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Hearing: *A Review of the National Earthquake Hazards Reduction Program*
U.S. House of Representatives
Committee on Science Space and Technology, Subcommittee on Research and Technology
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TESTIMONY

Introductory Remarks

Good morning and thank you for the opportunity to testify before the Congress as you work to reauthorize the National Earthquake Hazard Reduction Program. I am Julio Ramirez, a Professor of Structural Engineering in the School of Civil Engineering of Purdue University in West Lafayette Indiana.

Many of the world's global challenges, such as the mitigation of earthquake risk, can be best met with a stong presence engineers working in well-integrated teams with social scientists and other experts, yet the number of U.S. engineering students is declining. Purdue University and our College of Engineering will take a leadership role as part of the national call to graduate 10,000 more engineers per year, enhancing our state and national capacity for innovation, economic growth and solutions to global grand challenges. The effort will go beyond the already approved five-year plan that called for:

- Increasing Engineering graduate student enrollment by 750.
- Increasing Engineering undergraduate enrollment by 691.
- Hiring 107 new engineering faculty.
- Lowering undergrad-to-faculty ratio from 21-to-1 to 17-to-1.

The National Earthquake Hazard Reduction Program (NEHRP) is a vital program to help train the next generation of engineers with real-time research experiences. NEHRP provides the critical support structure for seismic protection in the United States. It provides federal support for research, information dissemination, development and implementation of technology, and the application of planning and management procedures to reduce seismic risk. Through the contributions of its four agency members, it provides the resources and leadership for understanding and reducing United States vulnerability to earthquakes and tsunamis, and supplies the support base for seismic monitoring, mapping, research, testing, code/guideline development, mitigation and emergency preparedness. The NEHRP vision is a nation that is earthquake-resilient with regard to public safety, economic strength, and national security. This support is critically important because the United States faces serious earthquake risk. According to a 2006 National Research Council Report (NRC) (1) quoted in the 2009-2013 NEHRP Strategic Plan (2), 42 States have some degree of earthquake risk and 18 of those States have areas of high or very high hazard. This risk is growing because population density, economic activity and infrastructure are increasing in locations affected by earthquakes. In the context of earthquakes and tsunamis, risk may be understood as the combination of two key factors: hazard and exposure. The hazard is represented by the probability of earthquake occurrence and magnitude. Exposure is represented by the vulnerability of the built environment. In this construct, regions of the nation where earthquakes are not frequent (i.e. low hazard), the risk is high if the exposure, represented by the civil infrastructure accumulated over the years designed without seismic considerations, is significant. Your letter of invitation asked me to respond to five specific items in my testimony, and each is addressed in the sections that follow.

Research and Code Development Experience

For the past 30 years I have been teaching and conducting research in structural engineering at the Purdue University School of Civil Engineering. My area of expertise is in the design, evaluation of performance and code development of reinforced and prestressed concrete bridges and buildings. I have been involved in the development of building codes since the late 1980s and conducted research on:

1. Durability of Concrete Bridges

2. Earthquake Safety of Buildings and Bridges

3. Bridge Design

4. Safety of Buildings and Bridges against man-made hazard

Since 1994, I have been involved in and led some eight-reconnaissance missions following the earthquakes of Northridge CA, Manzanillo Mexico, Kobe Japan, Duzce-Bolu Turkey, Puebla Mexico, Armenia Colombia, and Bingol Turkey. Many of us have seen firsthand how devastating an earthquake can be not only to the built infrastructure serving a society, but also to families, their businesses, the community and people's sense of security. Existing vulnerable buildings and infrastructure assets are the number one seismic safety problem in the world today. The central purpose of these missions was to gather perishable data on the performance of reinforced and prestressed concrete bridges and buildings immediately following major earthquakes in what constitutes a major real life and very costly test of the built environment in order to synthesize lessons that could help mitigate the impact of earthquakes on society.

I was engaged as project Co-PI in the recently completed NEESR- Grand Challenge research study aimed at identifying collapse triggers in non-ductile reinforced concrete buildings subjected to seismic actions. Presently, I am committed as project PI, Center Director and Chief Officer for the George E. Brown Jr. Network for Earthquake Engineering Simulation NEES Operations award for the period of 2010-2014 (NSF Award CMMI-0927178).

The focus of the NEESR Grand Challenge Project consisted of developing a consensus on the so-called “killer” buildings, project the scale of the problem, illustrate possible cost-effective retrofit, identify mitigation policy alternatives, and promote active mitigation programs. I was in charge of overseeing and coordinating the overall experimental program of column tests, beam-column subassembly tests, soil-structure-foundation interaction field tests and membrane tests. The test results were used to develop improved component models for use in the numerical analysis of building performance. The main code/specification contributions to date resulted from the work conducted by members of the research team of the NEESR Grand Challenge Project, "Mitigation of Collapse Risk in Vulnerable Concrete Buildings", through testing and numerical simulation of older concrete columns. The results of this phase of the overall research project expanded the database of laboratory tests in key gap areas thanks to the unique testing capabilities of the NEES MAST Facility at the University of Minnesota. Tests performed provided new data to study the drift ratio at axial failure of shear critical and captive columns subjected to various different loading protocols. Our evaluation of the test results indicate that bidirectional loading can lead to a reduction of nearly 50% in the deformation capacity of a column. No data on the effects of bidirectional loading on the performance of non-ductile columns were available before this project. Those new data together with the re-use of other existing data contributed to at least two major impacts of the overall project.

Namely:

- Project team members led the development of revisions to the concrete provisions of ASCE/SEI 41, which were accepted as the ASCE/SEI 41 Supplement and eventually incorporated into ASCE/SEI-06. The supplement to ASCE/SEI 41 Seismic Rehabilitation of Existing Buildings was developed for the purpose of updating provisions related to existing reinforced concrete buildings. Based on experimental evidence and empirical models, the proposed supplement includes revisions to modeling parameters and acceptance criteria for reinforced concrete beams, columns, structural walls, beam-column joints, and slab-column frames. The results of this work also have been incorporated into the ATC 72 report in support of the Pacific Earthquake Engineering Research (PEER) Center Tall Buildings Initiative.

- Findings from the project have been used in the development of ACI committee document 369R, Guide for Seismic Rehabilitation of Existing Concrete Frame Buildings and Commentary, which was published in 2011 by the American Concrete Institute. This guide, developed based on the format and content of ASCE/SEI 41-06 "Concrete", describes methods for estimating the seismic performance of both existing and new concrete components in an existing building. Under a newly established agreement between ASCE and ACI, Committee 369 will develop revisions to the concrete Chapter in the ASCE/SEI 41 Standard, and work continues on the implementation of project findings into the next revision of the Standard.

To mitigate the earthquake risk by reducing the exposure represented by the vulnerability of the built environment, fundamentally to save lives, the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) originated as a national, multi-user, research infrastructure to enable research and innovation in earthquake and tsunami loss reduction, create an educated workforce in hazard mitigation, and conduct broader outreach and lifelong learning activities. The mission for NEES aligns with the larger NEHRP national plan (2) for earthquake and tsunami risk reduction.

George E. Brown Jr., Network for Earthquake Engineering Simulation (NEES)

NEHRP is administered through four government agencies, with the National Institute of Standards and Technology (NIST) as the lead agency and the U.S. Geological Survey (USGS), National Science Foundation (NSF), and Federal Emergency Management Agency (FEMA) as the other partnering agencies. The NSF is the fundamental research arm of NEHRP, which supports research in engineering, earth sciences, and the social sciences. It provides the engine that drives fundamental discoveries related to earthquake processes; seismic response and failure mechanisms of the ground, buildings, and lifeline networks; and human behavior, social response, and the economic conditions pertaining to earthquakes.

In November 1998, the National Science Board approved the George E. Brown Jr., Network for Earthquake Engineering Simulation (NEES) for construction with funds totaling $82 million from the National Science Foundation (NSF) Major Research Equipment and Facilities Construction (MREFC) appropriation. Construction occurred during the period 2000-2004. As part of its contribution to the National Earthquake Hazards Reduction Program, the National Science Foundation (NSF) funds NEES operations (Award # CMMI-0927178) as well as many of the research projects that are conducted in NEES facilities. The NEEScomm Center at Discovery Park of Purdue University houses the headquarters of operations of a nationwide network of 14 laboratories. Each of these university-based laboratories enable researchers to explore a different aspect of the complex ways that soils and structures behave in response to earthquakes and tsunamis. The laboratories are available not just to researchers at the universities where they are located, but to investigators throughout the USA who are awarded grants through NSF's annual NEES Research (NEESR) Program and other NSF programs.

NEES laboratories are also used for research conducted or funded by other federal, state, and local agencies, by private industry, and by international researchers under the partnerships that NEES has cultivated with research facilities and agencies in Japan, Taiwan, Canada, and China. To date, more than 400 multi-year, multi-investigator projects have been completed or are in progress at NEES sites. These projects are yielding a wealth of valuable experimental data and continue to produce transformational research and outcomes that impact engineering practice from analytical models to design guidelines and codes. This information is annexed to this testimony in Reference 3, *"George E. Brown, Jr. Network for Earthquake Engineering Simulation, NEES, 2004-2014, A Decade of Earthquake Engineering Research"*.

Summary of Research Impacts to Practice

- Simulation methods used in engineering practice are improving due to NEES laboratory results of testing and researcher improvements to nonlinear modeling
- Fragilities used for loss analyses—particularly the FEMA P58 methodology--have been improved for several structural systems and nonstructural components
- Several projects contributed to the development of improved evaluation guidelines for existing structures and improved design procedures for new construction
- Next generation of systems that provide high performance including the ability to self-center are being studied by NEES researchers

The family of NEES researchers, educators, and students encompasses an ever increasing group of universities, industry partners, and research institutions in the US and abroad. Project teams and the NEEScomm team have developed a rich set of resources for research and education. An estimated 1300 graduate students have participated along side NEESR researchers based on a 56% return rate (n=171) from a longitudinal study. This study was intended to capture data of NEESR research and educational impact from NEES-funded research. Undergraduate and Post-Doc data were also included indicating an estimated 770 undergraduates and 50 post-docs benefiting from the NEES research experience, bringing the estimated total student participation to well over 2100. The human capital gained in this activity also supports the US in retaining a competitive globally in the STEM areas.

Linking the NEES experimental facilities to each other, to NEEScomm, and to off-site users is the NEES cyberinfrastructure. This unique system of information technology resources enables researchers participating on-site or remotely to collect, view, process, and store data from NEES experiments, to conduct numerical simulation studies, and to perform hybrid (combined experimental and numerical) testing involving one or more NEES equipment sites increasing research efficiency. At the heart of this system is NEEShub, a platform designed to facilitate information exchange and collaboration among earthquake engineering researchers, educators, students, practitioners, and stakeholders. Accessed via the NEES website at nees.org, NEEShub is powered by HUBzero software developed at Purdue University.

NEEShub features the NEES data repository a curated, centralized repository used to store and share data and research results. When launched in 2009, NEEScomm prioritized a strong partnership with the NEES sites and targeted what had been a seriously deficient central data repository and cyberinfrastructure for collaboration. Since the first release of the NEEShub "cloud" platform 4 years ago, the community has actively responded to user-focused cyberinfrastructure improvements with a pace of file and directory creation that has increased exponentially. Today, the NEES-curated central repository of research data features a vastly populated repository of NEES research data and showcases over 2.5 M data files and folders that engineers can search, sort, download, and manipulate. NEEShub also stores and shares a variety of other earthquake engineering resources, including publications, databases (4), computational models, simulation software, educational materials, and data management and visualization tools.

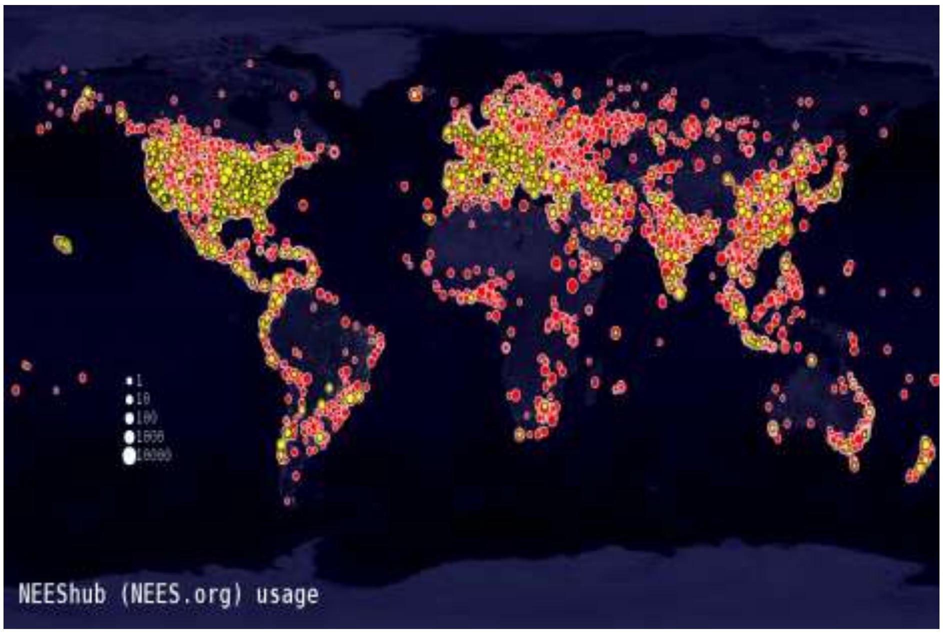

Figure 1. Usage of the NEEShub between 8/2010 to 3/2014

Since the first release of NEEShub in August 2010, researchers, students and practicing engineers from more than 200 countries have performed 1,428,026 web and 47,998 tool sessions (Figure 1). The arrival of the NEEShub has ushered in a new collaborative capability with vastly improved IT resources for research and development in earthquake engineering.

Nation's level of Earthquake Preparation and Resiliency

The current state of preparedness is much enhanced by advances made in the past decades, in large part supported through NEHRP funded research and implementation, but more must be done to protect our communities. Continued attention is required because of the growth of our cities and industrial centers, the new focus on resilience and the dependency of resilience on the performance of older, vulnerable construction. Advances in knowledge and information technologies can improve the rapid and efficient adoption of practices and technologies that improve resilience of communities by reducing damage after the event and by accelerating the pace of recovery, and these should be exploited.

Coordination between Federal, State and Local stakeholders for Earthquake Emergency Preparation

NEHRP, through its basic research and implementation agencies at NSF, NIST, and FEMA, is ideally positioned to provide proof of concept for emerging technologies as well as the evidence needed to sustain their implementation. Led by a State agency, each Emergency Function is designed to bring together discipline-specific stakeholders to collaborate and function within the four phases of emergency management: mitigation, preparedness, response, and recovery. State agencies, local governments and others must be prepared to respond to emergencies that might occur within their areas of responsibility within the first 72 hours of the event; and, must be able to assess whether their capabilities are sufficient to respond effectively. The Emergency Services functions of each State should be coordinated as far as possible with the comparable functions of its political subdivisions, of the federal government, of other states, and of private agencies of every type so the most effective use may be made of all manpower, resources, and facilities for dealing with an emergency. In instances where interstate cooperation needs to be promoted, the federal government should take the lead in fostering the collaboration for the benefit of the affected citizens.

Recommendations for Research and Development Measures in Earthquake Preparation and Mitigation, for the NEHRP Program

The importance of earthquake preparation and mitigation cannot be overemphasized. Addressing a challenge of this magnitude calls for a coordinated (agency and community-based) approach in the development of an effective research agenda to properly address it. There is precedent for this action, the Advisory Committee on Earthquake Hazards Reduction National Earthquake Hazards Reduction Program in its June 2012 Report (ACEHR12) (5) to the Director of the National Institute of Standards and Technology, the lead agency of the Interagency Coordinating Committee (ICC) assessed and reported on the NEHRP program effectiveness. ACEHR12 provides a series of key recommendations/initiatives for research and development measures that should serve as a roadmap for the future.

Maintaining a balanced program supporting research in the earth science, engineering, and social science areas is important. In achieving resilience of communities against earthquakes and tsunamis, engineering related research is of the highest priority as it directly impacts the mitigation of the extent of damage to built-environment and can reduce the time needed for recovery. Research that can efficiently identify older vulnerable construction and ways to mitigate the risk to people, community and businesses should be of the highest priority followed by research on new methods of construction and improved materials and technologies focused in the reduction of damage from these events. In the next level of importance is the support for research on impacts of earthquakes at the regional scale, especially as it relates to the ability of a community to re-establish its footing as a viable community; and, the support of implementation programs that will encourage cities to undertake studies and develop plans for resilience.

References

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