr. Bojidar Yanev, Assistant Commissioner of the New York City Department of Transportation.

The U.S. Steering Committee for the workshop consisted of Dr. Michael Constantinou, State University of New York at Buffalo, chair; Dr. Frieder Seible, University of California at San Diego; Mr. Tom Post, California Department of Transportation; and Mr. Ian M. Friedland, MCEER.

The Italian-side organizers and Steering Committee consisted of Dr. Paolo E. Pinto, Università di Roma "La Sapienza" and Dr. Gian Michele Calvi, Università Degli Studi di Pavia.

Dr. Raimondo Betti of Columbia University was instrumental in the success of the workshop through his help and efforts in organizing and making arrangements for the use of the facilities provided by Columbia University. Proceedings are currently being prepared by MCEER, and are scheduled for publication by the end of 1998.

AISC Steel Bridge and ASCE Concrete Canoe Competitions

MCEER, in conjunction with the Department of Civil, Structural and Environmental Engineering at the University at Buffalo, hosted the annual *ASCE Upstate New York Regional Concrete Canoe* and *Steel Bridge Competitions* at the University at Buffalo. More than 200 students from as many as fourteen universities participated in the event, held April 17-18. In addition to MCEER affiliate institutions University at Buffalo, Rensselaer Polytechnic Institute and Cornell University, the following schools participated: Clarkson University; Hudson Valley Community College; Rochester Institute of Technology; SUNY Canton College of Technology; SUNY Institute of Technology / Utica-Rome; Syracuse University; Union College; United States Military Academy; University of Ottawa; City College of New York; and Nassau Community College.

This was the eleventh annual national concrete canoe competition. ASCE Student Chapters and clubs have been involved in constructing and racing concrete canoes on the local and regional level since the early 1970s. However, the first national competition came into fruition in the summer of 1988 through the collaboration of ASCE and Master Builders.

Competition consists of a design paper submitted to a panel of judges in advance, and a formal oral presentatation of the day of the competition. The canoe races, which represent the less serious side of the competition, tend to be the highlight. Each element is separately evaluated, with plaques awarded to the highest scorers. The first and second place teams overall, Rochester Institute of Technology and Cornell University, advanced to the national competition.

The *Steel Bridge Competition* is sponsored by the American Institute of Steel Construction and co-sponsored by the American Society of Civil Engineers, the American Iron and Steel Institute, the James F. Lincoln Arc Welding Foundation and the National Steel Bridge Alliance. This intercollegiate challenge requires civil engineering students to design, fabricate and construct a steel bridge. Participating students gain practical experience in structural design, fabrication processes, construction planning, organization and teamwork.

The competition focuses on the development of a replacement of a century-old bridge that crosses a river valley in a mountainous region. The bridge carries heavy truck traffic to and from mines which are the basis for the local economy of the rural community. A quick replacement is necessary because no other river crossing is available for miles. The competition is then a scaled simulation of that project.

Standards for durability, constructibility, usability, strength and serviceability reflect the volumes of regulations that govern the design and construction of full-scale bridges. Criteria for excellence are represented by the award categories of stiffness, lightness, construction speed, aesthetics, efficiency and economy. As with a full-scale construction project, safety is the primary concern. Again, plaques were presented for excellence in the individual categories, and the top two bridge teams overall, SUNY Canton - College of Technology and Hudson Valley Community College, advanced to the national competition.

Other activities during the weekend included presentations by MCEER Director George Lee, Professor Andrei Reinhorn, Chairman, and Professor John Mander of the Department of Civil, Structural and Environmental Engineering at UB, and MCEER exhibits and tours. Two UB graduate students spoke to the group about a bridge design / build project, offering alternative design solutions to the real-world replacement of a major U.S.-Canada river crossing.

MCEER salutes the dedication of the participating students and their faculty advisors and acknowledges the enthusiastic support of the event by its sponsors.

Workshop on Earthquake Performance Criteria for Communication Systems

On April 16, 1998, MCEER conducted the *Workshop on Earthquake Performance Criteria for Communication Systems* at Stanford University. The event was organized by Anshel J. Schiff, Precision Measurement Instruments and consulting professor at Stanford University, who, together with Alex Tang of Northern Telecom Canada, served as the organizer of the workshop. The workshop focused on three issues:

- Identification of key issues necessary to establish earthquake performance criteria for communication systems
- Identification of areas of research necessary to develop performance criteria
- Formulation of measures for performance evaluation

Invited participants represented telephone service providers, government agencies, members of the emergency services community, consultants, and academics.

Several measures to characterize communication system performance were identified. Though it is possible for stakeholders (involved parties) to agree on the values of these parameters from several classes of communications systems users, it was agreed that it would be difficult or impossible to translate system performance criteria into specific measures that telephone companies could adopt that would assure that the criteria would be satisfied.

This concrete power pole was damaged following the Kobe earthquake.

Participants agreed that existing performance criteria for subsystems or components have and will continue to play an important role in assuring overall system performance (i.e. seismic performance (shake table testing)) required of communication equipment by major communication companies.

Finally, the participants of the workshop agreed that there was a need for additional performance criteria for emergency power and cooling systems.

The workshop proceedings contain a summary of the workshop and issues that were discussed, recommendations, and eleven papers. They are available by contacting MCEER Publications and ordering report number MCEER-98-0008. The cost is $15.00. For more information about the workshop, contact Anshel Schiff at *schiff@cive.stanford.edu*.

U.S.-Japan Joint Seminar on Civil Infrastructure Systems

The U.S. and Japan share common problems related to their civil infrastructure systems (CIS), such as physical aging and deterioration, functional obsolescence, high cost of maintenance, and huge outlays required for renewal and/or upgrade of CIS. Both nations need to develop cost-effective strategies for planning, design, construction, maintenance and retrofit of their respective CIS.

A two and one-half day *Bilateral Seminar on Civil Infrastructure Systems (CIS) Research* was held on August 28-30, 1997, in Honolulu, Hawaii, under the joint sponsorship of the NSF and the Japan Society for the Promotion of Science (JSPS), with supplementary support by MCEER and other non-federal sources. The objective of this seminar was to provide a forum to identify and compare common CIS issues existing in the U.S. and Japan, exchange ideas on dealing with common issues, promote cooperative research between the two nations, and formulate action plans.

The following topics were discussed:

- Science of aging and deterioration
- Health monitoring and condition assessment
- Renewal engineering
- Socioeconomic issues, and institutional effectiveness and productivity
- Research coordination

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The seminar consisted of five plenary technical sessions addressing each theme, five working group sessions and three plenary sessions to develop and adopt working group reports, seminar resolutions and recommendations. Executive sessions dealt with administrative needs and facilitated communications among conference and session chairs in developing the resolutions and recommendations. Each of the 28 participants from the U.S. and Japan presented a paper on CIS issues.

The seminar organizing committee consisted of Masanobu Shinozuka, University of Southern California; Makoto Watabe, Keio University; Adam Rose, Pennsylvania State University; and Manabu Yoshimura, Tokyo Metropolitan University. The Scientific Committee consisted of Joanne Nigg, Adam Rose, S. P. Shah and M. Shinozuka from the U.S. and M. Watabe and M. Yoshimura from Japan.

The proceedings of the seminar are being published by MCEER and include seminar resolutions, recommendations for the development of future cooperative U.S.-Japan research projects on CIS research, and the presented papers. It will be available this fall.

NSF Annual Review of EERCs

Representatives from MCEER, Mid-America Earthquake (MAE) Center and the Pacific Earthquake Engineering Research (PEER) Center met at PEER headquarters in Berkeley, California July 29 and 30 for their first joint annual review. The review, conducted by an independent panel selected by NSF, was intended to review progress and plans for the future as well as to evaluate and recommend areas of potential collaboration between the centers. Members of the oversight and coordination committee included Gonzalo Castro, GEI Consultants, Inc.; Liam Finn, University of British Columbia; Paula Gori, USGS; Le-Wu Lu, Lehigh University; Risa Palm, University of North Carolina; Leon Wang, Old Dominion University; James Wight, University of Michigan; and Sharon Wood, University of Texas.

Findings of the panel will be used to guide MCEER's Year 2 programs in Research, Education and Outreach and as the basis for future discussions with the other EERCs about collaborative projects.

Educational Activities and Outreach News

A number of MCEER educational activities were carried out during the last quarter. These include the co-organization and sponsorship of a steel bridge and concrete canoe competition for undergraduate engineering students (see article on page 14) and a pilot course on seismic retrofitting of highway bridges. The pilot course (see Center Activities, page 8) will be expanded over the coming months as part of MCEER's Professional and Continuing Education (PACE) program.

Incorporated Research Institutions for Seismology (IRIS) held a meeting in Warrenton, Virginia, April 22-25 to define the goals and activities of their education and outreach program in support of national science education advancement. Attendees represented IRIS member institutions, NSF, precollege and college-level educators and other education and outreach professionals. Andrea Dargush described MCEER’s education and outreach activities.

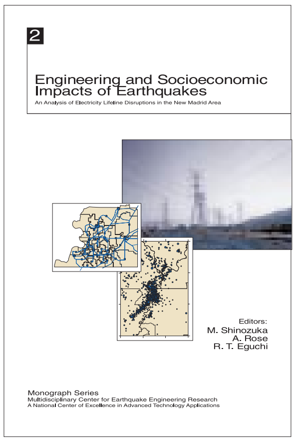
Education workshops have been held by the two new U.S. earthquake engineering research centers, the Mid-America Engineering (MAE) Center and Pacific Earthquake Engineering Research (PEER) Center, to help clarify their specific educational missions and define potential areas of cross-center collaboration. The PEER meeting was held this past spring and was attended by Andrei Reinhorn. The MAE education workshop was held in St. Louis, June 8-9. Andrei Reinhorn and Andrea Dargush discussed MCEER’s graduate education initiatives and K-12 activities.

MCEER will be an active participant in a day long program to be held October 14 in observance of national Earth Science week. Also this fall, the *Third Annual Seminar for Teachers* will be held in Buffalo. The seminar offers teachers insights into earthquake curricula, possible classroom activities and individual projects, as well as sources for additional information. A tutorial on using the internet for earthquake materials is offered, as well as a hands-on session to evaluate classroom projects. Educators from across the country are welcomed to attend. A limited number of travel stipends are available for qualified participants. For more information, contact Andrea Dargush at MCEER.

Center Resources

Monograph Series

Engineering and Socioeconomic Impacts of Earthquakes: An Analysis of Electricity Lifeline Disruptions in the New Madrid Area



The largest earthquakes ever to hit the contiguous 48 states were centered in the New Madrid Seismic Zone near Memphis, Tennessee, in 1811-1812. Reports of these events were phenomenal. Rivers were rerouted, trees were said to have popped right out of the ground, and the ground shaking itself was felt as far away as Boston. Yet, total dollar damages associated with the earthquakes were probably less than $1 million. The reason is that the area was relatively uninhabited, and the city of Memphis was not founded until several years later.

How would the situation differ today? An earthquake of a similar or even lesser magnitude is projected to be able to cause damage in the billions of dollars. The difference is that the Memphis area is now highly populated and is the center of a sophisticated and highly interdependent regional economy. Moreover, it is also a major crossroads for the national economy.

Engineering and Socioeconomic Impacts of Earthquakes: An Analysis of Electricity Lifeline Disruptions in the New Madrid Area, edited by M. Shinozuka, A. Rose, and R.T. Eguchi, examines the potential effects of a repeat of the New Madrid earthquake to the metropolitan Memphis area. The authors developed a case study of the impact of such an event to the electric power system, and analyzed how this disruption would affect society. In nine chapters and 200 plus pages, the book is a first of its kind effort to develop and apply a multidisciplinary methodology that traces the impacts of catastrophic earthquakes through a curtailment of utility lifeline services to its host regional economy and beyond. Chapters include:

- Modeling the Memphis economy
- Seismic performance of electric power systems
- Spatial analysis techniques for linking physical damage to economic functions
- Earthquake vulnerability and emergency preparedness among businesses
- Direct economic impacts
- Regional economic impacts
- Socioeconomic and interregional impacts
- Lifeline risk reduction policy formulation and implementation

Contributors include: Dr. Juan Benavides, University of the Andes, Bogota, Colombia; Dr. Stephanie E. Chang, University of Washington; Dr. H. Sam Cole, University of Buffalo; Mr. James M. Dahlhamer and Dr. Kathleen Tierney, Disaster Research Center, University of Delaware; Mr. Ronald T. Eguchi and Ms. Laurie A. Johnson, Center for Advanced Planning and Research, EQE, Inc.; Dr. Steven French, Georgia Institute of Technology; Dr. Howard H.M. Hwang, Center for Earthquake Research and Information, University of Memphis; Dr. Adam Rose, The Pennsylvania State University; Dr. Masanobu Shinozuka, University of Southern California; and Mr. Philip Szczesniak, Bureau of Economic Analysis Division, U.S. Department of Commerce.

The monograph costs $25. To order, contact MCEER publications, phone: (716) 645-3391; fax: (716) 645-3399; or email: *mceer@acsu.buffalo.edu*.

MCEER Technical Reports

Ten New Reports Reviewed

MCEER technical reports are published to communicate specific research data and project results. Reports are written by MCEER-funded researchers, and provide information on a variety of fields of interest in earthquake engineering. The proceedings from conferences and workshops sponsored by MCEER are also published in this series. To order a report reviewed in this issue, fill out the order form and return it to MCEER. To request a complete list of titles and prices, contact MCEER Publications, University at Buffalo, Red Jacket Quadrangle, Box 610025, Buffalo, New York 14261-0025; phone: (716) 645-3391; fax: (716) 645-3399; or email: *mceer@acsu.buffalo.edu*, or check MCEER's world wide web site at *http://mceer.buffalo.edu*. The web site offers a complete list of technical reports and their abstracts. The publications section allows users to search the report list by subject, title, author and keywords, and to place orders for these reports.

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Seismic Design of Bridge Columns Based on Control and Repairability of Damage

C-T. Cheng and J. B. Mander, 12/8/97, NCEER-97-0013, 211 pp., $20.00

This report describes development of a new seismic design paradigm, Control and Repairability of Damage (CARD). Replaceable / renewable sacrificial plastic hinge zones that use fuse-bar details form the basis of this approach. This special detailing permits repair of damage inflicted on that zone after an earthquake. Another advantage is that CARD lends itself to pre-cast and pre-stressed concrete construction. A fatigue theory based on well-known strain-life fatigue concepts for metals is proposed for structural concrete columns. Using this theory, plastic hinges are designed so that fatigue capacity exceeds the fatigue demand expected from a maximum capable ground motion. Well-known capacity design principles are applied to the rest of the structure. To validate the CARD approach, an experimental investigation was conducted. Three 1/3-scale and one near full-size specimens were tested under a variety of cyclic load regimes. Results show that the repaired column hinges performed as well as undamaged counterparts, and that damage was constrained within the hinge zone, thus verifying that CARD enables rapid restoration to full-service following an earthquake.

Seismic Resistance of Bridge Piers Based on Damage Avoidance Design

J. B. Mander and C-T. Cheng, 12/10/97, NCEER-97-0014, 142 pp., $15.00

This report concerns the development of a new seismic design paradigm called Damage Avoidance Design (DAD). Construction of bridge piers is based on modular (precast) beam and column elements that are free to rock under large lateral loads. Damage is avoided by special detailing of the connections. If desired, the lateral strength can be enhanced by using supplementary unbonded prestressing tendons. Due to the use of specially detailed steel-steel interfaces, the columns are expected to behave in a bilinear fashion with neither damage nor degradation in strength and stiffness. To validate the proposed design philosophy, the seismic performance of a near full-size precast concrete rocking column structure was investigated. Under large lateral (rocking) displacements, no damage to either the concrete column, connection or foundation was observed. The strength and stiffness was observed to remain the same after many cycles of loading. A complete force-deformation model for the rocking column accounting for structural flexibility (pre-rocking), rigid body kinematics (post-rocking) and the prestressing action of the tendons is proposed. Good agreement between the predictive theory and the experimentally observed force-deformation results was demonstrated.

Seismic Response of Nominally Symmetric Systems with Strength Uncertainty

S. Balapoulou and M. Grigoriu, 12/23/97, NCEER-97-0015, 208 pp., $20.00

This study focuses on the effects on seismic response and design of two aspects of system uncertainty: uncertainty in the functional form of the restoring force model of the lateral load resisting elements and uncertainty in the parameters of this model. The restoring force models selected for this study are the elastoplastic and the modified-Clough. Of the model parameters, only the yield strength is treated as a random variable following lognormal distribution. Input is deterministic, consisting of three earthquake records scaled to several peak ground accelerations. Two system types are considered: a simple one-story structure and a realistic seven-story building. Both systems are designed according to the 1994 Uniform Building Code. Both are symmetric in the elastic range but can experience torsional vibrations following yield, because of asymmetry in the element yield strengths caused by uncertainty. Each structural member is modeled by a set of inelastic springs. Yield strengths of springs modeling shear walls are treated as random variables. The study is based on Monte Carlo simulation. Dissipated energy, interstory displacement, and the maxima of displacement, ductility, and rotation are used to quantify the sensitivity of the response to strength uncertainty. The nondimensionalized ratio of the dynamic torsional moment to the design shear, called dynamic eccentricity, is used for code evaluation. The code accidental eccentricity appears inadequate, since it is significantly exceeded by the dynamic eccentricity for large fractions of the motion duration. Finally, if the modified-Clough were the correct restoring force model, use of the elastoplastic instead would not necessarily be conservative, since the latter may underestimate displacements and overestimate energy dissipation.

Evaluation of Seismic Retrofit Methods for Reinforced Concrete Bridge Columns

T. J. Wipf, F. W. Klaiber and F. M. Russo, 12/28/97, NCEER-97-0016, 222 pp., $20.00

The objective of this task was to collect and review information on the current state-of-the-art for seismically upgrading vulnerable concrete bridge columns. Over 200 references were collected. A questionnaire was developed and disseminated to obtain information on the column retrofitting activities of the various states (and Canadian provinces). The survey had a response rate of over 77%. The majority of published information concerns one of the most commonly used column retrofit techniques: steel jacketing and composite fiber jacketing. Several other techniques such as infilled walls in multi-column piers, external prestressing using high strength bars, and internal column strengthening, among others, were examined. The majority of research completed to date has been on reduced-scale laboratory specimens subjected to lateral loads. These tests have shown that column jacketing can substantially improve the ultimate ductility and lateral load capacity of reinforced concrete columns. An evaluation technique for assessing the relative merits of dissimilar retrofitting techniques was developed. Included in this technique are the following four parameters: structural performance, cost, environmental performance, and design process. To date, there is insufficient data available to use the technique developed. Areas requiring further investigation are presented in the final chapter of the report. A classification chart which assists the reader in determining the type of information a particular reference contains is presented in an appendix. Also included is a cross-reference list which assists the reader in locating where a specific reference is cited in the report.

Seismic Fragility of Existing Conventional Reinforced Concrete Highway Bridges

C. L. Mullen and A. S. Cakmak, 12/30/97, NCEER–97-0017, 121 pp., $15.00

Seismic fragility is estimated for an existing conventional reinforced-concrete highway bridge using nonlinear-dynamic finite element analysis. The bridge selected for analysis is the Meloland Road Overcrossing located near El Centro, California. The fundamental response modes of the bridge affecting damage involve three-dimensional interaction between deck flexure / torsion and column flexure. A beam-column damage element is used which allows for such an interaction between the column element and the deck elements. The column element uses fiber modeling of the basic kinematic interaction between axial force and biaxial bending moments using one-dimensional nonlinear constitutive relations that

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require only a few basic stress and strain parameters. The damage element is first shown to predict the capacity and ductility of cantilever specimens without sensitivity to scale or geometry. The selected bridge is then analyzed using the damage elements. By tuning the elastic moduli for the deck plate elements to match measured frequencies for the bridge under a moderate seismic event, a fixed-base model is able to predict acceleration time history records for the event. A soil-structure interaction model is then developed from the fixed-base model by adding lumped spring and lumped mass effects of the foundations. Artificially generated random motions are input to the soil-structure model to predict damage response over a range of input intensities. A damage index analogous to interstory drift is computed and is shown to correlate well with peak ground acceleration of the simulated time histories. Fragility curves are computed on the basis of linear regression analysis of the simulated data.

Loss Assessment of Memphis Buildings
Edited by D. P. Abrams and M. Shinozuka, 12/31/97, NCEER-97-0018, 262 pp., $20.00

The Loss Assessment of Memphis Buildings (LAMB) project integrated the efforts of researchers from various disciplines to estimate probable losses resulting from earthquake damage to concrete and masonry buildings in Memphis. Synthetic earthquake motions were created by seismologists and used with nonlinear structural models provided by structural engineers to generate sets of fragility curves for these building types. Losses were then assessed by socioeconomic researchers who applied damage probabilities and repair cost models to estimated inventories of concrete and masonry buildings. The overall purpose of the exercise was to develop a standard methodology that could be applied to other building types in other geographical regions. This report summarizes individual tasks of the Loss Assessment of Memphis Buildings (LAMB) project. Each chapter was written independently by the respective researcher(s) responsible for: building inventory; ground motion simulation; modeling response of concrete or masonry buildings; development of fragility curves; and estimating losses.

Seismic Evaluation of Frames with Infill Walls Using Quasi-Static Experiments
K. M. Mosalam, R. N. White, and P. Gergely, 12/31/97, NCEER-97-0019, 105 pp., $15.00

This report treats an experimental investigation of gravity load designed steel frames, i.e., steel frames with semi-rigid connections, infilled with unreinforced masonry walls and subjected to slowly applied cyclic lateral loads. An investigation of the mechanical properties of the materials used in constructing the masonry infill walls is included. Various geometrical configurations of the frame and the infill walls, and different material types of masonry walls, are considered. Based on the results, a hysteresis model for infilled frames is formulated and discussed. All parameters in the model have physical meaning and are calibrated with experimental data.

Seismic Evaluation of Frames with Infill Walls Using Pseudo-dynamic Experiments
K. M. Mosalam, R. N. White, and P. Gergely, 12/31/97, NCEER-97-0020, 98 pp., $15.00

An accurate and practical testing technique to study the seismic performance of multi-story infilled frames is formulated. This technique is based on the pseudo-dynamic method which can provide an acceptable approximation of the dynamic performance of structures under the influence of real earthquake excitation. The pseudo-dynamic experimental technique is outlined and applied for testing a two-bay, two-story gravity load designed steel frame infilled with unreinforced concrete block masonry walls. It was shown that careful implementation of the pseudo-dynamic technique may lead to excellent control over the experimental error propagation, even for stiff structures such as infilled frames. Based on the obtained results of the pseudo-dynamic experiments, the structural capacity as well as the corresponding seismic demand was assessed. From this study, it is concluded that the imparted energy and the hysteretic energy correlate well with the observed damage state of the infill walls. From the observed crack patterns of the infill walls, a macro-model for the infill panels is suggested.

Computational Strategies for Frames with Infill Walls: Discrete and Smeared Crack Analyses and Seismic Fragility
K. M. Mosalam, R. N. White, and P. Gergely, 12/31/97, NCEER-97-0021, 184 pp., $15.00

Several computational strategies for masonry structures, and particularly for frames with masonry infills, are presented. Three levels of details for the computational models are explored. Micro-modeling of masonry is presented first where the mortar joints are modeled using interface elements. Subsequently, a different approach is provided where various techniques for masonry composite are discussed. These models may be considered of an intermediate level of detail (meso-modeling) where damage mechanisms are accounted for in the form of smeared cracking using homogeneous properties for masonry. Numerical simulations involving smeared cracking face several problems due to mesh-sensitivity. To circumvent these problems, the standard smeared cracking is formulated to allow for a systematic adaptation of the crack band width. This idea led to the development of the evolutionary characteristic length method, along with an adaptive strategy for the finite element discretization with mesh enrichment. This technique can handle nonlinearities produced by both smeared cracking and interface conditions. The third level of modeling (macro-modeling) is special for masonry infill walls where equivalent nonlinear truss elements are used to replace the effect of the walls on the bounding frames. This modeling technique is useful as a design approach for masonry infills. Finally, further simplification of modeling frames with and without masonry infills is considered by using equivalent single degree of freedom systems based on the dynamic plastic hinge method. This approximate computational approach is utilized for the seismic fragility evaluation.

Proceedings of the NCEER Workshop on Evaluation of Liquefaction Resistance of Soils

Edited by T. L. Youd and I. M. Idriss, 12/31/97, NCEER-97-0022, 324 pp., $20.00

Following disastrous earthquakes in Alaska and in Niigata, Japan in 1964, Seed and Idriss developed and published the basic simplified procedure for evaluating liquefaction resistance of soils. The procedure, which is largely empirical, evolved over decades, until it has now established itself as the standard practice in North America and throughout much of the world. The purpose of this 1996 workshop was to convene a group of experts to review developments and gain consensus for further augmentations to the procedure. The scope was limited to evaluation of liquefaction resistance. Post-liquefaction phenomena, such as soil deformation and ground failure, although equally or more important, were beyond the scope of this workshop. The participants developed consensus recommendations on the following topics: use of the standard and cone penetration tests for evaluation of liquefaction resistance; use of shear wave velocity measurements for evaluation of liquefaction resistance; use of the Becker penetration test for gravelly soils; magnitude scaling factors; correction factors K1 and KaX; and evaluation of seismic factors required for the evaluation procedure. Probabilistic analysis and seismic energy considerations were also reviewed. Seismic energy concepts were judged to be insufficiently developed to make recommendations for engineering practice. Probabilistic methods have been used in some risk analyses, but are still outside the mainstream of standard practice.

News from the Information Service

The Quakeline ® database has installed NetAnswer™ as its search engine. NetAnswer, a product of Dataware Technologies, is a powerful software product that provides a variety of searching options designed to meet a wide range of database user needs—from novice searchers to highly experienced users.

Searches can be performed in the Quakeline database by specifying that search words appear either as: author(s); title word(s); keyword(s); word(s) in the abstract; or word(s) anywhere within a Quakeline record. Each individual condition of a search, i.e. searching for an author or searching for a keyword, can be combined with each other for more specific searching. The Boolean operators "and," "or," and "but not" are fully supported. In addition, it is also possible to build upon searches by using existing queries. Called "back referencing," this feature allows users to add additional parameters to an existing search without having to retype the entire search. A natural language search option makes it possible to perform searches based on English language sentence structure or on relevant words. An online word list can also be accessed to show variations in keyword assignments used in the database.

Search results from the Quakeline database can be viewed in three formats: brief; citation; or full record. Additionally, search results can be sorted by author, title or year.

The MCEER Information Service will continue to refine access to the Quakeline database in the coming months and welcomes any suggestions or comments from users. Please contact Carol A. Kizis, Quakeline Database Coordinator (*cakizis@acsu.buffalo.edu*) or Michael Kukla, Webmaster (*kukla@acsu.buffalo.edu*) with questions or comments.

Bulletin Board

7th U.S.-Japan Workshop on Earthquake Disaster Prevention for Lifeline Systems

The 7th *U.S.-Japan Workshop on Earthquake Disaster Prevention for Lifeline Systems* was held November 4-7, 1997 in Seattle, Washington. Forty-eight people attended the workshop, 31 from the U.S., and 17 from Japan. U.S. attendees included lifeline researchers and lifeline system owners that have the opportunity to apply research results. Japanese attendees included a contingent from the Public Works Research Institute, Japanese lifeline researchers and lifeline systems owners.

This event continued the direction set in the six previous workshops, to promote the exchange of lifeline earthquake research results that can reduce interruption of lifeline services by earthquakes and enhance post-event lifeline system operation.

The sixth workshop was held in Kobe, the summer following the 1994 Great Hanshin earthquake. The workshop is part of the U.S.-Japan Panel on Wind and Seismic Effects program. It was sponsored by the National Institute for Standards and Technology, National Science Foundation, and EQE International. The organizing committee consisted of Mr. Donald Ballantyne and Dr. Stephanie Chang, EQE International; Dr. Riley Chung, NIST; and Dr. Koichi Yokoyama and Dr. Keichi Tamura, PWRI.

Technical sessions focused on seismic damage and behavior of lifeline facilities, socioeconomic impacts, damage estimation, disaster prevention R&D, and lifeline facilities and urban earthquake disaster prevention. The workshop content was broadened to include a presentation by Mr. William Elliott of the Portland Water Bureau on a multi-hazard risk assessment they have underway.

Drs. Craig Weaver and Brian Atwater made enlightening presentations on Pacific Northwest seismicity and earthquake-induced liquefaction and tsunamis, respectively. Dr. Yokoyama made a special presentation on future long-span bridge projects in Japan. Dr. Tamura discussed the influence of liquefaction-induced ground flow on bridge foundations.

The second half of the workshop consisted of field study tours to regional lifeline facilities including: a Bonneville Power high voltage substation damaged in the Duvall earthquake, Seattle bridge seismic upgrades, Port of Seattle container and inter-modal facility projects, Seattle Public Utilities pump station and elevated tank seismic upgrades, King County's regional wastewater treatment plant, and the Washington Department of Transportation's Traffic Control Center.

The proceedings will be available this fall. A limited number of single copies will be available. Please contact Riley Chung at *rchung@nist.gov* or Don Ballantyne at *dbballan@eqe.com* to request a copy.

NIST Appoints Structures Division Chief

The National Institute of Standards and Technology (NIST) has announced the appointment of Dr. S. Shyam Sunder as chief of the Structures Division, Building and Fire Research Laboratory. In his new position, Dr. Sunder will oversee the development of measurements and standards for technologies supporting the structural safety and serviceability of buildings and infrastructure lifelines such as gas and electric utilities as well as offshore oil drilling and production platforms. Under the National Earthquake Hazards Reduction Program (NEHRP), the Structures Division endeavors to improve standards and codes for buildings and lifelines, to advance seismic design practices, and to provide technical leadership for NIST efforts in the Commerce Department's Natural Disaster Reduction Initiative. Dr. Sunder can be contacted at NIST, Building 226, Room B168, Gaithersburg, MD 20899-0001; phone: (301) 975-6061.

Mid-America Earthquake Center Appoints Deputy Director

Dr. James E. Beavers was appointed Deputy Director of the new NSF-sponsored Mid-America Earthquake (MAE) Center on April 27. Dr. Beavers is responsible for supervising coordinated research programs of the MAE Center, and stimulating new collaborative relations with industry and government. He was a longtime member of MCEER's Scientific Advisory Committee.

Dr. Beavers has extensive experience with earthquake problems in the eastern and central U.S. with over 25 years of engineering service with the Martin-Marietta Energy Services Corporation in Oak Ridge, Tennessee, as well as with his own consulting endeavors. His experience as Director of the Center for Natural Phenomena Engineering, and with management of numerous multidisciplinary programs, will be an asset to management of the Center's research programs. He holds a Ph.D. in Civil Engineering from Vanderbilt University with an emphasis in structural engineering.

Dr. Beavers can be contacted at the MAE Center, University of Illinois, Room 1241a Newmark Laboratory, 205 N. Mathews, Urbana, IL 61801; phone: (217) 244-4671.

Name Change for NCCEM

As of March 14, 1998, the name of the National Coordinating Council on Emergency Management (NCCEM) has been changed to the International Association of Emergency Managers (IAEM), to better reflect the growing international interest in the mission of the organization. Over 1,700 persons belong to IAEM, whose membership includes emergency managers and disaster response professionals from all levels of government as well as the military, private sector and volunteer organizations. For more information, contact Randall C. Duncan, IAEM President, 1997-1998; phone: (316) 221-0470; e-mail: *rduncan@hit.net*; or Elizabeth B. Armstrong, IAEM Executive Director, phone: (703) 538-1795; e-mail: *ebarm@aol.com*.

Earth Science Week Set for October

Earth Science Week, one of the American Geological Institute's most ambitious 50th anniversary initiatives, is scheduled for October 11-17. It offers the geoscience community new opportunities to demonstrate the importance of the earth sciences. Geoscience organizations have responded enthusiastically to the idea, and AGI member societies and state geological surveys are planning Earth Science Week activities and events. AGI's role in sponsoring an annual Earth Science Week is to provide a clearinghouse for ideas, activities, and special events and to provide support materials that make it easy for geoscientists to participate. Information about Earth Science Week is available from the American Geological Institute and on the World Wide Web at *http://www.earthsciweek.org*.

Call for Papers

IUGG-99 XXII General Assembly Inter-Association Symposium on Geophysical Hazards

The *IUGG XXII General Assembly Inter-Association Symposium on Geophysical Hazards* will be held July 22-27, 1999 in Birmingham, U.K. The aim of this Inter-Association Symposium is to stimulate synergistic interactions between all geophysicists on common interests in the field of natural hazards, especially across disciplinary boundaries. The scope seeks through contributed presentations to recognize the technical and scientific progress made during the last ten years in research related to any aspects of geophysical hazards to accomplishing the goals set forth for the decade, including risk assessment, the application of known preparedness and mitigation approaches, and the development and use of scientific and engineering knowledge to improve warning systems, disaster preparedness and mitigation in practice. In order to set the stage for this symposium, a series of invited keynote lectures will be presented on July 22 to evaluate the state-of-the-science in geophysical hazards and risks.

Instructions for abstract submission and format can be found at the IUGG website at *http://www.bham.ac.uk/IUGG99/* or contact Mohammed El-Sabh, Centre Oceanographique de Rimouski, Departement d'oceanographie, Universite du Quebec a Rimouski, 310 Allee des Ursulines, Rimouski (Quebec) G5L 3A1, Canada, email: *mohammed_el-sabh@jafar.uqar.uquebec.ca*, or *nayam@quebectel.com*. Abstracts are due by January 15, 1999.

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Published By:

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ISSN 1520-2933

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Some of the material reported herein is based upon work supported in whole or in part by the National Science Foundation, the State of New York, the Federal Highway Administration of the U.S. Department of Transportation, the Federal Emergency Management Agency and other sponsors. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of MCEER or its sponsors.

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