A Practical Approach to Protecting Infrastructure

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The September 11, 2001 terrorist attacks on the World Trade Center (WTC) in New York and on the Pentagon in Virginia vividly demonstrated the disastrous effects that extreme events can have, even on structures of monumental proportion and construction. It is universally accepted within the engineering and design communities that the loading produced by these events greatly exceeded design conditions. The ability of the twin World Trade Towers to remain standing, permitting most occupants to safely exit, and of the Pentagon to contain collapse within a small segment are tributes to the potential resiliency of construction. Even so, thousands of Americans lost their lives in these events.

Sadly, terrorist attacks are not the only credible extreme events that can cause staggering life and financial loss or of crippling our society. Earthquakes, tornadoes, fires and hurricanes can also cause such massive losses, and have at various times in the past. For example, the 1995 Kobe earthquake and the 1900 Galveston Hurricane each caused greater life and property loss than the September 11 attacks. Our building codes attempt to provide protection for our built environment against the effects of likely earthquake windstorm and fire scenarios. The basic intent of these mandatory code provisions is to protect life safety. However, they also have the effect of reducing future economic losses at the cost of additional involuntary investment on the part of the developer, at the time of construction. Just how much additional protection is to be provided and at what cost, is a question that has never directly been addressed by the codes. Rather this has been determined in an iterative manner by viewing the effects of disasters on the built environment and making qualitative judgments as to the acceptability of the losses sustained. For some hazards, such as tornadoes and terrorist attack, our codes provide no intentional protection at all.

While the level of protection afforded our built environment by the building codes may be appropriate for the general stock of buildings, clearly some buildings should be provided with greater levels of protection and protection against a broader range of hazards. Unfortunately, the prescriptive nature of our building code provide designers little information as to how they can effectively design to achieve better performance, or to address other hazards. Performance-based design is a developing technology that many engineers and building code officials hope will provide a solution for this need.

PERFORMANCE-BASED DESIGN TECHNOLOGY

For years, building codes have permitted performance-based design through provisions that permit the use of alternative rational approaches that demonstrate equivalent performance. However, as the codes were not clear in defining the target performance and few standards existed to define acceptable test protocols or alternative analysis procedures, building officials have been reticent to approve such designs and engineers, being risk adverse, have seldom proposed such designs. Over the past 10 years a number of important developments in performance-based design applications have occurred. Both the International Code Council and NFPA have published specific performance standards in the latest editions of their model building codes. This removes one impediment, the lack of a clear definition of the target performance. However, this still leaves a need for rational procedures to demonstrate performance capability that will be acceptable to engineers and building officials. Efforts have begun in this area as well. The American Institute of Steel Construction, for example, has begun development work on performance-based technologies for evaluation of fire-resistance of steel structures. However, some of the most important work in the development of

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For more than ten years, the Federal Emergency Management Agency (FEMA) has actively sponsored the development of performance-based design approaches as an effective means of hardening our infrastructure against earthquake losses. The FEMA-273/356 national seismic rehabilitation guidelines and pre-standard were an important step in this development process and presented the first rational, consensus-based procedures for implementing performance-based structural design. More recently, the FEMA/SAC program to reduce seismic hazards in steel moment-frame structures, an effort in which AISC had significant participation, extended these procedures to the design of new buildings and with the publication of FEMA-350, introduced a formal structural reliability approach to the process. However, the FEMA/SAC program addressed only one structural system while our building codes permit many different structural systems to be used. If performance-based design approaches are to become a practical design alternative, it is clear that much additional work will have to be done.

In June 2001, AISC, in cooperation with the University of Illinois at Urbana held an invitational workshop in the San Francisco Bay Area to determine how best to move performance-based design technology forward and to make it available for design of a broader class of steel structures. A number of prominent steel designers and researchers attended this workshop as did representatives of FEMA. Attendees heard presentations on the current state of performance-based design technology as embodied in the FEMA-273/356 and FEMA-350 documents as well as ongoing development work by the Structural Engineers Association of California and the three national earthquake engineering research centers. While it was clear that the steel industry was well-placed to extend performance-based technologies, by virtue of the FEMA/SAC program, much work remains to be done, including research into the cyclic inelastic behavior of different framing systems and components, identification of the variability and uncertainty inherent in our analysis procedures for different structural systems and perhaps most important, development of methods to characterize the performance of nonstructural building components. Attendees were in concurrence that AISC should continue to pursue development of performance-based design technologies, but felt that this work should be coordinated with parallel efforts being conducted by the industry at large. Fortunately, the Federal Emergency Management Agency and Applied Technology Council have initiated a project that will help to coordinate these various industry efforts. It is known as the ATC-58 project.

THE ATC-58 PROJECT

The purpose of the FEMA-sponsored ATC-58 program, a multi-year, multi-million dollar effort is to develop practical performance-based seismic design criteria that may be routinely used in the design of new structures and rehabilitation of existing structures. The design criteria will be capable of providing desired levels of performance for the full range of possible events, considering economic as well as safety concerns and addressing all aspects of building construction, including both structural and non-structural features. The project includes the establishment of a mechanism for characterizing different levels of building performance for different seismic hazard conditions as well as quantification of acceptable building performance characteristics. The ultimate goals of performance-based design are the development of practical design criteria that give the building owner and regulator the ability to select a building's desired performance for varying levels of earthquake hazard as well as to optimize the performance of our building codes relative to society's needs. While the project is funded under seismic programs, the intent is that the technologies developed in this program will be directly relevant and applicable to other extreme events, such as blast and tornadic winds.

The FEMA/ATC project will involve the two key constituencies. The first comprises the various engineering and construction experts and those who have performed applicable research and development of relevant material. The second are the building owners and financial stakeholders, those who are responsible for managing the risk associated with the building and its operations. These same constituencies are ultimately responsible for hardening our infrastructure against over extreme events and many of the same principals and technologies developed by this project will be directly applicable to these other events. The project will generally follow a work plan that was established by the Earthquake Engineering Research Institute and was published as FEMA-349. Persons interested in this project may obtain a free copy of FEMA-349 from the FEMA or visit the Applied Technology Council web site at www.atcouncil.org.

CONCLUSIONS

There is little doubt that performance-based design approaches will continue to be developed for application to earthquake resistant design, as well as design for other extreme events. While much of the foundation work in this development will be performed by the national earthquake engineering research centers and the new FEMA/ATC program, much of the work specific to individual structural systems will have to be performed by the individual materials industry groups. AISC expects to be a significant participant in these ongoing development efforts.

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