GUEST EDITOR'S NOTE

A PERSPECTIVE ON EXPERIMENTAL RESEARCH IN EARTHQUAKE ENGINEERING

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This Special Issue contains contributions that summarize studies in which various experimental techniques are utilized to address specific aspects of seismic behavior of structures and structural components. The information presented in the papers demonstrates that the techniques used in these studies have matured to a level that permits the compilation of reliable data and the deduction of concepts of much value for seismic protection of structures. This calls for an expression of confidence in the use of conventional experimental techniques. It also calls for a more extensive utilization of these techniques in developing countries. Such countries have a preponderance of indigenous construction with specific problems that are not being researched in high-tech laboratories. But these are the problems in which experimental research can lead to great leaps forward.

Indigenous construction does not lend itself to accurate analytical modeling, and for this reason experimentation should be the primary source of knowledge on behavior and its improvement. Well established experimental techniques, which provide reliable data in a relatively cost effective manner, are the best means for acquisition of this knowledge. This is in contrast to countries with advanced development, in which analytical simulation is replacing experimentation as the dominant vehicle for knowledge acquisition for performance assessment – at least for new construction. In such countries there is a realization that experimental research in earthquake engineering, like all other methods of research, must progress beyond the present state of the art in order to fulfill the ever increasing demands for rapid advancements. In fact, the need for physical experimentation as an independent knowledge acquisition method is being questioned in a recent project announcement by the US National Science Foundation. The following quotation is taken from the announcement of the NSF project on the establishment of a Network for Earthquake Engineering Simulation (NEES): "The NEES project will transform earthquake engineering research from its current reliance on physical experiments to investigations based on integrated models, databases and model-based simulation." (http://www.eng.nsf.gov/nees/)

This quotation indicates an intent to de-emphasize physical experimentation and move towards a more extensive reliance on simulation. Considering the high cost of experimentation, such a paradigm shift is understandable from the perspective of countries in which construction is becoming dominated by high-tech processes. Advances in computing technologies appear to make it feasible to use simulation as the exclusive predictor of seismic behavior – at some time in the future. This is an attractive challenge in today's age of rapidly advancing technologies. One may not want to agree with this perspective, but in the computer simulation age, experimental research indeed may become a second rate activity unless its importance is reconfirmed. This can be done by re-assessing the need for experimental research, and by working towards advancements in experimental techniques that provide new opportunities and make experimentation an attractive means for addressing important questions in earthquake engineering.

The following short discussion provides the writer's perspective on important needs for experimental research and for advancements in experimental techniques. This perspective is intended to demonstrate the need for experimentation, even for countries with advanced development. For reasons given before, the need for experimentation is even more evident for developing countries.

EXPERIMENTAL RESEARCH NEEDS

Experimentation, which may be defined as the process of acquiring knowledge through physical observations and measurements, has been and should remain to be an essential aspect of earthquake engineering research. We need to resort to experiments whenever we need answers that cannot be obtained with sufficient confidence through analytical predictions. Conventionally, experiments have been utilized to study fundamental phenomena that either have escaped our attention or have been inadequately understood, or to develop or verify analytical models, or to derive empirical detailing requirements for behavior modes too difficult to model analytically.

Future issues and trends in experimental research should be driven by the demand of the public for adequate seismic safety of new and existing structures. Experimentation should support analytical modeling, seismic code developments, and the assessment of seismic performance. In this context the following four major components of experimental research may become the focus of future activities.

Experimentation for Improvement of Design of New Structures. This research component comprises experimental research on materials, components, subassemblies, and structural systems. We have focused on this type of research for many years and have made considerable progress. However, we are far from comprehensive answers. In particular, we need to focus on experimentation on three-dimensional structural configurations utilizing two- or three-dimensional loading or excitation. Emphasis should be placed also on experimentation on innovative structural systems and on systems with passive or active control mechanisms. Also, the behavior of individual components and details is not well understood from the viewpoint of cumulative damage and needs to be investigated in much more detail to support analytical modeling and code detailing requirements.

Experimentation for Evaluation and Upgrading of Existing Structures. The research and engineering communities and the public are placing much emphasis, and rightfully so, on improving the seismic behavior of existing structures. Most of the procedures used in evaluating the seismic resistance of existing structures are questionable because of the lack of experimental information. Evaluation and upgrading of existing structures has to focus primarily on life safety and, therefore, the issue of collapse protection rather than damage control becomes the overriding consideration. Presently available analytical techniques are inadequate to assess collapse hazards of most existing structures, and much experimental research is needed to improve analytical predictions. More emphasis needs to be placed on field testing, particularly in cases in which structures or parts thereof are scheduled for demolition.

Life-Cycle Damage Detection and Health Monitoring. Throughout their service life, all structures experience cumulative damage from various environmental sources (temperature, humidity, dead and live loads, accidental loads, wind and earthquakes, etc.). Continuous monitoring of cumulative local damage (e.g., crack initiation and propagation) and global damage (reflected in measurable changes in dynamic characteristics) though electronic sensors is becoming a widely accepted practice for various types of structures (e.g., offshore structures, bridges). Much emphasis presently is placed on diagnostics for maintenance, but these techniques may have much value also for detection of damage that affects earthquake safety.

Integrated Assessment of Seismic Input, Demands, and Capacities. Earthquake engineering is moving towards performance-based design and evaluation, which requires comprehensive information on seismic input (free-field and basement motions), force and deformation demands imposed on structures, and structural capacities (strength and deformation capacities). At the present only a small number of mostly new structures are equipped with instruments that record part of the needed information. More emphasis should be placed on instrumentation around and in structures that are expected to experience severe damage in future earthquakes. To this date we have few comprehensive sets of data from structures that have been severely damaged in an earthquake. Neither do we have instruments that can measure all parameters of interest. For instance, there is no instrument known to the writer that directly measures interstory drift, even though this parameter is used most widely as a measure of seismic performance.

In summary, experimental research in earthquake engineering should strive for a balance between continuation of conventional laboratory and field experimentation and the development of more advanced experimental techniques suitable for monitoring the performance of existing structures. More emphasis should be placed on the development of experimental techniques for field testing, particularly for the evaluation of existing structures in need of seismic upgrading. Moreover, the earthquake engineering profession should take full advantage of recent developments made in sensor and signal processing technology.

EXPERIMENTAL TECHNIQUES

Experimentation in earthquake engineering relies heavily on quasi-static cyclic testing, pseudodynamic testing, and shaking table testing. These testing techniques have matured to the extent that further improvements are expected to be incremental. Two- and three-dimensional quasi-static and pseudodynamic testing of large full-size components, subassemblies, and even complete structures is being carried out in several laboratories. The pseudodynamic testing method, which for many years had to wrestle with measurement and control accuracy problems, has become a reliable and versatile experimental tool. Not only can the method be used for specimens too large and too heavy for existing shaking tables, it also can be used to simulate complex support conditions not possible with other laboratory test procedures. Substructuring concepts allow for more economical and realistic seismic testing of subassemblies.

Shaking tables have grown in size and capabilities, although only in isolated examples because of the almost prohibitive cost of large shaking table facilities and full-size test structures. The prime example of a shaking table capable of testing full-size structures to collapse under realistic ground motions is the yet to be completed facility in Miki City, Japan. The table of this facility will be 20m by 15m in size, capable of supporting a pay load of 1200 tons and of reproducing ground motions with maximum acceleration, velocity, and displacement of 1.5g, 200 cm/sec., and 100 cm, respectively. These capabilities are indeed impressive, but so are the costs of the facility and the challenges that were encountered when developing the actuators, servo-valves, and power supplies needed to drive the table with the specified capabilities. It is expected that this facility will be a unique resource for large-scale dynamic testing.

There are important issues that need to be addressed, or that put limitations on these established experimental techniques. For any reduced-scale testing the issue of size effects may become important, particularly in the evaluation of deterioration and local failure modes. For all tests not done in real time, strain rate effects may lead to distortions of reality. For quasi-static cyclic testing, which is expected to remain the primary technique for evaluation of local responses, the issue of history dependent cumulative damage is critical. Loading histories need to be developed that permit a consistent assessment of cumulative damage effects. The issue of cost will make it nearly impossible to perform laboratory experiments that incorporate the soil system in addition to a full-size structure, even at the Miki City facility. Thus, it must be recognized that laboratory experimentation cannot provide comprehensive answers to seismic performance questions.

The inability to model a complete full-size soil-foundation-structure system in the laboratory, as well as the increasing need for health monitoring, make field experimentation a critical aspect of the future of experimental research. This includes instrumentation for the purpose of capturing input and response from future seismic events, as well as instrumentation for the purpose of health monitoring or condition assessment. For both purposes a great need exists for the development of instrumentation plans, sensors, signal processing and data transmission techniques, and system identification techniques suitable for the measurement and interpretation of changes in structural response characteristics that may affect seismic behavior. The writer believes that a major challenge in earthquake engineering experimentation lies in developing these tools and methods through interdisciplinary research in which advantage is taken of technology developed in other fields.