PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

Seismic Performance Objectives for Tall Buildings

A Report for the Tall Buildings Initiatve

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ABSTRACT

The Pacific Earthquake Engineering Research Center is leading an initiative to develop guidelines for new high-rise construction that will meet intended safety and performance objectives following future earthquakes, particularly when alternative means of design are employed. An initial task of this initiative was to investigate the issues associated with identifying seismic performance equivalent to that achieved by code and whether a higher seismic performance should be targeted for these buildings. Many stakeholders were interviewed for this purpose, and a workshop was convened to discuss the results and to establish a direction for the technical design portions of the overall initiative. The investigation found that the establishment of a higher seismic performance objective for certain buildings was a public-policy issue that should not be decided by engineering studies, but also that many owners, tenants, and other stakeholders did not understand standard code building-performance objectives and thought that even a small chance of collapse was unacceptable for any building. Many thought that even building closure due to damage should not be expected or tolerated and that seismic risk should be disclosed to owners and tenants in an understandable format.

It is recommended that procedures to predict collapse (or to prevent collapse) be improved, that risks from cladding in tall buildings be investigated, and that the Tall Buildings Initiative cooperate with multidisciplinary efforts to minimize risks from egress and ingress characteristics of tall buildings.

ACKNOWLEDGMENTS

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Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect those of the National Science Foundation.

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FOREWORD

by

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Several West Coast cities in the U.S. are seeing a resurgence in the construction of high-rise buildings that involve a variety of configurations, innovative structural systems, and high-performance materials. To meet architectural requirements and achieve construction economy, many of these designs do not follow the prescriptive building code provisions but instead use the alternative design clause of the building code. Currently there is no industry standard for these alternative designs, requiring early adopters to experiment while designs are progressing, resulting in scheduling and cost uncertainties. Recognizing this urgent situation, several organizations and leading engineers have joined together with the Pacific Earthquake Engineering Research (PEER) Center to form the Tall Buildings Initiative. This initiative will develop a consensus on performance objectives, ground motion selection and modification procedures, modeling procedures, acceptance criteria, and, ultimately, seismic design guidelines suitable for adoption by building codes and local jurisdictions (Moehle et al. 2007)[1].

Currently the Tall Buildings Initiative has several active tasks ranging from ground motion issues for nonlinear structural analysis of tall buildings to computer modeling of components and systems, and to development of seismic design guidelines for tall buildings. A series of reports on various tasks will be published by PEER and other participating organizations.

One of the fundamental tasks in the Tall Buildings Initiative is the Seismic Performance Objectives for Tall Buildings. William Holmes has been the leader of this task, with the support of a group of researchers and practitioners. The scope of this task has been to investigate the issues related to the seismic performance objectives of tall buildings, and whether a higher seismic performance should be targeted for these buildings as compared with that implied by the prescriptive provisions of the seismic code. The current report is the final report for this task by Holmes et al. Currently PEER is organizing other tasks under the Tall Buildings Initiative to

[1] Moehle, J. P., Y. Bozorgnia, and T. Yang. The Tall Buildings Initiative, *Proceedings of the 2007 Convention of the Structural Engineers Association of California*, September 26–29, 2007, Lake Tahoe, California.

follow up Holmes's study to quantify some qualitative findings of this report. The extensive efforts and the cooperation of Bill Holmes and his group for successful completion of this task of the Tall Buildings Initiative are gratefully appreciated.

1 Background and Purpose

Economic and demographic trends in major West Coast cities in the last decade have created demands for middle- to high-cost housing near city centers. High-rise concrete condominium structures appeared to best suit this demand and, starting in the Northwest, the preferred structural system evolved to be a concrete core with minimal perimeter beams. Although seismic design regulations of building codes require a moment-frame structural system to be incorporated in taller structures (160 ft or 240 ft depending on conditions), systems without the girders required in moment frames were preferred by developers because lower floor-to-floor heights and floor to ceiling windows were possible at equal or lower construction cost. Such systems were developed and approvals obtained from local jurisdictions under the "Alternate Materials and Methods of Construction" (called Alternative Means in this report) provisions of the International Building Code (IBC), which is commonly used in the U.S. This code allows any rational seismic design if it is demonstrated to be at least equal in seismic resistance to that required by code. The IBC states:

> 104.11 Alternative materials, design and methods of construction and equipment. The provisions of this code are not intended to prevent the installation of any material or to prohibit any design or method of construction not specifically prescribed by this code, provided that any such alternative has been approved. An alternative material, design or method of construction shall be approved where the building official finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in quality, strength, effectiveness, fire resistance, durability and safety. (ICC 2006).

The approval requirements and process for these alternative designs have not been well developed, so issues were identified regarding code-equivalent seismic performance and the methods of demonstrating such equivalence. Although buildings have been designed and constructed that employed alternative design methods using approval methods based primarily on a peer review process, no systematic study of performance-based design as applied to tall buildings exists. The Pacific Earthquake Engineering Research Center is responding to this void by leading an initiative to develop design guidelines that will lead to safe and usable tall buildings following future earthquakes.

The specific tasks of this initiative are:

Task 1 Establish and Operate the Tall Buildings Project Advisory Committee (T-PAC)

Task 2 Develop consensus on performance objectives

Task 3 Conduct baseline assessment of dynamic response characteristics of tall buildings

Task 4 Create synthetically generated ground motions

Task 5 Review and validate synthetically generated ground motions

Task 6 Develop guidelines on selection and modification of ground motions

Task 7 Develop guidelines on modeling and acceptance values

Task 8 Generate input ground motions for tall buildings with subterranean levels

Task 9 Increase presentations at conferences, workshops, and seminars

Task 10 Develop document Performance-Based Seismic Design Guidelines for Tall Buildings

This report documents Task 2 of this program, which is intended to develop consensus on performance objectives for tall buildings. In order to design without certain prescriptive code limitations, whether intended to satisfy the alternative design requirements of the code or to generally improve the design, various forms of performance-based design techniques have been employed. The extent to which performance-based design is used is dependent on the specific prescriptive requirements that are not met, and the acceptance process of the approval authority. Generally, the requirements for approval are worked out in advance of submittal. The basis of the performance-based designs, when used, is the establishment of a performance objective consisting of design ground motion and a performance level. Equivalence to the code for alternative designs can then be shown by designing to meet the code performance objective. However, the performance objective of the code has never been formally established using engineering parameters and is open for individual interpretation. In addition, the recent focus of performance-based designs for qualification as alternative design methodologies has been on whether tall buildings should be considered as "normal" buildings or as buildings expected to have superior seismic performance, like schools, high-occupancy buildings, fire stations, or even hospitals. Task 2 is intended to clarify these issues as a basis for the balance of the tasks of the Tall Buildings Initiative.

The initial task description was as follows:

> Using an appropriate methodology, develop a consensus on performance objectives. Document methodology and performance objectives in a final report. Considered performance objectives should include serviceability and safety margin. Deliberations should include conventional performance objectives and alternative ways of expressing objectives. Alternative performance considerations may include reparability and re-occupancy. Final objectives should clearly define confidence levels associated with objectives. Some analysis of socio-economic impacts associated with tall building performance should be considered.

As documented in this report, the task group determined during the study that a "consensus performance objective," considering the breadth of stakeholders involved, could not be developed within this project. In addition, whether tall buildings should perform better than normal code buildings, and if so, how much better, is either a model code issue, to be debated on a national stage, or a local public-policy issue that could vary from city to city. Therefore, Task 2 was not concluded with the specificity suggested by the initial task description, and nothing in this report can be considered a consensus minimum standard of practice. However, significant input from representative stakeholders was obtained concerning seismic performance of tall buildings, and this information will be documented in this report. In response to this input, this report contains recommendations to the Tall Buildings Initiative regarding seismic performance issues.

2 Work Plan

As discussed in Chapter 1, the products of Task 2 were refined to be more pragmatic. Similarly, the original work plan was adapted to respond to input received during the task. However, the main subtasks of the work plan remained as originally formulated, as described below.

2.1 FORM CORE GROUP

The Core Group will formulate the activities in more detail and implement the work plan. The original Core Group consisted of the following members:

William T. Holmes, Structural Engineer, Rutherford & Chekene, Task Leader

Charles Kircher, Kircher and Associates

Laurence Kornfield, Chief Building Inspector, City of San Francisco

William Petak, Professor Emeritus, School of Policy Planning and Development, USC

Nabih Youssef, Structural Engineer, Nabih Youssef Associates

Karl Telleen, Staff Engineer, Rutherford & Chekene, who assisted the Task Leader and the Core Group

Mr. Kornfield, who retired from the Core Group because of reassignment of duties by the City and County of San Francisco

2.2 DEVELOP BACKGROUND ON EXPECTED SEISMIC PERFORMANCE OF CODE-DESIGNED BUILDINGS

A short primer on the development of building codes and seismic performance expectations is needed as background material for stakeholders prior to being interviewed by the Core Group. A more detailed review of this type of information will also be useful at the planned workshop. In order to discuss with stakeholders the adequacy of “normal” building design criteria for tall buildings, or the need for a superior design criterion, they must first understand the range of performance that could be possible for normal buildings.

Finally, a description of code seismic performance in engineering terms is needed for use in the performance-based design procedures used to show code-equivalence in designs using the alternative means of compliance provisions in the code.

2.3 OBTAIN INPUT REGARDING SEISMIC PERFORMANCE OF TALL BUILDINGS FROM SELECTED STAKEHOLDERS

Stakeholders in the determination of appropriate seismic performance for tall buildings, in addition to the designers themselves, include owners, tenants, neighbors, financial institutions, insurers, city governments and planners, community advocates, and many others. It is not practical to get formal input from these groups, but a sampling of input can be obtained by interviewing members of the various stakeholder groups. A standard interview procedure should be developed to obtain consistent and comparable input. Background material on current practice and performance expectation should be provided to stakeholders prior to the interview.

2.4 HOLD WORKSHOP TO DISCUSS AND CONSOLIDATE INTERVIEW MATERIAL

In the past, workshops to establish "acceptable seismic risk" or other seismic performance standards have had limited success largely because the topics of discussion were unfocused and open ended. Given specific input from stakeholders through the interview process, a workshop will be useful to expose and potentially resolve conflicts and to facilitate discussion between the stakeholder and the engineering community.

2.5 SYNTHESIZE INPUT TO FORMULATE CONCLUSIONS AND RECOMMENDATIONS REGARDING SEISMIC PERFORMANCE OF TALL BUILDINGS

Based on the input from the interviews, the workshop, and general knowledge of research and professional practice in the seismic design of tall buildings, recommendations will be made to the Tall Buildings Initiative regarding seismic performance of tall buildings.

3 Findings

The findings of this study include documentation of the expected seismic performance of code-designed buildings, the input received from interviews of stakeholders, and the opinions concerning seismic performance of tall buildings reached by consensus of the workshop participants.

3.1 EXPECTED SEISMIC PERFORMANCE OF CODE-DESIGNED BUILDINGS

3.1.1 Background of Building Codes and Seismic Provisions

A devastating fire in London in 1666 resulted in the first comprehensive building code enforced by government. Its purpose (performance intent) was clearly and narrowly framed to prevent another such disaster. Government control of design and construction (primarily of buildings) gradually spread throughout the world largely based on the London precedent. However, each country has its own, often unique, history and legal authorization for building code development and implementation (Meacham 2004).

In the U.S., an important principle of the Constitution, resulting from the original compromises concerning federal and state control of government, is the delegation of police power to the states. Police power is the authority to regulate for the health, the safety, and the general welfare of citizens. Building codes have always been interpreted as falling under the police power of the states, which is why the federal government does not promulgate building codes. Although the exact wording has varied between model codes, a typical statement of purpose in U.S. building codes is as shown below:

> The purpose of this code is to provide minimum standards to safeguard life or limb, health, property, and public welfare by regulating and controlling the design, construction, quality of materials, use and occupancy, location and maintenance of all buildings and structures...

The development of seismic codes in general has also been in reaction to catastrophic events, beginning after a 1755 earthquake destroyed much of Lisbon, after which prescriptive rules for construction of the most common building type (gaiola construction) were promulgated. Earthquakes in Messina, Italy (1911), and Tokyo, Japan (1923), resulted in the development of more technical guidelines that included the design of buildings for lateral forces of about 10% of the building weight. These developments were no more sophisticated than attempts to minimize the death and destruction observed in these events in future earthquakes.

In the U.S., earthquakes in the San Francisco Bay Area (1868, 1906), Charleston, South Carolina (1886), Santa Barbara (1925), and Long Beach (1933) all featured massive falls of masonry walls onto the streets and in many cases complete collapses of buildings. The intent of early U.S. codes clearly was to prevent such life-threatening and destructive failures in earthquakes. The size or frequency of the events was not considered, partially because determination of these parameters was not generally possible, but also because it did not matter to the code proponents—the serious damage was to be avoided in any case. The first code provisions in the U.S. appeared as a voluntary appendix (the Lateral Bracing Appendix) in the 1927 Uniform Building Code and contained the following introduction:

> The design of buildings for earthquake shocks is a moot question but the following provisions will provide adequate additional strength when applied to the design of buildings or structures (PCBOC 1928, p. 218).

3.1.2 SEAOC Blue Book

The 1933 Long Beach earthquake resulted in strict seismic design for schools in California (the Field Act) and began mandatory seismic design for all buildings in California (the Riley Act). These laws and the continuing occurrence of earthquakes in California generated continuous code development activity, primarily by the Structural Engineers Association of California (SEAOC), culminating with the publication of the *Recommended Lateral Force Requirements and Commentary* (the "Blue Book") in 1960 that contained a relatively clear performance objective:

The SEAOC recommendations are intended to provide criteria to fulfill the purposes of building codes generally. More specifically with regard to earthquakes, structures designed in conformance with the provisions and principles set forth therein should be able to:

1. Resist minor earthquakes without damage;
2. Resist moderate earthquakes without structural damage, but with some non-structural damage; and
3. Resist major earthquakes, of the intensity of severity of the strongest experienced in California, without collapse, but with some structural as well as non-structural damage.

In most structures, it is expected that structural damage, even in a major earthquake, could be limited to repairable damage. This, however, depends on a number of factors, including the type of construction selected for the structure (SEAOC 1960).

Since 1960 the Blue Book has continued to evolve, but the performance objective for new code-conforming buildings has remained similar. The parameter "earthquake" in the three-level description has been refined to "ground motion," the strongest level revised to include both "experienced" and "forecast" ground motions, and the somewhat speculative phrase, "expected that structural damage …could be limited to repairable damage" further diluted by adding "In some instances, damage may not be economically repairable." Finally, due to a growing realization of the great uncertainty in the exact nature of ground motions as well as a rapidly expanding inventory of various structural systems and building configurations, it was clarified that conformance with the Blue Book provisions should not be taken as a guarantee of the protection of life and limb:

> …While damage to the primary structural system may be either negligible or significant, repairable or virtually irreparable, it is reasonable to expect that a well planned and constructed structure will not collapse in a major earthquake. The protection of life is reasonably provided, but not with complete assurance (SEAOC. 1988).

This addition is significant because it documented the concept that building codes cannot provide a zero-risk building inventory even for the primary goal of providing life safety.

3.1.3 ATC 3 and Zero Risk

A major effort to update seismic design concepts and make them more applicable on a national level was funded by the federal government in the 1970s. The resulting document, *Tentative Provisions for the Development of Seismic Regulations for Buildings* (commonly known as

ATC 3) expanded and clarified the premise that seismic building codes should not be expected to produce a zero-risk environment. The commentary of ATC 3 includes the following discussion:

> It is not possible by means of a building code to provide a guarantee that buildings will not fail in some way that will endanger people as a result of an earthquake. While a code cannot ensure the absolute safety of buildings, it may be desirable that it should not do so as the resources to construct buildings are limited. Society must decide how it will allocate the available resources among the various ways in which it desires to protect life safety. One way or another, the anticipated benefits of various life protecting programs must be weighed against the cost of implementing such programs…
>
> If the design ground motion were to occur, there might be life-threatening damage in 1 to 2 percent of buildings designed in accordance with the provisions. If ground motions two or three times as strong as the design ground motions were to occur, the percentage of buildings with life-threatening damage might rise to about 10 to 50 percent, respectively (ATC 1978, p. 309).

There is no evidence that the writer of the above commentary calculated these probabilities based on detailed analyses of buildings designed in accordance with the provisions, and there is certainly no indication that the writers of the ATC 3 provisions tuned each requirement to provide this level of safety. Similarly, code writers improving and expanding the basic concepts of ATC 3 since 1978 have not had the resources or the methodology to test each new or revised provision against the stated performance objectives. Rather, code changes have resulted from observation of performance judged unacceptable in earthquakes or inferred from research. In many cases, the relationship between the code change and the governing performance objective has been unclear.

3.1.4 ATC 63

Only recently has a methodology been developed to calculate in a detailed manner the expected performance of buildings designed in accordance with the current code in the probabilistic framework suggested by ATC 3 (*Recommended Methodology for Quantification of Building System Performance and Response Parameters*, ATC 63, in progress) (ATC 2007). The preliminary results of application of this methodology on several structural systems defined in the current code indicate that for ground motions of 150% of our code design level, about 10% of buildings could collapse. Interestingly, this is of the same order of magnitude as estimated in ATC 3 in 1978. However, when considering the wide variety of lateral-force-resisting systems included in the code over the years (over 80 systems), each controlled by a complex patchwork of prescriptive design requirements and limitations, the large configuration variations allowed for in each system, and the large variation of seismic conditions in the U.S. for which they are designed, it is likely that this methodology if implemented on every system would show large inconsistencies in the code-defined collapse margin.

3.1.5 Definition of Ground Motions for Performance Objectives

An important aspect of defining performance expectations for code-designed buildings is the definition of ground motions. Initially (e.g., the 1927 UBC), the threat from ground motions was defined simply as earthquake shaking, and no intensity or probability was defined. The Blue Book used Minor, Moderate, and Major earthquakes, later revised to Minor, Moderate, and Major ground motion, but these levels were never defined in engineering terms. When the "code ground shaking" was finally tied down by specifying a 10% probability of exceedance in 50 years (in both ATC 3 and the Blue Book), it was probably not coincident with any of the three performance levels but somewhere between levels 2 and 3. This level of shaking, often called the design basis earthquake (DBE) ground motion, remained the code design level from the late 1970s until 1997, when a new national mapping was completed using the parameter, maximum considered earthquake ground motion (MCE). This work was associated with updating the *NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures* by the Building Seismic Safety Council (BSSC 1997). These provisions are a direct descendant of ATC 3 and form the basis of seismic provisions in the International Building Code, presently used as the basis for building design throughout most of the U.S.

The MCE is mapped using probabilistic concepts (2% chance of exceedance in 50 years) except near well-defined active faults where ground motions expected from specific events on those faults are used (called deterministic motions). The code design philosophy, as defined in the NEHRP provisions, was then to provide a uniform margin against collapse for the MCE, which was implemented, in simple terms, by using traditional design methods for motions 2/3 of the MCE. The 2/3 factor is based on a presumed margin of collapse of 1.5 in traditional designs based on the less intense DBE. More significantly, preventing collapse (considered the predominant cause of casualties) even for very rare ground motion, became the key performance objective for normal buildings.

3.1.6 FEMA 273

Parallel with but slightly ahead of the development of the MCE map for new buildings, a document was developed that provided guidelines for the retrofit of existing buildings (*NEHRP Guidelines for the Seismic Rehabilitation of Buildings*, BSSC 1997b). Due to the high cost and disruption of seismic rehabilitation, the document provided for retrofit to many different performance objectives, depending on the needs and resources of the owner. Performance objectives were highly flexible, defined by the selection of a limiting performance level and a ground motion intensity. Primary performance levels of Immediate Occupancy (IO), Life Safety (LS), and Collapse Prevention (CP) were defined, although designs could be accomplished for in-between levels as well. The performance of both structural and non-structural systems was considered, as shown in Table 3.1. Similarly, any ground motion intensity could be used, but a DBE and MCE was defined. The DBE could be the motion with a 10% chance of exceedance (to tie into old mapping) or the motion with intensity 2/3 MCE (to tie into the building code for new buildings). The MCE was defined to agree with that used in mapping for new buildings.

FEMA 273 defined a recommended, but not mandatory, performance objective called the Basic Safety Objective (BSO), which consisted of meeting both LS at the DBE and CP at the MCE. While FEMA 273 suggests that the BSO should provide a similar level of safety as new buildings, it also stipulates that the BSO should be considered to have a smaller margin against collapse, less reliability, and be susceptible to more economic loss than a new building.

Table 3.1 Combinations of structural and non-structural performance from FEMA 273 (BSSC 1997b)

Table C1-8 Target Building Performance Levels and Ranges

	Structural Performance Levels and Ranges					
Nonstructural Performance Levels	S-1 Immediate Occupancy	S-2 Damage Control Range	S-3 Life Safety	S-4 Limited Safety Range	S-5 Collapse Prevention	S-6 Not Considered
N-A Operational	Operational 1-A	2-A	Not recommended	Not recommended	Not recommended	Not recommended
N-B Immediate Occupancy	Immediate Occupancy 1-B	2-B	3-B	Not recommended	Not recommended	Not recommended
N-C Life Safety	1-C	2-C	Life Safety 3-C	4-C	5-C	6-C
N-D Hazards Reduced	Not recommended	2-D	3-D	4-D	5-D	6-D
N-E Not Considered	Not recommended	Not recommended	Not recommended	4-E	Collapse Prevention 5-E	No rehabilitation

3.1.7 Vision 2000

Following the 1994 Northridge earthquake, primarily in response to public concern over economic damage levels observed, the Structural Engineers Association of California developed a comprehensive blueprint for performance-based engineering called Vision 2000 (SEAOC 1995). Performance levels (damage states) were defined similar to those in FEMA 273 but labeled Fully Operational, Operational, Life Safe, Near Collapse, and Collapse. Among other products of Vision 2000 was a table of recommended performance objectives for buildings. Four design levels (ground motion intensities) were shown, rather than the three levels previously used by SEAOC in the Blue Book and previously described. The four design levels were matched with limiting performance levels as shown in Figure 3.1. The basic objective for normal buildings, defined as Life Safe for Rare ground motion plus Near Collapse for Very Rare ground motion is not unlike the BSO from FEMA 273. The concept of the Very Rare event is similar to the MCE later developed for national mapping but is defined with a 970-year return period versus the 2475-year return (2% chance of exceedance in 50 years) used for the MCE.

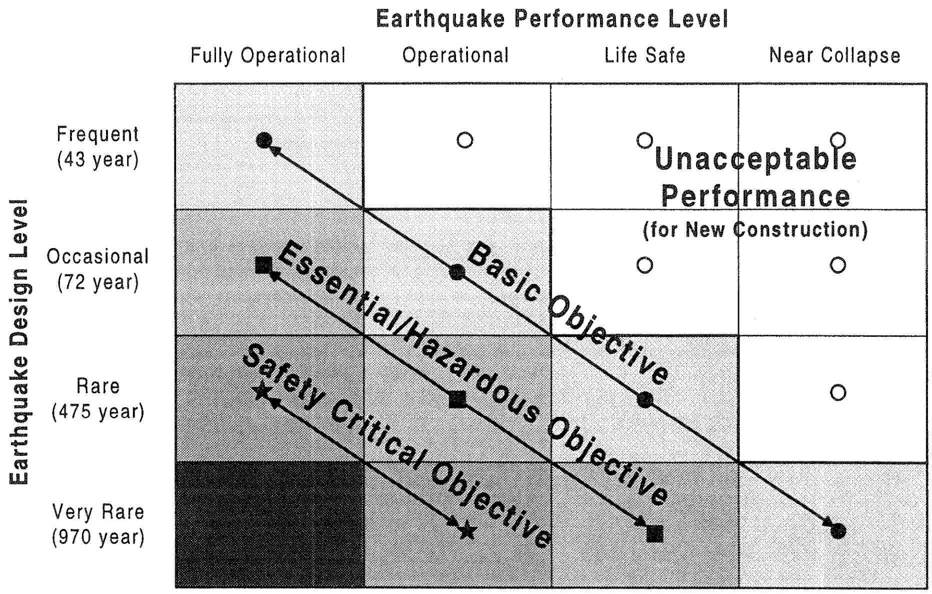

Figure 3.1 Seismic performance objectives from Vision 2000 (SEAOC 1995).

3.1.8 The ICC Performance Code

The International Code Council (ICC), developers of the International Building Code, also developed a performance code, the *International Code Council Performance Code for Buildings and Facilities*, an effort initiated in 1996 and culminating with the first edition in 2001. The performance matrix used in this document is intended for use in performance-based design of all aspects of buildings and facilities, including structure, fire safety, egress, moisture protection, and mechanical systems, and is therefore generalized as shown in Table 3.2.

The terminology in Table 3.2, when applied for use in earthquake design, is very similar, but not identical, to the Vision 2000 table shown in Figure 3.1. The design events and levels of performance are described in Table 3.3.

Table 3.2 Performance matrix from ICC Performance Code (ICC 2006)

TABLE 303.3
MAXIMUM LEVEL OF DAMAGE TO BE TOLERATED BASED ON PERFORMANCE GROUPS AND DESIGN EVENT MAGNITUDES

		INCREASING LEVEL OF PERFORMANCE → PERFORMANCE GROUPS			
		Performance Group I	Performance Group II	Performance Group III	Performance Group IV
MAGNITUDE OF DESIGN EVENT (INCREASING MAGNITUDE OF EVENT ↑)	VERY LARGE (Very Rare)	SEVERE	SEVERE	HIGH	MODERATE
	LARGE (Rare)	SEVERE	HIGH	MODERATE	MILD
	MEDIUM (Less Frequent)	HIGH	MODERATE	MILD	MILD
	SMALL (Frequent)	MODERATE	MILD	MILD	MILD

Table 3.3 Explanation of terminology used in Table 3.2

Design Level	Return Period	Performance Level	Description
Very Large	2475 years	Severe	Similar "Near Collapse"
Large	475 years	High	Similar "Life Safe"
Medium	50 years	Moderate	Low end of "Operational"
Small	25 years	Mild	Similar "Fully Operational"

3.1.9 The 2008 NEHRP Provisions (BSSC 2009)

The proposed *Intent* statement for the 2008 update of these provisions generalizes performance to be consistent with overall code goals ("safeguard life or limb, health, property, and public welfare"), while emphasizing avoiding collapse. The proposed wording is as follows:

> The intent of these *Provisions* is to provide reasonable assurance of seismic performance that will:
>
> - avoid serious injury and life loss;
> - avoid loss of function in critical facilities;
> - minimize non-structural repair costs when practical to do so.
>
> The *Provisions* seek to avoid such losses by allowing only a small risk of collapse for every building and structure covered, even in very rare extreme shaking at the

site. For smaller, more frequent shaking levels, the *Provisions* covering design and installation of both structural and non-structural systems seek to reasonably control damage that would lead to risks to life safety, economic losses, and loss of function. These design requirements include minimum lateral strength and stiffness for structural systems and guidance for anchoring, bracing, and accommodations of structural drift for non-structural systems.

Requirements for non-structural seismic protection have been in codes since the mid-1970s, mainly affecting components and systems representing only a small risk to life safety. However, previously published code performance objectives have not suggested that anchorage and bracing of non-structural systems is partially aimed at minimizing dollar losses, even for frequent events If specific serviceability checks become common in performance-based Alternate Means designs, the performance of non-structural systems should be included. Since basic anchorage of components will easily satisfy demands of the commonly used frequent ground motion (43-year return) and drifts will be small, it may be appropriate to define non-structural performance objectives for larger ground motions.

3.1.10 PEER Methodology and ATC 58—Next Generation of Seismic Performance-Based Design

The Pacific Earthquake Engineering Research (PEER) Center, the manager and director of the Tall Buildings Initiative, has had a major thrust toward the development of performance-based seismic design. With input from the private sector, PEER decided to develop methods to predict performance-based guidelines on losses, rather than on predefined performance states (Immediate Occupancy, Life Safety, etc.). The losses to be considered were repair costs, buildings downtime, and casualties. In addition, unlike previous performance-based assessment methodologies, uncertainties in the calculation parameters would be explicitly considered, including the probability that shaking of a given intensity will occur, the possible variation in structural response due to the specific dynamic characteristics of the shaking, the uncertainty in structural response analysis and resulting damage patterns, and the uncertainty as to what losses would accrue. Such a method was conceptually developed and implemented for several case studies.

The Federal Emergency Management Agency (FEMA) also has an interest in performance-based seismic design and began planning for its development for practical use with two community-based action plans (FEMA 283, 1996, and FEMA 349, 2000). The project began in 2002 as the *Development of Performance-Based Seismic Design Guidelines*, and, being implemented by the Applied Technology Council, is currently known as ATC 58 (ATC 2006). Considering input from stakeholders similar to that used by PEER, the ATC 58 project decided to build on the previous work done by PEER and to develop a similar loss-based probabilistic methodology for use by the design profession. To date, no one has attempted to translate traditional code performance objectives into acceptable losses, but eventually this system will allow a much more direct calculation of equivalence with target code performance objectives. The current action plan for the ongoing ATC 58 project is contained in FEMA 445, *Next-Generation-Performance-Based Seismic Design Guidelines: Program Plan for New and Existing Buildings* (ATC 2006).

3.1.11 Guidelines for Qualifying Designs under *Alternate Materials and Methods of Construction*

As previously indicated, the main impetus for the Tall Buildings Initiative was the increasing use of the Alternative Means section of the code to design tall buildings that exceed prescriptive height limits. Although these buildings have been subject to detailed peer review, there has been little or no guidance for jurisdictions or peer reviewers to determine appropriate equivalence with a code-designed building, as required by this section of the code. In response to this issue, the Los Angeles Tall Buildings Structural Design Council has developed a guideline document primarily for the City of Los Angeles, and the Structural Engineers Association of Northern California has developed a guideline document for use by the City of San Francisco. These documents contain recommendations for determination of site-specific ground motions, analysis procedures, and acceptability criteria that are intended to achieve code equivalence but will also significantly contribute to the reliability of designs. Although equivalence is primarily achieved by requirements parallel to the code itself, target performance objectives are also directly or indirectly described. These performance objectives are described below.

It should also be noted that these documents are relatively new and not well tested; with increased use and trials, they may be refined.

An Alternate Procedure for Seismic Analysis and Design of Tall Buildings Located in the Los Angeles Region. **2005 Edition (LATABSCD 2005)**

The stated intent of this guideline is to provide equivalence to the code by meeting the three-step performance objective given by SEAOC in the Blue Book (see Section 3.1.2). Since this performance objective lacks technical definition, the four-level SEAOC performance-based design recommendations for "basic objective" are specified (see Fig. 3.1). However, specific checks are required at only three levels as described below:

- Evaluation Step 1 is intended to show that the building remains serviceable when subjected to frequent ground motion (50% exceedance in 30 years or 43-year return period). Acceptability criteria for continued serviceability are given.
- Evaluation Step 2 is intended to provide life safety during a design basis earthquake ground motion (10% exceedance in 50 years or 475-year return period). This is achieved essentially by a check of prescriptive code requirements, although fixed minimum base shears will govern over code pseudo-dynamic formula in the tall building period ranges. This procedure will achieve life safety only to the extent that prescriptive code requirement will be successful in providing adequate life safety in tall buildings but is not a true performance-based assessment. However, this document specifies use of less than the standard code minimum base shear and direct correlation with the code is thus tenuous
- Evaluation Step 3 is intended to assure that the building does not experience collapse during Very Rare ground motion (the MCE as defined nationally by NEHRP). This design level is significantly different from the 970-year return shown in Figure 3.1, but is conceptually aligned with step 3 in the Blue Book performance objective and is nationally accepted as the largest ground motion to be considered in design. Due to the deterministic limits used for MCE, in the Los Angeles region the MCE often has about a 600-year return period.

Recommended Administrative Bulletin on the Seismic Design and Review of Tall Buildings Using Non-Prescriptive Procedures—AB 083 **(SFDBI 2007)**

Adopted in July 2007, this administrative bulletin will be used by the City of San Francisco to guide the design and review of tall buildings under the Alternative Means provisions of the code.

The bulletin does not describe itself as performance based. It outlines procedures, requirements, and guidelines for seismic design, with commentary, that are aimed at producing seismic performance at least equivalent to that of code-prescriptive seismic designs. This is the standard required by the building code for "non-prescriptive" seismic designs. The preface to the bulletin notes that it is not an effort "to create more purely 'performance-based' guidelines for seismic design."

It is similar in concept to the Los Angeles document in that three design levels are specified. However, the performance objectives and/or related acceptability criteria at each level are less specific, as discussed below (in the order presented in the AB).

- Code-Level Evaluation: A code-level evaluation/design is used to identify the exceptions being taken to the prescriptive rules and to identify the minimum required strength and stiffness for earthquake resistance. If nonlinear response is anticipated under MCE demands, capacity design principles shall be used to create suitable ductile yielding mechanisms. This code-level analysis will determine the required minimum strength of these mechanisms. The specified ground motion is the DBE for the San Francisco Building Code or motion with a 475-year return period. No performance level—as defined by FEMA 273 or Vision 2000—is specified.
- Serviceability Evaluation: The serviceability ground motion is defined as having a 43-year return period. The evaluation shall demonstrate that the elements being evaluated exhibit serviceable behavior, which could include minor yielding and minor repair. Tall buildings designs to date show that when primarily designed for code-level requirements, performance at this level is seldom a concern.
- MCE-Level Evaluation: The MCE is currently defined as ground motion with a 10% chance of exceedance in 100 years or a 975-year return period. When San Francisco updates their code to be compatible with the 2007 California Building Code, which in turn is based on the 2006 International Building Code, the MCE will likely be updated to agree with the national definition as previously discussed.

The MCE-level evaluation "uses nonlinear response-history analysis to demonstrate an acceptable mechanism of nonlinear lateral deformation and to determine the maximum forces to be considered for structural elements and actions designed to remain elastic." The evaluation level is included in the bulletin because all involved agreed that intended building code performance includes preventing collapse at the MCE level of ground motion. Realizing that there is no such thing as zero risk, this performance level is described in the bulletin with the words "an acceptably low probability of collapse." Further interpretation of this probability is not given and it is unclear if a calculation of the probability will ever be required by the city.

At the MCE level, the bulletin requires capacity design and advanced seismic analysis methods, which are not required for most code-prescriptive tall buildings. Thus, although the target of the bulletin is "at least equivalent" performance, the developers of the document think that it is likely to result in buildings that have more reliable performance against collapse compared with code-prescriptive designs.

3.1.12 Expected Seismic Performance of Code-Designed Buildings

This paragraph contains a summary of current trends in defining expected code-level performance based upon the documents reviewed in this section. The distinction should be emphasized between code objectives as described in code prefaces and commentaries, and actual performance of code-designed buildings in earthquakes. As previously noted almost all code development work has been done by judgment without the availability of analytical tools or sufficient field observations to test the results against stated objectives.

3.1.12.1 Structural

The primary concentration for structural performance is preventing collapse, with the ambiguous "life-safety" level being de-emphasized. The shaking intensity used for this performance level is consistently the MCE. However, California until recently has used a code based on the 1997 UBC and the MCE has been the 1000-year return ground motion. This definition differs from the national mapping of MCE done for the NEHRP provisions and the IBC. Beginning in 2007, when California adopted the IBC, the same rules for ground motion definition have applied in all of the U.S. With increased consideration of uncertainties in performance-based designs, the acceptable reliability of preventing collapse in the MCE will soon become an issue. The only study of this issue are the draft results of ATC 63, which indicate that code designs theoretically are providing approximately a 90% probability of preventing collapse in the MCE motion.

Code performance levels also include a consistent consideration of a serviceability level performance, although it is poorly defined. Use of prescriptive code design rules to achieve a consistent serviceability near-elastic response is difficult, given the many code design adjustment factors (e.g., R factor, drift limits, load factors, phi factors). The 43-year return motion (50% chance of exceedance in 30 years) has often been cited as an appropriate demand, but prescriptive site modifications due to soil conditions result in particularly wide variations in the spectra at low accelerations levels. The acceptability criteria for serviceability are not clear, although, conceptually, near-elastic behavior or behavior requiring little or no structural repair appears to be the goal.

3.1.12.2 Non-structural

Although non-structural performance has been part of published code performance expectations for some time, specific performance objectives are poorly defined.

Code design rules suggest that for 2/3 MCE, (a) anchored items will stay in place, (b) "designated systems" will stay operational, and (c) drift-related items will suffer only minor damage. These limit states do not translate well to a performance level, although the code development philosophy has been focused on preventing hazardous conditions and, in an unspecified way, limiting damage.

The *Intent* paragraph of the 2008 NEHRP provisions currently in preparation includes the statement "to minimize non-structural repair costs when practical to do so."

For consistency with structural performance objectives, a serviceability event with a 43-year return could be chosen, which, logically, would correspond to SEAOC's "minor earthquake" with no damage.

3.2 INPUT FROM INTERVIEWS

(See Appendix A for detailed description of interview process.)

The interviews followed a set questionnaire, but, in fact, were often free flowing. The content of the answers depended largely on the perspective of the interviewee, and often were not comparable from one interview to the next. Each answer could therefore not be tabulated in a coherent summary. The summary in this section is therefore based on the whole of the interview contents as interpreted by the Task 2 Core Group.

3.2.1 Authority of Model Codes or Local Jurisdiction to Increase Performance Objectives beyond Life Safety

Each state's authority to regulate buildings comes from the Constitution's delegation of police power to the state. As explained in Section 3.1, police power has long been interpreted as the authority to regulate for the health, safety, and general welfare of its citizens. "General welfare" can be interpreted as including concern for most types of earthquake losses, not only on a building-by-building basis but on a regional basis.

An example of the extension of building code coverage beyond protection of life safety can be found in the IBC occupancy categories, which, as measured by a building's importance, determine the performance objective. As defined in the International Code Council's performance code, Occupancy Category II is intended for "normal buildings" and Occupancy Category IV is for "essential facilities needed to be operational after an earthquake." Occupancy Category III is reserved for "buildings or facilities of an increased level of societal benefit or importance." This is a much broader definition than used in other current codes that use Occupancy Category III for "buildings or structures representing a substantial hazard to human life." The IBC itself places large buildings (occupancy load greater than 5000) in Category III. Thus, the IBC could also increase the performance objectives for tall buildings by placing them in Occupancy Category III, assuming such a change would be successful in the normal code change process.

California (and many other states) adopts a model code, or a model code with amendments, as the minimum standard for the state. Most states in turn give authority to local jurisdictions to make additional restrictive or conservative amendments considering local conditions. Using this process, a local jurisdiction could also increase the seismic performance objectives for tall buildings assuming that such a local public policy was desired and passed through the legislative process.

3.2.2 Expected Code Performance for Purpose of Interviews

Many various stakeholders were scheduled to be interviewed that would likely not have knowledge of the background and intent of seismic building codes. Two pre-interview background documents were prepared, one giving the philosophical background of building codes, and the second describing potential damage in tall buildings in the local city given a major earthquake. To emphasize that, due to many factors, damage would not be the same in all tall buildings, potential damage states were described for an inventory of 40 tall buildings, all designed to current code. The fragility relationship used to estimate the damage distribution was an average, but reasonable, fragility for normal buildings from the studies done in the ATC 63 project, previously described. It has been argued that tall buildings, on average, would demonstrate better performance than other buildings due to the likelihood of dynamic analysis, more careful design (due to prominence or icon status), and/or peer review. If so, this improved performance would not be due to requirements or intent, and the interview was directed at whether the standard code *intended* performance was adequate for tall buildings.

Among other descriptive information (see Appendix A), the damage distributions shown in Table 3.4 were included in the background paper. Data in the table represent three different performance objectives, Level C being the lowest and Level A the highest. For the purpose of the interview, Level B was intended to represent average performance for normal code buildings, based on a combination of fragilities developed in ATC 63 (see paragraph 3.1.4) and for HAZUS, a seismic-loss-estimating methodology developed by FEMA (www.fema.gov/plan/prevent/hazus/). The interviewees were not told this prior to the interview.

Table 3.4 Rare earthquake scenario damage, one in ten chance of occurring during life of condominium towers (e.g., 50 years)

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

3.2.3 Understanding of Expected Code Performance (Zero Risk)

In general, interviewees guessed that Level A in Table 3.4 represented the code. Although they could accept that some buildings could be damaged (many had seen such buildings in person or on television), they could not accept collapse as a real possibility, regardless of the size of the inventory, so Level B and C were not considered realistic.

Further generalizations by the task group concerning the interviewees include a complete lack of knowledge of the uncertainties in seismic design, disbelief that "modern science" couldn't prevent collapse, and the absence of ever relating normal benefit-to-cost relationships to safety in buildings. This "zero-risk" attitude about seismic performance of new buildings perhaps can be attributed to the infrequency of earthquakes and/or building collapses—unlike other risks like car or airplane crashes, or other natural hazards like tornado, hurricane, or flood. Although not directly asked, it is unlikely that the stakeholders would expect a wood frame house to withstand a tornado, or for that matter, a tall building to withstand a direct hit from a Boeing 767. The typical commercial building-safety stakeholder apparently doesn't think about the seismic threat enough to develop a realistic mental damage framework.

Not only was collapse of a new tall building in an earthquake unthinkable, but also, to the several condominium owners interviewed, the possible long-term closure of their building for structural repairs.

The task group concludes that the general public has a poor understanding of the possibility of serious structural damage to tall buildings in a major earthquake.

3.2.4 Communication of Risk to Users

When notified during the interviews that there was a risk, although small, of serious structural damage in tall buildings, there was general agreement that this risk—as well as information on a range of damage states—should somehow be communicated to potential owners or tenants. Currently, seismic performance disclosures are limited to very few situations relating to hazardous sites or older buildings. The arcane probable maximum loss (PML) rating is often assigned to an entire building for financial transactions, but this communicates little concerning safety and building closure and is seldom seen by tenants.

Several interviewees thought that a standardized seismic building rating system, understandable by the general public would be useful in this regard, and could eventually create a marketplace value on seismic performance.

A consistent seismic performance rating system that could be used both by the financial community and by building owners, buyers, tenants, and users has been discussed by the earthquake engineering community for years. In fact, the 2007–2008 Existing Buildings Committee of the Structural Engineers Association of Northern California is actively exploring the idea. The driving issues of this system include the development of adequate risk-measurement scales, economically feasible rating methodologies, and an infrastructure to assure standardization and quality control. The continuing development of performance-based earthquake engineering may eventually enable development of such a system (see Section 3.1.10).

Lacking a formalized seismic-rating system, the technical community there clearly still needs to greatly improve communication of risks and performance levels to the user community.

3.2.5 Financing

A broad cross section of the financial community was not interviewed. However, input was received that indicated that the current financial markets have developed complex risk dilution devices that minimize the effect of relatively small changes in performance expectations, particularly of only a small cross section of buildings. The conclusion is that tall buildings, although normally of high value, do not have any special characteristic that would make the financial community an interested stakeholder in setting the seismic performance objective.

3.2.6 Insurance Issues

3.2.6.1 Condominium Residential Buildings

Earthquake insurance is available both for individual owners of units and for the condominium association that is interested and responsible for buildings as a whole. The insurance coverage is normally broken down in accordance with responsibilities outlined in the covenants, conditions and restrictions agreement (CC&Rs). These agreements usually place responsibility for tenant improvements and contents of units on the individual owner and responsibility for the balance of the building on the tenant association. Generally, owners are responsible for finishes and contents within their unit. However, regardless of their location, the structure and exterior cladding are almost always the association's responsibility.

Condo owner's insurance consists of three main features, not all of which are included in every policy:

(a) Coverage for damage to tenant improvements and contents.

(b) Allowance for living expenses should the unit be uninhabitable due to damage in the unit or prohibited access. The duration covered varies but is often 60 days.

(c) Allowance to cover an assessment by the association for building damage repair (or the deductible on building-wide insurance coverage). The amount varies but is often 20% of the overall policy. This can be triggered only by a formal assessment of all tenants by the association.

Condominium association insurance, on the other hand, is limited to repair of damage in public spaces, building spaces such as mechanical rooms or the roof, cladding, and the structure. There normally is no living expense coverage for tenants with these policies.

Many potential conflicts or overlaps exist in these coverages, the most obvious being repair of structural damage within the space of a unit. Apparently the clarity of coverage varies with policies, but conflicts concerning repair of any kind of damage in condominiums are common.

Except for life-safety issues or exceptionally long building closures, it appears that losses in tall condominium buildings are insurable. The reasonableness of this solution for condo owners is, of course, dependent on the cost of insurance. Identifying these rates and comparing them with potential losses or with the owner's willingness and ability to pay was beyond the scope of this task group.

3.2.6.2 Commercial Buildings

Earthquake insurance for tall commercial buildings is not unlike that available for condos, with an owner or owner group similar to the condo association and building tenants similar to individual condo owners. The motives and attitudes concerning earthquake insurance in the case of commercial buildings will be governed by "business decisions" and is likely to be risk-based to some degree.

The relationship between insurance rates and risk for either residential or commercial tall buildings is unclear because there is limited ability to estimate potential losses and little or no experience data. It is not clear at the present time if buildings built to a higher-than-code standard could get better rates. Therefore, it is concluded, similar to the financing issues, there is negligible influence from insurance issues for the determination of appropriate seismic performance objectives for tall buildings.

3.2.7 Desired Performance of Tall Buildings Based on Interviews

Almost all of the interviewees thought that the performance expectation for normal buildings suggested by the task group (Table 3.4) was inadequate for tall buildings. Many thought this performance was inadequate even for normal buildings. As previously indicated, the judged inadequacy was focused on the possibility of collapse or unrepairable damage.

The interviews therefore would suggest that tall buildings should be designed to not collapse in any foreseeable earthquake with a high reliability (perhaps unrealistically high). Long-term or permanent closure (with eventual demolition), although not characterized as *unacceptable*, were viewed as having similar negative impacts far beyond those directly affected. Special characteristics of tall buildings that influenced the opinion of the interviewees included the following:

- Tall buildings should be considered a special class of buildings. The approval of tall buildings requires resolution of many issues having greater impacts on occupants, neighbors, and the city than other/low-rise buildings.
- Tall buildings have a great impact on a city and city services; and they produce high-occupant loads on small land area in these buildings, contributing to their overall importance.
- Because of few exits and other special conditions of high-rises, there is a need to increase resistance to the potential impacts of building fire or significant structural damage or failure.
- Many stakeholders felt that the loss consequences of collapse, long-term closure, or even serious damage would be devastating for commercial property owners, condo owners, and the community.

The interviewees were in general unable to relate to risk levels. Although many said that they had difficulty considering an event that might happen on average every 500 years as a realistic threat, at the same time they were judging that relatively rare cases of collapse were unacceptable. Similarly, moderate damage that might occur from events with a high probability was acceptable as "the price for living in earthquake country."

3.2.8 Residential versus Other Occupancies

Although residential (condominium) occupancies in tall buildings have different characteristics than commercial buildings, such as owner occupancy, 24-hour occupancy, more elderly occupancy on average, and the provision of permanent housing, the interviewees, in general, thought that these characteristics by themselves were not the dominant cause for their opinion on performance. Commercial tall buildings share all the characteristics listed in the previous section and the temporary or permanent loss of space would have a large economic impact on the city.

Therefore, the enhanced performance recommended for tall buildings by the interviewees was not dependent on occupancy.

3.2.9 Acceptable Premium Costs

Each interviewee was asked how much reliable, enhanced seismic performance was worth to them. This worth may be reflected in the cost of a building, the cost of a condominium, or the rental of space. The answers were "off the tops of their heads," since the task group did not present to them any estimates of the cost of improved seismic performance or any benefit-cost data. Nevertheless, most interviewees were willing to provide an answer, which fell between 5% and 10%. This range is larger than normally associated with the public's perception of the importance of seismic performance, and may have been influenced by the previous detailed discussion of seismic performance during the interview.

3.2.10 Implementation Options

Concern was expressed from enforcement, development, design, and construction stakeholders that a recommendation concerning seismic performance of tall buildings coming from the Tall Buildings Initiative would represent a standard of practice. The Core Group assured them that this study cannot be construed as representing a national or even regional consensus. The arguments for enhanced performance for tall buildings identified during the interviews are a reflection of appropriate public policy as perceived by the individuals interviewed. Legal adoption of such policy could only occur through the national code adoption process or by local ordinance, both of which would involve public input.

Implementation of enhanced performance objectives for tall buildings could also be market driven. This outcome is unlikely, however, until there is a reliable and consensus rating system to measure performance.

3.3 INPUT FROM WORKSHOP

(See Appendix B for detailed description of Workshop.)

As noted in Appendix B, the workshop brought together the Core Group, representatives of the interviewees, representatives of the Tall Buildings Initiative Project Advisory Committee, several other structural engineers familiar with tall building design and/or review, and other interested parties.

A plenary session included descriptions of the Tall Buildings Initiative as a whole and the purpose of the present study. A presentation on the background of seismic codes and performance expectations was given to serve as a common backdrop for all participants. Finally, the interview process was described and selected "consensus" opinions and issues were summarized. Five topics from this summary were identified by the Core Group for discussion at the workshop. Three break-out groups discussed the topics simultaneously. The leaders of the break-out groups reported on discussions in their groups in a final plenary session and after the workshop wrote summaries of their sessions, which are included in Appendix B.

3.3.1 Break-out Discussions

Break-out Number 1: Is the current performance objective of the building code acceptable?

The discussions indicated that stakeholders in general were not familiar with building code philosophy or performance expectations. The perception is that modern buildings will not be seriously damaged in earthquakes and that collapses would not occur unless mistakes were made in the design. However, at the same time, the stakeholders agreed with engineers and building designers who were present that a "zero-risk" philosophy is unrealistic. This apparent paradox exists because lay persons seldom think about the safety of buildings, particularly new buildings when under earthquake loading, and their first response considering safety does not take into consideration the possibility of low-frequency failures. In addition, while the risks of driving or flying are immediately and constantly perceived, the everyday stability of buildings may give an unrealistic confidence in their stability under extreme loading.

Stakeholders have difficulty combining the small probabilities of the occurrence of the big earthquake (MCE) with the probability of failure from that shaking level, and tend to relate only to the probability of collapse *given the MCE*. A 10% failure rate, as potentially suggested by ATC 63, was perceived by the majority of stakeholders at this workshop as not acceptable. These difficulties in understanding and relating to seismic risk were also noted in the interviews and led to the subject of Break-out Number 2.

Break-out Number 2: Issues relating to understanding risk and disclosing risk

As discussed in Break-out Number 1, stakeholders had difficulty relating to seismic risk, particularly the collapse of a building. The majority agreed that, if there is a real risk of serious damage and closure of a given building due to earthquake shaking, this risk should be disclosed to potential tenants. This may be truer in condominium buildings where tenants are making significant long-term investments in their unit and are depending on its availability for their domicile.

However, several individuals thought that disclosure in the format of a small probability would go un-noticed and suggested that a building rating system that would facilitate understanding the relative risk among all buildings would be necessary for effective disclosure. All break-out groups agreed that this would be a good idea, not only for tall buildings, but for all buildings. Technical representatives in the sessions noted that the idea of a building seismic-rating system has been suggested before, but that there are many practical difficulties in the development and implementation of such a system.

Break-out Number 3: Should tall buildings have better performance than normal buildings?

Two of the three break-out groups reported that there was general agreement within their group that tall buildings should be designed to provide better performance than normal buildings, not only in terms of reliability against collapse and protection of life safety, but also in terms of functionality. Primary reasons cited included:

- There will be an extreme demand on city services in case of collapse, instability, or need of evacuation.
- Occupants are more difficult to evacuate than in other types of buildings.
- The "neighborhood" affected by poor performance of a tall building is larger than that of other buildings.
- The resilience of the city, as measured by potential loss of residents or tenants, business activity, tourism, or general image, is more affected by poor seismic performance of tall buildings than by other measures of performance.

Arguments against this premise included:

- The ramifications of poor performance of tall buildings were not sufficiently different from all other buildings to warrant singling out.
- Development is governed by economics. Additional costs will reduce or eliminate construction of such buildings.
- Local adoption of such requirements will give a development advantage to neighboring cities, counties, or regions.

Break-out Number 4: Are residential buildings different from other tall buildings?

From a public-policy standpoint, it was agreed that residential buildings should not be treated differently with respect to seismic performance. Most arguments for better performance (see Break-out Number 3) apply to all tall buildings. Although condominium owners in tall buildings are concerned about both their long-term investment and the potential loss of their primary residence, it was argued that these concerns are not unique to tall buildings.

Break-out Number 5: How much of a cost premium is acceptable for enhanced seismic performance?

No economic analyses were available of building costs, potential seismic performance premiums, or cost-benefit relationships for enhanced performance. Therefore, the opinions given were not well-founded and were given primarily by potential building tenants, as opposed to owners or developers of buildings. Nevertheless, a premium of as much as 10% for enhanced seismic safety was often suggested as acceptable.

4 Task 2 Conclusions and Recommendations

Considering the totality of input obtained under this task, we make the following conclusions and recommendations:

4.1 SELECTION OF SEISMIC PERFORMANCE OBJECTIVES FOR CLASSES OF BUILDINGS IS PUBLIC POLICY

The primary purpose of this task, to establish seismic performance objectives for tall buildings, generated significant concern with some stakeholders, including:

- A building official was concerned that the Tall Buildings Initiative would recommend enhanced performance for tall buildings for specific jurisdictions that would place the jurisdiction in a difficult and controversial position.
- Structural engineers expressed concern that a recommendation by the Tall Buildings Initiative would become a standard of practice, even if not required by code.
- Designers and builders of tall buildings expressed concern that the potential extra cost of enhanced performance would significantly change the economic viability of such buildings and/or limit the locations where such buildings could be built.

Most of the unique characteristics of tall buildings that were identified during discussions of seismic performance are clearly related to public policy, most on a local level. Examples include details of emergency response plans, regional image, and control or limitation of the intensity and location of development. In addition, concern was expressed over precedent-setting consideration of the economic consequences of seismic performance for one class of building.

We therefore conclude that the establishment of mandatory enhanced structural seismic performance levels for tall buildings is a public-policy issue that should be publicly debated either on a national scale—through the model building codes—or at a local scale—through an ordinance process in local government.

However, given that the primary purpose of building codes is protection of life safety and public welfare, characteristics of tall buildings that present higher risks than normal buildings could be the targets of further study and recommendations by the technical community itself. Examples of such characteristics of tall buildings that fall into this category are cladding and its anchorage, and emergency ingress and egress.

4.2 EXPECTED CODE PERFORMANCE FOR NORMAL BUILDINGS

Current trends in defining the intent of the code seismic design rules are summarized in detail in Section 3.1.12.

4.2.1 Primary Objective Relating to Avoidance of Collapse

An objective of the Tall Buildings Initiative is to provide the tools to execute Alternative Means designs with improved clarity and reliability. It is clear that seismic provisions in building codes from their beginning have developed around the intent of protecting life safety in large earthquakes. However, it should be noted that the performance that now predominates descriptions of the intent of codes for normal buildings is structural Collapse Prevention, acting as a better-defined surrogate for Life Safety. Thus, if the Tall Buildings Initiative, for the purpose of improving Alternative Means designs, seeks to match the code intent independently of code prescriptive rules, conditions potentially leading to collapse should be identified and models developed to reliably predict them.

The seismic demand specified in recent code performance objectives for normal buildings is consistently the maximum considered earthquake motion (MCE), presumably intended to represent a reasonable worst case. The technical specification for the MCE, however, has been inconsistent, with the Uniform Building Code and its derivatives (notably the California Building Code) specifying motion with a 1000-year return, and the International Building Code specifying motion with a 2500-year return as modified by certain near-fault deterministic considerations.

New national probabilistic hazard mapping has been developed by USGS that includes the next generation attenuation (NGA) relationships developed by PEER. Currently, these data are being used to develop MCE maps for the IBC, and definitions are being proposed in committee that are different than previously used (1997, 2002) as follows:

- It is proposed that for the probabilistic regions, the nominal 2500-year return motions will be modified to create a more consistent risk of non-collapse. This would be achieved by considering the combination of a standard code collapse fragility and the local site hazard curve (the so-called "risk integral") and adjusting the 2500-year motions to achieve a uniform risk of collapse of 1% in 50 years. (Luco et al. 2007).
- It is proposed that response accelerations for both the probabilistic and deterministic MCE be determined using the maximum direction of ground motion rather than the geomean (GMRotI50) used in the NGA and by USGS.
- It is proposed that in near-fault regions the MCE spectral response accelerations be calculated as the 84th percentile of the controlling characteristic earthquake motions rather than 150% previously used.

Considering the concern among stakeholders (see Section 3.2.3) about the reliability against collapse of tall buildings and the dependence of most designs on the analysis results from scaled response histories, the ramifications of these proposed changes on the selection, the scaling, and the use of ground motion pairs for tall buildings should be studied.

4.2.2 Serviceability Objective

As noted in Section 3.1.12, it is generally accepted that the objectives of the building code, in addition to protection of life safety by avoiding collapse, include provision of avoiding significant losses in more frequent ground motions. This protection is often equilibrated to prescriptive design elastic behavior for code force levels (using the code response reduction factor, R).

When real earthquake motions are specified in guidelines for use in performance-based design or Alternative Means design, they are most often defined as demands with a 50% chance of exceedance in 30 years (43-year return). For serviceability, losses considered are primarily economic and include costs of repair of damage or lost use of the building. Such losses are generally not required to be zero, but needed repairs should be minor, should not be widespread in the building, and should not interfere with normal use of the building.

However, due to highly nonlinear code site coefficients (particularly Fv), amplification of small motions for C, D, and E sites create demands far greater than prescriptive code design values, which have been derived from large motions reduced by an R value. Performance-based design techniques for the serviceability check may therefore be inconsistent with the result of prescriptive design. In addition, if response histories are used for this check (given that nonlinearity may be allowed for serviceability), commonly used databases of ground motions may be inappropriate for scaling to small spectral ordinates.

It is recommended that the Tall Buildings Initiative investigate the response of tall buildings to small input motions to enable better definition of a useful serviceability check.

4.2.3 Stakeholder Concerns Regarding Seismic Performance of Tall Buildings

As discussed in Sections 3.2 and 3.3 covering the interview process and the workshop, a strong majority of stakeholders were very concerned about the risk of collapse suggested by code fragilities currently developed by the ATC 63 project. There was similar concern, most specifically directed at condominium towers, about the risk suggested for serious damage and building closure. Although we have concluded that recommendations concerning mandatory minimum seismic performance as specified in the building code is a public-policy issue, it is clear that there is great interest among stakeholders regarding the details of expected damage and its consequences in buildings, particularly tall or otherwise iconic buildings.

It should be noted that significant concerns were also expressed about the potentially negative effects of increased building costs due to the provision of enhanced performance. Such increased costs could suppress development of tall buildings completely, or cause development of tall buildings to locate in jurisdictions where enhanced performance is not required.

4.2.4 Additional Recommendations to Tall Buildings Initiative

The recommendations from this study regarding engineering analysis and design fit completely within the capabilities of the vision for performance-based design methodologies developed by

PEER and the ATC 58 project, and development of practical implementation methods for these visions should continue.

More specifically, the Tall Buildings Initiative should improve understanding and measurement of reliability of designs against collapse and develop approximations of the contributions to this reliability from:

- Targeting enhanced performance;
- Peer review or other quality control of the design process; and
- Quality control of the construction process.

In addition, potential damage patterns that could lead to significant repair costs or closure of the building should be understood and be reasonably predictable.

We have also concluded that the risk to life safety from falling hazards created by damage to cladding is potentially higher in tall buildings than in normal buildings due to increased uncertainty regarding drift amplitude and patterns and due to a larger falling radius. The Tall Buildings Initiative should study and quantify these risks. If cladding is confirmed to present a higher risk, the Tall Buildings Initiative should recommend measures to reduce the risk to be approximately the same as for normal buildings.

As previously mentioned, issues surrounding emergency ingress and egress in tall buildings is also completely different from other buildings. The risks presented by this unique characteristic of tall buildings should also be studied and the risk mitigated to the extent practicable. It is our understanding that other organizations are currently studying this issue. It is recommended that the Tall Buildings Initiative coordinate with these efforts and offer input concerning the seismic aspects of the overall problem.

4.2.5 Implementation Options

Regardless of the public-policy implications of adding mandatory enhanced seismic performance for tall buildings into national building codes and standards, a more specific code issue would make implementation difficult. Currently, buildings judged important or otherwise representing a high risk are given a special occupancy category in national codes and standards, which in turn triggers various special code requirements. Occupancy Category I consists of low-risk buildings with little or no occupancy; II includes all "normal" buildings; III is for buildings presenting a substantial hazard to human life; and IV is for buildings considered essential after disasters. For structural seismic design, a distinction between Occupancy Categories is made by use of an importance factor, up to 1.5, to be applied to design loading and varying drift limitations. There is additional specification of special requirements for certain non-structural components.

It is generally acknowledged that an importance factor of 1.25 or 1.5, by itself, would not necessarily provide improved performance in tall buildings, and that enhanced performance could be assured only by some form of performance-based design. There is no precedent for the requirement of performance-based design for any building type or occupancy in national model codes (although there is such a requirement in codes used by the military (DOD 2006)), and establishment of such a requirement would create additional complications.

If the Tall Buildings Initiative concludes that cladding in tall buildings presents a higher risk than normal buildings, mitigating design requirements could be proposed to national code committees. However, to be acceptable, it is likely that these special design requirements will have to be within the framework of normal code design parameters and not be dependent on the result of performance-based analysis or design techniques.

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Appendix A: Pre-Workshop Stakeholder Interviews

A.1 INTRODUCTION

This appendix documents interviews conducted in early 2007 to obtain input from a variety of "tall building" stakeholders with respect to their understanding and expectations of seismic performance and life-safety risk associated with tall condominium or commercial buildings. Summaries of opinions and perspectives gleaned from the stakeholder interviews and sorted by topic, were presented and discussed at a workshop (described in Appendix B) for further refinement and consensus building.

The following sections of this appendix describe the interview process, interviewees, background information (distributed to interviewees), the "Interview Outline and Response Form" used to record stakeholder interviews (including sample responses of one interviewee), and topical summaries of pre-workshop stakeholder opinions, respectively.

A.2 INTERVIEW PROCESS

The interview process included three phases:

- Phase 1 Pre-interview identification of prospective interviewees ("tall building" stakeholders) and development of interview background material,
- Phase 2 Interviews of stakeholders, and
- Phase 3 Post-interview compilations of stakeholder opinions and perspectives.

The members of the Task 2 team first identified "tall building" stakeholders by category, including building owners (with both personal and institutional perspectives), developers, and others having a commercial interest, city planners, government officials (e.g., responsible for public welfare), lenders, insurers, economists, and other interested professionals including engineers and architects. The individuals representing different stakeholder categories were contacted and if agreeable and available, interviewed. Since the team included engineers (and a building official) priority was given to individuals representing other stakeholder categories. A total of 12 "tall building" stakeholders were interviewed, as described in Section A.3.

The interviews were conducted at both northern and southern California locations to accommodate stakeholders who live or work in different parts of the state. Typically, interviews were conducted by at least two Task 2 team members. Recognizing the variety of stakeholders and their generally limited understanding of building codes and related earthquake performance of buildings, background documents were given to interviewees prior to or at the beginning of each interview, to initiate discussion on and establish a common interview basis. Background documents are described Section A.4. To achieve consistency between interviews, an interview form used to record stakeholder interviews (including responses of one interviewee), and topical summaries of pre-workshop stakeholder responses, respectively, was developed for prompting interviewer questions and recording interviewee responses. Section A.5 includes a copy of the "Interview Outline and Response Form" including sample responses of one interviewee.

As would be expected, stakeholders had a variety of opinions and perspectives. Rather than attempting to judge or rank interviewee responses, "raw data" in the form of stakeholder statements made during the interviews were compiled, by one of five topical areas, for discussion and potential consensus building at the workshop. Section A.6 includes compilations of stakeholder opinions by topic.

A.3 LIST OF STAKEHOLDERS INTERVIEWED

Table A.1 lists "tall building" stakeholders interviewed, identifying each stakeholder in terms of the "sector" they represent (private, public, or professional), their predominant point of view (POV), and their occupation (or title/position). For example, a condominium owner is shown as being from the "private" sector and predominantly interested in his or her own personal welfare. A condominium developer is shown as also being from the private sector but with a predominant commercial interest. A city government official is shown as being from the public sector and predominantly interested in the welfare of the public. Stakeholder names are not included in Table A.1, since stakeholders wished to remain anonymous.

Table A.1 List of "tall building" stakeholders interviewed

Stakeholder				
Name	**Sector**	**POV**	**Title/Position**	**Title/Position**
No. 1	Private	Personal Welfare	Property Owner, Condominium	President, Condo Owners Assoc.
No. 2	Professional	Public Welfare	Urban Planner	Emergency Management
No. 3	Professional	Commercial	Attorney, Condominium Owners	
No. 4	Professional	Commercial	Project Management, Condominium Construction	
No. 5	Private	Personal Welfare	Property Owner, Condominium	
No. 6	Public	Public Welfare	Attorney, City Government	
No. 7	Professional	Financial	Actuarial Consultant, Insurance Industry	
No. 8	Private	Commercial	Property Owner, Commercial Building	
No. 9	Private	Commercial	Representative, Buillding Owner's and Manager's Association (BOMA)	
No. 10	Private	Personal Welfare	Property Owner, Condominium	
No. 11	Public	Public Welfare	Official, City Government	
No. 12	Private	Financial	Mortgage Lender	

A.4 BACKGROUND MATERIAL

Two background documents were developed and distributed to stakeholders either before or at the beginning of each interview. These documents provided basic information on building codes and earthquake losses that most interviewees were not familiar with (i.e., most stakeholders were not earthquake experts). These documents also served as a consistent basis for soliciting stakeholder opinions and perspectives on tall building performance.

The first background document is a relatively simple, two-page description of the purpose and intent of building codes, purposely written in "non-engineering" language. The second document describes damage and loss scenarios for 40 (hypothetical) tall buildings due to either "Rare" or "Occasional" earthquake ground motions. Two almost-identical versions of these scenarios were developed, one for tall condominium (residential) buildings and a second for tall commercial buildings. The most appropriate version of the two scenario documents was given to each interviewee based on occupation and stakeholder POV.

Copies of "Tall Condominium Building Damage and Loss Scenarios" (Handout 1A, Section A.4.2), "Tall Commercial Building Damage and Loss Scenarios" (Handout 1B, Section A.4.3), and the "Purpose and Intent of Building Codes" (Handout 2), are included at the end of this section. The technical basis used to develop the tall building damage and loss scenario documents is described below.

A.4.1 Development of Tall Building Damage and Loss Scenarios

Tall building damage and loss scenarios were developed using the methods of the *Advanced Engineering Building Module* (*AEBM*) of FEMA's *HAZUS* earthquake loss estimation technology (NIBS 2002, NIBS 2005), and the detailed procedures for loss estimation (Appendix B) of *FEMA 351* (FEMA 2000). Key building-performance parameters were based on typical tall building geometry and representative building-performance properties, and "benchmarked" against related research, including the tentative 10% collapse safety goal (for MCE ground motions) of the ongoing ATC-63 project (ATC 2007), and building damage and loss estimates of "When the *Big One* Strikes Again" (Kircher et al., *Earthquake Spectra*, April 2006).

Table A.2 summarizes key building-related damage and loss results taken from "When the *Big One* Strikes Again," a study (referred to herein as the 1906 study) of the expected consequences of a repeat of the 1906 San Francisco earthquake in terms of current infrastructure and building inventory. Table A.2 shows that building damage is likely to be extensive and related losses large, consistent with observed building damage and losses for major earthquakes that have impacted a large developed region. For example, the 1995 Kobe earthquake caused over $100 billion in building losses, comparable to the $120 billion shown in Table A.2.

Table A.3 summarizes the distribution of structural damage to residential (RES) and commercial (COM) buildings, respectively, taken from the 1906 study for buildings located in San Francisco County. Table A-3 illustrates the broad distribution of structural damage expected to occur to buildings. Some buildings are expected to have no significant damage (None or Slight), some buildings are expected to have Moderate to Extensive damage, and others are expected to have Complete damage (100% economic loss), some of which are likely to also be at least partially collapsed. The broad distribution of damage reflects variability (and uncertainty) in building performance due to inherent differences in ground motions and building-performance characteristics.

Table A.2 Expected building-related losses—M7.9 earthquake on San Andreas fault (from Kircher et al. 2006)

Damage or Loss Parameter	Northern California		San Francisco County	
	Population or Exposure	Damage or Loss	Population or Exposure	Damage or Loss
Number of Severely Damaged Buildings				
Residential Buildings - SFD	2,750,000	91,000	125,000	24,000
Residential Buildings - MFD	270,000	26,000	37,000	11,000
Commercial Buildings	70,000	10,000	9,500	3,600
Social Losses due to Building Damage				
Displaced Households	3,700,000	250,000	330,000	88,000
Serious Injuries - Nighttime	10,300,000	8,000	780,000	3,000
Serious Injuries - Daytime		13,000		4,000
Immediate Deaths - Nighttime	10,300,000	1,800	780,000	600
Immediate Deaths - Daytime		3,400		850
Direct Economic Losses due to Building Damage (Dollars in Billions)				
Structural System	$300	$20	$30	$3.9
Nonstructural Systems	$800	$75	$80	$13.7
Contents and Inventory	$500	$17	$50	$3.1
Business Interruption (BI)	NA	$11	NA	$2.6
Total Building and Contents	$1,500	> $120	$150	> $23

Table A.3 Expected distribution of structural damage to San Francisco buildings—M7.9 earthquake on San Andreas fault (from Kircher et al. 2006)

Occupancy Class	Discrete Structural Damage State					
	None	Slight	Moderate	Extensive	Complete	Total
Single-Family Dwelling	23,833	40,648	36,885	13,919	9,891	125,176
SFD (percentage)	19%	32%	29%	11%	8%	100%
Other Residential	5,928	9,045	10,961	6,677	4,185	36,796
Other RES (percentage)	16%	25%	30%	18%	11%	100%
All Residential	29,762	49,692	47,846	20,596	14,076	161,972
All RES (percentage)	18%	31%	30%	13%	9%	100%
All Commercial	1,214	1,706	3,046	2,363	1,197	9,527
All COM (percentage)	13%	18%	32%	25%	13%	100%
All Other Non-RES/COM	194	271	448	336	182	1,432
All Non-RES/COM (%)	14%	19%	31%	23%	13%	100%
All Occupancy Classes	31,170	51,670	51,340	23,295	15,455	172,931
All (Percentage)	18%	30%	30%	13%	9%	100%

The same underlying methods of the *HAZUS AEBM* of the 1906 study were used to develop distributions of damage to a hypothetical portfolio of 40 tall condominium (or 40 tall commercial) buildings located in a high seismic region of coastal California. For stakeholder interviewees, it was considered important to have distributions of building damage that reflect differences in building performance (due to differences in building design and construction).

Accordingly, damage estimates were prepared for three hypothetical performance levels (labeled Level A, Level B, and Level C, respectively). The damage estimates for 40 total buildings with Level B performance are intended to approximately represent buildings designed and constructed to current building code requirements (for normal-occupancy buildings). Level A performance is substantially better than Level B, and Level C performance is substantially worse than Level B performance.

Fragility curves, based on lognormal distributions of discrete damage states, were used to estimate tall building damage. Consistent with the *HAZUS AEBM*, the damage states include None, Slight, Moderate, Extensive, and Complete structural damage. Structural damage was used to evaluate building performance, since the primary focus was on life safety, and roof drift ratio was used as the fragility variable. The median values of damage were developed for each hypothetical performance level by assigning roof drift ratios that reflect an appropriately different level of drift capacity of the structural system. For example, the median values of the roof (or average inter-story) drift ratios of the Complete state are 0.04 for Level A, 0.03 for Level B, and 0.02 for Level C performance, respectively. Inter-story drift is not uniformly distributed over the height of a tall building, and the average values of the inter-story drift ratio (over the height of the building) reflect reductions of 1.5–3.0 from the maximum inter-story drift ratio value of 0.06 assumed to represent the threshold of Complete structural damage. That is, the Complete state is assumed to occur when the drift ratio at any story exceeds 0.06.

Table A.4 summarizes the damage-state medians for each of the three hypothetical performance levels. The associated lognormal standard deviation is 0.60 for all damage states (and performance levels) and includes both aleatory and epistemic uncertainties associated with ground motions, structural response, and building damage. The Collapse damage state is effectively a subset of the Complete state, assumed to occur at a rate of 0.30 given Complete structural damage, That is, 30% of the area of tall buildings that have reached the Complete state are assumed to have collapse or other life-threatening damage. In the simplest sense (and for discussions with stakeholders), a collapse rate of 0.30 may be thought of as total collapse of 3 of 10 tall buildings that each have Complete structural damage. Occupants could safely evacuate the other 7 (of 10) buildings with Complete structural damage, but these buildings would be closed indefinitely with 100% economic loss.

Table A.4 Median roof drift ratios of tall building structural damage states

Hypothetical Performance	Roof (Average Inter-Story) Drift Ratio - Threshold of Structural Damage				
	None/Slight	Moderate	Extensive	Complete	Collapse
Level A	0.007	0.013	0.027	0.040	0.040
Level B	0.007	0.013	0.020	0.030	0.030
Level C	0.007	0.010	0.013	0.020	0.020

The damage-state probabilities were evaluated for various levels of ground motions, including "Occasional" earthquake ground motions (representing roughly 50% in 50-year hazard) and "Rare" earthquake ground motions (representing roughly 10% in 50-year hazard). Rigorous building response analyses were not performed; rather peak building response was characterized by discrete distributions of roof drift ratio. The median roof drift ratio of Occasional earthquake ground motions was taken as 0.005, and the median roof drift ratio of Rare earthquake ground motions as taken as 0.015.

The damage-state probabilities were calculated (using an Excel spreadsheet) for each performance level and converted to the approximate number of buildings (of the 40-building portfolio) in each damage state. For example, a 9% probability of Complete damage would imply 3.6 (40 times 0.09), or about 4 buildings with Complete structural damage. Tables A.5 and A.6 show the expected number of buildings in each structural damage state (including also the expected number of collapsed buildings) for Rare earthquake ground motions and Occasional earthquake ground motions, respectively.

Table A.5 Expected damage to 40 tall buildings—Rare earthquake ground motions

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

Table A.6 Expected damage to 40 tall buildings—Occasional earthquake ground motions

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

The distribution of structural damage shown in Table A.5 for tall buildings with Level B performance follows the trend in damage results of the 1906 study shown in Table A.3 for larger residential (RES) and commercial (COM) buildings. The expected number of collapsed buildings, 1 of 40, in Table A.5 for tall buildings with Level B performance is less than, but consistent with, the tentative 10% collapse safety goal of ATC-63 for MCE ground motions, considering that Rare ground motions are not as severe as those of the MCE (of ASCE 7-05). The relatively light damage shown in Table A.6 for Occasional ground motions is consistent with limited damage to tall buildings in San Francisco due to the 1989 Loma Prieta earthquake.

The tables of the expected number of damaged buildings were combined with other background and explanatory information, and included in "Tall Condominium Building Damage and Loss Scenarios" (Handout 1A) and "Tall Commercial Building Damage and Loss Scenarios (Handout 1B), copies of which follow.

A.4.2 Tall Condominium Building Damage and Loss Scenarios (Handout 1A)

This note describes earthquake damage and loss scenarios for a portfolio of 40 tall (50-story) condominium towers assumed to exist in a high seismic region of coastal California. The condominium towers do not actually exist (yet) but represent buildings now being proposed for a number of cities in California. Each of these tall condominium towers is assumed to have a reinforced-concrete core wall system with pre-stressed flat slab floor plates, similar to buildings now under construction.

Estimates of damage and loss are provided for two levels of earthquake ground motions (1) rare, very strong ground motions, corresponding to a large-magnitude earthquake occurring on a fault relatively close to the buildings and (2) occasional, strong ground motions corresponding to an event of smaller magnitude and more distant fault rupture. The first set of ground motions, or "Rare" earthquake scenario, has approximately a one in ten chance of occurring in 50 years. The second set of ground motions, or "Occasional" earthquake scenario, is likely to occur at least once in 50 years.

How a building will perform (in terms of damage and loss) in an earthquake is a function of the building's "seismic performance" properties (how the building was designed and constructed), as well as the strength of the ground motions at the building's site, all of which are different for different buildings (at sites). Hence, the amount or degree of damage and loss will be different for each building in an earthquake, even if they are all 50-story condominium towers).

Design and construction methods can significantly influence seismic performance and the distribution of damage and loss (e.g., among the 40 condominium towers) due to an earthquake. In this note, scenarios describe building damage for three hypothetical levels of seismic performance, identified as Level A, Level B, and Level C, respectively; reflecting differences in design and construction methods.

Tables 1 and 2 show the expected number of the 40 condominium towers to be damaged structurally for Rare and Occasional earthquake scenarios, respectively. In each table, the degree of structural damage is distinguished by one of five damage states: None/Slight, Moderate, Extensive, Complete and Collapse, respectively. For a given scenario and hypothetical performance level (i.e., a row in one of the tables) each of the 40 condominium towers must be in one of the five damage states (sum of the numbers in each row is 40).

Table 1 Rare earthquake scenario damage, one in ten chance of occurring during the life of condominium towers (e.g., 50 years)

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

Table 2 Occasional earthquake scenario damage, likely to occur at least once occurring during the life of 40 condominium towers (e.g., 50 years)

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

Building damage includes damage to non-structural systems and contents as well as the structural system, although damage to the structural system is most important in terms of the safety of building occupants and possible long-term closure of the building (for earthquake repairs). In this sense, the most important parameters for evaluating earthquake performance are the losses associated with structural damage. Table 3 provides some idea of how structural damage, described in Tables 1 and 2, would affect dollar losses and long-term building closure. Additional descriptions of the damage states and their consequences follow the table.

Table 3 General relationship between damage and loss

Damage State	Likely Amount of Damage, Loss, or Building Condition			
	Range of Possible Dollar Loss Ratios	Probability of Long-Term Building Closure	Probability of Partial or Full Collapse	Immediate Post-Earthquake Inspection
Slight	0% - 5%	P = 0	P = 0	Green Tag
Moderate	5% - 25%	P = 0	P = 0	Green Tag
Extensive	25% - 100%	P ≅ 0.5	P ≅ 0[1]	Yellow Tag
Complete	100%	P ≅ 1.0	P > 0	Red Tag

[1] Extensive damage may include some localized collapse of the structure.

None or Slight Structural Damage and Related Loss—Some evidence of core wall hinging (horizontal cracks at pore joints) and slight yielding of coupling beams at a few floor levels.

Condominium towers are open following the event and structural repairs are not required. However, there is some loss due to non-structural and contents damage, particularly at the lower floor levels (e.g., possible impact to commercial and retail businesses at ground and lower levels).

Moderate Structural Damage and Related Loss—Small/medium-sized shear cracks in core walls and significant yielding (cracking) of coupling beams at some floor levels. Cracks at core wall interface with podium/base diaphragms.

Occupants can safely vacate towers (using stairs). Building is deemed safe (green tag) for occupancy after inspection, but requires structural repair (e.g., epoxy grouting of coupling beams and possibly core walls). Non-structural and contents damage is similar to condominium towers with None or Slight structural damage, plus additional partition and cladding damage due to larger drifts at upper floor levels (i.e., due to additional rotation of core above hinge zone).

Extensive Structural Damage and Related Loss—Large shear cracks in core walls (fully developed hinge zone) and significant yielding (cracking) of coupling beams at many floor levels with some failures at certain floor levels. Large cracks at core wall interface with podium/base diaphragms and significant loss of lateral load transfer.

Occupants can safely vacate towers (using stairs). However, building is not deemed safe (yellow tag) after inspection, and requires significant structural repair before occupants can return. Non-structural and contents damage is similar to towers with Moderate structural damage.

Complete Structural Damage and Related Loss—Large shear cracks and localized crushing of core walls (fully developed hinge zone) and significant yielding (cracking) and failure of coupling beams at many floor levels. Some floor slabs have large cracks and loss of pre-stress. Very large cracks at core wall interface with podium/base diaphragms with near complete loss of lateral load transfer at this level. Building may be noticeably leaning.

Provided core walls have not collapsed, most occupants can safely vacate towers (using stairs). A few occupants may be trapped due to local structural failure, and require rescue. Building is not deemed safe (red tag) after inspection, and would require extensive structural repair before occupants can return. Building may not be economically repairable.

Collapse and Related Loss—Shear failure and localized crushing of core walls precipitates structural instability of the core and global collapse of the tower above the hinge zone. Most tower occupants are either killed immediately or trapped, requiring rescue. Collapse of the tower may affect other nearby buildings and structures, and the safety of people on the street. Building is a complete economic loss.

A.4.3 Tall Office Buildings Damage and Loss Scenarios (Handout 1B)

This note describes earthquake damage and loss scenarios for a portfolio of 40 tall (30- to 50-story) office towers assumed to exist in a high seismic region of coastal California. The office towers do not actually exist (yet) but represent buildings now being proposed for a number of cities in California. Each of these tall office towers is assumed to have a steel-frame system with metal deck and concrete fill floor plates, similar to buildings now under construction.

Estimates of damage and loss are provided for two levels of earthquake ground motions (1) rare, very strong ground motions, corresponding to a large-magnitude earthquake occurring on a fault relatively close to the buildings, and (2) occasional, strong ground motions corresponding to an event of smaller magnitude and more distant fault rupture. The first set of ground motions, or "Rare" earthquake scenario, has approximately a one in ten chance of occurring in 50 years. The second set of ground motions, or "Occasional" earthquake scenario, is likely to occur at least once in 50 years.

How a building will perform (in terms of damage and loss) in an earthquake is a function of the building's "seismic performance" properties (how the building was designed and constructed), as well as the strength of the ground motions at the building's site, all of which are different for different buildings (at sites). Hence, the amount or degree of damage and loss will be different for each building in an earthquake, even if they are all 30 to 50-story office towers).

Design and construction methods can significantly influence seismic performance and the distribution of damage and loss (e.g., among the 40 office towers) due to an earthquake. In this note, scenarios describe building damage for three hypothetical levels of seismic performance, identified as Level A, Level B, and Level C, respectively, reflecting differences in design and construction methods.

Tables 1 and 2 show the expected number of the 40 office towers to be damaged structurally for Rare and Occasional earthquake scenarios, respectively. In each table, the degree of structural damage is distinguished by one of five damage states: None/Slight, Moderate, Extensive, Complete and Collapse, respectively. For a given scenario and hypothetical performance level (i.e., a row in one of the tables) each of the 40 office towers must be in one of the five damage states (sum of the numbers in each row is 40).

Table 1 Rare earthquake scenario damage, one in ten chance of occurring during the life of office towers (e.g., 50 years)

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

Table 2 Occasional earthquake scenario damage, likely to occur at least once occurring during the life of 40 office towers (e.g., 50 years)

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

Building damage includes damage to non-structural systems and contents as well as the structural system, although damage to the structural system is most important in terms of the safety of building occupants and possible long-term closure of the building (for earthquake repairs). In this sense, the most important parameters for evaluating earthquake performance are the losses associated with structural damage. Table 3 provides some idea of how structural damage, described in Tables 1 and 2, would affect dollar losses and long-term building closure. Additional descriptions of the damage states and their consequences follow the table.

Table 3 General relationship between damage and loss

Damage State	Likely Amount of Damage, Loss, or Building Condition			
	Range of Possible Dollar Loss Ratios	Probability of Long-Term Building Closure	Probability of Partial or Full Collapse	Immediate Post-Earthquake Inspection
Slight	0% - 5%	$P = 0$	$P = 0$	Green Tag
Moderate	5% - 25%	$P = 0$	$P = 0$	Green Tag
Extensive	25% - 100%	$P \cong 0.5$	$P \cong 0$[1]	Yellow Tag
Complete	100%	$P \cong 1.0$	$P > 0$	Red Tag

[1] Extensive damage may include some localized collapse of the structure.

None or Slight Structural Damage and Related Loss—Some steel members experience minor yielding. The building has no residual drift and requires no structural repair.

Office towers are open following the event; elevators are operational. There is some loss due to non-structural and content damage.

Moderate Structural Damage and Related Loss—Some steel members experience significant yielding, fractured connections or localized buckling. Minor cracks in the floor slab and damage to ceiling and walls are expected near yielded or buckled members. The building may have some minor residual drift.

Occupants can safely vacate towers (using stairs—elevator not operational). Building is deemed safe (green tag) for occupancy after inspection, but requires structural repair. Non-structural and contents damage is more extensive than tower with None or Slight structural damage, with additional partition and cladding damage due to larger drift.

Extensive Structural Damage and Related Loss—Steel members experience significant yielding and some strength degradation, fractured connections or localized buckling. Large cracks in the floor slab and damage to ceiling and walls are expected near yielded or buckled members. The building may have a moderate level of residual drift.

Occupants can safely vacate towers (using stairs—elevator not operational). However, building is not deemed safe (yellow tag) after inspection, and requires significant structural repair before occupants can return. Non-structural and contents damage is similar to towers with Moderate structural damage in description, but is more extensive.

Complete Structural Damage and Related Loss—Steel members experience significant yielding and strength degradation, fractured connections or localized buckling. Significant cracking and possible deformation of floor slab and damage to ceiling and walls are expected near yielded or buckled members. Significant damage may be concentrated at one or more floors, resulting in partial building collapse. The building may have a significant level of residual drift.

Provided steel frames have not collapsed, most occupants can safely vacate towers (using stairs—elevator not operational). A few occupants may be trapped due to local structural failure, and require rescue. Building is not deemed safe (red tag) after inspection, and would require extensive structural repair before occupants can return. For moment-frame buildings, large residual deformation (on the order of 3–4%) is expected in the lower third of the building. Building may not be economically repairable.

Collapse and Related Loss—Significant damage (yielding and strength degradation, fractured connections, and buckling) to steel members are concentrated at one or more floors. Story mechanism forms resulting in partial building collapse.

Many tower occupants are trapped, requiring immediate rescue and some are killed. Collapse of the tower may affect other adjacent buildings and structures, and the safety of people on the street. Building is a complete economic loss.

A.4.4 Purpose and Intent of Building Codes (Handout 2)

Traditionally, a **building code** is a set of rules that specify the minimum acceptable level of safety for constructed objects such as buildings and other structures. The main purpose of the codes is to protect public health, safety, and general welfare as they relate to the construction and occupancy of buildings and other structures. The building code becomes law of a specific jurisdiction when formally enacted by an appropriate authority (i.e., city council).

Building codes that cover the earthquake hazard are intended to provide minimum standards for use in building design regulation to maintain public safety in the extreme ground shaking likely to occur during an earthquake. They are primarily intended to safeguard against major failures and loss of life, and are not intended to limit damage, maintain function, or provide for easy repair.

The building code used in California is based on the Uniform Building Code (UBC) which has been the model code used for many years. In addition to structural design, the Uniform Building

Code was amended to add an importance factor to be used in design based on the type of building occupancy. The objective of the assignment of an occupancy classification is to identify the primary uses of buildings and facilities and to identify risk factors associated with these uses to be considered in the design and construction in accordance with other provisions of this code. The risk factor for occupancy type is referred to as a building importance factor which is used in the design calculations.

More recently, the model codes used throughout the United States have been integrated into the International Conference Building Code (IBC) which will be the model code for California. The UBC and IBC include building-performance criteria appropriate for the various functions and uses. These performance criteria are expressed as occupancy categories. Each occupancy category has an importance factor (I) that is used in the structural design of buildings in the specific occupancy category. The IBC states that where differences occur between provisions of the IBC and referenced codes and standards, the provisions of the IBC will apply. The occupancy categories are summarized as follows:

<u>Occupancy Category I and II</u>:

> Earthquake-caused damage for a normal building in this category is to be limited so as to minimize the risk of serious or life-threatening injury to occupants and passers-by. Variations in local conditions (i.e., ground motions) and performance among various structural systems and designs will result in different levels of "minimal damage"; however, it is to be noted that code design requirements are not intended to minimize economic losses or preserve function.

<u>Occupancy Category III</u>:

> This occupancy category represents a higher risk to the health and safety of the general public than Category I or II because of the large number of building occupants and the potential that loss of function will result in significant disruption to the community. However, as with Category I and II, the requirements of the building code are not intended to minimize overall economic losses or preserve all functions for buildings.

<u>Occupancy Category IV</u>:

> Buildings in Category IV are deemed to be essential after an earthquake and the requirements of the code design requirements are intended to limit damage to allow continuous occupancy or rapid re-occupancy. The function or use of a building in this category is to remain continuously operational during and after an earthquake. Seismic damage of structural and non-structural systems directly associated with buildings in this occupancy category is to be limited to require only minor cleanup or repair.

The current Uniform Building Code provides the following importance factors, for building occupancies, which are to be used to amplify design seismic forces. However, there has been no research or field evidence (from actual earthquakes) that these amplified forces will deliver the performance indicated in the various occupancy categories.

Occupancy	Importance Factor
Essential Facility	1.5
Occupant Load Greater than 5000*	1.25
All Normal Buildings	1.00

*The current UBC specifies an occupancy load for this category of greater than 5000 as a "Special Occupancy" along with buildings containing toxic or explosive materials.

The intent of seismic building code design requirements is to produce buildings that provide reasonable assurance that in the event of an earthquake the seismic performance of the building will (1) avoid serious injury and life loss, (2) avoid loss of function in critical facilities, and (3) avoid unreasonable economic loss. The ability to accomplish these performance goals depends on a number of factors including the structural framing type, building configuration, materials, as-built details of construction, and the overall quality of design. It is important to note that a building with an occupancy classified as normal (i.e., building is not considered essential or does not have a large occupancy load), the basic seismic design importance factor of 1 would not normally require any special design consideration.

A.5 INTERVIEW OUTLINE AND RESPONSE FORM AND EXAMPLE INTERVIEWEE RESPONSES

An extensive form, titled "Interview Outline and Response Form" was developed for guiding the interview and documenting stakeholder responses.

A copy of the Interview Outline and Response Form follows and includes example responses (shown in italics font) of one of the stakeholders interviewed. As may be noted, not all form questions have a response. In some cases, redundant questions were simply skipped; in other cases, the interviewee opinions (although quite valuable) did not fit the structured approach of the form (and were documented at the end of the form as "Other related comments."

Stakeholder___________________________________
Date ___________________________________

Interview Outline and Response Form

PEER Tall Buildings Initiative Task 2: Consensus Seismic Performance Objectives

(1) Briefly explain to interviewee **Background of the Project**
  - (a) A resurgence of high-rise construction on the West Coast has renewed interest in the earthquake performance of tall buildings.
  - (b) The use of certain cost-effective structural systems and configurations has been proposed for condos that exceed the height limits specified for these seismic systems in the building code. Engineers have produced designs for these buildings aimed at providing performance that is "equivalent" to the code in order to obtain special approval to build them this way.
  - (c) Both the appropriate performance and the methods that engineers use to show equivalence have become issues of policy as well as engineering design.
  - (d) The Pacific Earthquake Engineering Research Center (PEER) has started a program to study these issues.
    - (i) Briefly describe PEER.
    - (ii) Briefly describe project.
  - (e) This project deals only with structural design; non-structural components, such as exterior cladding, elevators, and contents are not to be considered in detail in this study and are not included in damage descriptions that were sent out.
  - (f) The task that our group is working on is to establish the seismic performance (approximate level of damage in various sized earthquakes) that should be targeted in design of these buildings. The easiest way to describe such performance is to compare it with all other new buildings designed to building codes. That is, should tall buildings be considered as "normal" buildings or be considered special with better than normal performance.
  - (g) The purpose of this interview (and several others with other stakeholders) is to obtain opinions regarding appropriate seismic performance. These opinions can be personal opinions or opinions influenced by a professional interest.

Notes on this segment (if applicable):

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____
____
____
____

Stakeholder________________________________
Date ________________________________

(2) **Discussion of Background Material**

(a) Do you have any questions about the document that describes the Background of the Code (Petak document)?

(i) Note the main traditional intent of code.

(ii) Note that no current requirements would identify these buildings as "special" (Occupancy Category III or IV).

Areas of confusion with Background of Code or Occupancy Categories:

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____

(b) Do you have any questions about the Damage and Loss Scenario documents (Kircher and Youssef documents)?

(i) Specifically the spread of performance shown?

(ii) What are your reactions to any of the three seismic performance levels shown (Level A, Level B, and Level C)? Discuss the fact that some small possibility of serious damage and even collapse always exists (just like plane crashes).

Which level (A, B, or C) do you think the present code is expected by earthquake experts to give?

____
____

(1) Identify Level B as code. Is the interviewee surprised?

Did you expect better or worse performance from a normal "code-level" building?

____
____
____
____
____

Stakeholder__________________________________
Date ___________________________________

(3) **Questions about appropriate performance of tall buildings**

Based on our discussion so far,

Do you think a "tall" building should be designed to have seismic performance like a normal building?

Does this opinion vary by occupancy? That is, should a tall condo be different than a tall office building or a tall hotel?

If you think that these tall buildings are not particularly special, and should therefore be considered like all other buildings, is the "normal" performance expectation previously discussed adequate? If not, the implication is that the <u>*entire*</u> *seismic code should be upgraded (which is an acceptable answer).*

Stakeholder____________________________________
Date ____________________________________

(4) **Interviewee's Special Interests**

(a) Realistically, the interviewee may have trouble differentiating personal opinion from "professional" position affecting their business. This is ok. Record both.

(b) (**For developer/owner/lender/insurance reps**) Would the different levels of risk shown in any way affect your business interests?

How will expected performance levels affect your business?

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Does this lead you to want a specific seismic performance objective for tall buildings?

____
____

Like "normal building?"

____
____

Better than normal building?

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____

Improving code structural performance will increase construction cost. How much is this improvement (if desired) worth to you?

Circle acceptable cost premium: 2% 5% 10% Other____%

Stakeholder________________________________
Date ________________________________

(c) For non-business interested parties **(owner, development advocate, housing advocate**) Would different levels of performance affect your interests? Interests meaning loss of housing, loss of development in community, etc.)

How will expected performance affect your interests?

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____
____

Does this lead you to want a specific seismic performance objective for tall buildings?
____
____

Like "normal building?"
____
____

Better than normal building?
____
____
____

Improving code structural performance will increase construction cost. How much is this improvement (if desired) worth to you?

Circle acceptable cost premium: 2% 5% 10% Other____%

Stakeholder___________________________________
Date ___________________________________

(5) **Summary**

(a) Does this stakeholder think that tall buildings should have better performance than a "normal" code building?

Circle Interviewee's Response: Yes No

(i) Does this opinion vary by occupancy?

Circle Interviewee's Response: Yes No

If yes, explain (with "cutoff" occupancy numbers if possible):

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(ii) Can the improved performance goal (if recommended) be identified?

Recommended improved performance goal:

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Task 2 Interviewers:

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A.6 COMPILATION OF PRE-WORKSHOP STAKEHOLDER OPINIONS AND PERSPECTIVES

This section summarizes pre-workshop opinions and perspectives gleaned from "tall building" stakeholder responses recorded during interviews. These opinions and perspectives are grouped by one of the following five topical categories:

Topic 1 Code-Expected Performance of Normal Buildings

Topic 2 Disclosure and Understanding Risk.

Topic 3a Should Tall Buildings Perform Better? (Pro Opinions)

Topic 3b Should Tall Buildings Perform Better? (Con Opinions)

Topic 4a Should Residential Occupancies Perform Better? (Pro Opinions)

Topic 4b Should Residential Occupancies Perform Better? (Con Opinions)

Topic 5 Acceptable Cost Premium for Better Performance?

Topic 1 Code-Expected Performance of Normal Buildings

- For a major earthquake, this interviewee believed that this standard (Level B) was ***not acceptable.*** New buildings should ***not ever*** collapse or experience complete failure/irreparability.
- Interviewee was surprised that Level B was code level. Clearly expected better performance from a new building, even given the long return-period/relatively low risk of a large earthquake.
- Interviewee said that building failure was not acceptable for new buildings, and that life safety was certainly a minimum expectation for all construction.
- Interviewee understood that ordinarily the code minimum is a life-safety standard, but also indicated that the public expects more from buildings.
- Interviewee stated that collapse of any modern building in any considered earthquake is entirely unacceptable to the public.
- Interviewee's assumption and the implied promise for all new buildings is that buildings meet life-safety standards and will not suffer major damage in any anticipated earthquake, even a great quake. city and developers are well aware of the factors involved and should address them—it is irresponsible of the city officials not to.
- People have a right to expect no more than moderate damage even in a major earthquake.

Topic 2 Disclosure and Understanding Risk

- Buildings could be graded or otherwise disclosed so that buyers of new tall buildings will understand what they are getting. If such disclosure is provided, the purchasers and the marketplace will drive up performance.
- It is our moral responsibility, interviewee said, to disclose anticipated performance to buyers/users. Similar to very strong Australian disclosure laws, interviewee believes that any disclosure laws should be statewide, not local.
- Interviewee strongly advocates disclosure of risks and anticipated performance, including serviceability and fire risks. This disclosure is necessary as a part of the "risk management" of development, where risk is transferred from the developers to the owners/occupants/insurers/city. It must be made clear what risk is being transferred.
- Interviewee felt strongly that information about intended building performance and risk, both structural and non-structural, must be fully disclosed to buyers. Expressed a view that developers would likely not provide that information or to take other actions to build or provide information above minimum standards unless required to do so.
- Interviewee is currently researching insurance issues for the condo association and finds that straightforward information about coverage and costs is hard to get, and information is not user friendly. Just as in the building's structural performance, Interviewee feels he is not getting disclosure, and that condo owners could be embroiled in extensive insurance disputes after an earthquake.
- Interviewee said that public disclosure of anticipated building performance should be required; ideally, a posting would be at the entry of every building that rates the building's intended performance.
- The great need is to be able to clearly articulate performance levels and risks.
- Interviewee believes that the public needs education to develop reasonable expectations of building performance: building condo owners might reasonably use a method similar to the PML analysis used for lenders to evaluate their own risks.
- He said that interviewee does not expect there to be a MCE event in his lifetime, although interviewee does expect a Hayward event causing substantial infrastructure problems. Interviewee believes that it even might be somewhere between Table 1 and Table 2 (greater than MPE and less than MCE).
- I can't relate to risks described in a 100-year period of time.
- Interviewee believed that Loma Prieta had a negative effect on public interest in increased levels of seismic safety because there were few areas of damage and few seriously damaged buildings. The public thinks that most buildings will perform OK.

Topic 3a Should Tall Buildings Perform Better? (Pro Opinions)

- Yes, should be better than a "normal" building for a variety of reasons, including the possible impacts of building performance on adjoining buildings and properties, and the many concessions, accommodations, and special approvals allowing density, height and related views, and other factors that the city provides for these tall buildings.
- The performance of buildings will reflect on the reputation of the developer and builders.
- Interviewee believed that tall buildings should be designed and built to a higher performance standard (structural and non-structural) than other buildings because of the major investment in many ways on the part of the city, many other organizations, and agencies involved in the project entitlement and approval process for these buildings. Interviewee further bases this on the potential for severe impacts on the tall building occupants, on the neighborhoods that are created by these tall buildings, and on the city of a non-serviceable tall building.
- Yes, interviewee believed that a higher standard should be required for tall buildings. This is a special class of buildings. Noted that the approval of tall buildings requires resolution of many issues having greater impacts on occupants, neighbors, and the city than other/low-rise buildings; that tall buildings have a great impact on the city and city services; that there are high-occupant loads on small land area in high-rises; and, because of few exits and the other special conditions of high-rises, there is a need to increase resistance to the potential impacts of building fire, structural damage, or failure.
- Tall buildings should meet a higher standard due to their many special conditions, including glass and façade falling hazards from very high posing higher risks. They are given special approvals, sell at very high prices, and should require special standards of performance. Due to the higher risks posed by high-rise buildings, they need a higher level of confidence that buildings will perform as intended.
- All three interviewees (building owners) stated that performance levels for tall buildings should take community resilience into consideration in that recovery of a community following an event will be directly influenced by the numbers of people and businesses dislocated, and the longer the recovery takes the greater the economic effect on individual property owners.
- Building owner group agreed that tall buildings (30 to 70 stories) should have a higher performance. Tall buildings with their higher occupancy should be built at a higher performance level than a normal building and the code should reflect this higher risk in terms of life loss and community/economic resilience.
- All interviewees (in this case representatives of building owners) believe that the code should require a higher performance for tall buildings, specifically for the "Rare event." The loss consequences would be devastating for commercial property owners, condo owners, and the community
- The commercial property owner stated that property owners do not want to see large numbers of buildings badly damaged in an area because it will directly affect their business as property owners. The same applies to supporting infrastructure.
- Higher performance standards would result in less damage to the housing stock and thus may be less taxing on local government resources (emergency personnel, housing/shelter,

etc.) after an earthquake. Market would adjust to the higher standards, since requirements would be implemented industry wide; thus long-term tax base would not be affected

- Fire and other life-safety professionals are increasingly concerned about loss of elevators in tall buildings for any reason. An ASME committee is currently working on this issue.

Topic 3b Should Tall Buildings Perform Better? (Con Opinions)

- The owner representative also made clear that the position of the owner in terms of the business objectives of owning for the "long term" versus the "short term" (3–5 years) will influence attitudes toward performance levels and expectations. Interviewee made the point that it is really all about cost and business performance, although interviewee believes that all owners are interested in protecting people.
- No need for better. Current standards and intentions of developers to provide a quality product (at least this developer) do not require special requirements. Interviewee asks, rhetorically, if there is some past problem with tall buildings that needs to be addressed—how have they performed in past earthquakes?
- Financial: Only concern is making sure the PML is appropriate for the loan. PML is a major factor in the lending decision. PML as determined by a seismic professional/firm is what counts in the lending decision.
- As long as buildings are built to code there will be no affect on the lending business [if required performance levels were to change].
- The condition in the market is a major factor. Liquidity in the financial market makes a big difference in the perspective on risk of the investment. Today insurance is generally not required as a basis for a loan because there is a lot of competition due to the level of liquidity. A tight market allows for making demands by the lender to better protect lender. Small owners tend to be stuck with needing insurance, but large owners are not. The market manipulates the loan requirements. The rate of return to the investor and lender is the measure that really counts.

Topic 4a Should Residential Occupancies Perform Better? (Pro Opinions)

- Home has a unique value in our society. Currently, the corporate entities and developers are setting unknown standards for housing and selling homes to the naive, less-sophisticated consumer.
- Residential occupancies require a higher standard due to 24-hour/7-day use and the resulting direct impacts on people's lives. Also, public agencies have a greater responsibility to deal with displacement and other impacts on residential occupants. Modern buildings should not exacerbate the burdens [on city government] such as displacement problems.
- The uses of these high-rises are often residences for older persons who anticipate living in them for a long time, making them more vulnerable to impacts of structural and non-structural damage. Most of these people cannot use emergency stairs from upper floors if elevators are unusable, perhaps requiring a higher level of serviceability.
- If the elevators are not in service, a tall condo building is essentially out of business.

Topic 4b Should Residential Occupancies Perform Better? (Con Opinions)

- Building owner group agreed that types of occupancy of tall buildings should be of equal risk and the performance of tall buildings should not be governed by occupancy type.
- A lender is not likely to be concerned about the building occupancy as long as the package meets all the lending criteria in terms of quality of the borrower, the market, and meeting the loan PML requirements.

Topic 5 Acceptable Cost Premium for Better Performance?

- 10–15%
- 10%
- Increasing the cost of a unit from $1,000,000 to $1,100,000 would be acceptable.
- Level A performance should be required as a minimum standard at any cost, and should be considered part of the cost of development.
- YES, for tall buildings but ultimate decision will be based on the market according to commercial building owner—that is, the ability of the market place to pay higher rent, etc. Also, better performance is marketed to clients. (5% of cost of shell and core, pending market.

A.7 REFERENCES (APPENDIX A)

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Appendix B: PEER Tall Buildings Task Workshop

B.1 INTRODUCTION

The workshop was held April 18, 2007, at the Facility Club of the University of California, Berkeley. This appendix report is organized in the order of the Workshop Agenda in Section B.2. Following sections are B.3 Attendees, B.4 Presentations, and B.5 Summary of Break-out Sessions.

B.2 WORKSHOP AGENDA

Time	Topic	Leader
9:00	Welcome	Holmes
9:05	Description of tall buildings project	Moehle
9:15	Description and purpose of Task 2	Holmes
9:20	Self introductions	All
9:30	Background of seismic codes and performance expectations	Holmes
10:00	Interview process	Kircher
10:15	Brief summary of interview results and issues	Holmes
10:30	Break	
10:45	First break-out session*	
	Is current code goal acceptable?	
	Understanding risk and disclosure issues	Kircher, Petak, Youssef
12:00	Lunch	
1:00	Discussion of first break-out session	Holmes
1:30	Second break-out session*	
	Should tall buildings be better? If so, how?	
	Are residential tall buildings different?	
	Cost premium	Kircher, Petak, Youssef
2:45	Break	
3:00	Discussion of second break-out session	Holmes
3:30	Wrap-up	
4:00	Adjourn	

*Break-out Sessions: Intended to obtain mini-consensus on ideas from interviews.
Considering each summary interview statement, decide if point is persuasive (P), non-persuasive (NP), or not a factor (NF). If opinion on tall buildings actually applies to all buildings, classify it as non-persuasive (NP). Add any new ideas by the group.

B.3 WORKSHOP ATTENDEES

Peer Tall Buildings Task 2 Workshop Attendees	
Name	**Discipline**
William Holmes	Structural Engineer
Karl Telleen	Structural Engineer
Charles Kircher	Structural Engineer
William Petak	Public Policy
Nabih Youssef	Structural Engineer
Jack Moehle	Academic Structural Engineer
Yousef Bozorgnia	Ground Motion
Marshall Lew	Ground Motion/Geotech
Mark Moore	Structural Engineer
Don Strand	Structural Engineer
Jon Heintz	Structural Engineer /ATC
Nico Luco	USGS ground motion
Bob Hanson	Prof. familiar with current R/D
John Hooper	SE Designer of Tall Bldgs.
Joe Maffei	SE SF Ad Bulletin chair
Bob Anderson	SSC CEA
Mary Comerio	Architect, Housing
Laurie Johnson	city Planner
Tim Carey	The Related Companies
Brendan Dunnigan	HKS
Ken Paige	Condo Owner, Pres Condo Assoc.
Ned Fennie	Architect/SF Code Advisory Committee
Ross Asselstine	Developer
Asselstine	Son of Asselstine

B.4 WORKSHOP PRESENTATIONS

B.4.1 Presentation 1—Description of Tall Buildings Project (by Moehle)

Task 2

PEER Tall Buildings Initiative—Task 2 Workshop 1
April 18, 2007

Purpose of Task 2

- **Task Official Charge: "Using an appropriate methodology, develop a consensus on performance objectives [for tall buildings]."**
- Current design of many tall concrete condos under "Alternate Means" provisions of the code—forcing performance-based designs–generates the question of target performance and several sub-issues:
  – What is the performance expected of code buildings (that is to be matched in "Alternate Means" designs)?
  – Should these buildings be better than "normal code?"
  – Better in what performance category and how much better?

PEER Tall Buildings Initiative—Task 2 Workshop 2
April 18, 2007

Evolving Output of Task 2

- "Consensus" opinions for stakeholder groups larger than immediately associated with the project is difficult if not impossible to identify within the confines of this project.
- Based on interviews and a workshop, Task Group 2 will make recommendations to PEER on the following subjects:
  – Improved parameters to communicate earthquake risk to stakeholders
  – A reasonable interpretation of "normal" code performance if this is apparently acceptable
  – Whether there are strong feelings among stakeholders that tall building should be designed to perform better than normal buildings and for what reasons

PEER Tall Buildings Initiative—Task 2 Workshop 3
April 18, 2007

Follow-up of Conclusions of Task 2

- Follow-up, outside the PEER Tall Buildings Initiative is not planned as a formal activity of the Task 2 Group.
- Task 2 Group recognizes that recommendation to design tall buildings for enhanced performance:
  – Nationally is a code change issue and would be required to go through normal code change processes
  – Locally, as an alternate, is a public policy issue to be decides locally

PEER Tall Buildings Initiative—Task 2 Workshop 4
April 18, 2007

Preliminary Results
Understanding Risk and Disclosure

- Stakeholders were surprised by, and not necessarily accepting of, current code performance expectations for normal buildings, which could include long term closure or economically infeasible repair costs, and even a very small, but real, chance of collapse in the MCE.
- The public needs education to develop reasonable expectations of building performance: building condo owners might reasonably use a method similar to the PML analysis used for lenders to evaluate their own risks.
- The great need is to be able to clearly articulate performance levels and risks
- Stakeholders strongly advocate disclosure of risks and anticipated performance, including serviceability and fire risks. This disclosure is necessary as a part of the "risk management" of development, where risk is transferred from the developers to the owners/occupants/insurers/City. It must be made clear what risk is being transferred.

PEER Tall Buildings Initiative—Task 2 Workshop 5
April 18, 2007

Preliminary Conclusions
Tall Buildings should have "better" (or at least more reliable) performance than normal buildings

- Many believed that a higher standard should be required for tall buildings. This is a special class of buildings. Noted that the approval of tall buildings requires resolution of many issues having greater impacts on occupants, neighbors and the City than other/low-rise buildings; that tall buildings have a great impact on the City and City services; that there are high occupant loads on small land area in high-rises; and, because of few exits and the other special conditions of high-rises, there is a need to increase resistance to the potential impacts of building fire, structural damage or failure.
- Many stakeholders felt that the loss consequences of collapse, long term closure, or even serious damage would be devastating for commercial property owners, condo owners and the community, suggesting

PEER Tall Buildings Initiative—Task 2 Workshop 6
April 18, 2007

B.4.2 Presentation 2—Description and Purpose of Task 2 (by Holmes)

Description and Purpose of Task 2

PEER Tall Buildings Initiative—Task 2 Workshop
April 18, 2007 1

Purpose of Task 2

- Task Official Charge: "Using an appropriate methodology, develop a consensus on performance objectives [for tall buildings]."
- Current design of many tall concrete condos under "Alternate Means" provisions of the code—forcing performance-based designs–generates the question of target performance and several sub-issues:
  - What is the performance expected of code buildings (that is to be matched in "Alternate Means" designs)?
  - Should these buildings be better than "normal code?"
  - Better in what performance category and how much better?

PEER Tall Buildings Initiative—Task 2 Workshop
April 18, 2007 2

Evolving Output of Task 2

- Consensus (National? State? SF? and LA?) difficult if not impossible to identify within the confines of this project.
- Based on interviews and this workshop, Task Group 2 will recommend
  - Improved parameters to communicate earthquake risk to stakeholders
  - A reasonable interpretation of "normal" code performance if this is apparently acceptable
  - Whether there are strong feelings among stakeholders that tall building should be designed to perform better than normal buildings and for what reasons

PEER Tall Buildings Initiative—Task 2 Workshop
April 18, 2007 3

Evolving Output of Task 2

- A recommendation to design tall buildings for enhanced performance:
  - Nationally is a code change issue and would be required to go through normal code change processes
  - Locally, as an alternate, is a public policy issue
  - If recommended, will be an important consideration for the balance of the Tall Buildings Initiative

PEER Tall Buildings Initiative—Task 2 Workshop
April 18, 2007 4

Purpose of Workshop

- To present overall results of interviews
- To discuss and clarify important issues identified by interviews
- To identify and capture new issues or recommendations during discussions.

PEER Tall Buildings Initiative—Task 2 Workshop
April 18, 2007 5

What is next?

- Issue Group 2 will document main points from interviews and workshop in a report
- Issue Group 2 will make recommendations to the Tall Building Initiative regarding performance considerations

PEER Tall Buildings Initiative—Task 2 Workshop
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B.4.3 Presentation 3—Background of Seismic Codes and Performance Expectations (by Holmes)

Background of Seismic Codes and Performance Expectations

PEER Tall Buildings Initiative—Task 2 Workshop
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Background of Building Codes

- 1666 London fire resulted in first comprehensive building code and set precedent for government enforced codes
- Each country has its own somewhat unique history of how authority for building codes evolved.
- Important principal of U.S. Constitution is delegation of *police power* to states:
  - Police power is the authority to regulate for the health, safety, and general welfare of its citizens.
  - Typical Building Code *Purpose* statement:
    - The purpose of this code is to provide minimum standards to safeguard life or limb, health, property, and public welfare by regulating and controlling the design, construction, quality of materials, use and occupancy, location and maintenance of all buildings and structures…

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Background of Seismic Codes

- 1755 Lisbon devastating earthquake resulted in prescriptive rules for building certain kinds of buildings common in the area
- Events in Messina, Italy (1911), and Kanto (Tokyo) Japan (19023) led to guidelines for engineers to design buildings for horizontal forces of about 10% of the weight of the building.
- 1906 San Francisco, interestingly, produced little or no code development in the US.
- 1925 San Barbara convinces critical mass in California on the need for seismic requirements
- 1927 First seismic regulations as voluntary appendix in 1927 Uniform Building Code
- 1933 Long Beach results in CA legislature passing the Field Act (for schools) and the Riley Act (for all buildings).
- Code under constant evolution since 1927, with changes often instigated by earthquakes in CA.

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Charleston, 1886

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San Francisco, 1906

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Santa Barbara, 1925

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Long Beach, 1933

Purpose of First Codes Clear

- Prevent collapse
- Prevent heavy materials falling to street
- Size or rareness of earthquake not specified—and probably not understood. References are to "earthquake loading"

Introduction to 1927 UBC Lateral Bracing Appendix

"The design of buildings for earthquake shocks is a moot question but the following provisions will provide adequate additional strength when applied in the design of buildings or structures."

Enduring Performance Intent by Structural Engineers Association of California*

Recommended Lateral Force Requirements and Commentary, SEAOC, 1968

"The SEAOC Code is intended to provide criteria to fulfill the purposes of building codes generally. More specifically with regard to earthquakes, structures designed in conformance with the provisions and principles set forth therein should be able to:

1. Resist minor earthquakes without damage;
2. Resist moderate earthquakes without structural damage, but with some nonstructural damage;
3. Resist major earthquakes, of the intensity of severity of the strongest experienced in California, without collapse, but with some structural as well as nonstructural damage.

In most structures, it is expected that structural damage, even in a major earthquake, could be limited to repairable damage. This, however, depends on a number of factors…"

Current Evolution

- "Earthquake" changed to "ground motion":
- Item 3 word-smithed: "Resist a major level of earthquake ground motion—of an intensity equal to the strongest earthquake, either experienced or forecast, for the building site—without collapse, but possibly with some structural as well as nonstructural damage."
- "…damage limited to repairable level for most structures… In some instances, damage may not be economically repairable."
- "No Guarantee" paragraph added:
  "…While damage to the primary structural system may be either negligible or significant, repairable or virtually irrepairable, it is reasonable to expect that a well planned and constructed structure will not collapse in a major earthquake. The protection of life is reasonable provided, but not with complete assurance."

No Zero Risk*

First explicit discussion of actual risks for building construction appeared in commentary of ATC 3, which was intended to develop more rational and scientific seismic design provisions. (Tentative Provisions for the Development of Seismic Regulations for Buildings, ATC, 1978)

"It is not possible by means of a building code to provide a guarantee that buildings will not fail in some way that will endanger people as a result of an earthquake. While a code cannot ensure the absolute safety of buildings, it may be desirable that it should not do so as the resources to construct buildings are limited. Society must decide how it will allocate the available resources among the various ways in which it desires to protect life safety. One way or another, the anticipated benefits of various life protecting programs must be weighed against the cost of implementing such programs."

ATC 3 suggested that this risk is primarily due to uncertainty in the characteristics of the ground motion…

Now, we might also add a healthy dose of uncertainty due to our inability to write code provisions that will produce a narrow band of seismic performance for each of the many combinations of structural systems and building configurations built in the US.

More… No Zero Risk

- More from ATC 3: "If the design ground motion were to occur, there might be life-threatening damage in 1 to 2 percent of buildings designed in accordance with the provisions. If ground motions two or three times as strong as the design ground motions were to occur, the percentage of buildings with life-threatening damage might rise to about 10 to 50 percent respectively."
- Current research that studied only a couple of structural types concluded that for ground motions 1.5 times as great as our design ground motions, about 10% of code designed buildings may fail. (ATC 63, in progress).
- This led to the interview scenarios, describing <u>normal code buildings</u>

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

Definition of ground motions for performance objectives*

- Initially: "earthquake shaking"
- SEAOC: minor, moderate, major earthquake; later ground motion
- SEAOC/UBC: Design Basis Event (DBE): 10% chance of exceedance in 50 years or 475 year return period
  - Commonly called the 500 year event
  - Sometimes called the Rare event
- 1997 National Mapping of Maximum Considered Earthquake Ground Motions (MCE)
  - Sometimes called the Very Rare Event
  - The DBE became 2/3 of the MCE
  - Code focus became preventing collapse under MCE

Performance Based Engineering

- In 1991-1997, a new seismic retrofit guideline document (FEMA 273) became available that, for the first time, defined various performance levels:
  - Operational
  - Immediate Occupancy
  - Life Safety
  - Collapse Prevention
- When coupled with defined ground motion, a *Performance Objective* is formed. For example
  - Life Safety for the DBE
  - Collapse Prevention for the MCE
- Due to the many uncertainties involved, ability to predict or design to these objectives is limited, but the terminology forms a convenient system and has started a movement for better communication

B.4.4 Presentation 4—Interview Process (by Kircher)

Methodology

- Interview stakeholders
  - Owners—condo units
  - Owners---long term building owners
  - Developers
  - City Planners
  - Building Officials
  - Lenders
  - Insurers
  - Urban Economists
- Hold workshop to discuss and focus results
- Task 2 Committee to make recommendations for the balance of the Tall Buildings Initiative.

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Interview Material

- Prep materials developed
  - Two page primer on building codes
    - Target Life Safety
    - Buildings judged important designated by occupancy and function
    - Tall buildings generally not so designated (only if >5000 occupants)
  - Tall Building and Loss Scenario

Table 1. Rare earthquake scenario damage, one in ten chance of occurring during the life of condominium towers (e.g., 50 years)

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

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Interviews and Workshop

- Interview outline and response form
  - Explain background of project
  - Discuss background material
    - Specifically Performance Level A, B, and C
    - Specifically that code can not provide a "no-risk" condition
  - Seismic performance of tall buildings
    - Should tall buildings be designed to have seismic performance any different that "normal" buildings?
    - If better, in what way?
    - Does opinion vary by occupancy (condos vs. office/hotel, etc.)
- Committee performed 15 interviews.
- A total of 21 engineers, interviewees, and other interested parties attended an all day workshop to discuss responses given in interviews.

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B.4.5 Presentation 5—Brief Summary of Interviews: Results and Issues (by Holmes)

Performance Based Engineering

- Current development of PBE is concentrating on estimating in probabilistic terms the primary losses from earthquake shaking
  - Casualties
  - Repair costs
  - Loss of use of building
  - Politically incorrectly called "death, dollars, and downtime"
- Communication with stakeholders may be more direct, but the acceptability by stakeholders of the probabilistic basis is unclear.*

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Summary of Survey Results

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Code Expectations for Normal Buildings

- "For a major earthquake, this interviewee believed that this standard (Level B) was ***not acceptable.*** New buildings should ***not ever*** collapse or experience complete failure/irreparability. "
- "People have a right to expect no more than moderate damage in even a major earthquake."

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Understanding Risk and Disclosure

- Interviewee believes that the public needs education to develop reasonable expectations of building performance: building condo owners might reasonably use a method similar to the PML analysis used for lenders to evaluate their own risks.
- The great need is to be able to clearly articulate performance levels and risks
- Interviewee strongly advocates disclosure of risks and anticipated performance, including serviceability and fire risks. This disclosure is necessary as a part of the "risk management" of development, where risk is transferred from the developers to the owners/occupants/insurers/City. It must be made clear what risk is being transferred
- It is our moral responsibility, interviewee said, to disclose anticipated performance to buyers/users. Similar to very strong Australian disclosure laws, interviewee believes that any disclosure laws should be statewide, not local

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Not my building

- Interviewee was certain and quite emphatic that buildings in which he/she is involved perform at the high-end of code-required performance expectations. Interviewee noted that 10% risk of major damage or collapse meant that 90% of buildings would **not be** in that damage state.
- My condo is in a modern building. The poor end of Level B performance would not apply to in my circumstance

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Tall Buildings should have better performance

- Yes, interviewee believed that a higher standard should be required for tall buildings. This is a special class of buildings. Noted that the approval of tall buildings requires resolution of many issues having greater impacts on occupants, neighbors and the City than other/low-rise buildings; that tall buildings have a great impact on the City and City services; that there are high occupant loads on small land area in high-rises; and, because of few exits and the other special conditions of high-rises, there is a need to increase resistance to the potential impacts of building fire, structural damage or failure.
- All interviewees (in this case representatives of building owners) believe that the code should require a higher performance for tall buildings, specifically for the "rare event". The loss consequences would be devastating for commercial property owners, condo owners and the community

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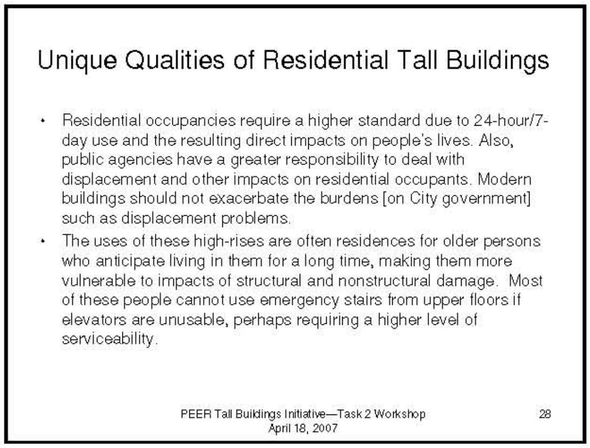

B.5 WORKSHOP HANDOUTS

Topics and interview summaries developed from the interviews with the stakeholders were the basis for the individual group discussions. Each break-out group made a judgment about the statements listed under the topics listed under compilation of Pre-Workshop Stakeholder Opinions and Perspectives, Section A.6 in Appendix A.

B.6 SUMMARY OF BREAK-OUT DISCUSSION GROUPS

B.6.1 BREAK-OUT GROUP 1 (DISCUSSION LEADER: C. KIRCHER)

FIRST BREAK-OUT SESSION (TOPICS I AND II)

Group Members:

Charles Kircher (Group Leader)
Don Strand—SE
Nico Luco—USGS
John Hooper—SE
Laurie Johnson—City Planner
Ross Asselstine—Developer

<u>Topic I:</u> Code-Expected Performance of Normal Buildings

Primary Findings: There is significant disconnect between code-expected performance of buildings in a major earthquake, and the level of performance acceptable to most stakeholders. In general, stakeholders expect significantly better performance of buildings (in a major earthquake) than that corresponding to the minimum life-safety requirements of the Code for Occupancy Category I and II buildings. Further, stakeholders expect buildings to be functional, as well as safe, in a major earthquake. Finally, stakeholders recognize that life safety and functionality (and limited damage) cannot be guaranteed in a major earthquake, but that normal buildings should be designed/constructed to meet these objectives (and that buildings should reliably meet these objectives in a major earthquake).

The following Topic I statements were scored (1) Non-Persuasive (NP), (2) Persuasive (P), or (3) Not a factor (NF) by the group for the reasons given below.

1. For a major earthquake, this interviewee believed that this standard (Level B) was not acceptable. New buildings should not ever collapse or experience complete failure/irreparability.

   NP—Okay as objective, but too absolute in terms of actual performance.

2. Interviewee was surprised that Level B was code level. Clearly expected better performance from a new building, even given the long return-period/relatively low risk of a large earthquake.

   NF—Disconnect between code and stakeholder expectations.

3. Interviewee said that building collapse was not acceptable for new buildings and that life safety was certainly a minimum expectation for all construction.

   P—Okay, recognizing that life safety cannot be guaranteed (with 100% certainty) and that failure may be taken to mean collapse (as edited above).

4. Interviewee understood that ordinarily the code minimum is a life-safety standard, but also indicated that the public expects more from buildings.

   NF—Disconnect between code and stakeholder expectations.

5. Interviewee stated that collapse of any modern building in any considered earthquake is entirely unacceptable to the public.

   NP—Okay as objective (for a major earthquake), but too absolute in terms of actual performance (and too strong for moderate earthquake).

6. Interviewee's assumption and the implied promise for all new buildings is that buildings meet life-safety standards and will not suffer major damage in any anticipated earthquake, even a great quake. City and developers are well aware of the factors involved and should address them—it is irresponsible of the city officials not to.

   NP—Okay as objective, but too absolute in terms of actual performance ("in any earthquake").

7. People have a right to expect no more than moderate damage even in a major earthquake.

   NP/P—Okay as objective, but too absolute in terms of actual performance (if the term "expect" taken to mean 100% certainty). Statement would be persuasive, however, if the term "expect" were taken to mean "50% of the time." That is, stakeholders generally expect to have limited damage to their buildings most of the time, even in a major earthquake.

<u>Topic II:</u> Disclosure and Understanding Risk

Primary Findings: In general, there is a significant need to better communicate the risk (anticipated performance of buildings in a major earthquake) to all stakeholders. Specifically, risk should be disclosed by owners (e.g., by developers) to potential building buyers (e.g., of condos) and other affected stakeholders. Risk disclosure requires a practical method (e.g., grading system), that can readily be understood and used in decision making by non-technical stakeholders.

The following Topic II statements were scored (1) Non-Persuasive (NP), (2) Persuasive (P), or (3) Not a factor (NF) by the group for the reasons given below.

1. Buildings could be graded or otherwise disclosed so that buyers of new tall buildings will understand what they are getting. If such disclosure is provided, the purchasers and the marketplace will drive up performance.

   P—Okay, provided that a practical grading system can be developed and be applicable to all buildings (not just tall buildings).

2. It is our responsibility, interviewee said, to disclose anticipated performance to buyers/users. Interviewee believes that any disclosure laws should be statewide, not local.

   P—Okay, but responsibility need not be "moral," nor similar to Australian law; disclosure laws should be broadly applicable (not just SF).

3. Interviewee strongly advocates disclosure of risks and anticipated performance, including serviceability and fire risks. This disclosure is necessary as a part of the "risk management" of development, where risk is transferred from the developers to the owners/occupants/insurers/city. It must be made clear what risk is being transferred.

   P—Okay, philosophically, but requires a practical method to implement.

4. Interviewee felt strongly that information about intended building performance and risk, both structural and non-structural, must be fully disclosed to buyers.

   P—Okay, philosophically (without second sentence), but requires a practical method to implement.

5. Interviewee is currently researching insurance issues for the condo association and finds that straightforward information about coverage and costs is hard to get, and information is not user friendly. Just as in the building's structural performance, Interviewee feels he is not getting disclosure, and that condo owners could be embroiled in extensive insurance disputes after an earthquake.

   P—Need for disclosure (and documentation).

6. Interviewee said that public disclosure of anticipated building performance should be required; ideally, a posting would be at the entry of every building that rates the building's intended performance.

   NP—Posting not considered to appropriate/effective method.

7. The great need is to be able to clearly articulate performance levels and risks.

   P+—Amen (but how?)

8. Interviewee believes that the public needs education to develop reasonable expectations of building performance: building condo owners might reasonably use a method to evaluate their own risks.

   P—Okay, but PML analysis is not considered to be the appropriate method.

9. He said that interviewee does not expect there to be a MCE event in his lifetime, although interviewee does expect a Hayward event causing substantial infrastructure problems. Interviewee believes that it even might be somewhere between Table 1 and Table 2 (greater than MPE and less than MCE).

   NF

10. I can't relate to risks described in a 100-year period of time.

    NF

11. Interviewee believed that Loma Prieta had a negative effect on public interest in increased levels of seismic safety because there were few areas of damage and few seriously damaged buildings. The public thinks that most buildings will perform OK.

    P—Need to communicate risk (due to a major earthquake) to stakeholders.

SECOND BREAK-OUT SESSION (TOPICS III, IV, AND V)

Group Members:
Charles Kircher (Group Leader)
Yousef Bozorgnia—PEER
Bob Hanson—FEMA
Ken Paige—Condo Owner
Ned Fennie—Architect (SFBC Advisory Comm.)

<u>Topic III:</u> Should Tall Buildings Have Better Performance Than Normal Buildings? Why? Which Loss Categories Are important? (Life Safety, Cost of Repair, Downtime)

Primary Findings: Yes, in general, "tall" buildings should perform better than "normal" buildings, not just in terms of life-safety, but also in terms of functionality (and by inference, also in terms of dollar loss due to less damage). Taller buildings require better performance (than normal buildings) due to greater risks posed to:

1. city services (e.g., impact on fire and emergency response, roadway operation, etc., due to building collapse),
2. building occupants (e.g., delayed response to fire and injured occupants on upper floors due to building damage/loss of elevator function),
3. the neighborhood (e.g., impact on adjoining buildings or properties due to building collapse, risk to folks on the street due to falling glass, etc.), and
4. the resilience of the community, in general.

The following Topic III statements were scored (1) Non-Persuasive (NP), (2) Persuasive (P) (with one to three check marks), or (3) Not a factor (NF) by the group for the reasons given below (e.g., by underlining persuasive portions of the statement, or striking out text that is not persuasive).

1. Yes, should be better than a "normal" building for a variety of reasons, including the possible impacts of building performance on adjoining buildings and properties, and the many concessions, accommodations, and special approvals allowing density, height and related views, and other factors that the city provides for these tall buildings.

   P—√√√

2. The performance of buildings will reflect on the reputation of the developer and builders.

   P—√ (but not very persuasive)

3. Interviewee believed that tall buildings should be designed and built to a higher performance standard (structural and non-structural) than other buildings because of the major investment in many ways on the part of the city, many other organizations, and agencies involved in the project entitlement and approval process for these buildings. Interviewee further bases this on the potential for severe impacts on the tall building occupants, on the neighborhoods that are created by these tall buildings, and on the city of a non-serviceable tall building.

   P—√√√

4. Yes, interviewee believed that a higher standard should be required for tall buildings. This is a special class of buildings. Noted that the approval of tall buildings requires resolution of many issues having greater impacts on occupants, neighbors, and the city than other/low-rise buildings; that tall buildings have a great impact on the city and city services; that there are high-occupant loads on small land area in high-rises; and, because of few exits and the other special conditions of high-rises, there is a need to increase resistance to the potential impacts of building fire, structural damage, or failure.

   P—√√√

5. Tall buildings should meet a higher standard due to their many special conditions, including glass and façade falling hazards from very high posing higher risks. Due to the higher risks posed by high-rise buildings, they need a higher level of confidence that buildings will perform as intended.

   P—√√√

6. All three interviewees (building owners) stated that performance levels for tall building should take community resilience into consideration in that recovery of a community following an event will be directly influenced by the numbers of people and businesses dislocated and that the longer the recovery takes, the greater the economic effect on individual property owners.

   P—√√√

7. Building owner group agreed that tall buildings (30–70 stories) should have a higher performance. Tall buildings with their higher occupancy should be built at a higher performance level than a normal building and the code should reflect this higher risk in terms of life loss and community/economic resilience.

   P—√√√

8. All interviewees (in this case representatives of building owners) believe that the code should require a higher performance for tall buildings, specifically for the "Rare event."

The loss consequences would be devastating for commercial property owners, condo owners, and the community.

NF (same for all buildings)

9. The commercial property owner stated that property owners do not want to see large numbers of buildings badly damaged in an area because it will directly affect their business as property owners. The same applies to supporting infrastructure.

   NF (same for all buildings)

10. Higher performance standards would result in less damage to the housing stock and thus may be less taxing on local government resources (emergency personnel, housing/shelter, etc.) after an earthquake.

    P—√√√ (more first responders are needed for tall buildings)

11. Fire and other life-safety professionals are increasingly concerned about loss of elevators in tall buildings for any reason. An ASME committee is currently working on this issue.

    P—√√ (requires special design of elevators, not just an earthquake issue).

Tall Buildings Do Not Need Better Performance

1. The owner representative also made clear that the position of the owner in terms of the business objectives of owning for the "long term" versus the "short term" (3–5 years) will influence attitudes toward performance levels and expectations. Interviewee made the point that it is really all about cost and business performance, although interviewee believes that all owners are interested in protecting people.

   NP—Not consistent with group's "better than normal building performance" position.

2. No need for better. Current standards and intentions of developers to provide a quality product (at least this developer) do not require special requirements. Interviewee asks, rhetorically, if there is some past problem with tall buildings that needs to be addressed—how have they performed in past earthquakes?

   NP—Not consistent with group's "better than normal building performance" position.

3. Financial: Only concern is making sure the PML is appropriate for the loan. PML is a major factor in the lending decision. PML as determined by a seismic professional/firm is what counts in the lending decision.

   NP—Not consistent with group's "better than normal building performance" position.

4. As long as buildings are built to code there will be no affect on the lending business [if required performance levels were to change].

   NP—Not consistent with group's "better than normal building performance" position.

5. The condition in the market is a major factor. Liquidity in the financial market makes a big difference in the perspective on risk of the investment. Today insurance is generally not required as a basis for a loan because there is a lot of competition due to the level of liquidity. A tight market allows for making demands by the lender to better protect lender. Small owners tend to be stuck with needing insurance, but large owners are not. The market manipulates the loan requirements. The rate of return to the investor and lender is the measure that really counts.

   NP—Not consistent with group's "better than normal building performance" position.

Topic IV **Reasons to Have Better Performance for Residential Occupancies**

Primary Findings: Residential building occupancies should have the same (very good) performance as commercial occupancies. In general, both commercial and residential occupancies should perform equally well, recognizing that "tall" commercial and residential buildings should perform better than "short" residential and commercial buildings.

The following Topic IV statements were scored (1) Non-Persuasive (NP), (2) Persuasive (P) (with one to three check marks), or (3) Not a factor (NF) by the group for the reasons given below (e.g., by underlining persuasive portions of the statement, or striking out text that is not persuasive).

1. Home has a unique value in our society. Currently, the corporate entities and developers are setting unknown standards for housing and selling homes to the naive, less-sophisticated consumer. Home represents investment "nest egg" for many.

   NP—√ (but group recognizes special nature of the home).
2. Residential occupancies require a higher standard due to 24-hour/7-day use and the resulting direct impacts on people's lives. Also, public agencies have a greater responsibility to deal with displacement and other impacts on residential occupants. Modern buildings should not exacerbate the burdens [on city government] such as displacement problems.

   NP—√ (but group recognizes shelter demand issues).
3. The uses of these high-rises are often residences for older persons who anticipate living in them for a long time, making them more vulnerable to impacts of structural and non-structural damage. Most of these people cannot use emergency stairs from upper floors if elevators are unusable, perhaps requiring a higher level of serviceability.

   NP—√ (but group recognizes emergency access issues).
4. If the elevators are not in service, a tall condo building is essentially out of business.

   NF (same for commercial building)

Residential Buildings should not be considered separately

1. Building owner group agreed that types of occupancy of tall buildings should be of equal risk and the performance of tall buildings should not be governed by occupancy type.

   P—√√√ (tall building should not be governed by occupancy type)
2. A lender is not likely to be concerned about the building occupancy as long as the package meets all the lending criteria in terms of quality of the borrower, the market, and meeting the loan PML requirements.

   P—√√√ (tall building should not be governed by occupancy type)

<u>Topic V:</u> Acceptable Cost Premium for Better Performance

Primary Findings: A cost premium of 10% (possibly greater) is considered reasonable to achieve improved performance (e.g., change from Level B to Level A performance) for tall buildings, recognizing that (1) cost premium applies to total building cost (e.g., 10% of $300/sq ft) and (2) improved performance would address both structural and non-structural systems (e.g., elevators, etc.).

The statements below were not evaluated on an individual basis.

1. 10–15%
2. 10%
3. Increasing the cost of a unit from $1,000,000 to $1,100,000 would be acceptable.
4. Level A performance should be required as a minimum standard at any cost, and should be considered part of the cost of development.
5. YES, for tall buildings but ultimate decision will be based on the market according to commercial building owner—that is, the ability of the market place to pay higher rent, etc. Also, better performance is marketed to clients. (5% of cost of shell and core, pending market.

B.6.2 BREAK-OUT GROUP 2 (DISCUSSION LEADER: W. PETAK)

FIRST BREAK-OUT SESSION (TOPICS I AND II)

Group Members:
William Petak (Discussion Leader)
Karl Telleen—SE
Yousef Bozorgnia—UC Berkeley
Bob Hanson– SE Professor—FEMA Advisor
Joe Maffei—SE
Ken Paige—Condo Owner—Pres Condo Association

<u>Topic I</u> Code-Expected Performance of Normal Buildings

Primary Findings: The break-out group discussion with regard to the Topic 1 statements led to a consensus that overall the statements indicated that the stakeholder interviewees are not willing to accept any risk, either as individuals or as part of the general public. There was a high degree of consistency among the perspectives presented on the charts. The group concluded that the stakeholders view current codes as providing a promise that all new buildings will meet life-safety standards and there will be no major damage, and further, that buildings will remain functional. There is an apparent real disconnect between expected performance of buildings designed to current code and stakeholder expectations of building performance. It was emphasized by the non-engineer member of the break-out group that if there is failure due to an earthquake, there would be immediate questions regarding “who is at fault” and the beginning of searching to assign blame. The basic expectation is that building failure/damage occurred because someone did not do the job correctly, a mistake was made.

The first topic statements were not scored by the break-out group. All were viewed as supporting the primary findings. The highlighted—underlined phrases support this conclusion.

1. For a major earthquake, this interviewee believed that this standard (Level B) was *not acceptable.* New buildings should *not ever* collapse or experience complete failure/irreparability.
2. Interviewee was surprised that Level B was code level. Clearly expected better performance from a new building, even given the long return-period/relatively low risk of a large earthquake.
3. Interviewee said that building failure was not acceptable for new buildings, and that life safety was certainly a minimum expectation for all construction.
4. Interviewee understood that ordinarily the code minimum is a life-safety standard, but also indicated that the public expects more from buildings.
5. Interviewee stated that collapse of any modern building in any considered earthquake is entirely unacceptable to the public.
6. Interviewee's assumption and the implied promise for all new buildings is that buildings meet life-safety standards and will not suffer major damage in any anticipated earthquake, even a great quake. City and developers are well aware of the factors involved and should address them—it is irresponsible of the city officials not to.
7. People have a right to expect no more than moderate damage even in a major earthquake.

Topic II: Disclosure and Understanding Risk

Primary Findings: The break-out group generally concluded that there is a need to develop a rating scale for buildings that provides an understanding of how the building is rated versus the code. The code provides an implicit rating for collapse, but provides no understanding of the expected performance for dollar loss and downtime. Full disclosure of expected building performance is important and should be the basis of a rating system. The non-engineer member of the group was proposing a rating system (1 to 100) which is more refined than A, B, C. He states that this is what the stakeholders need in order to judge the value and risk of a building. This is needed as a basis for communication of building performance. He also emphasized that a rating on all buildings similar to hospitals and schools is necessary

The following statements were scored Non-Persuasive (NP), Persuasive (P), or Not a factor (NF) by the group for the reasons given in italics.

1. Buildings could be graded or otherwise disclosed so that buyers of new tall buildings will understand what they are getting. If such disclosure is provided, the purchasers and the marketplace will drive up performance.

   P—There is a real need to develop a grading system that provides full disclosure about the risks associated with the building and it should be applicable to all buildings. A rating system would be market based and would take this information into consideration, which could possibly result in higher design performance.

2. It is our moral responsibility, interviewee said, to disclose anticipated performance to buyers/users. Similar to very strong Australian disclosure laws, interviewee believes that any disclosure laws should be statewide, not local.

   P—No one knew what the Australian laws state, but agreed that disclosure of what is expected in terms of building performance should be disclosed.

3. Interviewee strongly advocates disclosure of risks and anticipated performance, including serviceability and fire risks. This disclosure is necessary as a part of the "risk management" of development, where risk is transferred from the developers to the owners/occupants/insurers/city. It must be made clear what risk is being transferred.

   P—Same as number 1 above

4. Interviewee felt strongly that information about intended building performance and risk, both structural and non-structural, must be fully disclosed to buyers. Expressed a view that developers would likely not provide that information or to take other actions to build or provide information above minimum standards unless required to do so.

   P—Same as number 1 above

5. Interviewee is currently researching insurance issues for the condo association and finds that straightforward information about coverage and costs is hard to get, and information is not user friendly. Just as in the building's structural performance, Interviewee feels he is not getting disclosure, and that condo owners could be embroiled in extensive insurance disputes after an earthquake.

   P—Full disclosure is needed in order for insurance underwriting to take performance risk into consideration in establishing product and premium. It was noted during the discussion that most large condominium associations do not have earthquake insurance because it is either not available or very expensive.

6. Interviewee said that public disclosure of anticipated building performance should be required; ideally, a posting would be at the entry of every building that rates the building's intended performance.

   NP—Non-engineer member of the group strongly supported posting of buildings with a rating so that all stakeholders know the risks—all current full disclosure laws provide a basis for this position. Most others in the group were not generally persuaded.

7. The great need is to be able to clearly articulate performance levels and risks.

   P—All agree with this statement.

8. Interviewee believes that the public needs education to develop reasonable expectations of building performance: building condo owners might reasonably use a method similar to the PML analysis used for lenders to evaluate their own risks.

   P—Yes, but a better rating system than PML is necessary, since most people do not understand PML.

9. He said that interviewee does not expect there to be a MCE event in his lifetime, although interviewee does expect a Hayward event causing substantial infrastructure problems. Interviewee believes that it even might be somewhere between Table 1 and Table 2 (greater than MPE and less than MCE).

   NF

10. I can't relate to risks described in a 100-year period of time.

NF

11. Interviewee believed that Loma Prieta had a negative effect on public interest in increased levels of seismic safety because there were few areas of damage and few seriously damaged buildings. The public thinks that most buildings will perform OK.

    P—YES, it had a negative effect. The few overall losses in San Francisco from the earthquake gave the picture that buildings are designed OK for earthquakes. However members of the group understand that the public does not understand the relationship between location, depth, and period of the earthquake; most note that there continues a real need to better communicate and educate stakeholders.

SECOND BREAK-OUT SESSION (TOPICS III, IV, AND V)

Group Members:
William Petak (Discussion Leader)
Jack Moehle—Academic SE - PEER
Marshall Lew—Ground motion / Geotech
John Heintz—SE/ATC
Tim Carey— The Related Companies
Ron Asselestine—Developer

<u>Topic III:</u> Should Tall Buildings Have Better Performance than Normal Buildings? Why? Which Loss Categories Are Important? (Life Safety, Cost of Repair, Downtime)

Primary Findings: Based on the exposure and consequences of failure, tall buildings should be expected to perform better than normal buildings. Risk of loss and consequences associated with the losses (e.g., community resilience, impact on the social and economic elements of a city/community, public safety, and capacity of occupants of higher floors to mange egress) should be the basic driver of performance expectations, and performance-based design should be context related. Life safety is obviously most important, but cost of repair and downtime are very important to both occupants and the city/local community.

Current practice appears to suffer from a low ability to predict performance. With regard to "tall buildings," there is a high degree of uncertainty in the assessment of risk due to newness of design, materials used, lack of actual earthquake performance experience of designs, and an apparent low level of redundancy in a design.

The following Topic III statements were scored Non-Persuasive (NP), Persuasive (P), or Not a factor (NF) by the group for the reasons given in italics below.

1. Yes, should be better than a "normal" building for a variety of reasons, including the possible impacts of building performance on adjoining buildings and properties, and the many concessions, accommodations, and special approvals allowing density, height and related views, and other factors that the city provides for these tall buildings.

   P—Very persuasive—especially, since tall building failures are likely to have a significant impact of the city and the disaster recovery. This is a matter of serving the public interest by providing buildings that will not have a large negative impact on the operations of a city.

2. The performance of buildings will reflect on the reputation of the developer and builders.

   NP—Reputation is the responsibility of the individual firm.

3. Interviewee believed that tall buildings should be designed and built to a higher performance standard (structural and non-structural) than other buildings because of the major investment in many ways on the part of the city, many other organizations, and agencies involved in the project entitlement and approval process for these buildings. Interviewee further bases this on the potential for severe impacts on the tall building occupants, on the neighborhoods that are created by these tall buildings, and on the city of a non-serviceable tall building.

   P—Largely due to the impacts on occupants, neighborhood, and city. However, investment by city in project entitlement is Not Persuasive (NP).

4. Yes, interviewee believed that a higher standard should be required for tall buildings. This is a special class of buildings. Noted that the approval of tall buildings requires resolution of many issues having greater impacts on occupants, neighbors, and the city than other/low-rise buildings; that tall buildings have a great impact on the city and city services; that there are high-occupant loads on small land area in high-rises; and, because of few exits and the other special conditions of high-rises, there is a need to increase resistance to the potential impacts of building fire, structural damage or failure.

   P—Same as 1 above.

5. Tall buildings should meet a higher standard due to their many special conditions, including glass and façade falling hazards from very high posing higher risks. They are given special approvals, sell at very high prices, and should require special standards of performance. Due to the higher risks posed by high-rise buildings, they need a higher level of confidence that buildings will perform as intended.

   P—Same a 1 above along with the higher risks posed. Special approvals and selling at higher prices is Not Persuasive as a basis for standards of performance. Sale price should have nothing to do with design and reduction of risk, since all citizens are due equal performance and safety, not only those who can pay more.

6. All three interviewees (building owners) stated that performance levels for tall buildings should take community resilience into consideration in that recovery of a community following an event will be directly influenced by the numbers of people and businesses dislocated and that the longer the recovery takes, the greater the economic effect on individual property owners.

   P—Same as 1 above.

7. Building owner group agreed that tall buildings (30 to 70 stories) should have a higher performance. Tall buildings with their higher occupancy should be built at a higher performance level than a normal building and the code should reflect this higher risk in terms of life loss and community/economic resilience.

   P—Same as above.

8. All interviewees (in this case representatives of building owners) believe that the code should require a higher performance for tall buildings, specifically for the "Rare event." The loss consequences would be devastating for commercial property owners, condo owners, and the community.—

   P—Same as above

9. The commercial property owner stated that property owners do not want to see large numbers of buildings badly damaged in an area because it will directly affect their business as property owners. The same applies to supporting infrastructure.

   NF—Commercial property owners have personal responsibility for their business and reputations, and codes are not for that purpose.

10. Higher performance standards would result in less damage to the housing stock and thus may be less taxing on local government resources (emergency personnel, housing/shelter, etc.) after an earthquake. Market would adjust to the higher standards, since requirements would be implemented industry wide, thus long-term tax base would not be affected.

    P—Same as 1 above

11. Fire and other life-safety professionals are increasingly concerned about loss of elevators in tall buildings for <u>any</u> reason. An ASME committee is currently working on this issue.

    P—It appears that fire and life-safety professionals are considering the issues associated with tall buildings and special design of elevators, not solely as an earthquake-related issue is likely occur.

Tall Buildings Do Not Need Better Performance

The following Topic III statements were scored (1) Non-Persuasive (NP), (2) Persuasive, or (3) Not a factor (NF) by the group for the reasons given below.

1. The owner representative also made clear that the position of the owner in terms of the business objectives of owning for the "long term" versus the "short term" (3–5 years) will influence attitudes toward performance levels and expectations. Interviewee made the point that it is really all about cost and business performance, although interviewee believes that all owners are interested in protecting people.

   NP

2. No need for better. Current standards and intentions of developers to provide a quality product (at least this developer) do not require special requirements. Interviewee asks, rhetorically, if there is some past problem with tall buildings that needs to be addressed—how have they performed in past earthquakes?

   NP

3. Financial: Only concern is making sure the PML is appropriate for the loan. PML is a major factor in the lending decision. PML as determined by a seismic professional/firm is what counts in the lending decision.

   NP

4. As long as buildings are built to code there will be no affect on the lending business (if required performance levels were to change).

   NP

5. The condition in the market is a major factor. Liquidity in the financial market makes a big difference in the perspective on the risk of the investment. Today insurance is generally not required as a basis for a loan because there is a lot of competition due to the level of liquidity. A tight market allows for making demands by the lender to better protect lender. Small owners tend to be stuck with needing insurance, but large owners

are not. The market manipulates the loan requirements. The rate of return to the investor and lender is the measure that really counts.

NP

<u>Topic IV:</u> Reasons to Have Better Performance for Residential Occupancies

Primary Findings: All buildings of occupancy should have high design-performance requirements. Both commercial and residential occupancies should perform equally well. All tall commercial and residential buildings should be designed with the exposure of occupants to the earthquake risk taken into consideration. New tall residential buildings pose a higher exposure risk based on time of occupancy - 24 hours/day and 7 days/week occupancy, the high degree of uncertainty in the assessment of risk due to newness of design, materials used, actual experience with a design, and an apparent low level of redundancy in design are the reasons to seek better performance for residential occupancies.

The following Topic statements were scored Non-Persuasive (NP), Persuasive (P), or Not a factor (NF) by the group for the reasons given in italics below.

1. Home has a unique value in our society. Currently, the corporate entities and developers are setting unknown standards for housing and selling homes to the naive, less-sophisticated consumer. Home represents investment "nest egg" for many.

   NP—it is a public safety issue.

2. Residential occupancies require a higher standard due to 24-hour/7-day use and the resulting direct impacts on people's lives. Also, public agencies have a greater responsibility to deal with displacement and other impacts on residential occupants. Modern buildings should not exacerbate the burdens [on city government] such as displacement problems.

   P—Very persuasive—especially since tall residential building failures are likely to have a significant impact on the city and disaster recovery. This is a matter of serving the public interest by providing buildings that will not have a large negative impact on the operations of the public agencies in a city.

3. The uses of these high-rises are often residences for older persons who anticipate living in them for a long time, making them more vulnerable to impacts of structural and non-structural damage. Most of these people cannot use emergency stairs from upper floors if elevators are unusable, perhaps requiring a higher level of serviceability.

   P—somewhat persuasive, but not overwhelming. All occupants of high-rise residential buildings have similar concerns.

4. If the elevators are not in service, a tall condo building is essentially out of business.

   NF—this will be true for any tall building.

Residential Buildings Should Not Be Considered Separately

Primary Findings—The group did not get to discussion of this topic and the statements were not evaluated on an individual basis.

1. Building owner group agreed that types of occupancy of tall buildings should be of equal risk and the performance of tall buildings should not be governed by occupancy type.
2. A lender is not likely to be concerned about the building occupancy as long as the package meets all the lending criteria in terms of quality of the borrower, the market, and meeting the loan PML requirements.

Topic V: Acceptable Cost Premium for Better Performance

Primary Findings: The group did not get to discussion of this topic and the statements were not evaluated on an individual basis.

1. 10–15%
2. 10%
3. Increasing the cost of a unit from $1,000,000 to $1,100,000 would be acceptable.
4. Level A performance should be required as a minimum standard at any cost, and should be considered part of the cost of development.
5. YES, for tall buildings but ultimate decision will be based on the market according to commercial building owner—that is, the ability of the market place to pay higher rent, etc. Also, better performance is marketed to clients. (5% of cost of shell and core, pending market.)

B.6.3 BREAK-OUT GROUP 3 (DISCUSSION LEADER: N. YOUSSEF)

FIRST BREAK-OUT SESSION (TOPICS I AND II)

Group Members:
Nabih Youssef (Group Leader)
Don Strand—SE
Nico Luco—USGS
John Hooper—SE
Laurie Johnson—city Planner
Ross Asselstine—Developer

Topic I Code-Expected Performance of Normal Buildings

Primary Findings: Stakeholders in general believed that the current code expectation for "normal" buildings is adequate. However, when confronted with the probabilistic data of complete failure/irreparability for Level B (code compliance) in a major event, they concluded that this code performance was not expected or acceptable. They clearly voiced that the non-technical public expects more (better performance) from new buildings. Collapse of any modern building in any considered earthquake is entirely unacceptable. The non-technical public will consider city officials to be irresponsible and hold city officials and developers to the implied promise for all new buildings to meet life-safety standards and will not be subject to major damage (irreparable or collapse) in anticipated/even major earthquakes.

The following Topic I statements were scored (1) Non-Persuasive (NP), (2) Persuasive (P), or (3) Not a factor (NF) by the group for the reasons given below.

1. For a major earthquake, this interviewee believed that this standard (Level B) was not acceptable. New buildings should not ever collapse or experience complete failure/irreparability.

   P/NP—1st statement persuasive; 2nd statement "not ever" is too stringent.

2. Interviewee was surprised that Level B was code level. Clearly expected better performance from a new building, even given the long return-period/relatively low risk of a large earthquake.

   P

3. Interviewee said that building failure was not acceptable for new buildings, and that life safety was certainly a minimum expectation for all construction.

   NP - A very small probability of collapse would be acceptable.

4. Interviewee understood that ordinarily the code minimum is a life-safety standard, but also indicated that the public expects more from buildings.

   P

5. Interviewee stated that collapse of any modern building in any considered earthquake is entirely unacceptable to the public.

   NP—The term "entirely" makes the statement too stringent. A very small probability of collapse would be acceptable.

6. Interviewee's assumption and the implied promise for all new buildings is that buildings meet life-safety standards and will not suffer major damage in any anticipated earthquake, even a great earthquake. city and developers are well aware of the factors involved and should address them—it is irresponsible of the city officials not to.

   NP—Unreasonable expectation—no major damage in <u>any</u> anticipated earthquake.

7. People have a right to expect no more than moderate damage even in a major earthquake.

   NP

<u>Topic II:</u> Disclosure and Understanding Risk

Primary Findings: The design profession and city governments need to better educate the public to develop reasonable expectations of code-level seismic performance. The design profession has the responsibility to develop the tools and the data to clearly articulate risks and associated performance levels. More risk case studies are needed based on the latest ground motion simulation and structural modeling of proposed high-rise systems.

The following Topic II statements were scored (1) Non-Persuasive (NP), (2) Persuasive (P), or (3) Not a factor (NF) by the group for the reasons given below.

1. Buildings could be graded or otherwise disclosed so that buyers of new tall buildings will understand what they are getting. If such disclosure is provided, the purchasers and the marketplace will drive up performance.

   P

2. It is our moral responsibility, interviewee said, to disclose anticipated performance to buyers/users. Similar to very strong Australian disclosure laws, interviewee believes that any disclosure laws should be statewide, not local.

   P

3. Interviewee strongly advocates disclosure of risks and anticipated performance, including serviceability and fire risks. This disclosure is necessary as a part of the “risk management” of development, where risk is transferred from the developers to the owners/occupants/insurers/city. It must be made clear what risk is being transferred.

   P

4. Interviewee felt strongly that information about intended building performance and risk, both structural and non-structural, must be fully disclosed to buyers. Expressed a view that developers would likely not provide that information or to take other actions to build or provide information above minimum standards unless required to do so.

   NP—Questioned how this process would be regulated.

5. Interviewee is currently researching insurance issues for the condo association and finds that straightforward information about coverage and costs is hard to get, and information is not user friendly. Just as in the building’s structural performance, Interviewee feels he is not getting disclosure, and that condo owners could be embroiled in extensive insurance disputes after an earthquake.

Group did not reach a consensus.

6. Interviewee said that public disclosure of anticipated building performance should be required; ideally, a posting would be at the entry of every building that rates the building’s intended performance.

   P

7. The great need is to be able to clearly articulate performance levels and risks.

   P

8. Interviewee believes that the public needs education to develop reasonable expectations of building performance: building condo owners might reasonably use a method similar to the PML analysis used for lenders to evaluate their own risks.

   P

9. He said that interviewee does not expect there to be a MCE event in his lifetime, although interviewee does expect a Hayward event causing substantial infrastructure problems. Interviewee believes that it even might be somewhere between Table 1 and Table 2 (greater than MPE and less than MCE).

   NF

10. I can’t relate to risks described in a 100-year period of time.

    NP

11. Interviewee believed that Loma Prieta had a negative effect on public interest in increased levels of seismic safety because there were few areas of damage and few seriously damaged buildings. The public thinks that most buildings will perform OK.

    NF

SECOND BREAK-OUT SESSION (TOPICS III, IV, AND V)

Group Members:

Nabih Youssef (Discussion Leader)
Jack Moehle—Academic SE - PEER
Marshall Lew—Ground Motion / Geotech
John Heintz—SE/ATC
Tim Carey— The Related Companies
Ron Asselestine–Developer

<u>Topic III</u>: Should Tall Buildings Have Better Performance Than Normal Buildings? Why? Which Loss Categories are Important? (Life Safety, Cost of Repair, Downtime)

Primary Finding: Tall buildings in an urban community with high density represent a higher concentration of resources with a collective iconic value. The performance of these buildings will reflect on the reputation on the community, developers, and builders with a cumulative impact on city government resources for rescue and recovery. Stakeholders believed that tall buildings should meet higher standards due to their many special conditions, including serious falling hazards of facades and impacts from glass, as well as the associated longer recovery and greater economic effect. Codes should reflect this higher risk in terms of life loss and community economic resilience. Concerns were raised about cost and business financial performance.

The following Topic III statements were scored Non-Persuasive (NP), Persuasive (P), or Not a factor (NF) by the group for the reasons given in italics below.

1. Yes, should be better than a "normal" building for a variety of reasons, including the possible impacts of building performance on adjoining buildings and properties, and the many concessions, accommodations, and special approvals allowing density, height and related views, and other factors that the city provides for these tall buildings.

   P—Tall buildings require a higher intensity of resources and have an iconic value.

2. The performance of buildings will reflect on the reputation of the developer and builders.

   P

3. Interviewee believed that tall buildings should be designed and built to a higher performance standard (structural and non-structural) than other buildings because of the major investment in many ways on the part of the city, many other organizations, and agencies involved in the project entitlement and approval process for these buildings. Interviewee further bases this on the potential for severe impacts on the tall building occupants, on the neighborhoods that are created by these tall buildings, and on the city of a non-serviceable tall building.

   P

4. Yes, interviewee believed that a higher standard should be required for tall buildings. This is a special class of buildings. Noted that the approval of tall buildings requires resolution of many issues having greater impacts on occupants, neighbors, and the city than other/low-rise buildings; that tall buildings have a great impact on the city and city services; that there are high-occupant loads on small land area in high-rises; and, because

of few exits and the other special conditions of high-rises, there is a need to increase resistance to the potential impacts of building fire, structural damage or failure.

P

5. Tall buildings should meet a higher standard due to their many special conditions, including glass and façade falling hazards from very high posing higher risks. They are given special approvals, sell at very high prices, and should require special standards of performance. Due to the higher risks posed by high-rise buildings, they need a higher level of confidence that buildings will perform as intended.

   P

6. All three interviewees (building owners) stated that performance levels for tall building should take community resilience into consideration in that recovery of a community following an event will be directly influenced by the numbers of people and businesses dislocated and that the longer the recovery takes the greater the economic effect on individual property owners.

   P

7. Building owner group agreed that tall buildings (30 to 70 stories) should have a higher performance. Tall buildings with their higher occupancy should be built at a higher performance level than a normal building and the code should reflect this higher risk in terms of life loss and community/economic resilience.

   P/NP –Higher occupancy for high-end condo was questioned, since many of these units serve as second/part-time residence and the occupancy is less dense (2 persons living in 10,000 sf units).

8. All interviewees (in this case representatives of building owners) believe that the code should require a higher performance for tall buildings, specifically for the "Rare event." The loss consequences would be devastating for commercial property owners, condo owners, and the community.

   P—Poor performance of tall buildings in "Rare event" enforce perception of risk associated with this class of building in high seismic zone and adversely affect market for these buildings.

9. The commercial property owner stated that property owners do not want to see large numbers of buildings badly damaged in an area because it will directly affect their business as property owners. The same applies to supporting infrastructure.

   P—Do not want to be seen as New Orleans during Hurricane Katrina.

10. Higher performance standards would result in less damage to the housing stock and thus may be less taxing on local government resources (emergency personnel, housing/shelter, etc.) after an earthquake. Market would adjust to the higher standards, since requirements would be implemented industry wide, thus long-term tax base would not be affected.

    NF

11. Fire and other life-safety professionals are increasingly concerned about loss of elevators in tall buildings for <u>any</u> reason. An ASME committee is currently working on this issue.

    NF

Tall Buildings Do Not Need Better Performance

The following Topic III statements were scored (1) Non-Persuasive (NP), (2) Persuasive, or (3) Not a factor (NF) by the group for the reasons given below.

1. The owner representative also made clear that the position of the owner in terms of the business objectives of owning for the "long term" versus the "short term" (3–5 years) will influence attitudes toward performance levels and expectations. Interviewee made the point that it is really all about cost and business performance, although interviewee believes that all owners are interested in protecting people.

   NP—Owner does not need to disclose risk and passes risk onto subsequent owner.

2. No need for better. Current standards and intentions of developers to provide a quality product (at least this developer) do not require special requirements. Interviewee asks, rhetorically, if there is some past problem with tall buildings that needs to be addressed—how have they performed in past earthquakes?

   NF

3. Financial: Only concern is making sure the PML is appropriate for the loan. PML is a major factor in the lending decision. PML as determined by a seismic professional/firm is what counts in the lending decision.

   NF

4. As long as buildings are built to code there will be no affect on the lending business [if required performance levels were to change].

   NF

5. The condition in the market is a major factor. Liquidity in the financial market makes a big difference in the perspective on risk of the investment. Today insurance is generally not required as a basis for a loan because there is a lot of competition due to the level of liquidity. A tight market allows for making demands by the lender to better protect lender. Small owners tend to be stuck with needing insurance, but large owners are not. The market manipulates the loan requirements. The rate of return to the investor and lender is the measure that really counts.

   NF

<u>Topic IV:</u> Reasons to Have Better Performance for Residential Occupancies

Primary Findings: The proposed residential tall buildings are often residencies for older persons with 24-hour, 7-day use, making them more vulnerable to impacts of non-structural and structural damage. This user category requires a higher level of elevator serviceability if residents cannot use emergency stairs from upper floors. Also, public agencies have a greater responsibility for rescue and dealing with displacement and recovery of residential occupants/communities.

The following Topic statements were scored Non-Persuasive (NP), Persuasive (P), or Not a factor (NF) by the group for the reasons given in italics below.

1. Home has a unique value in our society. Currently, the corporate entities and developers are setting unknown standards for housing and selling homes to the naive, less-sophisticated consumer.

   NF—Disclosure issue.

2. Residential occupancies require a higher standard due to 24-hour/7-day use and the resulting direct impacts on people's lives. Also, public agencies have a greater responsibility to deal with displacement and other impacts on residential occupants. Modern buildings should not exacerbate the burdens (on city government) such as displacement problems.

   NP—Group agreed with the first two statements, but found the last statement unpersuasive.

3. The uses of these high-rises are often residences for older persons who anticipate living in them for a long time, making them more vulnerable to impacts of structural and non-structural damage. Most of these people cannot use emergency stairs from upper floors if elevators are unusable, perhaps requiring a higher level of serviceability.

   P

4. If the elevators are not in service, a tall condo building is essentially out of business.

   NF

Residential Buildings Should Not Be Considered Separately

1. Building owner group agreed that types of occupancy of tall buildings should be of equal risk and the performance of tall buildings should not be governed by occupancy type.

   P

2. A lender is not likely to be concerned about the building occupancy as long as the package meets all the lending criteria in terms of quality of the borrower, the market, and meeting the loan PML requirements.

   NP

<u>Topic V:</u> Acceptable Cost Premium for Better Performance

Primary Findings: The group concluded that a premium of 10% (max.) of overall costs for improved operability and comprehensive performance seems reasonable for a 1%–2.5% probability of collapse in a rare event and a maximum credible earthquake. However, a strict performance rating system needs to be developed and implemented, and full disclosure of expected building performance required.

1. 10–15%

   NP—Too costly

2. 10%

   P—Maximum for improved operability, structural and non-structural comprehensive performance

3. Increasing the cost of a unit from $1,000,000 to $1,100,000 would be acceptable.

P—Same as number 2 above.

4. Level A performance should be required as a minimum standard at any cost, and should be considered part of the cost of development

   NP—Cost is a factor.

5. YES, for tall buildings but ultimate decision will be based on the market according to commercial building owner—that is, the ability of the market place to pay higher rent, etc. Also, better performance is marketed to clients. (5% of cost of shell and core, pending market).

   NP—Developer requires incentives (regulatory, financial, etc.) and needs standard performance rating and disclosure requirements.

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