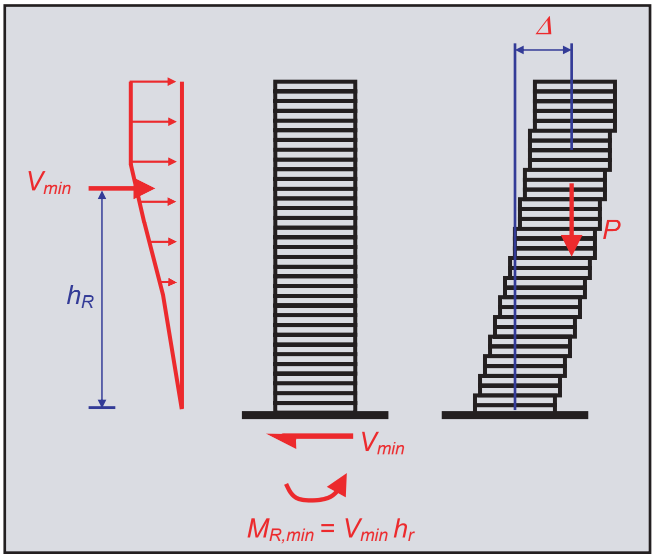
ATC 72

Proceedings of

Workshop on tall building seismic design and analysis issues



Applied Technology Council

In collaboration with
Pacific Earthquake Engineering Research Center

Prepared for
Building Seismic Safety Council
of the National Institute of Building Sciences

Funded by
Federal Emergency Management Agency

Applied Technology Council

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ATC-72

Proceedings of Workshop on Tall Building Seismic Design and Analysis Issues

Prepared by

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Berkeley, California

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Preface

In October 2006, the Applied Technology Council (ATC) began work on a contract assisting the Pacific Earthquake Engineering Research Center (PEER) in developing guidelines for the seismic design of tall buildings as part of the PEER Tall Buildings Initiative. The purpose of this work was to prepare recommended guidelines for modeling the behavior of tall building structural systems and acceptance values for use in seismic design. Shortly thereafter, ATC secured additional funding on behalf of PEER from the Federal Emergency Management Agency (FEMA), through the Building Seismic Safety Council (BSSC) of the National Institute of Building Sciences, to conduct a workshop in support of this effort. This additional funding was allocated to the specific task of identifying and prioritizing seismic design and analytical challenges related to tall buildings, which were to be addressed by the eventual recommended guidelines.

The purpose of the *Workshop on Tall Building Seismic Design and Analysis Issues* was to solicit the opinions and collective recommendations of leading practitioners, regulators, and researchers actively involved in design, permitting, and construction of tall buildings. The outcome of this workshop is a prioritized list of the most important tall building modeling and acceptance criteria issues needing resolution, based on the discussion of the multi-disciplinary stakeholders in attendance. This list will be used as the basis for future work in developing recommended guidelines for tall building design as part of the PEER Tall Buildings Initiative.

ATC gratefully acknowledges the work of the ATC-72/PEER Task 7 Project Core Group, including Jim Malley, Greg Deierlein, Helmut Krawinkler, Joe Maffei, Mehran Pourzanjani, and John Wallace, for their efforts in planning and conducting this workshop. The affiliations of these individuals are included in the list of Workshop Participants provided in Appendix A.

ATC also gratefully acknowledges Claret Heider (BSSC) and Michael Mahoney (FEMA) for their input and guidance in the completion of this report, Peter N. Mork for ATC report production services, and Charles H. Thornton as ATC Board Contact on this project.

Jon A. Heintz	Christopher Rojahn
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Chapter 1

Introduction

1.1 General

The development of seismic design provisions and construction practice has been based primarily on an understanding of the anticipated behavior of low- to moderate-rise construction. In extrapolating design and detailing provisions for use in high-rise construction, many structural systems have been limited in height or not permitted where combinations of spectral response acceleration parameters, site class, and building occupancy result in Seismic Design Categories D or higher, as defined in ASCE 7-05 *Minimum Design Loads for Buildings and Other Structures*.

The West Coast of the United States has been confronted with a major upsurge in the construction of buildings as tall as 1000 feet that involve a variety of unusual configurations, innovative structural systems, and high performance materials. Recent trends in high-rise residential construction have resulted in structural systems that challenge the limits of current seismic design provisions and procedures. Questions have arisen regarding the applicability of prescriptive code provisions to tall buildings, and whether or not prescriptive provisions can adequately ensure acceptable performance of this class of structure.

Building departments, with active input from peer review committees and advisory groups, have been considering performance-based methods to assess the adequacy of these new designs. At the same time, committees of professional organizations and others have also been working to define appropriate design methods for tall buildings. Use of alternative performance-based design procedures has led to challenges in the plan check and enforcement process, and use of currently available performance-based analytical methods has led to questions regarding the ability of these methods to reliably predict performance of tall structural systems.

The seismic design of tall buildings, or buildings exceeding 160 feet in height, introduces new challenges that need to be met through consideration of scientific, engineering, and regulatory issues specific to the modeling, analysis, and acceptance criteria appropriate for these unique structural systems.

1.2 Pacific Earthquake Engineering Research Center Tall Buildings Initiative

The Pacific Earthquake Engineering Research Center (PEER) is leading a multi-year collaborative effort, called the Tall Buildings Initiative, to develop performance-based seismic design guidelines for tall buildings. Guidelines resulting from this initiative are intended to promote consistency in design approaches, facilitate design and review, and help ensure that tall building designs meet safety and performance objectives consistent with the intent of current building codes and the expectations of various stakeholder groups.

Major collaborators on the PEER Tall Buildings Initiative include (in alphabetical order):

- Applied Technology Council (ATC),
- California Geological Survey,
- Charles Pankow Foundation,
- Department of Building Inspection, City & County of San Francisco (SFDBI),
- Federal Emergency Management Agency (FEMA),
- Los Angeles Tall Buildings Structural Design Council (LATBSDC),
- Los Angeles Department of Building and Safety (LADBS),
- Building Seismic Safety Council (BSSC) of the National Institute of Building Sciences (NIBS),
- National Science Foundation (NSF),
- Pacific Earthquake Engineering Research Center (PEER) (Lead Organization),
- Southern California Earthquake Center (SCEC),
- Structural Engineers Association of California (SEAOC),
- Structural Engineers Association of Northern California (SEAONC), and
- United States Geological Survey (USGS).

The Tall Buildings Initiative includes consideration of performance objectives, ground motion selection and scaling, modeling, acceptance criteria, and soil-foundation-structure interaction issues specific to the design of tall buildings. Guideline development activities are organized around the following tasks:

- Task 1 - Establish and Operate the Tall Buildings Project Advisory Committee (T-PAC)
- Task 2 - Develop consensus on performance objectives

- Task 3 - Assessment of ground motion selection and scaling procedures
- Task 4 - Synthetically generated ground motions
- Task 5 - Review and validation of synthetically generated ground motions
- Task 6 - Guidelines on selection and modification of ground motions for design
- Task 7 - Guidelines on modeling and acceptance values
- Task 8 - Input ground motions for tall buildings with subterranean levels
- Task 9 - Presentations at conferences, workshops, seminars
- Task 10 - Development of a design framework and publication of design guidelines

1.3 Issues in Tall Building Design

The following scientific, engineering, and regulatory issues specific to tall building design have been identified as part of the PEER Tall Buildings Initiative. These issues form the basis of the major technical development areas to be addressed by the Tall Buildings Initiative.

Building concepts and materials. Functional requirements for tall residential buildings have led to new building configurations and systems that do not meet the prescriptive definitions and requirements of current building codes. These include efficient framing systems with reduced redundancy as compared with more conventional buildings. High-strength materials and specialized products are also being proposed to help meet the unique challenges introduced by these structural systems.

Performance objectives and hazard considerations. High occupancy levels, associated safety considerations, and interest in re-occupancy following an earthquake have led to a reconsideration of performance objectives and ground shaking hazards. As a minimum, a building must be safe for rare (low-probability, long-return period) ground shaking demands, and must remain safe for significant aftershocks. However, there is increasing concern that serviceability for more frequent events should be considered as well. For very long vibration periods characteristic of tall buildings, special treatment of design ground motions is needed to ensure that these motions are representative in their damage potential, including consideration of duration and long-period energy content, so that designs based on them will safely represent the anticipated effects of future earthquakes. While equivalence to building code minimum performance requirements is likely to be the basic objective, there is no consensus on how to translate that performance objective into specific engineering demands and capacity checks in a performance-based procedure.

Ground motion time histories. The selection, scaling and spectral modification of ground motion time histories to represent a design response spectrum has a large impact on the results of nonlinear analyses. Earthquakes that dominate the seismic hazard in San Francisco, especially at sites near the San Andreas Fault, are for larger magnitudes and closer distances than are available in existing databases of strong motion recordings. This indicates a need to establish rational procedures for time history selection, scaling and modification. Validated seismological methods can be used to generate ground motion time histories that incorporate near-fault rupture directivity effects and basin effects to appropriately represent the duration and long period energy content of these large design events.

Modeling, simulation, and acceptance criteria. Current codes, although legally applicable to tall buildings, are based on, and emphasize design requirements for, low- to moderate-rise construction. As such, they fall short in conveying specific modeling, analysis, and acceptance criteria for very tall buildings because the dynamic and mechanical aspects of response that control the behavior of tall buildings are different from those of shorter buildings. Specialized engineering procedures, consensus-based and backed by research and experience, are needed. Criteria should appropriately address aspects of reliability of safety, capital preservation, re-occupancy, and functionality.

Input ground motions for tall buildings with subterranean levels. It is common practice to configure tall buildings with several levels below grade. Interaction between the soil, foundation, and structure is expected to significantly affect the character and intensity of the motion that is input to the superstructure. The issue is to define the input ground motions for tall buildings with subterranean levels considering this interaction.

Instrumentation. Tall building instrumentation can serve multiple purposes, including rapid occupancy evaluation following an earthquake, confirmation that building performance has met design expectations, and basic research leading to improved design criteria and analytical methods. Guidelines are needed for building instrumentation plans, and for data utilization following an earthquake.

1.4 Workshop Purpose

The *Workshop on Tall Building Seismic Design and Analysis Issues* was conducted as an integral part of PEER Task 7, and is related to the development of guidelines on modeling and acceptance values for tall buildings. The purpose of this workshop was to help identify design and modeling issues of critical importance to various tall building stakeholder groups, and to establish priorities for issues that should be addressed by the Task 7 work. The outcome of this workshop is a prioritized list of the most important tall building modeling and acceptance criteria issues needing resolution, based on the opinions of practitioners, regulators, and researchers in attendance, all of whom are actively involved in design, permitting, and construction of tall buildings.

Chapter 2

Pre-Workshop Activities

2.1 Workshop Planning

Workshop planning was conducted by the PEER Task 7 Project Core Group. Planning efforts included an initial brainstorming of tall building modeling and acceptance criteria issues, development of an initial draft scope for the Task 7 effort, identification and invitation of leading experts in design, permitting and construction of tall buildings, and collection of issues from invited participants in advance of the workshop. Issues collected in advance were used to structure the agenda for the workshop, including initial introductory presentations and the format for breakout discussions.

2.2 Development of PEER Task 7 Scope of Work

Development of the PEER Task 7 scope of work involved coordination with the overall Tall Buildings Initiative effort and an initial brainstorming of tall building modeling and acceptance criteria issues. Task 7 Project Core Group members developed these initial issues into a task description and preliminary outline for deliverables that were distributed to workshop participants as part of the pre-workshop invitation materials.

As defined in pre-workshop materials, PEER Task 7 is intended to develop practical guidance for acceptance criteria and for nonlinear modeling of tall buildings constructed using reinforced concrete and steel materials. Recommended guidance is expected to cover such topics as stiffness, strength, deformation capacity, hysteretic models, and implementation of nonlinear response-history (NLRH) analysis. It is also expected to cover guidance on appropriate parameters for use with capacity design procedures, including capacity-reduction factors and determination of overstrength demands from NLRH analysis. Recommended criteria are expected to appropriately address aspects of reliability, safety, capital preservation, re-occupancy, and functionality. Assessment of uncertainties is deemed an essential part of this effort.

The PEER Task 7 deliverable is envisioned to be a report that is included as part of the overall Tall Buildings Initiative report. The target audience for the eventual report and recommended guidance will be practicing structural engineers and building officials actively involved in the design and review of tall buildings for which seismic design is important.

2.3 Identification and Invitation of Workshop Participants

Workshop participation was by invitation only, and the distribution of participants was structured to be multidisciplinary. PEER Task 7 Project Core Group members identified leading experts involved in the design, research, permitting, and construction of tall buildings. Targeted participants included practicing engineers, researchers, and code officials. Proposed invitees were reviewed by members of the PEER Tall Buildings Project Advisory Committee (T-PAC), Michael Mahoney at FEMA, and Claret Heider at BSSC. Letters of invitation were sent to the final list of agreed upon invitees, along with a workshop agenda, summary of the PEER Tall Buildings Initiative, preliminary list of tall building modeling and acceptance criteria issues, and a call for input on additional tall building issues to be submitted in advance of the workshop. In all, 35 individuals participated in the workshop, including members of the Tall Buildings Project Advisory Committee and the PEER Task 7 Project Core Group. A list of workshop participants is included in Appendix A.

2.4 Collection of Pre-Workshop Issues

In response to pre-workshop materials, invited participants submitted more than 100 written comments. Many comments contained multiple design and analysis concerns on the part of the participants, resulting in over 500 individual tall building issues collected before the workshop. This input was used to set the workshop structure, seed workshop discussion, and target workshop content. It formed the basis of workshop introductory presentations and served as the starting point for focused breakout discussions. A brief summary of these issues can be found in the plenary presentations contained in Appendix B. The subset of these issues that rose to the top in workshop discussions are reported in Chapter 4, Workshop Findings and Conclusions.

Chapter 3

Workshop Program

3.1 Workshop Format and Agenda

The workshop format was structured around an initial plenary session of introductory presentations, a series of focused breakout discussions, and overall group prioritization of the resulting issues. Based on input received from invited participants in advance of the workshop, discussions were centered on four topical areas: (1) foundation modeling/base transfer issues; (2) capacity design; (3) general structural issues; and (4) shear wall issues. The workshop agenda is shown in Figure 3-1.

3.2 Workshop Description

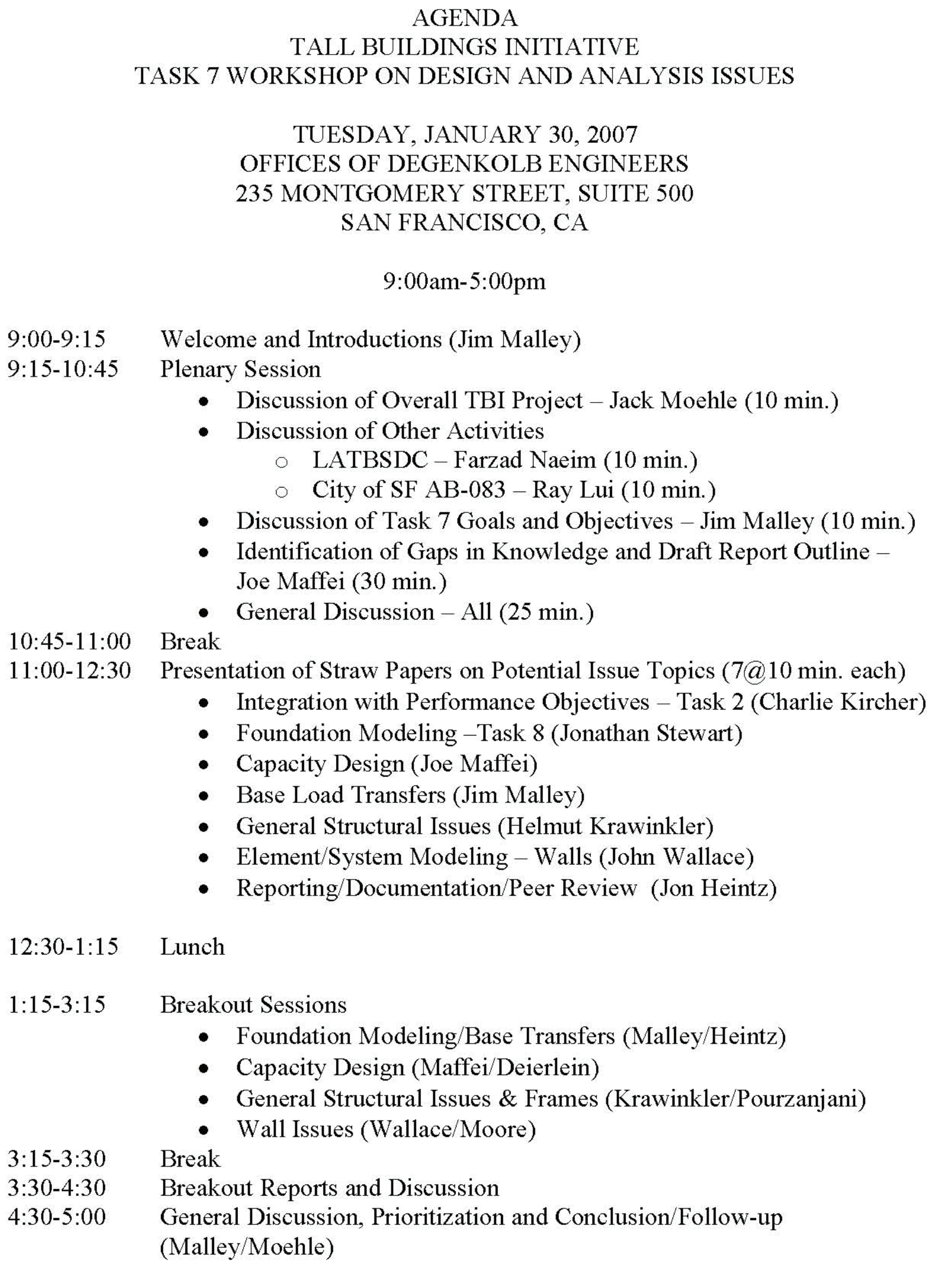
Introductory presentations in the initial plenary session included an overview of the PEER Tall Buildings Initiative, a discussion of the goals and objectives of PEER Task 7, identification of existing gaps in knowledge with regard to tall building modeling and acceptance criteria, and an overview of other activities related to the development of design criteria for tall buildings. These included the Los Angeles Tall Buildings Structural Design Council (LATBSDC) effort to develop their consensus document, *Alternative Procedure for Seismic Analysis and Design of Tall Buildings Located in the Los Angeles Region*, and the City of San Francisco Department of Building Inspection (SFDBI) effort to develop their Administrative Bulletin AB-083, *Requirements and Guidelines for the Seismic Design and Review of New Tall Buildings using Non-Prescriptive Seismic-Design Procedures*. The plenary session also included open discussion to allow participants to raise general issues of importance. Introductory presentations are provided for reference in Appendix B.

In a second plenary session, presentations were structured to orient participants to the specific modeling and acceptance criteria issues planned for the breakout sessions. These included a report on tall building performance objectives (from PEER Task 2), a report on foundation modeling issues (from PEER Task 8), and a series of presentations on the pre-workshop issues collected from participants in advance of the workshop. Issues were grouped into one of the four main topical areas for presentation (foundation modeling/base transfer, capacity design, general structural, and shear walls) as well as a fifth topic of general crosscutting issues involving reporting, documentation, and peer review. Pre-workshop issue presentations are provided for reference in Appendix B.

The four topical areas served as focal points for breakout discussions, with one topical area assigned to each breakout. To ensure multi-disciplinary discussion among the practitioner, researcher, and code official stakeholder groups in attendance, participants were assigned to each breakout group for the first half of the discussion period. During the second half of the discussion period, participants were permitted to move between breakout groups.

Breakout groups were led by members of the PEER Task 7 Project Core Group. Leaders were instructed to review the collection of pre-workshop issues with the breakout participants, discuss and clarify issues for common understanding, and to identify the most important issues in each topical area for reporting back the overall group.

Participants reconvened in a plenary session for breakout reporting, in which recorders presented the subset of pre-workshop issues that were identified by each breakout group as the most important needs in each focus area. To establish priorities across all focus areas, issues reported by the breakout groups were balloted by the overall combined group. Each participant was allowed five votes for identifying and assigning priorities among the issues. Results are reported in Chapter 4, Workshop Findings and Conclusions.



AGENDA
TALL BUILDINGS INITIATIVE
TASK 7 WORKSHOP ON DESIGN AND ANALYSIS ISSUES

TUESDAY, JANUARY 30, 2007
OFFICES OF DEGENKOLB ENGINEERS
235 MONTGOMERY STREET, SUITE 500
SAN FRANCISCO, CA

9:00am-5:00pm

9:00-9:15 Welcome and Introductions (Jim Malley)
9:15-10:45 Plenary Session
- Discussion of Overall TBI Project – Jack Moehle (10 min.)
- Discussion of Other Activities
    - LATBSDC – Farzad Naeim (10 min.)
    - City of SF AB-083 – Ray Lui (10 min.)
- Discussion of Task 7 Goals and Objectives – Jim Malley (10 min.)
- Identification of Gaps in Knowledge and Draft Report Outline – Joe Maffei (30 min.)
- General Discussion – All (25 min.)

10:45-11:00 Break
11:00-12:30 Presentation of Straw Papers on Potential Issue Topics (7@10 min. each)
- Integration with Performance Objectives – Task 2 (Charlie Kircher)
- Foundation Modeling –Task 8 (Jonathan Stewart)
- Capacity Design (Joe Maffei)
- Base Load Transfers (Jim Malley)
- General Structural Issues (Helmut Krawinkler)
- Element/System Modeling – Walls (John Wallace)
- Reporting/Documentation/Peer Review (Jon Heintz)

12:30-1:15 Lunch

1:15-3:15 Breakout Sessions
- Foundation Modeling/Base Transfers (Malley/Heintz)
- Capacity Design (Maffei/Deierlein)
- General Structural Issues & Frames (Krawinkler/Pourzanjani)
- Wall Issues (Wallace/Moore)

3:15-3:30 Break
3:30-4:30 Breakout Reports and Discussion
4:30-5:00 General Discussion, Prioritization and Conclusion/Follow-up (Malley/Moehle)

Figure 3-1 Agenda - Workshop on Tall Building Seismic Design and Analysis Issues, January 30, 2007, San Francisco, California.

Chapter 4

Workshop Findings and Conclusions

4.1 Breakout Group 1 Report on Foundation Modeling/Base Transfer Issues

Breakout Group 1 was charged with reviewing and discussing pre-workshop issues related to foundation modeling and load transfers at the base of the structure. The following issues were identified as the highest priority needs in this focus area:

- Guidance on how to model the podium (stiff base structure below the high-rise tower superstructure) including diaphragm stiffness, wall stiffness, and foundation stiffness.
- Guidance on how to properly address podiums that extend above grade, including differences from the recommended treatment of below-grade podiums or basements.
- Guidance on how to properly address hillside sites with respect to the effective height of the building, potential unbalanced soil forces, and unsymmetrical basement wall configurations.
- Recommendations for performance-based equivalencies to code-based foundation design.
- Information on whether or not current foundation modeling practices adequately capture tall building system behavior.
- Recommendations on whether or not foundation components should be required to remain elastic.
- Information on calculated uplift at the foundation that could be considered acceptable.
- Information on how boundary condition assumptions (i.e., base-fixity) affect the design of the superstructure (e.g. drift limits).
- Information on how much foundation rotation really affects the overall response of the superstructure.
- Appropriate tests for determining realistic geotechnical parameters.

- Realistic dispersions that can be expected in geotechnical parameters and recommendations on how this information should be used in tall building design.

4.2 Breakout Group 2 Report on Capacity Design Issues

Breakout Group 2 was charged with reviewing and discussing pre-workshop issues related to capacity design. The following issues were identified as the highest priority needs in this focus area:

- A clearly defined capacity design philosophy for tall buildings.
- Guidance on capacity protection factors, limit-state demands, and necessary margins.
- Guidance on how to properly quantify properties of inelastic components, including dispersion in those properties.
- Guidance on unintentional slab outrigger effects that should be considered in tall building design.
- Guidance on capacity design of foundations.
- Guidance on capacity design of diaphragms.
- Strategies to achieve capacity design for tall buildings, including hierarchies of behavior modes.

4.3 Breakout Group 3 Report on General Structural Issues

Breakout Group 3 was charged with reviewing and discussing pre-workshop issues related to general structural analysis considerations and acceptance criteria. The following issues were identified as the highest priority needs in this focus area:

- Guidance on how to include damping in structural models.
- Specification of minimum strength criteria for tall buildings.
- Guidance on modeling of P-delta effects and component deterioration.
- Definition of performance objectives that are acceptable to tall building stakeholder groups.
- Acceptance criteria for all structural systems and components used in tall building design.
- Guidance on how to properly model components including, initial stiffness, yield strength, and post-yield degradation.

- Guidance on how to properly model outrigger systems (systems with horizontal components that extend out to columns or walls that are not part of the main lateral-force-resisting core).
- Guidance on the determination of axial forces and their effects on walls and columns, including the effects of vertical acceleration.
- Guidance on what should be included in the structural model to properly simulate tall building behavior.

4.4 Breakout Group 4 Report on Shear Wall Issues

Breakout Group 4 was charged with reviewing and discussing pre-workshop issues related to analysis and design of concrete shear walls. The following issues were identified as the highest priority issues in this focus area:

- Guidance on flexure-shear interaction, including shear through the compression zone and wall geometry effects.
- Guidance on gravity system compatibility with the lateral-force-resisting system, including slab deformation demands and column/wall force demands.
- Guidance on coupling beam performance at service level demands (i.e., damage states at 10%, 20%, 30% of capacity)
- Recommendations on wall detailing both inside and outside the plastic-hinge region, including confinement based on strain demands.
- Guidance on effective initial stiffness for walls and coupling beams for service level and Maximum Considered Earthquake (MCE) level demands.
- Information on calibration of structural models with wall/coupling beam component testing using frame or fiber elements.
- Guidance on the length of the plastic-hinge region, and force and ductility demands outside of the region.
- Wall acceptance criteria for strain, displacement, rotation, and strength at service level demands.
- Guidance on direct-displacement-based design (setting of acceptable strain limits) in lieu of traditional force-based design.
- R-factors for Design Basis Earthquake (DBE) level analyses for systems using only concrete shear wall cores.
- Load combinations that should be used to determine the area of reinforcing steel in a wall.

- Axial restraint on coupling beam behavior including kinematics, post-tensioning, and the contribution of the floor slab.
- Recommendations on splices in longitudinal wall reinforcing.
- Recommendations on wall reinforcing anchorage to foundations

4.5 Prioritization of Issues

Issues identified by each breakout group as the most important needs in each focus area were balloted by the overall combined group to establish priorities across all focus areas. Issues were assigned to one of three overall priority ranges (highest, intermediate, or lower priority) as identified in the tables that follow.

The overall highest priority needs, identified by a cluster of issues with the four highest vote totals, are shown in Table 4-1. Interestingly enough, this short list includes one issue from each of the four focus areas.

Table 4-1 Highest Priority Tall Building Modeling and Acceptance Criteria Needs

Need	*Focus Area*
Guidance on how to model the podium (stiff base structure below the high-rise tower superstructure) including diaphragm stiffness, wall stiffness, and foundation stiffness.	Foundation Modeling/Base Transfer
Guidance on flexure-shear interaction, including shear through the compression zone and wall geometry effects.	Shear Walls
A clearly defined capacity design philosophy for tall buildings.	Capacity Design
Guidance on how to include damping in structural models.	General Structural

Intermediate priority needs, identified by a cluster of issues with mid-range vote totals, are shown in Table 4-2. This list also includes representation from each focus area, although general structural analysis and acceptance criteria issues are in the majority in this range.

Lower priority needs, identified by a cluster of issues receiving the lowest vote totals, are shown in Table 4-3. Issues that did not receive votes in overall plenary balloting are not included in the priority rankings, and pre-workshop issues that did not meet with consensus in breakout discussions are not reported. Summary information including these other issues can be found in the pre-workshop issue presentations provided in Appendix B.

Of the 41 high priority needs for each focus area identified in breakout group discussions, 29 received at least one vote in overall plenary balloting. The priority rankings of Table 4-1, Table 4-2, and Table 4-3 include the top six out of eleven foundation modeling/base transfer needs, the top six out of seven capacity design needs, the top eight out of nine general structural needs, and the top nine out of fourteen shear wall needs identified in the preceding sections.

Table 4-2 Intermediate Priority Tall Building Modeling and Acceptance Criteria Needs

Need	*Focus Area*
Specification of minimum strength criteria for tall buildings.	General Structural
Guidance on capacity protections factors, limit-state demands, and necessary margins.	Capacity Design
Guidance on how to properly quantify properties of inelastic components, including dispersion in those properties.	Capacity Design
Recommendations for performance-based equivalencies to code-based foundation design.	Foundation Modeling/Base Transfer
Guidance on modeling of P-delta effects and component deterioration.	General Structural
Guidance on gravity system compatibility with the lateral-force-resisting system, including slab deformation demands and column/wall force demands.	Shear Walls
Definition of performance objectives that are acceptable to tall building stakeholder groups.	General Structural

4.6 Use of Workshop Findings and Conclusions

The prioritized needs identified in Table 4-1, Table 4-2, and Table 4-3 will be reviewed by PEER Task 7 Project Core Group members. These needs will serve as the basis for a literature search on the state of available knowledge, and collection of emerging research on modeling techniques and acceptance criteria applicable to the analysis and design of tall buildings. This effort will ultimately result in a report, to be included as part of an overall PEER Tall Buildings Initiative report, that outlines recommendations for modeling of tall building structural systems and components, and provides recommended acceptance values for use in design. It is envisioned that this effort will address as many of the specific needs identified in this workshop as possible, subject to limitations in available information and funding.

Table 4-3 Lower Priority Tall Building Modeling and Acceptance Criteria Needs

Need	*Focus Area*
Guidance on how to properly address hillside sites with respect to the effective height of the building, potential unbalanced soil forces, and unsymmetrical basement wall configurations.	Foundation Modeling/Base Transfer
Information on whether or not current foundation modeling practices adequately capture tall building system behavior.	Foundation Modeling/Base Transfer
Recommendations on whether or not foundation components should be required to remain elastic.	Foundation Modeling/Base Transfer
Acceptance criteria for all structural systems and components used in tall building design.	General Structural
Guidance on coupling beam performance at service level demands (i.e., damage states at 10%, 20%, 30% of capacity)	Shear Walls
Guidance on unintentional slab outrigger effects that should be considered in tall building design.	Capacity Design
Guidance on capacity design of foundations.	Capacity Design
Guidance on how to properly model components including, initial stiffness, yield strength, and post-yield degradation.	General Structural
Guidance on how to properly model outrigger systems (systems with horizontal components that extend out to columns or walls that are not part of the main lateral-force-resisting core).	General Structural
Guidance on the determination of axial forces and their effects on walls and columns, including the effects of vertical acceleration.	General Structural
Recommendations on wall detailing both inside and outside the plastic-hinge region, including confinement based on strain demands.	Shear Walls
Guidance on effective initial stiffness for walls and coupling beams for service level and Maximum Considered Earthquake (MCE) level demands.	Shear Walls
Information on calibration of structural models with wall/coupling beam component testing using frame or fiber elements.	Shear Walls
Guidance on capacity design of diaphragms.	Capacity Design
Information on calculated uplift at the foundation that could be considered acceptable.	Foundation Modeling/Base Transfer
Guidance on the length of the plastic-hinge region, and force and ductility demands outside of the region	Shear Walls
Wall acceptance criteria for strain, displacement, rotation, and strength at service level demands.	Shear Walls
Guidance on direct-displacement-based design (setting of acceptable strain limits) in lieu of traditional force-based design.	Shear Walls

Appendix A

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David Hutchinson
Leonard Joseph
Marshall Lew
James O. Malley (Chair)
Steve Pfeiffer

Breakout Group 2: Capacity Design

Greg Deierlein (Recorder)
Robert Hanson
Eric Lemkuhl
Joseph Maffei (Chair)
Neville Matthias
John Price
Constantine Shuhaibar
Nabih Youssef

Breakout Group 3: General Structural Analysis and Acceptance Criteria

Larry Griffis
John Hooper
Helmut Krawinkler (Chair)
Nico Luco
Ray Lui
Mehran Pourzanjani (Recorder)
Graham Powell
Derrick Roorda

Breakout Group 4: Shear Walls

Charles Kircher
Steve Mahin
Mark Moore (Recorder)
Tom Sabol
Greg Schrader
John Wallace (Chair)
Atila Zekioglu

Appendix B

Plenary Presentations

B.1 Introductory Presentations

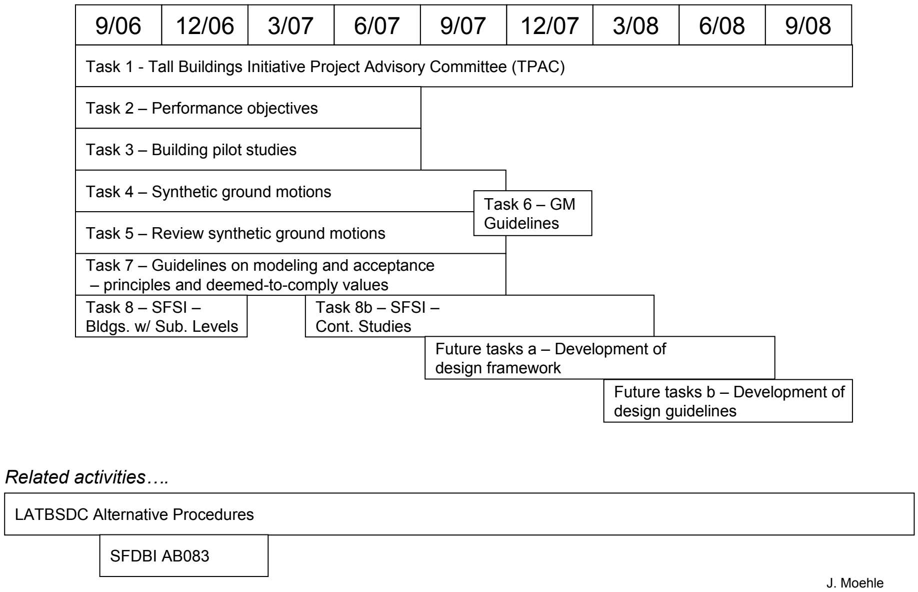
B.2 Summary Presentations on Pre-Workshop Issues

PEER Tall Buildings Initiative

Jack Moehle
Principal Investigator

January 30, 2007

Tall Buildings Initiative



9/06 12/06 3/07 6/07 9/07 12/07 3/08 6/08 9/08

Task 1 - Tall Buildings Initiative Project Advisory Committee (TPAC)

Task 2 – Performance objectives

Task 3 – Building pilot studies

Task 4 – Synthetic ground motions

Task 6 – GM Guidelines

Task 5 – Review synthetic ground motions

Task 7 – Guidelines on modeling and acceptance – principles and deemed-to-comply values

Task 8 – SFSI – Bldgs. w/ Sub. Levels

Task 8b – SFSI – Cont. Studies

Future tasks a – Development of design framework

Future tasks b – Development of design guidelines

Related activities….

LATBSDC Alternative Procedures

SFDBI AB083

J. Moehle
Task 7 Workshop
30 January 2007

PEER Tall Buildings Initiative

Task 7 Goals and Objectives

Jim Malley
TBI Workshop
January 30, 2007

Task 7 – Guidelines for Design, Including Modeling and Acceptance Values

- Team Members
  - Helmut Krawinkler – Stanford
  - Greg Deierlein – Stanford
  - John Wallace – UCLA
  - Joe Maffei – Rutherford & Chekene
  - Mehran Pourzanjani – Saiful/Bouquet
  - Jon Heintz – ATC
  - Jim Malley - Degenkolb

Task 7 – Guidelines for Design, Including Modeling and Acceptance Values

- Task Description – Develop practical guidance for acceptance criteria and nonlinear modeling.
  - R/C and Steel
    - Priority on R/C due to amount of residential projects either underway or in planning

Task 7 – Guidelines for Design, Including Modeling and Acceptance Values (Cont.)

- Not ALL topics related to design, modeling and acceptance criteria can be addressed! Topics will be selected (with the help of your input) could include:
  - Stiffness, strength and deformation capacity
  - Hysteretic models for NLRH
  - Implementation in software for NLRH

Task 7 – Guidelines for Design, Including Modeling and Acceptance Values (Cont.)

- Additional topics could include:
  - Guidance on capacity design, overstrength demands from NLRH, podium force transfer, etc.
  - Considering safety, capital preservation, re-occupancy and functionality
  - To be developed within uncertainty assessment framework

Task 7 -Significant Issues to be Addressed (Our first pass)

- General structural issues (effective damping, cyclic deterioration, post-capping stiffness, e.g.)
- Podium force transfer
- Capacity design concepts
- Modeling of various systems and elements (core walls, frames, coupling beams, etc.)
- Foundation modeling (with Task 8)
- January workshop of designers, researchers, regulators and other interested parties to identify specific issues to be addressed (This is US!)

Task 7 - Deliverable

- Report of findings. Tentative title is “Guidelines for the seismic/structural design of tall buildings”
  - Sounds like the entire project report, eh?
    - Don’t be fooled. Task 7 will only write our part!
  - Target audience
    - Practicing structural engineers and building officials involved in the design and review of tall buildings
      - So, it’s a technical document, not a legislative document
  - Tentative Outline (Presented by Joe Maffei)

Seismic/structural design issues for tall buildings

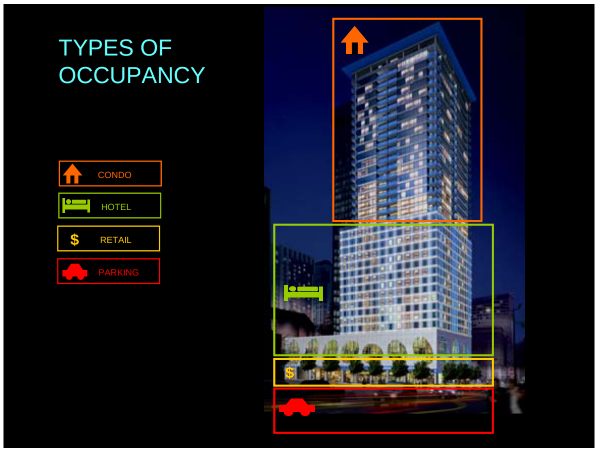
January 2007
Joe Maffei

RUTHERFORD & CHEKENE

TALL BUILDING DESIGN ISSUES

- Today's tall buildings
- Research applicable to tall buildings
  - Component tests
  - Need for benchmarks on analysis assumptions
  - Serviceability acceptance criteria
  - Effective concrete stiffness
- Minimum base shear
- Other issues
- Straw man report outline

EXAMPLES OF CONCRETE-WALL HIGH-RISES

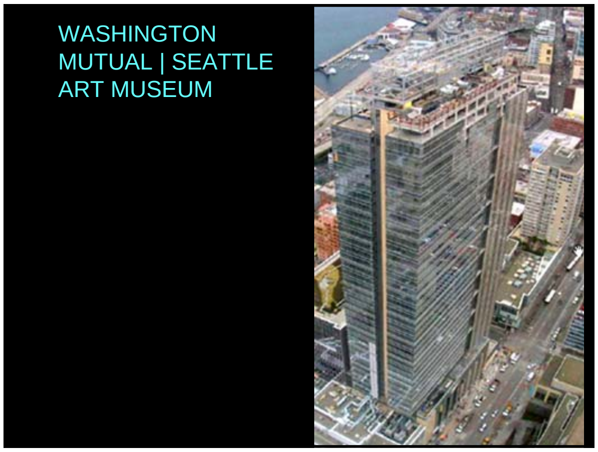


TYPES OF OCCUPANCY

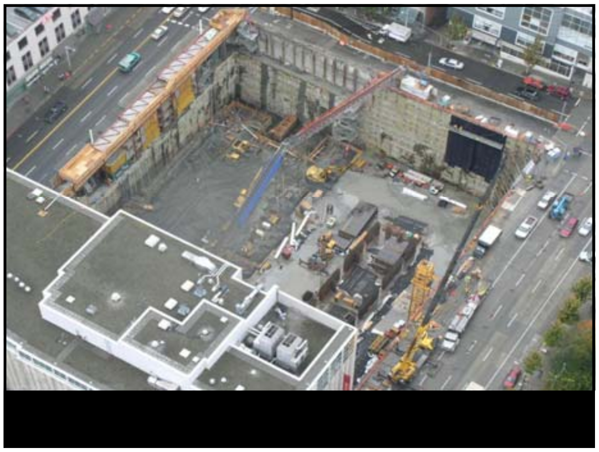
CONDO
HOTEL
$ RETAIL
PARKING

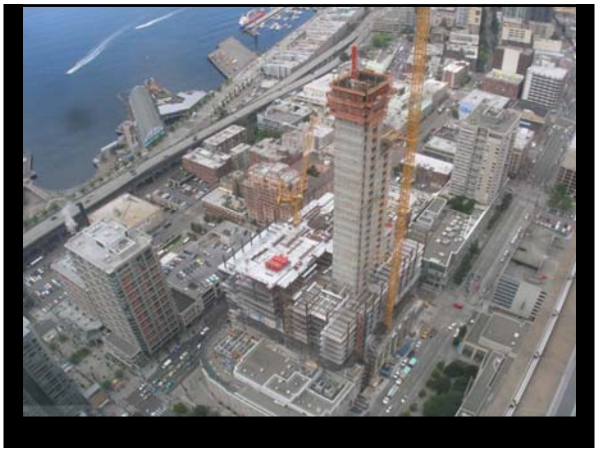
STEEL GRAVITY FRAMING

$

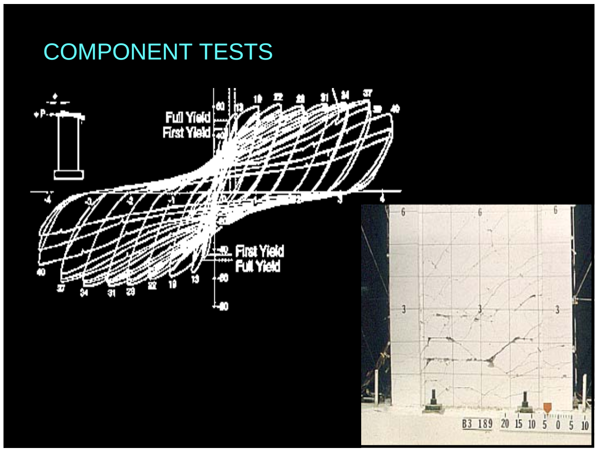


WASHINGTON MUTUAL | SEATTLE ART MUSEUM

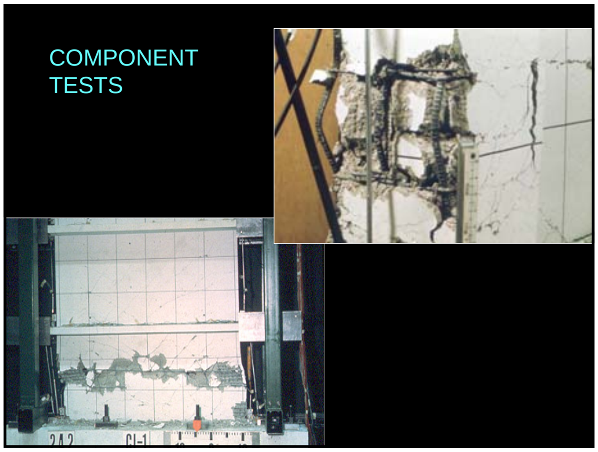




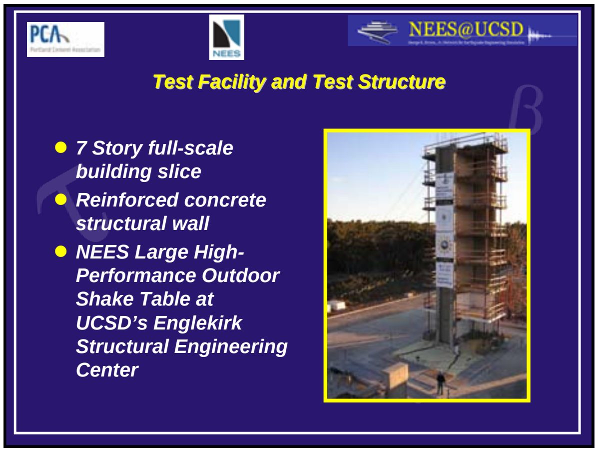
APPLICABLE RESEARCH



COMPONENT TESTS

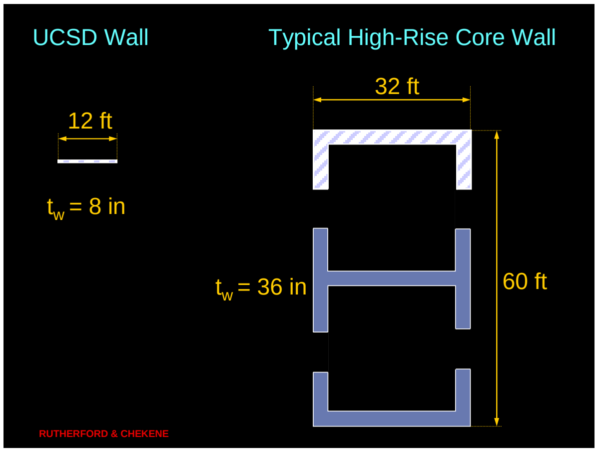


COMPONENT TESTS



Test Facility and Test Structure

- 7 Story full-scale building slice
- Reinforced concrete structural wall
- NEES Large High-Performance Outdoor Shake Table at UCSD's Englekirk Structural Engineering Center



UCSD Wall

Typical High-Rise Core Wall

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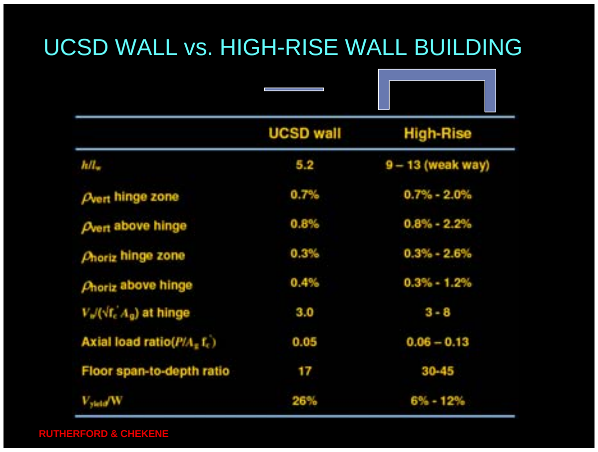

UCSD WALL vs. HIGH-RISE WALL BUILDING

	UCSD wall	High-Rise
h/l_w	5.2	9 – 13 (weak way)
ρ_{vert} hinge zone	0.7%	0.7% - 2.0%
ρ_{vert} above hinge	0.8%	0.8% - 2.2%
ρ_{horiz} hinge zone	0.3%	0.3% - 2.6%
ρ_{horiz} above hinge	0.4%	0.3% - 1.2%
$V_u/(\sqrt{f_c'}A_g)$ at hinge	3.0	3 - 8
Axial load ratio($P/A_g f_c'$)	0.05	0.06 – 0.13
Floor span-to-depth ratio	17	30-45
V_{yield}/W	26%	6% - 12%

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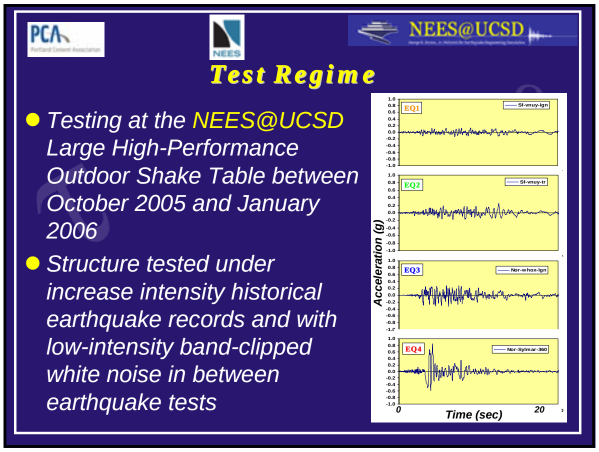
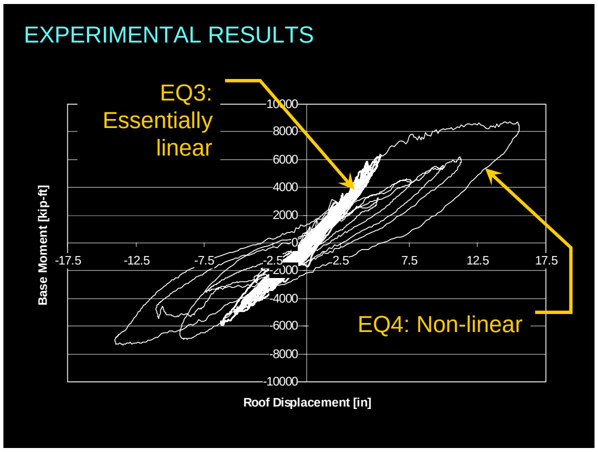
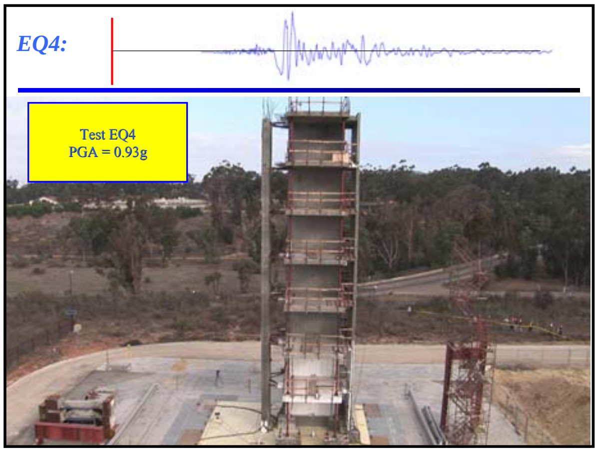


Test Regime

- Testing at the NEES@UCSD Large High-Performance Outdoor Shake Table between October 2005 and January 2006
- Structure tested under increase intensity historical earthquake records and with low-intensity band-clipped white noise in between earthquake tests

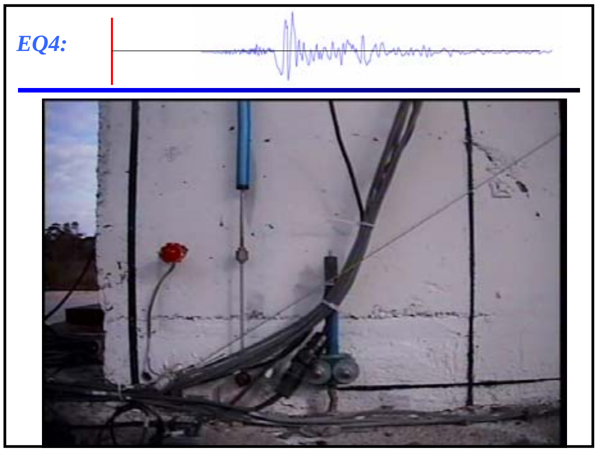


EXPERIMENTAL RESULTS

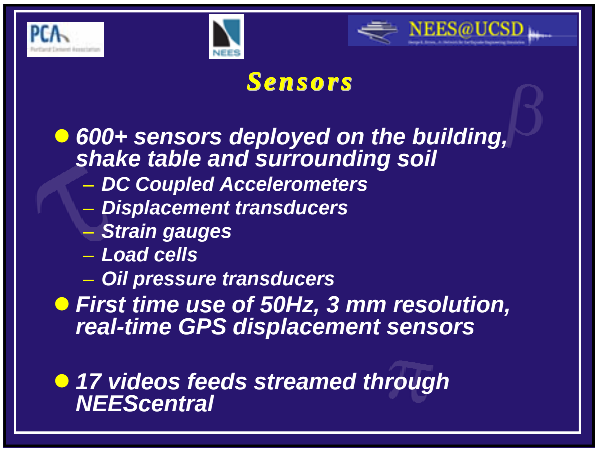


EQ4:

Test EQ4
PGA = 0.93g

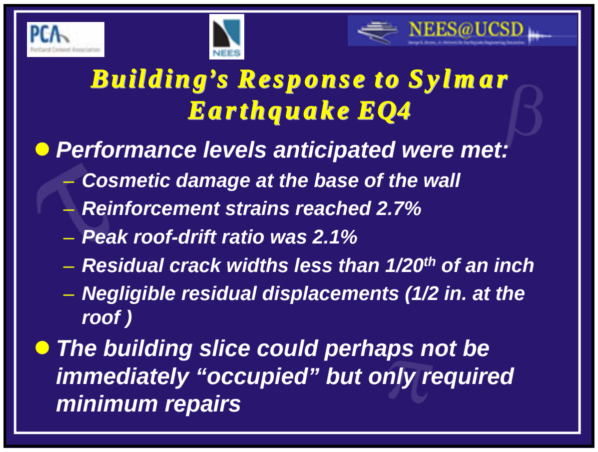


EQ4:



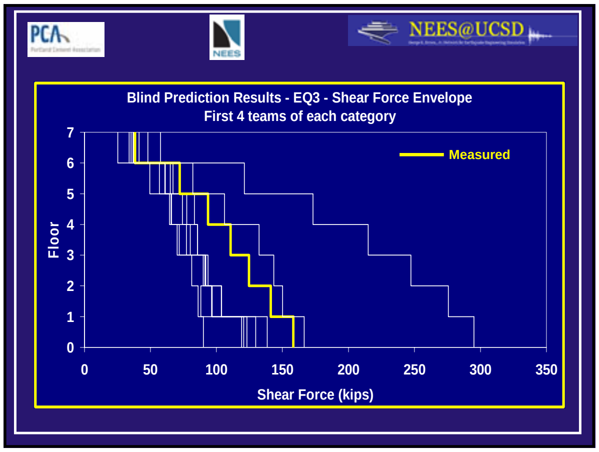
Sensors

- 600+ sensors deployed on the building, shake table and surrounding soil
  - DC Coupled Accelerometers
  - Displacement transducers
  - Strain gauges
  - Load cells
  - Oil pressure transducers
- First time use of 50Hz, 3 mm resolution, real-time GPS displacement sensors
- 17 videos feeds streamed through NEEScentral

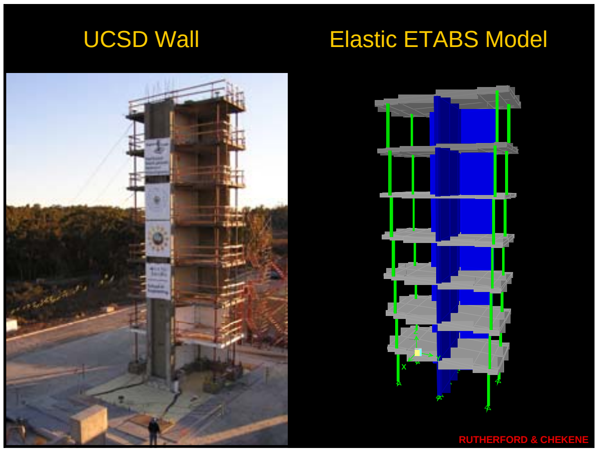


Building's Response to Sylmar Earthquake EQ4

- Performance levels anticipated were met:
  - Cosmetic damage at the base of the wall
  - Reinforcement strains reached 2.7%
  - Peak roof-drift ratio was 2.1%
  - Residual crack widths less than 1/20th of an inch
  - Negligible residual displacements (1/2 in. at the roof)
- The building slice could perhaps not be immediately "occupied" but only required minimum repairs



Blind Prediction Results - EQ3 - Shear Force Envelope
First 4 teams of each category



UCSD Wall

Elastic ETABS Model

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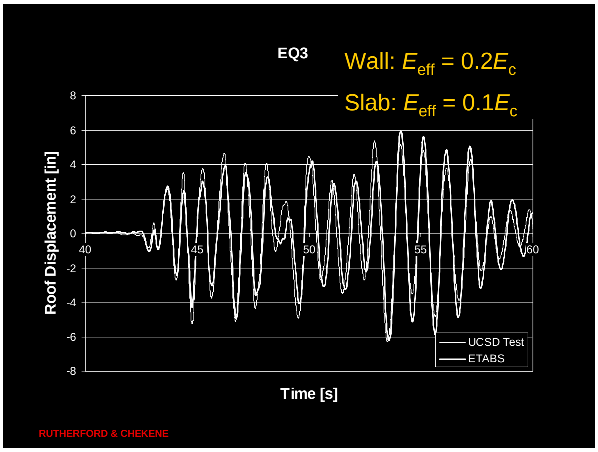

Wall: $E_{eff} = 0.2E_c$

Slab: $E_{eff} = 0.1E_c$

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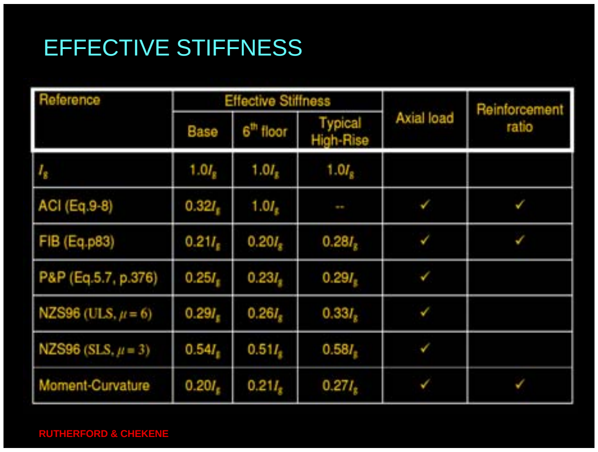

EFFECTIVE STIFFNESS

Reference	Effective Stiffness			Axial load	Reinforcement ratio
	Base	6th floor	Typical High-Rise		
I_g	$1.0I_g$	$1.0I_g$	$1.0I_g$		
ACI (Eq.9-8)	$0.32I_g$	$1.0I_g$	--	✓	✓
FIB (Eq.p83)	$0.21I_g$	$0.20I_g$	$0.28I_g$	✓	✓
P&P (Eq.5.7, p.376)	$0.25I_g$	$0.23I_g$	$0.29I_g$	✓	
NZS96 (ULS, $\mu = 6$)	$0.29I_g$	$0.26I_g$	$0.33I_g$	✓	
NZS96 (SLS, $\mu = 3$)	$0.54I_g$	$0.51I_g$	$0.58I_g$	✓	
Moment-Curvature	$0.20I_g$	$0.21I_g$	$0.27I_g$	✓	✓

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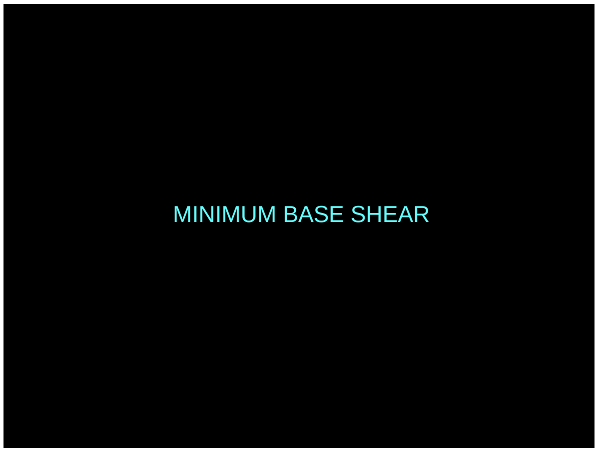
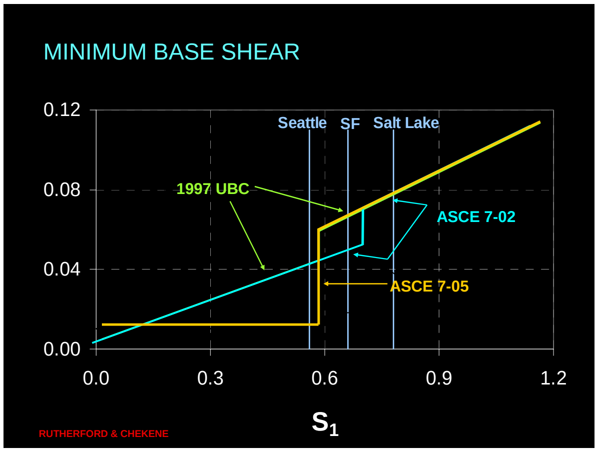
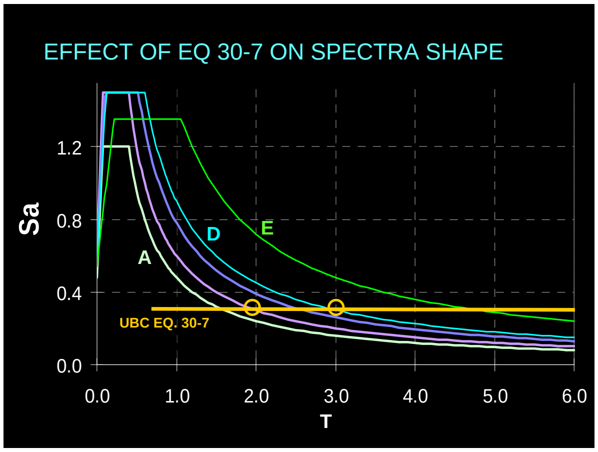


MINIMUM BASE SHEAR

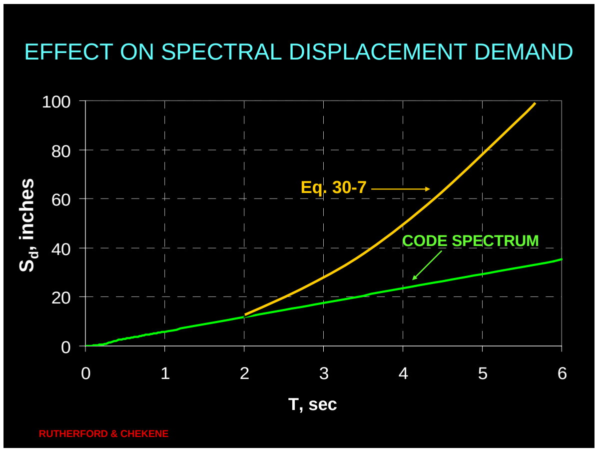


MINIMUM BASE SHEAR

RUTHERFORD & CHEKENE



EFFECT OF EQ 30-7 ON SPECTRA SHAPE



EFFECT ON SPECTRAL DISPLACEMENT DEMAND

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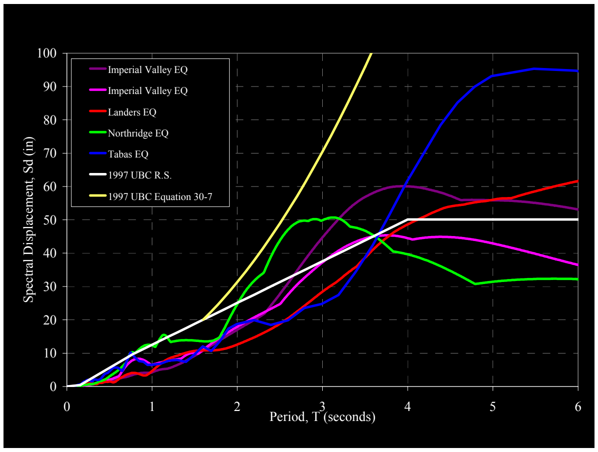

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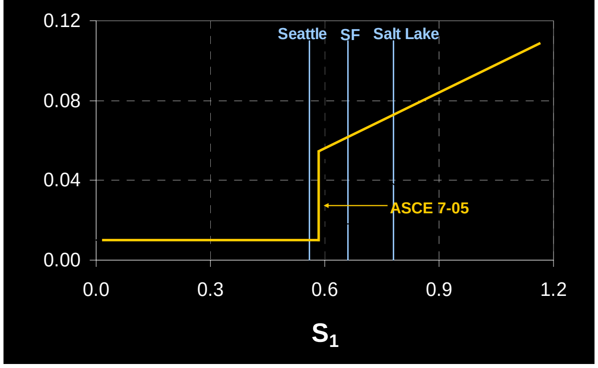
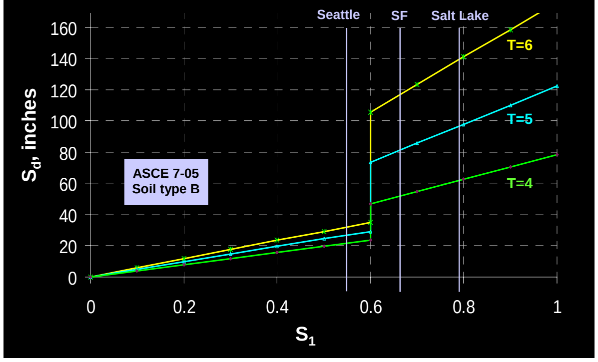
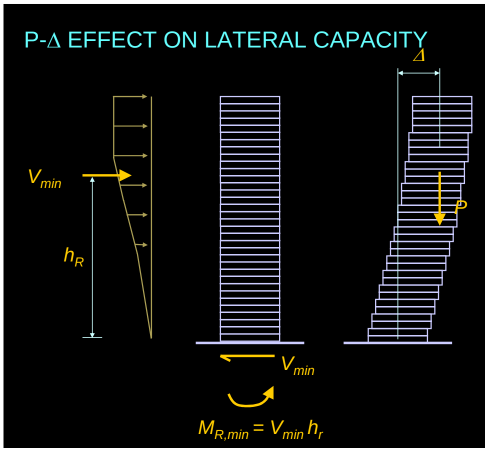


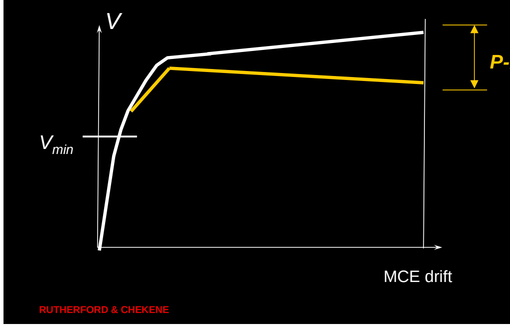
DISPLACEMENT DEMAND VS. S_1



P-Δ EFFECT ON LATERAL CAPACITY



LIMIT P-Δ REDUCTION IN LATERAL CAPACITY



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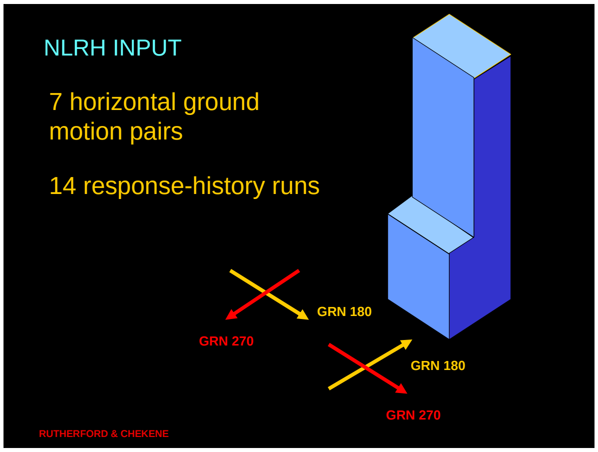
OTHER DESIGN ISSUES



NLRH INPUT

7 horizontal ground motion pairs

14 response-history runs

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NLRH ANALYSIS AT MCE

- Use **expected** strengths of materials, e.g., $f_y = 70$ ksi
- MCE analysis directly gives overstrength demands on elements designed to remain elastic
- Model element strengths at a gravity load of $1.0D + L_{exp}$
- Include inherent torsion but not accidental torsion

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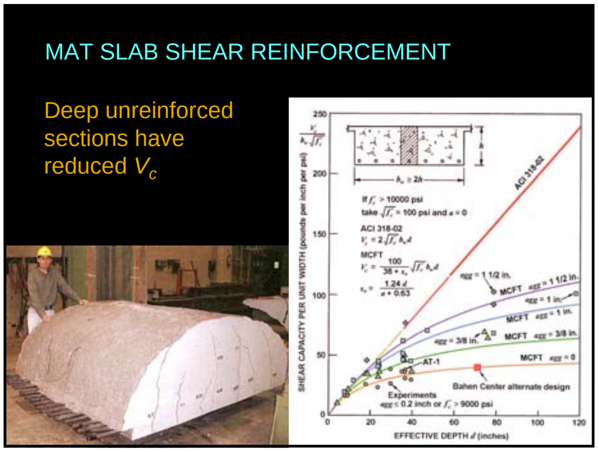

MAT SLAB SHEAR REINFORCEMENT

Deep unreinforced sections have reduced V_c

DETAIL GRAVITY SYSTEMS FOR INDUCED DRIFT

Design slab-column connections for ACI 2005 §21.11.5.

Use method (b), with additional consideration of bottom and integrity reinforcement

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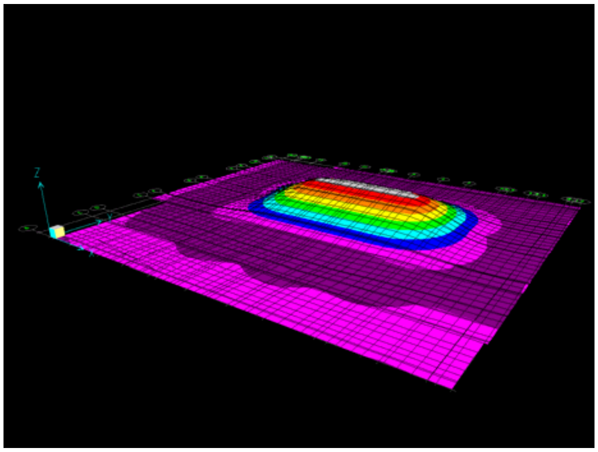
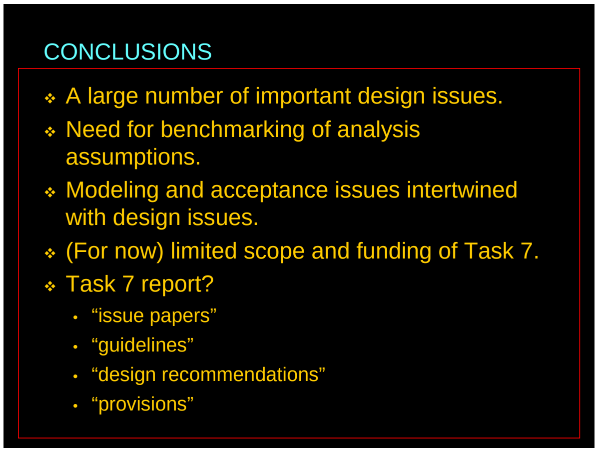
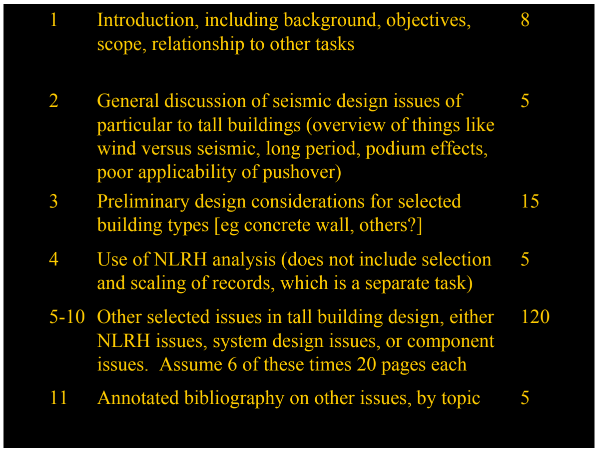


TASK GROUP 7 DELIVERABLE



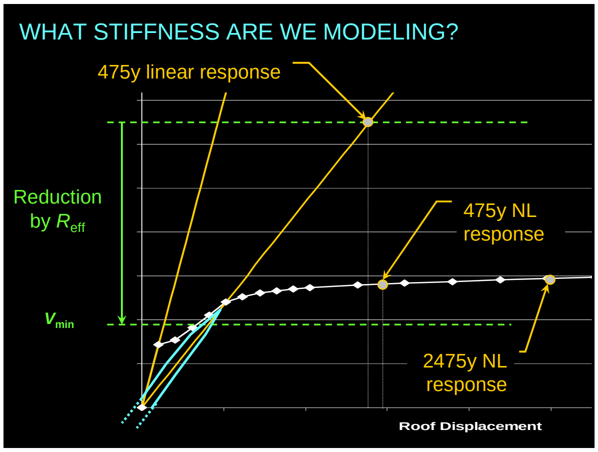
CONCLUSIONS

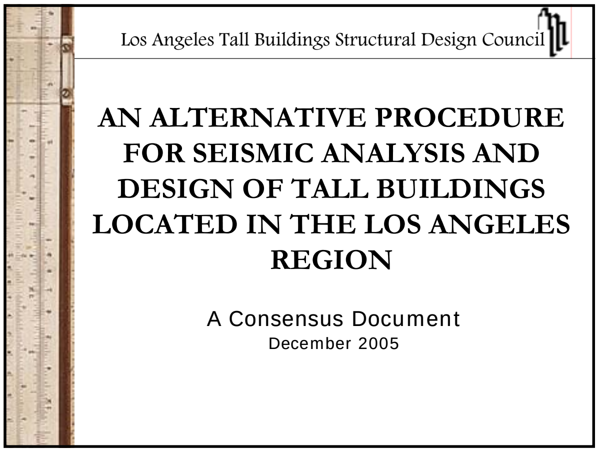
- A large number of important design issues.
- Need for benchmarking of analysis assumptions.
- Modeling and acceptance issues intertwined with design issues.
- (For now) limited scope and funding of Task 7.
- Task 7 report?
  - “issue papers”
  - “guidelines”
  - “design recommendations”
  - “provisions”



1	Introduction, including background, objectives, scope, relationship to other tasks	8
2	General discussion of seismic design issues of particular to tall buildings (overview of things like wind versus seismic, long period, podium effects, poor applicability of pushover)	5
3	Preliminary design considerations for selected building types [eg concrete wall, others?]	15
4	Use of NLRH analysis (does not include selection and scaling of records, which is a separate task)	5
5-10	Other selected issues in tall building design, either NLRH issues, system design issues, or component issues. Assume 6 of these times 20 pages each	120
11	Annotated bibliography on other issues, by topic	5

WHAT STIFFNESS ARE WE MODELING?





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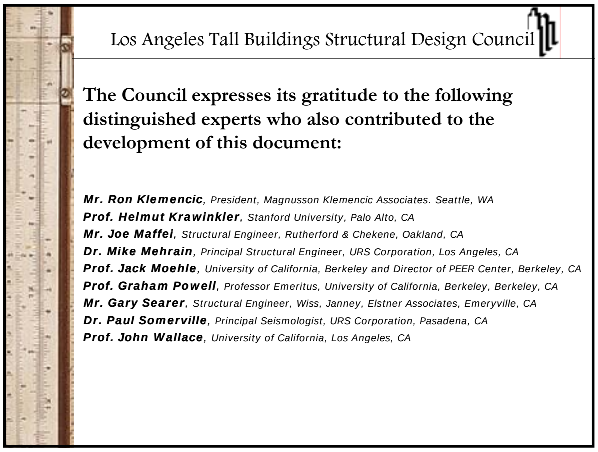
AN ALTERNATIVE PROCEDURE FOR SEISMIC ANALYSIS AND DESIGN OF TALL BUILDINGS LOCATED IN THE LOS ANGELES REGION

A Consensus Document
December 2005



Los Angeles Tall Buildings Structural Design Council

The Council expresses its gratitude to the following distinguished experts who also contributed to the development of this document:

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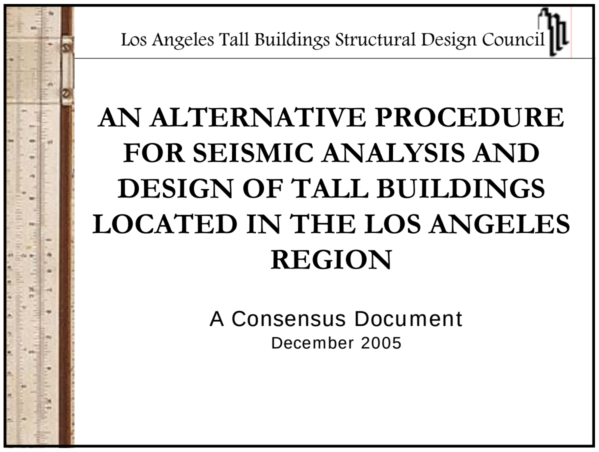
Prof. Helmut Krawinkler, *Stanford University, Palo Alto, CA*
Mr. Joe Maffei, *Structural Engineer, Rutherford & Chekene, Oakland, CA*
Dr. Mike Mehrain, *Principal Structural Engineer, URS Corporation, Los Angeles, CA*
Prof. Jack Moehle, *University of California, Berkeley and Director of PEER Center, Berkeley, CA*
Prof. Graham Powell, *Professor Emeritus, University of California, Berkeley, Berkeley, CA*
Mr. Gary Searer, *Structural Engineer, Wiss, Janney, Elstner Associates, Emeryville, CA*
Dr. Paul Somerville, *Principal Seismologist, URS Corporation, Pasadena, CA*
Prof. John Wallace, *University of California, Los Angeles, CA*



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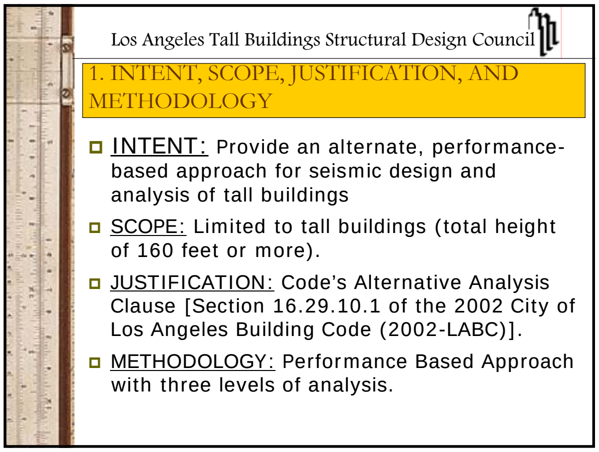
Link to the Document



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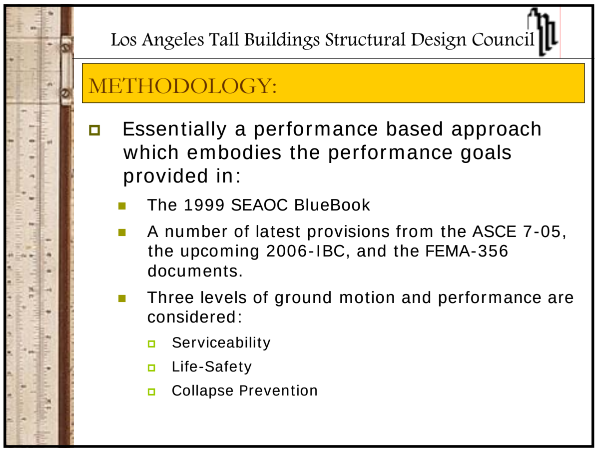
1. INTENT, SCOPE, JUSTIFICATION, AND METHODOLOGY

- INTENT: Provide an alternate, performance-based approach for seismic design and analysis of tall buildings
- SCOPE: Limited to tall buildings (total height of 160 feet or more).
- JUSTIFICATION: Code's Alternative Analysis Clause [Section 16.29.10.1 of the 2002 City of Los Angeles Building Code (2002-LABC)].
- METHODOLOGY: Performance Based Approach with three levels of analysis.



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METHODOLOGY:

- Essentially a performance based approach which embodies the performance goals provided in:
  - The 1999 SEAOC BlueBook
  - A number of latest provisions from the ASCE 7-05, the upcoming 2006-IBC, and the FEMA-356 documents.
  - Three levels of ground motion and performance are considered:
    - Serviceability
    - Life-Safety
    - Collapse Prevention

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SERVICEABILITY:

- The service level design earthquake is taken as an event having a 50% probability of being exceeded in 30 years (43 year return period).
- For this level, the building structural members are designed without a reduction factor (R = 1).
- This evaluation is not contained in current code requirements.
- The objective is to produce a structure that remains serviceable following such event.

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LIFE-SAFETY:

- This is a code-level seismic evaluation.
- The life-safety level design earthquake is taken as an event having a 10% probability of being exceeded in 50 years (475 year return period).
- For this level of earthquake, building code requirements are strictly followed with a small number of carefully delineated exceptions and modifications.
- The prescriptive connection detailing conforms to the requirements of the code.
- Standard code load combinations and material code standards are used.

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COLLAPSE-PREVENTION:

- The collapse-prevention level earthquake is taken as an event having a 2% probability of being exceeded in 50 years (2,475 year return period) with a deterministic limit.
- This is larger than the current 2002-LABC MCE event which has a return period of 975 years.
- Evaluation is performed using nonlinear response history analyses.
- Demands are checked against both structural members of the lateral force resisting system and other structural members.
- Nonstructural components are not evaluated at this level.

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- SEAOC PBD Framework (1999)

Earthquake Design Level	Earthquake Performance Level			
	Fully Operational	Operational	Life Safe	Near Collapse
Frequent (43 years)	Basic Objective	Unacceptable	Unacceptable	Unacceptable
Occasional (72 years)	Essential/Hazardous Objective	Basic Objective	Unacceptable	Unacceptable
Rare (475 years)	Safety Critical Objective	Essential/Hazardous Objective	Basic Objective	Unacceptable
Very Rare (975 years)	Not Feasible	Safety Critical Objective	Essential/Hazardous Objective	Basic Objective

- Our procedure is consistent with, but more stringent than SEAOC PBD Framework (1999)
- MCE level event is consistent with ASCE 7-05

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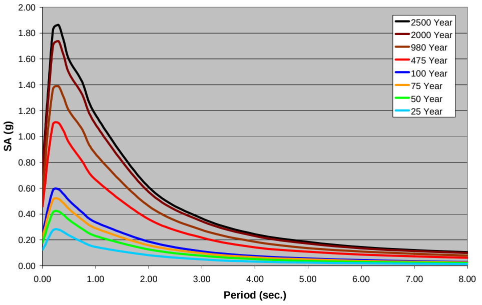

Figure C.2-1. Mean values of spectral acceleration obtained from three attenuation relations.

1. Abrahamson and Silva (1997)
2. Boore, Joyner and Fumal (1997)
3. Sadigh (1997)

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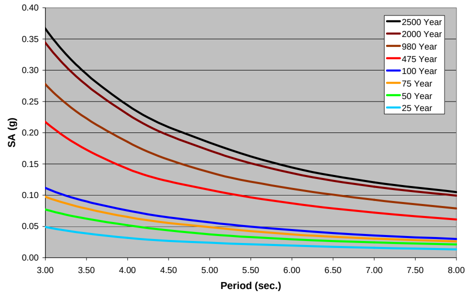

Figure C.2-1. Mean values of spectral acceleration obtained from three attenuation relations.

1. Abrahamson and Silva (1997)
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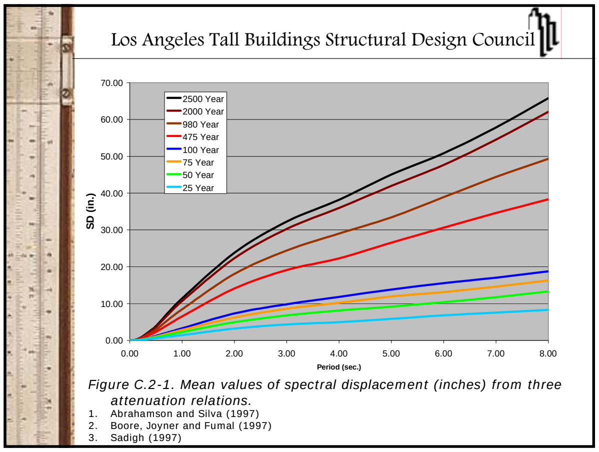

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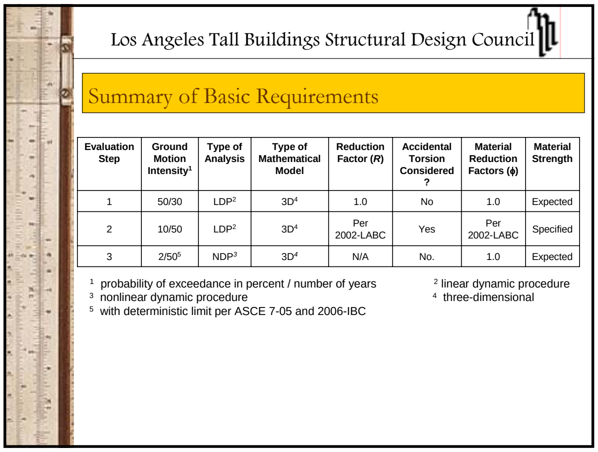
Figure C.2-1. Mean values of spectral displacement (inches) from three attenuation relations.

1. Abrahamson and Silva (1997)
2. Boore, Joyner and Fumal (1997)
3. Sadigh (1997)



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Summary of Basic Requirements

Evaluation Step	Ground Motion Intensity[1]	Type of Analysis	Type of Mathematical Model	Reduction Factor (*R*)	Accidental Torsion Considered ?	Material Reduction Factors (ϕ)	Material Strength
1	50/30	LDP[2]	3D[4]	1.0	No	1.0	Expected
2	10/50	LDP[2]	3D[4]	Per 2002-LABC	Yes	Per 2002-LABC	Specified
3	2/50[5]	NDP[3]	3D[4]	N/A	No.	1.0	Expected

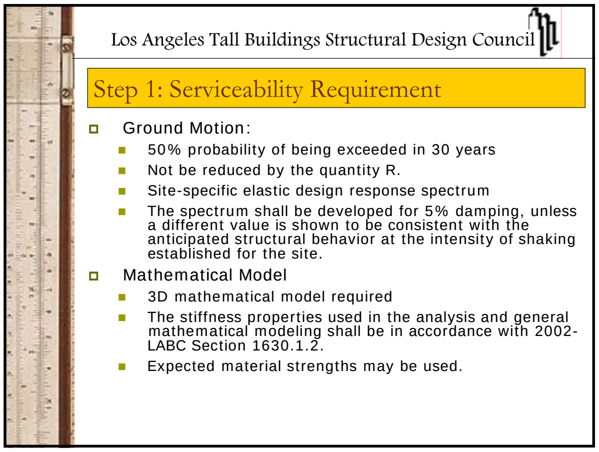
[1] probability of exceedance in percent / number of years

[2] linear dynamic procedure

[3] nonlinear dynamic procedure

[4] three-dimensional

[5] with deterministic limit per ASCE 7-05 and 2006-IBC



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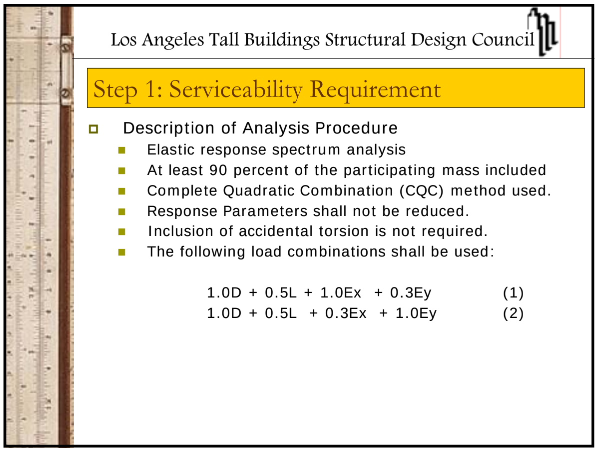
Step 1: Serviceability Requirement

- Ground Motion:
  - 50% probability of being exceeded in 30 years
  - Not be reduced by the quantity R.
  - Site-specific elastic design response spectrum
  - The spectrum shall be developed for 5% damping, unless a different value is shown to be consistent with the anticipated structural behavior at the intensity of shaking established for the site.
- Mathematical Model
  - 3D mathematical model required
  - The stiffness properties used in the analysis and general mathematical modeling shall be in accordance with 2002-LABC Section 1630.1.2.
  - Expected material strengths may be used.



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Step 1: Serviceability Requirement

- Description of Analysis Procedure
  - Elastic response spectrum analysis
  - At least 90 percent of the participating mass included
  - Complete Quadratic Combination (CQC) method used.
  - Response Parameters shall not be reduced.
  - Inclusion of accidental torsion is not required.
  - The following load combinations shall be used:

$$1.0D + 0.5L + 1.0Ex + 0.3Ey \qquad (1)$$

$$1.0D + 0.5L + 0.3Ex + 1.0Ey \qquad (2)$$

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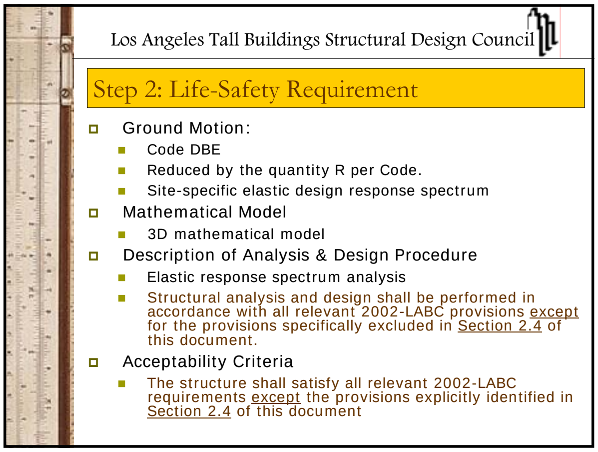
Step 1: Serviceability Requirement

- Acceptability Criteria
  - None of the members exceed the applicable LRFD limits for steel members or USD limits for concrete members (ϕ = 1.0).
  - Note that the design spectral values shall not be reduced by the quantity R.



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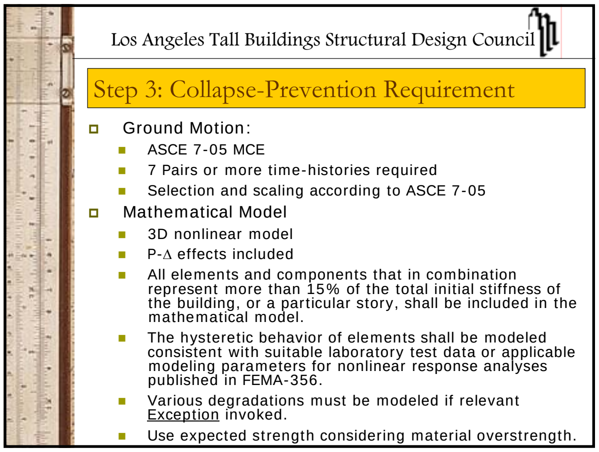
Step 2: Life-Safety Requirement

- Ground Motion:
  - Code DBE
  - Reduced by the quantity R per Code.
  - Site-specific elastic design response spectrum
- Mathematical Model
  - 3D mathematical model
- Description of Analysis & Design Procedure
  - Elastic response spectrum analysis
  - Structural analysis and design shall be performed in accordance with all relevant 2002-LABC provisions except for the provisions specifically excluded in Section 2.4 of this document.
- Acceptability Criteria
  - The structure shall satisfy all relevant 2002-LABC requirements except the provisions explicitly identified in Section 2.4 of this document



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Step 3: Collapse-Prevention Requirement

- Ground Motion:
  - ASCE 7-05 MCE
  - 7 Pairs or more time-histories required
  - Selection and scaling according to ASCE 7-05
- Mathematical Model
  - 3D nonlinear model
  - P-Δ effects included
  - All elements and components that in combination represent more than 15% of the total initial stiffness of the building, or a particular story, shall be included in the mathematical model.
  - The hysteretic behavior of elements shall be modeled consistent with suitable laboratory test data or applicable modeling parameters for nonlinear response analyses published in FEMA-356.
  - Various degradations must be modeled if relevant Exception invoked.
  - Use expected strength considering material overstrength.

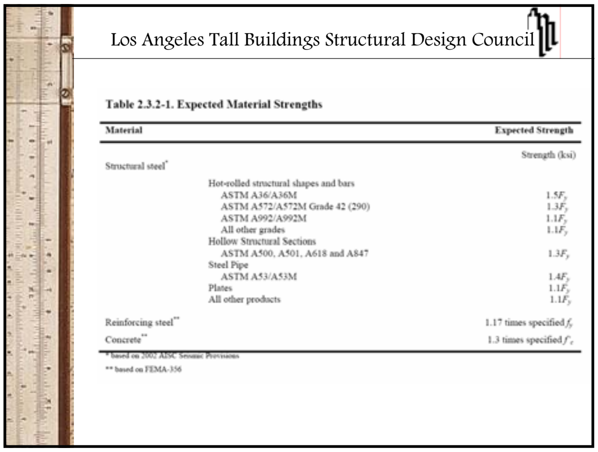

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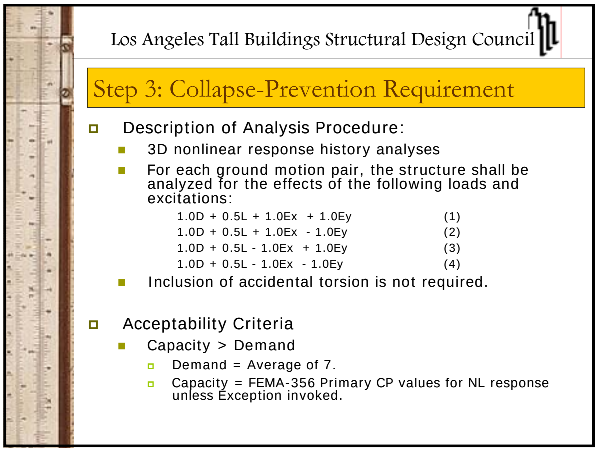
Table 2.3.2-1. Expected Material Strengths

Material		Expected Strength
		Strength (ksi)
Structural steel*		
	Hot-rolled structural shapes and bars	
	ASTM A36/A36M	$1.5F_y$
	ASTM A572/A572M Grade 42 (290)	$1.3F_y$
	ASTM A992/A992M	$1.1F_y$
	All other grades	$1.1F_y$
	Hollow Structural Sections	
	ASTM A500, A501, A618 and A847	$1.3F_y$
	Steel Pipe	
	ASTM A53/A53M	$1.4F_y$
	Plates	$1.1F_y$
	All other products	$1.1F_y$
Reinforcing steel**		1.17 times specified f_y
Concrete**		1.3 times specified f'_c

* based on 2002 AISC Seismic Provisions

** based on FEMA-356



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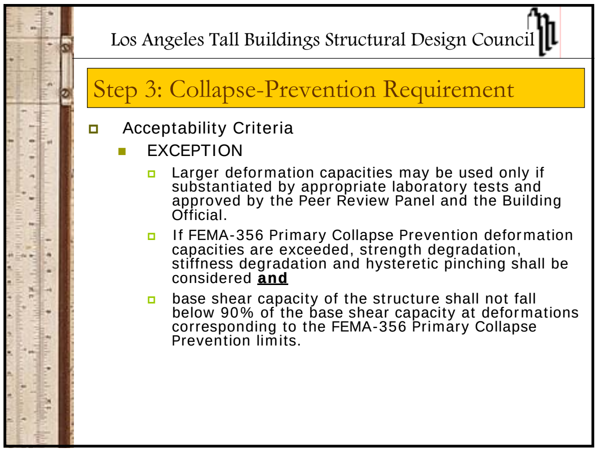
Step 3: Collapse-Prevention Requirement

- Description of Analysis Procedure:
  - 3D nonlinear response history analyses
  - For each ground motion pair, the structure shall be analyzed for the effects of the following loads and excitations:

    1.0D + 0.5L + 1.0Ex + 1.0Ey (1)
    1.0D + 0.5L + 1.0Ex - 1.0Ey (2)
    1.0D + 0.5L - 1.0Ex + 1.0Ey (3)
    1.0D + 0.5L - 1.0Ex - 1.0Ey (4)
  - Inclusion of accidental torsion is not required.
- Acceptability Criteria
  - Capacity > Demand
    - Demand = Average of 7.
    - Capacity = FEMA-356 Primary CP values for NL response unless Exception invoked.



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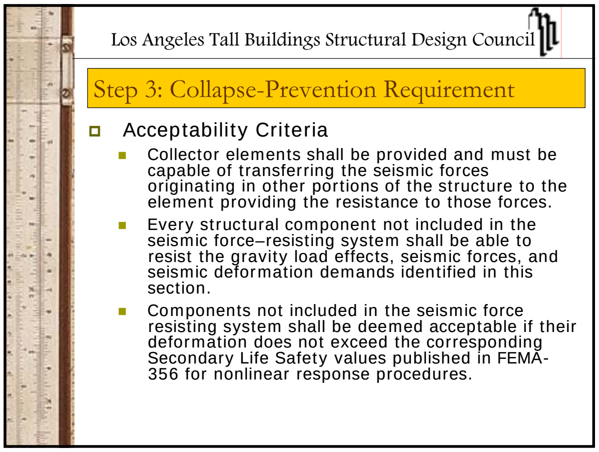
Step 3: Collapse-Prevention Requirement

- Acceptability Criteria
  - EXCEPTION
    - Larger deformation capacities may be used only if substantiated by appropriate laboratory tests and approved by the Peer Review Panel and the Building Official.
    - If FEMA-356 Primary Collapse Prevention deformation capacities are exceeded, strength degradation, stiffness degradation and hysteretic pinching shall be considered **and**
    - base shear capacity of the structure shall not fall below 90% of the base shear capacity at deformations corresponding to the FEMA-356 Primary Collapse Prevention limits.



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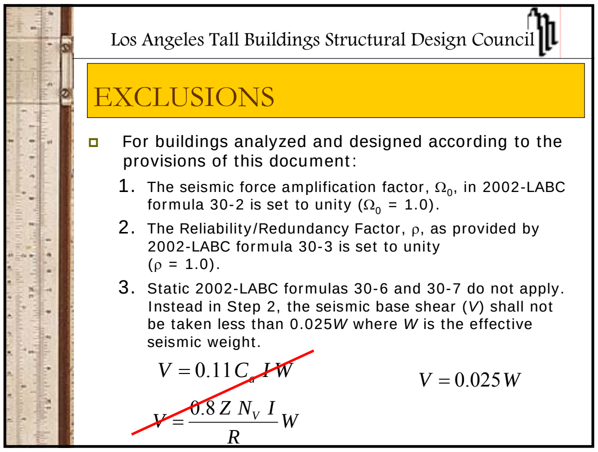
Step 3: Collapse-Prevention Requirement

- Acceptability Criteria
  - Collector elements shall be provided and must be capable of transferring the seismic forces originating in other portions of the structure to the element providing the resistance to those forces.
  - Every structural component not included in the seismic force–resisting system shall be able to resist the gravity load effects, seismic forces, and seismic deformation demands identified in this section.
  - Components not included in the seismic force resisting system shall be deemed acceptable if their deformation does not exceed the corresponding Secondary Life Safety values published in FEMA-356 for nonlinear response procedures.



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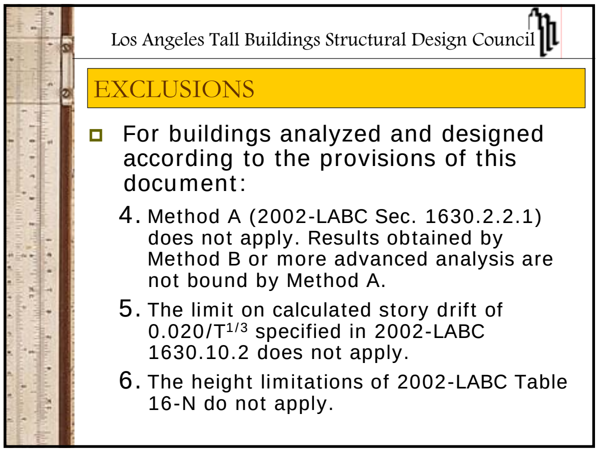
EXCLUSIONS

- For buildings analyzed and designed according to the provisions of this document:
  1. The seismic force amplification factor, Ω_0, in 2002-LABC formula 30-2 is set to unity (Ω_0 = 1.0).
  2. The Reliability/Redundancy Factor, ρ, as provided by 2002-LABC formula 30-3 is set to unity (ρ = 1.0).
  3. Static 2002-LABC formulas 30-6 and 30-7 do not apply. Instead in Step 2, the seismic base shear (*V*) shall not be taken less than 0.025*W* where *W* is the effective seismic weight.

$$\cancel{V = 0.11 C_a I W}$$

$$\cancel{V = \frac{0.8 Z N_V I}{R} W}$$

$$V = 0.025 W$$



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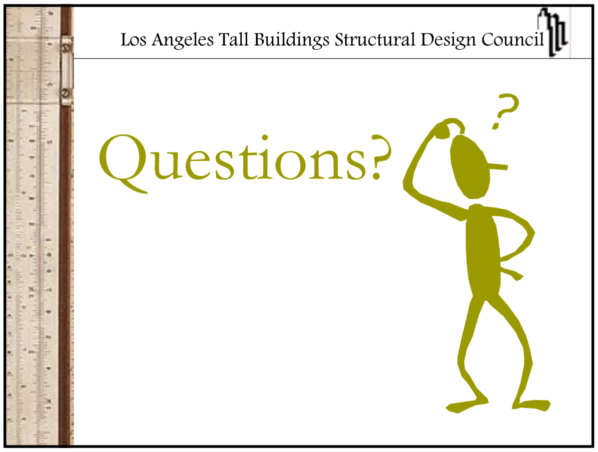
EXCLUSIONS

- For buildings analyzed and designed according to the provisions of this document:
  4. Method A (2002-LABC Sec. 1630.2.2.1) does not apply. Results obtained by Method B or more advanced analysis are not bound by Method A.
  5. The limit on calculated story drift of $0.020/T^{1/3}$ specified in 2002-LABC 1630.10.2 does not apply.
  6. The height limitations of 2002-LABC Table 16-N do not apply.



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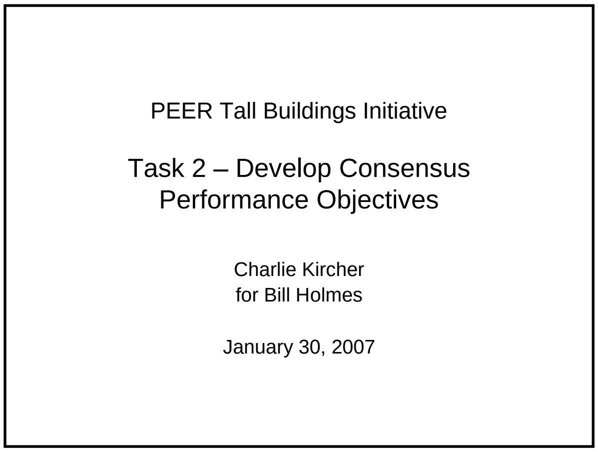
Questions?

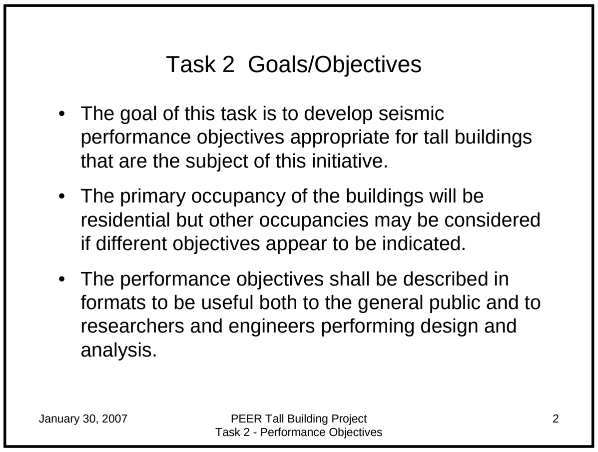


PEER Tall Buildings Initiative

Task 2 – Develop Consensus Performance Objectives

Charlie Kircher
for Bill Holmes

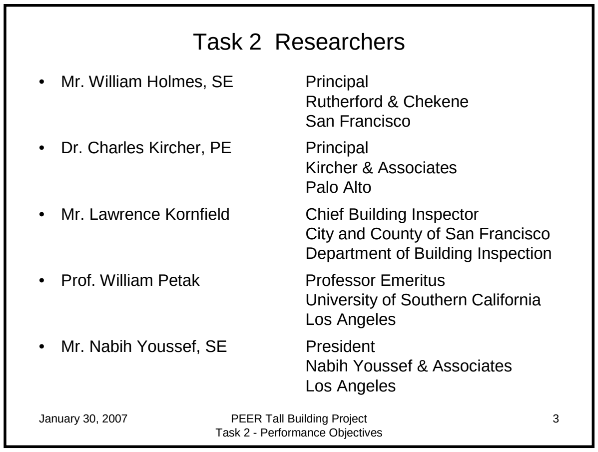
January 30, 2007



Task 2 Goals/Objectives

- The goal of this task is to develop seismic performance objectives appropriate for tall buildings that are the subject of this initiative.
- The primary occupancy of the buildings will be residential but other occupancies may be considered if different objectives appear to be indicated.
- The performance objectives shall be described in formats to be useful both to the general public and to researchers and engineers performing design and analysis.

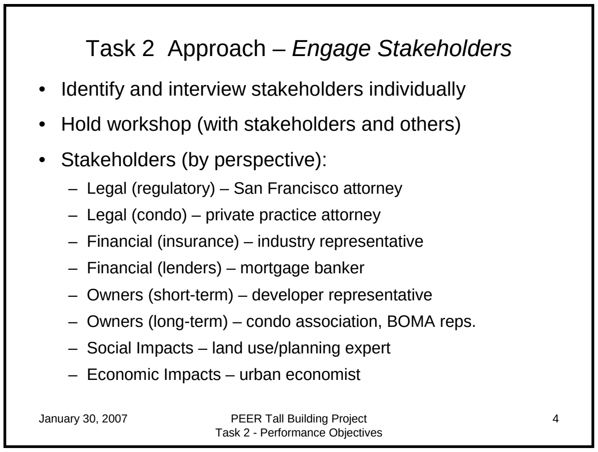
January 30, 2007 PEER Tall Building Project Task 2 - Performance Objectives 2



Task 2 Researchers

• Mr. William Holmes, SE	Principal Rutherford & Chekene San Francisco
• Dr. Charles Kircher, PE	Principal Kircher & Associates Palo Alto
• Mr. Lawrence Kornfield	Chief Building Inspector City and County of San Francisco Department of Building Inspection
• Prof. William Petak	Professor Emeritus University of Southern California Los Angeles
• Mr. Nabih Youssef, SE	President Nabih Youssef & Associates Los Angeles

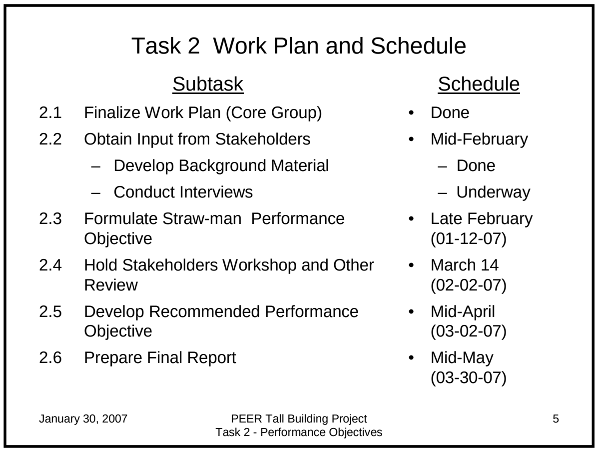
January 30, 2007 PEER Tall Building Project Task 2 - Performance Objectives 3



Task 2 Approach – *Engage Stakeholders*

- Identify and interview stakeholders individually
- Hold workshop (with stakeholders and others)
- Stakeholders (by perspective):
  - Legal (regulatory) – San Francisco attorney
  - Legal (condo) – private practice attorney
  - Financial (insurance) – industry representative
  - Financial (lenders) – mortgage banker
  - Owners (short-term) – developer representative
  - Owners (long-term) – condo association, BOMA reps.
  - Social Impacts – land use/planning expert
  - Economic Impacts – urban economist

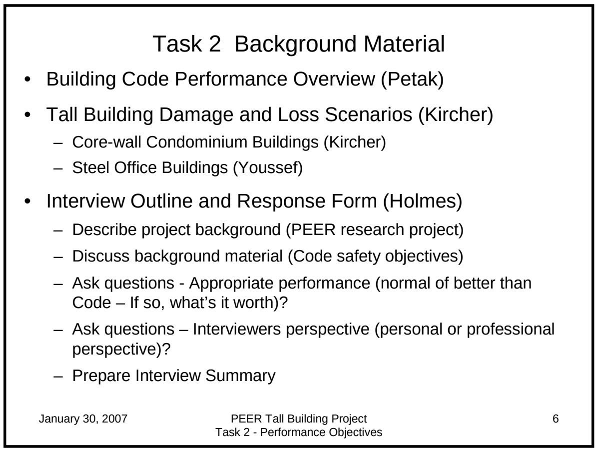
January 30, 2007 PEER Tall Building Project Task 2 - Performance Objectives 4



Task 2 Work Plan and Schedule

	Subtask	Schedule
2.1	Finalize Work Plan (Core Group)	• Done
2.2	Obtain Input from Stakeholders	• Mid-February
	– Develop Background Material	– Done
	– Conduct Interviews	– Underway
2.3	Formulate Straw-man Performance Objective	• Late February (01-12-07)
2.4	Hold Stakeholders Workshop and Other Review	• March 14 (02-02-07)
2.5	Develop Recommended Performance Objective	• Mid-April (03-02-07)
2.6	Prepare Final Report	• Mid-May (03-30-07)

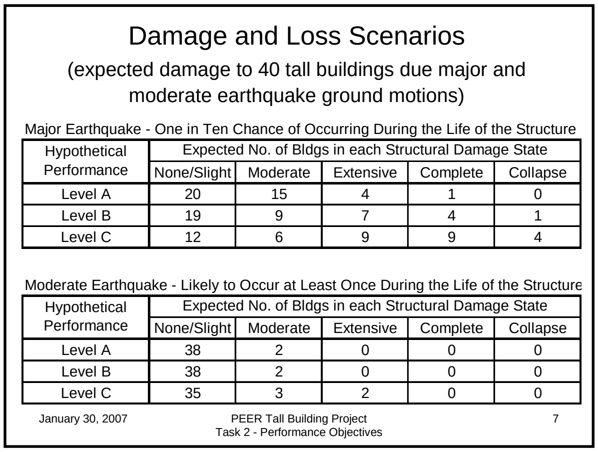
January 30, 2007 PEER Tall Building Project Task 2 - Performance Objectives 5



Task 2 Background Material

- Building Code Performance Overview (Petak)
- Tall Building Damage and Loss Scenarios (Kircher)
  - Core-wall Condominium Buildings (Kircher)
  - Steel Office Buildings (Youssef)
- Interview Outline and Response Form (Holmes)
  - Describe project background (PEER research project)
  - Discuss background material (Code safety objectives)
  - Ask questions - Appropriate performance (normal of better than Code – If so, what's it worth)?
  - Ask questions – Interviewers perspective (personal or professional perspective)?
  - Prepare Interview Summary

January 30, 2007 PEER Tall Building Project Task 2 - Performance Objectives 6



Damage and Loss Scenarios

(expected damage to 40 tall buildings due major and moderate earthquake ground motions)

Major Earthquake - One in Ten Chance of Occurring During the Life of the Structure

Hypothetical Performance	Expected No. of Bldgs in each Structural Damage State				
	None/Slight	Moderate	Extensive	Complete	Collapse
Level A	20	15	4	1	0
Level B	19	9	7	4	1
Level C	12	6	9	9	4

Moderate Earthquake - Likely to Occur at Least Once During the Life of the Structure

Hypothetical Performance	Expected No. of Bldgs in each Structural Damage State				
	None/Slight	Moderate	Extensive	Complete	Collapse
Level A	38	2	0	0	0
Level B	38	2	0	0	0
Level C	35	3	2	0	0

January 30, 2007

PEER Tall Building Project
Task 2 - Performance Objectives

7

Task 8 - Foundation Modeling

Input Ground Motions for Tall Buildings with Subterranean Levels

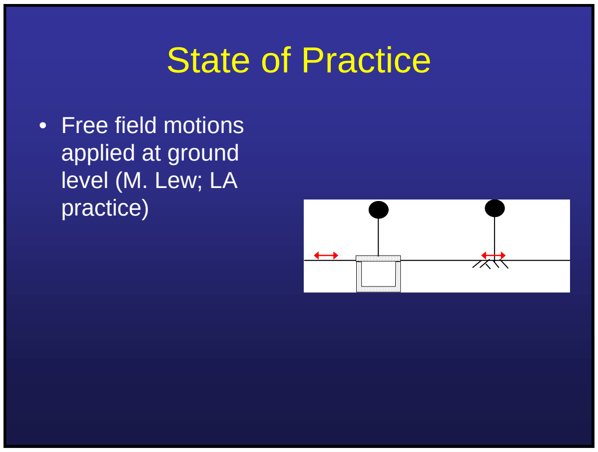
Jonathan P. Stewart
University of California, Los Angeles

Team

C.B. Crouse, URS, Seattle, WA
Marshall Lew, MACTEC, Los Angeles, CA
Atsushi Mikami, University of Tokushima, Japan
Farhang Ostadaan, Bechtel, San Francisco, CA
Ertugrul Taciroglu, UCLA

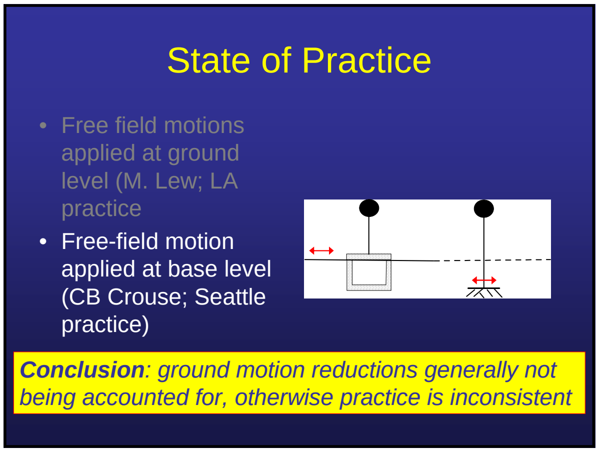
Project Plan and Schedule

- Group meeting (Nov 30 2006): review state-of-art/practice; identify knowledge shortcomings and research needs
- JPS + ET drafts preliminary report (Jan 07)
- Committee review
- Final report ready Mar 07



State of Practice

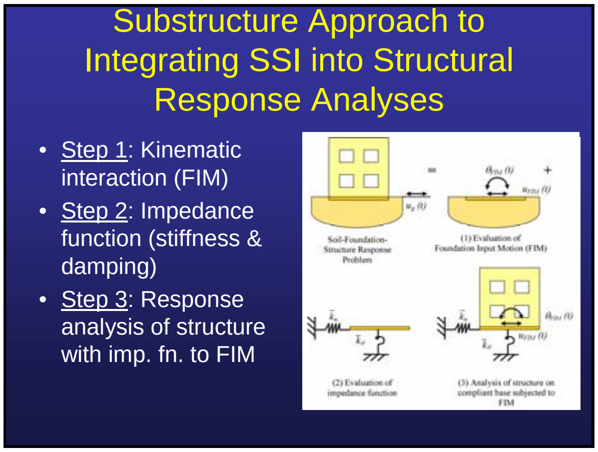
- Free field motions applied at ground level (M. Lew; LA practice)



State of Practice

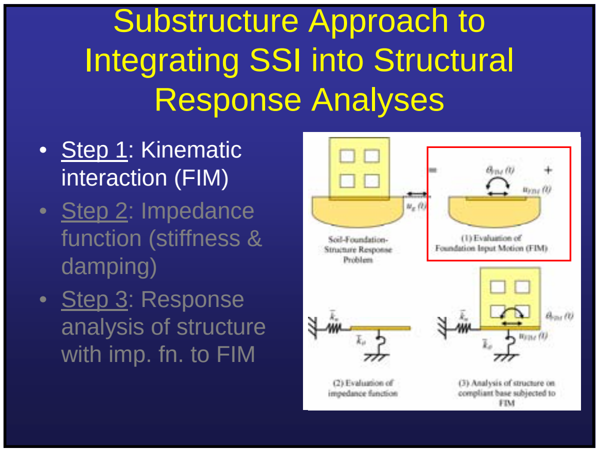
- Free field motions applied at ground level (M. Lew; LA practice)
- Free-field motion applied at base level (CB Crouse; Seattle practice)

Conclusion*: ground motion reductions generally not being accounted for, otherwise practice is inconsistent*



Substructure Approach to Integrating SSI into Structural Response Analyses

- Step 1: Kinematic interaction (FIM)
- Step 2: Impedance function (stiffness & damping)
- Step 3: Response analysis of structure with imp. fn. to FIM



Substructure Approach to Integrating SSI into Structural Response Analyses

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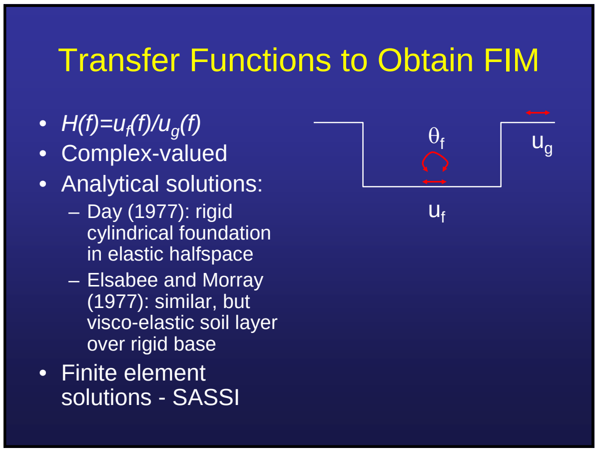
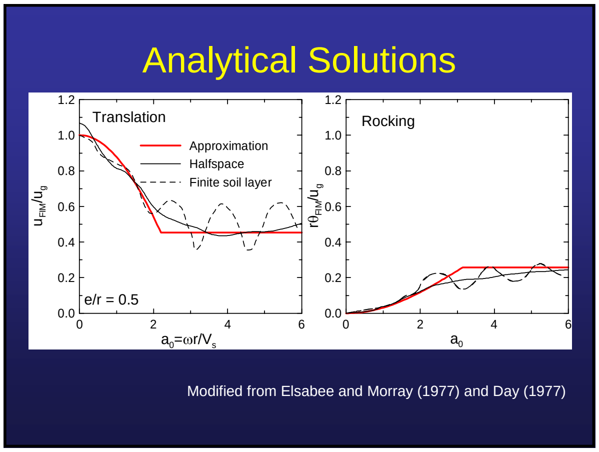


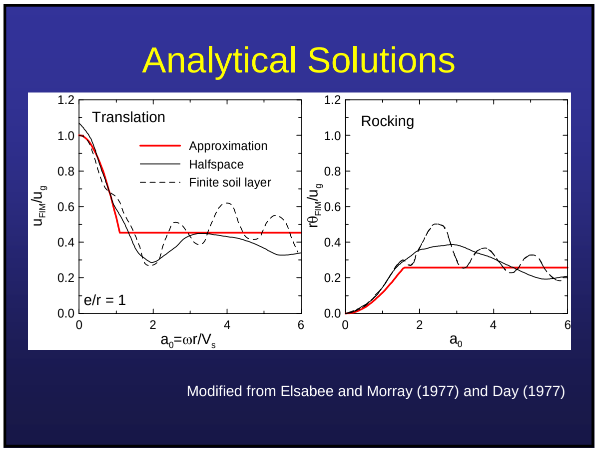
Transfer Functions to Obtain FIM

- $H(f)=u_f(f)/u_g(f)$
- Complex-valued
- Analytical solutions:
  - Day (1977): rigid cylindrical foundation in elastic halfspace
  - Elsabee and Morray (1977): similar, but visco-elastic soil layer over rigid base
- Finite element solutions - SASSI



Analytical Solutions

Modified from Elsabee and Morray (1977) and Day (1977)



Analytical Solutions

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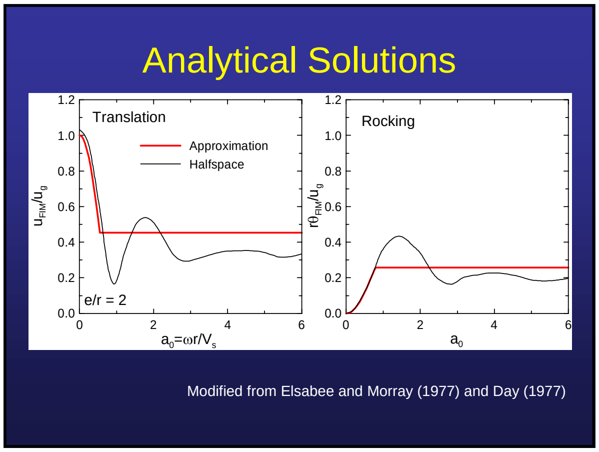
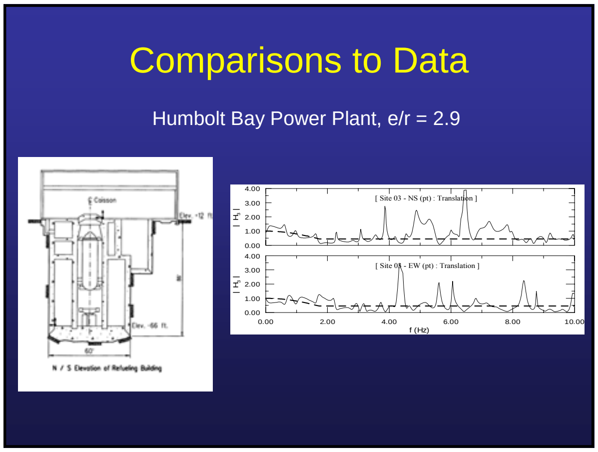


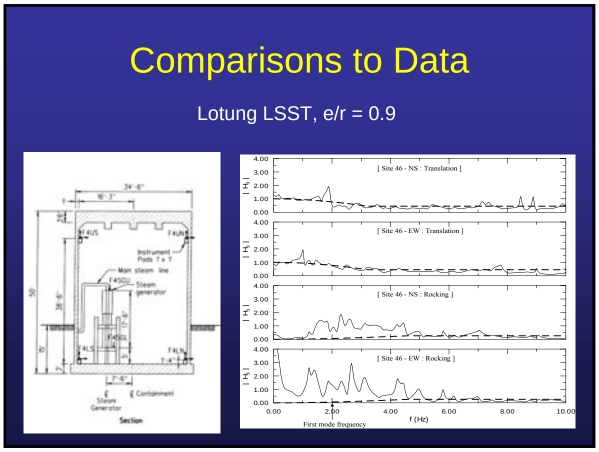
Analytical Solutions

Modified from Elsabee and Morray (1977) and Day (1977)



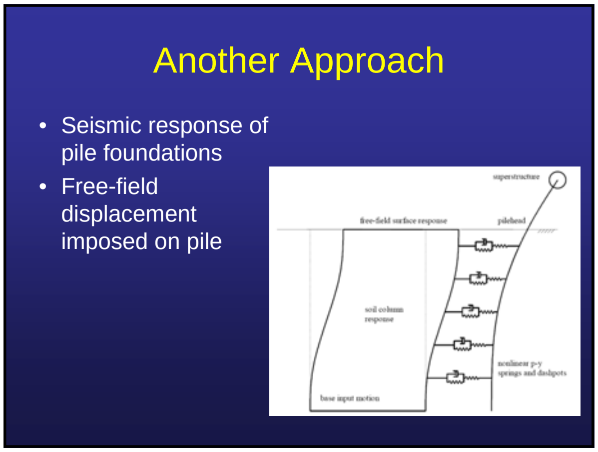
Comparisons to Data

Humbolt Bay Power Plant, e/r = 2.9



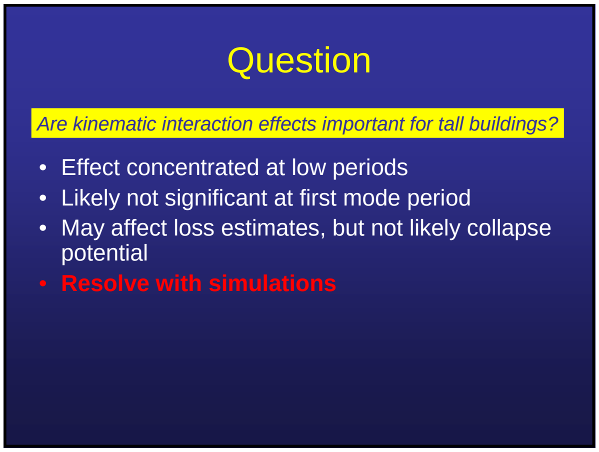
Comparisons to Data

Lotung LSST, e/r = 0.9



Another Approach

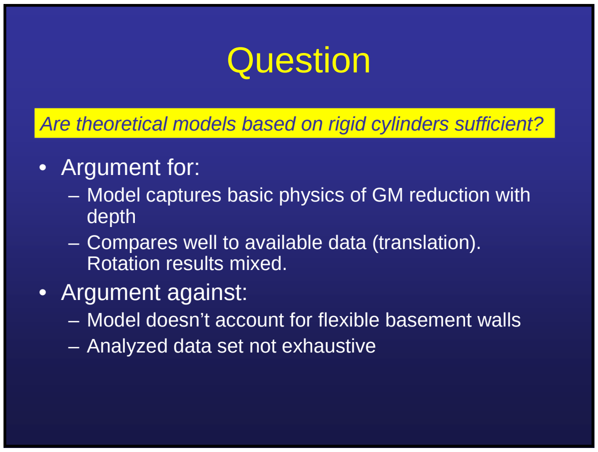
- Seismic response of pile foundations
- Free-field displacement imposed on pile



Question

Are kinematic interaction effects important for tall buildings?

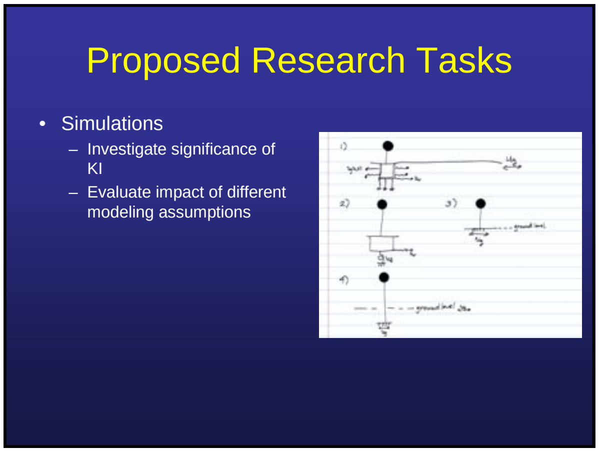
- Effect concentrated at low periods
- Likely not significant at first mode period
- May affect loss estimates, but not likely collapse potential
- **Resolve with simulations**



Question

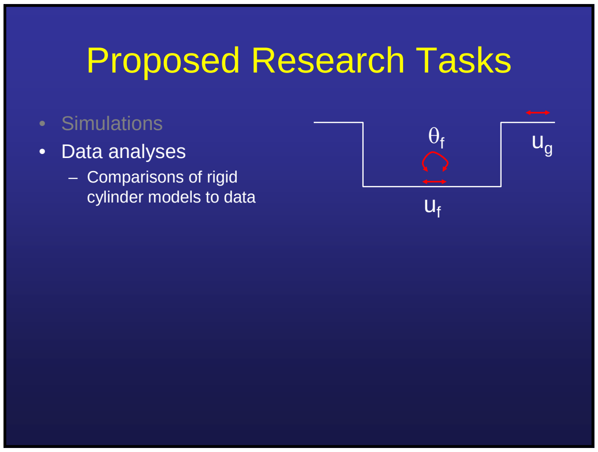
Are theoretical models based on rigid cylinders sufficient?

- Argument for:
  - Model captures basic physics of GM reduction with depth
  - Compares well to available data (translation). Rotation results mixed.
- Argument against:
  - Model doesn’t account for flexible basement walls
  - Analyzed data set not exhaustive



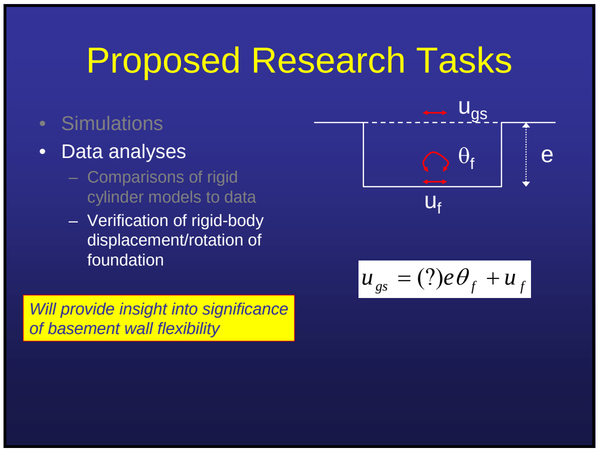
Proposed Research Tasks

- Simulations
  - Investigate significance of KI
  - Evaluate impact of different modeling assumptions



Proposed Research Tasks

- Simulations
- Data analyses
  - Comparisons of rigid cylinder models to data

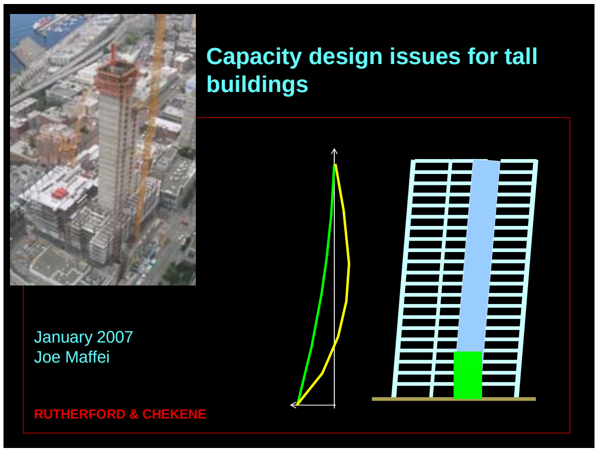


Proposed Research Tasks

- Simulations
- Data analyses
  - Comparisons of rigid cylinder models to data
  - Verification of rigid-body displacement/rotation of foundation

$$u_{gs} = (?)e\theta_f + u_f$$

Will provide insight into significance of basement wall flexibility



Capacity design issues for tall buildings

January 2007
Joe Maffei

RUTHERFORD & CHEKENE

WORKSHOP INPUT ON CAPACITY DESIGN

- Tom Sabol – column/beam strength ratios
- Mark Moore – wall flexure vs shear, and shear demand on walls below podium
- Mark Moore – wall yielding above designated hinge zone
- Mark Moore – flexural overstrength of walls and maximum demands on elastic elements

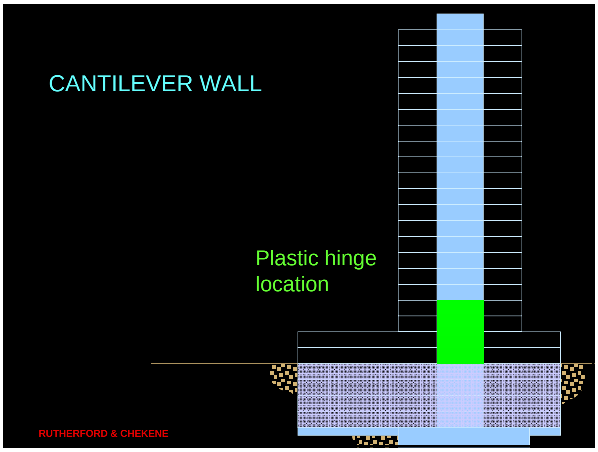
TWO-STAGE DESIGN

- Determine the strengths at hinging locations using the building code requirements
  - Code (DBE) level earthquake ÷ *R* factor
  - Minimum base shear
- All other actions are designed to remain elastic under MCE level ground motions:
  - Wall shear, shear friction, wall flexure outside of intended yield locations, floor and roof diaphragms and collectors and connections, foundation perimeter walls, foundations, etc.
  - Check drift limits

CAPACITY DESIGN

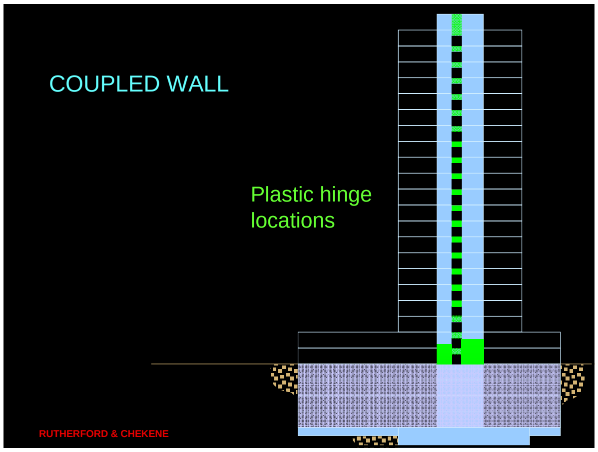
- Engineer designs where and how nonlinear response will occur.
- Capacity design is a pre-requisite to nonlinear analysis.

CAPACITY DESIGN | CONCRETE WALLS



CANTILEVER WALL

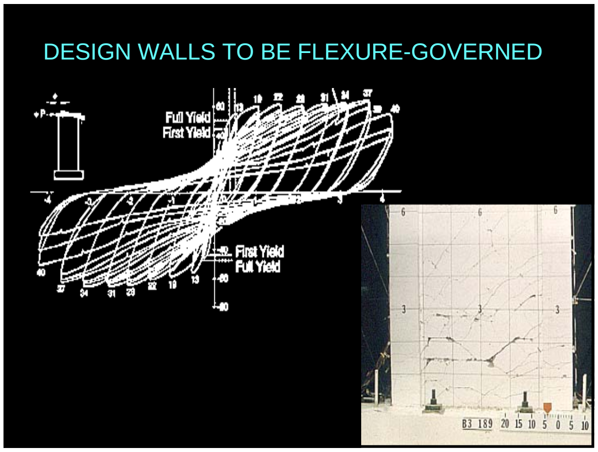
RUTHERFORD & CHEKENE



COUPLED WALL

Plastic hinge locations

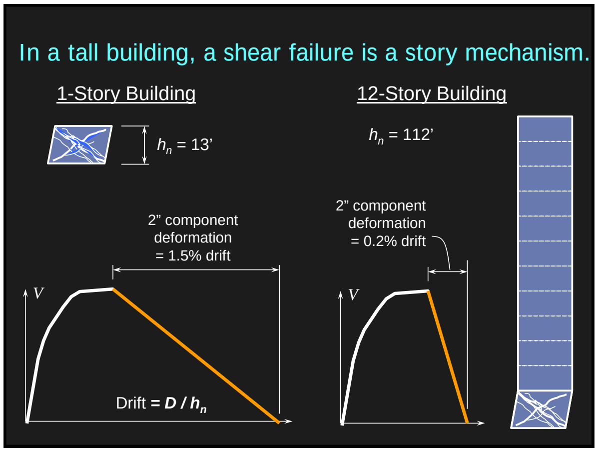
RUTHERFORD & CHEKENE



DESIGN WALLS TO BE FLEXURE-GOVERNED

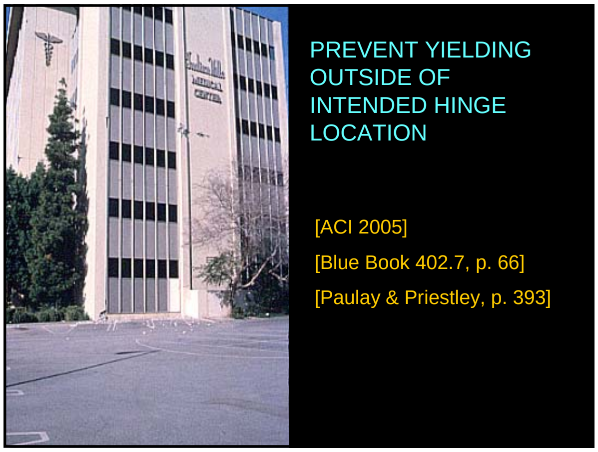
PROTECT AGAINST SHEAR FAILURE

Include inelastic-dynamic amplification effects



In a tall building, a shear failure is a story mechanism.

PREVENT SLIDING SHEAR FAILURE

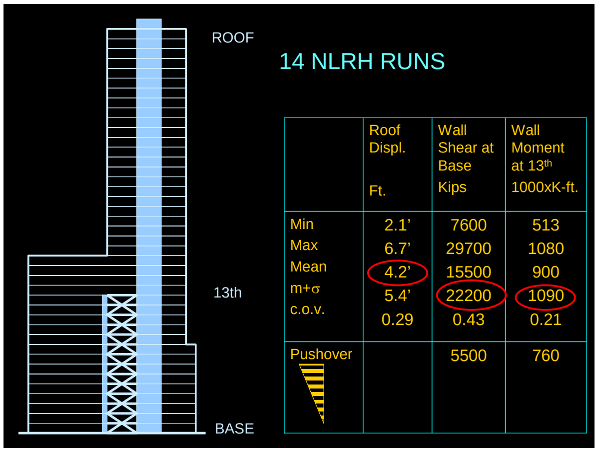


PREVENT YIELDING OUTSIDE OF INTENDED HINGE LOCATION

[ACI 2005]

[Blue Book 402.7, p. 66]

[Paulay & Priestley, p. 393]



14 NLRH RUNS

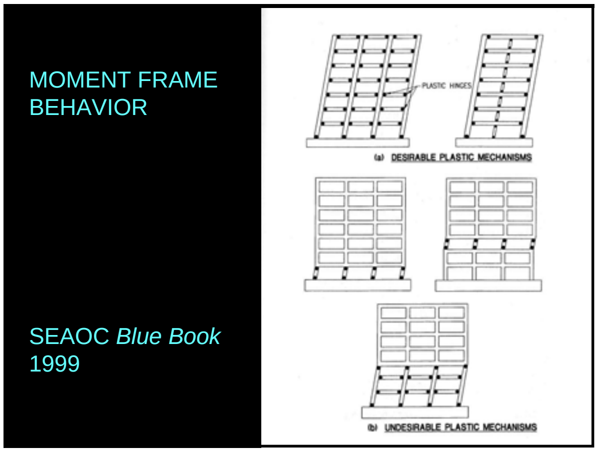
	Roof Displ. Ft.	Wall Shear at Base Kips	Wall Moment at 13th 1000xK-ft.
Min	2.1'	7600	513
Max	6.7'	29700	1080
Mean	4.2'	15500	900
m+σ	5.4'	22200	1090
c.o.v.	0.29	0.43	0.21
Pushover		5500	760

CAPACITY DESIGN | MOMENT FRAMES
DUAL SYSTEM
FOUNDATIONS

MOMENT FRAME STRUCTURES

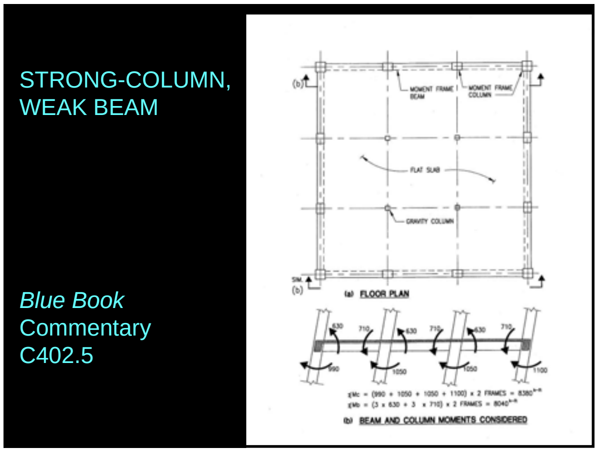
- Existing requirements for strong-column/weak-beam are usually not adequate to prevent story mechanisms.
- Use Blue Book recommendation, or NLRH analysis.

RUTHERFORD & CHEKENE



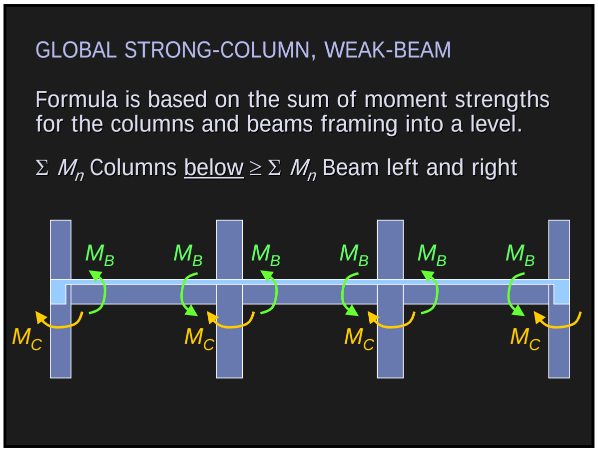
MOMENT FRAME BEHAVIOR

SEAOC *Blue Book* 1999



STRONG-COLUMN, WEAK BEAM

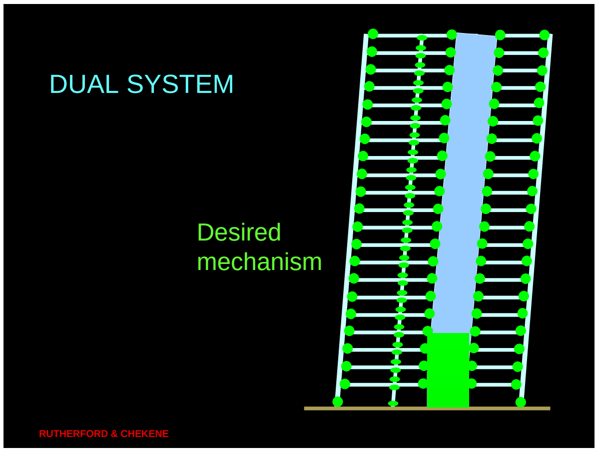
Blue Book Commentary C402.5



GLOBAL STRONG-COLUMN, WEAK-BEAM

Formula is based on the sum of moment strengths for the columns and beams framing into a level.

$\Sigma\ M_n$ Columns below $\geq \Sigma\ M_n$ Beam left and right



DUAL SYSTEM

Desired mechanism

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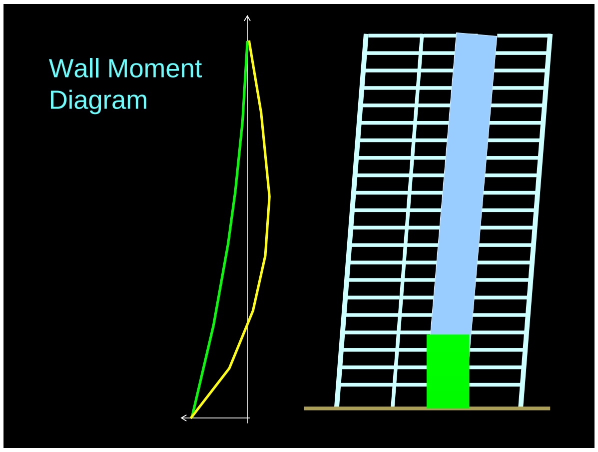
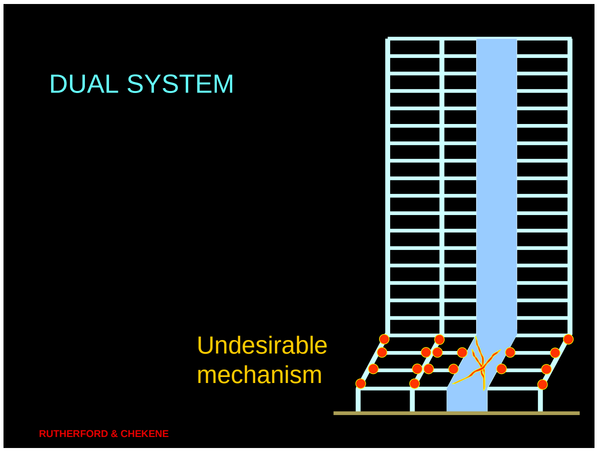


Wall Moment Diagram



DUAL SYSTEM

Undesirable mechanism

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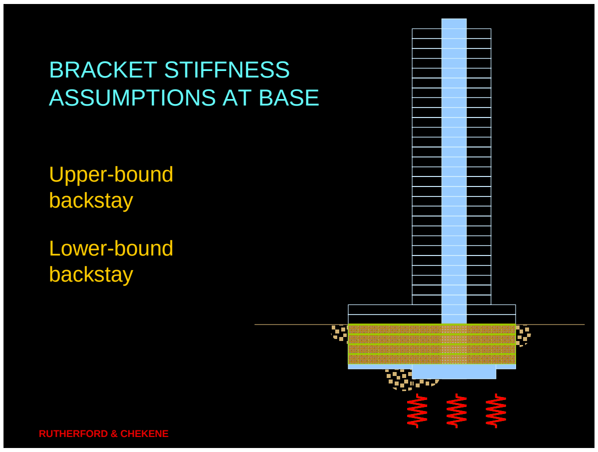

BRACKET STIFFNESS ASSUMPTIONS AT BASE

Upper-bound backstay

Lower-bound backstay

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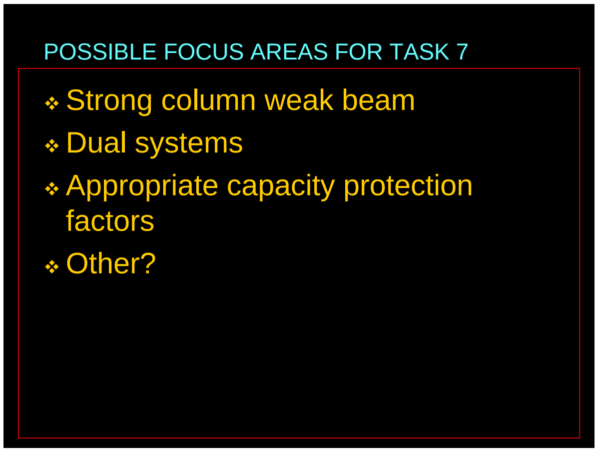


POSSIBLE FOCUS AREAS FOR TASK 7

- Strong column weak beam
- Dual systems
- Appropriate capacity protection factors
- Other?

Base Load Transfer Issues

Jim Malley
TBI Workshop
January 30, 2007

Description of the Issue

- Most tall buildings have at least one basement level
- Often the below grade footprint is larger than the tower, with solid basement retaining walls
- Offsets therefore between SLRS and basement walls
  - Large force transfer required due to large discrepancy in stiffness

So, How Has this Been Done in the Past?

- Assume rigid support at the ground floor level
  - Get huge transfer forces in ground floor diaphragm
  - Negative shears in interior walls and frames?
- Design the “below grade box” for the base reaction
- Simple, huh?

So, What’s the Big Deal?

- Forces get HUGE if you try to assume a completely rigid support and try to take the forces out in one diaphragm
  - And this is just the code base shear
    - Try putting on the Omega factor or use the element capacity
  - Modeling the diaphragm with openings for garage ramps, vertical transport, etc.
- True force transfer is much more complicated (Ignorance is bliss!)

Issues to be Considered in Base Transfer

- Relative stiffness between walls (or frames) and basement walls
- Actual stiffness of diaphragm with openings properly addressed
- Multiple below grade diaphragms
  - How much can they help with the transfer?
- Purely elastic diaphragm(s) at all times?
- Proper consideration of above grade system capacity (pushover, NLRH, etc.)

Issues to be Considered in Base Transfer (Cont.)

- Interaction with supporting soils (Rocking, passive pressure, etc.)
  - When is SSI really needed or helpful?
- Multiple towers above a single base
  - Have fun with that!
- Sloping sites with one side open. What about two sides?
- Parking structure ramps acting as struts?

Issues to be Considered in Base Transfer (Cont.)

- Are vertical offsets in ground floor diaphragm important?
- What about the change in wall openings below grade?
- Are the dreaded parameter studies needed to bound the solution? If so, on what parameters?

Issues to be Considered in Base Transfer (Cont.)

- Podium Effects: Therein is one of my main concerns. For a typical podium that has perimeter walls on two or three sides above grade and retaining walls on all four sides for the below grade structure, the wall overturning resistance is partially afforded by coupling of slabs. This we've all seen in our analysis. This generates shear reversals and very large demands on the diaphragm.

Issues to be Considered in Base Transfer (Cont.)

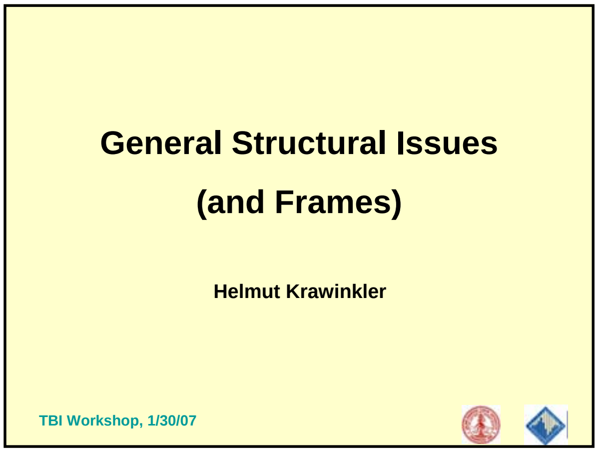
- …In reality I believe this load path is not as stiff, and, fortunately, the demands will not be as high as the analysis indicates. This can be somewhat overcome with detailed modeling of the diaphragms, walls, and SSI, and a parameter study. But I doubt the designers or the peer reviewers really spend the time, or have a good understanding for each case of this complex issue. What parameter studies I've seen do not address this in my humble opinion.…

Issues to be Considered in Base Transfer (Cont.)

- …The main issue with the podium is that core openings change at these levels during the design, the openings complicate the core wall behavior, the podium may have ramps and other complex geometric issues. All these issues make me concerned that they get overlooked, even after going through a peer review process. I'm not convinced that a peer review solves these and other modeling issues.….

Issues to be Considered in Base Transfer (Cont.)

- …. I'll close my rant on this issue by suggesting that at the least the approach of how and what to do be somewhat prescribed in regards to core openings, podium geometry issues (diaphragms, walls and ramps), shear reversals, and last but not least important SSI.
- *Simple, indeed!*

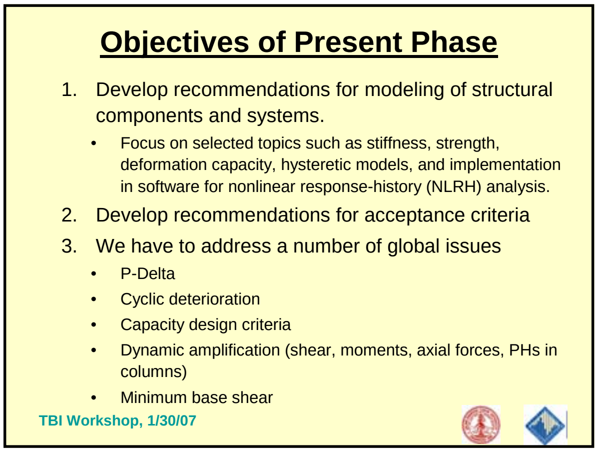


General Structural Issues

(and Frames)

Helmut Krawinkler

TBI Workshop, 1/30/07



Objectives of Present Phase

1. Develop recommendations for modeling of structural components and systems.
    - Focus on selected topics such as stiffness, strength, deformation capacity, hysteretic models, and implementation in software for nonlinear response-history (NLRH) analysis.
2. Develop recommendations for acceptance criteria
3. We have to address a number of global issues
    - P-Delta
    - Cyclic deterioration
    - Capacity design criteria
    - Dynamic amplification (shear, moments, axial forces, PHs in columns)
    - Minimum base shear

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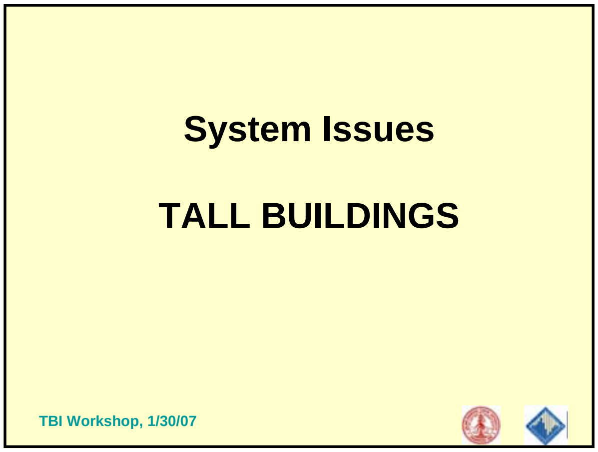

System Issues

TALL BUILDINGS

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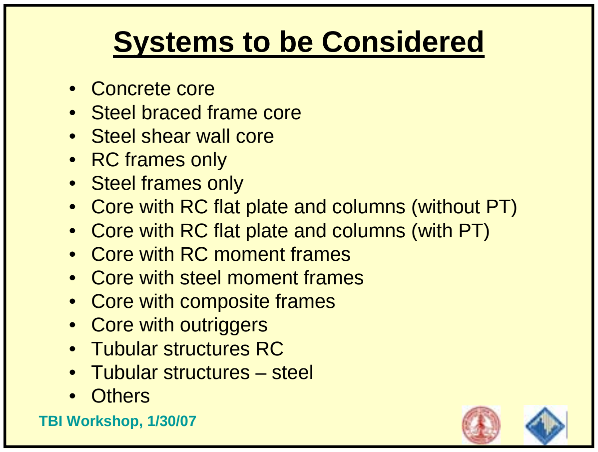

Systems to be Considered

- Concrete core
- Steel braced frame core
- Steel shear wall core
- RC frames only
- Steel frames only
- Core with RC flat plate and columns (without PT)
- Core with RC flat plate and columns (with PT)
- Core with RC moment frames
- Core with steel moment frames
- Core with composite frames
- Core with outriggers
- Tubular structures RC
- Tubular structures – steel
- Others

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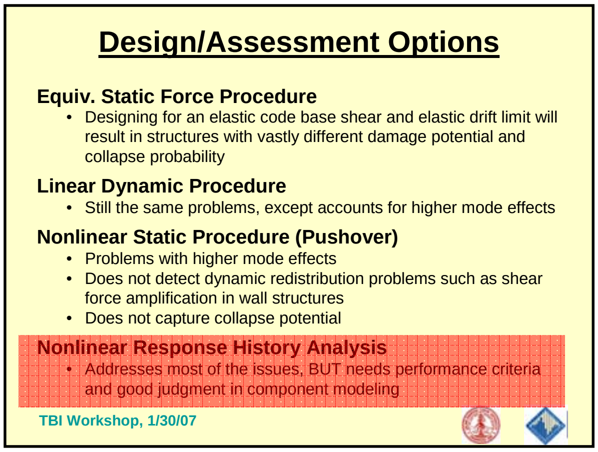

Design/Assessment Options

Equiv. Static Force Procedure
- Designing for an elastic code base shear and elastic drift limit will result in structures with vastly different damage potential and collapse probability

Linear Dynamic Procedure
- Still the same problems, except accounts for higher mode effects

Nonlinear Static Procedure (Pushover)
- Problems with higher mode effects
- Does not detect dynamic redistribution problems such as shear force amplification in wall structures
- Does not capture collapse potential

Nonlinear Response History Analysis
- Addresses most of the issues, BUT needs performance criteria and good judgment in component modeling

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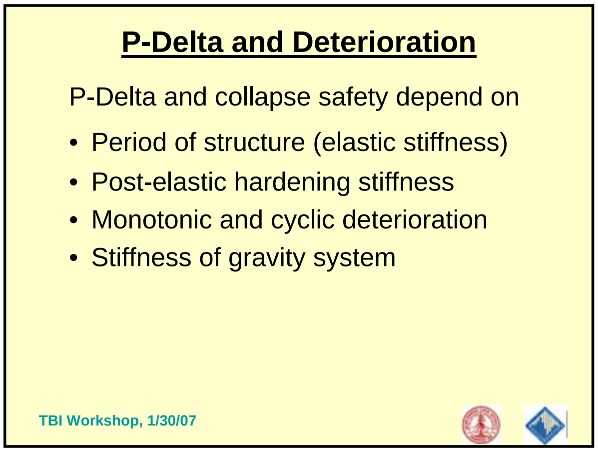

P-Delta and Deterioration

P-Delta and collapse safety depend on

- Period of structure (elastic stiffness)
- Post-elastic hardening stiffness
- Monotonic and cyclic deterioration
- Stiffness of gravity system

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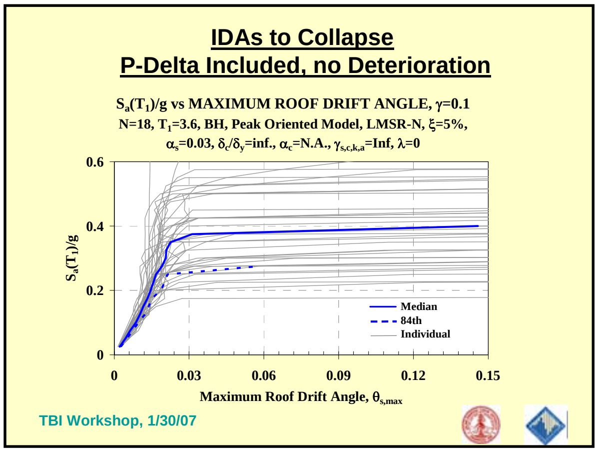

IDAs to Collapse
P-Delta Included, no Deterioration

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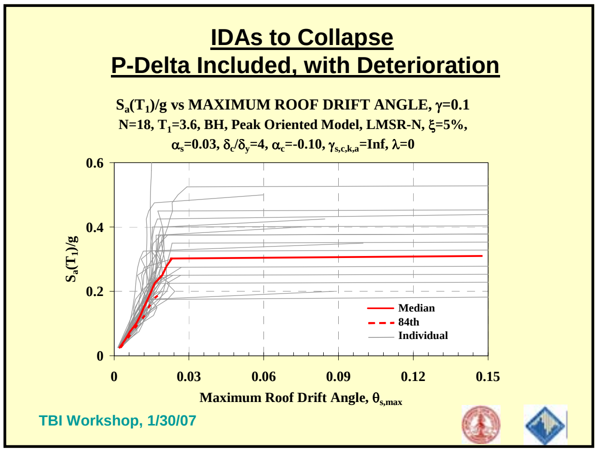

IDAs to Collapse
P-Delta Included, with Deterioration

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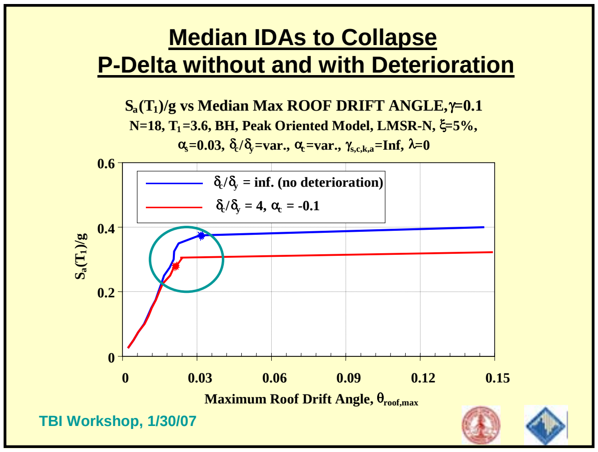

Median IDAs to Collapse
P-Delta without and with Deterioration

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Dynamic Amplification

- Strong column criteria
- Amplification of story shear forces and moments in shear walls
- Amplification of axial forces (due to OTM amplification)
- Dynamic floor diaphragm forces

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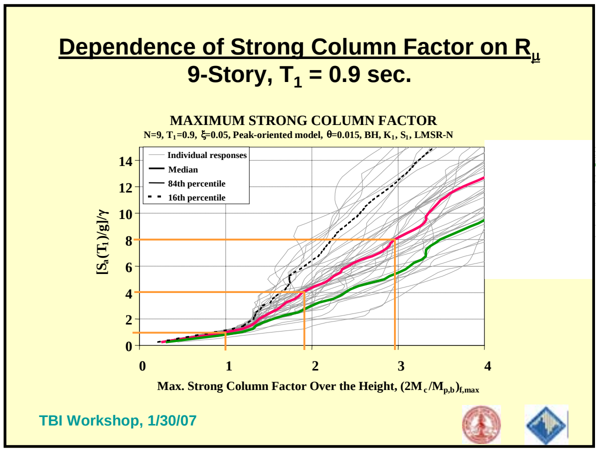

Dependence of Strong Column Factor on R_μ
9-Story, T_1 = 0.9 sec.

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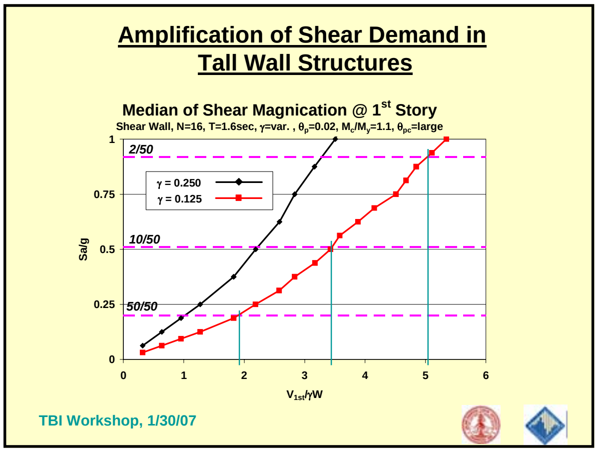

Amplification of Shear Demand in Tall Wall Structures

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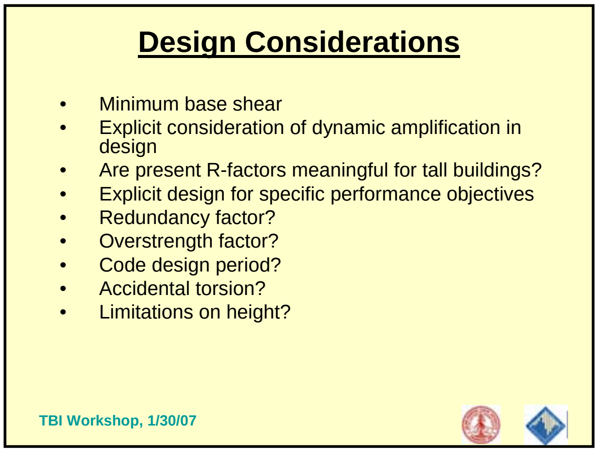

Design Considerations

- Minimum base shear
- Explicit consideration of dynamic amplification in design
- Are present R-factors meaningful for tall buildings?
- Explicit design for specific performance objectives
- Redundancy factor?
- Overstrength factor?
- Code design period?
- Accidental torsion?
- Limitations on height?

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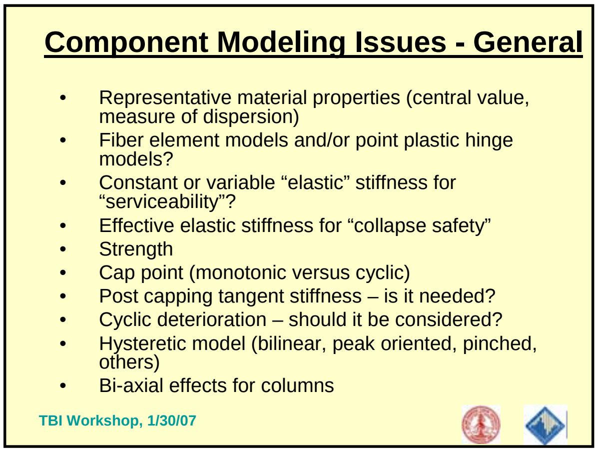

Component Modeling Issues - General

- Representative material properties (central value, measure of dispersion)
- Fiber element models and/or point plastic hinge models?
- Constant or variable “elastic” stiffness for “serviceability”?
- Effective elastic stiffness for “collapse safety”
- Strength
- Cap point (monotonic versus cyclic)
- Post capping tangent stiffness – is it needed?
- Cyclic deterioration – should it be considered?
- Hysteretic model (bilinear, peak oriented, pinched, others)
- Bi-axial effects for columns

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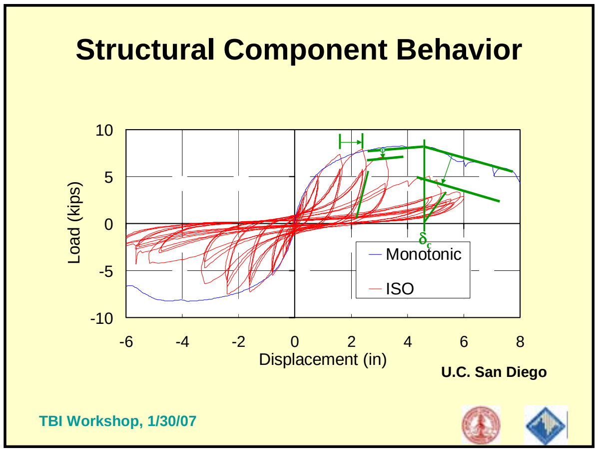

Structural Component Behavior

U.C. San Diego

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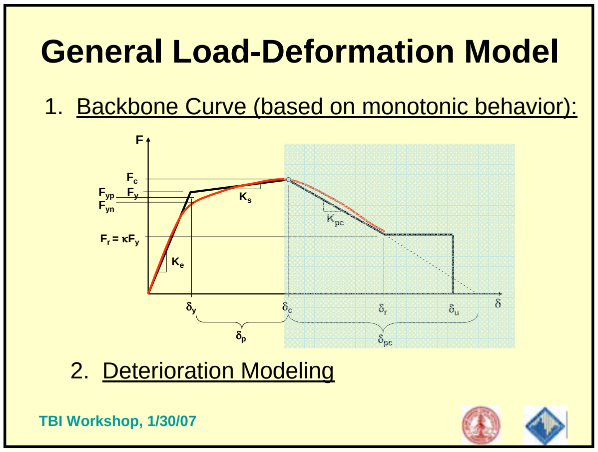

General Load-Deformation Model

1. Backbone Curve (based on monotonic behavior):

2. Deterioration Modeling

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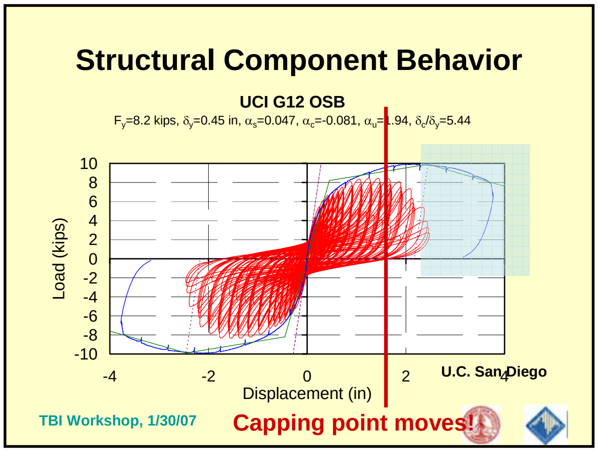

Structural Component Behavior

UCI G12 OSB

F_y=8.2 kips, δ_y=0.45 in, α_s=0.047, α_c=-0.081, α_u=1.94, δ_c/δ_y=5.44

U.C. San Diego

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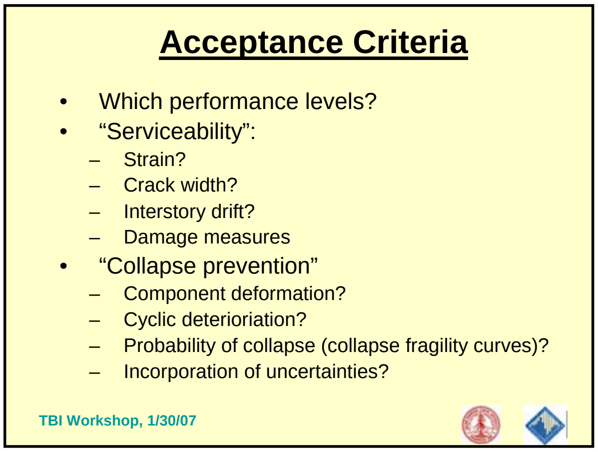
Capping point moves!



Acceptance Criteria

- Which performance levels?
- “Serviceability”:
  - Strain?
  - Crack width?
  - Interstory drift?
  - Damage measures
- “Collapse prevention”
  - Component deformation?
  - Cyclic deterioriation?
  - Probability of collapse (collapse fragility curves)?
  - Incorporation of uncertainties?

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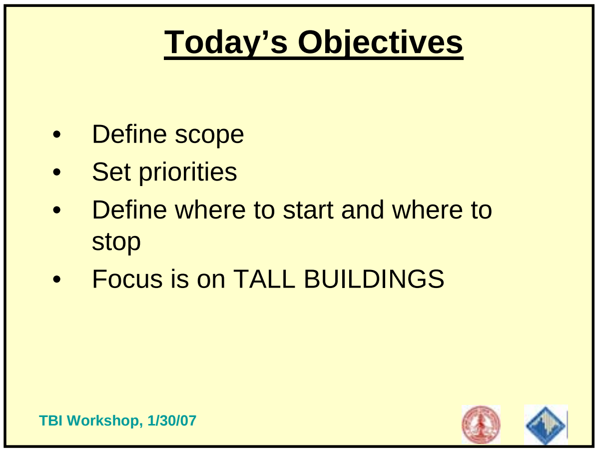

Today's Objectives

- Define scope
- Set priorities
- Define where to start and where to stop
- Focus is on TALL BUILDINGS

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Element/System Modeling - Walls

John Wallace

University of California, Los Angeles

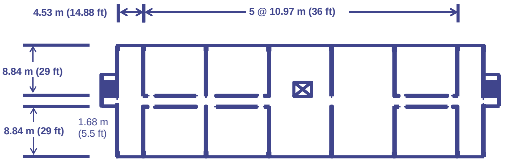
PEER Center – Tall Buildings Workshop
January 30, 2007

Issues, Walls

- Effective (cracked) linear stiffness
  - DBE, MCE, ACI-318, Flange contribution
  - Influence of concrete in tension
- Detailing
  - Core confinement requirements (excessive)
  - Variable Req'ts (e.g., bar size, strain demand)
  - Outside of the "hinge" zone (higher modes)
- Shear - openings, demand variation
- Hybrid walls: R-value (always 5.5)

Stiffness – SMIP Data

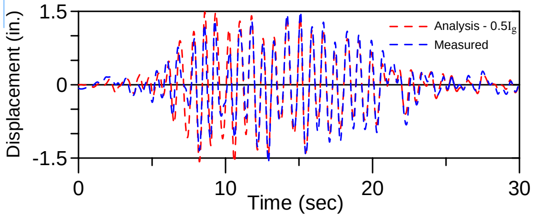
- Ten Story Building in San Jose, California
- Instrumented: Base, 6th Floor, and Roof
- Moderate Intensity Ground Motions – Loma Prieta



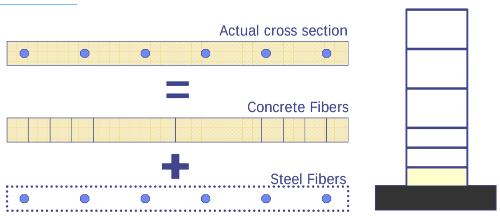
PLAN VIEW: CSMIP BUILDING 57356

Response Correlation Studies

- Ten Story Building in San Jose, California
- Roof longitudinal response – Loma Prieta
- $0.5I_g$ including soil springs (modest)



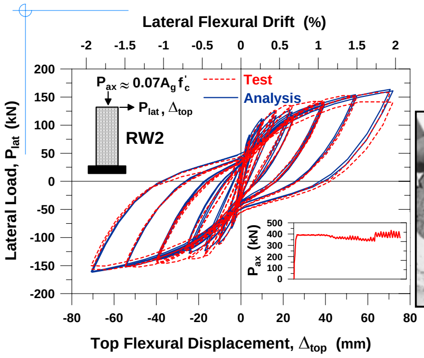
Fiber Section Model



- Typically use a more refined mesh where yielding is anticipated; however,
- Nonlinear strains tend to concentrate in a single element, thus, typically use an element length that is approximately equal to the plastic hinge length (e.g., $0.5l_w$). Might need to calibrate them first (this is essential).
- Calibration of fiber model with test results, or at least a plastic hinge model, is needed to impose a "reality" check on the element size and integration points used.

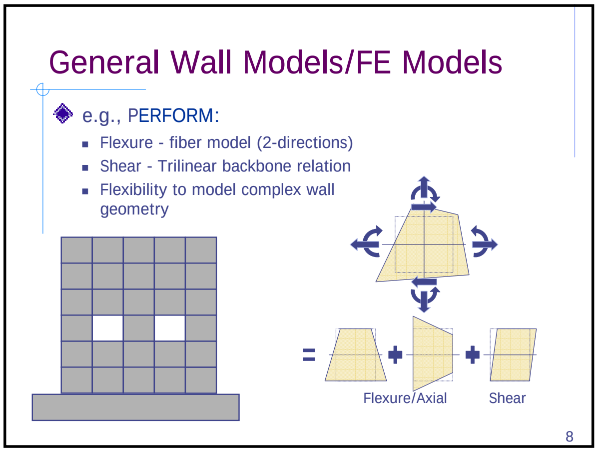
Model Assessment – RW2

Fiber model – material stress vs strain



Stiffness: $0.5EI_g$

Core/Flanged Walls

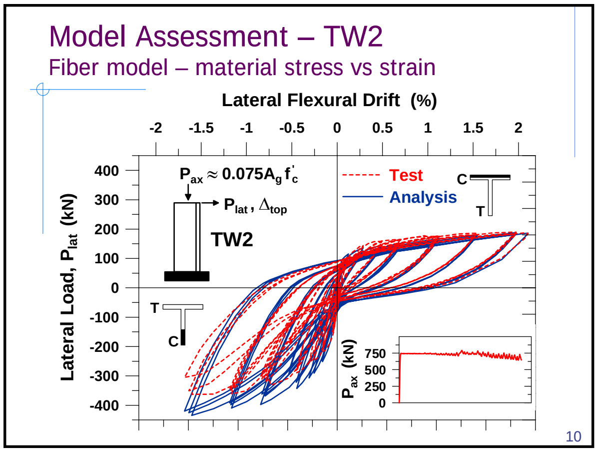


General Wall Models/FE Models

- e.g., PERFORM:
  - Flexure - fiber model (2-directions)
  - Shear - Trilinear backbone relation
  - Flexibility to model complex wall geometry

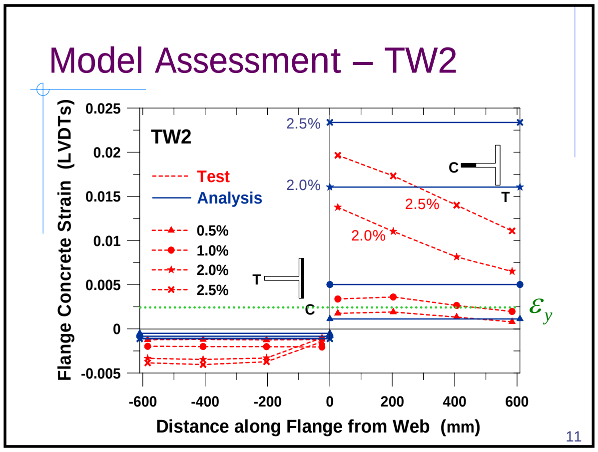
Experimental Results: 4" thick

Thomsen & Wallace, ASCE JSE, April 2004.
Displacement-based design of T-shape

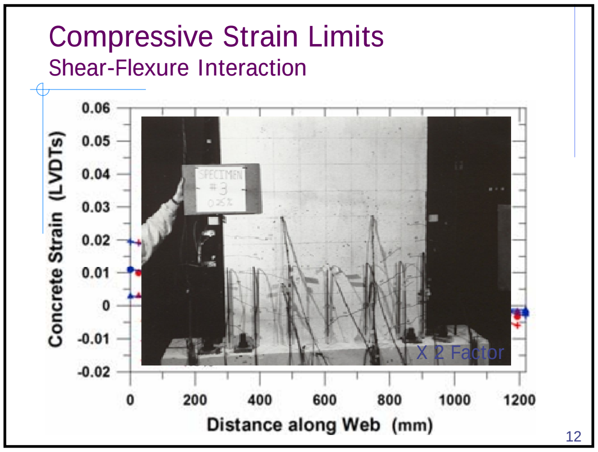


Model Assessment – TW2

Fiber model – material stress vs strain



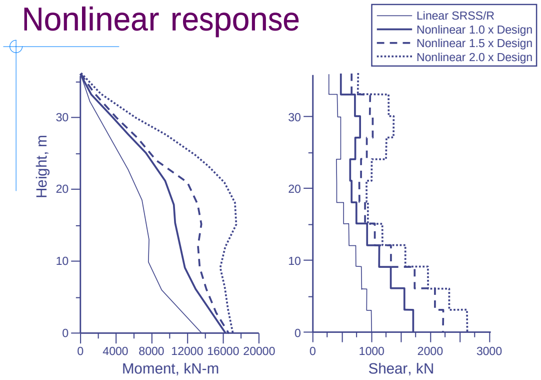
Model Assessment – TW2



Compressive Strain Limits

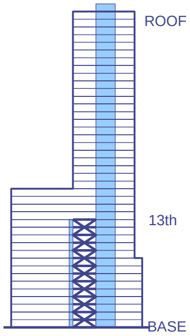
Shear-Flexure Interaction

Nonlinear response



after Priestley and Amaris, 2003

Design values?



(a) Building elevation

	Roof drift, ft	Wall base shear, k	Wall moment at 13th floor, 1000 x k-ft
Minimum	2.1	7600	513
Maximum	6.7	29700	1080
Mean (m)	4.2	15500	900
m + σ	5.4	22200	1090
c.o.v.	0.23	0.43	0.21
Nonlinear static		5500	760

(b) Summary of results

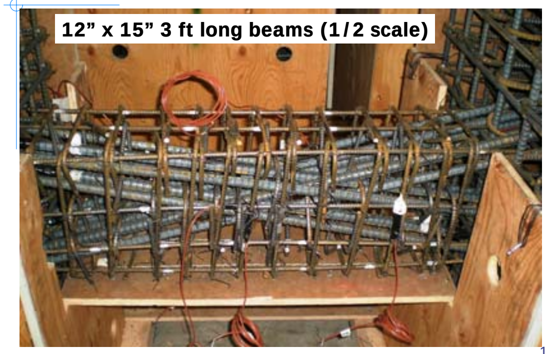
Link Beams

Link Beams

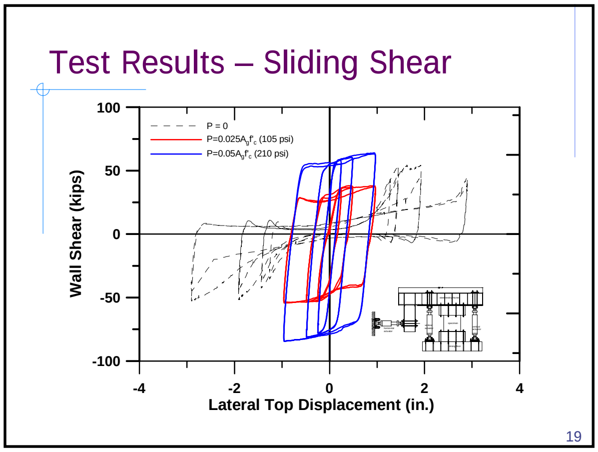
Issues, Continued

- Link beams
  - Calibration of models (Stiff/Strength/Detail)
  - Steel encased design and detailing
  - New ACI 318-08 detailing requirements
  - Impact of post-tensioning on strength
  - Testing – relatively small scale beams
- Slab-column connections
  - Punching

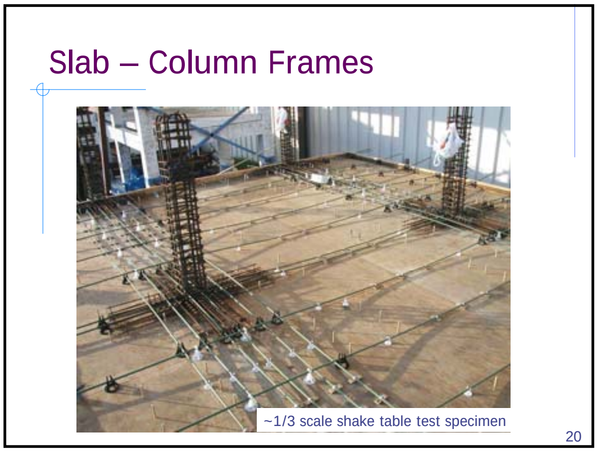
Upcoming Tests: 318-08 Details



12” x 15” 3 ft long beams (1/2 scale)

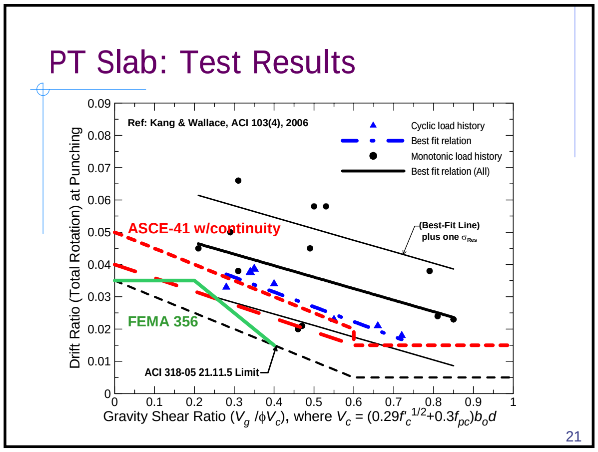


Test Results – Sliding Shear

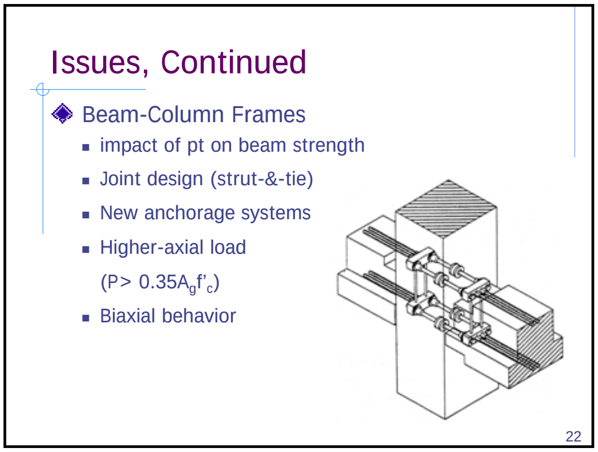


Slab – Column Frames

~1/3 scale shake table test specimen



PT Slab: Test Results



Issues, Continued

- Beam-Column Frames
  - impact of pt on beam strength
  - Joint design (strut-&-tie)
  - New anchorage systems
  - Higher-axial load (P> 0.35A$_g$f'$_c$)
  - Biaxial behavior

Advance Workshop Input

Other Issues

Jon A. Heintz

Applied Technology Council

Advance Feedback

- More than 100 written comments
- More than 500 individual issues
- Categories
  - – Integration with Performance Objectives
  - – Foundation modeling
  - – Capacity Design
  - – Base Load Transfers
  - – General Structural Issues
  - – Element/System Modeling

Advance Feedback

- “Other”

Other Input

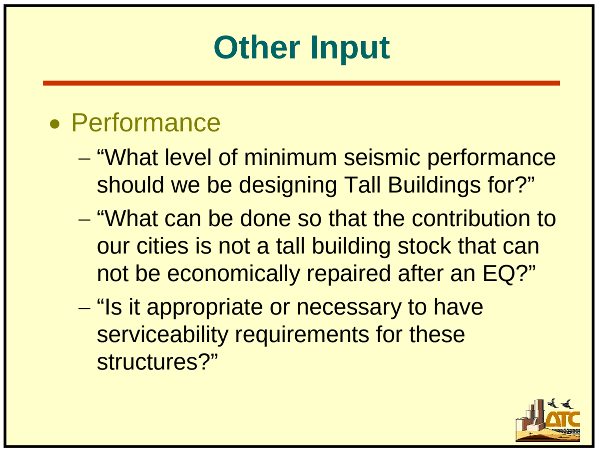
- General comments
  - – “There are probably an infinite number of technical questions that could be asked…”
  - – “Your task list hits most of my favorites…”
  - – “I applaud the effort to assemble this research topic and bring together the different stake holders to advance the state of the art..”

Other Input

- General comments
  - – “…we have serious concerns about the particular direction and focus of Task Group 7
  - – “As a practitioner, I have some real concerns about how the information that comes out of this will be used and applied in practice….”
  - – “We must ensure that we do not raise the bar so high that only a few can jump over it…”
  - – “…we do not support an agenda that attempts to define a “how to” approach to specific systems and/or element design…”

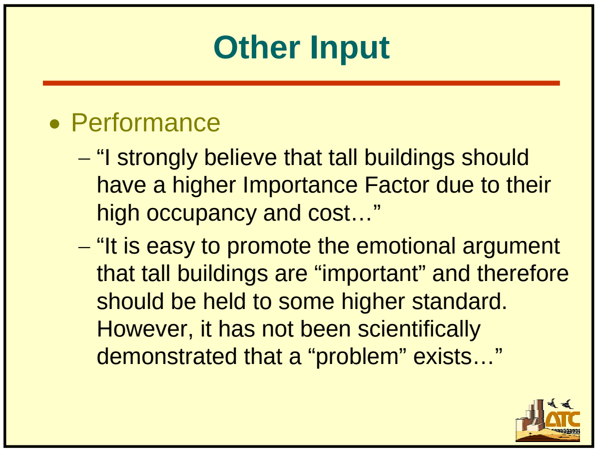
Other Input

- General comments
  - – We believe the TBI efforts should be clearly focused in four areas:
    - Define appropriate demand levels
    - Define performance expectations and consistent, quantifiable acceptance criteria
    - Provide guiding design principles (i.e., capacity design strategies)
    - Provide modeling guidelines which promote consistency in the industry



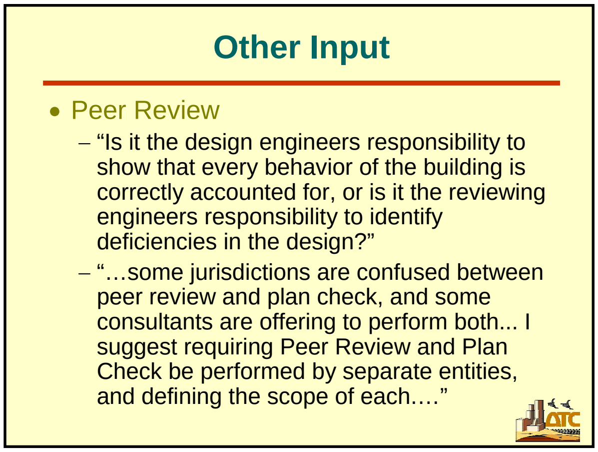
Other Input

- Performance
  - “What level of minimum seismic performance should we be designing Tall Buildings for?”
  - “What can be done so that the contribution to our cities is not a tall building stock that can not be economically repaired after an EQ?”
  - “Is it appropriate or necessary to have serviceability requirements for these structures?”



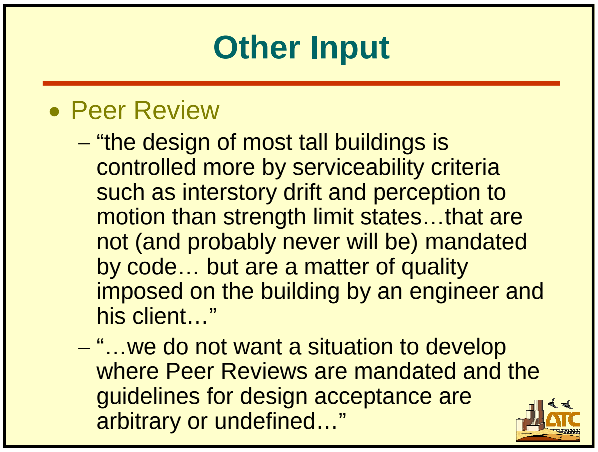
Other Input

- Performance
  - “I strongly believe that tall buildings should have a higher Importance Factor due to their high occupancy and cost…”
  - “It is easy to promote the emotional argument that tall buildings are “important” and therefore should be held to some higher standard. However, it has not been scientifically demonstrated that a “problem” exists…”



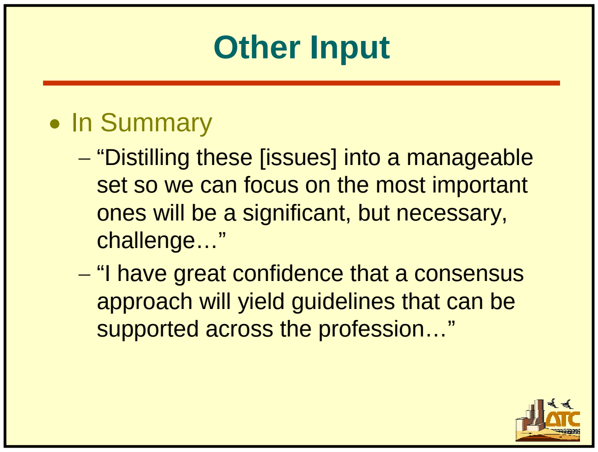
Other Input

- Peer Review
  - “Is it the design engineers responsibility to show that every behavior of the building is correctly accounted for, or is it the reviewing engineers responsibility to identify deficiencies in the design?”
  - “…some jurisdictions are confused between peer review and plan check, and some consultants are offering to perform both... I suggest requiring Peer Review and Plan Check be performed by separate entities, and defining the scope of each.…”



Other Input

- Peer Review
  - “the design of most tall buildings is controlled more by serviceability criteria such as interstory drift and perception to motion than strength limit states…that are not (and probably never will be) mandated by code… but are a matter of quality imposed on the building by an engineer and his client…”
  - “…we do not want a situation to develop where Peer Reviews are mandated and the guidelines for design acceptance are arbitrary or undefined…”



Other Input

- In Summary
  - “Distilling these [issues] into a manageable set so we can focus on the most important ones will be a significant, but necessary, challenge…”
  - “I have great confidence that a consensus approach will yield guidelines that can be supported across the profession…”

Applied Technology Council Projects and Report Information

One of the primary purposes of the 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 ATC project reports often 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.
    1. 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 Building and Other Structures*. 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 Dwelling*s, 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*, *Second Edition*, was funded by Applied Technology Council. Available through the ATC office (Published 2004, 143 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. The Second Edition has been updated to include improved versions of the posting placards and evaluation forms, as well as more detailed information on steel moment-frame buildings, mobile homes, and manufactured housing. It also includes new information on barricading and provides a list of internet resources pertaining to postearthquake safety evaluation.

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 first edition of 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 Second Edition,* was developed under a contract with FEMA. Available through the ATC office. (Published 2004, 148 pages and PowerPoint presentation on companion CD)

ABSTRACT: This training manual and CD is intended to facilitate the presentation of the contents of the FEMA 154 report (*Second Edition*). The training materials consist of 120 slides in PowerPoint™ format and a companion training presentation narrative coordinated with the presentation. 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. (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; revised and published as ASCE 31-03, a standard of the American Society of Civil Engineers, in 2003). Available through ASCE, Reston, Virginia.

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. (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 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-29-2: The report, *Proceedings of Seminar on Seismic Design, Performance, and Retrofit of Nonstructural Components in Critical Facilities*, was developed under a grant from MCEER and NSF. Available through the ATC office. (Published 2003, 574 pages)

ABSTRACT: These Proceedings contain 43 papers presented at a seminar in Newport Beach, California, in 2003. The purpose of the Seminar was to present state-of-the-art technical information pertaining to the seismic design, performance, and retrofit of nonstructural components in critical facilities (e.g., computer centers, hospitals, manufacturing plants with especially hazardous materials, and museums with fragile/valuable collection items). The technical papers address the following topics: current practices and emerging codes; seismic design and retrofit; risk and performance evaluation; system qualification and testing; and advanced technologies.

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 then-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. (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; new linear static and nonlinear static analysis 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 OES 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 ATC and by calling FEMA: 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 ATC and by calling FEMA: 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 ATC and by calling FEMA: 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 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 ATC and by calling 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 ATC and by calling 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 ATC and by calling 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 ATC and by calling FEMA: 1-800-480-2520)

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

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

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

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

FEMA-355D, *State of the Art Report on Connection Performance*. (Published 2000, 292 pages; available on CD-ROM through ATC and by calling FEMA: 1-800-480-2520. Printed version also available through ATC).

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

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

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-45: The *Field Manual*, *Safety Evaluation of Buildings After Wind Storms and Floods* was developed with funding from ATC, the ATC Endowment Fund, and the Institute for Business and Home Safety (Published 2004, 132 pages).

ABSTRACT: The Field Manual provides guidelines and procedures to determine whether damaged or potentially damaged buildings are safe for use after wind storms or floods, or if entry should be restricted or prohibited. Formatted as an easy-to-use pocket guide, the Manual is intended to be used by structural engineers, building inspectors, and others involved in postdisaster building safety assessments. Advice is provided on evaluating structural, geotechnical, and nonstructural risks. Also included are procedures for Rapid Safety Evaluation, procedures for Detailed Safety Evaluation, information on how to deal with owners and occupants of damaged buildings, information on field safety for those making damage assessments, and example applications of the procedures.

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-49: The 2-volume report, *Recommended LRFD Guidelines for the Seismic Design of Highway Bridges; Part I: Specifications* and *Part II: Commentary and Appendices*, were developed under the ATC/MCEER Joint Venture partnership with funding from the Federal Highway Administration (Published 2003, *Part I*, 164 pages and *Part II*, 294 pages)

ABSTRACT: The Recommended Guidelines are based on significant enhancements in the state of knowledge and state of practice resulting from research investigations and lessons learned from earthquakes over the last 15 years. The Guidelines consist of specifications, commentary, and appendices developed to be compatible with the existing load-and-resistance-factor design (LRFD) provisions for highway bridges published by the American Association of State Highway and Transportation Officials (AASHTO). The new, updated, provisions are nationally applicable and cover all seismic zones, as well as all bridge construction types and materials. They reflect the latest design philosophies and design approaches that will result in highway bridges with a high level of seismic performance.

ATC-49-1: The document, *Liquefaction Study Report, Recommended LRFD Guidelines for the Seismic Design of Highway Bridges,* was developed under the ATC/MCEER Joint Venture partnership with funding from the Federal Highway Administration (Published 2003, 208 pages)

ABSTRACT: This report documents a comprehensive study of the effects of liquefaction and the associated hazards — lateral spreading and flow. It contains detailed discussions on: (1) recommended procedures to evaluate liquefaction potential and lateral spread effects; (2) ground mitigation design approaches and procedures to evaluate the beneficial effects of pile pinning in straining lateral spread; (3) study results from two bridge sites (one in the western U. S. and one in the central U. S.) that provide an assessment of liquefaction effects based on several types of analyses; an assessment of implications of predicted lateral spread/flow using a pushover-type analysis; and development and evaluation of structural and/or geotechnical mitigation alternatives; and (4) study conclusions, including cost implications.

ATC-49-2: The report, *Design Examples, Recommended LRFD Guidelines for the Seismic Design of Highway Bridges*, was developed under the ATC/MCEER Joint Venture partnership with funding from the Federal Highway Administration (Published 2003, 316 pages)

> ABSTRACT: The report contains two design examples that illustrate use of the *Recommended LRFD Guidelines for the Seismic Design of Highway Bridges*. These design examples are the eighth and ninth in a series originally developed for the Federal Highway Administration (FHWA) to illustrate the use of the American Association of State Highway and Transportation Officials (AASHTO) Division 1-A Standard Specifications for Highway Bridges. The design examples contain flow charts and detailed step-by-step procedures, including: preliminary design; basic requirements; determination of seismic design and analysis procedure; determination of elastic seismic forces and displacements; determination of design forces; design displacements and checks; design of structural components; design of foundations; design of abutments; and consideration of liquefaction.

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 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. 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-51-2: The report, *Recommended U.S.-Italy Collaborative Guidelines for Bracing and Anchoring Nonstructural Components in Italian Hospitals*, was developed under a contract with the Department of Civil Protection, Italy. (Published 2003, 164 pages)

> ABSTRACT: The report supports one of the short-term recommendations — implement bracing and anchorage for new installations of nonstructural components — made in the first phase of the ATC-51 project. The report contains: (1) technical background information, including an overview of nonstructural component damage in prior earthquakes;(2) generalized recommendations for assessment of nonstructural components and recommended performance objectives and requirements; (3) specific recommendations pertaining to twenty-seven different types of

nonstructural components; (4) design examples that illustrate in detail how a structural engineer evaluates and designs the retrofit of a nonstructural component; (5) additional seismic design considerations for nonstructural components; and (6) guidance pertaining to the design and selection of devices for seismic anchorage.

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 that commenced 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-54: The report, *Guidelines for Using Strong-Motion Data and ShakeMaps in Postearthquake Response*, was developed under a contract with the California Geological Survey. Available through the ATC office. (Published 2005, 222 pages)

> ABSTRACT: The report addresses two main topics: (1) effective means for using computer-generated ground motion maps (ShakeMaps) in postearthquake emergency response; and (2) procedures for rapidly evaluating (on a near-real-time basis) strong-motion data from ground sites and instrumented buildings, bridges, and dams to determine the potential for earthquake-induced damage in those structures. The document also provides guidance on the form, type, and extent of data to be collected from structures in the vicinity of strong-motion recordings, and pertinent supplemental information, including guidance on replacement of strong-motion instruments in/on and near buildings, bridges, and dams.

ATC-55: The report, FEMA 440, *Improvement of Nonlinear Static Seismic Analysis Procedures*, was developed under a contract with FEMA. Available through FEMA or the ATC office. (Published 2005, 152 pages)

> ABSTRACT: The report presents the results of a four year study carried out to develop guidelines for improved application of the Coefficient Method, as detailed in the FEMA-356 *Prestandard and Commentary for the Seismic Rehabilitation of Buildings,* and the Capacity Spectrum Method, as detailed in the ATC-40 Report, *Seismic Evaluation and Retrofit of Concrete Buildings*. The report also addresses improved application of nonlinear static analysis procedures in general, including new procedures for incorporating soil-structure interaction effects, and options for addressing multiple-degree-of-freedom effects. An example application of the recommended nonlinear static analysis procedures is included to illustrate use of the procedures in estimating the maximum displacement of a model building.

ATC-56: The report, FEMA 389, *Primer for Design Professionals: Communicating with Owners and Managers of New Buildings on Earthquake Risk*, was developed under a contract with FEMA. Available through FEMA or the ATC office. (Published 2004, 194 pages)

> ABSTRACT: The report has been developed to facilitate the process of educating building owners and managers about seismic risk management tools that can be effectively and economically employed by them during the building development phase—from site selection through design and construction—as well as the operational phase. Written principally for design professionals (architects

and structural engineers), the document introduces and discusses (1) seismic risk management and the means to develop a risk management plan; (2) guidance for identifying and assessing earthquake-related hazards during the site selection process; (3) emerging concepts in performance-based seismic design; and (4) seismic design and performance issues related to six specific building occupancies—commercial office facilities, commercial retail facilities, light manufacturing facilities, healthcare facilities, local schools (kindergarten through grade 12), and higher education facilities (universities).

ATC-56-1: The report, FEMA 427, *Primer for Design of Commercial Buildings to Mitigate Terrorist Attacks – Providing Protection to People and Buildings*, was developed under a contract with FEMA. Available through FEMA or the ATC office. (Published 2003, 106 pages)

> ABSTRACT: The report provides guidance to building designers, owners and state and local governments to mitigate the effects of hazards resulting from terrorist attacks on new buildings. While the guidance provided focuses principally on explosive attacks and design strategies to mitigate the effects of explosions, the document also addresses design strategies to mitigate the effects of chemical, biological and radiological attacks. Qualitative discussions are provided on the following topics: terrorist threats; weapons effects, building damage, design approach, design guidance, occupancy types, and cost considerations.

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-58: This project, *Development of Next-Generation Performance-Based Seismic Design Guidelines for New and Existing Buildings*, is a multi-year, multi-phase effort funded by FEMA. Reports prepared under this project include:

> FEMA 445, *Next-Generation Performance-Based Seismic Design Guidelines, Program Plan for New and Existing Buildings*. (Published 2006, 131 pages, available through FEMA or the ATC office). This Program Plan offers background on current code design procedures, introduces performance-based seismic design concepts, identifies improvements needed in current seismic design practice, and outlines the tasks and projected costs for a two-phase program to develop next-generation performance-based seismic design procedures and guidelines.

> FEMA 461, *Interim Testing Protocols for Determining the Seismic Performance Characteristics of Structural and Nonstructural Components* (Published 2007, 113 pages, available through FEMA or the ATC office). Two interim protocol types are provided in this document: Interim Protocol I, Quasi-Static Cyclic Testing, which should be used for the determination of performance characteristics of components whose behavior is primarily controlled by the application of seismic forces or seismic-induced displacements; and Interim Protocol II, Shake Table Testing, which should be used to assess performance characteristics of components whose behavior is affected by the dynamic response of the component itself, or whose behavior is velocity sensitive, or sensitive to strain-rate effects.

ATC-60: The 2-volume report, *SEAW Commentary on Wind Code Provisions, Volume 1* and *Volume 2 - Example Problems,* was developed by the Structural Engineers Association of Washington (SEAW) and edited and published by the Applied Technology Council. (ATC). Available through the ATC office. (Published 2004; *Volume 1*, 238 pages; *Volume 2*, 245 pages)

> ABSTRACT: Written for designers, building code officials, instructors and anyone who designs and/or analyzes structures for wind, this report provides commentary on the wind provisions in the 2000 and 2003 editions of

the *International Building Code* (IBC), and the 1998 and 2002 editions of ASCE Standard No. 7, *Minimum Design Loads for Buildings and Other Structures*. Volume 1 contains the main body of the commentary, including a technical and historic overview of wind codes and discussions on a broad range of topics: basic wind speed; importance factors; exposure and topographic effects; gust response; design for wind pressures on main wind-force-resisting systems; wind pressures on components and cladding of structures; glass and glazing; prescriptive provisions; miscellaneous and non-building structures; unusual wind loading configurations; high winds, hurricanes, and tornadoes; serviceability; wind tunnel tests applied to design practice; and wind design of equipment and non-building systems. Volume 2 consists of appendices containing over a dozen example problems with solutions.

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 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 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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