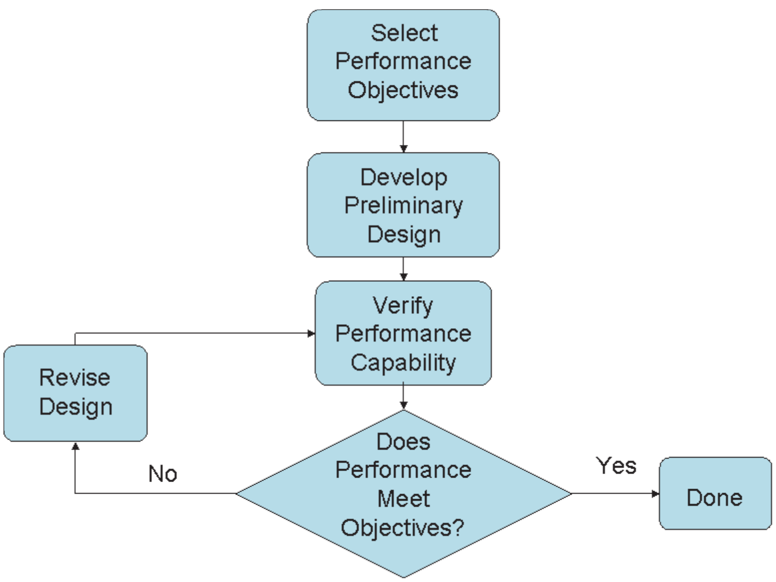
ATC 58-3

Proceedings of

FEMA-sponsored workshop on performance-based design



ATC Applied Technology Council

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Applied Technology Council

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ATC-58-3

Proceedings of

FEMA-Sponsored Workshop on Performance-Based Design

February 24-25, 2003
San Francisco, California

by

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Funded by

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Preface

In September 2001 the Applied Technology Council (ATC) was awarded a contract by the Federal Emergency Management Agency (FEMA) to conduct a long-term project to prepare next-generation Performance-Based Seismic Design Guidelines (ATC-58 project). The project is to consider and build on the FEMA-349 report, *Action Plan for Performance-Based Seismic Design* (EERI, 2000), which provides an action plan of research and development activities to produce and implement design guidelines that specify how to design buildings having a predictable performance for specified levels of seismic hazard. Ultimately FEMA envisions that the end product from this overall project will be design criteria for performance-based seismic design that could be incorporated into existing established seismic design resource documents, such as the *NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures,* and the *NEHRP Guidelines for the Seismic Rehabilitation of Buildings* (FEMA, 273), and its successor documents (e.g., FEMA-356 *Prestandard and Commentary for the Seismic Rehabilitation of Buildings*).

The ATC-58 project is being conducted in several phases, as resources become available. In Phase 1, which commenced in late 2001, ATC developed a management process for the project, identified and engaged key project management and oversight personnel, developed a project Work Plan, commenced development of a report on performance characterization, and conducted two workshops to obtain input on project needs and goals.

Workshop One focused on communicating earthquake risk and was held on June 18, 2002 in Chicago, Illinois (ATC, 2002). The purpose of Workshop One was to obtain preliminary feedback from a cross section of building stakeholders, including real estate developers, building owners, corporate tenants, lenders, insurers and other interested parties as to how performance-based seismic design guidelines can most usefully deal with issues of earthquake risk.

Workshop Two, the proceedings of which are presented in this document, was held on February 24-25, 2003 in San Francisco, California, to introduce the ATC-58 project to the building design, research and regulation communities, to obtain feedback on significant advances that have occurred since the development of the FEMA-349 report, and to assist in identifying appropriate updates to the FEMA-349 recommendations considering the state of current knowledge. The Workshop program included updates on recent international developments, updates on relevant research conducted by the National Science Foundation-funded earthquake engineering research centers, and breakout sessions that focused on the following program components; performance-based design of structures, performance-based design of nonstructural components and systems, and risk management and communication considerations.

The Applied Technology Council gratefully acknowledges the members of the ATC-58 Project Team, who planned and organized the Workshop, and the representatives from a broad range of organizations who participated in the workshop: Daniel Abrams, Daniel Alesch, Donald Anderson, Mark Aschheim, Nuray Aydinoglu, Robert Bachman, Deborah Beck, Fouad Bendimerad, Vitelmo Bertero, David Bonowitz, Roger Borcherdt, Michel Bruneau, Philip Caldwell, James Carlson, Kelly Cobeen, Craig Comartin, Allin Cornell, Anthony Court, Gregory Deierlein, Weimin Dong, Richard Drake, John Eidinger, Amr Elnashai, Mohammed Ettouney, Gregory Fenves, Andre Filiatrault, William Gates, John Gillengarten, Barry Goodno, James Hackett, Ronald Hamburger, Robert Hanson, Perry Haviland, William Holmes, John Hooper, Ahmad Itani, William Iwan, James Jirsa, Brian Kehoe, Robert Kennedy, Petros Keshishian, Andrew King, Stephanie King, Charles Kircher, Anne Kiremidjian, Helmut Krawinkler, H.S. Lew, Joe Maffei, Michael Mahoney, Praveen Malhotra, James Malley, Zeno Martin, Peter May, Gary McGavin, Brian Meacham, Ali Memari, Andrew Merovich, Eduardo Miranda, Elliott Mittler, Jack Moehle, Andrew Mole, Linda Noson, James Partridge, William Petak, Maryann Phipps, Chris Poland, Andrei Reinhorn, Charles Roeder, Christopher Rojahn, Daniel Shapiro, John Silva, M.P. Singh, Paul Somerville, T.T. Soong, William Staehlin, Jonathan Stewart, Akira Tasai, James Tauby, Andrew Taylor, Craig Taylor, Christine Theodoropoulos, Jon Traw, and John Wallace. Bernadette Mosby coordinated all workshop logistics and served as the workshop registrar. The affiliations of these individuals are provided in Appendix A.

ATC also gratefully acknowledges the financial support provided by the Federal Emergency Management Agency and the guidance and oversight provided by Michael Mahoney (FEMA Project Officer) and Robert Hanson (FEMA Technical Monitor).

Christopher Rojahn
ATC Executive Director

Table of Contents

Executive Summary

The Applied Technology Council, on behalf of the Federal Emergency Management Agency of the Department of Homeland Security, is engaged in a multi-year program to develop practical and effective design criteria and guidelines for performance-based design of buildings to resist the effects of earthquakes (ATC-58 project). The goal of this project is to reduce economic costs and life losses associated with earthquakes by permitting buildings to be designed and constructed so that they are reliably capable of providing acceptable and appropriate levels of seismic risk. The guidelines and procedures are to be applicable to the design and construction of new facilities as well as the upgrade of existing facilities. It is also intended that the performance-based approaches developed under this program would be applicable to the development of similar design procedures for resistance to other extreme hazards including wind storms, fire and blast.

The development of performance-based structural and seismic design procedures has received wide spread interest for more than a decade, both in the United States and abroad. In the period 1993-1997, the Applied Technology Council, Building Seismic Safety Council and American Society of Civil Engineers collaborated under FEMA-sponsorship to develop performance-based design procedures for seismic rehabilitation of existing buildings. The resulting FEMA-273 *NEHRP Guidelines for the Seismic Rehabilitation of Buildings* and companion FEMA 274 *Commentary on the Guidelines for the Seismic Rehabilitation of Buildings*, were later developed into a national consensus standard and published as the FEMA-356 *Prestandard and Commentary for the Seismic Rehabilitation of Buildings.* These documents formed the first comprehensive performance-based seismic design methodology, which has experienced rapid acceptance and application by the design professions. the rehabilitation guidelines for existing buildings ,however, were not intended to be applicable to the design of new facilities. Therefore, in 1997, FEMA entered into a cooperative agreement with the Earthquake Engineering Research Institute to prepare an action plan for the development of a next generation of performance-based design guidelines applicable to both new and existing buildings. The resulting FEMA-349 report, *Action Plan for Performance-Based Seismic Design* (EERI, 2000), recommended a comprehensive, ten-year effort for this development and serves as the initial framework for the conduct of the ATC-58 Project.

In the time since publication of the FEMA-356 and FEMA-349 reports, a large number of research and development efforts related to performance-based design have been undertaken. In the United States, the American Society of Civil Engineers, the Applied Technology Council, the Consortium of Universities for Earthquake Engineering Research, the Structural Engineers Association of California, and the three national Earthquake Engineering Research Centers have all have performed significant work in this area. Other important work has been undertaken in the earth science community and by individual engineers and researchers. Significant work has also been undertaken in Europe, Japan and New Zealand.

In February 2003, a number of the researchers and engineers involved in these efforts were invited to attend a 2-day workshop at the Miyako Raddison Hotel in San Francisco, California. The objectives of this workshop were to introduce the community to the ATC-58 project, identify the significant development efforts that had been undertaken since publication of the FEMA-349 *Action Plan*, and obtain community input into the preparation of an updated action plan for conduct of the ATC-58 Project.

The workshop was attended by 86 participants from the structural engineering, earth science, and social science business communities, as well as selected members of the project Steering Committee. In plenary session, the ATC-58 project objectives and work plan, and overview summaries of relevant work underway by the three national earthquake engineering research centers, as well as in Europe and New Zealand, were presented. Following the plenary session, participants were separated into three breakout sessions, respectively focused on performance-based design of structures, performance-based design of nonstructural components and systems, and risk management and communication considerations. In each break out session, participants were provided opportunity to present information on recent significant developments in the focus area. Breakout sessions were chaired by members of the ATC-58 project development team, who presented preliminary proposed updates to the FEMA-349 *Action Plan*. Participants were asked to critique these proposed updates and assist the project team in developing an appropriate revised *Action Plan*.

The workshop resulted in the collection of much useful information on recent developments in performance-based earthquake engineering that permitted the project team to develop a new vision for the way in which the ATC-58 should be developed. This represents a significant departure from the basic *Action Plan* presented in FEMA-349. Chapter 1 of this report presents an overview of the workshop, its objectives and the way in which it was conducted. Chapter 2 presents an overview of the revised vision for the conduct of the ATC-58 project. This vision is currently being further developed into a detailed work plan. Appendices to this document include a list of the participants, abstracts of presentations, and summary notes from sessions.

Chapter 1: Introduction

General

This document provides a summary of the proceedings of a Workshop on Performance-based Seismic Design, held in San Francisco, California on February 24-25, 2003. This workshop was held as part of the FEMA-funded ATC-58 project to develop performance-based seismic design guidelines. The purpose of the workshop was to:

- introduce the earthquake engineering community to the ATC-58 project;
- obtain information on recent significant technical developments relevant to performance-based seismic design; and
- obtain community input into the process of updating and revising the FEMA 349 *Action Plan for Performance-Based Seismic Design* (EERI, 2000), which, will serve as the basic road map for conduct of the ATC-58 project.

In addition to providing a summary of the workshop proceedings, this document also presents a summary vision for the conduct of the ATC-58 project developed based on feedback obtained at the workshop. This summary vision forms the basis for the revised action plan, which is still undergoing development.

ATC-58 Project Description and Background

Most design of buildings and structures today is performed in accordance with prescriptive criteria contained in the building codes. These prescriptive criteria regulate the types of structural systems that can be used to resist earthquake forces in structures, the materials these systems can be constructed from, the minimum levels of strength and stiffness that must be provided, the specific details of construction that must be employed and the strength of attachment of various nonstructural components mounted within the structure. These prescriptive criteria have been developed over a period of many years primarily based on observation of the behavior of real buildings and structures in earthquakes, bolstered by analysis of the response of simplified structures to earthquake motion and laboratory testing of various structural and nonstructural components to simulated earthquake loading.

Present code requirements are primarily intended to protect "life safety", meaning their goal is to prevent the loss of life or life-threatening injury to building occupants or pedestrians, in any event likely to affect a building, primarily by preventing building collapse. During a design level earthquake, buildings designed to such codes are anticipated to potentially experience significant structural and nonstructural damage, possibly to the point of having to be demolished. However, as long as a building does not collapse during an earthquake or generate large quantities of heavy falling debris, it would have met the intent of current code design requirements. While this may be an acceptable minimum design level for many types of buildings, it is not adequate for certain occupancies, such as critical facilities, or buildings where the owner wants to have damage limited to either a repairable level or have the facility functional immediately after an earthquake. As has been vividly demonstrated during recent earthquakes, even well designed buildings conforming to contemporary codes can perform as specified and still be unfit for normal occupancy and use for an extended period of time following an earthquake, resulting from both structural and non-structural damage and the necessary repair operations. However, it is not clear how to adjust or modify current prescriptive criteria to reliably obtain performance different than desired for typical buildings.

Based on performance of modern buildings in recent earthquakes, including the 1989 Loma Prieta and 1994 Northridge earthquakes, prescriptive criteria contained in contemporary building codes are generally effective in minimizing life-safety hazards. However, they are less reliable in controlling damage and facility occupancy and use interruption, even in locations that experience only moderate levels of ground shaking intensity. This resulted in a demand by design professionals, emergency management professionals, and some members of the business community for the development of design criteria that could reliably be used to design buildings to control the economic as well as life losses associated with earthquakes. Such design criteria and designs developed implementing such criteria have come to be known as performance-based design.

Following the 1994 Northridge earthquake, FEMA funded the Earthquake Engineering Research Institute (EERI) in a project to prepare an action plan for the development of reliable performance-based criteria for the design of new buildings and upgrade of existing buildings. The resulting action plan was published in 2000 as FEMA-349, *Action Plan for Performance Based Seismic Design*. Developed with broad input from the earthquake engineering community, FEMA-349 lays out a roadmap for the development of performance-based design criteria that includes development of detailed technical criteria for design of structural and nonstructural systems and components, as well as methods for building owners, tenants, and investors and government agencies to determine minimum acceptable performance goals to be used as the basis for design.

The ATC-58 project, initiated in September 2001, is intended to implement the FEMA-349 *Action Plan* for the development of performance-based design guidelines. The FEMA-349 *Action Plan* was broken into six basic components, each of which would be responsible for an identifiable portion of the program and the development and publication of products in specific areas. These included:

- **Project Planning and Management Program** – This component addresses basic management of the program and includes establishment and communication with a project steering committee, consisting of representatives of various stakeholder groups, who would both provide feedback to the project team on the needs of the community and also act as advocates within their own individual communities for the effective development and use of performance-based approaches. Stakeholder groups include building developers, corporate risk managers, lenders, insurers, tenants, government planners, building regulators and design professionals, among others.
- **Structural Performance Products –** This component consists of the development of technical tools and guidelines to allow building structures to be designed to achieve specified performance.
- **Nonstructural Performance Products** – This component consists of the development of technical tools and guidelines to allow the design of buildings such that architectural, mechanical, and electrical systems and components and critical tenant contents and furnishing can achieve desired performance.
- **Risk Management Products –** This foundational component consists of developing the means to communicate issues of performance design between the design professionals and those who must pay for performance and will be affected by poor performance including building owners, developers, tenants, lenders, insurers, community planners and regulators.
- **Performance Based Design Guidelines** – This task consists of developing resource documents, primarily intended for use by design professionals and building regulators, that can be implemented as criteria and procedures for doing performance-based designs and which can eventually be developed into consensus standards or code provisions.
- **Stakeholder's Guides** – This task consists of developing resource documents, primarily intended for stakeholders, including owners, developers, tenants, lenders, insurers, community planners and regulators, that assist these stakeholders in selecting appropriate performance criteria as the basis for building development and upgrade projects.

Ultimately, FEMA envisions that the end product from this overall project will be design criteria for performance-based seismic design that could then be incorporated into existing established seismic design resource documents, specifically the *NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures* for new construction and the *NEHRP Guidelines for the Seismic Rehabilitation of Buildings* and its successor documents, for existing buildings. The performance-based seismic design criteria is intended to be implemented on a voluntary basis by individual development teams or adopted into the provisions of the building codes and become either an alternative or basic minimum standard for the design and upgrade of buildings.

The FEMA-349 *Action Plan* was developed during the period 1997-1998. Upon initiation of the ATC-58 project in 2001, it was recognized that significant work towards the development of performance-based design procedures and criteria had likely been accomplished by the three national earthquake centers, by individual researchers and the practicing profession at large. Accordingly, one of the first tasks the project team was charged with was to obtain input on advances in the state of the art since the development of FEMA-349, to obtain community consensus as to the continued viability of the *Action Plan*, and to develop a revised action plan as appropriate that would serve as the basic work plan for the project. The February 24-25, 2003 workshop was a key element of this process of revising the FEMA-349 *Action Plan*.

In the interim period, prior to development of this revised action plan, FEMA-349 continues to serve as the basis for the project work plan. As of the time of the workshop, the project had accomplished the following:

- established a project management structure, including the appointment of a 6-person Project Management Committee, including a Project Executive Director, Project Technical Director and four at-large members of the research, regulation, and practice communities;
- appointed Team Leaders to lead the effort in each of the Structural Performance Products, Nonstructural Performance Products, and Risk Management Products component areas;
- appointed team members in the aforementioned product areas to assist with project planning tasks;
- performed a preliminary project task in the Risk Management Products area to define preferred ways of communicating performance between stakeholders and design professionals, and to begin to establish a system of design performance levels or goals; and
- developed a preliminary revised Work Plan for the project, based on the FEMA-349 *Action Plan*, the results of the preliminary Risk Management Product task, and the project participant's personal knowledge of recent developments in performance-based design.

The performance-based design workshop was a key input to the process of revising the *Action Plan* and finalizing the project work plans.

Attendees

The Workshop was attended by members of the ATC-58 Project Management Committee and the Project Steering Committee, the Structural Performance Products Team Leader, the Nonstructural Performance Products Team Leader, the Risk Management Products Team Leader and Associate Risk Management Products Team Leader, as well as members of the three product development teams. In addition the workshop was attended by a large number of invited participants selected on the basis of response to a broad call for presentations, issued in December 2002, as well as recognized achievement in the field of performance-based seismic design. Appendix A includes a complete list of all workshop participants. Appendix B contains a copy of the call for presentations.

Workshop Overview

Appendix C presents an agenda for the workshop. This section provides a brief narrative of the agenda and proceedings.

The workshop occurred on two days, starting at 9:00 am on February 24 and continuing through the afternoon of February 25, 2003. The morning and a portion of the afternoon of the first day were held in plenary session. In this plenary session, introductory remarks were made by the FEMA Project Officer (M. Mahoney), the Project Executive Director (C. Rojahn) and Project Technical Director (R. Hamburger). These remarks included an overview of the purpose of the project, a summary of project accomplishments and technical recommendations to date, an overview of the FEMA-349 *Action Plan*, which serves as the initial basis for development of project work plans, and a discussion of the purpose of the workshop.

Following the introductory presentations on the purpose of the project and the workshop, two invited presentations were made on the status of development and implementation of performance-based seismic design approaches in Europe (by A. Elnashi) and Australia/New Zealand (by A. King.) Representatives of the Mid-America Earthquake Center (D. Abrams), the Multidisciplinary Center for Earthquake Engineering Research (M. Bruneau) and the Pacific Earthquake Engineering Research Center (G. Deierlein) presented a summary of relevant research underway that could support the project. Appendix D contains a reproduction of the slides used in the initial project presentations and abstracts of the focused plenary presentations.

Upon completion of the plenary session, attendees were assembled into three pre-assigned breakout groups, focused respectively on the three product areas: Structural Performance Products, Nonstructural Performance Products, and Risk Management Products. Each breakout session was chaired by the ATC-58 project team leader for that product area. Prior to the workshop, these team leaders, with the assistance of the project teams, had prepared initial drafts of an update to the FEMA-349 work tasks and budgets, termed a Straw Work Plan. This initial Straw Work Plan was distributed to workshop attendees prior to the workshop, and is contained in Appendix E. The FEMA-349 *Action Plan* had also been distributed to all workshop participants, prior to the workshop, together with a questionnaire, containing the following questions:

Question 1: Are you aware of any significant advances that have been made, since 1998, in the development of technologies that permit the performance of building structures and building nonstructural components to be predicted? Please provide a brief description of any such advances that you are aware of, and also indicate the primary investigators who performed this work.

Question 2: Are there specific tasks contained in the FEMA 349 *Action Plan* that you believe need no longer be performed or that you believe should be performed in a radically different manner than indicated? Please identify the tasks, your proposed modification or elimination of the task, and the reason for this.

Question 3: Are there tasks that you believe should be performed as part of the ATC-58 project that are not currently contained in the FEMA 349 *Action Plan*? Please identify any such tasks and the reason you believe these tasks should be performed.

Question 4: Are there specific project reports or deliverables that you believe the ATC-58 project should produce, that are not identified in the FEMA 349 *Action Plan*? Please identify these reports or deliverables and indicate why you believe they are important.

Question 5: Do you wish to make a specific presentation at the workshop, on any of the items noted above?

A few of the workshop participants provided written response to these questions prior to the workshop and indicated that they desired to make specific presentation on the points noted. In addition, several attendees were provided an opportunity to present papers for which abstracts had been submitted in the original call for presentations (Appendix B). For the most part, the breakout sessions consisted of a review of the straw work plan previously prepared by the Team Leaders. In some cases, the discussion of the straw work plan was quite general and did not directly result in modification of specific work tasks contained in the straw work plan, but rather resulted in a general refocusing of the goals and approach to the work. In other cases, detailed evaluation of the work tasks were achieved with budgets and even relative scheduling agreed to.

A summary of each of the breakout sessions is contained in Appendices F, G and H of this proceedings for the Structural Performance Products, Nonstructural Performance Products and Risk Management Products Breakout Sessions, respectively. Each summary includes the session chair's notes and the written abstracts received from participants for presentations made during the session.

With the substantial help and assistance provided by the workshop participants, the project team developed a new vision for the basis upon which the new performance-based design guidelines should be developed. The Project Technical Director presented this new vision in a summary presentation at the closing plenary session. Following the closing plenary session, the Project Team engaged in a process of revising the Straw Work Plan to incorporate the new vision and to finalize the revised action plan. The summary presentation from the closing plenary session is contained in Appendix I of this proceedings.

Chapter 2: Summary of Workshop Findings and Work Plan Recommendations

Original Project Concept

The ATC-58 project was established to implement the development of Performance-based Seismic Design Guidelines as outlined in the FEMA-349 *Action Plan for Performance-Based Seismic Design*. Although published in April 2000, most of the work performed in development of FEMA-349 occurred in the period 1997-98. In the context of that time period, most participants conceived of performance-based seismic design as it was implemented through the Structural Engineers Association of California (SEAOC) Vision 2000 Report (*Performance Based Seismic Engineering of Buildings*), the FEMA-273 *Guidelines for the Seismic Rehabilitation of Buildings* and companion FEMA-274 *Commentary on the Guidelines for the Seismic Rehabilitation of Buildings*, and the detailed guidance on implementation of performance-based design contained in the ATC-40 report, *Seismic Evaluation and Retrofit of Concrete Buildings*, all of which were recently published at the time.

In this context, the performance-based design paradigm had the following characteristics:

- Buildings are designed to provide targeted minimum performance for specified design ground shaking (and ground failure) events;
- Design ground shaking events are discrete and represent either a specific scenario, e.g. a magnitude 6.5 event on a designated fault, or a level of ground shaking having a stated mean return period; and
- Building performance levels are discrete and are characterized based on such factors as the ability of the building to continue to provide postearthquake function, enable postearthquake occupancy, protect life safety during the event, or avoid collapse.

The proposed next-generation seismic design guidelines document, as described in the FEMA-349 Action Plan was intended to:

- Extend the applicability of the rehabilitation guidelines to design of new construction;
- Address the issue that many structures designed to current prescriptive building codes would not be deemed acceptable when evaluated using the performance-based design approaches of the day;
- Free the guidelines from the use of elastic structural analysis procedures, which were perceived as an outmoded and inaccurate technology that was rapidly going to become obsolete;
- Expand and improve the library of acceptance criteria used to judge structural performance, and to the maximum extent possible improve the database of actual laboratory data upon which these acceptance criteria were based;
- Upgrade the procedures employed to evaluate and design nonstructural components and systems to be compatible with the level of sophistication employed in structural evaluation and design;
- Evaluate and characterize the reliability of the guidelines and improve the reliability to the extent permitted by current knowledge and technology;
- Establish procedures and systems to collect earthquake performance data in a manner that will permit the establishment of statistically valid databases that can be used to benchmark and improve the guidelines;
- Educate stakeholders as to the benefits of performance-based design approaches and create an advocacy and demand for the application of these approaches in practice; and

- Educate the practicing professionals so as to be able to implement the new procedures and improve the level of practice.

FEMA-349 indicated that this work could be accomplished in a 10-year period, acknowledging that this would be aggressive given the massive amount of work that must be performed. A major component of the program consisted of basic engineering research. That included:

- Improvement in hazards characterization with a particular goal of reducing variability inherent in current hazards assessments;
- Improvement in the available database of hysteretic and performance data for various structural components and systems;
- Improvement in the ability of analytical tools to predict damage and performance of structural systems; and
- Development of a database on the performance characteristics of typical nonstructural components and systems found in buildings.

Although success of the program outlined in FEMA-349 relied on the successful accomplishment of these research items, the research itself was viewed as outside the scope of the performance-based design guidelines development project. The project included tasks for setting research priorities, for advocating funding and performance of the necessary research, and for assimilating and employing the results of this research but not for actual doing any such research. It was recognized that the 10-year schedule proposed for the project was largely dependent on the timely availability of the results of this research.

Even given the exclusion of direct research from the scope of the project, the proposed budget was large. Therefore, two levels of effort were provided for. The first of these was considered a "bare-bones" effort, which would establish a framework for the guidelines and populate the guidelines with acceptance criteria for a few representative structural and nonstructural systems and components, with procedures established and published for how to extend the guidelines as additional funding and research became available. The cost of this "bare-bones" program was projected at $20 million (1998 dollars). A more comprehensive program, termed the optimal program, which would more fully populate the guidelines with information required for application to the broad range of structural and nonstructural systems commonly found in the building stock was budgeted at $27 million (1998 dollars). In publication of the *Action Plan*, FEMA noted in a foreward that the proposed level of effort was substantially in excess of that which could reasonably be anticipated to be funded by that agency and indicated hopes that a lesser program of endeavor could accomplish many of the stated goals.

As of the time of the workshop, the ATC-58 project was being funded incrementally, at a level sufficient to perform project organization and setup tasks and to initiate a few foundational tasks. It was clear at the time this workshop was held that funding for the program likely could not exceed 1/3 to 1/2 that projected in FEMA 349 as required for the bare-bones effort.

Clearly to accomplish the intended guidelines development under these funding limitations will require that the project call heavily on the resources of outside agencies and parties. Identified among these outside agencies and parties are the following:

- the U.S. Geological Survey (USGS) – for work related to improvement of hazards assessment capability, particularly with regard to achieving reductions in variability;
- the National Science Foundation (NSF) National Earthquake Engineering Research Centers – basic research into development of performance-prediction technologies and approaches, analytical tools, performance data for various structural and nonstructural systems, and for identifying direct design as opposed to evaluation methodologies;
- Materials Industry Associations and individual Building Products Suppliers – support of basic research into the performance characteristics of specific structural and nonstructural systems and components; and

- the NSF-funded Network for Earthquake Engineering Simulation (NEES) – validation of earthquake performance simulation capability.

Updated Vision and Concept

Through initial project work conducted by the ATC-58 project and through discussions held at the workshop, it has become clear that the performance-based design paradigm, which served as the basis for the development of FEMA-349, is no longer valid and is in need of updating. Specifically, the old paradigm is lacking in that it:

- does not directly address the concerns of most stakeholders/decision makers when selecting appropriate performance for a building, which is the potential losses in life, direct economic loss, and downtime (loss of facility use);
- is not sufficiently flexible to accommodate the decision-making styles of many stakeholders/decision makers, which are varied and sometimes complex; and
- depends on judgmentally defined performance levels, which by their very nature are unpredictable as to their probability of occurrence, precluding either characterization or improvement of reliability.

The new paradigm proposed to be adopted by the ATC-58 project is based in large part on methodologies under development at the Pacific Earthquake Engineering Research (PEER) Center, in which the total probability that a building will experience certain performance outcomes is calculated and used as a basis for decisions as to whether performance is acceptable. In this approach, performance outcomes are expressed directly in terms of the probable loss of life, probable cost of damage repair (or building replacement), and probable hours/days of lost use resulting from damage. Uncertainty and variability associated with predicting the intensity of earthquake motion (hazards), the response of structures and nonstructural components, the damage sustained by structural and nonstructural systems and components, and the losses that result from this damage are explicitly accounted for in this approach. Further, the performance outcomes associated with this approach can be expressed in a variety of ways to accommodate the needs of various stakeholders/decision makers, including:

- the average annual loss (in lives, dollars, hours of downtime) per year;
- the expected loss (in lives, dollars, hours of downtime) over the life of a building or facility project;
- the mean return period (in years) between losses (in lives, dollars, hours of downtime) exceeding a specified size;
- probable maximum loss (PML) (90% confidence of non-exceedance) in a 500-year mean return period; and
- the expected, lower-bound or upper-bound loss (in lives, dollars, hours of downtime) for various scenario events, or for ground shaking having a specified probability of exceedance.

In this approach, design criteria for buildings would be specified in terms of the desired outcomes, expressed as indicated above, which are then translated into structural design criteria that form the basis for configuring and proportioning structural systems. A form of application of the PEER methodology is embodied in the algorithms used by loss estimation software commonly used in the insurance industry and by public planners. HAZUS, the national loss estimation software developed by the National Institute of Building Sciences on behalf of the Federal Emergency Management Agency, also incorporates a similar approach.

The basic work-flow for conducting a performance-based design is illustrated in Figure 2-1 below. As illustrated in the figure, performance-based design is comprised of three basic steps. The first of these steps consists of selection of appropriate performance objectives. Selection of performance objectives is a task that must be performed by the stakeholders, either the owner (or the owner's lender and/or insurer), the tenants, or in the interest of protecting the public welfare, by the public authority, typically with guidance and participation by design professionals. Under the proposed approach, performance objectives may be expressed in terms of a desired PML, average annual loss, 500-year loss, or any of the other expressions of loss discussed previously, with loss considering lives, repair/replacement costs, and downtime.

The second step in the process consists of formulation of a preliminary design. In the rehabilitation guidelines, this was a trivial task as the preliminary design would start with the existing structure, which would then be evaluated to determine if it was capable of providing the desired performance. For new buildings, this task is less trivial as there are a wide range of structural systems, configurations, and details that can be selected. A major task of the ATC-58 project will be to develop preliminary design guidance that will assist the engineer in efficient preliminary selection of appropriate systems and configurations, strength, stiffness and detailing, that will be capable or close to capable of meeting the desired performance goals. Currently, this process is performed on a largely intuitive basis, often by making arbitrary modifications to prescriptive code criteria.

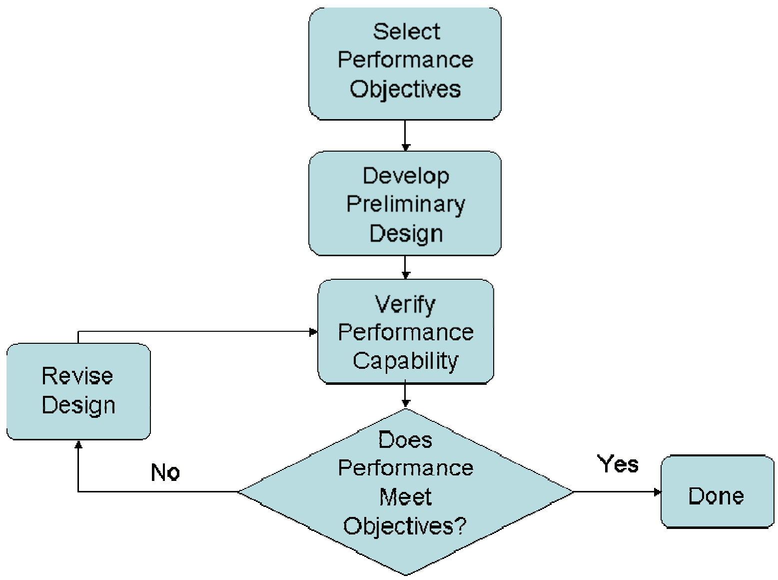

Figure 2-1 Performance-Based Design Work Flow

The third and final step in the process is one of confirming that the design is capable of providing the desired performance, both of the structure and the nonstructural components and systems, and of iterating the design until conformance is obtained. In the context of this project, unlike in past performance-based design efforts, this will be conducted by estimating the probable losses (life, repair/replacement cost, and downtime) for the preliminary design, in the same context in which these losses are expressed by the stakeholder as performance criteria an determining if the losses are suitably low. Figure 2-2 illustrates the performance verification process.

Regardless of the way in which performance is measured, that is as an average annual loss of life, an expected mean return period for more than a number of hours of lost facility use, or the maximum probable repair cost given a specified earthquake event, or by another means, the process is essentially the same. It initiates with characterization of the hazard in terms of a hazard function. The hazard function indicates the probability of experiencing ground motion intensity of a given level, together with an expression of confidence bounds. The hazard function may be either conditioned on the occurrence of a specific scenario earthquake, or may be an expression of all possible earthquakes and the probability of occurrence of each. Earthquake intensity must be expressed in the form of a parameter that is useful and efficient for predicting structural response. A parameter is useful, if it can be used in structural analysis to predict earthquake effects. A parameter is efficient if the variability in response as a function of the parameter is relatively small. In the PEER methodology, these parameters are termed Intensity Measures. Figure 2-3 is illustrative of a hazard curve for a hypothetical building site, using peak ground acceleration as the Intensity Measure. Other Intensity Measures, such as spectral response accelerations, are likely to be more efficient than peak ground acceleration.

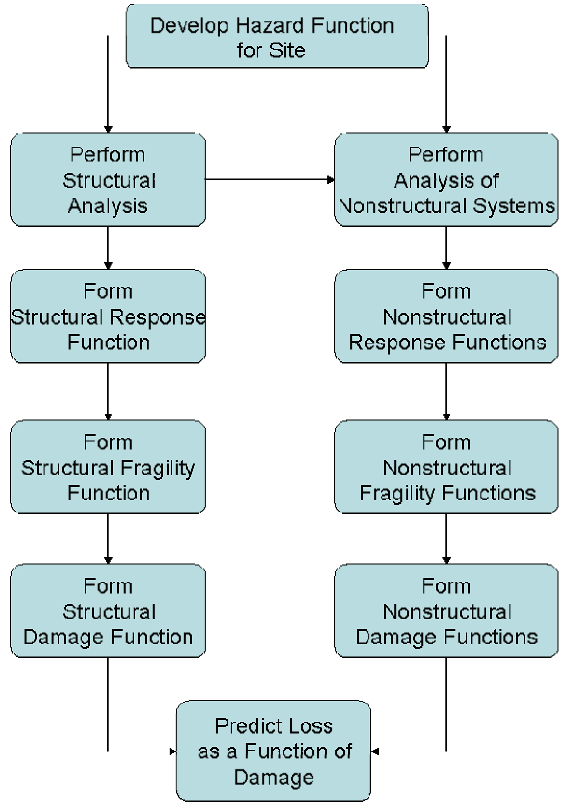

Figure 2-2 Performance Verification Process

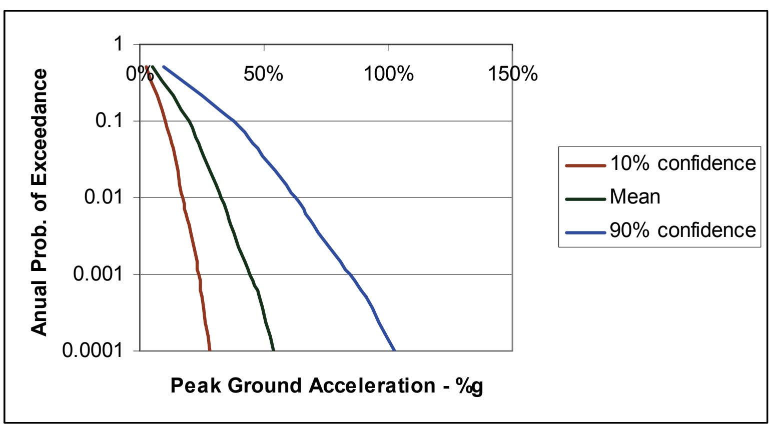

Figure 2-3 Illustrative Hazard Curve for Site

Once the hazard for a building site has been determined, structural analysis must be used to understand how structural response varies as a function of ground motion intensity. Structural response must be characterized by a series of Engineering Demand Parameters (EDPs) that are useful and efficient for predicting damage. EDPs may be such quantities as, for example, interstory drift, total drift, joint plastic rotation, and axial column force. Since these response quantities will typically vary in a nonlinear manner with intensity, it will usually be necessary to perform a series of analyses to predict response at various intensities. It is also necessary to account for potential variability and uncertainty in response relating to ground motion, modeling, material properties, construction quality, and other factors. The end product of structural calculations are a series of response functions that relate the probability of exceeding various values of each EDP at different ground motion intensity levels. Figure 2-4 is illustrative of one such a response function.

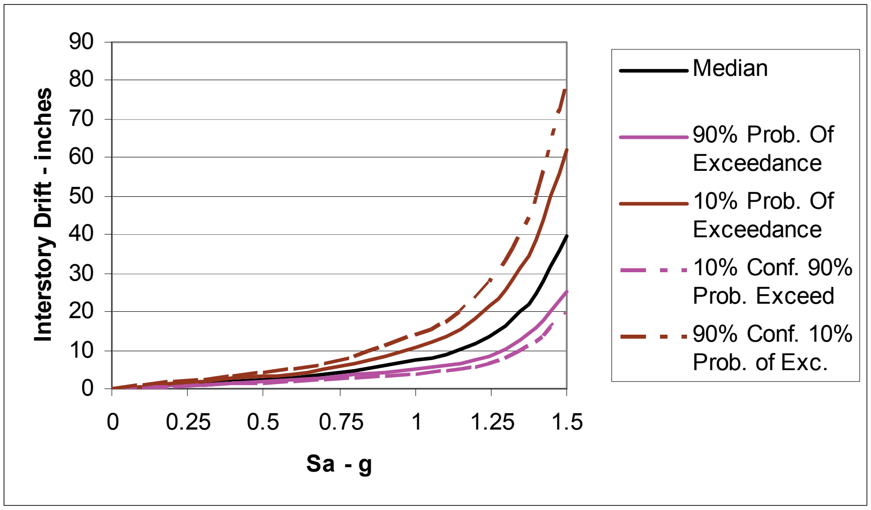

Figure 2-4 Representative Response Function for a Building

Engineering Design Parameters, predicted by structural analysis at various levels of intensity are used for several purposes. One purpose is to predict damage to the structure and to nonstructural elements and components. Damage is related to EDPs by means of fragility functions. Fragility functions indicate the probability of experiencing damage of different types, given the occurrence of various levels of the EDPs. Damage levels can be characterized in terms of specific damage states that are meaningful with respect to life loss, repair cost, and downtime. Figure 2-5 is an example fragility curve for moment-resisting steel frames using beam yielding, beam flange buckling and beam flange fracture as the damage states. Figure 2-6 is an example of a fragility curve for a curtain wall system, using panel cracking, glass cracking, glass fallout, and connection failure as damage states. Fragilities can be established through a combination of laboratory testing and analysis. For some nonstructural components and analysis, an interim step must be performed, consisting of structural analysis of the nonstructural component, using a structural EDP, e.g., interstory drift, or floor acceleration as an input parameter, similar to the way in which intensity measures are used for analysis of the structure, and then predicting response EDPs for the nonstructural components.

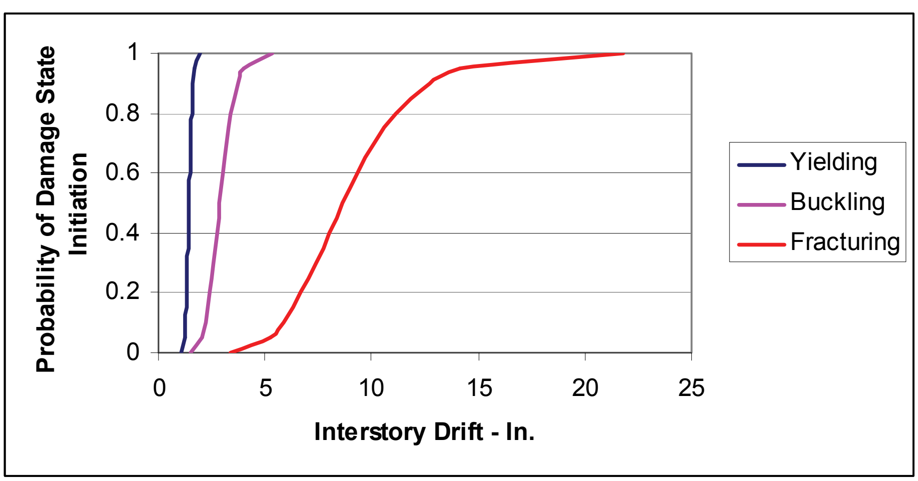

Figure 2-5 Fragility Curve for Moment-Resisting Steel Frame Structure

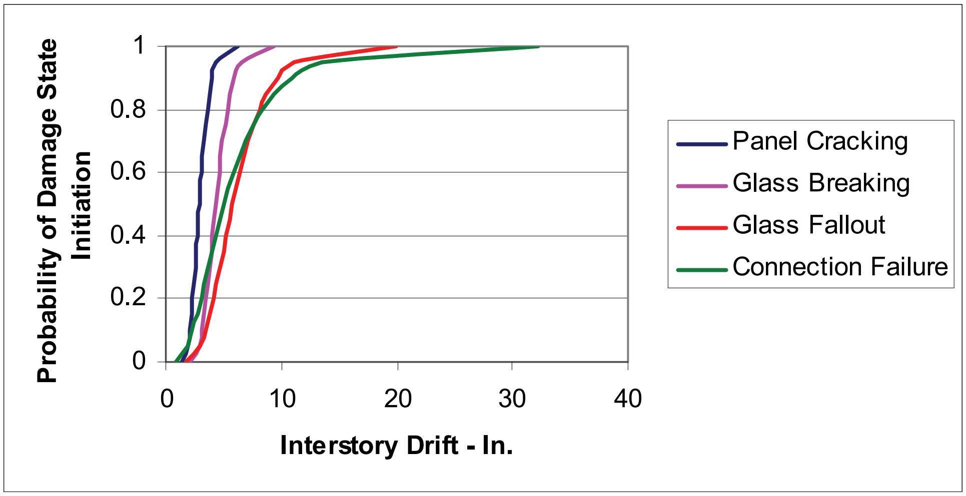

Figure 2-6 Fragility Curve for Exterior Curtain Wall System

Once the probability of a structure being damaged to given levels is understood, in order to predict performance, expressed in the form of loss, it is necessary to have loss functions. Loss functions relate the probable value of life loss, repair/replacement cost, and downtime to the occurrence of damage. Figure 2-7 is a representative loss curve indicating repair cost per framing connection in a steel frame building for the various damage levels contained in the fragility function of Figure 2-5. Figure 2-8 is a similar curve indicating the probable loss of life in a building, given building collapse. Similar loss curves are required for each of the structural and nonstructural components, as well as for the entire structural system and individual nonstructural systems. Loss functions can be established on the basis of historical data, expert opinion and judgment, analysis, or by a combination of these.

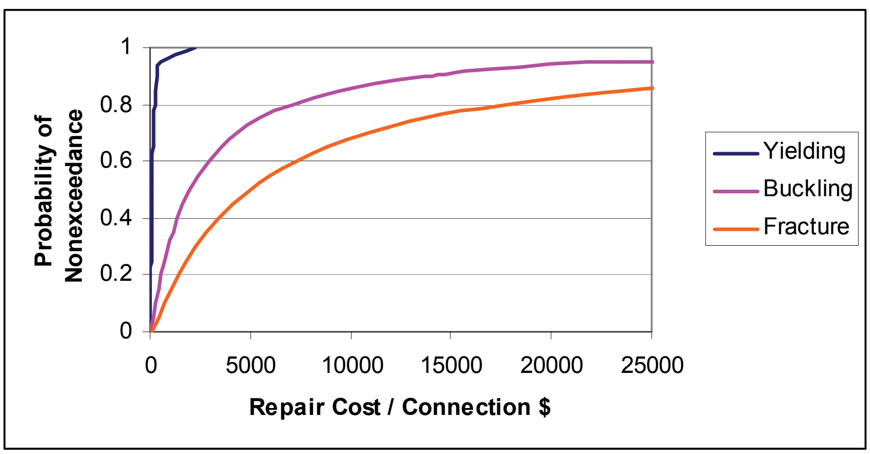

Figure 2-7 Loss Curve for Connection Repair Costs in Steel Frame Buildings

Once the intensity, response, damage and loss curves are established for the structure as a whole, as well as individual structural components and nonstructural components and systems, it is possible to estimate building performance, in any of the ways previously discussed, by integrating the intensity, response, damage and loss functions. This can either be done numerically, or, if certain simplifying assumptions are made with regard to the form of distribution of these various functions, in a closed form solution.

Although this performance verification/prediction approach has been in use for some time in loss estimation software and is similar to methods used in probabilistic risk assessments conducted in the nuclear, offshore and aerospace industries, relatively few structural design professionals are familiar with these methods and they vary substantially from current performance verification procedures. Consequently, a substantial program of simplification, explanation, and education will be necessary to allow the implementation of this approach.

Figure 2-8 Loss Curve for Lives, Given Story Collapse for a Hypothetical Building

Work Plan Recommendations

Workshop Participants recommended that the ATC-58 project follow the general model described in the previous section in developing performance-based design guidelines. To carry out this effort, it was recommended that the project be executed in two basic phases. The first phase should focus on development of the performance verification methodology described in the previous section. It should include development of a detailed generalized methodology for developing hazard, response, damage and loss functions for buildings and for integrating these functions to predict performance in ways meaningful to the various stakeholders. It should also include fully developed, simplified procedures and tools that can be readily implemented by the design professional to use this methodology to predict the performance of a limited series of building and structure classes for which adequate data exists to permit development of response, damage and loss functions. It is anticipated that available funding may be sufficient so that perhaps 3 to 4 types of structures may be fully developed, with the framework for other types of structures sufficiently developed so that the process may be completed for other structure types as sufficient data and funding become available. As part of this phase, the methodology should be employed for a series of case-study buildings, designed to current prescriptive code requirements, in order to validate the methodology and also to obtain an understanding of the performance provided by current code procedures. This phase should culminate with the publication of a performance evaluation guidelines that could be implemented immediately to perform performance verification as part of the performance-base design process, starting with intuitively derived preliminary designs.

The second phase of the project should focus on the development of design guidance that will assist the engineer in developing efficient preliminary designs, and for some structures to directly proceed to final designs, deemed capable of passing performance-verification for certain performance objectives, should they actually be subjected to this process. This phase should include use of the performance verification methodology developed in the first phase, to evaluate a large number of structures and determine those combinations of structural system, configuration, stiffness, strength, damping and ductility that are capable of achieving certain desired performance capability, in different seismic hazard environments. This phase should culminate with the publication of performance-based seismic design guidelines.

Based on the anticipated funding, each of these two project phases is anticipated to have a duration of 5 years. As of the time of publication of this proceedings, the project team is engaged in the development of detailed work plans, which will replace the FEMA-349 *Action Plan*, for implementation of this plan.

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Appendix B: Call for Presentations

SPECIAL ANNOUNCEMENT
December 30, 2002

For More Information, Contact
Ronald Hamburger, 415/495-3700

ATC Seeks Input on Significant Advances in Performance Based Engineering for Presentation at Upcoming FEMA-funded Workshop on Performance-Based Design

The Applied Technology Council (ATC), under contract to the Federal Emergency Management Agency (FEMA), is seeking input from structural and earthquake engineering researchers and practitioners on significant advances over the last decade in the development of performance-based structural and seismic design technologies. This knowledge will be used by ATC during the planning stages of a long-term project to develop a next-generation performance-based seismic design procedure (ATC-58 Project), a FEMA-funded effort that is being planned based on recommendations in the *FEMA 349 Action Plan for Performance-Based Seismic Design*, which was prepared by the Earthquake Engineering Research Institute and published in 2000. Although the project is focused primarily on development of seismic design procedures, the intent is to maintain relevance and transportability to structural design for other hazards, including blast, wind and fire. Persons selected to provide information on significant advances in performance-based structural engineering, as a result of this solicitation, will be asked to participate in an upcoming ATC-58 Workshop on Programming the Development of Performance-Based Seismic Design Procedures, to be held February 24-25, 2003, in San Francisco. Each presentation on new advances presented at the workshop will be limited to 15 minutes.

Persons interested in making a presentation (at the upcoming ATC-58 Workshop) on significant advances in performance-based structural engineering since 1997 should submit a one-page description of said advances to the Applied Technology Council by January 31, 2003. Statements should be submitted to ATC-58 Project, Applied Technology Council, 555 Twin Dolphin Drive, Suite 550, Redwood City, California 94065 (e-mail: ATC@ATCouncil.org). Applicants selected for participation at the Workshop will be notified by February 7, 2003.

For additional information, see the ATC-58 Call for Workshops Presentations on the ATC web site (www.ATCouncil.org), which contains a copy of the ATC-58 Work Plan, or contact Ron Hamburger (Project Technical Director) at 415/495-3700 (email: rohamburger@sgh.com).

Appendix C: Workshop on Performance-Based Design Agenda

Miyako Raddison Hotel
San Francisco, California
February 24-25, 2003

February 24, 2003

9:00 am	Registration and Coffee	
10:00 am	Welcome	Rojahn/Mahoney
10:15 am	Project Introduction	Hamburger
10:45 am	FEMA 349 Overview	Hamburger
11:15 am	Workshop Purpose and Agenda	Hamburger
	Update on Recent International Developments	
11:30 am	- Australia/New Zealand	King
11:45 am	- United Kingdom	Elnashi
12:00	Lunch	
	Update on Relevant Research by NSF Centers	
1:15 pm	- MAE Center	Abrams
1:35 pm	- MCEER	Bruneau
1:55 pm	- PEER	Deierlein
	Breakout Session 1 – Structural Performance Products	
2:15 pm	- Strawman Presentation - Individual Presentations - Discussion	Whittaker
	Breakout Session 2 – Nonstructural Performance Products	
2:15 pm	- Strawman Presentation - Individual Presentations - Discussion	Bachman
	Breakout Session 3 – Risk Management Products	
2:15 pm	- Strawman Presentation - Individual Presentations - Discussion	Comartin
4:00 pm	Coffee Break	
4:15 pm	Resume Breakout Sessions	
6:00-7:00 pm	No-Host Reception	

February 25, 2003

7:30 am	Continental Breakfast	
8:00 am	Resume Breakout Sessions (presentation and review of revised workplan) - Presentations of revised strawman work plans - Discussion	
10:00 am	Coffee Break	
10:15 am	Resume Breakout Sessions (finalize workplans)	
12:00	Lunch	
1:15 pm	Concluding Plenary	
	Preliminary Vision of Guidelines	Hamburger
1:45 pm	Structural Performance Products Summary and Discussion	Whittaker
2:15 pm	Nonstructural Performance Products Summary and Discussion	Bachman
2:45 pm	Risk Management Products Summary and Discussion	Comartin/Meacham
3:15 pm	Stakeholders Guide Summary	Comartin/Meacham
3:45 pm	Next Steps	Hamburger
4:00 pm	Closure	Rojahn
4:15-5:00 pm	PMC Executive Session	(PMC Only)

Appendix D: Opening Plenary Session Materials

Recent Advances in Performance Based Earthquake Engineering – the New Zealand Experience

Andrew King
Section Manager – Active Landscapes, Institute for Geological and Nuclear Sciences New Zealand

Over the past five years a major review of the New Zealand Earthquake Loadings Standard, NZS 4203 has been underway. This has culminated in the development of a joint Australia/ New Zealand earthquake standard now at its final draft stage. The standard operates within the performance based regulatory environment set down by the New Zealand Building Code. The design profession requested that the performance parameters objectives be clearly prescribed within the standard and transparent to enable designers to appreciate the in-service performance expected from compliant buildings.

Section 2 therefore prescribes the earthquake design performance objectives of the standard. These include damage control under moderate earthquake attack (serviceability limit state II), the provision of resistant earthquake mechanisms under severe loading (ultimate limit state) with some reserve capacity (unspecified), and collapse avoidance under the maximum considered event. The earthquake intensity associated with ‘moderate’ ‘severe’ and ‘maximum’ varies with the building importance class. For buildings with ‘ordinary’ occupancy the annual probability of exceedence of the design event was 25 years, 500 years and 2500 years respectively. Buildings classified as having a ‘Critical post-disaster function attain their special ranking because of the expectation that they would remain operational (serviceability limit state I) when other buildings were experiencing their ultimate limit state design actions (500 year recurrence interval. Thus the operational continuity performance expectation was incorporated for this class of building as a mandatory requirements but is also available for should owners or operators elect to engage this performance level.

The life safety hazard created by building collapse has been extended to cover other life threatening failures such as the shedding of elevated facades and the collapse of heavy suspended ceiling systems. The necessity for building evacuation paths to maintain operational continuity following severe earthquake attack was also considered and parts required to ensure compliance with this expectation classified accordingly.

With the clear shift of focus to post earthquake performance including both life safety, damage control and operational continuity, the importance of adequate design of building parts and non-structural components was highlighted. A research programme was instigated to investigate the known and predicted behaviour of non-structural and secondary systems. Reference was made to the behaviour of instrumented buildings during the Northridge earthquake. The study involved the design and analysis of over 40 buildings in both high and low seismicity regions of New Zealand. Variations include consideration of different materials, different structural forms and different building heights. The selection of the ground motion records to be used during the analysis followed the procedure set out in the standard (similar to those prescribed in ATC 40 and FEMA 273) were used. The resulting floor response spectra was used to determine the design spectra for building parts and non-structural systems supported within the primary structural frame.

The next phase of the programme involved determining the in-elastic response capability of different non-structural components and items of mechanical plant. Such response needs to include both the behaviour of the item and its connectivity to the building itself. Work is now being planned as to how to evaluate these dynamic response characteristics for different systems and to develop a cost-efficient means by which the necessary design parameters can be determined.

New Zealand proposes to adopt a national earthquake standard which includes clearly stated earthquake performance objectives. We are keen to participate an international research effort to quantify response parameters, particularly for damage control and operational continuity.

Performance-Based Seismic Design in Europe

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Preamble

For the past decade or more, a group of European earthquake engineering experts have been co-operating in the challenging environment of research and development towards seismic risk reduction, fostered by the European Commission (EC). Funding was provided by the EC under the successive frameworks 3, 4 and 5, through competitive network applications. The projects in which the writer is/was involved are:

- Prenormative Research in Support of Eurocode 8 (PREC8)
- Innovative Concepts in Seismic Design of New and Existing Structures (ICONS)
- Safety Assessment for Earthquake Risk Reduction (SAFERR)

This does not include a number of earthquake engineering-related projects that the writer was affiliated with or knew about, such as the Large Installations projects ECOEST I and II, as well as their successor, ECOLEADER, which are basically consortia of large scale laboratories, most of which are shaking table facilities. Other networks of a smaller number of partners, such as NODISASTR and SPEAR, are more focused research groupings that are mainly concerned with reinforced concrete structures. Other networks concerned with geotechnical and engineering seismology aspects of seismic hazard are not reviewed here, with the exception of the Eurosei-series of projects, since the latter is a multi-disciplinary activity that includes structural engineering research. Efforts are currently underway to amalgamate and enlarge the European networks under the auspices of Framework Program 6, the call-for-proposals of which has been recently announced.

Philosophy of the European Research Networks

European earthquake engineering community has maintained a consistent underlying research philosophy. This comprises two main strings, one is topical and the other managerial. The topical philosophy consists in dealing with earthquake effects in a holistic manner. All the sub-topics deemed important in the areas of earthquake ground motion, seismic hazard and geotechnical and structural effects of earthquakes need to be addressed. This is necessary in order to successfully investigate issues of Demand (the severe requirements imposed by the ground shaking during earthquakes), Supply (the capacity to resist forces and deformations imposed by earthquakes on civil engineering works), and their interaction. However, consideration of the entire range of problems, from earthquake source to structural design and detailing, requires the careful selection of the constituent organisations of the EEEC in order that the necessary talent is brought to bear. Table 1 lists the participant institutions and their involvement in the three networks here presented. Once the research topics and contributing organisations are established, in order for the network to be successful a clear managerial framework is necessary to combine research, development, application and training into an integrated whole.

Table D-1 Participants and Involvement in Network Subtopics

Institution	Responsible Scientist	PREC8	ICONS	SAFERR
1. University of Liege (Belgium)	A. Plumier	- T1	-T2, T4	-T1, T2
2. Géodynamique et Structure (France)	A. Pecker	- T5	-T1, T3	-T1, T3
3. GRECO/GEO-French Group for Coordinated Research (France)	J. Mazars J.M. Reynouard	- T1, T5	-T2, T3, T5	-T1, T2, T3
4. Darmstadt University of Technology (Germany)	J. Woerner	- T1	-T2, T4	-T2, T3
5. University of Patras (Greece)	M.N. Fardis	- T1, T2	-T2, T3, T5	-T2, T3, T4
6. University of Basilicata (Italy)	M. Dolce	- T1	N/A	N/A
7. Politecnico di Milano (Italy)	E. Faccioli	- T5	-T1, T3	-T1, T4
8. Università di Pavia (Italy)	G.M. Calvi	- T1, T2, T4	-T1, T2, T3	-T3, T4
9. Università di Roma "La Sapienza" (Italy)	P.E. Pinto	- T4	-T2, T3, T5	-T2, T3
10. Universidad Politecnica de Madrid (Spain)	E. Alarcon	- T4	-T2, T4	-T3, T4
11. Imperial College, London (UK)	A.S. Elnashai	- T1, T4	-T1, T2, T4	-T1, T3, T4
12. University of Ljubljana (Slovenia)	P. Fajfar	N/A	N/A	-T2, T4
ECOEST (I & II) and ECOLEADER Institutions:				
1. TAMARIS-CEA, Saclay (France)	P. Sologoup	N/A	-T3, T4, T5	N/A
2. National Technical University of Athens (Greece)	G. Gazetas P. Carydis	- T1, T5	-T4	N/A
3. ISMES, Bergamo (Italy)	M. Casirati	-T4	-T4	N/A
4. Joint Research Center, Ispra (Italy)	A.V. Pinto	- T1, T2, T4	-T2, T3, T4, T5	N/A
5. National Laboratory for Civil Engineering, Lisbon (Portugal)	E.C. Carvalho	- T1, T4	-T1, T2	N/A
6. University of Bristol (UK)	R. Severn	- T2, T5	-T4	N/A

Notes: PREC8 Tasks: T1: RC Frames, T2: Infills, T3: Reinforcing steel, T4: RC Bridges, T5: Foundations
ICONS Tasks: T1: Hazard, T2: Assessment/Repair, T3: Design Concepts, T4: Composite Structures, T5: Shear Walls
SAFERR Tasks: T1: Hazard, T2: Low Seismicity Regions, T3: Assessment/Repair, T4: Risk Assessment Systems

Within the running of each network, the European group has managed to maintain a balance between the amount of research, development and training provided, regardless of the bias of the EC proposal requirements. Furthermore, fore-vision and the use of a clear global framework have enabled the EEEC to gear the seemingly disparate network applications of Programmes 3, 4 and 5 of the EC, towards the achievement of the final objective of creating a European Earthquake Risk Centre.

Research Highlights

All research activities undertaken by the successive European earthquake engineering networks are considered 'performance-based'. This includes the development of rigorous displacement spectra, long-period spectra, better site characterizations, targeted repair and strengthening, displacement-based assessment and design and local ductility assessment and design. One of the most spectacular achievements of the European networks is large and full-scale testing of structures and foundations. Examples of such tests are shown in Figure 1. The tests were preceded by extensive analysis and assessment studies to bracket the limit states of the structure and the required input motion characteristics and the testing was focused on providing data at pre-assigned performance levels.

Figure D-1 Full scale testing of infilled frame, bare RC and composite frame at JRC Ispra, Italy

The experimental results were used to calibrate models and to adjust limit state definitions in terms of local and global response parameters corresponding to performance targets. One of the interesting performance-based concepts developed in Europe is that of 'selective intervention', whereby one of the three most important structural characteristics (stiffness, strength and ductility) is affected without affecting the two others, thus optimally tuning the response to meet the identified performance target. Stiffness is most relevant to serviceability, strength to damage control and ductility to collapse prevention. Therefore, the three parameters map well onto the three limit states. This approach was utilized in shear walls tests as well as full scale RC frame tests with excellent results, manifested in achieving the target performance with minimum cost and intrusion, as shown in Figure 2.

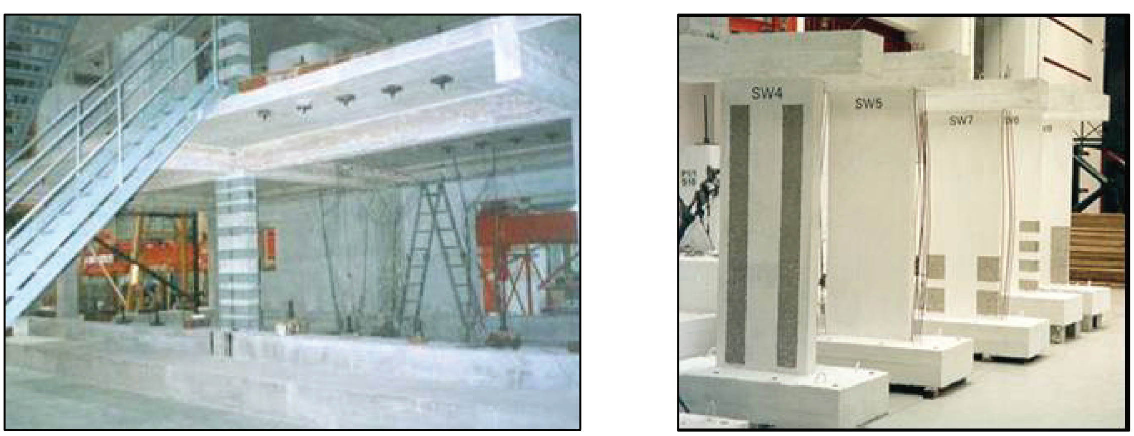

Figure D-2 Application of selective intervention on RC walls and full scale frame

Considerable analytical work has also been undertaken to enhance tools of seismic performance evaluation as well as to advance their application in a framework of performance targets For example, refined methods of deriving fragility relationships by using adaptive pushover analysis alongside defining the hazard per limit state have been derived and tested. Analytical and experimental work aimed at deriving criteria for performance-based design of foundations to match structural limit states has also been undertake. In short, since Eurocode 8 is a performance-based design document, European research has been focusing on the explicit definition and means to satisfy performance objectives under earthquake loading.

Focus of Mid-America Earthquake Center's Research Relative to FEMA 349 Action Plan for Performance Based Seismic Design

Daniel P. Abrams,
Willett Professor of Engineering and Director
Mid-America Earthquake Center University of Illinois at Urbana-Champaign

Abstract

The Mid-America Earthquake Center was founded in 1997 with a mission to address the infrequent, high-consequence earthquakes common to the central and eastern United States. The primary target for MAE research is the development of new methodologies that can be utilized by practitioners and their non-expert stakeholder clients for estimating probable losses and consequences of severe seismic events. Because many civil infrastructure systems in the eastern half of the United States have not been engineered to resist seismic shaking, one pertinent role of the center is to develop mitigation strategies for reducing seismic vulnerability of existing construction through rehabilitation. This is done through a central paradigm known as Consequence-Based Engineering (CBE) which implicitly considers losses across respective stakeholder systems in the engineering process.

MAE research is directed towards refinement of methods for estimating damage and consequences across regions. A series of research projects are being done to improve or develop methods for: (a) collecting inventory information on the built environment of a selected region, (b) estimating dynamic response of structures with simplified approaches, (c) approximating vulnerabilities or fragilities of specific types of construction, (d) determining vulnerabilities of network systems, (e) estimating socio-economic impact and (f) assessing overall seismic risk. All of this research is coordinated under the banner of "damage synthesis." Research projects are done in a generic manner so that results can be extrapolated to multiple, diverse stakeholder groups. Research results are synthesized using an advanced visualization module known as "MAEVIZ".

Other research is done to identify optimal solutions to minimize consequences from future earthquakes and includes projects on: (a) how decisions are made with respect to seismic intervention, (b) what levels of consequences are acceptable to various stakeholder groups, (c) how to establish optimal rerouting or retrofit strategies for network systems or building structures, (d) how to minimize losses and risk through better land-use planning practices and (e) how a multi-hazard approach to reducing consequences can be used. As well, fundamental scientific research is done to better understand and model the earthquake hazard in the central United States.

MAE research, driven by an interdisciplinary emphasis, takes a wider vision towards development of new engineering approaches, while the FEMA plan is more focused on individual structural systems. Yet, MAE stakeholder-specific research has produced products that can be used to augment development done under the FEMA 349 plan with respect to performance of bridge and building structures and their non-structural components.

Much more information on these concepts can be found on the MAE Center website at: http://mae.cee.uiuc.edu.

A Methodology Framework for Performance-Based Earthquake Engineering and Related Research by the Pacific Earthquake Engineering Center

Greg Deierlein
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Abstract

Efforts are underway in Pacific Earthquake Engineering Research (PEER) center to develop a performance-based earthquake engineering methodology for buildings and bridges. The performance assessment process is described through four generalized variables that characterize information from the relevant scientific and engineering disciplines in a logical and consistent manner. One variable is a ground motion *Intensity Measure*, which is determined through a probabilistic seismic hazard analysis and is often described by a seismic hazard curve for spectral acceleration or other quantity. Next, nonlinear computer simulations are used to determine response of a facility to earthquake ground motions. Output from these simulations is defined in terms of *Engineering Demand Parameters*, which may consist of interstory drifts, floor accelerations, local ductility demands, or other engineering response quantities. *Engineering Demand Parameters* are then related to *Damage Measures*, which describe the physical damage to the structure and its components. Damage states are delineated by their consequences or impact on *Decision Variables*, consisting of dollar losses (repair and restoration costs), downtime, and casualty rates. A key aspect of the methodology is consistent representation and tracking of uncertainties in predicting performance metrics that are relevant to decision making for seismic risk mitigation.

In addition to summarizing the proposed methodology, the presentation will highlight accomplishments and ongoing research by PEER that relate to the ATC 58 effort.

Appendix E: Straw Work Plan

ATC-58 Performance-based Seismic Design Guidelines
Radisson Miyako Hotel
San Francisco, California
Feb 24-25, 2003
Straw Work Plan

Table of Contents

E.1 Introduction

E.1.1 General

The Federal Emergency Management Agency (FEMA) has entered into a contract with the Applied Technology Council to develop a next-generation of performance-based seismic design guidelines, applicable to the design of new buildings and to the seismic retrofit of existing buildings. This program is planned to be a multi-year interdisciplinary effort that will provide reliable and practical guidelines that will permit the design of building structures, as well as their nonstructural components and critical systems and contents, to reliably provide desired levels of performance in future earthquakes. It also includes the development of tools that will enable regulators as well as individual building owners, investors and tenants to make decisions as to appropriate acceptable levels of performance for various buildings.

On a preliminary basis, the project is planned to follow the general outline presented in the *FEMA-349 Action Plan for Performance-based Seismic Design*. However, the project will not include any direct research components, such as testing of structural or nonstructural components, nor does it directly include the broad educational components contained in the original FEMA-349 document. Instead it will include the development of:

- protocols that may be used by others to qualify the performance capability of specific structural systems and nonstructural components,
- methods for characterizing performance in a way that is meaningful to stakeholders as well as designers,
- analytical tools and procedures that can be used to predict the performance of individual building structures and their nonstructural components in terms that are meaningful to stakeholders
- procedures and tools for the design of buildings to achieve desired performance
- procedures and tools for determining appropriate minimum performance for specific buildings or broad classes of buildings
- guidelines for use by various stakeholders in determining appropriate performance criteria for buildings
- guidelines for use by design professionals in performing designs intended to achieve specified performance criteria
- prescriptive criteria that may be used for the design of selected classes of structures to achieve specified performance criteria

The project is currently being funded in annual increments. In the first year, the project developed a project management structure, retained key members of the project management team and an oversight committee, and performed a preliminary task to determine how best to characterize and communicate performance as a basis for design. The project has recently initiated a second year, in which it will continue to develop tools for characterizing performance and begin the process of developing tools for quantifying performance and also to develop this overall project work plan, which will provide the basis for project tasks performed in future years.

The current state of the art contains valuable and practical information that has been implemented on some individual projects. In addition, substantial research applicable to the development of performance-based seismic design has been conducted by the United States Geologic Survey, by the three national earthquake engineering research centers, funded by the National Science Foundation, as well as by individual researchers in the United States and abroad. A goal is to use this information where possible, filling in the gaps with new evaluation methods and identifying where further research is required.

The project is intended primarily to address the performance-based design of buildings to resist earthquake effects. However, it is recognized that parallel development of performance-based criteria for the design of structures to resist fire, blast and other extreme loads is concurrently being developed and that much of the technology applicable to performance-based design for these various hazards is broadly applicable. It is intended to develop the performance-based seismic design criteria so that it is compatible with and transportable to parallel performance-based design procedures for these other hazards

E.1.2 Purpose

When completed, this Draft Work Plan will state the basic tasks and budget allocations to be used by the ATC-58 project to develop performance-based seismic design guidelines. The primary purpose of this document is to define the tasks and resources necessary to perform those tasks that will be directly performed by the ATC-58 project. A secondary purpose is to identify those tasks which must be performed by others to support the fulfillment of the projects goals and objectives.

E.1.3 Organization

This document is, as its name implies, focuses on the specific tasks that must be accomplished to develop performance-based seismic design guidelines, together with those tools necessary to encourage its appropriate implementation. The Plan centers about development of six "products." Each contributes to meeting a specific portion of the primary goal. The term "product" does not refer exclusively to written documents, but implies tools, procedures, guidelines and educational means by which these tools and procedures may be communicated to the end users. These product categories are as follows:

E.1.4 Planning and Management Program

The planning and management program includes the establishment of a project management structure for the project to conduct the overall planning and management tasks.

E.1.5 Structural Performance Products

The Structural Performance Products will quantify methods for predicting structural performance considering the range of seismic hazards. They will contain design and evaluation methodologies for both new and existing buildings. A focus of the development will include the characterization of reliability in the design and analysis process, so that the inherent uncertainties may be directly quantified and so that as advances in relevant science and technology occur, the resulting reductions in uncertainty may be recognized. Effort will be made to address existing as well as new construction. Early in the development of this product, an effort will be made to address the current state of the art and inherent uncertainties and gaps therein, and from that identify research needs and goals appropriate to reducing these uncertainties and gaps.

E.1.6 Nonstructural Performance Products

The Nonstructural Performance Products function similar to the Structural Performance Products but focus on the nonstructural components of a building: partitions, piping, equipment, contents, etc. The Nonstructural Performance Products will address new components and components already in place within existing buildings. Development of guidelines for component testing and certification will be part of these products. The goals and scope of separately funded programs to collect information on performance in past and future earthquakes and to test equipment will also be developed. Similar to the SPP, an initial effort will be made to assess the state of the art and develop a research plan.

E.1.7 Risk Management Products

The Risk Management Products will be financially oriented and will develop methodologies for calculating the costs and benefits of designing to various performance criteria. A major effort will be to combine various levels of risk, performance and hazard to allow a wide range of design objectives to be evaluated as potential bases for new procedures. Studies will include consideration of reliability, cost-benefit modeling, loss reduction, capital planning, etc. A focus will be to provide owners with tools that can reliably be used to select appropriate performance objectives for projects. The information produced in the RMP should also serve as the basis for the development of a building rating system.

E.1.8 Performance-Based Seismic Design Guidelines

The Guidelines will be the actual document(s) containing the performance based design procedures. It is intended that this document(s) will be published as FEMA guidelines and can be incorporated into future codes and practice. The documents will form the technical basis for design and analysis and be written to bring consistency throughout the industry. The Guidelines will be usable for both new design and existing building retrofit and will also contain technical commentaries.

E.1.9 Stakeholders Guides

These documents will function as reference and planning guides for regulators, owners, financial interests and other stakeholders. The documents will include tools that permit regulators to select appropriate minimum performance-criteria for use as the basis of prescriptive building codes as well as for owners to make financial decisions about buildings using performance based design concepts. The guides will be written for a non-technical audience and contain graphic aids and example applications

E.2 Planning and Management Program

E.2.1 Objective

The objective of the planning and management program is to establish an effective project organization for conducting the work outlined in this plan to develop performance-based seismic design guidelines and to conduct the project in an efficient and expeditious manner.

E.2.2 Overview

Overall planning and management of the project will be conducted by a Project Management Committee, assisted by a series of three product development teams: Structural Performance Products Team, Nonstructural Performance Products Team, and Risk Management Products Team. Each team will be headed by a team leader. In addition the team will have a number of team members and may have a series of consultants who work as part of the team to perform specific development tasks. The Structural Performance Products Team and Nonstructural Performance Products team will work together to develop the Performance-based Seismic Design Guidelines. The Risk Management Products team will develop the Stakeholders Guides.

The entire project will be conducted under the oversight and with the consultation of a Project Steering Committee. The Project Steering Committee will be selected to broadly include representatives of pertinent stakeholder communities including engineering researchers, engineering practitioners, regulators, institutional building owners, developers, lenders, insurers and corporations.

Figure 1 presents a project organization chart for the project. Following sections describe the Project Management and Project Steering Committees. Product development teams are described in the chapters relating to each Product Development area.

E.2.3 Task 1.1 Project Management Committee

The Project Management Committee (PMC) will be composed of the Applied Technology Council Executive Director, who will serve in the role of Project Executive Director, a Project Technical Director, a representative of the Applied Technology Council Board of Directors and three at-large members. It is intended that together, the Project Management Committee be composed of individuals with expertise in guidelines development, performance-based design, earthquake engineering research, building regulation, and policy development and decision making. Management of the project will be performed on a consensual basis with all member of the Project Management Committee provided an opportunity to identify issues, suggest solutions and vote on appropriate courses of action. The PMC will meet at approximately 6-8 week intervals throughout the project, with more intense activity occurring during the active selection of project participants and the production of project products and deliverables.

The Project Management Committee will be responsible for developing the project work plan including identification of specific tasks to be performed, their associated budgets, interrelationships and scheduling. The Project Management Committee will select project personnel and approve all project consulting contracts. It will also be responsible for guiding and monitoring the technical and administrative progress of the project and for developing progress reports to FEMA.

Personnel: Applied Technology Council Executive Staff and Directors, Leading representatives of earthquake engineering practice, research, social science and regulation

Budget: $1,200,000

Duration: Throughout the project

Project Steering Committee

The Project Steering Committee will serve as an advisory body to the PMC and will provide diverse perspective on key technical issues and conduct of the project, including the making of recommendations pertaining to the identification of needed products, the selection of project personnel, timetables for various activities, and technical and content review of documents produced under the project. The Project Steering Committee will be comprised of leading engineers, regulators, researchers and representatives of key stakeholder groups.

Personnel: Design professionals, Researchers, Contractors, Material suppliers, Financial interests, Owners, Building officials, Government agencies

Budget: $750,000

Duration: Throughout the project

E.2.4 Product Team Leaders

Product team leaders will be selected for each of the Structural Performance Products Team, the Nonstructural Performance Products Team and Risk Management Products Team. In addition, a Guidelines Development Team leaders will be retained. Team leaders will have broad knoweldge and practical experience in earthquake engineering aspects of the paticular team's subject area and will be acknolwedged leaders in their fields. The Team Leaders will be responsible for developing detailed work plans in their respective areas of product development, for recommending personnel and consulants to fill project team positions and to provide technical leadership of the tasks in each of the three product areas. It is anticipated the Structural Performance Proudcts Team Leader, Nonstructural Performance Products Team Leader and Risk Management Products Team Leader, in addition to leading their individual product development teams will also serve as members of the Guidelines Development team.

Personnel: Design Professionals with extensive experience in structural performance, nonstructural performance and risk management.

Budget: $1,300,000

Duration: Throughout the project

E.3 Structural Performance Products

E.3.1 Objective

These products will form the core technical basis for the predicting the structural performance of buildings. They will include three main areas of focus:

- *Methodologies for quantifiably and reliably defining structural performance and acceptability criteria on a building and component basis.*

  This effort will define structural performance in terms of probable damage, occupancy and life losses, and develop engineering demand parameters (force, drift, dissipated energy, etc.) that can be used to predict these outcomes for various structural systems. The work will synthesize the results of analytical and experimental data. It will consider the variability and uncertainties involved, with the goal of obtaining reliable estimates of building structural performance.

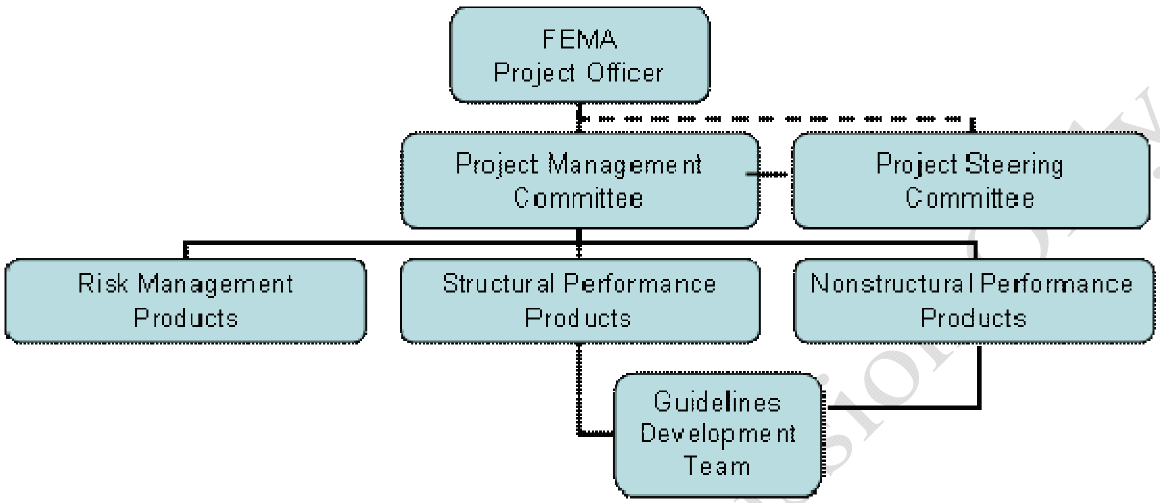

Figure E-1 Project Organization

- *Analytical and design procedures by which engineers can predict a building's expected performance with well defined reliability.*

  Performance engines will need to be developed to permit structural evaluation by the entire engineering community. It is important that they be sophisticated, but broadly usable. Methodologies need to be developed for design of new and retrofit of existing buildings. Techniques need to account for current computer technology that is widely available and that which can be expected in the future.

- *Tools that can more reliably predict and appropriately quantify expected ground motions.*

  These tools will characterize the seismic demand requirements for linear and nonlinear analyses, using response spectra and time-histories. Ground motion parameters that correlate to performance will be identified and quantified. Simplified representations of these parameters into static base shear and lateral force distribution formulas will also need to be developed. Issues of reliability, uncertainty and confidence levels need to be incorporated into the determination and effects of ground motion. The information will have to be flexible enough to be used by a wide audience. A procedure for data collection through instrumentation will be developed.

E.3.1 Task 2.1 Identify Current Performance-Based Design Information and Additional Research Needs

The team will gather existing information on structural analysis and design methods and identify gaps in current knowledge. A strong effort will be made to use available information so that research funding can be most efficiently spent. The current state of the art should not define the scope of this project or limit the direction research might take, but rather allow researchers to avoid unnecessary duplication of effort. The team will also assess the usefulness of available information on material performance, component acceptability, geotechnical parameters and hazard quantification. An effort will be made to characterize the reliability of existing procedures and information.

Personnel: Design professionals, Researchers

Budget: $100,000

Duration: 1 year

E.3.2 Task 2.1.1 Develop Research Plan

Once gaps in existing knowledge have been identified, the group will develop a research plan to fill them. The goal will be to develop a road map of research needed to accomplish a fully developed performance-based design criteria for structural systems. The plan will be detailed enough to be used by stakeholders, laying out tasks and schedules. An effort will be made to identify outside sources of funding to augment the budgets assigned to each task within the Plan, considering public and private resources.

Personnel: Design professionals, Researchers,

Budget: $100,000

Duration: 1 year

E.3.3 Task 2.2.1 Structural Performance Characterization

The team will reach consensus on the definitions of structural performance to be used as the basis for performance-based design. These characterizations will be quantified in a later task. The goal in this task is to agree on concepts such as life safety, immediate occupancy, etc. The team will decide what these terms mean in relation to casualties, down time, and other important parameters. Reaching a firm decision on performance definitions is critical to the rest of the project. It therefore must incorporate the opinions of all stakeholders. Meetings among stakeholder groups will be held to determine which measures of performance are considered the most important and how they relate to analytically predictable behavior. These performance measures will later be coupled with hazard information from Task 2.3, to obtain performance and overall design criteria.

Personnel: Design professionals, Researchers, Owners, Building officials, Government agencies, Financial interests

Budget: $250,000

Duration: 2 years

E.3.4 Task 2.2.2 Develop Structural Acceptance Criteria

The team will gather and review existing information on applicable engineering demand parameters and acceptance criteria, and identify gaps in current knowledge. Research will be targeted to fill in these gaps and will include both analytical and empirical processes. Collaboration with testing programs will be important to obtain useful information on component behavior.

A strong effort will be dedicated to extrapolating component behavior, which is more clearly known, to building behavior, which currently contains more uncertainty. A goal will be to identify and quantify in practical terms criteria for overall building performance.

Personnel: Engineers, Researchers, Material suppliers

Budget: $1,000,000

Duration: Throughout the project

E.3.5 Task 2.2.3 Develop Geotechnical Predictors of Building Performance

The team will gather and review existing information on the effects on building performance of subsurface conditions and appropriate engineering parameters to quantify these effects. These will include the effects of foundations, soils, and soil-structure interaction. The team will identify gaps in current knowledge. Research will be targeted to fill in these gaps and will include both analytical and empirical processes. A strong effort will be dedicated to identifying ways to reduce uncertainties related to geotechnical and substructure analysis and design.

Personnel: Engineers, Researchers, Material suppliers

Budget: $500,000

Duration: Throughout the project

E.3.6 Task 2.2.4 Quantify Structural Performance Levels

Using the definitions developed in Tasks 2.2.1 and 2.2.2, the team will quantify performance levels using appropriate parameters (drift, damage, loss, business interruption, casualties, etc.). The goal in this task is to set the performance parameters so that the evaluation and design methodologies developed in the PBSD Guidelines product can be targeted to definitive numerical quantities.

Personnel: Engineers, Researchers, Government agencies, Building officials,

Budget: $600,000

Duration: Throughout the project

E.3.7 Task 2.2.5 – Develop and Validate Analytic Methodologies for Achieving Performance Levels

The team will fill in the key gaps in existing knowledge identified in Task 2.1.1. Research will consist primarily of analytical efforts and development of practical tools. The team will identify promising new techniques and devote research to making them usable within the PBSD framework. A forum will be held, bringing together engineers and building officials to discuss design and analysis methodologies. The purpose of this activity is to understand the broad range of engineering styles used throughout the country.

Following this, the team will develop design and analysis methodologies, which will be usable by the entire design community. A focus will be on developing comprehensive and accurate methods that can be refined and made more practical within the Guidelines product. The methods will include consideration of geotechnical conditions and design of foundations as well as methods for practical assessment of reliability and safety. Modeling strategies will also be developed in this task. The team will keep in mind the limitations of computer applications currently available and anticipated in the future.

Personnel: Engineers, Researchers

Budget: $1,250,000

Duration: Throughout the project

E.3.8 Task 2.2.6 – Develop Analytical Predictors of Existing Building Structural Performance

This effort will proceed in a similar manner to Task 2.2.5, but will focus on existing buildings. The team will research successful examples of retrofit and identify features that should be employed typically. It will quantify uncertainties within the existing built environment.

Personnel: Engineers, Researchers (Material suppliers)

Budget: $1,000,000

Duration: Throughout the project

E.3.9 Task 2.3 – Develop Hazard Quantification and Prediction Methodologies

The team will develop processes to obtain ground motion information for use in Performance-based Seismic Design. It will identify and describe in measurable terms the parameters of ground motion which have the most important effects on buildings. The team will create a standard for characterizing ground motion and will include issues of damping, nonlinearity, and duration effects. The team will develop rules for applying ground motion information, to create uniformity of use. Working with members of the earth sciences community, the team will put substantial effort into understanding, quantifying and building a consensus on the effects of edges and basins, soft soils, soil-structure interaction and near-fault ground motion. Similarly, methods to quantify the amount of and consequences of permanent ground displacement will be developed. Close collaboration with, and additional funding by USGS is assumed.

Personnel: Engineers, Researchers

Budget: $500,000

Duration: Throughout the project

E.3.10 Develop Means to Check and Increase Reliability

The team will identify and quantify uncertainties in quantifying seismic hazards, building response and the variability of construction quality. This information will be developed in conjunction with the Risk Management Products, which will focus on the cost implications of these uncertainties. The team will research existing reliability techniques, identifying usable information and gaps. The team will use reliability theory to select and refine the design events and material acceptability. The team will develop simplified methods of reliability analysis, or identify software needs, understandable and usable by engineers. These may include equations, fragility curves for building classes and performance levels, and other tools to help the engineer prepare a design with a defined level of reliability and confidence. The team will also evaluate and reach consensus on appropriate target levels of reliability for specific performance levels (such as life safety or immediate occupancy) and for various building classes and uses.

Personnel: Researchers, Engineers, Financial interests

Budget: $1,000,000

Duration: 5 years

E.3.11 Establish a Framework for Materials and Component Testing

The team will develop testing protocols for obtaining and cataloguing information on the performance capability of various structural systems. Close collaboration with NEES researchers and the NEES Inc committee on data archival is assumed.

Personnel: Design professionals, Researchers, Materials suppliers

Budget: $150,000 (does not include testing)

Duration: 3 years

E.3.12 Task 2.6 – Prepare Documents and Reports for Use in Performance-Based Design Guidelines

This task will occur at milestones within the research plan developed in Task 2.1.2 and in preparation for each of the Guidelines development phases. The team will gather the technical information and prepare reports and documents for the writers of the Guidelines. Coordination with the risk management products and nonstructural performance products will occur to insure that information is presented in a consistent manner. Once the Guidelines teams have reviewed the work and identified changes or refinements to the research plan, this team will work with the research team for Task 2.1.2 to set out the goals for the next phase of research.

Personnel: Engineers, Researchers, Material suppliers, Building officials, Government agencies

Budget: $500,000

Duration: Throughout the project

E.4 Nonstructural Performance Products

E.4.1 Objectives

These products will form an important reference component of the performance-based seismic design guidelines. They will include information similar to that developed in the Structural Performance Products, but relating to nonstructural building components. They will also include the following concentrations:

- *Prediction of the demands on nonstructural components and the evaluation of their performance under these demands*.

  Just as forces on a structure are developed due to ground shaking and are affected by the interaction between the soil and the structure, nonstructural component demands are developed due to the building shaking and are affected by the interaction between the structure and the components. It will be necessary to study and develop methods by which these demands can be predicted. It will also be important to develop techniques for evaluating the performance of the components under these demands.

- *Testing and certification programs to bring uniformity to the design of manufactured components.*

  More so than buildings, modeling of nonstructural performance is difficult at best and needs to be supplemented with testing. The testing program will have to be broad enough to account for the placement of equipment and contents in different areas within various building types. It will also need to allow certification of equipment and contents bracing for an expected performance objective.

- *Post-earthquake data acquisition and analysis.*

  A detailed plan is needed for acquiring and analyzing performance data from future earthquakes. The nature of this data needs to be defined. Following a major earthquake, the data will be processed and compared to the Guideline provisions. The Guidelines will be modified in future editions by using lessons learned from performance of nonstructural components.

- *Evaluation of nonstructural components in existing buildings*

  In addition to developing procedures for the installation of nonstructural elements in new buildings, it will be important to devise methods for assessing and increasing the performance of components already installed within existing buildings.

The nonstructural performance products will be developed by a team of design professionals, scientists, equipment manufacturers and researches expert in the behavior of nonstructural components. Testing agencies will be employed as part of the certification program. User groups will be brought in to develop goals and strategies and to assist in the verification process.

Successful development of the NPP will require outside funding of testing. A comprehensive program will cost millions of dollars and will be an ongoing effort. Funding identified herein must be augmented by research dollars provided by industries and manufacturers which have a stake in the performance of nonstructural systems. Table E-1 below presents a summary schedule for the proposed tasks which are further described in following sections.

E.4.2 Task 1 – Review and Revise Action Plan for Nonstructural Work Products

Under this task, the specific work products and deliverables for the nonstructural work products area are to be identified along with the tasks necessary to develop the deliverables, estimated budgets, task durations and task interdependencies. These will be incorporated into an updated *Action Plan.*

Deliverables: Tasks, task schedules, task budgets, identification of who will perform the tasks, task interdependencies and deliverables.

Personnel: NPP Product Team (Bachman, Bonnowitz, Kennedy and McGavin)

Start Date: Jan. 17, 2003

Finish Date: Dec. 26, 2003

Task Interdependency: Need workshop to occur on Feb. 24-25, Completion of *Action Plan* is dependent on completion of this task.

Budget this Phase: $ 15,000 (does not include workshop costs)

Table E-1 Summary of Proposed Budget Yearly Distribution by Task for Nonstructural Performance Products (Budgets in thousands of $)

Task	2003	2004	2005	2006	2007	2008	2009	2010	Total
1	15								15
2	15								15
3		150	150	50					350
4		100	100	100					300
5		50	50	50					150
6		150	100						250
7			150	150					300
8			200	200	200	200	200		1000
9			150						150
10			200	200	200	250			850
11			40	40	40	30			150
12			300						300
13								300	300
14							150	150	300
15				100	100	100	100	100	500
Total	30	450	1140	1190	540	580	450	550	4930*

*The total is $ 330 K higher than the total in *FEMA-349* because Tasks 1 and 2 have been added ($ 30 K) and Task 14 (*FEMA-349* Task 5.5) has been shifted from the Guideline Products to the NPP Products ($ 300 K).

E.4.3 Commence Process of Quantifying Nonstructural Performance Levels (initiation of Task 3.2.1 of FEMA-349)

This task initiates the process of developing a basic performance prediction tool that can be used to quantify the performance of nonstructural building components, subjected to earthquake hazards. This initial effort will consist of performing a brief literature search of the Engineering Demand Parameters (EDPs) that have been suggested by various researchers and engineers as appropriate to characterize the performance of different building components. These EDPs may include floor acceleration, interstory drift, ductility demand, cumulative dissipated energy demand, floor response spectra, standardized floor response time histories, or other similar parameters. These EDPs may be different for the several types of nonstructural components. This work will be extended into future phases of the project during which communications will be made for the preferred EDPs for use in performance-based engineering analysis of building components and non-structural systems.

Deliverables: Preliminary Nonstructural EDP Report

Personnel: NPP Product Team (Bachman, Bonnowitz, Kennedy and McGavin) in part from input from the Feb. 24-25 ATC-58 Workshop Attendees and PEER annual meeting breakout session

Start Date: Jan. 17, 2003

Finish Date: Dec. 26, 2003

Task Interdependency: Need workshop to occur on Feb. 24-25

Budget this Phase: $ 15,000 (does not include workshop costs)

E.4.4 Task 3 – Continue Process of Quantifying Nonstructural Performance (Levels Continuation of Task 3.2.1 of FEMA-349)

This task continues the process of developing a basic performance prediction tool that can be used to quantify the performance of nonstructural building components, subjected to earthquake hazards. Engineering Demand Parameters (EDPs) that have been suggested by various researchers and engineers as appropriate to characterize the performance of different building components will continue to be evaluated. These EDPs may include floor acceleration, interstory drift, ductility demand, cumulative dissipated energy demand, floor response spectra, standardized floor response time histories, or other similar parameters. These EDPs may be different for the several types of nonstructural components. This work will be extended into future phases of the project during which communications will be made for the preferred EDPs for use in performance-based engineering analysis of building components and non-structural systems.

Working with the performance definitions developed in the structural performance products, the team will also quantify nonstructural performance levels using appropriate EDPs (drift, damage, loss, business interruption, casualties, etc.). The overall goal in this task is to set the performance parameters so that the evaluation and design methodologies developed in later tasks can be targeted to definitive numerical quantities.

Deliverables: Nonstructural EDP Report, Nonstructural Performance Levels and their relationship to the EDPs.

Personnel: 8 person team of Design Professionals, Researchers, Material Suppliers(government agencies) and 1 consultant.

Start Date: Jan. 1, 2004

Finish Date: Dec. 26, 2006

Task Interdependency: Tied to identification of components and SPP performance level definitions.

Budget for 2004: $150,000

Budget for 2005: $150,000

Budget for 2006: <u>$50,000</u>

Task Total: = $350,000

E.4.5 Task 4 – Develop Demand Prediction Methodologies (Task 3.2.2 of FEMA-349)

The team will develop processes to calculate the demands on nonstructural components based on their location within various building types. It will identify and describe in measurable terms the parameters that have the most important effects on these demands (height above grade, building stiffness, building non-linear behavior, anchorage, etc.). The goal is to be able to extrapolate from the basic building acceleration, velocity and displacement characteristics, the effects on nonstructural components.

Deliverables: Nonstructural Demand Prediction Report

Personnel: 8 person team of Design Professionals, Researchers, Material Suppliers(government agencies) and 1 consultant.

Start Date: Jan. 1, 2004

Finish Date: Dec. 26, 2006

Task Interdependency: Tied to identification of components and establishment of EDPs.

Budget for 2004: $100,000

Budget for 2005: $100,000

Budget for 2006: $100,000

Task Total: = $300,000

E.4.6 Task 5 – Develop Non-Building Dependent (Generic) Demand Prediction Methodologies (New Task)

The team will develop processes to calculate the demands on nonstructural components that envelope the full spectrum of locations within a building and the full range of types and sizes. This will build upon the work developed in Task 4. The goal is to develop numerical quantities of the EDPs for non-structural components without the need for specific knowledge of the structure. This will allow generic evaluation of nonstructural components by analysis or test without the need to specifically determine the building response prior to performing such evaluations.

Deliverables: Nonstructural Non-Building Dependent (Generic) Demand Prediction Report

Personnel: 4 person team of Design Professionals, Researchers, and 1 consultant.

Start Date: Jan. 1, 2004

Finish Date: Dec. 26, 2006

Task Interdependency: Tied to develop of EDP prediction methodologies and provides input to testing protocols.

Budget for 2004: $50,000

Budget for 2005: $50,000

Budget for 2006: $50,000

Task Total: = $150,000

E.4.7 Task 6 – Identify Nonstructural Components and Their Impacts on Performance (Task 3.1.1 in FEMA-349)

The team will identify the various types of nonstructural components and systems that are vulnerable to loss. It will utilize existing efforts in this area. In addition to looking at individual components, a goal will be to understand how the components fit together into systems (i.e. pumps and fans are parts of a chiller system), and what the effects of damage to one component means to the system. Identifying weak links in systems is important. The team will then identify what systems are typically present in various building types, and what the weak links are when considering overall building performance. The team will take advantage of the work done in FEMA 412.

Another focus of this task will be to identify the scope of the Nonstructural Performance Products. The team will determine the detail with which issues of design, installation and maintenance of nonstructural components will be evaluated.

Deliverables: Report on the identification of nonstructural components of significance and a scoping report on the issues to be evaluated in this project.

Personnel: 8 person team of Design Professionals, Researchers, Material Suppliers and 1 consultant.

Start Date: Jan. 1, 2004

Finish Date: Dec. 26, 2005

Task Interdependency: Tied to development of EDPs and prediction methodologies and overall scope of this project for nonstructural components

Budget for 2004: $150,000

Budget for 2005: $100,000

Task Total: = $250,000

E.4.8 Task 7 – Evaluate Effectiveness of Current Nonstructural and Contents Installation Standards and Practices (Task 3.1.2 in FEMA-349)

With the list of components and systems from Task 6, the team will identify information on performance in past earthquakes. It will catalogue and quantify performance of components and systems by themselves and in relation to overall building performance, in terms of capital and contents loss and down time. The team will compare the effectiveness of different designs of the same components. Issues which play the greatest role in performance will be prioritized (i.e. anchorage design vs. installation quality, equipment ruggedness, etc.). A goal will be to assess the current state of the art and identify gaps in existing knowledge.

Deliverables: An assessment report on the current state of the art on the design and installation standards and practices for nonstructural performance and the historical seismic performance of these installations.

Personnel: 8 person team of Design Professionals, Researchers, Material Suppliers and 1 consultant.

Start Date: Jan. 1, 2005

Finish Date: Dec. 26, 2006

Task Interdependency: Tied to Task 6 and to development of NPP Analysis Methods

Budget for 2005: $150,000

Budget for 2006: $150,000

Task Total: = $300,000

E.4.9 Task 8 – Establish Comprehensive Testing and Certification Protocols (Task 3.3.1 of FEMA-349)

The team will catalogue all relevant testing information to date. It will identify gaps in this knowledge with respect to nonstructural component effects on building performance. Research programs will be developed and established to fill these gaps.

A distinction will be made between component "ruggedness:" the ability of the piece of equipment to stay together in a functional black box, and "anchorage:" the ability of the equipment to remain where it was installed.

The team will identify *sources of funding* for extensive testing. These sources will include equipment manufacturers, owners, insurers, government agencies, etc. This may include developing collaborative efforts between equipment buyers and equipment manufacturers, for example. The team will develop a consensus on the technical description of testing protocols. The team will develop a means of obtaining certification of tested equipment for various seismic regions, building types and usage, and locations within buildings. If financially feasible, some testing should be conducted within this task to calibrate certification parameters.

Deliverables: Needs analysis and Comprehensive Testing and Certification Protocols

Personnel: 8 person team of Design Professionals, Researchers, Material Suppliers and 1 consultant.

Start Date: Jan. 1, 2005

Finish Date: Dec. 26, 2009

Task Interdependency: Dependent on partial completion of Tasks 4, 5 and 6.

Budget for 2005: $200,000

Budget for 2006: $200,000

Budget for 2007: $200,000

Budget for 2008: $200,000

Budget for 2009: $200,000

Task Total = $1,000,000

E.4.10 Task 9 – Develop a Research Plan to Advance the State-of-the-Art (Task 3.1.3 of FEMA-349)

Once gaps in existing knowledge have been identified, the group will develop a research plan to fill them. The goal will be to develop a road map by which the tasks within this *Action Plan* can be accomplished. The plan will be detailed enough to be used by stakeholders, laying out tasks and schedules. An effort will be made to identify outside sources of funding to augment the budgets assigned to each task with the Plan, considering public and private resources.

Deliverables: Research plan to advance the state-of-the-art and identification of funding sources for research

Personnel: 6 person team of Researchers, Design Professionals, Material Suppliers and 1 consultant.

Start Date: Jan. 1, 2005

Finish Date: Dec. 26, 2006

Task Interdependency: Dependent on partial completion of Tasks 6, 7 and 8

Budget for 2006: $150,000

Task Total: = $150,000

E.4.11 Task 10 – Develop Analytic Methodologies for Achieving Performance Levels (Task 3.2.3 of FEMA-349)

The team will fill in the gaps in existing knowledge identified in earlier tasks. Research will consist primarily of analytical efforts. The team will identify promising new techniques and devote research to making them applicable to the performance-based seismic design framework. A forum will be held, bringing together design professionals and manufacturers to discuss design and analysis methodologies.

Following this, a strong effort will be made to develop design and analysis methodologies, consistent with the efforts in the structural performance products.

A focus will be on developing modeling or other techniques to lend consistency to design and analysis. Modeling will account for the range of computer applications currently available and anticipated in the future. It will also account for the financial investments various design engineers are able to make in obtaining modeling technology.

Deliverables: Design and analysis methodologies/Design Application Report

Personnel: 6 person team of Design Professionals, Researchers, Material Suppliers and 1 consultant.

Start Date: Jan. 1, 2005

Finish Date: Dec. 26, 2008

Task Interdependency: Dependent on partial completion of Tasks 4, 5, 6, 7 and 8

Budget for 2005: $200,000

Budget for 2006: $200,000

Budget for 2007: $200,000

Budget for 2008: $250,000
$850,000

E.4.12 Task 11 – Coordinate Design and Analysis Methods with SPP (Task 3.2.4 of FEMA-349)

The team will compare the design and analysis methods of the structural performance products and nonstructural performance products to ensure that they are compatible and that they lead to the same measures and prediction of performance. The team should check that the level of reliability is similar between the two and that structural and nonstructural performance measures can be combined to form overall performance goals for buildings. The team will also make a focused effort to describe the functions of the performance products in relation to the overall goal of performance-based seismic design and of the guidelines. A task will be to describe building behavior from both points of view in technical and financial terms and identify where structure and nonstructural components overlap or come in conflict.

Deliverables: Annual Coordination Report and Overall Building/Contents Behavior Report.

Personnel: 4 person team of Design Professionals, Researchers, Material Suppliers and 1 consultant.

Start Date: Jan. 1, 2005

Finish Date: Dec. 26, 2008

Task Interdependency: Dependent on partial completion of Tasks 11 and SPP methodologies.

Budget for 2005: $40,000

Budget for 2006: $40,000

Budget for 2007: $40,000

Budget for 2008: $30,000
$150,000

E.4.13 Task 12 – Establish a Postearthquake Data Collection and Analysis Program (Task 3.3.2 in FEMA-349)

The team will *establish* a program for collecting nonstructural performance information after an earthquake. This will be coordinated with the efforts in the structural performance products. Existing earthquake performance data will be reviewed for its usefulness and as appropriate will be assembled and catalogued into a database. The team will develop ways to distill and use this information and identify where gaps remain. A workshop will be held to identify the types of information that are the most valuable. The team will develop data collection forms, binders, instructions and databases in preparation for use. It will establish a methodology for creating and maintaining a team of inspectors and will hold seminars on a regular basis to train them. A focus will be to identify how the collected information will be used within the development and refinement of the PBSD Guidelines. The team will identify sources of funding for post-earthquake data collection, so that these groups may be approached in a timely fashion after a damaging event.

Deliverables: A postearthquake data collection and analysis program for nonstructural components

Personnel: 6 person team of Researchers, Design Professionals, Material Suppliers and 1 consultant.

Start Date: Jan. 1, 2006

Finish Date: Dec. 26, 2006

Task Interdependency: Dependent on partial completion of Tasks 6, 7 and 8

Budget for 2006: $300,000

Task Total = $300,000

E.4.14 Task 13- Establish a Program for Developing Innovative Nonstructural Design (Task 3.3.3 in FEMA-349)

The team will *establish* a program for encouraging manufacturer's to develop innovative nonstructural designs that take advantage of the performance- based criteria developed within this project. The team will identify sources of funding to implement this program. Implementation will include offering incentives for use, marketing the program and tracking its success.

Deliverables: A Report explaining to manufacturer's how to take advantage of the PBD criteria developed in this document

Personnel: 8 person team of Design Professionals, Material Suppliers and Owners, (Government Agencies) and 1 consultant.

Start Date: Jan. 1, 2010

Finish Date: Dec. 26, 2010

Task Interdependency: Dependent on partial completion of Tasks 1-11

Budget for 2010: $300,000

Task Total = $300,000

E.4.15 Task 14 – Develop a Plan for Verifying Nonstructural Component Design and Installation. (Task 5.5 In FEMA-349)

The team will develop a standard format for checking the adequacy of nonstructural component and system design, manufacture and installation. Much like peer review and inspection procedures for the structure, this system will be designed to track nonstructural elements through a similar process. The team will establish a system for identifying and training qualified inspectors and reviewers. The team will use the information developed in the nonstructural performance products to make easier reevaluation of existing components and determine expected performance.

Deliverables: Standard format for checking adequacy of nonstructural component system design, manufacture and installation.

Personnel: 8 person team of Design Professionals, Material Suppliers and Owners, (Government Agencies) and 1 consultant.

Start Date: Jan. 1, 2009

Finish Date: Dec. 26, 2010

Task Interdependency: Dependent on partial completion of Tasks 6, 7, 8 and 10

Budget for 2009: $150,000

Budget for 2010: $150,000

Task Total = $300,000

E.4.16 Task 15 – Develop Documents and Reports for Use in PBSD Guidelines (Task 3.4 of FEMA-349)

This task will occur at milestones within the research plan developed in Task 3.1.3 and in preparation for each of the Guidelines development phases. The team will gather the technical information and prepare reports and documents for the writers of the Guidelines. Coordination with the risk management and structural performance products will occur to insure that information is presented in a consistent manner. The team will coordinate verification studies to be run on the analysis and design methodologies. Once the Guidelines teams have reviewed the work and identified changes or refinements to the research plan, this team will work with the research team of Task 3.1.3 to set out the goals for the next phase of research.

Deliverables: Guideline Documents

Personnel: 8 person team of Design Professionals, Researchers, Material Suppliers, Building Officials, Government agencies and 1 consultant.

Start Date: Jan. 1, 2006

Finish Date: Dec. 26, 2010

Task Interdependency: Dependent on partial completion of Tasks 6,7,8 and 10

Budget for 2006: $100,000

Budget for 2007: $100,000

Budget for 2008: $100,000

Budget for 2009: $100,000

Budget for 2010: $100,000

Task Total = $500,000

E.5 Risk Management Products

E.5.1 Objectives

These products will provide information for the Stakeholders' Guide and the Performance-based seismic design Guidelines. The goal is to identify and develop procedures and tools by which performance-based engineering can deliver the most benefit to a wide variety of potential users. A central premise is that these procedures and tools must be customized to address the individual needs of the various types of users.

This effort is particularly critical since the performance-based approach differs significantly from traditional procedures and practices for evaluating and mitigating catastrophic risks. Decision makers in institutions and industry have previously dealt with such risks indirectly in the capital planning and management process. They rely on the design professions to implement the prescriptions of current codes and standards as acceptable protection against the perils of fire, earthquake, flooding, and other hazards. In some cases, insurance provides supplemental protection when deemed affordable or required by lenders. Investors and developers likewise assume that compliance with legal and financial imperatives is satisfactory consideration of such risks. Engineers, architects, and the construction industry are the prime influences on building codes and standards. One of their primary motivations is to formalize design and construction procedures for uniformity of application to projects. Most design and construction professionals are not accustomed to advising facilities owners and investors directly on the evaluation and management of catastrophic risks for specific projects. Similarly, building officials and regulators routinely use the prescriptive provisions of codes and standards to judge design acceptability. Performance-based engineering shows great promise for improving this overall process and providing society with better protection from catastrophic risks economically. But to do so implies some fairly radical changes for stakeholders and the design professions. This transition is further impeded by the fact that the benefits of performance based engineering are not obvious to most stakeholders.

In recognition of the current state of practice, the strategic development of risk management products requires three key steps.

- First, a fundamental understanding of stakeholder decision-making processes is essential to the successful implementation of performance-based procedures. To date, communication with stakeholders has tended toward presentation and explanation of performance-based concepts. Many stakeholders have difficulty in imagining how these can be applied to their day-to-day activities. Most of those who are developing and presenting performance-based concepts are unfamiliar with how stakeholders incorporate consideration of catastrophic risks into their investment and resource allocation decisions. The mechanism of communication will be a number of focus groups comprised of stakeholders that will essentially serve as consultants to the Risk Management Products team through the project (see Task RMP-1).
- Based on this understanding, the continued development of the overall performance framework (see Task RMP-2) will result in a **set of performance characterization options**. It is important to continue to illustrate the inter-relation among various parameters and options (discrete performance milestones vs. continuum, deterministic vs. probabilistic, etc.). The same basic underlying information on hazard and fragility can be cast in many different ways to meet the needs and preferences of the decision maker.
- Finally, the risk management products will establish a **connection between the performance characterization framework and stakeholder decision-making processes**. PBE essentially provides a wide array of tools to deal effectively and efficiently with the challenges posed by catastrophic risks. The perspective of the various stakeholders within the context of their prevailing business practices will lead to selecting the right tool for the specific needs of the decision maker. The Guidelines for Performance-based Engineering will encompass the broad range of potential risk management tools (see Task RMP-3). The Stakeholder Guides (see Task RMP-) will illustrate the selection and implement of the right tools based on the stakeholders' individual needs.

Table E-2 below presents an overview of the specific tasks proposed and their budgets. The following sections present a more detailed summary of each of the major tasks of the Risk Management Products Plan.

E.5.2 Form and Coordinate Stakeholder Focus Groups (Task RMP-1)

The task is to identify representative stakeholder groups and engage their on-going participation in the PBE development process. This is essential, as preliminary outcomes reflect the fact that each stakeholder group views risk and performance decisions from a different base, and thus characterization of performance and risk needs to be flexible enough to address the spectrum of stakeholder needs.

Once the stakeholder groups and their decision processes are well defined, the intent is to produce:

a. a description of the decision criteria that are necessary to facilitate stakeholder acceptance and utilization of PBEE by stakeholder group, and

b. a way for those developing PBEE to relate risk and performance parameters to stakeholders in a language that stakeholders readily understand, and which are related to the stakeholders' critical decision criteria.

Table E-2 Summary of Tasks

Task No.	Task	*FEMA 349* Budget	*FEMA 349* Schedule
RMP-1	Formulate and conduct stakeholder focus groups	TBD	Throughout
RMP-2	Develop comprehensive performance framework		
RMP-2.1	Develop performance objectives	$350,000	1 year
RMP-2.2	Develop minimum performance objectives	$350,000	1 year
RMP-2.3	Quantify performance in terms of loss and risk	$400,000	4 years
RMP-3	Develop tools for measuring and managing risk and performance		
RMP-3.1	Develop a research plan to advance current risk evaluation methods	$150,000	1 year
RMP-3.2	Develop financial life cycle and damage cost models	$650,000	Throughout
RMP-3.3	Define cost-benefit relationships for improving performance	$500,000	Throughout
RMP-3.4	Calibrate financial models	$500,000	Throughout
RMP-3.5	Develop cost-effective design strategies	$500,000	Throughout
RMP-4	Educate users about risk management concepts	$500,000	Throughout
RMP-5	Identify legal implications of PBSD	$250,000	2 years
RMP-6	Produce documents and reports for use in PBSD Guidelines and Stakeholders' Guide	$400,000	Throughout

WORKSHOP DISCUSSION POINTS:
Are there any other major tasks to be considered?
Are there any tasks that are not necessary?

At this point, four principal stakeholder categories have been identified (see Table E-3).

The first category comprises owners and managers. These individuals have the responsibility for designing, building, acquiring, maintaining, and/or operating facilities. They make decisions about catastrophic risks that lead to action (or inaction) on a relatively narrow scale. Motivations generally spring from the best interests of the specific business or institution. Within the owner/manager category, three perspectives have been identified for focus groups:

- Investors
- Institutions
- Industry

This distinction reflects the assumption that the different groups have characteristically different motivations and criteria for decisions relative to catastrophic hazard mitigation, and it is important to capture these distinctions (e.g., investment risk, operational risks, and market risks).

Table E-3 Stakeholder Categories

Principal Category	Focus Group Perspective	Examples	Potential Participants
Owner/manager	Investor	Developer (speculative) Developer (holder) Financial	???? Shorenstein ?????
	Institutional	University Healthcare	UC Berkeley University of Washington University of Memphis Kaiser ?????
	Industry	Manufacturing Retail ???	Unilever Intel Nordstrom ???
Societal/governmental	Public policy	Government agency Legislator	CSSC ?? Jackie Speiers ??
	Regulatory	Government agency Local jurisdiction Code organization	OSHPD ?? SF LA Seattle ?? ICC
	Special industry and advocacy groups	ADA Housing groups Tenant associations	????
Financial	Lenders	Banks Mortgage companies	???
	Insurers	Primary insurers Re-insurers	FMGlobal SwissRe? ???? RMS?
	Securities	Investment bankers	Goldman Sachs Morgan Stanley ????
Professional/research	Architects/Planners		
	Structural/Geotech		
	New Researchers		

The second stakeholder category includes those that represent broader societal and governmental interests. These individuals view catastrophic risk in a different context than owners/managers. Their focus is on public safety and the impact of catastrophes on local/regional/national economies. Their decisions relate primarily to public policy, legislation, and administration. The societal/governmental category is separated into three perspectives for focus groups:

- Policy makers
- Regulators
- Special interest and advocacy groups

This division reflects the different levels of decision problem and criteria used by the three groups (e.g., policy makers are making broadly applicable decisions for the community, regulators are considered more as "enforcers," focused on the problem one building at a time, and special interest and advocacy groups reflect "speaking" for the interested and affected public).

The third stakeholder category is primarily financial in nature. The societal and owner groups have a direct stake in decisions about risks associated with facilities (e.g., protect community interest and protect the assets). The primary distinction of the financial group is that these stakeholders have an indirect interest in performance decisions made by others. Their decisions relate primarily to whether or not to assume risk associated with facilities and at what compensation. The financial category might be represented by three focus groups:

- Lenders
- Insurers
- Securities

As noted above, this category differs from the previous two in that the stake is indirect: the concern is on the financial risk associated with the decision to finance or assume risk, rather than in protection of people or owned assets. The three groups in this category represent different views with respect to when and how the financial decisions are made, which in turn may impact how they characterize the risk and performance issues

Finally, design professionals, consultants, researchers and others comprise a service and research stakeholder category. The development of PBE has advanced primarily within this group. Yet many from the same, and related, disciplines are not familiar or conversant with PBE. The design and consulting communities are the conduits through which PBE will be implemented. New advances will be founded on future research. The purpose of this category is to expand awareness and input on both fronts. Focus groups include:

- Architects and Planners
- Geotechnical and Structural Engineers
- Potential New Researchers

For each of the nine identified stakeholder focus groups the ATC 58 team will identify and solicit a total of from four to six representative individuals. These groups will meet periodically with the RMP team and others to monitor and advise the development of the risk management products. Members of the RMP team will serve as liaisons with the focus group. Focus group members will be selected as much as possible from relatively high level and influential candidates. This will result in the development of longer term relations that will facilitate the transfer of PBE to the stakeholders over time.

Workshop discussion points:

Are there additional stakeholder perspectives?

How can we secure the participation we envision?

E.5.3 Development of a Performance Framework(Task RMP-2)

FEMA 349: Action Plan for Performance Based Seismic Design specifies that the team develop performance characterization as one important initial step (Product 1). This task requires:

- Consensus on the definitions of performance.
- Agreement on performance-related concepts (e.g., life safety, immediate occupancy)
- Communication and input from stakeholders.

The current Product 1 draft reflects a fairly complete assembly and review of current performance characterization options. The general consensus is that most of these have utility depending upon the needs of specific stakeholders and applications. The draft also initiates an organizational framework for performance options. The project team conducted a workshop for stakeholders in which various characterizations of performance were reviewed and discussed. This effort provided initial insight as to preferences for various types of performance characterization. The draft document identifies four performance metrics as key elements for effective communication with stakeholders:

- Direct losses including both the cost of damage and cost of repair.
- Downtime associated with the loss of use of a building.
- Indirect losses associated with the loss of use of a building.
- Life loss and injuries to the occupants and those in the immediate vicinity of a building.

The Product 1 Draft also provides initial discussion and summary of the optional forms of assembling performance metrics including:

- Performance continuum
- Discrete performance objectives
- Deterministic approach
- Probabilistic formulation

The purpose of the current effort as outlined in the sub-tasks below is to continue the development of the performance framework and to respond to the various stakeholder needs identified within the focus groups.

E.5.3.1 RMP 2.1: Match Performance Levels with Hazards to Develop Performance Objectives (FEMA 349 Task 4.1.1)

The team will take the performance levels and hazards developed in the performance products and combine them in order to understand expected performance over measurable and meaningful time spans (building life, a typical mortgage, careers, etc.). The team will select performance objectives for various building types, occupancies, construction eras, etc, and develop performance expectations for these buildings over their lifetimes. A focus will be to define the goals that owners and design professionals can utilize for capital planning and design purposes.

Personnel: Design professionals, Researchers, Owners, Financial interests

Budget: $350,000

Duration: 1 year

Workshop discussion points:

Can this be accomplished independently of Task RMP-2.3?

Can this encompass a rating system for existing facilities?

E.5.3.2 Task RMP 2.2 Develop Minimum Performance Objectives Considering Social and Economic Drivers (FEMA 349 Task 4.1.2)

The team will identify the various social and economic drivers that affect decisions about designing to a particular performance objective. The team will evaluate issues of cost, safety, construction duration, building function, etc. and will consider how each affect the various stakeholders. The goal will be to establish a set of minimum performance goals that protect the interests of all the parties involved in the building environment and provide for the protection of the public welfare. The team will discuss minimum performance standards for external elements that affect building performance, such as infrastructure, utilities and lifelines.

Personnel: Design professionals, Researchers, Financial interests, Owners, Building officials, Government agencies

Budget: $350,000

Duration: 1 year

Workshop discussion points:

Can this be accomplished independently of Task RMP-2.3 ?

Does this imply that ATC 58 will establish acceptable levels of risk?

E.5.3.3 Task RMP 2.3 Quantify Performance in Terms of Loss and Risk (FEMA 349 Task 4.1.3)

The team will develop a set of acceptable risk levels quantified in terms of loss (capital, lives, down time, etc.), considering building type, usage, age or other parameters. It will link performance objectives with these acceptable risk levels. Risk will be defined in agreed upon terminology with varying levels of reliability. The team will define a set of maximum loss thresholds for each performance objective. The Stakeholders' groups will be tapped to provide input. A methodology will be developed to convert loss into financial terminology.

Personnel: Design professionals, Researchers, Financial interests, Owners, (Other stakeholders)

Budget: $400,000

Duration: 4 years

Workshop discussion points:

Do we really want to establish acceptable levels of risk?

Doesn't this effort require some benchmarking to evaluate what levels of risk we now accept? This could come from Task RMP-3.4.

E.5.4 Develop Tools for Measuring and Managing Risk and Performance (Task RMP-3)

The third major task for the Risk Management Products effort is to develop procedures and tolls for measuring and managing risks utilizing the basic performance framework of the previous task. It is anticipated that these tools will be adapted to the specific needs of the various stakeholder groups. Major sub-tasks are:

E.5.4.1 Task RMP-3.1 Formulate a Research Plan to Advance Current Risk Evaluation Methods (FEMA 349 Task 4.2.1)

The team will gather existing information on risk analysis and financial modeling methods and identify gaps in current knowledge. A strong effort will be made to use available information so that future research funding can be most efficiently spent. The current state of the art should not define the scope of this project or limit the direction research might take, but rather allow researchers to avoid unnecessary duplication of effort.

Once gaps in existing knowledge have been identified, the group will develop a research plan to fill them. The goal will be to develop a road map by which the tasks within this *Action Plan* can be accomplished. The plan will be detailed enough to be used by stakeholders, laying out tasks and schedules. An effort will be made to identify outside sources of funding to augment the budgets assigned to each task with the Plan, considering public and private resources.

Personnel: Financial interests, Researchers (Design professionals, Owners)

Budget: $150,000

Duration: 1 year

Workshop discussion points:

How can the case be made for funding of such research?

How does this relate to other similar efforts (e.g. EERI)?

E.5.4.2 Task RMP-3.2 Develop Performance and Risk Models (FEMA 349 Task 4.2.2)

The team will use the structural and nonstructural performance acceptability criteria in the performance products to calculate life-cycle and annualized losses relative to each performance objective. Combinations of performance objectives will be evaluated to help users minimize overall life-cycle and damage costs. The team will extrapolate costs for individual buildings, to look at classes of buildings and regional implications for cities, states and the federal government. Costs of repair, business interruption and casualties will also be developed. The goal is to quantify expected losses in a manner that stakeholders can use in long term capital planning. Example applications will be developed. The information developed within this and other tasks should also form the basis for building rating systems, which will integrate structural and nonstructural quality with financial and social performance measures.

Personnel: Researchers, Financial interests, Owners, Government agencies

Budget: $650,000

Duration: Throughout the project

Workshop discussion points:

How does this relate to Tasks 2.1, 2,2 and 2.3?

E.5.4.3 Task RMP-3.3 Define Cost Effective Models for Improving Performance (FEMA 349 Task 4.2.3)

The team will develop tools by which the costs of different retrofit measures (existing buildings) or design criteria (new buildings) can be weighed against the expected reduction in loss and life-cycle costs. A comparison of individual components will be necessary (such as bolting down a wood building vs. bracing sprinkler pipes). The combination of components into design systems will also be considered. Cost-benefit relationships need to be developed in ways that can be calculated by design professionals and are meaningful to owners and financial interests. Cost-benefit ratios should be applicable to individual buildings or portfolios. The goal should be to provide owners with methods for performing economic loss management of their facilities. Efforts will be made to look at how this can be expanded to a regional basis.

Personnel: Design professionals, Researchers, Financial interests, Owners, Government agencies

Budget: $500,000

Duration: Throughout the project

Workshop discussion points:

Might this be combined with Task RMP 3.5 ?

E.5.4.4 Task RMP-3.4 Calibrate Performance and Risk Models (FEMA 349 Task 4.2.4)

The team will develop a series of example applications and will calibrate and compare them against current design techniques. Calibration parameters will include cost, duration, responsibility, liability, etc. The team will establish subgroups to carry out these studies, and will develop a standard reporting method by which the results can be quantitatively compared. If the team decides that the results diverge too significantly from existing methodologies, revisions to the procedures will be made, or a schedule for incremental application of the procedures will be developed. The team will develop methodologies to project costs and other data into the future. In this way, the information can function as a capital planning tool.

Personnel: Design professionals, Researchers, Financial interests

Budget: $500,000

Duration: Throughout the project

Workshop discussion points:

This task seems particularly important to the overall effort and be used .

Can experiences in past earthquakes lend credibility to this effort ?

E.5.4.5 Task RMP-3.5 Develop Cost-Effective Design Strategies (FEMA 349 Task 4.2.5)

With information from previous tasks the performance products, the team will develop strategies to improve performance based on building class, usage, location, etc. The team will consider components and systems, identifying which individually and which combinations typically will provide the minimum expected life-cycle cost involving tradeoffs between the initial cost and potential damage costs. The information will be presented in a manner that is usable by engineers for design and will give owners and financial interests a numerical valuation of the money spent. The team may use information obtained in past earthquakes, coupled with testing research previously done.

Personnel: Design professionals, Researchers, Financial interests, Owners

Budget: $500,000

Duration: Throughout the project

Workshop discussion points:

Might this be combined with Task RMP 3.3 ?

E.5.5 Educate Users about Risk Management Concepts (Task RMP-4) (FEMA 349 Task 4.3)

The team will establish a program to teach stakeholders about risk management. Representatives of lending agencies, insurance and financial institutions and researchers will write papers and create tools to apply the concepts developed in the above tasks. The team will hold workshops and seminars to discuss this information. The goals for design professionals, contractors, material suppliers and building officials are to recognize that performance-based seismic design involves choices about risk, and to be able to use the risk management tools provided in the Guidelines. For building owners, the goal is to bring awareness of how these tools fit in with current risk management techniques they use when purchasing space, making renovations, considering deferred maintenance, etc. A strong effort will be made to identify ways to coordinate current risk analysis techniques used by owners and financial institutions (probable maximum loss, ratings, etc.) with these new tools.

Personnel: Design professionals, Researchers, Contractors, Material suppliers, Financial interests, Owners, Building officials, Government agencies

Budget: $500,000

Duration: Throughout the project

Workshop discussion points:

Focus groups provide forum for this purpose.

Information must be cast in context with stakeholders' individual "world views".

E.5.6 Identify Legal Implications of PBSD (Task RMP-5) (FEMA 349 Task 4.4)

The team will contract with attorneys to address the legal implications of moving towards performance-based design oriented building codes. The team will develop a list of issues that need to be evaluated, including: liability in the event of unexpected performance, cost allocation, long-term responsibility for the building or components, definitions of terms such as "significant," "reliable," etc. The goal will be to develop strategies to make PBSD more attractive to stakeholders from a legal standpoint.

Personnel: Attorneys, Design professionals, Financial interests, Owners, Building officials, Government agencies

Budget: $250,000

Duration: 2 years

Workshop discussion points:

How much is really feasible in this effort ?

Should focus groups include legal perspective?

E.5.7 Produce Documents and Reports for Use in PBSD Guidelines and Stakeholders' Guide (Task RMP-6) (FEMA 349 Task 4.5)

This task will occur at milestones within the research plan developed in Task 4.2.1 and in preparation for each of the Guidelines development phases. The team will gather the technical information and prepare reports and documents for the writers of the Guidelines. Coordination with the performance products will occur to insure that information is presented in a consistent manner. The team will coordinate verification studies to be run on the analysis and design methodologies. Once the Guidelines teams have reviewed the work and identified changes or refinements to the research plan, this team will work with the research team for Task 4.2.1 to set out the goals for the next phase of research.

Personnel: Design professionals, Researchers, Financial interests, Owners, (Government agencies)

Budget: $400,000

Duration: Throughout the project

Workshop discussion points:

How is the entire RMP effort to be coordinated with SPP and NPP?

E.6 Performance-Based Seismic Design Guidelines

E.6.1 Objectives

The Guidelines form the most important product resulting from this project. They distill the information developed in the performance and risk management products into the application document used by design professionals, manufacturers, government agencies and building officials in design and construction. These guidelines can form the basis for the next generation of building codes and earthquake resistant design practice. When implemented, these guidelines should permit economical design that can reliably attain desired seismic performance.

The Guidelines will have to be broad in scope yet deep in level of detail. They need to be usable by a wide range of design professionals. They will focus on:

- *Selecting and quantifying performance objectives, including cost performance.*

  A set of consistent performance levels for new and existing buildings is essential. To be useful and reliable, predictors of structural and nonstructural performance must be characterized in a manner that can be understood by building owners.

- *Defining minimum and standard performance objectives.*

  Although the concept of performance based design permits owners to specify custom objectives for each building, presumably codes will need to have a single set of minimum and standard objectives used for enforcement purposes. These will need to be defined and incorporated into the performance objectives. They should be based on considerations of acceptable risk and should be based on input from multiple stakeholders. In addition, the desired reliability level in achieving these objectives needs to be specified.

- *Characterizing performance and hazard levels consistent with the objective.*

  The performance objectives must be quantified in engineering terms. This includes defining specific acceptable damage levels for various elements, both structural and nonstructural as well as permissible global behavior of the structure itself. Characterization of ground motion will also be important.

- *Performance prediction and evaluation methods.*

  The methods in the guidelines will facilitate design of structures of any configuration for any desired performance and can be used to calibrate building codes for new buildings or develop new codes. Methodologies used for evaluation and retrofit of existing buildings can also be calibrated. Lastly, the financial industry can use the guidelines as a basis to develop methods of ranking the design performance of buildings for underwriting purposes.

- *Means of verification.*

  The various analytical procedures used to evaluate performance and demonstrate acceptability, together with suitable modeling rules and prescriptive requirements on configuration and detailing must be verified. The uncertainty inherent in each of these procedures for buildings of different sizes, types, and configurations, and for different performance levels must be quantified. While a minimum level review is essential, a broad program of verification will be optimal.

- *Procedures for installing and maintaining nonstructural components and contents in buildings.*

  This information will focus on the issues related to installation and maintenance of nonstructural components. Not least among these is the division of responsibilities and liability between the component manufacturer and installer. As the design engineer observes building construction, equipment installation should also be observed for compliance to the manufacturer's specifications.

- *A technical commentary serving as backup for the Guidelines.*

  No matter how well stated in the PBSD Guidelines, the rationale and history behind the provisions will be subject to the interpretation of the engineers and building officials employing them. A comprehensive commentary is necessary to give these users a fuller picture of PBSD and direction when implementing it. The commentary should also include a series of example applications of the guidelines.

The Guidelines will involve major participation from all stakeholders, including design professionals, researchers, manufacturers, owners, financial institutions, building officials and governing agencies. A comprehensive program of verification will require input and involvement from a broad range of users. Technical writers and code officials will also be employed to produce the highest quality document.

The guidelines will be developed in phases. The first, or the 25% phase, will include a basic framework for the Guidelines, to be filled in with research and tools from the performance and risk management products. Review by the Guidelines teams at this stage will focus on refining or changing the direction of the technical research efforts for these products. The next phases at 50% and 75% will continue to take information from the technical products and flesh out the Guidelines, again returning comments to refine the research. The 100% phase will consist of final review, formatting, wordsmithing and publication. An important task within the Guidelines product is to develop this phasing further and to coordinate overall efforts with the steering committee.

E.6.1.1 Task 5.1 – Reach Consensus on Guidelines Format and Development Process

The main goal of this effort will be to reach a consensus on the format of the Guidelines, and to develop a conceptual framework. The team will also establish a procedure for taking the information from the performance and risk management products and writing the guideline provisions.

Personnel: Design professionals, Researchers, Material suppliers, Contractors, Financial interests, Owners, Building officials, Government agencies

Budget: $150,000

Duration: 1 year

E.6.1.2 Task 5.2.1 – Develop Systematic Design and Analysis Processes

Using the analysis and design methodologies defined in the performance products, the team will create design and analysis processes that take a building through concepts into final design, identifying major steps along the way. Procedures will be developed for new and retrofit conditions. The team will develop minimum performance objectives to be included in the standards based on the economic and social drivers developed in the risk management products**.** A focus will be on developing modeling guidelines to lend consistency to the design and analysis process. The team will work closely with the verification team in Task 5.3, to ensure that the provisions are tested and are acceptable. This team will be responsible for suggesting refinements or changes to the technical product research as necessary to accommodate the provisions. A goal should be to minimize this as much as possible, to maintain the schedule and budget. The committees will write the provisions using consistent and appropriate language, figures, equation styles, procedures for implementation, etc.

Personnel: Design professionals, Researchers, Material suppliers, Building officials, Government agencies, (Financial interests)

Budget: $1,200,000

Duration: Throughout the project

E.6.1.3 Task 5.2.2 – Write a Technical Commentary to Support the Guidelines

The team will write a technical commentary to support the information in the PBSD Guidelines. It will develop the format of the commentary to track the outline of the Guidelines. The goal of the commentary is to give specific background on the development of the procedures within the Guidelines and to explain the concepts in technical terms. It should also contain many references to allow users to obtain additional guidance. The team will consider the advantages of discussing the broader implications of decisions that were made in the Guidelines (financial, political, based on reliability, etc.). The team will have the commentary reviewed for accuracy by a panel of experts set up by the Steering Committee. This panel will include members of the performance and risk management product teams.

Personnel: Design professionals, Researchers,

Budget: $500,000

Duration: 2 years

E.6.1.4 Task 5.2.3 – Develop Administrative Guidelines for Building officials

The team will establish administrative provisions for the use of PBSD by building officials. It will detail the process by which buildings, including structural and nonstructural components, are reviewed, plan checked and field inspected. The team will also develop tools for building officials to ease the burden of reviewing PBSD design. The team will consider the benefits of third party plan check and peer review and other means of streamlining the process while maintaining quality

Personnel: Design professionals, Owners, Building officials, Government agencies

Budget: $200,000

Duration: 1 year

E.6.1.5 Task 5.3.1 – Run Examples to Check Accuracy of Provisions

The team will establish subgroups to verify the accuracy of the design and analysis procedures. The subgroups will create and test a series of parametric examples. The team will set up a means by which the results of the testing can be checked for accuracy and acceptability. The team will identify and make necessary changes in the procedures in cooperation with the technical product teams.

Personnel: Design professionals, Researchers, Building officials,

Budget: $600,000

Duration: Throughout the project

E.6.1.6 Task 5.3.2 – Compare Resulting Designs and Costs against Current Methodologies

The team will evaluate the effects of the resulting guidelines on each of the major stakeholders, looking at costs, level of effort and responsibility. A series of example applications will be developed and compared against current design techniques. The various methods that are developed will be calibrated against each other. Calibration will consider at least: the effort to implement, resulting performance and expected construction costs. Information from the risk management products will be incorporated into the calibration study. The team will establish subgroups to carry out these studies, and will develop a standard reporting method by which the results can be quantitatively compared. If the team decides that the results diverge too significantly from existing methodologies, revisions to the procedures will be made, or a schedule for incremental application of the procedures will be developed.

Personnel: Design professionals, Researchers, Financial interests

Budget: $400,000

Duration: Throughout the project

E.6.1.7 Task 5.4 – Develop Procedures for Quality Control during Construction

The team will write a set of guidelines for maintaining quality during construction. Information on reliability and uncertainty developed in the performance products will be used to evaluate the various stages of construction. The team will address such issues as material fabrication and inspection, installation, testing, uniformity in construction practices, field changes, etc. The goal is to provide a clear statement about the need for a high level of construction quality, and to provide standard procedures to attain this quality. It may be desirable to permit different levels of quality control based on expected performance or on building usage, etc.

Personnel: Design professionals, Contractors, Material Suppliers, Owners, Building officials

Budget: $300,000

Duration: 2 years

E.6.1.8 Task 5.5 – Develop a Plan for Verifying Nonstructural Component Design and Installation

The team will develop a standard format for checking the adequacy of nonstructural component and system design, manufacture and installation. Much like peer review and inspection procedures for the structure, this system will be designed to track nonstructural elements through a similar process. The team will establish a system for identifying and training qualified inspectors and reviewers. The team will use the information developed in the nonstructural performance products to make easier reevaluation of existing components and determine expected performance.

Personnel: Design professionals, Contractors, Material suppliers, Building officials

Budget: $300,000

Duration: 2 years

E.6.1.9 Task 5.6 – Publish Guidelines and Create an Adoption Process

The team will set up milestone deliverables at 25%, 50%, 75% and 100% and will describe the content to be included in each. It will establish and implement a final review and adoption process. A peer review procedure will be established at each milestone. A technical writing team will be created and a consensus reached on the style and voice of the guidelines. The Guidelines will be written and reviewed. A small team of reviewers will focus on the presentation of the information, both graphically and textually.

Personnel: Design professionals, Researchers, Material suppliers, Financial interests, Owners, Building officials, Government agencies

Budget: $600,000

Duration: Throughout the project

E.6.1.10 Task 5.7 – Develop a means for future revisions

After the guidelines are completed, the team will assess the project and identify future goals, research efforts, etc. that will build upon the work completed. The team will write a framework for the next generation of PBSD related projects. The goal of the task is to provide a plan for the continuing evolution of PBSD. The team will establish a procedure for updating the guidelines

Personnel: Design professionals, Researchers, Government agencies

Budget: $150,000

Duration: 1 year

E.7 Stakeholders Guide

E.7.1 Objectives

The Stakeholders' Guide will serve to educate the non-engineering audience about the benefits of PBSD. It will be their reference and planning tool much as the PBSD Guidelines serve a similar purpose for the engineering community. The Guide needs to be written in a non-technical style, and emphasize graphic presentation. The financial information should be presented in a way that will be useful to owners and financial professionals. It needs to communicate the concept and application of PBSD to these primary stakeholders. It will include the following components:

- *Background on codes and performance based design.*

  The Guide should give background on the history of code development and the reasons for moving toward performance based design. It should describe in general terms the principles of PBSD and its benefits over current methods. The goal is to show stakeholders that this move is necessary and that performance based design standards are in their financial and business interests.

- *Financial and other benefits of using PBSD.*

  Tables, charts, equations, examples and text, should convey the advantages and appropriate uses of PBSD in terms of financial and other models. Adoption will require that the document include the issues that stakeholders see as concerns and benefits. It will need to specify and quantify these benefits and provide a mechanism for making incremental changes to current practice.

- *Guidance for implementing PBSD.*

  The owner and financial professionals need to be guided through the process of implementing PBSD. Much more than in current practice these stakeholders will form an integral part of the design team. They must assist in making decisions about the direction of a project and be involved throughout its implementation.

- *Example applications of PBSD*

  The guide will contain example applications of the guidelines, covering structural and nonstructural design, and financial planning issues. The examples will contain technical information for the design professionals as well as nontechnical information for building owners and financial interests.

Table E-4 below summarizes the major tasks associated with the stakeholders' guide. Each task is described in more detail in the following discussion.

Table E-4 Stakeholders Guidelines Development Tasks

Task No.	Task	FEMA 349 Budget	FEMA 349 Schedule
6.1	Define content and format of Stakeholders' Guide	$150,000	1 year
6.2	Present and explain modeling techniques	$300,000	Throughout
6.3	Describe the design and construction process	$250,000	2 years
6.4	Develop examples for the guide	$400,000	2 years
6.5	Develop a plan to maintain or monitor the designed performance objective	$250,000	1 year
6.6	Publish the stakeholders' guide	$400,000	Throughout
6.7	Develop a means for future revisions	$100,000	1 year

Workshop discussion points:
Are there any other major tasks to be considered?
Are there any tasks that are not necessary?

E.7.2 Task 6.1 – Define content and Format of Stakeholders' Guide

The team will convene a series of workshops with stakeholder representatives to create the format and content of the Stakeholders' Guide. The team will determine the level of complexity of the information and equations presented. The goal is to layout the format for the guide so that it is usable to a non-technical audience. A strong effort will be made to involve owners and financial representatives, as these will be the primary users of the information. Another goal is to be able to quantify the level of effort that will be required of these groups in the planning, design and construction processes, in terms of cost and time. A consensus about the style of presentation will also be reached.

Personnel: Design professionals, Researchers, Financial interests, Owners, Contractors, Material suppliers, Building officials, Government agencies, Legal professionals

Budget: $150,000

Duration: 1 year

Workshop discussion points:

Focus groups for the RMP effort would provide a good forum for stakeholder communication?

E.7.3 Task 6.2 Present and Explain Financial Modeling Techniques

The team will present and explain the financial modeling tools developed in the Guidelines and the Risk Management Products. In the same manner as the Guidelines these tools should be presented with different levels of complexity, so that the user can employ the most appropriate to a specific situation. The technical and financial research will have been done as part of the risk management product. In this task the goal is to provide descriptions of and practical ways to employ these tools.

Personnel: Design professionals, Researchers, Financial interests, Owners

Budget: $300,000

Duration: Throughout the project

Workshop discussion points:

Why would this be limited to financial modeling ?

What about the needs of regulators (e.g. peer review) ?

E.7.4 Task 6.3 – Describe the Design and Construction Process

As with the Guidelines, the team will develop a road map to move from the concept stage to completion of construction, identifying major steps along the way. Retrofit and new design will be considered. The responsibilities and qualifications of each of the stakeholders (including owners and design professionals) throughout the design and construction process will be identified and described. The team will review these responsibilities and evaluate their effects on the groups. The team will prepare the information using language, figures, equation styles, procedures for implementation, etc., consistent with the Guidelines. The team will consult with legal professionals to evaluate possible changes in liability.

Personnel: Design professionals, Owners, Financial interests, Building officials, Government agencies, Legal professionals

Budget: $250,000

Duration: 2 years

Workshop discussion points:

What about stakeholders that may not relate to a single construction project (e.g. policy makers)?

E.7.5 Task 6.4 – Develop Examples for the Guide

The team will develop a series of examples for the financial and engineering application of PBSD, which will serve as teaching and reference tools. The team will set up a verification means and check the examples for accuracy and acceptability. The examples will include photographs and other graphic aids to increase understanding of the process.

Personnel: Design professionals, Researchers, Financial interests, Owners

Budget: $400,000

Duration: 2 years

E.7.6 Task 6.5 – Develop a Plan to Maintain or Monitor the Designed Performance Objective

The team will identify maintenance needs for nonstructural components, based on type, function, age, etc. It will develop a program that owners can follow, similar to deferred maintenance or tenant improvement, for maintaining the performance quality of existing equipment. A similar program will be developed to maintain and monitor the overall structural performance goals of a building throughout its life, accounting for changes in occupancy, advancements in the state of the art, structural modifications, etc. This information will be published as part of the Stakeholders' Guide. The team will prepare educational material to inform owners, contractors, and others about the procedures for maintaining a building's designed performance.

Personnel: Design professionals, Contractors, Manufacturers, Owners

Budget: $250,000

Duration: 1 year

E.7.7 Task 6.6 – Publish the Stakeholders' Guide

The team will set up milestone deliverables at 25%, 50%, 75% and 100% and will describe the content to be included in each. It will establish a final review and adoption process. The team will also include a nontechnical background and history of the PBSD process and of current code evolution. The goal will be to show the non-engineering audience the need for PBSD and the expected changes with respect to the current design and construction practice. A peer review procedure will be established at each milestone. A writing team will be created and a consensus reached on the style and voice of the guide. A small team of reviewers will focus on the presentation of the information, both graphically and textually. This group will have the responsibility, along with the steering committee of ensuring that the presentation compliments the Guidelines themselves.

Personnel: Design professionals, Financial interests, Owners, Government agencies, Outside experts in information outreach

Budget: $400,000

Duration: Throughout the project

Workshop discussion points:

Is it possible to publish a single guide?

Are there enough difference is perspectives to require several different guides?

E.7.8 Task 6.7 – Develop a Means for Future Revisions

The team will set up dates for considering revisions to the Guide and a procedure for doing so.

Personnel: Design professionals, Owners, Financial interests, Government agencies

Budget: $100,000

Duration: 1 year

Appendix F: Structural Performance Products Breakout Session Materials

1. Session Agenda

2. Session Attendees

3. Presentations

   a. Cobeen, K. Resources and Issues From the CUREE Caltech Woodframe Project Structural Breakout\Cobeen-Curee-Caltech-Woodframe.pdf

   b. Martin,Z. and Skaggs, T., Wood Shear Wall Stiffness and Performance-Based Design Structural Breakout\Martin-wood-wall-stiffness.pdf

   c. Stewart, J., Soil-Foundation-Structure Interaction: Implications For Performance Based Engineering Structural Breakout\Stewart-soil-structure-foundation.pdf

   d. Reinhorn, A.**,** Fragility Techniques for Performance-based Earthquake Engineering Structural Breakout\Reinhorn-fragility.pdf

   e. Kesheshian, P. Performance-Based Risk Analysis Structural Breakout\Kesheshian-risk-analysis.pdf

   f. Iwan, W., An Improved Capacity Spectrum Method Of Analysis Structural Breakout\Iwan-capacity-specctrum.pdf

   g. Aschheim, M. A New Technique for Performance-based Design Structural Breakout\aschheim-yield-point-spectra.pdf

   h. Mole, A. High-Performance Computing in Performance-Based Seismic Design Structural Breakout\Mole-High-Performance-Computing.pdf

   i. Ettourney, M. Performance-Based Design Methodology for Columns Subjected to Blast Loading Structural Breakout\Ettourney.pdf

   j. Maffei, J. Resources and Recommendations for Developing “Structural Performance Products Structural Breakout\Maffei.pdf

Structural Performance Products Breakout Session

February 24, 2003

2:15 pm	Breakout Session Overview	Whittaker
	- Goals of Breakout Session	
	- Introduction of Phase 2 SPP Team	
	- Introduction of Attendees	
2:20	- "Performance assessment incorporating SSI"	Stewart
2:35	- "Resources and issues from the Caltech/CUREE Woodframe project"	Cobeen
2:50	- "Performance based engineering of word structures"	Skaggs
3:05	- "Performance based engineering of precast concrete structures"	Maffei
3:20	- "Fragility techniques for performance-based earthquake engineering"	Reinhorn
3:35	- "Performance based risk analysis"	Keshishian
4:00	Coffee Break	
4:15	- "An improved capacity spectrum method of analysis"	Iwan
4:30	- "A new technique for performance-based design"	Aschheim
4:45	- High-performance computing for performance based earthquake engineering"	Mole
5:00	- "Performance based engineering for blast loading"	Ettourney
5:15	Presentation of Draft Work Plan	Whittaker
5:30	Preliminary Discussion of Draft Work Plan	
6:00	No Host Reception	
7:00	Dinner (on your own)	

February 25, 2003

7:30 am	Continental Breakfast	
8:00 am	Resume Breakout Session	
	Presentation of Revised Work Plan	Whittaker
	Discussion and Changes to Work Plan	
10:00	Coffee Break	
10:15	Resume Breakout Session	
	Refine Plan	
12:00	Lunch	

Summary Notes

Structural Performance Products Breakout Session

The key points of discussion and/or consensus arising from the Structural Performance Products breakout session during the January 2003 workshop in San Francisco are listed below. The discussion on the straw work plan was arranged by focus area and task. Comments are presented below under three headings: general comments, comments on the three focus areas, and comments on the tasks and subtasks.

General

1. The broad objectives of the ATC-58 project are appropriate but likely cannot be achieved given (a) the level of funding available, and (b) no research will be conducted as part of the ATC-58 project.

2. One key product of the project must be a framework for performance-based earthquake engineering (PBEE) that is broadly applicable to all structural framing systems.

3. Given the restrictions of (a) limited funding, and (b) no funded research to support the guidelines-development effort, consider reducing the scope of the guidelines to a small number of building types, say, to moment frames in steel and reinforced concrete; shear walls in steel, reinforced concrete, and timber; and braced frames in steel.

4. Validation of the PBEE guidelines is a key step that is not currently addressed in the action plan. Validation of SPP, NPP, and system products will be needed, and validation engines must be developed at the start of the project. Validation could be undertaken using model building structures, perhaps similar in concept to the 3-, 9- and 20-story SAC steel buildings.

5. Metrics for project success should be drafted at the start of the project rather than midway through the project. All should have a clear understanding of whether project goals are being achieved. Adjustment of the metrics throughout the duration of the project may be required to reflect new information, results from outside research and available funding.

6. The goal of the project is the PBEE of buildings. Overarching tasks that embrace SP and NP products will be needed to ensure that this goal is achieved. The action plans for the SP and NP teams must be carefully integrated to facilitate integration.

7. The action plan should be structured so that integrated SP and NP products are released at intermediate times in the project (perhaps similar to the SAC Interim Guidelines).

8. The guidelines should build on the work presented in FEMA 356 but neither necessarily be structured similarly to FEMA 356 nor be bound to the analysis and design methodologies of FEMA 356.

9. Immediate consideration should be given to the make-up of the SPP technical teams. One option is separate technical teams on hazard, analysis methods, foundations, materials, and new technologies similar to the ATC-33 project. Alternate make-ups should be considered that merge participants from the SP and NP technical teams.

Focus Areas

1. There was no broad disagreement with the three focus areas discussed in the action plan.

2. Given the level of funding available to the project, consideration should be given to addressing new building construction (see above discussion on model buildings) *first* and retrofit building

construction *second*, if additional funds become available. Regardless, the PBEE framework should be applicable to both new and retrofit construction.

3. The revised action plan should clearly state that no research will be conducted as part of the ATC-58 project, similar to the ATC-33 project. That said, mechanisms must be developed to sweep new research information and data into the PBEE guidelines.

Task 2.1.1

1. Drop the work related to validation of existing procedures and information because such work likely cannot be accomplished with a budget of $1M rather than the proposed $0.15M.

2. Assessment of performance and analysis tools should be an on-going endeavor and not a Year 1 endeavor. This task could form the basis of the validation program.

TASK 2.1.2

1. Replace the research plan with a prioritized list of research *needs*. A list of needs is more valuable to both the research community and the ATC-58 project. No agency will fund the research plan but agencies might fund research projects that address one or more of the research needs. Researchers could be encouraged to work with ATC-58 SP technical teams to (a) enhance the utility of their work, and (b) speed the research results into practice.

2. Identification of research needs should be an on-going endeavor and not a Year 1 endeavor. The list of needs should be updated yearly with input from the SP, NP, and RM product teams.

3. One list of prioritized research needs that includes input from the SP, NP, and RM product teams should be prepared, not three disparate lists.

Task 2.2.1

1. Some tasks are finely subdivided into sub-tasks and other tasks are broad in scope. The revised action plan should be consistent in this regard.

2. Consider repackaging part of the work plan around framing systems or building types. The key to success with this approach is to ensure consistency over all building types considered.

3. There is considerable overlap in the sub-task statements in Task 2.1. Consider merging all sub-tasks and eliminating overlap.

4. The sub-task as written addresses discrete performance levels and not a continuum approach to performance. The latter approach was preferred by many at this time and so allowance should be made in the guidelines to accommodate both approaches.

Task 2.2.2

1. The task statement should be rewritten to better address the proposed work.

2. See above comments on the merging of all sub-tasks in Task 2.1.

3. Eliminate the reference to research because the plan is unable to *target* and then *fund* research.

4. The collaboration with testing programs is unclear. What testing programs?

5. Key to the success of this sub-task is the linkage of component and building acceptance criteria. Consider developing such criteria for the model buildings only, otherwise the scope is too broad and the impact of the funding will be substantially diluted.

Task 2.2.3

1. Eliminate overlap with Task 2.3.

2. Change the title of the sub-task because subsurface response will not predict building performance but rather influence performance.

3. Eliminate the reference to research because the plan is unable to *target* and then *fund* research.

4. The last sentence in the subtask is unclear because the only way to reduce uncertainty is to increase knowledge through research.

Task 2.2.4

1. Eliminate *level* from the first sentence.

Task 2.2.5

1. Eliminate all references to research in the sub-task statement.

2. The level of funding proposed for this task appears too small to support a research effort and too large to move currently available analysis methodologies into guidelines.

3. Task 2.2.5 is missing the work necessary in the materials chapters of the guidelines to develop unbiased values for acceptance criteria, etc. Much of the funds assigned to this sub-task could be spent completing such work.

Task 2.2.6

1. Consider deleting the work on existing buildings until additional funds become available. That is, develop the skeleton or framework for PBEE and add tissue, organs, and skin for a small number of (new) model framing systems. Use the funds to increase the number of model framing systems.

2. Eliminate all reference to research from the task statement.

3. The funding necessary to "quantify uncertainties within the existing built environment" is likely in the $5M range: an order of magnitude greater than that assigned to the sub-task.

4. If the guidelines must address existing buildings, limit the scope to those framing systems considered for the new model buildings.

Task 2.3

1. Much work has been completed on the subjects of permanent ground displacement and near-field shaking since FEMA 349 was published.

Task 2.4.1

1. The task statement is broad and over-reaching. The identification and quantification of uncertainties in seismic hazard and building response, for a large number of building types and geometries is an

immense undertaking. Consider identification and quantification of uncertainty and randomness for the (new) model framing systems only.

2. Eliminate all reference to research from the task statement.

3. Consider eliminating this task and sweeping some of the activities and all of the funds into other tasks.

4. Include verification in the task statement, if the task is to be retained.

Task 2.4.2

1. The task statement as written is neither clear nor focused. Repair costs and life-cycle costs are likely not related as indicated in the task statement.

2. Delete the task and sweep the QA/QC work and funds into another task.

3. Identification of structural systems that have predictable building performance is not straightforward and would require full-scale testing. The objective should be to identify framing systems with the least sensitivity in response due to uncertainties and randomness in the hazard, modeling, material characteristics etc. Such work could form the basis of a research project and could be listed in research needs.

Task 2.4.3

1. The work of identification of separate sources of funding, especially materials suppliers, for component testing does not belong in a task statement. Those sources would have been tapped years ago had the suppliers been interested in such collaboration.

2. Consider broadening the scope to include field testing of systems.

3. Close collaboration with NEES Inc. should be encouraged.

4. Testing protocols should be developed but not imposed on the research community.

Task 2.5

1. The straw man work plan at the meeting dropped this task from the action plan. Many participants in the breakout session disagreed with this proposal but agreed that the task statement had to be re-written.

2. The task statement notes that existing data should be reviewed. To aid in the development of the PBEE guidelines, detailed studies of *modern* instrumented buildings that have been (a) subjected to severe earthquake shaking, and (b) carefully studied by reconnaissance teams after such shaking are needed. Candidate buildings must be identified. Consider selecting buildings similar to the model buildings discussed above. The budget of $0.3M is far too small for such work.

3. The product of this subtask should also include recommendations for (a) building instrumentation that if implemented and the building subjected to earthquake shaking would yield key performance data for validation of the PBEE guidelines, and (b) a list of performance-oriented data to be collected by future reconnaissance teams. Formal coordination with EERI and the NSF-funded EERCs would maximize the impact of this work.

Task 2.6

1. Decisions should be made in this phase of the project regarding how the guidelines will be prepared. Two options are (1) the team-writing approach used in ATC-33, and (2) individual consultants as lead writers similar to the SAC project. No consensus regarding the best approach for this project was reached.

2. One product of the work should be model-building applications of the PBEE guidelines. These applications could be published a number of times over the course of the project, reflecting advances in both knowledge and the guidelines.

Structural Performance Products Break Out Session

Attendees

Whittaker, Andrew (Facilitator), Univ. at Buffalo
Abrams, Daniel, University of Illinois
Anderson, Don, CH2M Hill
Aschheim, Mark, Univ. of Illinois, Urbana
Bertero, Vitelmo, Univ. of California, Berkeley
Cobeen, Kelly, Cobeen & Associates
Deierlein, Gregory, Stanford University
Elnashai, Amr, MAE Center
Ettouney, Mohammed, Weidlinger Associates
Fenves, Gregory, Univ. of California, Berkeley
Hooper, John, Skilling Ward Magnusson Barkshire
Iwan, Wilfred, California Institute of Technology
Jirsa, James, University of Texas at Austin
Kesheshian, Petros, ABS Consulting
King, Andrew, Inst. of Geol. & Nuclear Sciences, NZ
Krawinkler, Helmut, Stanford University
Maffei, Joe, Consulting Engineer
Malley, James, Degenkolb Engineers
Martin, Zeno, APA The Engineered Wood Assoc.
Moehle, Jack, Univ. of California, Berkeley
Mole, Andrew, Ove Arup and Partners
Partridge, James, Smith-Emery Company
Reinhorn, Andrei, University of Buffalo
Roeder, Charles, University of Washington
Shapiro, Daniel, SOHA Engineers
Stewart, Jonathan, Univ. of California, Los Angeles
Tasai, Akira, Yokohama National University
Taylor, Andrew, KPFF Consulting Engineers
Wallace, John, Univ. of California, Los Angeles
Wen, Y.K., University of Illinois

Resources and Issues from the CUREE Caltech Woodframe Project

Kelly E. Cobeen, SE

Abstract

First, available resources that are pertinent to the tasks and products proposed in the ATC 58 action plan will be highlighted. Resources include:

- Full-building demand data from shake table testing,
- Full-building demand data from analytical studies,
- Analysis tools developed,
- Component testing results,
- Efforts to correlate component behavior with full building behavior,
- Compiled descriptions of drift versus visual damage for structure and finishes,
- Observations of building dynamic properties, and
- Observations of distribution of force and deformation demand.

Second, issues and concerns impacting the continued development of performance-based methods will be noted. Among these is the observation of low-deformation behavior and resulting concerns regarding quantification of seismic hazard.

Third, the use of Index Buildings (Model Buildings) for analytical quantification of demand and loss estimation studies will be briefly introduced as an approach of possible interest to the ATC 58 project.

Wood Shear Wall Stiffness and Performance-Based Design

Zeno A. Martin, P.E. and Thomas D. Skaggs PhD.. P.E.

Abstract

Past seismic events have illustrated the vulnerability of woodframe construction to significant expensive damage. Although life safety, the current implicit performance objective of modern building codes has been reasonably preserved, damage is common. Over half the property damage caused by the Northridge earthquake was attributed to woodframe construction. With the exception of rehabilitation of historical and multi-family wood framed projects, performance-based design are seldom considered in the design process. Some of the impediments to performance-based design with wood buildings include lack of simple design procedures, and a relatively low level of engineering performed for many wood framed structures.

Keeping these impediments in mind and understanding that the linear and non-linear behavior of structural elements is essential for performance-based design procedures. Accurately estimating interstory drift is a key parameter in designing for damage control. The presentation will provide a concept such that a bilinear pushover curve up to ultimate wall strength can be established. The focus is on a single method to estimate linear wood shear wall stiffness up to a so-called yield point, but parameters essential to describe post yield behavior in simple terms will also be presented.

In the past five years, there has been an unprecedented amount of research on wood shear wall performance. Sufficient information exists to create and verify by extensive independent test data, a simple and practical method to predict linear elastic wood shear wall stiffness up to the wall yield point. The presentation will provide a concept for a mathematical model for wall stiffness up to the wall yield point as follows:

$$K = \frac{V \cdot H}{\Delta \cdot L}$$

where Δ = shear wall deflection, in. V= load applied, kips H = wall height (in same units as L), L = wall length (in same units as H). The H/L serves to normalize the stiffness value for different aspect ratios. Wall stiffness can bthen be modified for such things as openings, length of wall, tie down stiffness, fasteners, end posts and even effects of finishes. Recent research provides some quantitative values for these empirical relationships.

Wood shear walls do not have as clearly defined point of yield as other materials, such as steel. A point of yield essentially describes the region on a load displacement curve where linear elastic behavior ends. Researchers have developed two methods in an attempt to quantify the point of yield. The first defines elastic stiffness to be represented at the line from the origin to the point the load-displacement curve where the load equals a percentage of the ultimate load. The second method assigns a yield point based on strength degradation from repeated cyclic loads at a given displacement.

Wood frame design provisions are in need of advancements in the analysis tools available such that performance based designs are practical and feasible for wood framed structures. A simple matrix of shear wall stiffness values can be developed from existing models, and adjusted or verified by empirical test data. Recent cyclic wall test and shake table test data shows that there is reasonably good agreement with modeled elastic stiffness and observed stiffness. The limits of validity for a bi-linear stiffness model are also presented.

Soil-Foundation-Structure Interaction: Implications for Performance Based Engineering

Jonathan P. Stewart

University of California at Los Angeles

Abstract

A number of advances in knowledge have occurred since 1998 with respect to soil-foundation structure interaction. Moreover, new issues have been raised based on observations from recent earthquakes. These advances/issues can be divided into three general categories, as follows:

1. *Soil-structure interaction, kinematic interaction*: Advances in knowledge have occurred with respect to the variations between ground motions at the foundation level of structures vs. the free-field. Simple models suitable for use in practice have been developed to predict these ground motion variations as a function of frequency, shear wave velocity of soil, and foundation dimensions. These advances are being studied within the ATC-55 project, and should be incorporated into the ATC-58 effort as well.

2. *Soil-structure interaction, inertial interaction*: In recent years, research has been conducted to support the development of recommendations for the use of simple impedance function models for realistic site conditions. These advances have been partially incorporated into the 2000 version of the NEHRP Provisions for new buildings (analysis of foundation stiffness), and are being considered as part of the ATC-55 project as well (primarily with respect to analysis of foundation damping effects on seismic demand).

3. *Soil-structure interaction, ground failure*: The 1999 earthquakes in Turkey and Taiwan caused many incidents of ground failure apparently induced by soil-foundation interaction. In many cases there was no apparent ground failure in the free-field, and permanent deformations were concentrated beneath and immediately surrounding the foundation. Models to predict this type of ground failure are not yet available, and basic research directed toward improving our understanding of this complicated problem are in their preliminary stages. It is important for the ATC-58 project to be aware of this important subject of ongoing research.

   Each of the above will be discussed in the presentation by the author at the ATC-58 workshop.

Fragility Techniques for Performance-based Earthquake Engineering

Andrei Reinhorn

State University of New York at Buffalo

Abstract

Due to the uncertain information about the structures' demand resulting form the uncertain ground motions and structural systems and due to the "fuzzy" description of performance limits, the performance of structures cannot be well defined and measured precisely. An attempt is made to use for the quantification of performance, the relation between the response demands and the performance limits using probability functions, usually defined as fragility. The quantification of such fragility is presented using an example of a structure of a hospital building previously damaged in Northridge 1994 earthquake. The sensitivity of several parameters on performance is presented.

Performance-Based Risk Analysis

Petros Keshishian

AIR-Worldwide Corp., 101 Huntington Ave., Boston, MA

Abstract

Performance Based Design allows to design or retrofit buildings for a higher performance level than those foreseen by the building codes. For example FEMA-356 (2000) defines three basic performance levels, namely, Immediate Occupancy, Life Safety and Collapse Prevention. It is recommended that the buildings be designed for a given return period earthquake for a given performance level, but there is no clear criterion or methodology how to choose those performance levels and their respective earthquakes.

The earthquake risk mitigation has two aspects: (1) Life Safety which is concerned in providing certain level of reliability that the building retains a margin against onset of partial or complete collapse; and (2) Economic Loss – which recognizes that designing a building to meet the Life Safety criterion has very little to do with economical design. A building could successfully meet the Life Safety criterion, but still be a complete economic loss after an earthquake. Economic Loss aspect of earthquake risk analysis deals with finding the optimal design, be it new or retrofit design, that reduces the present value of all the potential losses that a building could incur during its useful lifetime.

This paper addresses those two aspects of earthquake risk mitigation. It defines a clear methodology on choosing the design earthquake based on predefined criterion of providing either a certain performance level reliability or minimizing the expected monetary losses given the seismic hazard and expected lifespan of the building.

Assuming that earthquake occurrences constitute a Poisson process, the conditional probability distribution function of the spectral accelerations, derived from the hazard function, is used in conjunction with the fragility functions to derive basic criteria for choosing design earthquakes to provide certain performance level, e.g. Life Safety, or to minimize the anticipated economic losses due to earthquakes. The hazard function represents the probability of exceedance of a certain level of earthquake ground motion at a site within a given number of years. The economic loss is assumed to be proportional to the physical damage. The latter is defined in terms of a fragility function that represents the probability of the building attaining or exceeding a pre-specified damage state for a given earthquake intensity.

It is demonstrated that choosing the design earthquake based on earthquake return period only does not guarantee uniform probability of failure since the latter is a function of both the shape of the hazard function as well as the exposure time. For a simple fragility function it is shown that one can choose the design earthquake based on required reliability (acceptable probability of failure), exposure period and the seismic hazard. This outlined approach is suggested as an alternative way of choosing design earthquakes for performance based design.

An Improved Capacity Spectrum Method of Analysis

W. D. Iwan and A. C. Guyader

California Institute of Technology, Pasadena, California, USA

Abstract

The Capacity Spectrum Method (CSM) is widely employed as a tool for performance-based analysis and design of structures. Although rooted in concepts of linear elastic analysis, the CSM may be generalized to treat inelastic structural behavior. This may be accomplished by modifying either the Capacity or the Demand or both in some manner so as to approximately account for the differences between elastic and inelastic response behavior. As initially conceived, the CSM uses the Secant Stiffness as the equivalent linear stiffness parameter along with formulas or rules that provide the equivalent viscous damping parameter. However, it is generally known that the Secant Stiffness is not an optimal equivalent linear stiffness parameter for inelastic systems subjected to earthquake excitation. Recently, new equivalent linear parameters have been defined for a broad range of inelastic systems based on a statistical approach which maximizes the probability that the solution error will lie within some range of Engineering Acceptability. The new equivalent linear parameters may be used to provide improved estimates of structural performance. Since the Secant Stiffness is no longer employed with these new parameters, an adjustment must be made in order to use these parameters within the context of the CSM approach. This presentation describes a procedure for adapting the CSM for use the new equivalent linear parameters. The new procedure provides an efficient means of obtaining consistent response Performance Point results without resorting to cumbersome iteration schemes.

A New Technique for Performance-Based Design

Mark Aschheim

University of Illinois, Urbana-Champaign

Abstract

This talk proposes that the process of design for seismic performance be viewed from a new perspective. Introduced are the concepts of Yield Point Spectra, the determination of Admissible Design Regions, and design based on an estimated yield displacement. Examples illustrate a simple design approach that can be used to address multiple performance objectives. The design approach produces a design base shear coefficient that can be used for design along the lines of current code Equivalent Lateral Force approaches.

The fundamental basis is the use of "equivalent" SDOF systems, with inelastic spectral demands estimated from elastic spectra (using either displacement modification or equivalent linearization). The approach is effective for limiting drift (associated with non-structural damage) and system ductility (associated with structural damage) to prescribed values. This approach may be sufficient for many ordinary structures, and can be used for the preliminary design of those structures whose performance must be assessed through more rigorous analysis procedures.

1. Aschheim, M.A. (2002). "Seismic Design Based on the Yield Displacement," *Earthquake Spectra*, Earthquake Engineering Research Institute, Vol. 18, No. 4, Nov., pp. 581-600.
2. Aschheim, M., and Black, E. (2000). "Yield Point Spectra for Seismic Design and Rehabilitation," *Earthquake Spectra*, Earthquake Engineering Research Institute, Vol. 16, No. 2, May, pp. 317-335.
3. Tjhin, T,. Aschheim, M., and Wallace, J. (2002) "Displacement-Based Seismic Design of Reinforced Concrete Structural Walls" *7th US National Conference on Earthquake Engineering*, Boston, July 21-25.
4. Black, E. F., and Aschheim, M., (2000). *Seismic design and evaluation of multistory buildings using Yield Point Spectra*, CD Release 00-04, Mid-America Earthquake Center, July.

High-Performance Computing in Performance-Based Seismic Design

Andrew Mole

Arup

Abstract

ATC-58 identified structural and non-structural analysis tools as areas for development. Since then there have been advances in both hardware and software. These are of particular relevance to performance-based design. This presentation offers a review of high-performance computing tools, past and present, with an assessment of future developments. Applications relevant to Performance-Based Seismic Design are presented.

Performance-Based Design Methodology for Columns that are Subjected to Blast Loading

Mohammed Ettourney

Weidlinger Associates

Abstract

Analysis and design of reinforced concrete (RC) columns that are subjected to blast loading have gained considerable importance in the past few years. A new method of analyzing RC columns was recently developed. The method has the efficiency of the SDOF method and the fidelity of the FEM method. The method is based on assembling a database of common column designs, which was accomplished by designing more than 3000 buildings of several shapes, structural systems, number of floors, and seismic zones. The columns of each building were designed and detailed following the ACI-318-99 design code. The different column attributes included:

1. Column cross sectional dimensions as well as height
2. Number, distribution and sizes of longitudinal steel reinforcement
3. Number, distribution and sizes of lateral steel reinforcement
4. Axial stress ratio
5. Concrete and steel strengths.

In addition, a survey was conducted to establish the most commonly used blast loadings (charge weight and standoff). A total of ten blast loadings were chosen. The resulting complete structure-load database, DB-1, had 11,400 records.

A numerical simulation of all the columns and blast loads was accomplished with the FLEX (FEM). FLEX is a high resolution FEM computer code that is especially well suited for this type of highly nonlinear dynamic analysis. For each simulation (11,400 in total) three output measures were obtained. They are: a) maximum lateral displacement, b) maximum shear strains and c) an overall damage measure.

The development of this new method is timely with the advent of Performance based engineering for the blast design community. The analytical accuracy and the wealth of output measures that the method produces are utilized to produce a performance-based design for blast-subjected columns. The performance based blast design of this document is consistent with the newly developed performance based seismic designs, yet it is specialized for blast environment. For example, an additional performance level was deemed necessary, and the performance limit states are specialized for blast environment. The three output measures were utilized to identify performance levels, while accounting for the inter-dependability of those performance levels.

Resources and Recommendations for Developing “Structural Performance Products

J. Maffei

Abstract

Three key resources are available to advance the state of performance-based design of concrete structures.

For reinforced concrete structures, both new and existing, the FEMA 306 and 307 documents provide an opportunity to improve on seismic evaluation and design methods used in FEMA 356 and for new buildings. Compared to the FEMA 356 acceptance criteria for concrete members, the procedures of FEMA 306 are more transparent to the engineer because they relate directly to identified behavior modes of structural members or actions. Use of such procedures would lead to more accurate criteria, with less uncertainty in the resulting seismic performance.

Pagiotakos and Fardis [ACI Structural Journal March-April 2001] have studied the ultimate deformation capacity of reinforced concrete members using an extensive database. They have compared rotation capacities directly with the limits given in FEMA 356. The results show a potential for improved accuracy. Professor Fardis reports the current status of the work:

“We have been building up a data base with test results of concrete components (mainly columns, but also beams, piers and walls, no joints though). The data base now includes about 1400 components with rect. section (including walls and beams), about 225 circular columns or piers and about 70 hollow (or T, U, etc.) sections. Most of the components are flexure-critical but about 150 have a ductile shear failure mode (yielding in flexure, failing then apparently in shear). There are also smaller databases on components with rect. section strengthened with concrete, steel or FRP jackets We are currently now working on the database (extending it, checking, etc.), so it is not in a publishable form. An earlier version, with about 1000 components with rect. section (including walls and beams) was made available to ACI, in hardcopy and electronic form, as an Annex to a paper of myself and a co-worker that appeared in the ACI Struct. J., Vol.98, No.2 (March-April 2001). That database has very few bugs, though. I will be happy to provide further info.”

For new precast and prestressed concrete structures, the Federation International du Beton is finalizing a state-of-the-art report that describes design approaches from a performance-based perspective. The document gives a brief discussion of performance-based terminology and covers key issues like the unique types of nonlinear behavior for jointed precast systems. [Contact me for more details on the document.]

I believe that to provide the best benefit to stakeholders, the principal objective of the performance-based action plan should be to produce design provisions (in specific language), commentary, and example applications. The chart below gives my recommendation on the relative amount of effort for the principal tasks toward this aim. Example applications should be used early in the process, and provisions for selected building types should be developed before general frameworks are chosen.

Appendix G: Nonstructural Performance Products Breakout Session Materials

Contents

1. Agenda
2. Summary Notes
3. Session Attendees
4. Presentations

   a. Carlson, J. Today's Design and Installation of Non-Structural Components Nonstructural\carlson-nonsructural.pdf

   b. Memari, A. Recent Developments in Earthquake Resistant Design of Nonstructural Buildings Wall Systems Nonstructural\ATC 58 Worshop _ Slide Presentation _ Memari _ 2 24 03.pdf

   c. Caldwell, P. Shake Table Testing as Means of Equipment Qualification Nonstructural\Caldwell ATC-58 SFO Feb 03 NPP.pdf

   d. Malholtra, P. Cyclic-Demand in Performance-Based Seismic Design Nonstructural\Praveen_malhotra.pdf

   e. Filiatrault, A. Development Of Experimental Performance-Based Seismic Qualification Procedures For Nonstructural Building Components Nonstructural\ATC-58-Filiatrault.pdf

   f. Gillengerten, J. Seismic Demands and Acceptance Criteria for Seismic Qualification Testing of Nonstructural Components Nonstructural\Gilleng-Seismic1.pdf

Nonstructural Performance Products Breakout Session

Agenda

February 24, 2003

2:15 pm	Breakout Session Overview	Bachman
	- Goals	
	- Phase 2 NPP Team Introduction	
	- Introduction of Attendees	
	Individual Presentations	
2:30	- "Today's Design & Installation of Nonstructural Components"	Carlson
2:50	- "Recent Developments in Earthquake Resistant Design of Nonstructural Building and Wall Systems"	Memari
3:10	- "Seismic Demands and Acceptance Criteria for Seismic Qualification Testing of Nonstructural Components"	Gillengerten
3:30	- "Shake Table Testing of Electrical Equipment for Commercial Applications from an Equipment Supplier's Perspective"	Caldwell
3:50	Discussion	
4:00	Coffee Break	
4:15	- "Cyclic Demand in Performance Based Design"	Malhorta
4:35	- "Development of Experimental Performance-Based Seismic Qualification Procedures for Nonstructural Components"	Filiatrault
4:55	Presentation of NPP Strawman Work Plan	Bachman
5:00	Discussion and Feedback	
6:00	No Host Reception	
7:00	Dinner (on your own)	

February 25, 2003

7:30 am	Continental Breakfast	
8:00 am	Resume Breakout Session	
	Presentation of Revised Workplan	Bachman
	Discussion and Changes	
10:00	Coffee Break	
10:15	Resume Breakout Session	
	Refine Plan	
12:00	Lunch	

Summary Notes

Nonstructural Performance Products Breakout Session

The nonstructural performance products breakout session took place on the afternoon of Feb. 24th and the morning of Feb. 25th. The session was attended by approximately 25 invited researchers, practicing engineers and supplier representatives.

The session was organized into two parts. On the first day, Bob Bachman, Team Leader for Nonstructural Performance Products gave an overview regarding the goals, organization and ground rules for the breakout session. After Bob gave his overview, the following presentations were made during the remaining portion of the afternoon which provided an understanding of current practice and recent developments in the design, installation and testing of nonstructural components which may impact the development of the project work plan.

Today's Design and Installation of Nonstructural Components	Jim Carlson
Recent Developments in Earthquake Resistant Design of Nonstructural Building and Wall Systems	Ali Memari
Seismic Demands and Acceptance Criteria for Seismic Qualification Testing of Nonstructural Components	John Gillengerten
Shake Table Testing of Electrical Equipment for Commercial Applications from an Equipment Supplier's Perspective	Phil Caldwell
Cyclic Demand in Performance Based Design	Praveen Malhotra
Development of Experimental Performance Seismic Based Qualification Procedures for Nonstructural Components	Andre Filiatrault

The next morning breakout session focused on reviewing and providing comments on the Nonstructural Performance Product Straw Work Plan that was provided in the workshop workbook. The comments of the participants were captured in two ways by two different scribes. They were annotated in real time on table below each task as the task was discussed during the session. These real time comments were projected on a screen so everyone could see the comments as they occurred. Secondly, a note taker took notes as each task was discussed.

The participation in the feedback session was excellent. Virtually all 25 attendees participated significantly. In general, the attendees were supportive of the plan but made suggested changes to it. There were 3 areas where they were critical.

1. Some of the audience expressed disappointment that representatives from Canada were not invited. Canada is currently moving forward with a PBSE code for nonstructural components which we should take advantage of.
2. Many of the researchers were disappointed that there would be no funding available for testing. They felt testing was critical in this area especially if uncertainty bands was desired to establish fragility data.
3. There was consensus that Table 6 and 7 should occur before or concurrently with Tasks 2 and 3. Task 4 should be delayed until Task 3 is mostly completed.

The result of the review and comments was a revised Straw Work plan for Nonstructural Performance Products. This revised work plan is provided below and is the consensus of the participants of the breakout session regarding suggested changes to the work plan.

ATC-58 Nonstructural Performance Products Strawman Work Plan, February 25, 2003

#	Task	$K	03	04	05	06	07	08	09	10
1	Revised Action Plan	15								
2	Define possible EDPs and NPLs	15								
3	Choose EDPs and define NPLs	350								
4	Develop building-specific demand prediction methods	300								
5	Develop generic demand prediction methods	150								
6	Identify component types and performance impacts	250								
7	Evaluate current practice	300								
8	Define testing protocols	1000								
9	Develop research plan	150								
10	Develop analysis & design methods	850								
11	Coordinate design & analysis with SPP	150								
12	Define post-eq data collection program	300								
13	Define program to encourage PBSD use and innovation	300								
14	Develop seismic design implementation, QA/QC plan	300								
15	Document results for Guidelines, do verification studies	500								

Nonstructural Performance Products Break Out Session

Attendees

Bachman, Robert (Facilitator), Consulting Engineer
Bonowitz, David, Consulting Engineer
Borcherdt, Roger, U.S. Geological Survey
Bruneau, Michel, MCEER
Caldwell, Philip, Square D Company
Carlson, James, Seismic Source Company
Drake, Richard, Fluor Daniel
Filiatrault, Andre, Univ. of California, San Diego
Gates, William, URS Corporation
Gillengerten, John, OSHPD
Goodno, Barry, Georgia Institute of Technology
Itani, Ahmad, University of Nevada, Reno
Kehoe, Brian, Wiss, Janney, Elstner Associates
Kennedy, Robert, RPK Structural Mech. Consultant
Makris, Nicos, University of California, Berkeley
Malhotra, Praveen, FM Global Research
McGavin, Gary, McGavin Architecture
Memari, Ali, Pennsylvania State University
Miranda, Eduardo, Stanford University
Phipps, Maryann, ESTRUCTURE
Scawthorn, Charles, ABS Consulting
Silva, John, Hilti Inc.
Singh, M. P., Virginia Polytechnic Inst. & State Univ.
Soong, Larry, MCEER
Staehlin, William, OSHPD
Tauby, James, Mason Industries
Theodoropoulos, Christine, University of Oregon

Today's Design and Installation of Non-Structural Components

James A. Carlson, P.E.

Abstract

With the advent of the International Building Code and the National Fire Protection Association (NFPA) Building Code, numerous jurisdictions are changing their minimum requirements with respect to seismic issues especially those associated with non-structural components. Many new areas will be looking for guidance to design and install seismic restraints on equipment. Areas where seismic restraints are common may now face more stringent requirements. Requirements found in the code do not utilize performance based design guidance, but define the minimum requirements. This is where performance based seismic design guides are imperative to provide support to the building construction industry.

In 1999, American Society of Heating Refrigeration Air-conditioning Engineers (ASHRAE) published "A Practical Guide for Seismic Restraint" and it's said to be the highest selling guide that ASHRAE publishes. This reflects a real need of the design community for application type information regarding the seismic restraint design for non-structural components. Except for structural engineers versed in the seismic design, most professionals dealing with non-structural components lack even the basic knowledge and require seminars, training and guides to evaluate seismic installations.

Contractors have historically ignored seismic restraints or did not properly install these restraints. A FEMA funded project is in process to develop a multi-part manual that identifies and illustrates best practices in the installation of seismic restraint devices for mechanical, electrical, and plumbing (MEP), so that equipment will perform more satisfactorily in response to earthquakes. Contractors can take advantage of performance based designs to better implement information in these installation manuals.

Many standards specify installation properties that may be incomplete or in conflict with the minimum seismic requirements contained in building codes. For example, the piping support spacing tables do not meet the minimum 16.66 Hz natural frequency stiffness to assume rigid installations or include refrigeration piping which uses thin walled copper tubing. Design methods and analysis procedures need to be developed for appropriate performance based seismic design.

Recent Developments in Earthquake Resistant Design of Nonstructural Buildings Wall Systems

Ali M. Memari

Department of Architectural Engineering, Penn State University, University Park, PA

Abstract

Three types of nonstructural wall systems in buildings consisting of curtain walls that include architectural glass, brick veneer wall systems, and masonry infill walls have been the subject of recent research at Penn State. According to building codes, nonstructural (architectural) walls shall be designed to accommodate the design interstory building drifts in order to avoid damage to such systems. In past earthquakes, the architectural glass used in curtain walls, windows and storefronts has been damaged, extensively in some earthquakes. In one recent study at Penn State, a modified geometry architectural glass panel has been developed that can increase the drift capacity by almost 100% for some glass types. Glass panels with rounded corners and specially polished edges have been tested and shown to have such an increased drift capacity, which will satisfy the building drift requirements in most cases. Moreover, a type of curtain wall has been developed that will provide complete seismic isolation from story to story through seismic decoupler joints for any level of seismic input to the building. With such a system, as long as the building does not collapse, there is little chance for damage to the curtain wall. Another aspect of recent research on architectural glass is the investigation of the performance of safety film covered architectural glass under dynamic racking tests.

With respect to masonry infill walls, a seismic isolation system has been developed that can be placed between structural frame and the infill wall to act as a sacrificial subframe in order to prevent damage to the structural frame and the infill wall. This system is designed to preserve the tight-fit contact between the wall and the frame under low to moderate seismic events, but to disengage the contact between the frame and the wall under a high seismic event. The system is designed based on the "fuse" concept. Finally, a panelized brick veneer on steel stud wall system is under development that can be suitable for a multi-hazard resistant design situation, where resistance without cracking under high wind, in-plane seismic isolation under seismic events, and out-of-plane resistance under impact or blast loading may be desirable. The presentation will include brief explanations on these topics and how such developments fit in the overall efforts in the area of performance-based design.

Shake Table Testing as Means of Equipment Qualification

Phillip Caldwell

Abstract

1) When to use a seismic simulation shaker table to verify compliance with model building code requirements
2) Overview of a seismic simulation shaker table test program campaign
   a) Rationalization of product line to be qualified
      i) Role of high end computer simulation tools
      ii) Methods to validate computer simulation
   b) Identification and evaluation of model codes to evaluate for compliance
   c) Selection criteria for table (when to use 1-D, 2-D or 3-D table)
   d) Development of a test plan
      i) Specification of test protocol (i.e. ICBO ES AC156)
      ii) Identification of test samples
      iii) Specification of test parameters to be instrumented
      iv) Other documentation requirements
      v) Pre-test requirements
      vi) Test motions (Required Response Spectra) and time duration
      vii) Post test requirements
      viii) Evaluation criteria for pass/fail
   e) Selection of test samples to envelop full range of engineering investigation
      i) Computer simulation validation
      ii) Verification of design options
         (1) Example of anticipated passing test
         (2) Example of anticipated test failure
   f) Conducting test
      i) Review of test plan with test facility
      ii) Test facility preparations prior to test
      iii) Conducting test
         (1) Criteria for documenting pre-test and post test
         (2) Be prepared to be flexible with the order of test plan execution
         (3) Maintain constant awareness of test setup and execution and conformance to test plan
3) Development of test reports
   a) Content of test report
   b) Working with test facility to insure accuracy of test report and all required information to verify compliance or failure is contained in report
   c) How to use the results of test reports
      i) Development of self certification documents
      ii) Review with third party listing agency in preparation for obtaining third party certification (i.e. ICC Evaluation Services – formerly ICBO Evaluation Services)
4) Some of the shortcomings of the current process
   a) Confidence in the demand motions
5) How to engage more suppliers into the PBSE process
   a) Examples and results of previous efforts within electrical industry to get an industry effort
   b) Suggestions for future efforts

Cyclic-Demand in Performance-Based Seismic Design

Praveen K. Malhotra, Ph.D., P.E.

FM Global Research, Norwood, MA 02062

Abstract

The amplitude of the seismic load is insufficient to evaluate the seismic performance of structures or non-structural components. The number of cycles for which the seismic load is applied should also be considered. However, there has been no simple way to consider the cyclic-demand, because numerous definitions of strong-motion duration are only an indirect measure of the number of load cycles. Furthermore, duration derived from the acceleration history is meaningless for flexible systems which respond to support velocities and displacements, rather than accelerations.

FM Global Research has established a test protocol for evaluating the strength of sprinkler-pipe seismic-brace components. Because the components can fail in low-cycle fatigue, it was necessary to consider the number of load cycles in evaluating the seismic strength. Strong-motion records from 18 severely shaken buildings were incorporated into a low-cycle fatigue model to determine the number of load cycles for which the components must resist their rated capacity. The protocol is currently under use to evaluate the seismic strength of brace components. With slight modifications, the protocol may be used for various other piping components — hanger rods, couplings, flexible hoses, fasteners, etc.

The concept of cyclic-demand is expanded for general application in performance-based seismic design of structures. A cyclic-demand spectrum is proposed, which, in conjunction with the amplitude spectrum, provides a more complete definition of the seismic load — hence a way to consider the degradation in strength, stiffness and energy-dissipation capacity in a rational manner. Similar to three amplitude parameters (peak ground acceleration, peak ground velocity, and peak ground displacement), three cyclic-demand parameters are proposed for stiff, medium-stiff, and flexible systems.

Development of Experimental Performance-Based Seismic Qualification Procedures for Nonstructural Building Components

Andre Filiatrault

Professor of Structural Engineering, University of California, San Diego

Abstract

In many strong earthquakes that have struck the United States in the twentieth century, damage to nonstructural building components has exceeded the cost of structural damage in most affected buildings. Failures of interior partitions, finishes and hung ceilings pose hazards to occupants. With the development of performance-based earthquake engineering, harmonization of the performance levels between structural and nonstructural components is necessary. Even if the structural components of a building achieve an immediate occupancy performance level during a seismic event, building contents and interior architectural components failure inside the building can lower the performance level of the entire building system.

In comparison to structural components and systems, there is little information available giving specific guidance on the seismic design of nonstructural building components for multiple-performance levels. Little basic research has been done in this area and often design engineers are forced to start almost from square one: observe what goes wrong and try to prevent repetitions. This is a consequence of the empirical nature of current of existing seismic regulations and guidelines for nonstructural components. The code information currently available for the most part is based on judgment and intuition rather than on experimental and analytical results.

The development of experimental protocols to asses the seismic performance of nonstructural building components is urgently needed. The development of static and dynamic (shake table) test protocols is required to characterize the physical properties of nonstructural components and qualify both their structural and functional performances during seismic events.

This presentation will briefly review past experimental studies conducted by the author and others on the seismic performance of nonstructural building components. A rational methodology for the construction of experimental fragility functions for acceleration-sensitive building contents and cantilevered interior architectural components will be described.

Seismic Demands and Acceptance Criteria for Seismic Qualification Testing of Nonstructural Components

John Gillengerten

Office of Statewide Health Planning and Development

Abstract

The NEHRP *Provisions* contain requirements for the seismic qualification of designated seismic systems that must function following an earthquake. These requirements can be met through shake table testing, three-dimensional shock tests, or rigorous analysis that considers the nature of the input floor motion and the component dynamic response characteristics. This presentation outlines the current NEHRP design provisions, and the method used to develop floor response spectra for component testing. The test spectrum is incorporated into a new testing specification for non-structural components.

The test specification, adopted by the ICBO Evaluation Services as AC-156, *Acceptance Criteria for Seismic Qualification of Nonstructural Components*, is discussed. The presentation provides a brief background about measured building floor response spectra, and the concept of generic floor spectra. Nonstructural code forces, the relationship to generic floor spectra, and the relationship to the spectra specified in AC156 are discussed.

Appendix H: Risk Management Products Breakout Session Materials

Contents

1. Agenda
2. Summary Notes
3. Session Attendees
4. Presentations

    a. Eidenger, J. Benefits and Costs of Meeting Different Seismic Retrofit Design Criteria for the BART System Risk Management Breakout\eidenger-bart.pdf

    b. Cornell, C.A. Communicating PBEE-based Alternatives: Scenarios versus Probabilities Risk Management Breakout\Cornell-Hazard-Communication.pdf

    c. Hackett, J. Implementation Concerns of Performance Based Seismic Engineering (PBSE) from the Perspective of The Division of the State Architect, a Regulatory Agency

    d. Noson, L. Hazard Mapping And Risk Assessment Risk Management Breakout\LLN-risk_atc.pdf

    e. Kircher, C.A. HAZUS AEBM – Potential ATC-58 Risk Management Tool Risk Management Breakout\Kircher-HAZUS.pdf

Risk Management Products Breakout Session

Agenda

February 24, 2003

2:15 pm	Breakout Session Overview	Comartin
	- Introductions of Attendees	
	- Goals	
	- Reintroduction of Attendees	
2:20	Overview of RMPP Straw Work Plan	Comartin
2:40	- "Application of the AEBM module of HAZUS to selecting appropriate performance goals as the basis for design"	Kircher
3:00	- "Case study of the application of economic loss and cost benefit analysis to development of retrofit criteria for the BART system"	Eidinger
3:20	- "A process for seismic risk management and selection of criteria"	Nosen
3:40	- "Probabilistic Approach to PBEE"	Cornell
4:00	Coffee Break	
4:15	- "Risk-Informed Performance-Based Design for Fire: Similarities and Differences to Seismic Design"	Meacham
4:35	- "The implementation of PBE in the regulatory environment"	Hackett
4:55	- "Context matters in performance based engineering"	Petak
5:15	Group Discussion of Draft Work Plan	
6:00	No Host Reception	
7:00	Dinner (on your own)	

February 25, 2003

7:30 am	Continental Breakfast	
8:00 am	Resume Breakout Session	
	Presentation of Revised Workplan	Comartin
	Discussion and Changes	
10:00	Coffee Break	
10:15	Resume Breakout Session	
	Refine Plan	
12:00	Lunch	

Summary Notes

Risk Management Products Breakout Session

H.1 Introduction and Overview

Craig Comartin started the session with introductions of participants, a review of the schedule for the breakout session, and an overview of the RMP scope and aims of the breakout group. He identified the aim to better understand stakeholder seismic risk management needs in the context of the performance-based seismic engineering design process, as each stakeholder type will have a different perspective on this issues. To facilitate discussion, a set of stakeholder types was identified for closer consideration:

- Owner/Manager, consisting of Investor, Institution and Industry
- Societal/Government, consisting of Public Policy, Regulatory, and Special Interest/Advocacy (Public)
- Financial, consisting of Lenders, Insurers and Securities
- Professionals, consisting of Architects/Planners, Engineers/Scientists, and Researchers

There was general agreement that the different perspectives are important, and that risk management products need to exist for each group.

H.2 Presentations

Following the session overview, a number of presentations were made on topics associated with the overall scope and aim of the RMP area, including benefit-cost analysis, risk management issues, and stakeholder communication. The following are brief summaries of each presentation.

Application of the AEB Module of HAZUS to Selecting Appropriate Performance Goals as the Basis for Design, Charles Kircher

Kircher began his presentation with a discussion of earthquake risk, which in a comparative sense, is fairly low. In his comparison of losses in the Northridge, Kobe and Kocaeli earthquakes, in terms of lives, property damage and economic impact, Northridge had the lowest losses. Kircher pointed to the need for the seismic risk assessment process to cover a broad range of issues, not only in terms of life safety and property damage, but the downtime/business interruption/recovery time costs. This discussion then transitioned into an overview of the HAZUS AEBM module, which is a useful tool for helping to understand earthquake loss estimation, including such factors as injuries, damage costs and downtime costs for single building evaluation. Kircher used examples to demonstrate the benefits of HAZUS AEBM, including an analysis of an instrumented building in San Jose and the development of fragility curves using the SAC steel-frame building database.

Key points from Kircher's presentation include:

- Seismic risk in US is comparatively low
- Seismic risk assessment needs to consider downtime costs as well as life and property damage costs
- HAZUS AEBM is an existing tool that can be applied to these issues
- How to properly develop a fragility curve is the key factor

Case Study of the Application of Economic Loss and Cost Benefit Analysis to Development of Retrofit Criteria for the BART System, John Eidinger

The focus of Eidinger's presentation was on the use of cost benefit analysis for making seismic risk mitigation decisions for the BART system. The study developed out of an assessment that indicated a need for greater than $3 Billion of seismic upgrades to obtain a "full operability" level following a significant event, and the desire to determine if there were some other level that may not be full operability, yet may be "good enough." The range of potential options included "life safety" at one end, "full operability" at the other, with numerous variants in between. Six retrofit alternatives were identified, with ranges in performance levels and cost, from $600 Million to $1.44 Billion, based on a total replacement cost estimate of some $10.8 Billion. Eidinger outlined the process of inventory development, component descriptions, mapping, and so forth, and discussed the use of scenario earthquakes for hazard characterization. In total, 166 sets of fragility curves were used in some 100 simulations to assess system performance, which was measured in terms of passenger trips/day, economic loss, and life safety. Operation levels were measured in terms of riders vs. days after the event. Benefit-cost analysis was applied to the retrofit alternatives. In the end, the analysis indicated that retrofit for return to full operability was not best approach given the uncertainty in the ability to return to full operability and the marginal benefits for the magnitude of cost expenditure.

A Process for Seismic Risk Management and Selection of Criteria, Linda Noson

The presentation by Noson fit well with the earlier discussion on stakeholder needs, as she focused in on the fact that one needs to work with stakeholders to understand what they want to accomplish, with the recognition that different organizations handle risk management decisions differently, with varying degrees of decision-making flexibility and budget. Noson outlined various organizational risk management issues, identifying components of the process, including risk identification, decision-making and management. She identified terminology as a significant concern, as people with different backgrounds have different interpretations (e.g., engineer versus CFO), and that care must be taken to properly differentiate between such terms as vulnerability, hazard, exposure is discussions and assessments.

Risk-Informed Performance-Based Design for Fire: Similarities and Differences to Seismic Design, Brian Meacham

Meacham began with an overview of how fire protection engineering developed as a discipline, and how the building regulatory system changed as well, allowing more use of engineered approaches to problems such as fire resistance, smoke control, suppression and egress design. Advances in fire protection engineering and changes in the building codes overlapped in the 1990s when performance-based building codes were being explored, and funding was invested to research performance-based fire engineering (PBFE). A key aspect of PBFE is the three-level approach to analysis and design: the Component Level (e.g., performance comparison of like components, such as sprinkler heads), the System Level (e.g., performance comparison between dissimilar systems, such as fire resistance and sprinklers), and the Building Level (e.g., comparing all systems holistically). The Building Level is where probabilistic (risk) modeling comes in, and is the least developed area. Similarities with PBSE include challenges in defining performance and tying risk tolerability with performance levels, the sources and range of uncertainty and variability and how to best address, and how to ensure stakeholders buy in. Differences from PBEE include the fact that PBFE already exists (engineers are using it and authorities are becoming familiar with the concepts), with the focus now on developing reviewer guides and other stakeholders support tools. Also, unlike PBSE, PBFE is currently focused on deterministic analysis, as probabilistic data are sparse.

The Implementation of PBE in the Regulatory Environment, James Hackett

Hackett outlined the challenges associated with the California Department of the State Architect (DSA) requirement to write performance-based regulations for retrofit of non-Field Act buildings (the Field Act outlines seismic requirements for schools) that may be used for schools in the future (including some charter schools now). The first step was to try and determine what the Field Act requires for performance and to establish appropriate criteria. The challenge then became one of implementation, where the concerns include: retrofit measures; educating staff; evaluation; peer review; quality assurance; pre-purchase review; educating the public; levels of damage control that need to be defined; wide range of structural types that need to be considered; historic structures. A significant focus now is on outlining and developing a process for design engineers to use something other than current code for seismic retrofit (with the FEMA guidance being a good starting point). As this goes forward, it is important to note that DSA does not certify compliance: engineers do this as SEs and thus carry the liability. Quality assurance is a critical issue, and the DSA is exploring the formation of an internal group for ensuring uniformity and consistency. This is not intended to result in prescriptive design, but rather, to help assure the appropriate use of methods for choosing performance levels and developing design solutions.

Context Matters in Performance-Based Engineering, William Petak

In this presentation, Petak focused on the interconnection between the decision-making process and performance characterization within the context of a complex socio-technical system. If one focuses on one component or aspect of the system, without consideration of the other factors, significant problems can be expected. Of concern are the issues of a reduce capacity for individual decision-making, limited stakeholder participation, and an increased need for experts. Petak went on to describe the STAPLE framework for adopting and understanding diverse/complex issues within the socio-technical system, where STAPLE reflects the **S**ocial, **T**echnological, **A**nalytical, **P**olitical, **L**egal, and **E**conomic environments/influences. In conjunction with the STAPLE approach, one also needs to be cognizant of how organizations make decisions. Petak cautioned against the use of "decision criteria," which may lead to "one best way" solutions and is not the way most organizations operate. Rather, he urged consideration of key organizational decision factors: perception of risk; technology; regulations; financial capacity/economy; and insurance, coupled and addressed within a decision matrix. He also pointed out that there are different issues when considering new designs (small increments in design and construction cost) and retrofit (larger increments). Finally, Petak advocated having stakeholders in development process, not just having them as a focus group, and offered BICEPP and CREW as examples.

Probabilistic Approach to PBEE, Allin Cornell

In this presentation, Cornell discussed the issue of a probabilistic approach versus a hybrid approach. He began by laying out the key factors, including annual probabilities of exceedence, economic loss, inter-story drift and ground motion, discussing issues associated with scenario events, and illustrating how the issues can be addressed in a full probabilistic or in a hybrid approach. Each approach has benefits and detriments depending on such factors as whether a first order approximation is sufficient, and the level of understanding of the client.

H.3 Group Discussion

Discussion was held by the group at the end of Day 1 and after the presentation by Cornell on Day 2. On Day 1, one point of considerable discussion was the role of stakeholders in the process. In the Straw Work Plan, it was proposed to formulate stakeholder groups to facilitate input. However, several people voiced concerns about including stakeholders only as focus group participants, and preferred to see stakeholder become an integral part of development team for this effort.

Day 2 focused on a task-by-task evaluation of the Straw Work Plan. Whereas the primary focus was on the tasks and not the funding, no group discussion regarding funding occurred. The following represents a summary of the RMP Breakout Group discussion and recommendations.

Task No.	**Task**	***FEMA 349* Budget**	***FEMA 349* Schedule**	***Comments***
RMP-2.1	Identify performance considerations and metrics	$350,000	1 year	Look at what issues of concern are and tabulate how various stakeholders view issues.
RMP-2.2	Establish process to relate PBEE to stakeholder performance objectives	$350,000	1 year	Establish process to relate objectives to performance. Performance considerations and decision process and metrics. Suggest potential criteria. Don't set "acceptable" or "minimum" criteria.
RMP - 2.3 (new)	*Establish mechanism to translate damage to consequences (DDD) and calibrate methodologies with other groups.*	*$400,000*	*4 years*	Need to develop way that engineers can translate damage states into consequences of value to stakeholders. Need to coordinate with structural and non-structural products groups. Need to make sure method works before developing tools.
RMP – 2.4 (new)	*Consider implications for multiple structures in the same or multiple settings (community).*			Need to look at how building performance characterization can be translated to community, portfolio or systems.

Risk Management Products Break Out Session

Attendees

Comartin, Craig (Facilitator), Comartin-Reis
Alesch, Daniel, Univ. of Wisconsin, Green Bay
Aydinoglu, Nuray, Bogazici University
Beck, Deborah, Real Estate Board of New York
Bendimerad, Fouad, Risk Management Solutions
Cornell, Allin, Stanford University
Court, Anthony, Curry Price Court
Dong, Weimin, Risk Management Solutions
Eidinger, John, G&E Engineering Systems
Ellingwood, Bruce, Georgia Institute of Tech.
Green, Henry, Bureau of Construction Codes
Hackett, James, Cal. Div of State Architect
Haviland, Perry, Haviland Associates Architects
Holmes, William, Rutherford & Chekene
King, Stephanie, Weidlinger Associates
Kircher, Charles, Charles Kircher & Associates
Kiremidjian, Anne, Stanford University
Lew, H. S., NIST
May, Peter, University of Washington
Meacham, Brian, Ove Arup and Partners
Merovich, Andrew, A. T. Merovich & Associates
Mittler, Elliott, Public Policy Consultant
Noson, Linda, Linda Noson Associates
Petak, William, University of Southern California
Poland, Chris, Degenkolb Engineers
Somerville, Paul, URS Greiner Woodward Clyde
Taylor, Craig, Natural Hazards Management
Traw, John, Traw Associates Consulting

Benefits and Costs of Meeting Different Seismic Retrofit Design Criteria for the BART System

John Eidenger

Abstract

BART has embarked on a multi-year effort to seismically retrofit its original 1968-vintage rail system. The original system was built using reasonably ductile design methods, for a site-specific motion of about ZPA = 0.5g (some variation for rock and soil sites) More recent understanding of seismology and structural design have been applied to evaluate the existing BART system. This includes site specific ground motions, fault "fling", current understanding of ductility, etc. Following FEMA / NEHRP criteria, essentially 100% of the existing BART infrastructure fail these more "rigorous" year 2002 design guidelines standards.

The cost to retrofit all of BART's original infrastructure to meet either "Life Safety" or "Full Operability" guidelines, as suggested in various current FEMA documents, would easily exceed $3 billion, possibly more. recognizing the cost implications, BART performed a more system-wide approach to seismic retrofit of its system. This approach explicitly considers that every component between two stations must perform reasonably well in order to safely run a train between the two stations. Damage to components could be acceptable, along with reduction in train speeds or service, as long as economic impacts to the community were not too great.

We examined numerous alternative levels of seismic retrofit standards. We performed system wide benefit cost models with / without the retrofits installed. We generally found that the lowest level of seismic retrofit, ie "life safety" was the most cost effective for purposes of retrofitting BART. More expensive retrofits, ie "full operability" (lower allowable strains, etc.) were found to be not cost effective, even after consideration of system-wide impacts, for more than 905 of the BART system. This study illustrates the use of performance evaluation on a system wide basis and cost-benefit analyses to assist in selection of seismic design criteria.

Communicating PBEE-based Alternatives: Scenarios versus Probabilities

C. Allin Cornell

Stanford University

Abstract

The questions addressed are the relative benefits of two of the more extreme ways of presenting, communicating and defining risk information with clients as a basis for design criteria. One of these consists of an expression of the total probability of exceeding or experiencing defined limit states or performance levels, such as collapse, specified repair costs, deaths, downtime, etc. Detailed development of such approaches are underway by researchers at PEER and elsewhere. The alternative and more traditional approach relates to definition of an expected performance level given a single definition of a design scenario event, such as a magnitude, M, on the San Andreas Fault.

The full probabilistic approach can provide a wide range of information upon which decisions can be based, (e.g., mean annual frequency of collapse, the probability that some number of lives > n lives may be lost, the probability that economic loss in excess of x$ will occur; plus, perhaps, even confidence levels on such estimates.) Scenario formats (e.g., Magnitude M, Magnitude M at distance R; ground motion level x, etc.). while providing less information, and which potentially address events that may never occur, while not addressing events that could occur, are none the less, easier to understand for many.

A proposal is presented for a hybrid approach which starts from the "full probabilistic" form of information and translates that into an "equivalent" scenario format. Use with absolute assessments and relative comparisons between alternative designs is suggested.

Implementation Concerns of Performance Based Seismic Engineering (PBSE) from the Perspective of The Division of the State Architect, a Regulatory Agency

James P. Hackett

State of California, Division of the State Architect

Abstract

The Division of the State Architect (DSA) provides plan review and observation of construction for over 2000 public school districts, 900 California Community College districts and a rapidly expanding population of charter schools throughout the state. The increasing demand for new facilities combined with the lack of available unimproved land in urban areas has prompted the legislature to enact legislation requiring DSA to promulgate regulations for the conversion of non-Field Act buildings to a performance level equivalent with the implementing provisions of the Field Act.

The performance objectives defined in the Field Act is protection of life and property (Section 17280, California Education Code). These objectives are being achieved in the California Building Code through prescriptive technical provisions adopted for state use, thorough plan review and continuous inspection of construction.

The DSA is currently considering implementing regulations that will incorporate the PBSE processes of FEMA 356. However, implementing these provisions will have a significant impact on the operations of DSA, and the following issues will pose a challenge to put into practice in a manner that will allow for consistent implementation across the four regional offices of DSA:

1. Analysis of structures utilizing non-linear PBSE analysis techniques will require development of a program to provide extensive training of staff and management.
2. A credible procedure for acceptance of alternative design and acceptance criteria of existing conditions that do not comply with prescriptive modal code provisions must be developed.
3. Development of a peer review process providing credible expertise is necessary. Peer review consultants to DSA may need to be retained until staff obtains the necessary expertise.
4. Protection of life and property as identified in the Field Act require definition of the performance objectives in the damage control range. Developing a numerical equivalent accounting for the effects of thorough plan review and continuous inspection is problematic and may be difficult to technically justify.
5. Since DSA expects a wide range of building types, materials and sizes to be candidates for conversion, procedures must be developed to determine when PBSE methods are appropriate for use.

HAZARD MAPPING AND RISK ASSESSMENT

Linda Noson, Principal, Linda Noson Associates

Abstract

This paper provides an introduction to Performance-Based Risk Management for the purpose of developing a conceptual and theoretical background on which to prepare guidance materials... Performance-Based Risk Management provides a comprehensive, consistent methodology to help those in authority address the affects of natural, technological, and human hazards on an organization's capability to carry out it's mission and on a department's capability to accomplish operational roles and responsibilities. .Risk management provides a comprehensive approach for developing and implementing sustainable and effective risk policies and interventions to manage the adverse effects of accidental losses, such as those related to natural hazard impacts, and business losses. Risk management consists of both a management process and a decision-making process. The five steps of the risk management decision-making process include: (1) Identify and Analyze Loss Exposures; (2) Examine Alternative Risk Management Techniques; (3) Select Risk Management Techniques; (4) Implement techniques; and (5) Monitor Results (Table 1). The traditional elements of management – planning, organizing, leading, and controlling – are applied to each of the steps shown in Table 1. Table 2 shows an example of applying each of the elements of management to Step 1 in the decision making process (Identifying and Analyzing Loss Exposures).

Table 1 Steps in the Risk Management Process

Step	Risk Management Process	Description
One	Identifying and Analyzing Loss Exposures	Define essential exposures: Mission Statement, Policies and Legal Arrangements Risk Assessment Risk Evaluations (Significance of Risk)
Two	Examine alternative Risk Management Techniques	Mitigation Planning and Implementation (Mitigation sensitivity, Feasibility, Cost))
Three	Select Risk Management Techniques	Mitigation Planning and Implementation (cost/benefit analysis)
Four	Implement Techniques	Mitigation Planning and Implementation (Contract Selection, Schedule)
		Public Awareness and Social Marketing
		Capacity Building
		Promoting Safer Building Construction Community Based Approaches to Disaster Mitigation
		Climate Applications and Preparedness
Five	Monitor Results	

HAZUS AEBM – Potential ATC-58 Risk Management Tool

C. A. Kircher

Abstract

The FEMA/NIBS earthquake loss estimation methodology, commonly known as *HAZUS*, is a complex collection of components that work together to estimate casualties, loss of function and economic impacts of earthquake ground shaking and ground failure. The methodology is documented in the *HAZUS Technical Manual* and a number of technical papers. One of the main components of the methodology estimates the probability of various states of structural and nonstructural damage to buildings using quantitative descriptions of ground shaking and nonlinear response analysis of the structure. Damage state probabilities are used by other components of the methodology to estimate various types of building-related loss.

The *Advanced Engineering Building Module* (*AEBM*) was recently added to the methodology to allow expert users to create "building-specific" damage and loss functions for detailed evaluation of an individual building (or group of similar buildings). The *AEBM* provides seismic/structural engineers with the requisite set of tools for evaluating the performance of structural and nonstructural systems of buildings. These tools may be used to evaluate the relative performance of alternative designs of a new building, or similarly different rehabilitation schemes for an existing building. These tools can also provide the "metrics" for judging the benefits of performance-based seismic design, by quantifying performance in terms of lives saved or injuries avoided, reduction in business interruption and functional downtime and reduction in direct and indirect economic losses.

The *HAZUS AEBM* bridges the gap between quantitative measures of ground shaking and estimates of damage and loss due to this ground shaking. A research opportunity exists for extending and adapting the methods of the *HAZUS AEBM* as a risk management tool of the ATC-58 effort to develop performance-based design guidelines. Current performance-based methods typically focus on improved prediction and understanding of building response (e.g., inelastic building drift). This is understandable, since engineers (and engineering researchers) tend to think in terms of engineering parameters, such as building drift, as the primary measure of building performance. While engineering parameters are important (to engineers), stakeholders (e.g., building occupants and owners) are more interested in judging performance in terms of threats to life safety, possible loss of building use (e.g., shelter or business), and cost of repair or replacement of systems damaged by the earthquake. The methods off the *HAZUS AEBM* technology can provide a key link between earthquake hazard, engineering measures of performance (e.g., building drift), and those measures of performance (e.g., life safety) that are more meaningful to stakeholders and society in general.

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Applied Technology Council Projects and Report Information

One of the primary purposes of Applied Technology Council is to develop resource documents that translate and summarize useful information to practicing engineers. This includes the development of guidelines and manuals, as well as the development of research recommendations for specific areas determined by the profession. ATC is not a code development organization, although several of the ATC project reports serve as resource documents for the development of codes, standards and specifications.

Applied Technology Council conducts projects that meet the following criteria:

1. The primary audience or benefactor is the design practitioner in structural engineering.
2. A cross section or consensus of engineering opinion is required to be obtained and presented by a neutral source.
3. The project fosters the advancement of structural engineering practice.

Brief descriptions of completed ATC projects and reports are provided below. Funding for projects is obtained from government agencies and tax-deductible contributions from the private sector.

ATC-1: This project resulted in five papers that were published as part of *Building Practices for Disaster Mitigation, Building Science Series 46*, proceedings of a workshop sponsored by the National Science Foundation (NSF) and the National Bureau of Standards (NBS). Available through the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22151, as NTIS report No. COM-73-50188.

ATC-2: The report, *An Evaluation of a Response Spectrum Approach to Seismic Design of Buildings*, was funded by NSF and NBS and was conducted as part of the Cooperative Federal Program in Building Practices for Disaster Mitigation. Available through the ATC office. (Published 1974, 270 Pages)

ABSTRACT: This study evaluated the applicability and cost of the response spectrum approach to seismic analysis and design that was proposed by various segments of the engineering profession. Specific building designs, design procedures and parameter values were evaluated for future application. Eleven existing buildings of varying dimensions were redesigned according to the procedures.

ATC-3: The report, *Tentative Provisions for the Development of Seismic Regulations for Buildings* (ATC-3-06), was funded by NSF and NBS. The second printing of this report, which includes proposed amendments, is available through the ATC office. (Published 1978, amended 1982, 505 pages plus proposed amendments)

ABSTRACT: The tentative provisions in this document represent the results of a concerted effort by a multi-disciplinary team of 85 nationally recognized experts in earthquake engineering. The provisions serve as the basis for the seismic provisions of the 1988 and subsequent issues of the *Uniform Building Code* and the *NEHRP Recommended Provisions for the Development of Seismic Regulation for New Buildings*. The second printing of this document contains proposed amendments prepared by a joint committee of the Building Seismic Safety Council (BSSC) and the NBS.

ATC-3-2: The project, "Comparative Test Designs of Buildings Using ATC-3-06 Tentative Provisions", was funded by NSF. The project consisted of a study to develop and plan a program for making comparative test designs of the ATC-3-06 Tentative Provisions. The project report was written to be used by the Building Seismic Safety Council in its refinement of the ATC-3-06 Tentative Provisions.

ATC-3-4: The report, *Redesign of Three Multistory Buildings: A Comparison Using ATC-3-06 and 1982 Uniform Building Code Design Provisions*, was published under a grant from NSF. Available through the ATC office. (Published 1984, 112 pages)

ABSTRACT: This report evaluates the cost and technical impact of using the 1978 ATC-3-06 report, *Tentative Provisions for the Development of Seismic Regulations for Buildings*, as amended by a joint committee of the Building Seismic Safety Council and the National Bureau of Standards in 1982. The evaluations are based on studies of three existing California buildings redesigned in accordance with the ATC-3-06 Tentative Provisions and the 1982 *Uniform Building Code*. Included in the report are recommendations to code implementing bodies.

ATC-3-5: This project, "Assistance for First Phase of ATC-3-06 Trial Design Program Being Conducted by the Building Seismic Safety Council", was funded by the Building Seismic Safety Council to provide the services of the ATC Senior Consultant and other ATC personnel to assist the BSSC in the conduct of the first phase of its Trial Design Program. The first phase provided for trial designs conducted for buildings in Los Angeles, Seattle, Phoenix, and Memphis.

ATC-3-6: This project, "Assistance for Second Phase of ATC-3-06 Trial Design Program Being Conducted by the Building Seismic Safety Council", was funded by the Building Seismic Safety Council to provide the services of the ATC Senior Consultant and other ATC personnel to assist the BSSC in the conduct of the second phase of its Trial Design Program. The second phase provided for trial designs conducted for buildings in New York, Chicago, St. Louis, Charleston, and Fort Worth.

ATC-4: The report, *A Methodology for Seismic Design and Construction of Single-Family Dwellings*, was published under a contract with the Department of Housing and Urban Development (HUD). Available through the ATC office. (Published 1976, 576 pages)

ABSTRACT: This report presents the results of an in-depth effort to develop design and construction details for single-family residences that minimize the potential economic loss and life-loss risk associated with earthquakes. The report: (1) discusses the ways structures behave when subjected to seismic forces, (2) sets forth suggested design criteria for conventional layouts of dwellings constructed with conventional materials, (3) presents construction details that do not require the designer to perform analytical calculations, (4) suggests procedures for efficient plan-checking, and (5) presents recommendations including details and schedules for use in the field by construction personnel and building inspectors.

ATC-4-1: The report, *The Home Builders Guide for Earthquake Design*, was published under a contract with HUD. Available through the ATC office. (Published 1980, 57 pages)

ABSTRACT: This report is an abridged version of the ATC-4 report. The concise, easily understood text of the Guide is supplemented with illustrations and 46 construction details. The details are provided to ensure that houses contain structural features that are properly positioned, dimensioned and constructed to resist earthquake forces. A brief description is included on how earthquake forces impact on houses and some precautionary constraints are given with respect to site selection and architectural designs.

ATC-5: The report, *Guidelines for Seismic Design and Construction of Single-Story Masonry Dwellings in Seismic Zone 2*, was developed under a contract with HUD. Available through the ATC office. (Published 1986, 38 pages)

ABSTRACT: The report offers a concise methodology for the earthquake design and construction of single-story masonry dwellings in Seismic Zone 2 of the United States, as defined by the 1973 *Uniform Building Code*. The Guidelines are based in part on shaking table tests of masonry construction conducted at the University of California at Berkeley Earthquake Engineering Research Center. The report is written in simple language and includes basic house plans, wall evaluations, detail drawings, and material specifications.

ATC-6: The report, *Seismic Design Guidelines for Highway Bridges*, was published under a contract with the Federal Highway

Administration (FHWA). Available through the ATC office. (Published 1981, 210 pages)

ABSTRACT: The Guidelines are the recommendations of a team of sixteen nationally recognized experts that included consulting engineers, academics, state and federal agency representatives from throughout the United States. The Guidelines embody several new concepts that were significant departures from then existing design provisions. Included in the Guidelines are an extensive commentary, an example demonstrating the use of the Guidelines, and summary reports on 21 bridges redesigned in accordance with the Guidelines. In 1991 the guidelines were adopted by the American Association of Highway and Transportation Officials as a standard specification.

ATC-6-1: The report, *Proceedings of a Workshop on Earthquake Resistance of Highway Bridges*, was published under a grant from NSF. Available through the ATC office. (Published 1979, 625 pages)

ABSTRACT: The report includes 23 state-of-the-art and state-of-practice papers on earthquake resistance of highway bridges. Seven of the twenty-three papers were authored by participants from Japan, New Zealand and Portugal. The Proceedings also contain recommendations for future research that were developed by the 45 workshop participants.

ATC-6-2: The report, *Seismic Retrofitting Guidelines for Highway Bridges*, was published under a contract with FHWA. Available through the ATC office. (Published 1983, 220 pages)

ABSTRACT: The Guidelines are the recommendations of a team of thirteen nationally recognized experts that included consulting engineers, academics, state highway engineers, and federal agency representatives. The Guidelines, applicable for use in all parts of the United States, include a preliminary screening procedure, methods for evaluating an existing bridge in detail, and potential retrofitting measures for the most common seismic deficiencies. Also included are special design requirements for various retrofitting measures.

ATC-7: The report, *Guidelines for the Design of Horizontal Wood Diaphragms*, was published under a grant from NSF. Available through the ATC office. (Published 1981, 190 pages)

ABSTRACT: Guidelines are presented for designing roof and floor systems so these can function as horizontal diaphragms in a lateral force resisting system. Analytical procedures, connection details and design examples are included in the Guidelines.

ATC-7-1: The report, *Proceedings of a Workshop on Design of Horizontal Wood Diaphragms*, was published under a grant from NSF. Available through the ATC office. (Published 1980, 302 pages)

ABSTRACT: The report includes seven papers on state-of-the-practice and two papers on recent research. Also included are recommendations for future research that were developed by the 35 workshop participants.

ATC-8: This report, *Proceedings of a Workshop on the Design of Prefabricated Concrete Buildings for Earthquake Loads*, was funded by NSF. Available through the ATC office. (Published 1981, 400 pages)

ABSTRACT: The report includes eighteen state-of-the-art papers and six summary papers. Also included are recommendations for future research that were developed by the 43 workshop participants.

ATC-9: The report, *An Evaluation of the Imperial County Services Building Earthquake Response and Associated Damage*, was published under a grant from NSF. Available through the ATC office. (Published 1984, 231 pages)

ABSTRACT: The report presents the results of an in-depth evaluation of the Imperial County Services Building, a 6-story reinforced concrete frame and shear wall building severely damaged by the October 15, 1979 Imperial Valley, California, earthquake. The report contains a review and evaluation of earthquake damage to the building; a review and evaluation of the seismic design; a comparison of the requirements of various building codes as they relate to the building; and conclusions and recommendations pertaining to future building code provisions and future research needs.

ATC-10: This report, *An Investigation of the Correlation Between Earthquake Ground Motion and Building Performance*, was funded by the U.S. Geological Survey (USGS). Available through the ATC office. (Published 1982, 114 pages)

ABSTRACT: The report contains an in-depth analytical evaluation of the ultimate or limit capacity of selected representative building framing types, a discussion of the factors affecting the seismic performance of buildings, and a summary and comparison of seismic design and seismic risk parameters currently in widespread use.

ATC-10-1: This report, *Critical Aspects of Earthquake Ground Motion and Building Damage Potential*, was co-funded by the USGS and the NSF. Available through the ATC office. (Published 1984, 259 pages)

ABSTRACT: This document contains 19 state-of-the-art papers on ground motion, structural response, and structural design issues presented by prominent engineers and earth scientists in an ATC seminar. The main theme of the papers is to identify the critical aspects of ground motion and building performance that currently are not being considered in building design. The report also contains conclusions and recommendations of working groups convened after the Seminar.

ATC-11: The report, *Seismic Resistance of Reinforced Concrete Shear Walls and Frame Joints: Implications of Recent Research for Design Engineers*, was published under a grant from NSF. Available through the ATC office. (Published 1983, 184 pages)

ABSTRACT: This document presents the results of an in-depth review and synthesis of research reports pertaining to cyclic loading of reinforced concrete shear walls and cyclic loading of joints in reinforced concrete frames. More than 125 research reports published since 1971 are reviewed and evaluated in this report. The preparation of the report included a consensus process involving numerous experienced design professionals from throughout the United States. The report contains reviews of current and past design practices, summaries of research developments, and in-depth discussions of design implications of recent research results.

ATC-12: This report, *Comparison of United States and New Zealand Seismic Design Practices for Highway Bridges*, was published under a grant from NSF. Available through the ATC office. (Published 1982, 270 pages)

ABSTRACT: The report contains summaries of all aspects and innovative design procedures used in New Zealand as well as comparison of United States and New Zealand design practice. Also included are research recommendations developed at a 3-day workshop in New Zealand attended by 16 U.S. and 35 New Zealand bridge design engineers and researchers.

ATC-12-1: This report, *Proceedings of Second Joint U.S.-New Zealand Workshop on Seismic Resistance of Highway Bridges*, was published under a grant from NSF. Available through the ATC office. (Published 1986, 272 pages)

ABSTRACT: This report contains written versions of the papers presented at this 1985 workshop as well as a list and prioritization of workshop recommendations. Included are summaries of research projects being conducted in both countries as well as state-of-the-practice papers on various aspects of design practice. Topics discussed include bridge design philosophy and loadings; design of columns, footings, piles, abutments and retaining structures; geotechnical aspects of foundation design; seismic analysis techniques; seismic retrofitting; case studies using base isolation; strong-motion data acquisition and interpretation; and testing of bridge components and bridge systems.

ATC-13: The report, *Earthquake Damage Evaluation Data for California*, was developed under a contract with the Federal Emergency Management Agency (FEMA). Available through the ATC office. (Published 1985, 492 pages)

ABSTRACT: This report presents expert-opinion earthquake damage and loss estimates for industrial, commercial, residential, utility and transportation facilities in California. Included are damage probability matrices for 78 classes of structures and estimates of time required to restore damaged facilities to pre-earthquake usability. The report also describes the inventory information essential for estimating economic losses and the methodology used to develop loss estimates on a regional basis.

ATC-13-1: The report, *Commentary on the Use of ATC-13 Earthquake Damage Evaluation Data for Probable Maximum Loss Studies of California Buildings*, was developed with funding from ATC's Henry J. Degenkolb Memorial Endowment Fund. Available through the ATC office. (Published 2002, 66 pages)

ABSTRACT: This report provides guidance to consulting firms who are using ATC-13 expert-opinion data for probable maximum loss (PML) studies of California buildings. Included are discussions of the limitations of the ATC-13 expert-opinion data, and the issues associated with using the data for PML studies. Also included are three appendices containing information and data not included in the original ATC-13 report: (1) ATC-13 model building type descriptions, including methodology for estimating the expected performance of standard, nonstandard, and special construction; (2) ATC-13 Beta damage distribution parameters for model building types; and (3) PML values for ATC-13 model building types.

ATC-14: The report, *Evaluating the Seismic Resistance of Existing Buildings*, was developed under a grant from the NSF. Available through the ATC office. (Published 1987, 370 pages)

ABSTRACT: This report, written for practicing structural engineers, describes a methodology for performing preliminary and detailed building seismic evaluations. The report contains a state-of-practice review; seismic loading criteria; data collection procedures; a detailed description of the building classification system; preliminary and detailed analysis procedures; and example case studies, including nonstructural considerations.

ATC-15: The report, *Comparison of Seismic Design Practices in the United States and Japan*, was published under a grant from NSF. Available through the ATC office. (Published 1984, 317 pages)

ABSTRACT: The report contains detailed technical papers describing design practices in the United States and Japan as well as recommendations emanating from a joint U.S.-Japan workshop held in Hawaii in March, 1984. Included are detailed descriptions of new seismic design methods for buildings in Japan and case studies of the design of specific buildings (in both countries). The report also contains an overview of the history and objectives of the Japan Structural Consultants Association.

ATC-15-1: The report, *Proceedings of Second U.S.-Japan Workshop on Improvement of Building Seismic Design and Construction Practices*, was published under a grant from NSF. Available through the ATC office. (Published 1987, 412 pages)

ABSTRACT: This report contains 23 technical papers presented at this San Francisco workshop in August, 1986, by practitioners and researchers from the U.S. and Japan. Included are state-of-the-practice papers and case studies of actual building designs and information on regulatory, contractual, and licensing issues.

ATC-15-2: The report, *Proceedings of Third U.S.-Japan Workshop on Improvement of Building Structural Design and Construction Practices*, was published jointly by ATC and the Japan Structural Consultants Association. Available through the ATC office. (Published 1989, 358 pages)

ABSTRACT: This report contains 21 technical papers presented at this Tokyo, Japan, workshop in July, 1988, by practitioners and researchers from the U.S., Japan, China, and New Zealand. Included are state-of-the-practice papers on various topics, including braced steel frame buildings, beam-column joints in reinforced concrete buildings, summaries of comparative U. S. and Japanese design, and base isolation and passive energy dissipation devices.

ATC-15-3: The report, *Proceedings of Fourth U.S.-Japan Workshop on Improvement of Building Structural Design and Construction Practices*, was published jointly by ATC and the Japan Structural Consultants Association. Available through the ATC office. (Published 1992, 484 pages)

ABSTRACT: This report contains 22 technical papers presented at this Kailua-Kona, Hawaii, workshop in August, 1990, by practitioners and researchers from the United States, Japan, and Peru. Included are papers on postearthquake building damage assessment; acceptable earth-quake damage; repair and retrofit of earthquake damaged buildings; base-isolated buildings, including Architectural Institute of Japan recommendations for design; active damping systems; wind-resistant design; and summaries of working group conclusions and recommendations.

ATC-15-4: The report, *Proceedings of Fifth U.S.-Japan Workshop on Improvement of Building Structural Design and Construction Practices*, was published jointly by ATC and the Japan Structural Consultants Association. Available through the ATC office. (Published 1994, 360 pages)

ABSTRACT: This report contains 20 technical papers presented at this San Diego, California workshop in September, 1992. Included are papers on performance goals/acceptable damage in seismic design; seismic design procedures and case studies; construction influences on design; seismic isolation and passive energy dissipation; design of irregular structures; seismic evaluation, repair and upgrading; quality control for design and construction; and summaries of working group discussions and recommendations.

ATC-16: This project, "Development of a 5-Year Plan for Reducing the Earthquake Hazards Posed by Existing Nonfederal Buildings", was funded by FEMA and was conducted by a joint venture of ATC, the Building Seismic Safety Council and the Earthquake Engineering Research Institute. The project involved a workshop in Phoenix, Arizona, where approximately 50 earthquake specialists met to identify the major tasks and goals for reducing the earthquake hazards posed by existing nonfederal buildings nationwide. The plan was developed on the basis of nine issue papers presented at the workshop and workshop working group discussions. The Workshop Proceedings and Five-Year Plan are available through the Federal Emergency Management Agency, 500 "C" Street, S.W., Washington, DC 20472.

ATC-17: This report, *Proceedings of a Seminar and Workshop on Base Isolation and Passive Energy Dissipation*, was published under a grant from NSF. Available through the ATC office. (Published 1986, 478 pages)

ABSTRACT: The report contains 42 papers describing the state-of-the-art and state-of-the-practice in base-isolation and passive energy-dissipation technology. Included are papers describing case studies in the United States, applications and developments worldwide, recent innovations in technology development, and structural and ground motion issues. Also included is a proposed 5-year research agenda that addresses the following specific issues: (1) strong ground motion; (2) design criteria; (3) materials, quality control, and long-term reliability; (4) life cycle cost methodology; and (5) system response.

ATC-17-1: This report, *Proceedings of a Seminar on Seismic Isolation, Passive Energy Dissipation and Active Control,* was published under a grant from NCEER and NSF. Available through the ATC office. (Published 1993, 841 pages)

ABSTRACT: The 2-volume report documents 70 technical papers presented during a two-day seminar in San Francisco in early 1993. Included are invited theme papers and competitively selected papers on issues related to seismic isolation systems, passive energy dissipation systems, active control systems and hybrid systems.

ATC-18: The report, *Seismic Design Criteria for Bridges and Other Highway Structures: Current and Future***,** was developed under a grant from NCEER and FHWA. Available through the ATC office. (Published, 1997, 151 pages)

ABSTRACT: Prepared as part of NCEER Project 112 on new highway construction, this report reviews current domestic and foreign design practice, philosophy and criteria, and recommends future directions for code development. The project considered bridges, tunnels, abutments, retaining wall structures, and foundations.

ATC-18-1: The report, *Impact Assessment of Selected MCEER Highway Project Research on the Seismic Design of Highway Structures***,** was developed under a contract from the Multidisciplinary Center for Earthquake Engineering Research (MCEER, formerly NCEER) and FHWA. Available through the ATC office. (Published, 1999, 136 pages)

ABSTRACT: The report provides an in-depth review and assessment of 32 research reports emanating from the MCEER Project 112 on new highway construction, as well as recommendations for future bridge seismic design guidelines. Topics covered include: ground motion issues; determining structural importance; foundations and soils; liquefaction mitigation methodologies; modeling of pile footings and drilled shafts; damage-avoidance design of bridge piers, column design, modeling, and analysis; structural steel and steel-concrete interface details; abutment design, modeling, and analysis; and detailing for structural movements in tunnels.

ATC-19: The report, *Structural Response Modification Factors* was funded by NSF and NCEER. Available through the ATC office. (Published 1995, 70 pages)

ABSTRACT: This report addresses structural response modification factors (R factors), which are used to reduce the seismic forces associated with elastic response to obtain design forces. The report documents the basis for current R values, how R factors are used for seismic design in other countries, a rational means for decomposing R into key components, a framework (and methods) for evaluating the key components of R, and the research necessary to improve the reliability of engineered construction designed using R factors.

ATC-20: The report, *Procedures for Postearthquake Safety Evaluation of Buildings*, was developed under a contract from the California Office of Emergency Services (OES), California Office of Statewide Health Planning and Development (OSHPD) and FEMA. Available through the ATC office (Published 1989, 152 pages)

ABSTRACT: This report provides procedures and guidelines for making on-the-spot evaluations and decisions regarding continued use and occupancy of earthquake damaged buildings. Written specifically for volunteer structural engineers and building inspectors, the report includes rapid and detailed evaluation procedures for inspecting buildings and posting them as “inspected” (apparently safe, green placard), “limited entry” (yellow) or “unsafe” (red). Also included are special procedures for evaluation of essential buildings (e.g., hospitals), and evaluation procedures for nonstructural elements, and geotechnical hazards.

ATC-20-1: The report, *Field Manual: Postearthquake Safety Evaluation of Buildings*, was developed under a contract from OES and OSHPD. Available through the ATC office (Published 1989, 114 pages)

ABSTRACT: This report, a companion Field Manual for the ATC-20 report, summarizes the postearthquake safety evaluation procedures in a brief concise format designed for ease of use in the field.

ATC-20-2: The report, *Addendum to the ATC-20 Postearthquake Building Safety Procedures* was published under a grant from the NSF and funded by the USGS. Available through the ATC office. (Published 1995, 94 pages)

ABSTRACT: This report provides updated assessment forms, placards, including a revised yellow placard (“restricted use”) and procedures that are based on an in-depth review and evaluation of the widespread application of the ATC-20 procedures following five earthquakes occurring since the initial release of the ATC-20 report in 1989.

ATC-20-3: The report, *Case Studies in Rapid Postearthquake Safety Evaluation of Buildings,* was funded by ATC and R. P. Gallagher Associates. Available through the ATC office. (Published 1996, 295 pages)

ABSTRACT: This report contains 53 case studies using the ATC-20 Rapid Evaluation procedure. Each case study is illustrated with photos and describes how a building was inspected and evaluated for life safety, and includes a completed safety assessment form and placard. The report is intended to be used as a training and reference manual for building officials, building inspectors, civil and structural engineers, architects, disaster workers, and others who may be asked to perform safety evaluations after an earthquake.

ATC-20-T: The *Postearthquake Safety Evaluation of Buildings Training CD* was developed by FEMA to replace the 1993 ATC-20-T Training Manual that included 160 35-mm slides. Available through the ATC office. (Published 2002, 230 PowerPoint slides with Speakers Notes)

ABSTRACT: This Training CD is intended to facilitate the presentation of the contents of the ATC-20 and ATC-20-2 reports in a 4½-hour training seminar. The Training CD contains 230 slides of photographs, schematic drawings and textual information. Topics covered include: posting system; evaluation procedures; structural basics; wood frame, masonry, concrete, and steel frame structures; nonstructural elements; geotechnical hazards; hazardous materials; and field safety.

ATC-21: The report, *Second Edition, Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook*, was developed under a contract from FEMA. Available through the ATC office, or from FEMA by contacting 1-800-480-2520, as *FEMA 154 Second Edition*. (Published 2002, 161 pages)

ABSTRACT: This report describes a rapid visual screening procedure for identifying those buildings that might pose serious risk of loss of life and injury, or of severe curtailment of community services, in case of a damaging earthquake. The screening procedure utilizes a methodology based on a "sidewalk survey" approach that involves identification of the primary structural load-resisting system and its building material, and assignment of a basic structural hazards score and performance modifiers based on the observed building characteristics. Application of the methodology identifies those buildings that are potentially hazardous and should be analyzed in more detail by a professional engineer experienced in seismic design. In the Second Edition, the scoring system has been revised and the *Handbook* has been shortened and focused to ease its use.

ATC-21-1: The report, *Rapid Visual Screening of Buildings for Potential Seismic Hazards: Supporting Documentation*, *Second Edition*, was developed under a contract from FEMA. Available through the ATC office, or from FEMA by contacting 1-800-480-2520, as *FEMA 155 Second Edition*. (Published 2002, 117 pages)

ABSTRACT: Included in this report is the technical basis for the updated rapid visual screening procedure of ATC-21, including (1) a summary of the results from the efforts to solicit user feedback, and (2) a detailed description of the development effort leading to the basic structural hazard scores and the score modifiers.

ATC-21-2: The report, *Earthquake Damaged Buildings: An Overview of Heavy Debris and Victim Extrication*, was developed under a contract from FEMA. (Published 1988, 95 pages)

ABSTRACT: Included in this report, a companion volume to the ATC-21 and ATC-21-1 reports, is state-of-the-art information on (1) the identification of those buildings that might collapse and trap victims in debris or generate debris of such a size that its handling would require special or heavy lifting equipment; (2) guidance in identifying these types of buildings, on the basis of their major exterior features, and (3) the types and life capacities of equipment required to remove the heavy portion of the debris that might result from the collapse of such buildings.

ATC-21-T: The report, *Rapid Visual Screening of Buildings for Potential Seismic Hazards Training Manual* was developed under a contract with FEMA. Available through the ATC office. (Published 1996, 135 pages; 120 slides)

ABSTRACT: This training manual is intended to facilitate the presentation of the contents of the ATC-21 report (*First Edition*). The training materials consist of 120 slides and a companion training presentation narrative coordinated with the slides. Topics covered include: description of procedure, building behavior, building types, building scores, occupancy and falling hazards, and implementation.

ATC-22: The report, *A Handbook for Seismic Evaluation of Existing Buildings (Preliminary)*, was developed under a contract from FEMA. Available through the ATC office. (Originally published in 1989; revised by BSSC and published as FEMA 178: *NEHRP Handbook for the Seismic Evaluation of Existing Buildings* in 1992, 211 pages; revised by ASCE for FEMA and published as FEMA 310: *Handbook for the Seismic Evaluation of Buildings – a Prestandard* in 1998, 362 pages, available from FEMA by contacting 1-800-480-2520)

ABSTRACT: The ATC-22 handbook provides a methodology for seismic evaluation of existing buildings of different types and occupancies in areas of different seismicity throughout the United States. The methodology, which has been field tested in several programs nationwide, utilizes the information and procedures developed for the ATC-14 report and documented therein. The handbook includes checklists, diagrams, and sketches designed to assist the user.

ATC-22-1: The report, *Seismic Evaluation of Existing Buildings: Supporting Documentation*, was developed under a contract from FEMA and is available as the FEMA 175 report by contacting 1-800-480-2520. (Published 1989, 160 pages)

ABSTRACT: Included in this report, a companion volume to the ATC-22 report, are (1) a review and evaluation of existing buildings seismic evaluation methodologies; (2) results from field tests of the ATC-14 methodology; and (3) summaries of evaluations of ATC-14 conducted by the National Center for Earthquake Engineering Research (State University of New York at Buffalo) and the City of San Francisco.

ATC-23A: The report, *General Acute Care Hospital Earthquake Survivability Inventory for California, Part A: Survey Description, Summary of Results, Data Analysis and Interpretation*, was developed under a contract from the Office of Statewide Health Planning and Development (OSHPD), State of California. Available through the ATC office. (Published 1991, 58 pages)

ABSTRACT: This report summarizes results from a seismic survey of 490 California acute care hospitals. Included are a description of the survey procedures and data collected, a summary of the data, and an illustrative discussion of data analysis and interpretation that has been provided to demonstrate potential applications of the ATC-23 database.

ATC-23B: The report, *General Acute Care Hospital Earthquake Survivability Inventory for California, Part B: Raw Data*, is a companion document to the ATC-23A Report and was developed under the above-mentioned contract from OSHPD. Available through the ATC office. (Published 1991, 377 pages)

ABSTRACT: Included in this report are tabulations of raw general site and building data for 490 acute care hospitals in California.

ATC-24: The report, *Guidelines for Seismic Testing of Components of Steel Structures*, was jointly funded by the American Iron and Steel Institute (AISI), American Institute of Steel Construction (AISC), National Center for Earthquake Engineering Research (NCEER), and NSF. Available through the ATC office. (Published 1992, 57 pages)

ABSTRACT: This report provides guidance for most cyclic experiments on components of steel structures for the purpose of consistency in experimental procedures. The report contains recommendations and companion commentary pertaining to loading histories, presentation of test results, and other aspects of experimentation. The recommendations are written specifically for experiments with slow cyclic load application.

ATC-25: The report, *Seismic Vulnerability and Impact of Disruption of Lifelines in the Conterminous United State*s, was developed under a contract from FEMA. Available through the ATC office. (Published 1991, 440 pages)

ABSTRACT: Documented in this report is a national overview of lifeline seismic vulnerability and impact of disruption. Lifelines considered include electric systems, water systems, transportation systems, gas and liquid fuel supply systems, and emergency service facilities (hospitals, fire and police stations). Vulnerability estimates and impacts developed are presented in terms of estimated first approximation direct damage losses and indirect economic losses.

ATC-25-1: The report, *A Model Methodology for Assessment of Seismic Vulnerability and Impact of Disruption of Water Supply Systems*, was developed under a contract from FEMA. Available through the ATC office. (Published 1992, 147 pages)

ABSTRACT: This report contains a practical methodology for the detailed assessment of seismic vulnerability and impact of disruption of water supply systems. The methodology has been designed for use by water system operators. Application of the methodology enables the user to develop estimates of direct damage to system components and the time required to restore damaged facilities to pre-earthquake usability. Suggested measures for mitigation of seismic hazards are also provided.

ATC-26: This project, U.S. Postal Service National Seismic Program, was funded under a contract with the U.S. Postal Service (USPS). Under this project, ATC developed and submitted to the USPS the following interim documents, most of which pertain to the seismic evaluation and rehabilitation of USPS facilities:

ATC-26 Report, *Cost Projections for the U. S. Postal Service Seismic Program* (completed 1990)

ATC-26-1 Report, *United States Postal Service Procedures for Seismic Evaluation of Existing Buildings (Interim)* (Completed 1991)

ATC-26-2 Report, *Procedures for Post-disaster Safety Evaluation of Postal Service Facilities (Interim)* (Published 1991, 221 pages, available through the ATC office)

ATC-26-3 Report, *Field Manual: Post-earthquake Safety Evaluation of Postal Buildings (Interim)* (Published 1992, 133 pages, available through the ATC office)

ATC-26-3A Report, *Field Manual: Post Flood and Wind Storm Safety Evaluation of Postal Buildings (Interim)* (Published 1992, 114 pages, available through the ATC office)

ATC-26-4 Report, *United States Postal Service Procedures for Building Seismic Rehabilitation (Interim)* (Completed 1992)

ATC-26-5 Report, *United States Postal Service Guidelines for Building and Site Selection in Seismic Areas (Interim)* (Completed 1992)

ATC-28: The report, *Development of Recommended Guidelines for Seismic Strengthening of Existing Buildings, Phase I: Issues Identification and Resolution*, was developed under a contract with FEMA. Available through the ATC office. (Published 1992, 150 pages)

ABSTRACT: This report identifies and provides resolutions for issues that will affect the development of guidelines for the seismic strengthening of existing buildings. Issues addressed include: implementation and format, coordination with other efforts, legal and political, social, economic, historic buildings, research and technology, seismicity and mapping, engineering philosophy and goals, issues related to the development of specific provisions, and nonstructural element issues.

ATC-29: The report, *Proceedings of a Seminar and Workshop on Seismic Design and Performance of Equipment and Nonstructural Elements in Buildings and Industrial Structures*, was developed under a grant from NCEER and NSF. Available through the ATC office. (Published 1992, 470 pages)

ABSTRACT: These Proceedings contain 35 papers describing state-of-the-art technical information pertaining to the seismic design and performance of equipment and nonstructural elements in buildings and industrial structures. The papers were presented at a seminar in Irvine, California in 1990. Included are papers describing current practice, codes and regulations; earthquake performance; analytical and experimental investigations; development of new seismic qualification methods; and research, practice, and code development needs for specific elements and systems. The report also includes a summary of a proposed 5-year research agenda for NCEER.

ATC-29-1: The report, *Proceedings of a Seminar on Seismic Design, Retrofit, and Performance of Nonstructural Components*, was developed under a grant from NCEER and NSF. Available through the ATC office. (Published 1998, 518 pages)

ABSTRACT: These Proceedings contain 38 technical papers presented at a seminar in San Francisco, California in 1998. The paper topics include: observed performance in recent earthquakes; seismic design codes, standards, and procedures for commercial and institutional buildings; seismic design issues relating to industrial and hazardous material facilities; design analysis, and testing; and seismic evaluation and rehabilitation of conventional and essential facilities, including hospitals.

ATC-30: The report, *Proceedings of Workshop for Utilization of Research on Engineering and Socioeconomic Aspects of 1985 Chile and Mexico Earthquakes*, was developed under a grant from the NSF. Available through the ATC office. (Published 1991, 113 pages)

ABSTRACT: This report documents the findings of a 1990 technology transfer workshop in San Diego, California, co-sponsored by ATC and the Earthquake Engineering Research Institute. Included in the report are invited papers and working group recommendations on geotechnical issues, structural response issues, architectural and urban design considerations, emergency response planning, search and rescue, and reconstruction policy issues.

ATC-31: The report, *Evaluation of the Performance of Seismically Retrofitted Buildings*, was developed under a contract from the National Institute of Standards and Technology (NIST, formerly NBS) and funded by the USGS. Available through the ATC office. (Published 1992, 75 pages)

ABSTRACT: This report summarizes the results from an investigation of the effectiveness of 229 seismically retrofitted buildings, primarily unreinforced masonry and concrete tilt-up buildings. All buildings were located in the areas affected by the 1987 Whittier Narrows, California, and 1989 Loma Prieta, California, earthquakes.

ATC-32: The report, *Improved Seismic Design Criteria for California Bridges: Provisional Recommendations,* was funded by the California Department of Transportation (Caltrans). Available through the ATC office. (Published 1996, 215 pages)

ABSTRACT: This report provides recommended revisions to the current *Caltrans Bridge Design Specifications* (BDS) pertaining to seismic loading, structural response analysis, and component design. Special attention is given to design issues related to reinforced concrete components, steel components, foundations, and conventional bearings. The recommendations are based on recent research in the field of bridge seismic design and the performance of Caltrans-designed bridges in the 1989 Loma Prieta and other recent California earthquakes.

ATC-32-1: The report, *Improved Seismic Design Criteria for California Bridges: Resource Document,* was funded by Caltrans. Available through the ATC office. (Published 1996, 365 pages; also available on CD-ROM)

ABSTRACT: This report, a companion to the ATC-32 Report, documents pertinent background material and the technical basis for the recommendations provided in ATC-32, including potential recommendations that showed some promise but were not adopted. Topics include: design concepts; seismic loading, including ARS design spectra; dynamic analysis; foundation design; ductile component design; capacity protected design; reinforcing details; and steel bridges.

ATC-33: The reports, NEHRP Guidelines for the Seismic Rehabilitation of Buildings (FEMA 273), NEHRP Commentary on the Guidelines for the Seismic Rehabilitation of Buildings (FEMA 274), and Example Applications of the NEHRP Guidelines for the Seismic

Rehabilitation of Buildings (FEMA 276), were developed under a contract with the Building Seismic Safety Council, for FEMA. Available through FEMA by contacting 1-800-480-2520 (Published 1997, Guidelines, 440 pages; Commentary, 492 pages; Example Applications, 295 pages.) FEMA 273 and portions of FEMA 274 have been revised by ASCE for FEMA as FEMA 356 Prestandard and Commentary for the Seismic Rehabilitation of Buildings. Available through FEMA by contacting 1-800-480-2520 (Published 2000, 509 pages)

ABSTRACT: Developed over a 5-year period through the efforts of more than 60 paid consultants and several hundred volunteer reviewers, these documents provide nationally applicable, state-of-the-art guidance for the seismic rehabilitation of buildings. The FEMA 273 *Guidelines* contain several new features that depart significantly from previous seismic design procedures used to design new buildings: seismic performance levels and rehabilitation objectives; simplified and systematic rehabilitation methods; methods of analysis, including linear static and nonlinear static procedures; quantitative specifications of component behavior; and procedures for incorporating new information and technologies, such as seismic isolation and energy dissipation systems, into rehabilitation.

ATC-34: The report, *A Critical Review of Current Approaches to Earthquake Resistant Design***,** was developed under a grant from NCEER and NSF. Available through the ATC office. (Published, 1995, 94 pages)

ABSTRACT: This report documents the history of U. S. codes and standards of practice, focusing primarily on the strengths and deficiencies of current code approaches. Issues addressed include: seismic hazard analysis, earthquake collateral hazards, performance objectives, redundancy and configuration, response modification factors (*R* factors), simplified analysis procedures, modeling of structural components, foundation design, nonstructural component design, and risk and reliability. The report also identifies goals that a new seismic code should achieve.

ATC-35: This report, *Enhancing the Transfer of U.S. Geological Survey Research Results into Engineering Practice* was developed under a cooperative agreement with the USGS. Available through the ATC office. (Published 1994, 120 pages)

ABSTRACT: The report provides a program of recommended "technology transfer" activities for the USGS; included are recommendations pertaining to management actions, communications with practicing engineers, and research activities to enhance development and transfer of information that is vital to engineering practice.

ATC-35-1: The report, *Proceedings of Seminar on New Developments in Earthquake Ground Motion Estimation and Implications for Engineering Design Practice*, was developed under a cooperative agreement with USGS. Available through the ATC office. (Published 1994, 478 pages)

ABSTRACT: These Proceedings contain 22 technical papers describing state-of-the-art information on regional earthquake risk (focused on five specific regions—Northern and Southern California, Pacific Northwest, Central United States, and northeastern North America); new techniques for estimating strong ground motions as a function of earthquake source, travel path, and site parameters; and new developments specifically applicable to geotechnical engineering and the seismic design of buildings and bridges.

ATC-35-2: The report, *Proceedings: National Earthquake Ground Motion Mapping Workshop*, was developed under a cooperative agreement with USGS. Available through the ATC office. (Published 1997, 154 pages)

ABSTRACT: These Proceedings document the technical presentations and findings of a workshop in Los Angeles in 1995 on several key issues that affect the preparation and use of national earthquake ground motion maps for design. The following four key issues were the focus of the workshop: ground motion parameters; reference site conditions; probabilistic versus deterministic basis, and the treatment of uncertainty in seismic source characterization and ground motion attenuation.

ATC-35-3: The report, *Proceedings: Workshop on Improved Characterization of Strong Ground Shaking for Seismic Design,* was developed under a cooperative agreement with USGS. Available through the ATC office. (Published 1999, 75 pages)

ABSTRACT: These Proceedings document the technical presentations and findings of a workshop in Rancho Bernardo, California in 1997 on the Ground Motion Initiative (GMI) component of the ATC-35 Project. The workshop focused on identifying needs and developing improved representations of earthquake ground motion for use in seismic design practice, including codes.

ATC-37: The report, *Review of Seismic Research Results on Existing Buildings***,** was developed in conjunction with the Structural Engineers Association of California and California Universities for Research in Earthquake Engineering under a contract from the California Seismic Safety Commission (SSC). Available through the Seismic Safety Commission as Report SSC 94-03. (Published, 1994, 492 pages)

ABSTRACT: This report describes the state of knowledge of the earthquake performance of nonductile concrete frame, shear wall, and infilled buildings. Included are summaries of 90 recent research efforts with key results and conclusions in a simple, easy-to-access format written for practicing design professionals.

ATC-38: This report, *Database on the Performance of Structures near Strong-Motion Recordings: 1994 Northridge, California, Earthquake*, was developed with funding from the USGS, the Southern California Earthquake Center (SCEC), OES, and the Institute for Business and Home Safety (IBHS). Available through the ATC office. (Published 2000, 260 pages, with CD-ROM containing complete database).

ABSTRACT: The report documents the earthquake performance of 530 buildings within 1000 feet of sites where strong ground motion was recorded during the 1994 Northridge, California, earthquake (31 recording sites in total). The project required the development of a suitable survey form, the training of licensed engineers for the survey, the selection of the surveyed areas, and the entry of the survey data into an electronic relational database. The full database is contained in the ATC-38 CD-ROM. The ATC-38 database includes information on the structure size, age and location; the structural framing system and other important structural characteristics; nonstructural characteristics; geotechnical effects, such as liquefaction; performance characteristics (damage); fatalities and injuries; and estimated time to restore the facility to its pre-earthquake usability. The report and CD also contain strong-motion data, including acceleration, velocity, and displacement time histories, and acceleration response spectra.

ATC-40: The report, *Seismic Evaluation and Retrofit of Concrete Buildings***,** was developed under a contract from the California Seismic Safety Commission. Available through the ATC office. (Published, 1996, 612 pages)

ABSTRACT: This 2-volume report provides a state-of-the-art methodology for the seismic evaluation and retrofit of concrete buildings. Specific guidance is provided on the following topics: performance objectives; seismic hazard; determination of deficiencies; retrofit strategies; quality assurance procedures; nonlinear static analysis procedures; modeling rules; foundation effects; response limits; and nonstructural components. In 1997 this report received the Western States Seismic Policy Council "Overall Excellence and New Technology Award."

ATC-41 (SAC Joint Venture, Phase 1): This project, Program to Reduce the Earthquake Hazards of Steel Moment-Resisting Frame Structures, Phase 1, was funded by FEMA and conducted by a Joint Venture partnership of SEAOC, ATC, and CUREe. Under this Phase 1 program SAC prepared the following documents:

SAC-94-01, *Proceedings of the Invitational Workshop on Steel Seismic Issues, Los Angeles, September 1994* (Published 1994, 155 pages, available through the ATC office)

SAC-95-01, *Steel Moment-Frame Connection Advisory No. 3* (Published

1995, 310 pages, available through the ATC office)

SAC-95-02, *Interim Guidelines: Evaluation, Repair, Modification and Design of Welded Steel Moment-Frame Structures* (FEMA 267 report) (Published 1995, 215 pages, available through FEMA by contacting 1-800-480-2520)

SAC-95-03, *Characterization of Ground Motions During the Northridge Earthquake of January 17, 1994* (Published 1995, 179 pages, available through the ATC office)

SAC-95-04, *Analytical and Field Investigations of Buildings Affected by the Northridge Earthquake of January 17, 1994* (Published 1995, 2 volumes, 900 pages, available through the ATC office)

SAC-95-05, *Parametric Analytical Investigations of Ground Motion and Structural Response, Northridge Earthquake of January 17, 1994* (Published 1995, 274 pages, available through the ATC office)

SAC-95-06, *Surveys and Assessment of Damage to Buildings Affected by the Northridge Earthquake of January 17, 1994* (Published 1995, 315 pages, available through the ATC office)

SAC-95-07, *Case Studies of Steel Moment Frame Building Performance in the Northridge Earthquake of January 17, 1994* (Published 1995, 260 pages, available through the ATC office)

SAC-95-08, *Experimental Investigations of Materials, Weldments and Nondestructive Examination Techniques* (Published 1995, 144 pages, available through the ATC office)

SAC-95-09, *Background Reports: Metallurgy, Fracture Mechanics, Welding, Moment Connections and Frame systems, Behavior* (FEMA 288 report) (Published 1995, 361 pages, available through FEMA by contacting 1-800-480-2520)

SAC-96-01, *Experimental Investigations of Beam-Column Subassemblages, Part 1 and 2* (Published 1996, 2 volumes, 924 pages, available through the ATC office)

SAC-96-02, *Connection Test Summaries* (FEMA 289 report) (Published 1996, available through FEMA by contacting 1-800-480-2520)

ATC-41-1 (SAC Joint Venture, Phase 2): This project, Program to Reduce the Earthquake Hazards of Steel Moment-Resisting Frame Structures, Phase 2, was funded by FEMA and conducted by a Joint Venture partnership of SEAOC, ATC, and CUREe. Under this Phase 2 program SAC has prepared the following documents:

SAC-96-03, *Interim Guidelines Advisory No. 1 Supplement to FEMA 267 Interim Guidelines* (FEMA 267A Report) (Published 1997, 100 pages, and superseded by FEMA-350 to 353.)

SAC-99-01, *Interim Guidelines Advisory No. 2 Supplement to FEMA-267 Interim Guidelines* (FEMA 267B Report, superseding FEMA-267A). (Published 1999, 150 pages, and superseded by FEMA-350 to 353.)

FEMA-350, *Recommended Seismic Design Criteria for New Steel Moment-Frame Buildings*. (Published 2000, 190 pages, available through FEMA: 1-800-480-2520)

FEMA-351, *Recommended Seismic Evaluation and Upgrade Criteria for Existing Welded Steel Moment-Frame Buildings*. (Published 2000, 210 pages, available through FEMA: 1-800-480-2520)

FEMA-352, *Recommended Postearthquake Evaluation and Repair Criteria for Welded Steel Moment-Frame Buildings*. (Published 2000, 180 pages, available through FEMA: 1-800-480-2520)

FEMA-353, *Recommended Specifications and Quality Assurance Guidelines for Steel Moment-Frame Construction for Seismic Applications*. (Published 2000, 180 pages, available through FEMA: 1-800-480-2520)

FEMA-354, *A Policy Guide to Steel Moment-Frame Construction*. (Published 2000, 27 pages, available through FEMA: 1-800-480-2520)

FEMA-355A, *State of the Art Report on Base Materials and Fracture*. Available from the ATC office. (Published 2000, 107 pages; available on CD-ROM through FEMA: 1-800-480-2520)

FEMA-355B, *State of the Art Report on Welding and Inspection*. Available from the ATC office. (Published 2000, 185 pages; available on CD-ROM through FEMA: 1-800-480-2520)

FEMA-355C, *State of the Art Report on Systems Performance of Steel Moment Frames Subject to Earthquake Ground Shaking*. Available from the ATC office. (Published 2000, 322 pages; available on CD-ROM through FEMA: 1-800-480-2520)

FEMA-355D, *State of the Art Report on Connection Performance*. Available from the ATC office. (Published 2000, 292 pages; available on CD-ROM through FEMA: 1-800-480-2520)

FEMA-355E, *State of the Art Report on Past Performance of Steel Moment-Frame Buildings in Earthquakes*. Available from the ATC office. (Published 2000, 190 pages; available on CD-ROM through FEMA: 1-800-480-2520)

FEMA-355F, *State of the Art Report on Performance Prediction and Evaluation of Steel Moment-Frame Structures*. Available from the ATC office. (Published 2000, 347 pages; available on CD-ROM through FEMA: 1-800-480-2520)

ATC-43: The reports, *Evaluation of Earthquake-Damaged Concrete and Masonry Wall Buildings, Basic Procedures Manual* (FEMA 306), *Evaluation of Earthquake-Damaged Concrete and Masonry Wall Buildings, Technical Resources* (FEMA 307), and *The Repair of Earthquake Damaged Concrete and Masonry Wall Buildings* (FEMA 308), were developed for FEMA under a contract with the Partnership for Response and Recovery, a Joint Venture of Dewberry & Davis and Woodward-Clyde. Available on CD-ROM through ATC; printed versions available through FEMA by contacting 1-800-480-2520 (Published, 1998, *Evaluation Procedures Manual*, 270 pages; *Technical Resources*, 271 pages, *Repair Document*, 81 pages)

ABSTRACT: Developed by 26 nationally recognized specialists in earthquake engineering, these documents provide field investigation techniques, damage evaluation procedures, methods for performance loss determination, repair guides and recommended repair techniques, and an in-depth discussion of policy issues pertaining to the repair and upgrade of earthquake damaged buildings. The documents have been developed specifically for buildings with primary lateral-force-resisting systems consisting of concrete bearing walls or masonry bearing walls, and vertical-load-bearing concrete frames or steel frames with concrete or masonry infill panels. The intended audience includes design engineers, building owners, building regulatory officials, and government agencies.

ATC-44: The report, *Hurricane Fran, North Carolina, September 5, 1996: Reconnaissance Report*, was funded by the Applied Technology Council. Available through the ATC office. (Published 1997, 36 pages)

ABSTRACT: Written for an intended audience of design professionals and regulators, this report contains information on hurricane size, path, and rainfall amounts; coastal impacts, including storm surges and waves, forces on structures, and the role of erosion; the role of beach nourishment in reducing wave energy and crest height; building code requirements; observations and interpretations of damage to buildings, including the effect of debris acting as missiles; and lifeline performance.

ATC-48 (ATC/SEAOC Joint Venture Training Curriculum): The training curriculum, *Built to Resist Earthquakes, The Path to Quality Seismic Design and Construction for Architects, Engineers, and Inspectors*, was developed under a contract with the California Seismic Safety Commission and prepared by a Joint Venture partnership of ATC and SEAOC. Available through the ATC office (Published 1999, 314 pages)

ABSTRACT: Bound in a three-ring notebook, the curriculum contains training materials pertaining to the seismic design and retrofit of wood-frame buildings, concrete and masonry construction, and nonstructural components. Included are detailed, illustrated, instructional material (lessons) and a series of multi-part Briefing Papers and Job Aids to facilitate improvement in the quality of seismic design, inspection, and construction.

ATC-51: The report, *U.S.-Italy Collaborative Recommendations for Improved Seismic Safety of Hospitals in Italy*, was developed under a contract with Servizio Sismico Nazionale of Italy (Italian National Seismic Survey). Available through the ATC office. (Published 2000, 154 pages)

ABSTRACT: Developed by a 14-person team of hospital seismic safety specialists and regulators from the United States and Italy, the report provides an overview of hospital seismic risk in Italy; six recommended short-term actions and four recommended long-term actions for improving hospital seismic safety in Italy; and supplemental information on (a) hospital seismic safety regulation in California, (b) requirements for nonstructural components in California and for buildings regulated by the Office of U. S. Foreign Buildings, and (c) current seismic evaluation standards in the United States.

ATC-51-1: The report, *Recommended U.S.-Italy Collaborative Procedures for Earthquake Emergency Response Planning for Hospitals in Italy*, was developed under a second contract with Servizio Sismico Nazionale of Italy (Italian National Seismic Survey, NSS). Available through the ATC office. (Published 2002, 120 pages)

ABSTRACT: The report addresses one of the short-term recommendations — planning for emergency response and postearthquake inspection — made in the first phase of the ATC-51 project, and considers both current practices for emergency response planning in the United States and available NSS information and regulations pertaining to hospital emergency response planning in Italy. The report contains: (1) descriptions of current procedures and concepts for emergency response planning in the United States and Italy, (2) an overview of relevant procedures for both countries for evaluating and predicting the seismic vulnerability of buildings, including procedures for postearthquake inspection, (3) recommended procedures for earthquake emergency response planning and postearthquake assessment of hospitals, to be implemented through the use of a Postearthquake Inspection Notebook and demonstrated through the application on two representative hospital facilities; and (4) recommendations for emergency response training, postearthquake inspection training, and the mitigation of seismic hazards.

ATC-52: The project, "Development of a Community Action Plan for Seismic Safety (CAPSS), City and County of San Francisco", was conducted under a contract with the San Francisco Department of Building Inspection. Under Phase I, completed in 2000, ATC defined the tasks to be conducted under Phase II, a multi-year ATC effort scheduled to commence in 2001. The Phase II tasks include: (1) development of a reliable estimate of the size and nature of the impacts a large earthquake will have on San Francisco; (2) development of technically sound consensus-based guidelines for the evaluation and repair of San Francisco's most vulnerable building types; and (3) identification, definition, and ranking of other activities to reduce the seismic risks in the City and County of San Francisco.

ATC-53: The report, *Assessment of the NIST 12-Million-Pound (53 MN) Large-Scale Testing Facility*, was developed under a contract with NIST. Available through the ATC office. (Published 2000, 44 pages)

ABSTRACT: This report documents the findings of an ATC Technical Panel engaged to assess the utility and viability of a 30-year-old, 12-million pound (53 MN) Universal Testing Machine located at NIST headquarters in Gaithersburg, Maryland. Issues addressed include: (a) the merits of continuing operation of the facility; (b) possible improvements or modifications that would render it more useful to the earthquake engineering community and other potential large-scale structural research communities; and (c) identification of specific research (seismic and non-seismic) that might require the use of this facility in the future.

ATC-57: The report, *The Missing Piece: Improving Seismic Design and Construction Practices*, was developed under a contract with NIST. Available through the ATC office. (Published 2003, 102 pages)

ABSTRACT: The report was developed to provide a framework for eliminating the technology transfer gap that has emerged within the National Earthquake Hazards Reduction Program (NEHRP) that limits the adaptation of basic research knowledge into practice. The report defines a much-expanded problem-focused knowledge development, synthesis and transfer program to improve seismic design and construction practices. Two subject areas, with a total of five Program Elements, are proposed: (1) systematic support of the seismic code development process; and (2) improve seismic design and construction productivity.

ATC-R-1: The report, *Cyclic Testing of Narrow Plywood Shear Walls,* was developed with funding from the Henry J. Degenkolb Memorial Endowment Fund of the Applied Technology Council. Available through the ATC office (Published 1995, 64 pages)

ABSTRACT: This report documents ATC's first self-directed research program: a series of static and dynamic tests of narrow plywood wall panels having the standard 3.5-to-1 height-to-width ratio and anchored to the sill plate using typical bolted, 9-inch, 5000-lb. capacity hold-down devices. The report provides a description of the testing program and a summary of results, including comparisons of drift ratios found during testing with those specified in the seismic provisions of the 1991 *Uniform Building Code*. The report served as a catalyst for changes in code-specified aspect ratios for narrow plywood wall panels and for new thinking in the design of hold-down devices. It also stimulated widespread interest in laboratory testing of wood-frame structures.

ATC Design Guide 1: The report, *Minimizing Floor Vibration***,** was developed with funding from ATC's Henry J. Degenkolb Memorial Endowment Fund. Available through the ATC office. (Published, 1999, 64 pages)

ABSTRACT: Design Guide 1 provides guidance on design and retrofit of floor structures to limit transient vibrations to acceptable levels. The document includes guidance for estimating floor vibration properties and example calculations for a variety of currently used floor types and designs. The criteria for acceptable levels of floor vibration are based on human sensitivity to the vibration, whether it is caused by human behavior or machinery in the structure.

ATC TechBrief 1: The ATC TechBrief 1, *Liquefaction Maps*, was developed under a contract with the United States Geological Survey. Available free of charge through the ATC office. (Published 1996, 12 pages)

ABSTRACT: The technical brief inventories and describes the available regional liquefaction hazard maps in the United States and gives information on how to obtain them.

ATC TechBrief 2: The ATC TechBrief 2, *Earthquake Aftershocks − Entering Damaged Buildings*, was developed under a contract with the United States Geological Survey. Available free of charge through the ATC office. (Published 1996, 12 pages)

ABSTRACT: The technical brief offers guidelines for entering damaged buildings under emergency conditions during the first hours and days after the initial damaging event.

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