CTBUH Technical Guides

Performance-Based Seismic Design for Tall Buildings 2nd Edition

An output of the CTBUH Performance-Based Seismic Design Working Group

Ramin Golesorkhi, Leonard Joseph, Ron Klemencic, David Shook & John Viise

Council on Tall Buildings and Urban Habitat

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Bibliographic Reference:
Golesorkhi, R., Joseph, L., Klemencic, R., Shook, D. & Viise, J. (2019). ***Performance-Based Seismic Design for Tall Buildings: An Output of the CTBUH Performance-Based Seismic Design Working Group.*** *Second Edition*. Chicago: Council on Tall Buildings and Urban Habitat.

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Printed in the USA

Library of Congress Cataloging-in-Publication Data
A catalog record has been requested for this book

ISBN 978-0-939493-72-2

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Front Cover Image: Wilshire Grand, Los Angeles, under construction in 2015. © Gary Leonard/AC Martin
Opening Chapter Image: 350 Mission St., San Francisco, designed using PBSD principles. © Cesar Rubio

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1.0 Introduction

Performance-Based Seismic Design (PBSD) is a structural design methodology that has become more common in urban centers of the western United States, especially for the design of high-rise buildings. It is a design methodology that allows for design flexibility and offers design opportunities to enhance building performance and encourage innovation. The most common use of PBSD in practice is to substantiate exceptions to specific prescribed code requirements, such as height limits on select structural systems. A second use of PBSD is the ability to demonstrate higher performance levels for a structure at various intensities of a seismic event.

▲ **Figure 1.1: One Rincon Hill, San Francisco, designed using PBSD principles.** © Magnusson Klemencic Associates

An integral component of PBSD is Nonlinear Response History Analysis (NRHA). This advanced method of analysis has been incorporated into the design process in regions with high seismicity, such as in China, Philippines, Indonesia, Turkey, Japan, etc. The design considerations required by the process of PBSD are extensive and require substantial knowledge of nonlinear structural behavior, seismic design, building performance, and analytical modeling. These demands have not limited the design of structures, but instead led to a number of highly efficient tall building designs that would not be possible following a traditional code-prescriptive design approach.

PBSD is currently accepted in numerous urban centers of the United States such as Los Angeles (see Figures 1.1 and 1.2), San Francisco, Seattle, San Diego, Oakland, and Salt Lake City. The current version of the American Society of Civil Engineers loads standard (ASCE 7–16) includes a detailed framework for PBSD, making it possible to use PBSD methods in all US jurisdictions adopting this standard. The broad acceptance of this methodology in the United States will lead to a more detailed understanding of building response in seismic events and allow for further innovations in seismic design.

This publication provides structural engineers, developers, and contractors—in the United States and internationally—a general understanding of the PBSD process and examples from leading structural engineering firms with a history of designing tall buildings in high seismic zones. This publication is not intended as a standard such as ASCE 7, or as a group of guidelines such as PEER/TBI and LATBSDC. Instead, this is a bridging document to introduce PBSD methods to an international audience. Structural engineers should look to develop a project-specific basis of design founded on the references provided and engage their local jurisdictions for appropriate steps needed for project approval. The PBSD process is regularly evolving and the latest standards and guidelines should be referenced.

1.1 Overview of Performance-Based Seismic Design

Performance-based seismic design is a highly developed design methodology that provides greater design flexibility to structural engineers than that afforded by prescriptive code-based approaches. However, the methodology also involves significantly more effort in the analysis and design stages, with verification of building performance required at multiple seismic hazard levels using linear and advanced nonlinear analysis techniques. PBSD uses first principles of engineering to proportion and detail structural systems and components to meet specific performance objectives.

Using PBSD methodology, the focus of the structural engineer changes from a prescriptive "check list" approach of code provisions to requiring the designer to more fully understand building performance and the code's intent. Developing structural designs through a more detailed knowledge of building behavior during a seismic event often results in solutions that satisfy the targeted performance levels more efficiently. Although PBSD requires additional design effort, the benefits can be significant: reduced construction costs, improved lease spaces, and enhanced seismic performance.

▲ **Figure 1.2: Wilshire Grand Center, Los Angeles, designed using PBSD principles.** © Gary Leonard/AC Martin

1.2 Goals of PBSD

Developers and structural engineers utilize PBSD for a variety of reasons. Common goals of PBSD include:

- the ability to make exceptions to specific code requirements, such as height limits for select seismic force-resisting systems;
- the use of seismic force-resisting systems and innovative designs not prescribed by code;
- the use of high-strength materials and mechanical devices not prescribed by code; and
- the reduction of structural and non-structural damage through enhanced seismic performance objectives at specified levels of seismic intensity.

A common example of a seismic force-resisting system not recognized by code is a core-and-outrigger seismic force-resisting system. In the United States, this is not one of the seismic force-resisting systems recognized in ASCE 7. The use of PBSD methods facilitates a method to evaluate and design such seismic force-resisting systems.

1.3 Historical Development of PBSD Provisions

Historically significant earthquake events (e.g., 1971 San Fernando, 1989 Loma Prieta, and 1994 Northridge) caused significant damage and down-time to businesses, residences, and infrastructure in California. As a result of these seismic events, major market sectors like the airline industry in the Los Angeles area and the computing industry in Silicon Valley desired to enhance the performance of their buildings to minimize the risk of casualties, damage to facilities, and down-time of their existing and new facilities should a more frequent event occur. This demand served as a catalyst to the engineering community in the United States to develop design methods to assess performance of existing structures and to develop design methodologies to enhance the performance of these systems, as well as ways to quantify the impact of these enhancements. Performance of existing structures is quantified by the development of performance objectives that are defined for structural systems and components of the system.

Principles central to PBSD were developed to rationally and efficiently guide the design of seismic retrofits to enhance the performance of existing structures. These provisions ultimately resulted in ASCE 41. The current ASCE 41-13 (Seismic Evaluation and Retrofit of Existing Buildings) outlines a series of evaluation levels for existing buildings. Some levels of these types of retrofits are defined as Tier 1 and 2, which involve more prescriptive procedures. The Tier 3 methodology utilizes PBSD principles and includes performance objectives that are implied in the code and illustrated in Figure 1.3.

Current PBSD documents such as PEER/TBI (The Pacific Earthquake Engineering Research Center/Tall Buildings Initiative) and LATBSDC (Los Angeles Tall Buildings Structural Design Council) refer to ASCE 41-13 for one source of acceptance criteria at performance levels described in Section 1.6 of deformation-controlled elements such as coupling beams, shear walls, and moment frames. Although these acceptance criteria are provided in a

3.0 Design Using Linear Analysis

The initial proportioning of a building consists of a complete design process whereby all members of the seismic force-resisting system are proportioned. Linear design can be done using SLE-, DE-, or MCE_R-level earthquake demands. Most engineers prefer using SLE demands, with design methods appropriately adjusted for the lower demand level. Some engineers have utilized DE or MCE_R level demands based on particular building types or preference. When this is done, additional verification at DE or SLE may be required to substantiate building performance and code equivalency. SLE-based design is primarily considered in this document and is described in detail in PEER/TBI and LATBSDC documents. The intent of designing using SLE-level demands is to inherently satisfy DE performance objectives by verifying performance under SLE and MCE_R demands. If specific performance objectives are targeted at SLE-, DE-, and MCE_R-level ground shaking, verification at each level may be required.

3.1 Modeling and Analysis

For initial design using linear analysis, modeling and design methods appropriate for the level of earthquake demands should be considered. Response spectrum analysis is typically used. As mentioned above, for this document SLE demands are used for initial linear design. Material strength and stiffness assumptions, section property modifiers, and material strength reduction factors appropriate for SLE demands should be used and differ from DE-level assumptions. Material and section property modifiers appropriate for SLE-level design are described in detail in PEER/TBI and LATBSDC, with key parameters in Tables 3.1 & 3.2.

The analysis model should include all lateral force-resisting elements, primary gravity system elements, and basements. P-Delta effects should be included. Slab openings affecting diaphragm stiffness should be included with semi-rigid diaphragm modeling.

Materials

For SLE-level design, expected material properties should be utilized for realistic estimates of stiffness. For projects using ASCE 7 criteria and specified ASTM material standards, unless more detailed justification can be produced, expected material properties as shown in Table 3.1 can be used. In jurisdictions not using ASCE 7 and associated ASTM standards, robust testing of local materials or historical information

Material		**Expected Strength**	
		Expected Yield Strength, f_{ye}, psi	**Expected Ultimate Strength, f_{ue}, psi**
Reinforcing Steel	A615 Grade 60	70,000	106,000
	A615 Grade 75	82,000	114,000
	A706 Grade 60	69,000	95,000
	A706 Grade 80	85,000	112,000
Structural Steel***	Hot-rolled structural shapes and bars		
	ASTM A36/A36M	$1.5 f_y$*	$1.2 f_u$**
	ASTM A572/A572M Grade 50	$1.1 f_y$*	$1.1 f_u$
	ASTM A913/A913M Grade 50, 60, 65 or 70	$1.1 f_y$*	$1.1 f_u$
	ASTM A992/A992M	$1.1 f_y$*	$1.1 f_u$
	Plates		
	ASTM A36/A36M	$1.3 f_y$	$1.2 f_u$
	ASTM A572/A572M Grade 50, 55	$1.1 f_y$	$1.2 f_u$
Concrete		$f'_{ce} = 1.3 f'_c$†	

*f_y is used to designate the specified (nominal) yield strength of steel materials in this Guideline. It is equivalent to f_y or f_{yt} used in ACI 318 and F_y used in AISC (2006) standards.
**f_u is used to designate the specified (nominal) ultimate strength of steel materials in this Guideline. It is equivalent to F_u used in AISC (2006) standards.
***For steel materials not listed, refer to Table A3.1 of ANSI/AISC 341-16
†f'_c = specified compressive strength. Expected strength f'_{ce} is strength expected at approximately one year or longer. Note that the multiplier on f'_c may be smaller for high-strength concrete, and can also be affected by (1) use of fly ash and other additives, and/or (2) local aggregates.

▲ **Table 3.1: Expected Material Strength.** Source: PEER/TBI

Component	Service-Level Linear Models			MCE_R-Level Nonlinear Models		
	Axial	Flexural	Shear	Axial	Flexural	Shear
Structural walls[1] (in-plane)	$1.0E_cA_g$	$0.75E_cI_g$	$0.4E_cA_g$	$1.0E_cA_g$	$0.35E_cI_g$	$0.2E_cA_g$
Structural walls (out-of-plane)	–	$0.25E_cI_g$	–	–	$0.25E_cI_g$	–
Basement walls (in-plane)	$1.0E_cA_g$	$1.0E_cI_g$	$0.4E_cA_g$	$1.0E_cA_g$	$0.8E_cI_g$	$0.2E_cA_g$
Basement walls (out-of-plane)	–	$0.25E_cI_g$	–	–	$0.25E_cI_g$	–
Coupling beams with conventional or diagonal reinforcement	$1.0E_cA_g$	$0.07\left(\frac{\ell}{h}\right)E_cI_g \le 0.3E_cI_g$	$0.4E_cA_g$	$1.0E_cA_g$	$0.07\left(\frac{\ell}{h}\right)E_cI_g \le 0.3E_cI_g$	$0.4E_cA_g$
Composite steel / reinforced concrete coupling beams [2]	$1.0(EA)_{trans}$	$0.07\left(\frac{\ell}{h}\right)(EI)_{trans}$	$1.0E_sA_{sw}$	$1.0(EA)_{trans}$	$0.07\left(\frac{\ell}{h}\right)(EI)_{trans}$	1.0EsAsw
Non-PT transfer diaphragms (in-plane only)[3]	$0.5E_cA_g$	$0.5E_cI_g$	$0.4E_cA_g$	$0.25E_cA_g$	$0.25E_cI_g$	$0.1E_cA_g$
PT transfer diaphragms (in-plane only)[3]	$0.8E_cA_g$	$0.8E_cI_g$	$0.4E_cA_g$	$0.5E_cA_g$	$0.5E_cI_g$	$0.2E_cA_g$
Beams	$1.0E_cA_g$	$0.5E_cI_g$	$0.4E_cA_g$	$1.0E_cA_g$	$0.3E_cI_g$	$0.4E_cA_g$
Columns	$1.0E_cA_g$	$0.7E_cI_g$	$0.4E_cA_g$	$1.0E_cA_g$	$0.7E_cI_g$	$0.4E_cA_g$
Mat (in-plane)	$0.8E_cA_g$	$0.8E_cI_g$	$0.8E_cA_g$	$0.5E_cA_g$	$0.5E_cI_g$	$0.5E_cA_g$
Mat[4] (out-of-plane)	–	$0.8E_cI_g$	–	–	$0.5E_cI_g$	–

[1] Values are relevant where walls are modeled as line elements. Where walls are modeled using fiber elements, the model should automatically account for cracking of concrete and the associated effects on member stiffness.
[2] *(EI)trans* is intended to represent the flexural rigidity of the cracked transformed section. It is acceptable to calculate the transformed section properties based on structural mechanics or to use *(EI)trans* = $E_cI_g/5 + E_sI_s$ per ACI 318.
[3] Specified stiffness values for diaphragms are intended to represent expected values. Alternative values may be suitable where bounding analyses are used to estimate bounds of force transfers at major transfer levels. For diaphragms that are not associated with major force transfers, common practice is to model the diaphragm as being rigid in its plane. Flexural rigidity of diaphragms out of plane is usually relatively low and is commonly ignored. The exception is where the diaphragm acts as a framing element to engage gravity columns as outrigger elements, in which case out-of-plane modeling may be required.
[4] Specified stiffness values for mat foundations pertain to the general condition of the mat. Where the walls or other vertical members impose sufficiently large forces, including local force reversals across stacked wall openings, the stiffness values may need to be reduced.

▲ **Table 3.2: Reinforced Concrete Effective Stiffness Values.** Source: PEER/TBI

is needed to estimate appropriate expected material parameters.

PEER/TBI recommends the use of expected material properties for analysis-model component stiffness, but specified material properties for component strength capacity.

LATBSDC recommends expected material properties for analysis-model component stiffness and strength capacity.

Since MCE_R evaluation using NRHA is also conducted, either method is valid, but the PEER/TBI method is more conservative.

Section Properties

In linear elastic analyses, section properties need to be reduced to account for cracking and damage to the components, through section property modifiers with reduced effective stiffness of the member. Property modifiers are based on experimental testing. Since SLE demands are often considered, LATBSDC and PEER/TBI have published concrete section property modifiers for use in SLE-and MCE_R-level events. The application of property modifiers can have a significant impact on member force levels and should be carefully considered for each project. Other resources that engineers should review include PEER/TBI (see Table 3.2), ASCE 41-13 Table 10-5 for all concrete elements, and ATC 72-1 Table 4-1 for link beams. For link beams reinforced with steel wide flanges, AISC 341-10 Commentary H4 can be consulted. It should be noted that there are

In jurisdictions not using ASCE 7 and associated ASTM standards, robust testing of local materials or historical information is needed to estimate appropriate expected material parameters.

5.0 Basis of Design Example

The purpose of a Basis of Design (BOD) document or design criteria document is to state deviations from governing code requirements, either exceptions or enhancements, and describe subsequent methods justifying these exceptions or enhancements. Content will often include descriptions of all structural systems, description of design procedure, performance objectives, analytical modeling methods, and acceptance criteria. It is not intended to contain all information used for the design of the building, but should be a standalone document with references to all needed information. No structural engineering results should be presented in the Basis of Design document. Typically, Basis of Design documents range from 10 to 25 pages in length. The BOD should be included in the design drawings for future reference by the building owner, especially if exceptions to code provisions are taken.

The Basis of Design document is generally submitted to the peer review panel and local governing jurisdictions involved in building permitting for review and comment early in the building design process. In some jurisdictions, the BOD is submitted with the architectural building site permit. Typically, the document can be updated and revised through the design process, as appropriate, to reflect the final design.

Engineers should review Appendix B of PEER/TBI for additional information.

5.1 General

Describe project location, structural system types used, and the most important building considerations.

Describe the primary load path if multiple systems are used, and, if so, their intended purposes. If higher occupancies require higher performance levels by the governing building code, specify.

Describe the site in terms of geographic coordinates and include a description of site considerations. Describe the relationship of local and national building code requirements to this project.

Describe locations of anticipated inelastic behavior and any enhanced seismic devices such as buckling restrained braces, isolation bearings, dampers, etc.

Representative design drawings should be included. This can be satisfied by placing the BOD on a drawing sheet as part of the set of building structural drawings.

5.2 Superstructure

This section will describe the superstructure, which includes the ground floor and above. For sloped sites, this would include all elements above grade.

If the building is connected to multiple buildings sharing a common basement, describe how they are interconnected (i.e., seismic joints, common transfer diaphragm, etc.). Include a schematic diagram showing their overall configuration.

Lateral System
Describe the lateral system in more detail, with typical dimensions and material strengths. Identify primary transfer diaphragms at- and above-grade.

Gravity System
Describe the gravity system in more detail, with typical dimensions and material strengths. Describe if gravity system components are intended to resist seismic actions as part of the seismic-force resisting system.

5.3 Substructure

Basement Levels
Describe basement levels in more detail, with typical dimensions and material strengths. For sloped sites, describe how the site slopes. Provide plans/sections that schematically describe unique considerations.

5.4 Foundation System

Describe the foundation system for the tower and podium including details, dimensions, and material strengths.

Geotechnical Investigations and Reports
Reference geotechnical investigations undertaken by the project geotechnical engineer and provide a reference to their report. Specify if site-specific information is being used in the design of the building.

5.5 Code Analysis and Design Criteria

Building Codes, Standards, Regulations and Computer Software

Building Codes, Standards and Regulations
List all codes progressing from local to national. Also, list non-code sources of information that are directly used in the design. Examples would include supporting publications of nonlinear material/component behavior and their acceptance criteria.

Computer Software

List all software, versions used, and structural elements designed with them.

Code Exceptions

State the specific section(s) of governing code that are excepted, if any. It is best to specifically quote the appropriate portions of code. Include a brief justification for how the exception is justified.

In jurisdictions where PBSD is accepted, there are typically clear design steps and criteria that are expected to be followed. Describe those requirements here and how they are satisfied. If multi-step sequencing is used, describe this sequence in general and how each step leads to the next.

Provide a description of the scope of peer review. This may already be specified by the governing jurisdiction if PBSD is already adopted.

Performance Objectives

Provide a table that describes the intended building performance. The table may specify actions, as in some cases a single element may have different objectives for different actions, such as shear walls. An example is found in Table 3.3.

If performance of non-structural components varies from the governing building code, specify their performance, including cladding, partitions, elevators, exit stairs, etc.

Structural Gravity Load Criteria

Include a summarized version of gravity loading criteria for typical floors and conditions. This helps the document stand alone. Not all gravity load criteria need to be stated, but the exterior wall should be included.

Structural Lateral Load Criteria

Provide a summary of seismic- and wind-code-based load criteria, listing all key code values. For wind, include all key parameters, such as exposure category and basic wind speed. For seismic, include all parameters used to calculate code base shear. Include response modification factors such as R and Ω_o.

Seismic Loads Utilizing Site-Specific Response Spectra and Ground Motions

Describe the site-specific seismic information provided by the geotechnical engineer and a brief description of their methods. The geotechnical engineer should help develop this text, or text should be adopted from the geotechnical engineer's report. Specify the level of damping assumed in the spectra.

Specify the target spectrum for the selection and development of ground motions. If target spectra are other than MCE_R, such as conditional mean spectrum (CMS), are used, then describe their development. Provide a plot of spectral acceleration versus period with code-based and seismic-specific MCE_R, DE, and SLE design spectra. Also provide a similar plot showing MCE_R and developed CMS target spectra. Examples of these two plots are found in Figure 5.1. Black-and-white should be used, as they may be placed on a drawing sheet.

Structural Materials

Provide a list of all typical materials used, and organize the list by concrete, reinforcement, and structural steel. State the grade, yield strength, and appropriate ASTM designation for reinforcement and steel. State the typical application for each.

5.6 Structural Analysis and Design

The following sections provide appropriate detail for each step in the structural system design and verification process. This information should be conveyed in a logical, sequential manner.

Typically, the initial design of the seismic force-resisting system is based on response spectrum analysis. Then, subsequent verification is conducted using NRHA. The specifics of this process can vary based on the requirements of the jurisdiction, project-specific requirements, and on-going advancements of the PBSD design process.

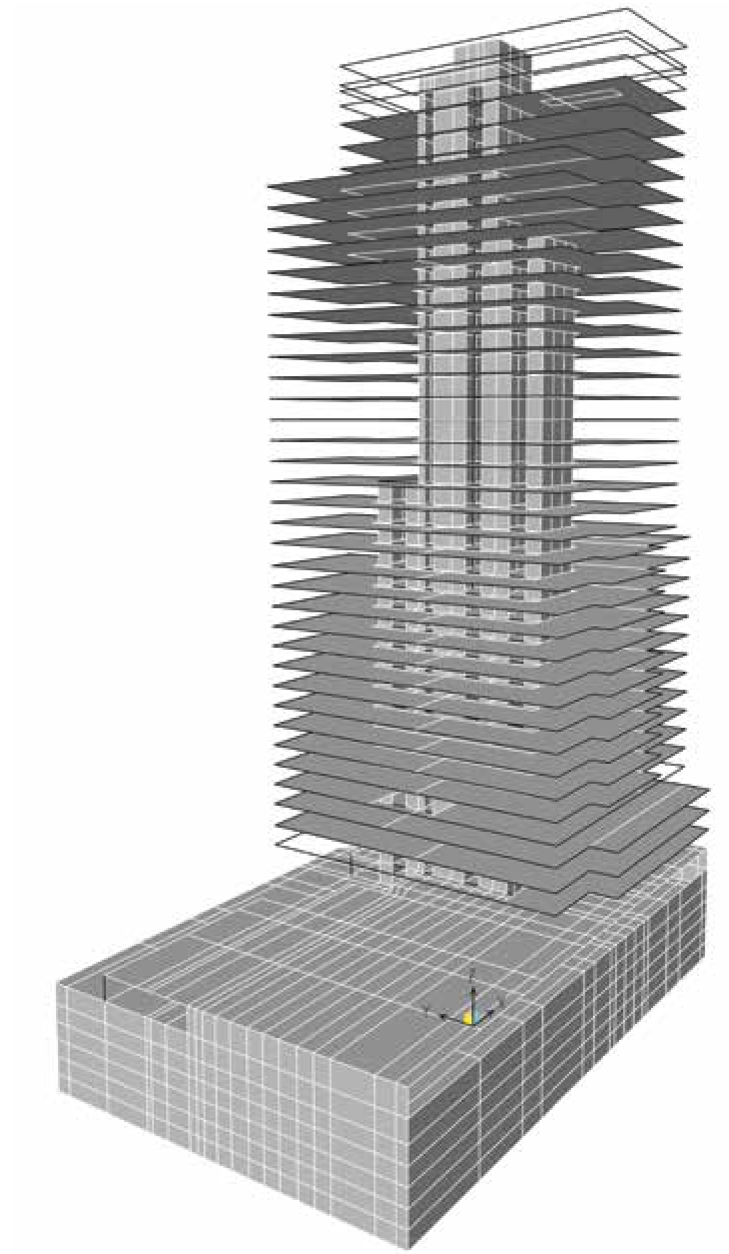
Each step in the described process should include common information such as performance objectives, design criteria, analysis model information (including particulars of nonlinear component modeling), and acceptance criteria of global performance and individual members. This common format will help convey differences between each step in the design and verification process.

The initial member designs using linear analyses are not always reviewed by the peer review panel, but could be very important to the governing jurisdiction looking to ensure a basic standard of care was utilized, similar to code-based buildings. Thus, including the entire design process in this document is advantageous.

Step 1: Design Using Linear Analysis

The purpose of this step is to describe the methods used for design of the seismic force-resisting system. Often, a service-level linear analysis is used with adjusted acceptance criteria to ensure appropriate performance under MCE_R

Design Example 1: Tall High-Occupancy Office Tower



▲ Figure 6.1: Service-Level Analysis Model. © Magnusson Klemencic Associates

Mode Number	Mode Description	SLE Model Period (Seconds)
1	X direction (translation)	4.12
2	Y-direction (translation)	2.45
3	Torsion	2.30

▲ Table 6.1: Service-Level Periods of Vibration.

This design example includes documentation to demonstrate the implementation of a performance-based design approach. A performance-based design approach should follow an approved Basis of Design document that establishes criteria for determining performance acceptability at both a service-level earthquake (SLE) and a maximum considered earthquake (MCE_R). The objectives of the performance in these events are further described in the Basis of Design, which is not provided with this document. The examples included are not intended to present complete or comprehensive results. The example presented is representative of the state of practice at the time of this project's design, and therefore the acceptance criteria or other metrics will vary from current practice depending on when the project was designed, project type, jurisdiction, design guidelines referenced, and peer reviewers. This example focuses on extracts from PBSD reports that highlight specific element types, show effective formats for presenting results, and display acceptance criteria evaluations that occurred for this design.

This design example is for a 525-foot (160-meter), 36-story office tower (see Figure 6.1). The design consists of a reinforced concrete central core, with floor framing consisting of steel floors with composite steel decking. This example highlights a building that is designed as Risk Category III due to the number occupants, and, therefore, with acceptance criteria modified accordingly.

6.1 Serviceability Event Analysis and Verification

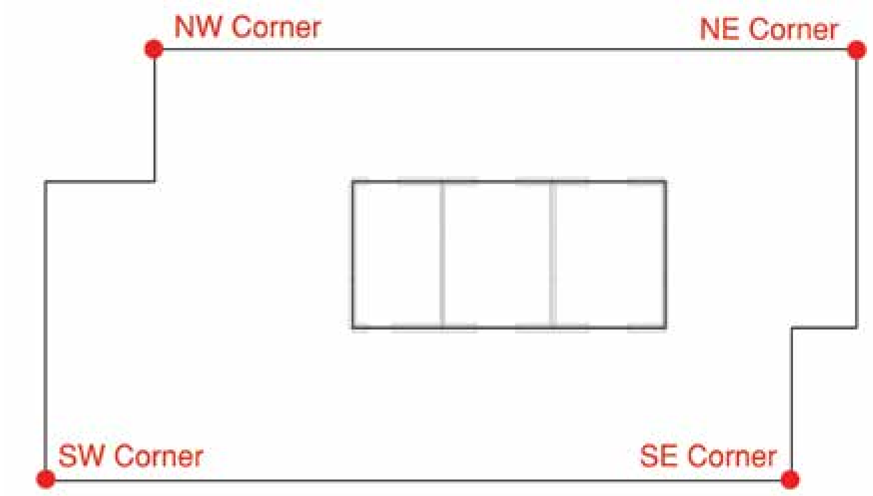
Evaluation at the service-level earthquake (SLE) is required in order to quantify response characteristics that relate to the serviceability performance of the structure.

[1] The following sections present design examples of real buildings designed using a performance-based seismic design approach. These designs generally follow the guidelines described in this document. However, because the designs were completed for real buildings in various jurisdictions within the United States, there are some `differences in the design processes specific to each building.

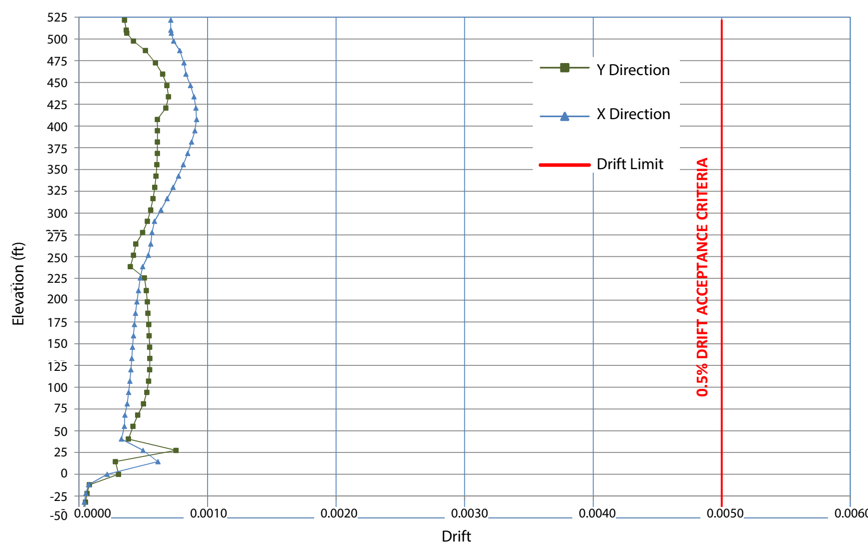
These characteristics are items such as story drift, coupling beam demands, and shear wall demands. The acceptance criteria for this serviceability-level event are selected to encourage essentially elastic behavior of the elements under consideration.

6.2 Elastic Model Description

The analysis model used for the service-level verification is a three-dimensional, linear elastic, 2.5 percent damped mathematical model. Walls and slabs are modeled as elastic shell elements. Columns are modeled as frame elements. Torsion in the model is limited to inherent torsion; accidental torsion is not included. Cracked section properties are included in the model as described in the Basis of Design document. The analysis performed is a modal response spectrum analysis procedure, including a minimum mass participation of 90 percent of the seismic mass, with the results combined using the complete quadratic combination (CQC) method. The seismic mass includes the building's estimated self-weight, the superimposed dead load, and any live load required by ASCE 7 to be included, such as mechanical equipment and a portion of storage loads. Mass is only assigned above the seismic base (ground level in this case).



▲ **Figure 6.2: Example Corner Points for Drift Determination.** © Magnusson Klemencic Associates



▲ **Figure 6.3: Max SLE Seismic (Site-Specific) Story Drift.** © Magnusson Klemencic Associates

Acceptance Criteria: Story Drift
Story drift is a measure of the building deformations under the SLE event. By placing a limitation on building drift, damage of nonstructural elements (such as cladding, wall partitions, etc.) can be limited. The three-dimensional lateral analysis model includes the stiffness modification parameters identified above, which are consistent with the anticipated behavior at SLE.

For the design example, the acceptance criteria value for drift at SLE is 0.5 percent. The full SLE response spectrum is applied with no scaling and no accidental torsion. Story drift is calculated at each corner of the building by taking the difference in elastic displacement of adjacent floors divided by the story height. Story drift is calculated on a per-corner basis in order to correctly include the effects of inherent torsion and the rotational response. An example of the corner points considered is identified in Figure 6.2. Many software analysis tools have the ability to directly output story drift. The diagram in Figure 6.3 indicates the maximum story drift recorded for all

Performance-Based Seismic Design (PBSD) is a structural design methodology that has become more common in urban centers around the world, particularly for the design of high-rise buildings. The primary benefit of PBSD is that it substantiates exceptions to prescribed code requirements, such as height limits applied to specific structural systems, and allows project teams to demonstrate higher performance levels for structures during a seismic event.

However, the methodology also involves significantly more effort in the analysis and design stages, with verification of building performance required at multiple seismic demand levels using Nonlinear Response History Analysis (NRHA). The design process also requires substantial knowledge of overall building performance and analytical modeling, in order to proportion and detail structural systems to meet specific performance objectives.

This CTBUH Technical Guide provides structural engineers, developers, and contractors with a general understanding of the PBSD process by presenting case studies that demonstrate the issues commonly encountered when using the methodology, along with their corresponding solutions. The guide also provides references to the latest industry guidelines, as applied in the western United States, with the goal of disseminating these methods to an international audience for the advancement and expansion of PBSD principles worldwide.

ISBN 978-0-939493-72-2

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