A Review of the US-PRC Cooperative Research Program on Earthquake Engineering

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ABSTRACT :

Important milestones of the cooperative earthquake engineering research program between China and US over the past 25 years are briefly reviewed. In light of the many lessons learned from the recent great Wenchuan Earthquake, a new agenda for cooperative earthquake engineering research under the PRC-US Protocol for Scientific and Technical Cooperation in Earthquake Studies, Annex III (Cooperative Research on Earthquake Engineering and Hazards Mitigation) is articulated.

KEYWORDS: Earthquake engineering, US-PRC cooperative research

1. INTRODUCTION

In the design of civil engineering structures, it has always been standard practice to consider different loading conditions and various potential hazards. Over the years, the methods of analysis and design have been improved through theoretical and experimental research efforts, advances in computing and other emerging technologies, as well as lessons learned from destructive earthquakes. At the same time, loadings acting on a structure can be estimated more accurately through accumulated experience and new measurement technologies such as strain gages, accelerometers and new sensors.

Earthquake engineering, including earthquake ground motion estimation, geotechnical engineering factors, methods of dynamic response analysis, rational design approaches, and development of advanced technologies to gather ground motions and structural response information and to regulate and reduce structural responses, have been systematically developed during the past 50 years in the US. A special aspect of this advancement in knowledge is the result of international cooperative research activities. During the past 25 years, some significant advances have been achieved through long-term bilateral research programs powered by the cooperative earthquake engineering research program (Annex III “Cooperative Research on Earthquake Engineering and Hazards Mitigation”) of the PRC-US Protocol for Scientific and Technical Cooperation in Earthquake Studies.

2. US-CHINA COOPERATIVE RESEARCH PROGRAM

The PRC-US Protocol for Scientific and Technical Cooperation in Earthquake Studies formally went into effect the date of signature, January 1980, in Beijing. Annex 3 of the Protocol, entitled "Cooperative Research on Earthquake Engineering and Hazards Mitigation", started to work together with the other attachments as one of the important contents of the Protocol. The Protocol was one of the original state-to-state S&T agreements established shortly after the resumption of bilateral diplomatic relations between USA and China. NSF has been responsible for, since 1980, in counterpart with the Ministry of Construction (MOC) of China, the development and implementation of Annex III of the protocol, covering mutually beneficial and challenging research activities in earthquake engineering and hazard mitigation. These included cooperative investigations in strong-motion array and data analysis, structural control techniques including a large-scale demonstration project using active mass driver to control wind vibration caused on Nanjing TV Tower (3,000 meters plus in height), comparative hazard risk and mitigation strategy study of urban cities, and others. These projects, which have been coordinated through an annual protocol joint staff meeting, and have greatly expanded natural hazard databases and produced new knowledge in safe and cost-effective engineering design methods, construction

practices and other countermeasures for seismic and wind safety of structures.

In 1994, a research exchange component to the Annex III protocol program was created. This program was used as a means to enhance its efficiency and to build a long-term base for cooperative research through steady data and personnel exchange between the two countries. The Multidisciplinary Center for Earthquake Engineering Research (MCEER) has acted, on behalf of NSF, to implement and administer this exchange program since then. Under this program approximately 40 man-trips for short research visits have been made. These studies covered a broad area diverse disciplines, including lifeline systems performance, and use of emerging technologies such as GIS and image simulation technique to determine systems vulnerabilities in areas of moderate to high seismic risk. Studies were also initiated to develop loss estimation methodologies for use in large urban areas. Results of this work were first featured at the 11th World Conference on Earthquake Engineering in Acapulco, Mexico. Important interactions to investigate social and economic impacts of earthquake damage to engineered structures and systems were also made under this program.

In subsequent years, the joint effort has been largely focused on such subjects as comparisons of ground motion characteristics for intraplate regions in US and China, use of reliability based seismic design for bridges, development of test models and testing platforms to provide refinements to parallel computer simulations and analyses, large-scale structural control device/system development and deployment, reconstruction strategies through synthesis of experiences learned from past and future damaging events such as Lijiang, Yunnan (1996), Kobe (1995) and Northridge (1994) earthquakes.

A Millennium Symposium to commemorate the 20-year Protocol Program and to shapely define the future directions of the joint research was held in Beijing in 2000. During that symposium, two additional Chinese agencies, the China Earthquake Administration(CEA) and National Natural Science Foundation of China (NSFC) official joined the Chinese Ministry of Construction in a partnership relation in the Annex III Protocol (Chinese United Coordination Committee, which is led by Earthquake Resistance Office, Ministry of Construction, formed by Department of International Cooperation, China Earthquake Administration and Division of Civil and Environmental Engineering, National Natural Science Foundation of China; the US National Science Foundation), thus greatly expanded the scope and support base of US-China cooperation research in the future (Spencer and Hu, 2001).

This symposium and a subsequent international workshop on 9/21 ChiChi Earthquake in Taiwan both strongly recommended that a center-to-center research program be initiated to implement an integrated program of diverse investigations. This particular form of center research, which has been proven successful in a number of cases involving US-Japan cooperative studies, has advantages in overcoming the lack of a critical mass of diverse manpower required, maintaining the research direction over the course of the joint research, and facilitate coordination among investigators. Critical to these ends, a Joint Technical Coordination Committee (JTCC) is to be established. Possible players in such center-to-center programs are the current three earthquake engineering research centers in the US, i.e., PEER, MCEER and MAE centers, and IEM(China), NCREE(Chinese Taipei), KEERC(Korea), DPRI(Japan). These 7 centers eventually networked themselves into a unique research consortium called Asian-Pacific Network of Earthquake Engineering Research (ANCER) in October 2001. There are 13 centers in the ANCER now.

Earthquake engineering practice has been benefited greatly from research results motivated by lessons learned from destructive earthquakes. Since the Loma Preuta earthquake in 1989, lessons learned from several major earthquakes world-wide, particularly those around the Pacific Rim, have been able to result in considerable improvement of the state-of-the-practice in earthquake engineering in North America and Eastern Asian countries. The May 12, 2008 great Wenchuan Earthquake in China, based on preliminary post-event observations, will provide many important insights into the research needs for scientific and engineering understanding of the demands of seismic hazards and to establish design guidelines for the capacity of constructed facilities to meet these special demands. This Wenchuan disaster will provide many new horizons and challenges for US-PRC cooperative research in earthquake engineering in the years ahead.

3. LOOKING AHEAD AND FUTURE RESEARCH CHALLENGES

While lessons learned from the Wenchuan Earthquake are still being studied and formally published, it is clear from reports of various reconnaissance trips and the information available from the media that research needs exist in most of the earthquake engineering. They include but are not limited to:

(1) Characteristics of ground motions with special features on near-fault motions, vertical acceleration component and process of ground motion attenuation.
(2) Geotechnical hazards and their cascading effects, including landslide, debris flow, formation of "quick lacks" and damages and blockage of the transportation and lifeline systems.
(3) Damages and failures of buildings in the rural area (non-engineered or semi-engineered buildings) and critical buildings (professional designed school and hospital buildings).
(4) Integrated consideration of regional planning, mitigation, preparedness and emergency response for mountainous population centers.

Looking ahead, many emerging technologies may be applied or further developed to address many of the issues mentioned above:

- Deployment of strong motion and geotechnical monitoring systems with smart, micro sensors
- Theories and models for site effects
- New sensor and actuator technology, an integrated structural design for safety and health monitoring for critical buildings and facilities
- Theories and physical models of structural damage as functions of material types, components, or sub-assemblies, or total systems, modeling of nonlinear dynamic responses of structures
- High-tech methods of warning, control, and minimization of disastrous damage against tsunami, hurricane, induced fire, and large-scale landslides.
- Extend earthquake engineering technologies to multiple hazard mitigations (Liu and Lee, 2005).

5. CONCLUDING REMARKS

Earthquake engineering and hazard mitigation research has been a major component of science and engineering in the US, and for years has made major contributions to improve the ways constructed environment is designed and built, and to the safety protection of the public. It is clear that the research has undergone significant transformation in terms of technical direction and emphasis, scope and size, and mode changes. It is also evident that international cooperative research, as represented by US-China and the current ANCER programs played a major role in pushing the frontier of earthquake engineering with rapid speed. Looking at the future, we expect to see increased demand for research that responds to the society's needs, and also research that responds to push by the continuous waves of new technologies (Frosh and Sozen, 1999). Integrated approaches to hazard mitigation will be the central future theme. This will require increased international collaboration.

China and the US have benefited from 25 years of successful cooperation in earthquake engineering and it is anticipated that a renewed and more futuristic-oriented cooperative program can be developed based on the Wenchuan disaster.

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