



**VIRTUAL/TELECONFERENCE
MASS TIMBER TASK FORCE
4822 Madison Yards Way, Virtual, Madison
Contact: Brad Wojciechowski (608) 266-2112
November 3, 2021**

The following agenda describes the issues that the Task Force plans to consider at the meeting. At the time of the meeting, items may be removed from the agenda. Please consult the meeting minutes for a record of the actions of the Task Force.

AGENDA

9:00 A.M.

OPEN SESSION – CALL TO ORDER – ROLL CALL

- A. Adoption of Agenda (1-2)**
- B. Approval of Minutes of October 5, 2021 (3)**
- C. Reminders: Scheduling Concerns**
 - 1) Attendance Conflicts Impacting November 3, 2021 Meeting
 - 2) Attendance Confirmation for December 3, 2021 Meeting
- D. Administrative Matters – Discussion and Consideration**
 - 1) Department and Staff Updates
 - 2) 2022 Meeting Availability
- E. Administrative Rules Matters – Discussion and Consideration**
 - 1) SPS 361-366 as it Relates to Mass Timber Construction (4)
- F. Alternative Procedures for Design of Mass Timber Tall Buildings – Discussion and Consideration (5-32)**
 - 1) Developing Table of Contents for Alternative Procedures for Mass Timber Guidebook
 - 2) Relating Mass Timber to Other Alternative Building Procedures
- G. Public Comments**

ADJOURNMENT

NEXT MEETING: DECEMBER 3, 2021

MEETINGS AND HEARINGS ARE OPEN TO THE PUBLIC, AND MAY BE CANCELLED WITHOUT NOTICE.

Times listed for meeting items are approximate and depend on the length of discussion and voting. All meetings are held at 4822 Madison Yards Way, Madison, Wisconsin, unless otherwise noted. In order to confirm a meeting or to

request a complete copy of the board's agenda, please call the listed contact person. The board may also consider materials or items filed after the transmission of this notice. Times listed for the commencement of disciplinary hearings may be changed by the examiner for the convenience of the parties. Requests for interpreters for the deaf or hard of hearing, or other accommodations, are considered upon request by contacting the Affirmative Action Officer, 608-266-2112, or the Meeting Staff at 608-266-5439.

**VIRTUAL/TELECONFERENCE
MASS TIMBER TASK FORCE
MEETING MINUTES
OCTOBER 5, 2021**

PRESENT: Justin Gavin, Laura Hasburgh, Michael Mazmanian, Richard Paur, Erich Roden, Alexander Timmer

EXCUSED: John Peronto

STAFF: Brad Wojciechowski, Executive Director; Jon Derenne, Legal Counsel; Benjamin Jones, Legal Counsel; Branden Piper, Administrator, Division of Industry Services; Garry Krause, Bureau Director, Safety and Buildings; Erik Hansen, Consultant, Building Systems-Senior; Kimberly Lee, Consultant, Building Systems-Senior; Jason Hansen, Consultant, Building Systems-Adv; Kimberly Wood, Program Assistant Supervisor-Adv.; Megan Glaeser, Bureau Assistant; and other Department Staff

CALL TO ORDER

Richard Paur, Chairperson, called the meeting to order at 9:03 a.m. A quorum was confirmed with six (6) members present.

ADOPTION OF AGENDA

MOTION: Erich Roden moved, seconded by Laura Hasburgh, to adopt the Agenda as published. Motion carried unanimously.

APPROVAL OF MINUTES OF SEPTEMBER 8, 2021

MOTION: Alexander Timmer moved, seconded by Erich Roden, to approve the Minutes of September 8, 2021 as published. Motion carried unanimously.


ADJOURNMENT

MOTION: Laura Hasburgh moved, seconded by Michael Mazmanian, to adjourn the meeting. Motion carried unanimously.

The meeting adjourned at 10:17 a.m.

**State of Wisconsin
Department of Safety & Professional Services**

AGENDA REQUEST FORM

1) Name and title of person submitting the request: Brad Wojciechowski		2) Date when request submitted: October 25, 2021 <small>Items will be considered late if submitted after 12:00 p.m. on the deadline date which is 8 business days before the meeting</small>	
3) Name of Board, Committee, Council, Sections: Choose an item. Mass Timber Task Force			
4) Meeting Date: November 3, 2021	5) Attachments: <input checked="" type="checkbox"/> Yes <input type="checkbox"/> No	6) How should the item be titled on the agenda page? A. Administrative Rules Matters – Discussion and Consideration 1) SPS 361-366 as it Relates to Mass Timber Construction B. Alternative Procedures for Design of Mass Timber Tall Buildings – Discussion and Consideration 1) Developing Table of Contents for Alternative Procedures for Mass Timber Guidebook 2) Relating Mass Timber to Other Alternative Building Procedures	
7) Place Item in: <input checked="" type="checkbox"/> Open Session <input type="checkbox"/> Closed Session	8) Is an appearance before the Board being scheduled? <i>(If yes, please complete Appearance Request for Non-DSPS Staff)</i> <input type="checkbox"/> Yes <Appearance Name(s)> <input type="checkbox"/> No	9) Name of Case Advisor(s), if applicable: <Click Here to Add Case Advisor Name or N/A>	
10) Describe the issue and action that should be addressed: <Click Here to Add Description>			
11) Authorization <div style="display: flex; justify-content: space-between; align-items: flex-end;"> <div style="text-align: center;">  <hr/> Signature of person making this request </div> <div style="text-align: center;"> 10/25/2021 <hr/> Date </div> </div> <div style="display: flex; justify-content: space-between; align-items: flex-end; margin-top: 10px;"> <div style="width: 60%;"> <hr/> Supervisor (Only required for post agenda deadline items) </div> <div style="width: 20%;"> <hr/> Date </div> </div> <div style="display: flex; justify-content: space-between; align-items: flex-end; margin-top: 10px;"> <div style="width: 60%;"> <hr/> Executive Director signature (Indicates approval for post agenda deadline items) </div> <div style="width: 20%;"> <hr/> Date </div> </div>			
Directions for including supporting documents: 1. This form should be saved with any other documents submitted to the Agenda Items folders. 2. Post Agenda Deadline items must be authorized by a Supervisor and the Policy Development Executive Director. 3. If necessary, provide original documents needing Board Chairperson signature to the Bureau Assistant prior to the start of a meeting.			



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

A CONSENSUS DOCUMENT



2005 EDITION



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

A consensus document developed by the Council:

Dr. Gregg Brandow

President, Brandow & Johnston Associates

Dr. Lauren Carpenter

Principal Engineer, Wong Hobach Lau

Mr. Brian L. Cochran

President, Brian Cochran and Associates

Dr. Gary C. Hart

Professor Emeritus of UCLA and Head of Hart-Weidlinger Div. of Weidlinger Associates

Dr. Sampson C. Huang

Associate Principal, Saiful/Bouquet, Inc.

Dr. Marshall Lew

Senior Principal/Vice President, MACTEC, Inc.

Mr. John A. Martin, Jr.

President, John A. Martin & Associates, Inc.

Dr. Farzad Naeim

Vice President and General Counsel, John A. Martin & Associates, Inc.

Mr. Clarkson W. Pinkham

President, S.B. Barnes Associates

Dr. Thomas A. Sabol

President, Englekirk & Sabol

Mr. Barry Schindler

Vice President, John A. Martin & Associates, Inc.

Mr. Donald R. Strand

Principal, Brandow & Johnston Associates

Mr. Nabih Youssef

President, Nabih Youssef & Associates

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

Mr. Ron Klemencic, *President, Magnusson Klemencic Associates, Seattle, WA*

Prof. Helmut Krawinkler, *Stanford University, Palo Alto, CA*

Dr. Joe Maffei, *Structural Engineer, Rutherford & Chekene, Oakland, CA*

Dr. Mike Mehrain, *Principal Structural Engineer, URS Corporation, Los Angeles, CA*

Prof. Jack Moehle, *University of California, Berkeley and Director of PEER Center, Berkeley, CA*

Prof. Graham Powell, *Professor Emeritus, University of California, Berkeley, Berkeley, CA*

Mr. Gary Searer, *Structural Engineer, Wiss, Janney, Elstner Associates, Emeryville, CA*

Dr. Paul Somerville, *Principal Seismologist, URS Corporation, Pasadena, CA*

Prof. John Wallace, *University of California, Los Angeles, CA*



CONTENTS

1. INTENT, SCOPE, JUSTIFICATION, AND METHODOLOGY.....	4
1.1. Intent.....	4
1.2. Scope.....	4
1.3. Justification.....	5
1.4. Methodology.....	5
2. ANALYSIS AND DESIGN PROCEDURE.....	7
2.1. STEP 1 – Serviceability Requirement	
(3D Response Spectrum Analysis, 50% in 30 Years Event, No Reductions)	12
2.1.1. Ground Motion	12
2.1.2. Mathematical Model.....	12
2.1.3. Description of Analysis Procedure	13
2.1.4. Acceptability Criteria.....	13
2.2. STEP 2 – Life Safety Requirement	
(3D Response Spectrum Analysis, 10% in 50 Years Event, Code Reductions).....	15
2.2.1. Ground Motion	15
2.2.2. Mathematical Model.....	15
2.2.3. Description of Analysis Procedure	16
2.2.4. Acceptability Criteria.....	16
2.3. STEP 3 – Collapse Prevention Requirement	
(3D Nonlinear Response History Analysis, 2% in 50 Years Event with Deterministic Limit) 17	17
2.3.1. Ground Motion	17
2.3.1.1 Design Spectra.....	17
2.3.1.2 Time Histories	17
2.3.1.3 Scaling of Time Histories	18
2.3.2. Mathematical Model.....	18
2.3.3. Description of Analysis Procedure	21
2.3.4. Acceptability Criteria.....	22
2.4 Exclusions.....	24
2.5. Design Review	26
2.5.1 Peer Review Panel.....	26
2.5.2 Assurance of Consistency and Quality of the Peer Review Process	26
References:	27



ABOUT THE COUNCIL

The Los Angeles Tall Buildings Structural Design Council was formed in 1988 to provide a forum for the discussion of issues relating to the design of tall buildings. The Council seeks to advance state-of-the-art structural design through interaction with other professional organizations, building departments, and university researchers as well as recognize significant contributions to the structural design of tall buildings. The Council is an affiliate of the Council on Tall Buildings and Urban Habitat (CTBUH).

The Council is a nonprofit California corporation whose members are those individuals who have demonstrated exceptional professional accomplishments in the structural design of tall buildings. The annual meeting of the Council represents a program for engineers, architects, contractors, building officials and students. The annual meeting program includes research reports on areas of emerging importance, case studies of current structural designs, and consensus documents by the membership on contemporary design issues.



1. INTENT, SCOPE, JUSTIFICATION, AND METHODOLOGY

1.1. Intent

The intent of the document is to provide an alternate, performance-based approach for seismic design and analysis of tall buildings with predictable and safe performance when subjected to earthquake ground motions. These provisions result in more accurate identification of relevant demands on tall buildings. As such, it is expected that application of the procedure contained in this document results in buildings that resist earthquake forces more effectively and reliably.

C.1.1. Code provisions are intended to provide a minimum level of safety for engineered buildings. Many of the code provisions are prescriptive in nature. Most of the Code provisions are not developed with the requirements of tall buildings in mind since these buildings comprise a very small minority of new construction projects. As a result, there are a certain number of provisions in the codes that were never intended for application to tall buildings. Conversely, there are provisions lacking in the prescriptive codes that are essential for proper behavior of tall buildings. By replacing a small number of code provisions with a comprehensive performance-based linear and nonlinear evaluation of system performance, this document provides a rational approach to seismic design of reliable and effective tall building structures.

1.2. Scope

Application of the procedure contained in this document is limited to tall buildings. For the purpose of this procedure, tall buildings are defined as buildings with a total height of 160 feet or more.

C.1.2. Although there is nothing in this document that limits its applicability to shorter buildings, its scope of application has been intentionally narrowed to tall buildings. The reason for this is twofold. First, the Council considers shorter buildings outside its scope of activities. Second, the procedure contained in this document is complex and time-consuming and therefore it is doubtful that such an elaborate procedure would be justified for smaller, less complex buildings.



1.3. Justification

This document is based on the Section 16.29.10.1 of the 2002 City of Los Angeles Building Code (2002-LABC) which permits the application of alternative lateral-force procedures using rational analysis based on well-established but complex principles of mechanics in lieu of some of the provisions of the 2002-LABC.

1.4. Methodology

The alternative procedure contained in this document is essentially a performance based approach which embodies the performance goals provided in the SEAOC BlueBook (C101.1.1 of the 1999 Bluebook) complimented with a number of latest provisions from the ASCE 7-05, the upcoming 2006-IBC, and the FEMA-356 documents. Three levels of ground motion and performance are considered:

1. Serviceability. This is a service level earthquake evaluation where the building and nonstructural components associated with the building are to be undamaged. The service level design earthquake is taken as an event having a 50% probability of being exceeded in 30 years (43 year return period). For this level, the building structural members are designed without a reduction factor ($R = 1$). This evaluation is not contained in current code requirements. The purpose of this evaluation is to check the structural members. The objective is to produce a structure that remains serviceable following such event.
2. Life-Safety. This is a code-level seismic evaluation where the building and nonstructural components are expected to experience some damage. The life-safety level design earthquake is taken as an event having a 10% probability of being exceeded in 50 years (475 year return period). For this level of earthquake, building code requirements are strictly followed with a small number of carefully delineated exceptions and modifications. The prescriptive connection detailing conforms to the requirements of the code. The purpose of these analyses is to



check that the strength and stiffness of structural members, their connections, and nonstructural components meet or exceed the corresponding demands. As implicit in building codes, damage is permitted as long as life-safety is not compromised. Standard code load combinations and material code standards are used.

3. Collapse-Prevention. This is an evaluation intended to safeguard against collapse during an extremely rare event. The collapse-prevention level design earthquake is taken as an event having a 2% probability of being exceeded in 50 years (2,475 year return period) with a deterministic limit. This is the MCE event as defined by ASCE 7-05 and the upcoming 2006-IBC and is larger than the current 2002-LABC MCE event which has a return period of 975 years. This evaluation is performed using nonlinear response history analyses. This level of evaluation substantially exceeds current code level evaluations. This document contains the criteria to be used for such evaluation. The purpose of this level of evaluation is to check that the demands on the structural members and connections are less than the corresponding capacities, and that collapse does not occur when the building is subjected to the above-mentioned MCE ground motions. Demands are checked against both structural members of the lateral force resisting system and other structural members. Nonstructural components are not evaluated at this level.

A summary of the basic requirements for each step of analysis is presented in Table 1. More detailed information regarding these steps is contained in the following sections of the document.



Table 1. Summary of Basic Requirements

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

¹ probability of exceedance in percent / number of years

³ nonlinear dynamic procedure

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

² linear dynamic procedure

⁴ three-dimensional

2. ANALYSIS AND DESIGN PROCEDURE

Seismic analysis and design of the building shall be performed in three steps as follows. These steps are intended to provide a building which:

- STEP 1. Remains serviceable when subjected to frequent earthquakes (50% in 30 years);
- STEP 2. Provides life safety during a design basis earthquake (10% in 50 years) and;
- STEP 3. Does not experience collapse during an extremely rare event (2% in 50 years with deterministic limit).



C.2. The three-step procedure contained in this document is an explicit state-of-the-art embodiment of the philosophy deeply rooted and implicit in most building codes requiring that buildings be able to¹:

1. Resist minor levels of earthquake ground motion without damage;
2. Resist moderate levels of earthquake ground motion without structural damage, but possibly experience some nonstructural damage;
3. Resist major levels of earthquake ground motion having an intensity equal to strongest either experienced or forecast for the building site, without collapse, but possibly with some structural as well as nonstructural damage.

In its conceptual framework for performance based design, SEAOC² suggests the following levels for design and verification:

Event	Recurrence Interval	Probability of Exceedance
Frequent	43 years	50% in 30 years
Occasional	72 years	50% in 50 years
Rare	475 years	10% in 50 years
Very Rare	975 years	10% in 100 years

The same SEAOC performance based design framework recommends the following seismic performance objectives for new construction:

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

The intent of the procedure contained in this document is that buildings designed according to it meet or exceed the Basic Objective delineated.

1. SEAOC, *Recommended Lateral Force Requirements and Commentary*, 1967 Edition, Section 2313(a).
2. SEAOC, *Recommended Lateral Force Requirements and Commentary*, 1999, 7th Edition, Appendices G and I.



C.2. (continued).

This objective is achieved by requiring serviceability at a 50% in 30 years event, life safety at a 10% in 50 years event, and collapse prevention at a 2% in 50 years event (with deterministic limit). The selection of hazard levels for various performance levels is based on an evaluation of typical probabilistic response spectra for a typical site (Class D soil) in downtown Los Angeles as shown below. These figures show probabilistic equal-hazard spectral values corresponding to various return periods and represent the mean values computed after calculation of spectral ordinates using three attenuation relations^{1, 2, 3}. Dispersion of data in the attenuation relations was considered in the probabilistic seismic hazard analyses.

Figure C.2-1 shows 5% damped spectral accelerations calculated as above for the period range of 0.0 to 8.0 seconds. Figure C.2-2 shows the same results for the period range of primary interest for tall buildings (3.0 to 8.0 seconds) and Figure C.2-3 shows 5% damped spectra displacements for the period range of 0.0 to 8.0 seconds.

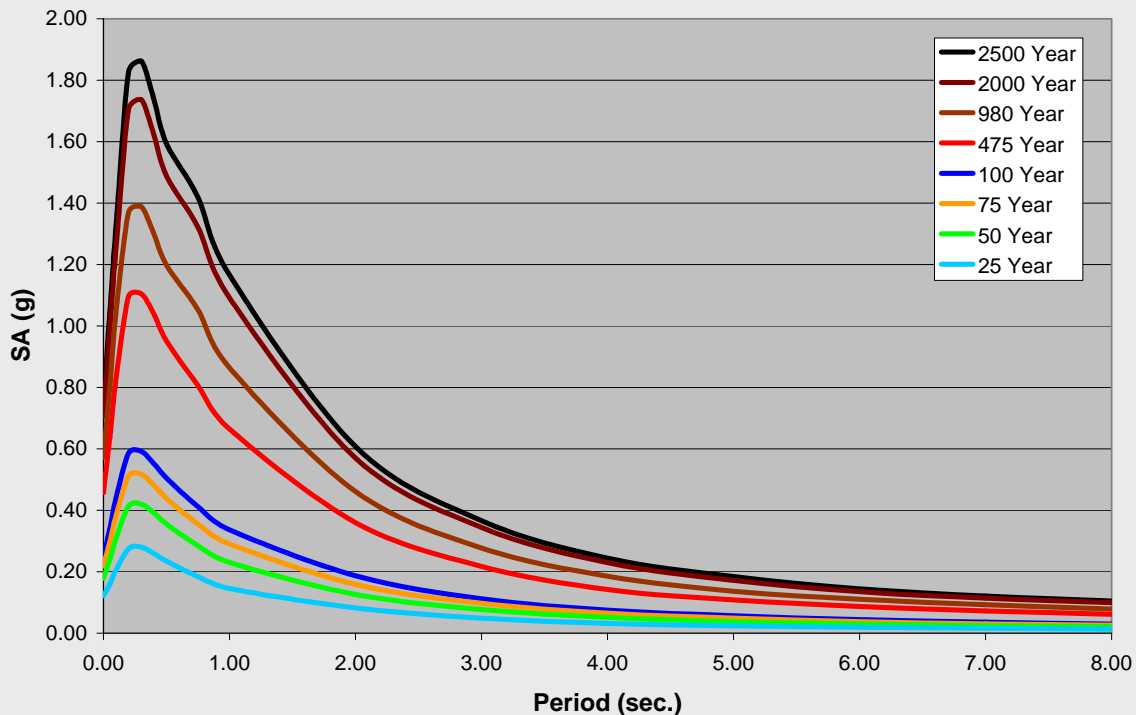


Figure C.2-1. Mean values of spectral acceleration obtained from three attenuation relations.

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



C.2. (continued).

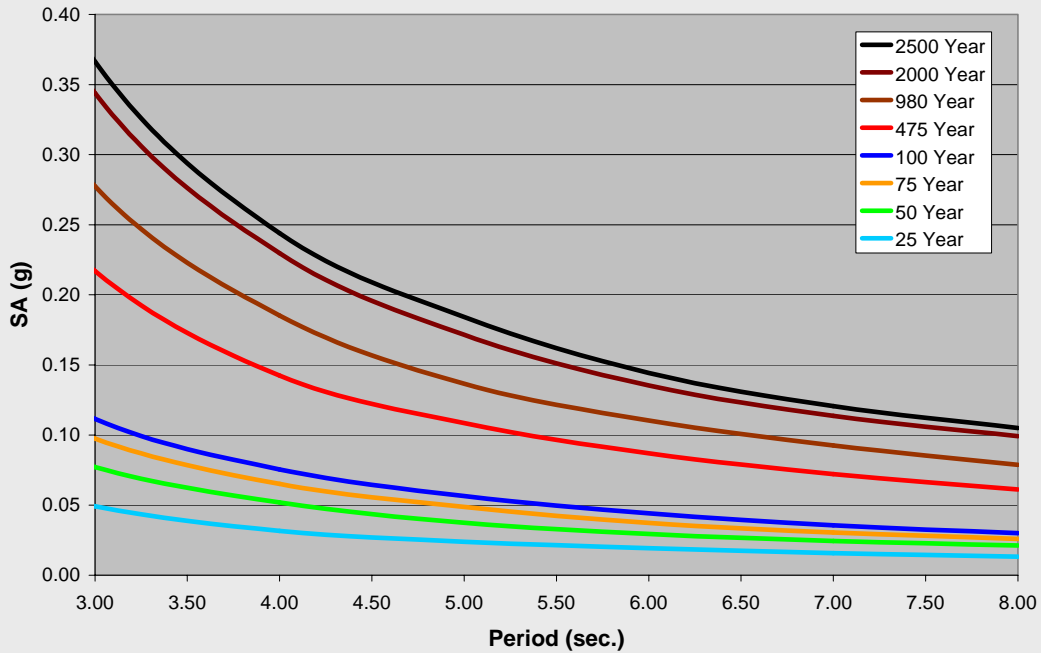


Figure C.2-2. Mean values of spectral acceleration obtained from three attenuation relations for period ranges of 3.0 to 8.0 seconds.

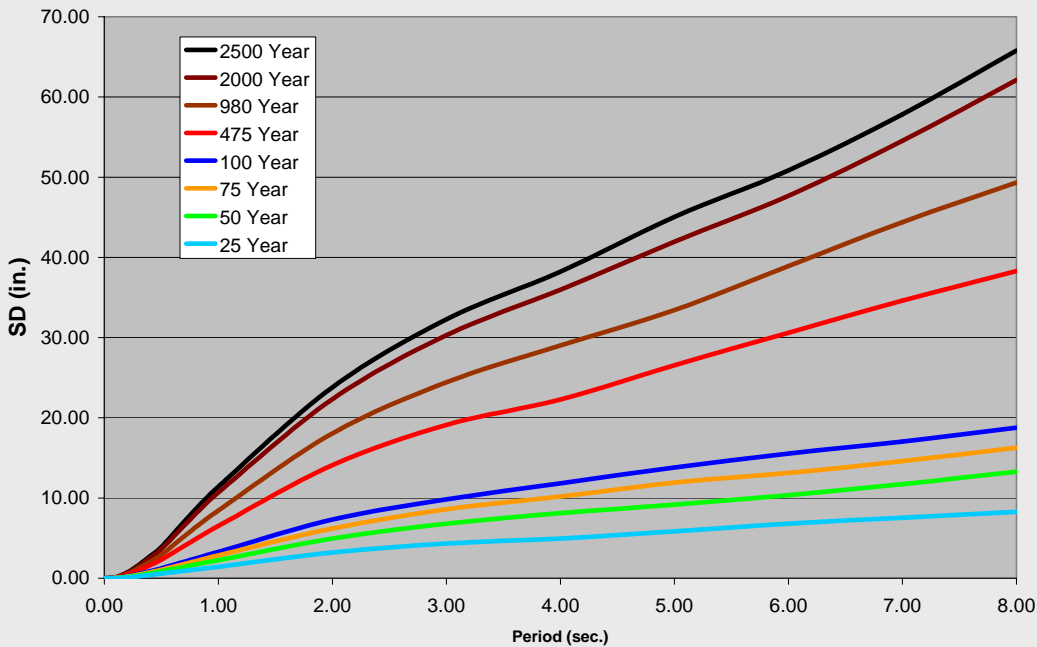


Figure C.2-3. Mean values of spectral displacement (inches) obtained from three attenuation relations.



C.2. (continued).

Values of spectral displacements depicted in Figure C.2-3 are presented in Table C.2-1. Values of spectral values normalized to the corresponding value for the 475 year event are presented in Table C.2-2.

Table C.2-1. Mean values of spectral displacement (inches) obtained from three attenuation relations. Accelerations (in/sec²) may be obtained by multiplying the tabulated values by

$$\left(\frac{2\pi}{\text{Period}} \right)^2$$

Period (sec.)	25-Year	50-Year	75-Year	100-Year	475-Year	980-Year	2,000-Year	2,500-Year
0.10	0.02	0.03	0.04	0.04	0.08	0.10	0.12	0.13
0.20	0.11	0.16	0.20	0.23	0.43	0.54	0.67	0.72
0.30	0.25	0.37	0.46	0.52	0.97	1.22	1.53	1.64
0.50	0.57	0.87	1.07	1.24	2.33	2.93	3.64	3.90
1.00	1.43	2.25	2.84	3.29	6.51	8.46	10.69	11.41
2.00	3.22	4.95	6.21	7.31	14.10	18.06	22.34	23.80
3.00	4.32	6.80	8.58	9.81	19.11	24.44	30.29	32.27
4.00	4.95	8.11	10.20	11.82	22.28	29.02	35.96	38.21
5.00	5.84	9.16	11.92	13.82	26.55	33.42	41.96	45.05
6.00	6.82	10.34	13.14	15.56	30.60	38.90	47.67	50.84
7.00	7.52	11.73	14.59	17.04	34.61	44.40	54.53	57.84
8.00	8.29	13.28	16.26	18.78	38.31	49.33	62.11	65.77

Table C.2-2. Ratio of spectral ordinates (accelerations and displacements) to the corresponding 475 year values

Period (sec.)	25-Year	50-Year	75-Year	100-Year	475-Year	980-Year	2,000-Year	2,500-Year
0.10	0.25	0.37	0.46	0.53	1.00	1.26	1.51	1.60
0.20	0.25	0.38	0.47	0.53	1.00	1.25	1.56	1.67
0.30	0.25	0.38	0.47	0.54	1.00	1.26	1.57	1.69
0.50	0.25	0.37	0.46	0.53	1.00	1.26	1.56	1.67
1.00	0.22	0.35	0.44	0.51	1.00	1.30	1.64	1.75
2.00	0.23	0.35	0.44	0.52	1.00	1.28	1.58	1.69
3.00	0.23	0.36	0.45	0.51	1.00	1.28	1.59	1.69
4.00	0.22	0.36	0.46	0.53	1.00	1.30	1.61	1.71
5.00	0.22	0.35	0.45	0.52	1.00	1.26	1.58	1.70
6.00	0.22	0.34	0.43	0.51	1.00	1.27	1.56	1.66
7.00	0.22	0.34	0.42	0.49	1.00	1.28	1.58	1.67
8.00	0.22	0.35	0.42	0.49	1.00	1.29	1.62	1.72



2.1. STEP 1 – Serviceability Requirement (3D Response Spectrum Analysis, 50% in 30 Years Event, No Reductions)

2.1.1. Ground Motion

The ground motion representation for this step shall be one having a 50% probability of being exceeded in 30 years (mean recurrence interval of 43 years) and shall not be reduced by the quantity R . The ground motion representation for this step shall consist of a site-specific elastic design response spectrum based on the geologic, tectonic, seismologic, and soil characteristics associated with the specific site. The spectrum shall be developed for 5% damping, unless a different value is shown to be consistent with the anticipated structural behavior at the intensity of shaking established for the site.

2.1.2. Mathematical Model

A three-dimensional mathematical model of the physical structure shall be used that represents the spatial distribution of the mass and stiffness of the structure to an extent that is adequate for the calculation of the significant features of its dynamic response. The stiffness properties used in the analysis and general mathematical modeling shall be in accordance with 2002-LABC Section 1630.1.2. Expected material strengths may be used (see Table 2.3.2-1).

C.2.1.2. Three-dimensional mathematical models of the structure are required for all analyses and evaluations. Given the current state of modeling capabilities and available software systems, there is no reason to estimate the actual three-dimensional behavior of tall buildings by relying on approximate two-dimensional models. The accuracy obtained by using three-dimensional models substantially outweighs the advantage of the simplicity offered by two-dimensional models.

Expected material strengths provide a more realistic measure of performance than the specified values.



2.1.3. Description of Analysis Procedure

Elastic response spectrum analysis of the three dimensional structure shall be performed. At least 90 percent of the participating mass of the structure shall be included in the calculation of response for each principal horizontal direction. Modal responses shall be combined using the Complete Quadratic Combination (CQC) method.

The corresponding response parameters, including forces, moments and displacements, shall be denoted as Elastic Response Parameters. Elastic Response Parameters shall not be reduced.

Inclusion of accidental torsion is not required.

The following load combinations shall be used:

$$1.0D + 0.5L \pm 1.0E_x \pm 0.3E_y \quad (1)$$

$$1.0D + 0.5L \pm 0.3E_x \pm 1.0E_y \quad (2)$$

C.2.1.3. The intention of this step of analysis is to verify that the building remains serviceable following a frequent earthquake. Therefore, the number of load combinations utilized is limited to two containing 100% earthquake excitation in one direction and 30% in the other. More detailed load combinations are utilized in the life-safety analyses (Step 2).

Use of Complete Quadratic Combination (CQC) method is required because it provides more reliable results for flexible structures such as tall buildings compared to the Square Root of Sum of Squares (SRSS).

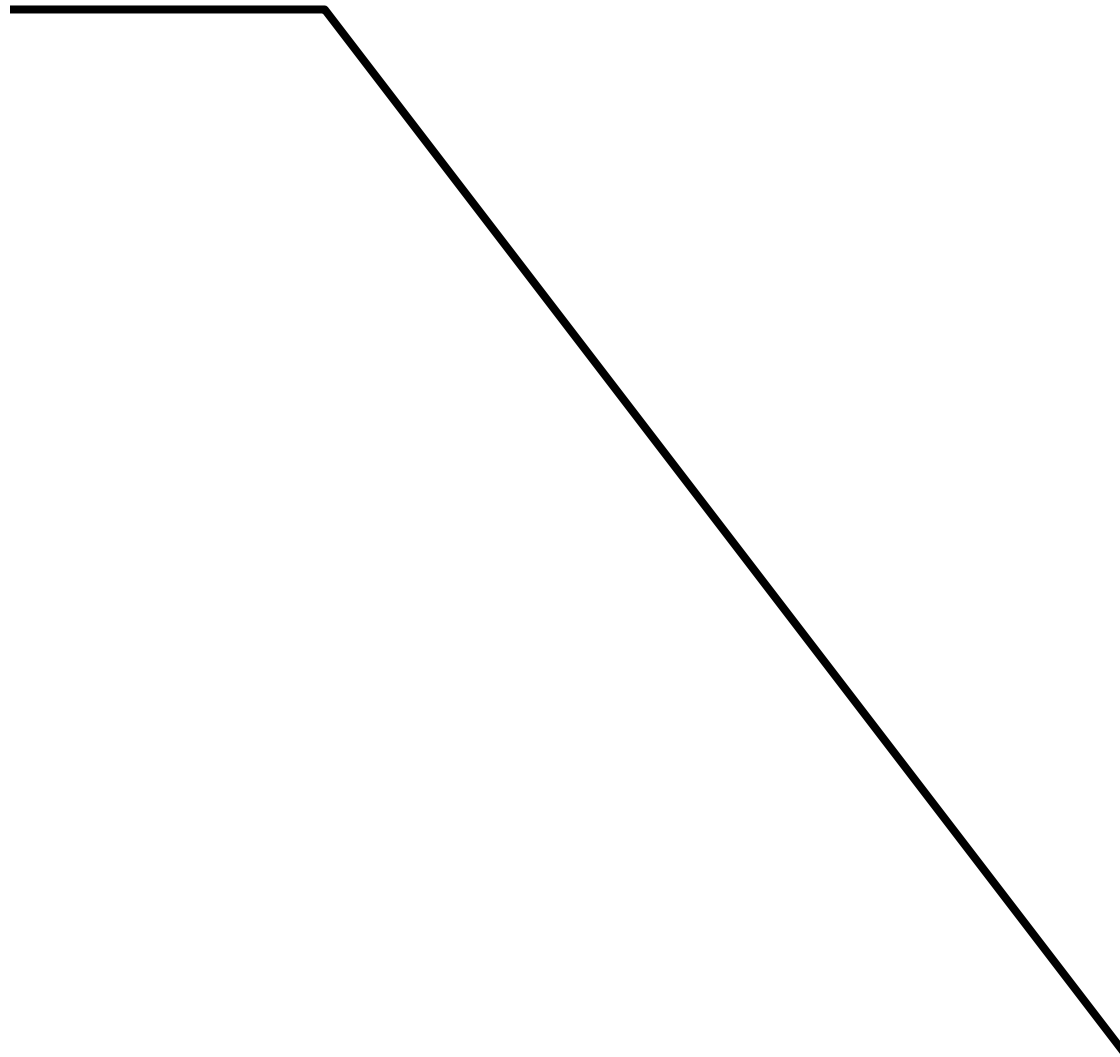
Inclusion of accidental eccentricity is not required because accidental eccentricities are considered in Step 2 of the analysis which parallels 2002-LABC prescriptive requirements.



2.1.4. Acceptability Criteria

The structure shall be deemed to have satisfied the acceptability criteria for this step if none of the members exceed the applicable LRFD limits for steel members or USD limits for concrete members ($\phi = 1.0$). Note that the design spectral values shall not be reduced by the quantity R .

C.2.1.4. This document's use of $R=1$ for this level of analysis and the corresponding acceptability criteria is consistent with the recommendations of Appendix I of the 1999 SEAOC BlueBook.





2.2. STEP 2 – Life Safety Requirement (3D Response Spectrum Analysis, 10% in 50 Years Event, Code Reductions)

2.2.1. Ground Motion

A site-specific elastic design spectrum consistent with the requirements of 2002-LABC Sec. 1631.2 and 1631.2.2 shall be developed and used. The ground motion representation for this step shall consist of a site-specific elastic design response spectrum based on the geologic, tectonic, seismologic, and soil characteristics associated with the specific site. The spectrum shall be developed for 5% damping, unless a different value is shown to be consistent with the anticipated structural behavior at the intensity of shaking established for the site.

C.2.2.1. The second step described in this section is intended to satisfy basic life-safety requirements. The use of a site-specific response spectrum is required to provide consistency across steps because steps 1 and 3 require site-specific ground motion information. The response spectrum developed and utilized in this step is in strict conformance with the 2002-LABC provisions.

2.2.2. Mathematical Model

A three-dimensional mathematical model of the physical structure shall be used that represents the spatial distribution of the mass and stiffness of the structure to an extent that is adequate for the calculation of the significant features of its dynamic response. The stiffness properties used in the analysis and general mathematical modeling shall be in accordance with 2002-LABC Section 1630.1.2.

C.2.2.2. Three-dimensional mathematical models of the structure are required for all analyses and evaluations. See C.2.1.2 for the justification.



2.2.3. Description of Analysis Procedure

Elastic response spectrum analysis of the three dimensional structure shall be performed. At least 90 percent of the participating mass of the structure shall be included in the calculation of response for each principal horizontal direction. Modal responses shall be combined using the Complete Quadratic Combination (CQC) method. The corresponding response parameters, including forces, moments and displacements, shall be denoted as Elastic Response Parameters. Elastic Response Parameters may be reduced for purposes of design in accordance with the provisions of 2002-LABC Section 1631.5.4.

Structural analysis and design shall be performed in accordance with all relevant 2002-LABC provisions except for the provisions specifically excluded in Section 2.4 of this document.

C.2.2.3. The intention of this step of analysis is to verify that the building remains life-safe following a rare event. The rare event as used in the 1999 SEAOC Blue Book corresponds with the Design Basis earthquake in the 2002-LABC (10% probability of exceedance in 50 years). Dynamic (response spectrum) analysis is required for all buildings in this step.

Analysis and design in this step is in compliance with the provisions of the 2002-LABC except that this document contains a number of requirements not specifically mandated by the 2002-LABC (i.e., three-dimensional model, mandatory dynamic analysis and CQC combination) as well as a number of exceptions to 2002-LABC provisions that are explicitly addressed in Section 2.4 of this document.

Use of Complete Quadratic Combination (CQC) method is required because it provides more reliable results for flexible structures such as tall buildings compared to the Square Root of Sum of Squares (SRSS).

Accidental eccentricities must be considered and code specified load combinations must be used as this step closely parallels 2002-LABC prescriptive provisions.

2.2.4. Acceptability Criteria

The structure shall satisfy all relevant 2002-LABC requirements except the provisions explicitly identified in Section 2.4 of this document.



2.3. STEP 3 – Collapse Prevention Requirement (3D Nonlinear Response History Analysis, IBC-2006 / ASCE 7-05 Maximum Considered Event – 2% in 50 Years Event with Deterministic Limit, No Reductions)

2.3.1. Ground Motion

2.3.1.1 Design Spectra

Maximum Considered Earthquake (MCE) ground motions represented by response spectra and coefficients derived from these spectra shall be determined in accordance with the site specific procedure of Section 21 of ASCE 7-05. The MCE ground motions shall be taken as that motion represented by a 5% damped acceleration response spectrum having a 2% probability of exceedance within a 50-year period subject to a deterministic limit. The deterministic limit on MCE shall be taken as that defined in Sections 21.2.2 and 21.2.3 of ASCE 7-05.

C.2.3.1.1. There is a national trend towards using a 2,475 year event with a deterministic limit as representative of the MCE event instead of the 975 year event used by 2002-LABC and previous editions of the Uniform Building Code. The 2,475 year event represents larger ground motions than the 975 year event. Therefore, buildings designed not to collapse during a 2,475 year event would perform better during a 975 year event and would be somewhere between life-safety and collapse prevention following a 975 year event.

FEMA-356, 2006-IBC and ASCE 7-05 have all adapted the concept of a 2,475 year event with a deterministic limit as representative of the MCE event. With the certain adoption of IBC in California on the horizon, this more conservative national definition of MCE is adopted in this document.

The MCE event as used in this document and procedures for development of corresponding site specific response spectra are defined in ASCE 7-05. Therefore, this document adopts the relevant ASCE 7-05 provisions by reference as indicated above.

2.3.1.2 Time Histories

A suite of seven or more appropriate ground motion time histories shall be used in the analysis. Ground motion histories and their selection shall comply with the requirements of Section 17.3.2 of ASCE 7-05.



C.2.3.1.2. Larger suites of appropriate ground motion time histories provide a more reliable statistical basis for analysis. Since three pairs of ground motions provide less statistical accuracy, the use of seven or more pairs of ground motions is recommended. Section 17.3.2 of ASCE 7-05 contains well-established procedures for selection of time-histories and, therefore, is adopted by reference in this document.

2.3.1.3 Scaling of Time Histories

Ground motion time histories shall be scaled according to the provisions of Section 17.3.2 of ASCE 7-05.

C.2.3.1.3. Scaling of ground motion histories so that on average the resulting response spectrum does not fall below the MCE spectrum in the period range of interest provides a level of consistency that would be lacking if reliance was made solely on the judgment of a particular geotechnical engineer who selected the time histories. Section 17.3.2 of ASCE 7-05 contains well-established procedures for scaling time-histories and, therefore, is adopted by reference in this document.

2.3.2. Mathematical Model

A three-dimensional mathematical model of the physical structure shall be used that represents the spatial distribution of the mass and stiffness of the structure. P- Δ effects shall be included in all nonlinear response history analyses. In addition to the designated elements and components of the lateral force resisting system, all other elements and components that in combination represent more than 15% of the total initial stiffness of the building, or a particular story, shall be included in the mathematical model.

The hysteretic behavior of elements shall be modeled consistent with suitable laboratory test data or applicable modeling parameters for nonlinear response analyses published in FEMA-356. The nonlinear deformations shall be limited to the FEMA-356 Primary Collapse Prevention limits unless the exception noted in Section 2.3.4 of this document is invoked. Modeling of strength



degradation, stiffness degradation and hysteretic pinching is not necessary unless the exception noted in Section 2.3.4 of this document is invoked.

Strength of elements shall be based on expected values ($\phi = 1.0$) considering material overstrength. The following values may be assumed:

Table 2.3.2-1. Expected Material Strengths

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

* based on 2002 AISC Seismic Provisions

** based on FEMA-356

Elastic or equivalent elastic properties consistent with 2002-LABC provisions shall be permitted to be used for those elements demonstrated by analysis to remain within their linear range of response.

Realistic assumptions with regard to the stiffness and load carrying characteristics of the foundations consistent with site-specific soils data and rational principles of engineering mechanics shall be used, or alternatively the structure may be designed to have a fixed-base.



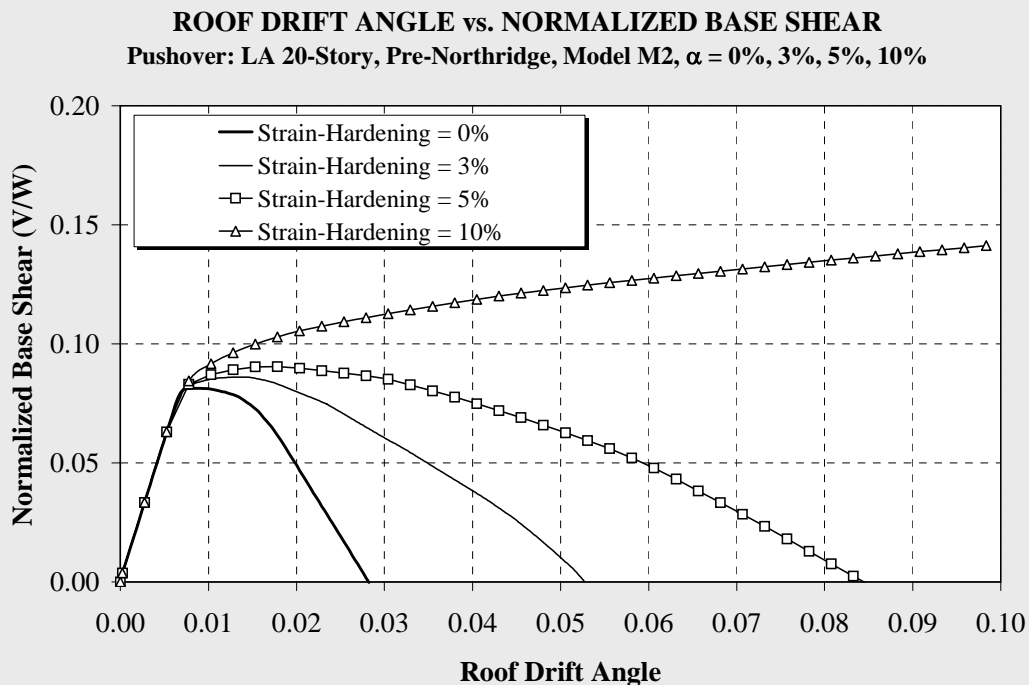
C.2.3.2. Three-dimensional mathematical models of the structure are required for all analyses and evaluations. See C.2.1.2 for the rationale.

Realistic inclusion of P- Δ effects is crucial for establishing the onset of collapse because collapse is ultimately P- Δ related¹. The push-over curves shown on the Figure below are illustrative of this point.

FEMA-356 Primary Collapse Prevention limits are conservative limits that are selected so that significant degradation would not occur prior to reaching them. Therefore, modeling of degradation is not necessary if deformations are kept below these limits.

Suggested material strength values considering overstrength are based on FEMA-356 for concrete and reinforcing steel; and 2002 AISC Seismic Provisions for structural steel.

Realistic modeling of the interface between the building and foundations are important.



Typical push-over analysis curves when P- Δ effects are properly considered¹.

1. Krawinkler, H. (2005), *A few comments on P-Delta, Overstrength, Drift, Deformation Capacity, Collapse Capacity, and other issues*, Presentation at the LATBSDC Invitational Workshop, September 22, Los Angeles.



2.3.3. Description of Analysis Procedure

Three-dimensional nonlinear response history analyses of the structure shall be performed. For each horizontal ground motion pair, the structure shall be analyzed for the effects of the following loads and excitations:

$$1.0D + 0.5L + 1.0E_x + 1.0E_y \quad (1)$$

$$1.0D + 0.5L + 1.0E_x - 1.0E_y \quad (2)$$

$$1.0D + 0.5L - 1.0E_x + 1.0E_y \quad (3)$$

$$1.0D + 0.5L - 1.0E_x - 1.0E_y \quad (4)$$

Inclusion of accidental torsion is not required for three dimensional nonlinear response history analyses as specified in this document.

C.2.3.3. Three-dimensional mathematical models of the structure are required for all analyses and evaluations. See C.2.1.2 for the rationale.

In contrast to Step 1 where the 100%-30% rule was invoked for modeling the orthogonal effects in a linear regime, both horizontal components of the ground motion pair are applied simultaneously in Step 3.

Application of vertical accelerations is not required because these accelerations mostly contain high-frequency vibrations that do not control the behavior of tall buildings. However, it may become necessary to consider vertical accelerations for structures or components which are sensitive to such motions such as structures with long cantilevers. In such cases, the analyses should account for vertical acceleration effects.

Inclusion of accidental eccentricity is not necessary as it significantly complicates the nonlinear analysis in the absence of superposition rules and the fact that accidental eccentricity is considered in Step 2.



2.3.4. Acceptability Criteria

Structural strength and deformation capacities shall not be less than demands determined under Section 2.3.3 of this document.

Deformation capacities shall be assumed to be equal to the corresponding Primary Collapse Prevention values published in FEMA-356 for nonlinear response procedures.

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

The demand values (for member forces, member inelastic deformations, and inter-story drift) shall be permitted to be taken respectively as the average of the values determined from the seven or more pairs of records used in the analyses.

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

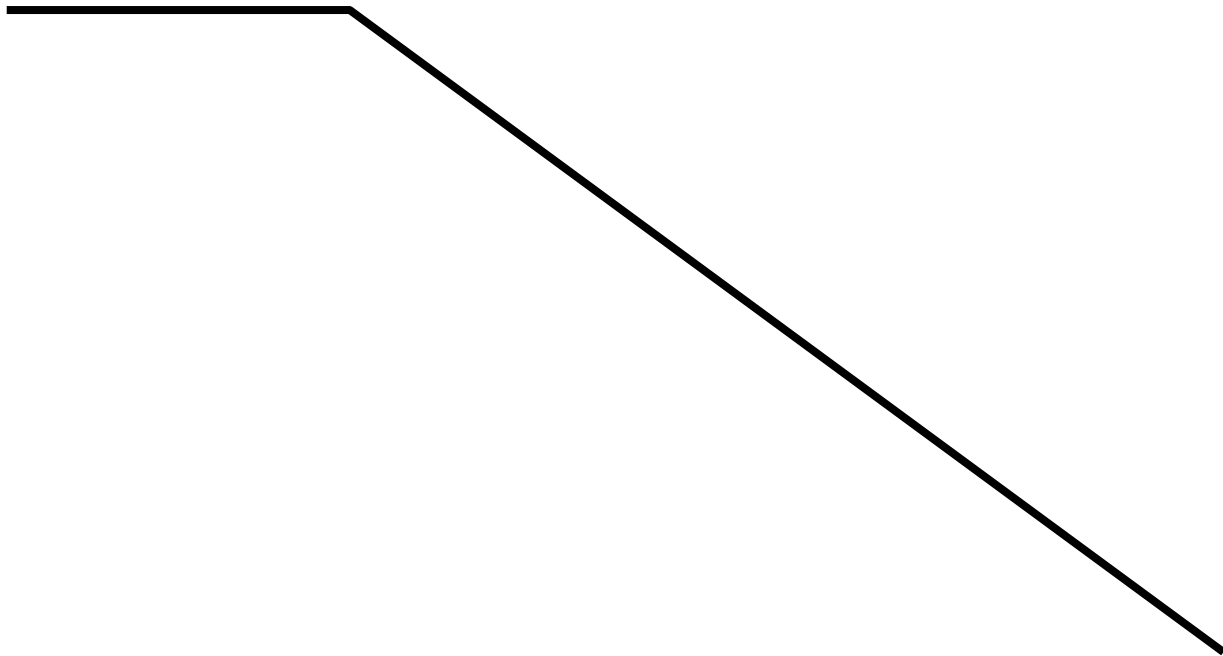


C.2.3.4. FEMA-356 Primary Collapse Prevention limits for nonlinear response procedures are conservative limits that are selected so that significant degradation would not occur prior to reaching them. Therefore, modeling of degradation is not necessary if deformations are kept below these limits (see C.2.3.2.). If, however, the relevant FEMA-356 tabulated Primary Collapse limits are exceeded, the mathematical model must explicitly contain various material degradations and pinching effects and hysteretic models that must be approved by the peer review panel and building officials.

Use of seven or more ground motion pairs is required because it provides a more reliable statistical basis for the demand values.

Proper performance of collector elements is essential for transferring and delivering the seismic forces to resisting elements. Therefore, proper design and proportioning of these elements is vital for the successful performance of the building.

All structural elements, whether or not their strength is considered in determining the lateral strength of the building (i.e., whether or not they are designated as part of the seismic-force-resisting system), shall be designed and detailed to accommodate the seismic deformations imposed.





2.4 Exclusions

For buildings analyzed and designed according to the provisions of this document:

- a. The seismic force amplification factor, Ω_0 , in 2002-LABC formula 30-2 is set to unity ($\Omega_0 = 1.0$).
- b. The Reliability/Redundancy Factor, ρ , as provided by 2002-LABC formula 30-3 is set to unity ($\rho = 1.0$).
- c. Static 2002-LABC formulas 30-6 and 30-7 do not apply. Instead in Step 2, the seismic base shear (V) shall not be taken less than $0.025W$ where W is the effective seismic weight.
- d. Method A (2002-LABC Sec. 1630.2.2.1) does not apply. Results obtained by Method B or more advanced analysis are not bound by the results obtained from Method A.
- e. The limit on calculated story drift of $0.020/T^{1/3}$ specified in 2002-LABC 1630.10.2 does not apply.
- f. The height limitations of 2002-LABC Table 16-N do not apply.

C.2.4. The specific provisions itemized and excluded in this section are either unnecessary or have adverse or unintended effects on the performance of tall buildings analyzed and designed according to the three-step procedure contained in this document.

- (a) The seismic force amplification factor, Ω_0 , is intended to implicitly model the effects of structural overstrength. The material and structural overstrength, however, are explicitly modeled via nonlinear dynamic response analyses (Step 3) of the procedure contained in this document. Therefore, double-counting of overstrength by inclusion of values of Ω_0 larger than unity is not necessary.
- (b) The Reliability/Redundancy Factor, ρ , is intended to promote reliability of structural systems by encouraging redundant systems and penalize or prohibit non-redundant structural systems. The approximate nature of ρ has been well documented (Searer 2000; Searer and Freeman 2002AB). Given the fact that the reliability of the structural system is explicitly modeled and verified in this procedure by a set of nonlinear dynamic response analyses under a very severe MCE event, utilization of a Reliability/Redundancy Factor, ρ , is not necessary. Therefore, the value of ρ is set to unity.

**C.2.4. (Continued)**

- (c) Static 2002-LABC formulas 30-6 and 30-7 were added to the code following the 1994 Northridge earthquake. They are intended to provide a lower limit on design for systems analyzed according to code static lateral force procedure and code linear dynamic (response spectrum) procedure. They were never intended to apply to buildings analyzed and designed using nonlinear dynamic response analysis as contained in this document where site specific response spectra and selected time histories are specifically selected to consider the near field effects and others effects of significance (Bachman, 2005). The procedure contained in this document verifies the adequacy of the performance of the building using nonlinear dynamic response analyses of the building when subjected to a 2,475 year event (with deterministic cap) which is larger than LABC's design basis event (475 year) or MCE event (975 year). Therefore, application of these formulas to buildings designed according to this procedure is unwarranted. Although not necessary, in order to provide an absolute minimum value for base shear equal to 250% of the minimum base shear required by Eq. 12.8-5 of ASCE 7-05 is adopted.
- (d) Method A (2002-LABC Sec. 1630.2.2.1) is based on empirical formulas calibrated to underestimate the period in order to conservatively estimate the base shear used in code static lateral force procedure and code linear dynamic (response spectrum) procedure (see Chopra and Goel, 2000). These formulas are almost entirely based on observations obtained from low-rise and mid-rise buildings and as such are not reliable for application to tall buildings. Furthermore, the procedure contained in this document calculates and uses the periods of the building according to scientifically approved methods in three distinct stages of building behavior (serviceability, life-safety, and collapse prevention stages). Therefore, application of Method A procedure is not necessary.
- (e) The limit on calculated story drift of $0.020/T^{1/3}$ specified in 2002-LABC 1630.10.2 is intended to rectify an anomaly where in some cases the calculated drift using the 1997 UBC fell below the similar values calculated using the 1994 UBC (LARUCP 2001-2002). This provision was never intended to apply to buildings analyzed and designed using nonlinear dynamic response analysis as contained in this document (Bachman, 2005). The procedure contained in this document verifies the adequacy of the performance of the building using nonlinear dynamic response analyses of the building when subjected to a 2,475 year event which is significantly larger than LABC's design basis event (475 years) or MCE event (975 years). Therefore, application of this formula to buildings designed according to this procedure is not necessary.
- (f) The height limitations contained in Table 16-N are based more on tradition and results obtained from conventional analysis and design rather than on science. Given the extensive three-step analysis and design procedure contained in this document, application of the height limitations contained in Table 16-N are not necessary.



2.5. Design Review

2.5.1 Peer Review Panel

Design review shall be conducted according to the provisions of 2002-LABC Section 1631.6.3.2. In addition, the review need not be limited to lateral system and may include review of the entire system including the gravity system, acceptance criteria, configuration of structural elements, and performance/design philosophy, design ground motions, and quality assurance measures.

When this document is used as the basis of design, the cost for the peer review process shall be borne by the owner.

C.2.5.1. The procedure contained in this document is significantly more complex and burdensome than the current 2002-LABC provisions. Therefore extensive peer review by a recognized panel of experts is an essential element of this procedure. The peer review process must be complete and comprehensive. The peer review panel must be involved with the project during all stages, from preliminary design to final design.

2.5.2 Assurance of Consistency and Quality of the Peer Review Process

It is strongly recommended that an advisory board appointed by the region's building and safety authorities be formed. This advisory board shall consist of experts who are widely respected and recognized for their expertise in relevant fields, including but not limited to, structural engineering, performance-based design, nonlinear analysis techniques, and geotechnical engineering. The advisory board members may be elected to serve for a predetermined period of time on a staggered basis. The advisory board shall oversee the design review process across multiple projects periodically; assist the building department in developing criteria and procedures spanning similar design conditions, and resolve disputes arising under peer review.



When this document is used as the basis of design, the cost for maintaining an advisory board shall be borne by the owner, through additional plan check fees or other means as deemed necessary and appropriate by the Building Official.

C.2.5.2. Establishment of an advisory board is necessary to provide consistency of peer review across multiple projects. The role of the advisory board is particularly important during the first few years of application of the procedure contained in this document.

References:

American Institute of Steel Construction (2002), *Seismic Provisions for Structural Steel Buildings*, ANSI/AISC 341-02, Chicago, Illinois, May 21.

American Society of Civil Engineers (2000), *FEMA-356 Prestandard and Commentary for the Seismic Rehabilitation of Buildings*, Reston, VA.

American Society of Civil Engineers (2005), *ASCE 7-05 Minimum Design Loads for Buildings and Other Structures Including Supplement 1*, Reston, VA.

Bachman, R. (2005), *Personal Communication with F. Naeim*, September 22.

Chopra, A.K. and Goel, R.K. (2000), "Building Period Formulas for Estimating Seismic Displacements," *Earthquake Spectra*, EERI, Volume 16, Issue 2, pp. 533-536.

International Code Council (2002), *2002 City of Los Angeles Building Code, Volume 2*, Falls Church VA.

International Code Council (2003), *International Building Code*, Falls Church VA.

International Conference of Building Officials (1997), *Uniform Building Code*, Whittier, CA.

Krawinkler, H. (2005), *A few comments on P-Delta, Overstrength, Drift, Deformation Capacity, Collapse Capacity, and other issues*, Presentation at the LATBSDC Invitational Workshop, September 22, Los Angeles.

Los Angeles Uniform Code Program (LARUCP 2001-2002), *Structural Code Committee Resolution 6-27r7-2*. Fax from Los Angeles Department of Building and Safety to John A. Martin & Associates, Inc. dated May 28, 2004.

Maffei, J. (2005), *Personal Communication with F. Naeim*.

Searer, G.R. (2000), "Evaluation of the Reliability/Redundancy Factor," Wiss, Janney, Elstner Associates, Emeryville, CA

Searer, G.R. and Freeman, S.A. (2002A), "Impact of the Reliability/Redundancy Factor on Design," Proceedings of the 7th U.S. National Conference on Earthquake Engineering, EERI.

Searer, G.R. and Freeman, S.A. (2002B), "Unintended Consequences of Code Modification," Proceedings of the 7th U.S. National Conference on Earthquake Engineering, EERI.

Somerville, P. (2005), *Personal Communication with F. Naeim*.

Structural Engineers Association of California (SEAOC), *Recommended Lateral Force Requirements and Commentary*, 1967 Edition, Section 2313(a)..

Structural Engineers Association of California (SEAOC), *Recommended Lateral Force Requirements and Commentary*, 1999, 7th Edition, Appendices I and G.