OVERVIEW OF THE MULTIDISCIPLINARY CENTER FOR EARTHQUAKE ENGINEERING RESEARCH (MCEER)

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Abstract: New strategies and technologies to reduce escalating losses are the thrust of MCEER's program. Center research seeks to define innovative approaches to improve performance assessment of engineered structures and infrastructure systems, and to develop cost-effective advanced techniques for the design of new construciton and the rehabilitation of existing critical facilities—those that must remain operational after an earthquake—namely hospitals, lifeline systems (water and power distribution networks) and highway systems.

1. INTRODUCTION

The Multidisciplinary Center for Earthquake Engineering Research (MCEER) is a national center of excellence that develops and applies knowledge and advanced technologies to reduce earthquake losses. Headquartered at the University at Buffalo, the Center was established in 1986 by the National Science Foundation (NSF) as the country's first National Center for Earthquake Engineering Research (NCEER). MCEER unites a group of leading researchers from numerous disciplines and institutions throughout the United States to integrate knowledge, expertise, and interdisciplinary perspective with state-of-the-art experimental and computational facilities in the fields of earthquake engineering and socioeconomic studies. The result is a systematic "engineered" program of basic and applied research that produces solutions and strategies to reduce the structural and socioeconomic impacts of earthquakes. Sponsored principally by NSF, the State of New York and the Federal Highway Administration (FHWA), MCEER garners additional support from the Federal Emergency Management Agency (FEMA), other state governments, academic institutions, foreign governments and private industry.

The Center's mission is to reduce earthquake losses through research, development and application of knowledge and advanced technologies that improve engineering, pre-earthquake planning, and post-earthquake response and recovery. In pursuit of this goal, MCEER coordinates a nationwide program of problem-focused, multidisciplinary team research, education and outreach activities that include collaboration with business, industry, consultants and government.

This paper describes some of MCEER's specific characteristics and current activities.

2. EARTHQUAKE-RESILIENT COMMUNITIES VIA USE OF ADVANCED TECHNOLOGIES

The Multidisciplinary Center for Earthquake Engineering Research (MCEER) seeks solutions to reduce earthquake losses, and help communities stand better prepared and increasingly resilient when faced with earthquakes. MCEER believes that the future of earthquake engineering and loss reduction lies in advanced and emerging technologies.

Therefore the center seeks to discover, nurture, develop, promote, help implement, and in some cases pilot-test innovative measures and advanced and emerging technologies to reduce losses in future earthquakes, in a cost-effective manner. Research includes innovative applications of engineered systems and materials, scientific methodologies, and concepts and analytical approaches not previously used in earthquake engineering and loss reduction. Projects focus on use of technologies to strengthen the most critical of facilities – hospitals, highways, and utilities – that communities become increasingly dependent upon in times of crisis, and to improve post-earthquake emergency response, crisis management, recovery and reconstruction efforts.

MCEER's nationwide program of problem-focused, multidisciplinary team research, education and outreach, includes collaboration with business, industry, and government. Advanced and emerging technologies being studied, include but are not limited to: Site remediation technologies; Structural control and simulation; Advanced systems analysis and high performance materials; Condition assessment technologies (including those for estimating potential and actual earthquake losses); Decision support systems

3. SAFEGUARDING LIFELINES, HOSPITALS, RESPONSE & RECOVERY SYSTEMS, AND HIGHWAYS

Advanced technologies are principally examined within four research programs – three funded by the National Science Foundation (NSF), and a fourth involving Federal Highway Administration (FHWA) contracts.

3.1 Seismic Evaluation and Retrofit of Lifeline Networks (NSF)

MCEER collaborates with Memphis Light, Gas and Water (MLGW) Division and the Los Angeles Department of Water and Power (LADWP) to study real-world systems, scenarios, and strategies to retrofit existing water and power systems. The objective is to identify, explore, and develop advanced technologies to rehabilitate critical water supply and electrical power networks to ensure a high level of performance following earthquakes. The goal is to substantially improve the reliability of these networks and demonstrate this through the Los Angeles and Memphis test beds.

3.2 Seismic Retrofit of Hospitals (NSF)

Hospitals must remain operational after an earthquake to render emergency medical care. This may require retrofit of the building, its foundation, and its non-structural components and contents. While other critical buildings house important emergency services (i.e., fire, police, etc.), hospitals pose unique challenges, as they integrate complex structural and non-structural systems. Consequently, retrofit techniques developed for hospitals will apply in improving seismic performance of other less complicated critical facilities.

MCEER's hospital project involves a team with varying expertise, including representation from both the New York and California Offices of State Health Planning & Development (OSHPD), to account for differences in hospital construction types, seismic environments, and societal concern for earthquake risk in the eastern and western US.

3.3 Emergency Response and Recovery (NSF)

Emergency response and recovery represent a community's final line of support following a damaging earthquake. In contrast to more "routine" emergencies, earthquakes can produce multiple emergencies that overwhelm response and recovery authorities. Optimal response depends on quality advance planning and preparation.

The most significant challenge after an earthquake is to accurately assess the impact of the disaster, and to prioritize response needs accordingly. MCEER studies examine use of remote-sensing technologies for rapid damage assessment and loss estimation, and advanced decision support systems to ease and improve decision making in the immediate post-earthquake emergency period as well as during the following recovery and reconstruction.

3.4 Seismic Performance and Reliability of the Nation's Highway System (FHWA)

Improving seismic performance and reliability of the nation's highway system is the aim of MCEER's Highway Project. Initiated in 1992 with contracts from the Federal Highway Administration (FHWA), the project uniquely examines earthquake impacts on the highway system as an integrated network, rather than individual roads, bridges, embankments, etc.

Projects seek to ensure usability of highways following earthquakes by improving performance of interconnected components. Goals are to improve understanding of seismic hazards and improve and develop analysis methods, screening procedures and tools, retrofit technologies, design criteria, and methods to reduce vulnerability of existing and future highway infrastructure.

3.5 Engineering and Organizational Issues Related to The World Trade Center Terrorist Attack

With funding from the National Science Foundation (NSF), MCEER initiated a research project to collect perishable data in the aftermath of the WTC attack for later study to gain a better understanding of how resilience is achieved in physical, engineered systems, and in organizational systems. Reports on Engineering and Organizational Issues Related to The World Trade Center Terrorist Attack presents these findings. Each report in the series focuses on a narrow aspect of the disaster as studied by MCEER researchers. The series is based on the premise that the World Trade Center attack could be seen as a "proxy" for what a major earthquake might do in a complex, densely populated, modern urban environment. Like an earthquake, the terrorist attack occurred with virtually no warning. As would be expected in an earthquake, fires broke out and multiple structural collapses occurred. As has been observed in major urban earthquakes and in other disasters, structures that performed critical emergency functions were destroyed, heavily damaged, or evacuated for life-safety reasons.

4. DEMONSTRATION PROJECTS AND EARTHQUAKE RECONNAISSANCE INVESTIGATIONS

MCEER demonstration projects enable researchers and partners in industry and government to examine the promise of advanced technologies in real-world situations. For example, projects involving water supply and electrical power systems in California, infrastructure networks in Memphis, hospital facilities in New York and California, and bridge sites in Utah, provide opportunities to evaluate engineering and socioeconomic strategies for urban risk assessment and rehabilitation of critical facilities in a systematic integrated fashion.

Post-earthquake reconnaissance investigations offer additional real-world insight to MCEER's research. Though tragic in nature, the devastation of earthquakes in the U.S. and abroad serves as a real-life learning laboratory for Center investigators of all disciplines. Quickly dispatched to stricken regions, MCEER researchers learn valuable lessons from field investigations and on-site interviews which often bring new perspectives to the nation's and the Center's research agendas. Post-investigation technical briefings and reports contribute immeasurably to the worldwide body of knowledge in earthquake engineering and hazards mitigation.

5. MCEER OUTREACH

Center outreach efforts include broad-based dissemination of information and technology through research reports, national and international conferences and workshops, industry partnerships, and a national Information Service that provides convenient access to published, recorded and on-line materials on engineering, geological, social, political, and economic aspects of earthquakes. MCEER also engages in cooperative research programs with institutions outside the U.S., including Japan, the People's Republic of China, Mexico, Taiwan, and others. The international alliances promote global co-operation, collaborative experimental research, and information exchange that advance earthquake engineering and loss mitigation principles in the U.S. and abroad.

5.1 Partnerships

MCEER's partnerships program forges strategic alliances with manufacturers, consultants, end-users and other public- and private-sector stakeholders to develop, adapt, test and help implement the use of new and emerging technologies to mitigate earthquake losses. The program creates opportunities for cross-participation in collaborative research and demonstration projects enabling partners to widely examine and assess the reliability of new and emerging technologies. It also provides partners with access to a variety of research, education and technology transfer opportunities including state-of-the-art knowledge, experimental facilities, information resources, publications, meetings, seminars, short courses and distance learning.

5.2 Publications

MCEER publications foster knowledge and technology transfer by communicating the latest developments in earthquake engineering research and loss reduction practices to academic researchers, consultants, practitioners and policymakers in government and the private sector. Since its inception, the Center has published more than 300 technical reports, workshop and conference proceedings, special publications and monographs to address the needs of these important audiences.

Examples of practical research publications developed through MCEER include:

- Monographs that synthesize MCEER's technical achievements for a wider range of readers than the technical report series. Each book provides an in-depth view of the topic addressed, by summarizing the essence and significance of the problems investigated, the methods used, and the various solutions/issues proposed. Topics include passive energy dissipation systems for structural design and retrofit, engineering and socioeconomic impacts of earthquakes, and the response of buried pipelines to earthquakes.
- Research and Accomplishments volumes that summarize research and education achievements, highlighting MCEER work in progress on improving community resilience to earthquakes. MCEER researchers, practitioners and students, contribute reports on applications and development of a wide range of advanced technologies, conceptualizing decision support systems, modeling and loss estimation, and the research-education interface.
- A manual to help engineers retrofit major components of existing U.S. highways against earthquakes, developed with funding from the Federal Highway Administration (FHWA). The two-volume guide includes procedures to evaluate and retrofit all components comprising the nation’s highway system. Guidelines apply to all regions and seismic zones in the U.S., and to all bridge construction projects that receive federal funding.
- Advanced design specifications aimed at improving strength and safety of U.S. bridges, developed through a joint venture between MCEER and the Applied Technology Council (ATC). The new specifications address all aspects of seismic design for highway bridges, defining the seismic hazard for each of the 50 United States, and including state-of-the-art design and performance criteria to help engineers better safeguard new highway bridges from damage and collapse during earthquakes.
- An MCEER-developed guide to improve and simplify screening of soils at highway bridge sites, for possible liquefaction problems. The guide, which includes simple state-of-the-art procedures, improves on other existing screening tools, which tend to be complex, difficult to apply in the field, and often produce inconsistent results. It is useful on any type of construction project, to reduce uncertainties in the design of foundations and the stability of underlying soils. The guide has been distributed to chief bridge engineers in all 50 states, and are widely used by engineers across the USA.
- Earthquake reconnaissance reports, workshop and conference proceedings, software users manuals, and many others.

5.3 Information Services

MCEER’s national Information Service is a comprehensive source for earthquake engineering and loss reduction information. Housed in the University at Buffalo Science and Engineering Library, the Information Service provides reference services including literature searches and document delivery to academics, practitioners, policymakers and at-large publics worldwide. Information professionals on staff fulfill an average of 200 requests per week, and the Center’s World Wide Web site, offering additional online information and resources, receives more than 56,000 distinct visits annually. MCEER’s Quakeline database, updated monthly and also available online, provides easy access to tens of thousands of records on books, journals, technical reports and other earthquake engineering and natural hazards mitigation literature.

6. MCEER EDUCATION

MCEER's education initiatives provide learning opportunities for students and educators at the K-12 and university undergraduate and graduate levels, as well as practitioners seeking specialized training through continuing education. Consistent with the Center's goals, educational activities aim to stimulate interest in engineering and sciences at the earliest levels, develop future leaders in earthquake engineering and hazards mitigation at the undergraduate and graduate levels, and help today's engineering and emergency management practitioners keep pace with changes in their respective fields. Programs include an undergraduate internship program, providing students with extensive involvement in ongoing research; a professional Master of Engineering program that offers focused and intensive graduate study in earthquake engineering and the current state-of-practice; and Professional and Continuing Education (PACE) short courses to help practitioners gain new knowledge of advancements in research and application of emerging technologies in earthquake engineering and hazards mitigation.

7. EXPERIMENTAL RESEARCH FACILITIES AND THE GEORGE E. BROWN JR. NETWORK FOR EARTHQUAKE ENGINEERING SIMULATION (NEES)

The establishment of the National Science Foundation-funded George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) is a milestone event in earthquake engineering. This network of 15 state-of-the-art experimental facilities will bring the U.S. experimental earthquake engineering capabilities to a leadership position worldwide. These facilities will make it possible to conduct advanced research and create new knowledge not possible until now.

Since its inception in 1986, MCEER has provided leadership in establishing a tradition of multi-institution distributed research programs. Currently, all MCEER-affiliated institutions with large-scale experimental testing capabilities are home to NEES equipment sites. These sites are located at the University at Buffalo (UB), University of Nevada, Reno (UNR), Rensselaer Polytechnic Institute (RPI) and Cornell University. The laboratories at UNR and RPI are already operational, as two of three early adopter sites of NEESgrid, a network infrastructure that will link earthquake engineering sites across the United States and create a national virtual earthquake engineering laboratory. The facilities at UB and Cornell are on schedule for completion in 2004. MCEER plans to become a major user of the NEES facilities, as well as a facilitator of multi-institute research using these facilities.

A brief description of the facilities underway at MCEER-affiliated institutions follows:

- The University at Buffalo's Structural Engineering and Earthquake Simulation Laboratory (SEESL), housed within the department of civil, structural and environmental engineering, will add twin six-degrees-of-freedom shake tables, as part of its $10.5 million NSF grant. The new shake tables will be capable of seismic testing of structures up to 120 feet in length. The facility will also house two 30-foot high reaction walls, 41 and 23 feet in length. When complete, the $20 million construction project will make the facility one of the most versatile in the world.

- Two shake tables at the University of Nevada, Reno (UNR) will be upgraded, and a third shake table will be added, as part of the institution's $4.4 million NSF grant. The three shake tables, each measuring 14 square feet, will offer biaxial, or two directional testing of earthquake ground motions on structures. Each table can be operated independently of the others, or in-phase with the other two. The tables can also be moved together to form a single large table. The new and upgraded tables will more accurately simulate real earthquakes. Total cost of the expansion and upgrade is $7 million.
- Rensselaer Polytechnic Institute's (RPI) 100-g ton Geotechnical centrifuge will undergo a $2.5 million upgrade. This will include the installation of new equipment and software, including a two-dimensional in-flight earthquake simulator and a four dimensional in-flight robot, that will enable geotechnical engineers to better study earthquake impacts on soils.
- A $2 million NSF grant will enable geotechnical engineers at Cornell University to for develop advanced experimental facilities for both full-scale and centrifuge-scale for testing, evaluation , and analysis of soil-structure- foundation interaction. This will dramatically enhance the ability to study the impact of this phenomenon on buried pipelines and other utilities. The upgrade will also include a new reaction wall 50 feet long and 24 feet high.

In a complementary way, the Center's Computational Network in Earthquake Engineering links computing facilities and resources at each of the MCEER member institutions, providing researchers and research partners with access to the most advanced computational tools for simulation and analysis of ground motion and structural behavior, loss and damage assessment, and emergency response.

8. CONCLUSIONS

The engineering of sound, cost-effective solutions to the problems posed by earthquakes, requires more than engineering alone. It requires a coordinated, unified effort of stakeholders from varied disciplines. Through a systematic integration of researchers, facilities and research partners in industry and government, research centers such as MCEER can engineer solutions to today's earthquake challenges, mobilizing expert multidisciplinary teams to investigate, test and develop strategies and technologies that lessen the impacts of earthquakes on society. This paper provided an overview of how a research center experience can help fulfill the goal of enhancing the seismic resilience of communities.

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