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NEW SEISMIC PROVISION IN ASCE/SEI 7-10

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ABSTRACT

An extensive effort was undertaken by the Structural Engineering Institute (SEI) of ASCE to solicit external proposals to modify the seismic requirements of ASCE/SEI 7-05. In all, the Seismic Subcommittee (SSC) of ASCE 7 reviewed, modified, or developed over 200 proposed changes to ASCE/SEI 7-05. The majority was editorial in nature, serving to clarify the intent of the requirements, and included modifications to nearly all of the seismic chapters (11 through 23). However, technical changes also made their way into the 2010 version of the Standard (ASCE/SEI 7-10), with the vast majority of these occurring in Chapters 11, 12, 13, 15, 21, and 22. This paper will highlight the important technical changes to Chapters 11, 12, and 21.

Among these changes are the following:

- Introduction of new ground motion maps and associated terminology (MCE_R)
- Changes to Section 11.8, "Geologic Hazards and Geotechnical Investigation"
- Changes to Section 12.6, "Analysis Procedure Selection"
- Clarification of the base shear equations for computing drift
- Introduction of scaling requirements for drift when using Modal Response Spectrum Analysis
- Changes to Section 12.11, "Structural Walls and their Anchorage"
- Changes to requirements for structure separations
- Changes to Section 21.2, "Ground Motion Hazard Analysis"

Introduction

The primary goal of the ASCE/SEI 7-10 update was to improve the overall clarity of the requirements and to incorporate new technical material generated from the 2009 update of the Building Seismic Safety Council's (BSSC's) National Earthquake Hazards Reduction Program (NEHRP) *Recommended Provisions for Seismic Regulations for New Buildings and Other Structures* as well as numerous externally-generated proposals. With over 200 proposals promulgated by the ASCE Seismic Subcommittee, both technical and editorial improvements have been made.

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Significant modifications were made Chapters 11, 12, 13, 15, 21, and 22. The focus of this paper is to describe the key technical changes that occurred since the previous version of the standard (ASCE/SEI 7-05).

Changes in Chapter 11

New Ground Motion Maps and Terminology

Based on work originally developed for the 2009 update of the NEHRP *Provisions*, the Maximum Considered Earthquake (*MCE*) Ground Motion Spectral Response Acceleration maps were completed revised. In addition to the work performed by the United States Geological Survey (USGS) to update the "scientific" aspects of the underlying probabilistic seismic hazard maps, a new approach to convert them into use as design maps was implemented. In lieu of utilizing a uniform hazard approach as has been done in the past, uniform risk of collapse has been introduced, resulting in "risk-targeted" Maximum Considered Earthquake (MCE_R) Ground Motion Spectral Response Acceleration maps and associated design parameters. Also included in this new approach is the use of the maximum direction of ground motion (in lieu of the previously used "geomean" approach) along with an increase of the deterministically-based values to an 84^{th}-percentile (in lieu of a 1.5 factor for all faults).

While *MCE* is now changed to MCE_R, the parameters used to determine the design base shear, and other technical provisions, are unchanged. Familiar parameters such as S_S, S_1, S_{DS}, and S_{D1} are still used. Only the technical basis of determining S_S and S_1 has changed. As with ASCE/SEI 7-05, it is recommended that the ground motion spectral acceleration parameters be determined using the USGS website based on the project's latitude and longitude. While the maps included in ASCE/SEI 7-10 continue to provide spectral acceleration contours for the United States and its Territories, the resulting resolution makes it difficult to determine design values in many geographic locations.

Using this new uniform risk of collapse (targeting a 1 percent probability of collapse within a 50-year period) generally results in maximum seismic design parameter changes over the previous uniform hazard method of approximately 10 to 20 percent (both up and down). In general, in locations that are controlled by earthquake with long return periods, which exist extensively in the Central and Eastern United States, the resulting seismic design parameters are lower. It should be noted that in locations that are governed by large, highly active faults, deterministic values are still used. The majority of these locations are found in California.

The rational, technical details and results associated with the development of this new approach can be found in the commentary to the 2009 NEHRP *Provisions*.

Changes to Section 11.8, "Geologic Hazards and Geotechnical Investigation"

Section 11.8, "Geologic Hazards and Geotechnical Investigations," is another important section that changed as a result of the work done in the 2009 update to the NEHRP *Provisions*.

The section was updated editorially to help clarify the intent, but clarifications and technical changes also were made to the resulting requirements, consisting of the following:

- The dynamic lateral seismic earth pressures on basement and retaining walls were set at the design earthquake ground motion level.

- The potential for liquefaction and soil strength loss evaluated for site peak ground acceleration, earthquake magnitude, and source characteristics was set at the maximum considered earthquake ground motion level, using geomean (not maximum direction) values. New PGA maps, along with soil amplification factors, are included in the standard.

In ASCE/SEI 7-05, the ground motion level for dynamic lateral seismic pressures was not defined, and the potential for liquefaction and soil strength loss was associated with design earthquake ground motion levels. Assessment of the potential for liquefaction and recommended mitigation measures is still the focus of the geotechnical investigation.

Changes in Chapter 12

Changes to Section 12.6, "Analysis Procedure Selection"

Based on work originally developed for the 2009 update of the NEHRP *Provisions*, a 160-foot height limitation was added to the structural characteristics associated with selection of the appropriate analytical procedure outlined in Section 12.6. Table 1 below replicates Table 12.6-1 from ASCE/SEI 7-10. The 160-foot height limitation requirement is added to require structures of this height and taller with a building period exceeding $3.5T_s$ to use the Modal Response Spectrum Analysis procedure. Studies of the previous requirements show that building in excess of 200 feet and located in Seismic Design Category D are often allowed to utilize the Equivalent Lateral Force Analysis procedure, thereby missing the influence of the important higher modes. In addition to this technical change, the table is revised editorially to simplify its use.

Table 1. Permitted Analytical Procedures (Table 12.6-1 from ASCE/SEI 7-10).

Seismic Design Category	Structural Characteristics	Equivalent Lateral Force Analysis Section 12.8 [a]	Modal Response Spectrum Analysis Section 12.9 [a]	Seismic Response History Procedures Chapter 16 [a]
B, C	All structures	P	P	P
D, E, F	Risk Category I or II buildings not exceeding 2 stories above the base	P	P	P
	Structures of light frame construction	P	P	P
	Structures with no structural irregularities and not exceeding 160 feet in structural height	P	P	P
	Structures exceeding 160 feet in structural height with no structural irregularities and with $T < 3.5\ T_s$	P	P	P
	Structures not exceeding 160 feet in structural height and having only horizontal irregularities of Type 2, 3, 4, or 5 in Table 12.3-1 or vertical irregularities of Type 4, 5a, or 5b in Table 12.3-2	P	P	P
	All other structures	NP	P	P

[a] P: Permitted; NP: Not Permitted; $T_s = S_{D1} / S_{DS}$

Base Shear Equations for Computing Drift

For the Equivalent Lateral Force Analysis procedure, a simple exception was added to Section 12.8.6.1, "Minimum Base Shear for Computing Drift," to eliminate the requirement of using Eq. 12.8-5 ($C_s = 0.044 S_{DS} I \geq 0.01$) when computing drift. While this appears to be a minor change to the drift requirements, the elimination of this base shear equation affects the design of structures with fundamental building periods in excess of approximately 2 seconds, especially for seismic force-resisting systems that are controlled by drift. It should be noted that Eq. 12.8-6 ($C_s = 0.5\ S_1 / (R/I_e)$ is not included in the exception and is required to be used when checking building drift.

A companion change to scaling drifts when using Modal Response Spectrum Analysis was also implemented as described below.

Scaling Requirements for Drift Using Modal Response Spectrum Analysis

To be consistent with the requirements of the Equivalent Lateral Force Analysis (ELFA) procedure, scaling requirements were added to the Model Response Spectrum Analysis (MRSA) procedure. ASCE/SEI 7-05 did not require the scaling of drifts, which is consistent with the ELFA procedure of not limiting the building period to *CuTa* when determining drifts. However, this also allowed the MRSA procedure to ignore Eq. 12.8-5 and Eq. 12.8-6, both of which were required to be met for drift when using the ELFA procedure. Deliberations at ASCE's Seismic Subcommittee resulted in resolving this inconsistency by requiring that both procedures be scaled to Eq. 12.8-6 but not Eq. 12.8-5. The rationale for this decision was based on the fact that Eq. 12.8-5 is a minimum strength provision that was first adopted following the 1933 Long Beach earthquake (Riley Act)—often referred to as the three percent rule which is the original percentage of the building's weight that was applied laterally to account for earthquake effects—while Eq. 12.8-6 represents anticipated near source ground shaking that was originally adopted in the 1997 Uniform Building Code to account for this effect.

The specific requirement in ASCE/SEI 7-10 regarding scaling of drifts when using the MRSA procedure is reproduced below:

> "Where the combined response for the modal base shear (V_t) is less than $0.85C_sW$, where C_s is determined in accordance with Eq. 12.8-6, drifts shall be multiplied by $0.85C_sW/V_t$."

Changes to Section 12.11, "Structural Walls and their Anchorage"

A major effort was undertaken by the ASCE Seismic Subcommittee to review and update the provisions associated with structural walls and their anchorage. An ad-hoc anchorage task committee was formed to evaluate the provisions outlined in ASCE/SEI 7-05 and to provide recommendations for change as appropriate. After over two years of effort, a modified approach was suggested and ultimately approved.

The basic design for structural walls and their anchorage remained consistent with past standards: $F_p = 0.4S_{DS} I_e$ times the weight of the structural wall. The section on wall anchorage forces has been clarified to pertain to all structural walls, and the three design checks, including the minimum requirement of 280 plf, are replaced with the following requirements which include amplification for flexible diaphragms (through the use of the term k_a):

$$F_p = S_{DS} k_a I_e W_p \quad (12.11\text{-}1)$$

F_P shall not be taken less than $0.2k_a I_e W_P$

$$k_a = 1.0 + \frac{L_f}{100} \quad (12.11\text{-}2)$$

k_a need not be taken larger than 2.0.

where:

F_p = the design force in the individual anchors
S_{DS} = the design spectral response acceleration parameter at short periods per Section 11.4.4
I_e = the importance factor determined in accordance with Section 11.5.1
k_a = amplification factor for diaphragm flexibility
L_f = the span, in feet, of a flexible diaphragm that provides the lateral support for the wall; the span is measured between vertical elements that provide support to the diaphragm; use zero for rigid diaphragms
W_p = the weight of the wall tributary to the anchor

Where the anchorage is not located at the roof and diaphragms are not flexible, the value from Eq. 12.11-1 is permitted to be multiplied by the factor $(1+2z/h)/3$, where z is the height of the anchor above the base of the structure and h is the height of the roof above the base.

While the results of this approach are similar to those of the previous standards, the formulation of the design values are more consistent with the geometry of the diaphragm (where flexible) and the location in elevation of the anchorage.

Changes to Requirements for Structure Separations

The separations requirements in ASCE/SEI 7-05 simply state, "All portions of the structure shall be designed and constructed to act as an integral unit in resisting seismic forces unless separated structurally by a distance sufficient to avoid damaging contact under total deflection (δ_x) as determined in Section 12.8.6." Minimal guidance was given as to the actual size of the separation. Based on the requirements specified in the 1997 Uniform Building Code and the 2009 International Building Code, δ_M is introduced as the maximum inelastic response displacement as is given by the following equation:

$$\delta_M = \frac{C_d \delta_{max}}{I} \qquad (12.12\text{-}1)$$

Adjacent structures on the same property are separated a minimum distance of δ_{MT}, determined using the square-root-of-the-sum-of-the-squares as follows:

$$\delta_{MT} = \sqrt{(\delta_{M1})^2 + (\delta_{M2})^2} \qquad (12.12\text{-}2)$$

Where a structure adjoins a property line not common to a public way, provisions are made for the structure to be back from the property line by at least the displacement δ_M of that structure. As with previous requirements, smaller separations are permitted where justified by "rational analysis" based on inelastic response to design ground motions.

Changes in Chapter 21

Changes to Section 21.2, "Ground Motion Hazard Analysis"

To be consistent with the new ground motion approach and associated terminology (*MCE_R*), the ground motion hazard analysis section was updated and is based on work originally developed for the 2009 update of the NEHRP *Provisions*. While this section is only used when developing site-specific ground motions values, the approach had to be updated to provide consistent results with ground motion values determined from Section 11.4 and the associated maps. The approach to determining the site-specific MCE_R consists of taking the lesser of the probabilistic and deterministic ground motions, subject to a minimum of 80 percent of the values determined in Section 11.4.

Two methods are available to develop the probabilistic ground motions. The resulting probabilistic spectral response accelerations are taken in the direction of maximum horizontal response represented by a 5 percent damped acceleration response spectrum that is expected to achieve a 1 percent probability of collapse within a 50-year period.

Method 1 is the product of the risk coefficient (C_R) and the spectral response acceleration from a 5 percent damped acceleration response spectrum having a 2 percent probability of exceedance within a 50-year period. The value of C_R is determined using values of C_{RS} and C_{R1} from Figs. 22-3 and 22-4, respectively, for the 0.2-second and 1.0-second spectral response accelerations.

Method 2 involves an iterative integration of a site-specific hazard curve with a lognormal probability density function representing the structure's collapse fragility (i.e., the probability of collapse as a function of spectral response acceleration). The ordinate of the probabilistic ground-motion response spectrum at each period is to achieve a 1 percent probability of collapse within a 50-year period for a collapse fragility having a 10 percent probability of collapse at the particular ordinate of the probabilistic ground motion response spectrum and a logarithmic standard deviation value of 0.6.

The accelerations for the deterministic ground motions are calculated for the known characteristic earthquakes on the known active faults that affect the site The calculated deterministic spectral response accelerations, at each period, are to result in an 84th percentile, 5 percent damped spectral response acceleration in the direction of maximum horizontal response. The ordinates of the deterministic MCE_R ground motion response spectrum are not to taken as less than the corresponding ordinates of the response spectrum determined in accordance with Fig. 21.2-1. This required minimum was also required in the ASCE/SEI 7-05.

The rational and technical details and results associated with the development of this new approach can be found in the commentary to the 2009 NEHRP *Provisions*.

Conclusions

The primary goal of the ASCE/SEI 7-10 update was to improve the clarity of the requirements and to incorporate new technical material generated during the process of updating the 2009 NEHRP *Provisions* as well as externally generated proposals. With over 200 proposals promulgated by the ASCE Seismic Subcommittee, this goal has been achieved. Both technical and editorial improvements have been made, with the change to the basis of the ground motions being the most extensive.

It is intended that ASCE/SEI 7-10 will be adopted in the 2012 IBC and that the updated provisions will serve the seismic design community for years to come.

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