

Changes to the seismic provisions

Updated format and content for the ASCE 7-05



By S.K. Ghosh, Ph.D.;
Susan Dowty, S.E.;
and Robert Bachman, S.E.

The seismic provisions of the 2005 edition of the American Society of Civil Engineers' (ASCE) Minimum Design Loads for Buildings and Other Structures (ASCE 7-05) will be dramatically different in format and organization than those found in the current edition, ASCE 7-02. In addition, the seismic provisions of ASCE 7-05 will include several significant technical changes. This article will first explain the format and organizational changes followed by a description of the significant technical changes.

Format and organizational changes

Through a two-year effort funded by the Building Seismic Safety Council (BSSC) and ASCE, the ASCE 7-02 seismic provisions were reformatted completely and reorganized with the goal of creating a set of requirements that are more user friendly, enforceable, and understandable, with conflicts, repetitions, redundancies, and ambiguities removed to the extent practicable. The thorough, and sometimes tedious, iterative process by which the seismic provisions were rearranged resulted in a much improved document that should be easier to use and result in more correct and uniform application of seismic requirements.

In ASCE 7-02, the seismic provisions were contained completely within Section 9.0 Earthquake Loads and Appendix A.9 Supplemental Provisions, and comprised more than half of the content of the standard. However, only one section and one appendix were allotted to the seismic requirements. This resulted in an inordinate number of subsections. For example, Section 9.14.7.3.10.6.2 (Structure Period) is six subsections deep. Through the reformat effort, the seismic provisions were subdivided into Sections 11 through 23 and Appendices 11A and 11B, as shown in the abbreviated

Table of Contents listed in Table 1 (page 20). Every effort was made to limit the number of subsections.

The ultimate goal of the reformatting effort was to make the seismic provisions easier to use and to better clarify the requirements. One way to achieve this goal was to relocate to later sections those provisions that are not frequently used. For example, most design engineers will not use the materials found in new Sections 16 through 21, while all engineers will use the material found in Section 11. All Seismic Design Category (SDC) A requirements are located up front in Section 11.7 for the convenience of the user designing a structure assigned to SDC A; and it is not necessary for that designer to go any further in the provisions. Also, a common complaint was that the ground motion maps took up too many pages and interrupted the flow of the provisions. Furthermore, most engineers no longer use the maps for obtaining seismic ground motion values, but instead use the mapped seismic values provided on the CD-ROM. The remedy for this situation was to relocate the seismic maps to Section 22.

Another significant formatting change is the manner in which references are handled. In ASCE 7-02, references were listed in different sections and referred to by a refer-

ence number within the text. In ASCE 7-05, they are referred to by their common name within the text and all are listed in one central location, Section 23. The reference documents listed in Section 23 are classified as either consensus standards or other reference documents. Any non-consensus standard falls under the title "other reference documents" and is identified as such with an asterisk in Section 23.

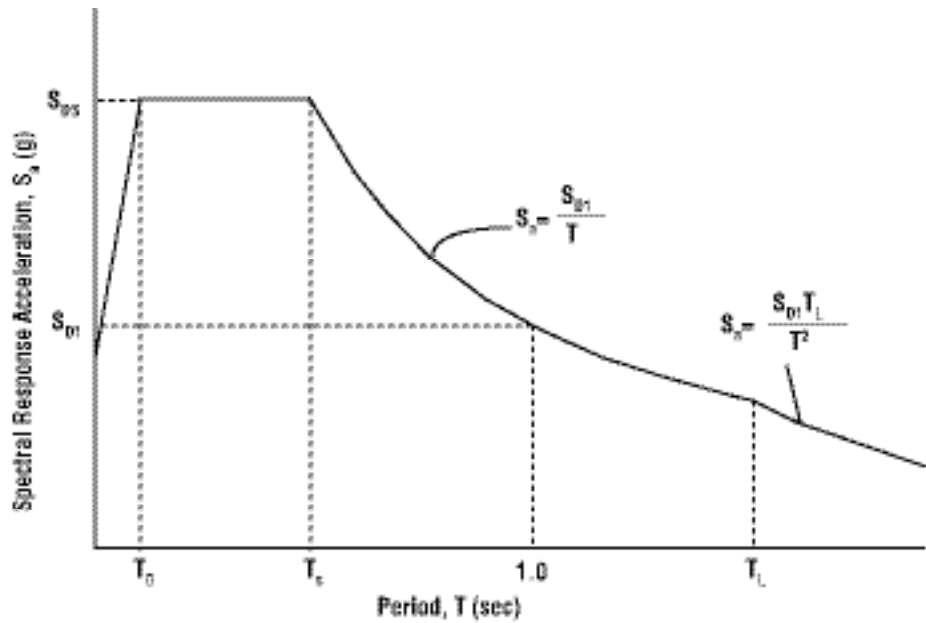
Technical changes

There are an extensive number of technical changes to ASCE 7-05, but because of space limitations, this article only focuses on the major revisions. Most of the technical changes reflect revisions approved for the 2003 National Earthquake Hazards Reduction Program (NEHRP) Recommended Provisions for Seismic Regulations for New Buildings and Other Structures prepared by BSSC's NEHRP Provisions Update Committee.

Ground motion — The spectral acceleration maps are reduced in number and size and are based upon the latest version of the U.S. Geological Survey's hazard maps. Also, there is a new set of maps for the long-period transition period, T_L .

The design spectrum, which defines the design ground motion at a given site in terms

Figure 1: This is the spectral response acceleration, S_a , versus the elastic fundamental period, T , however, in ASCE 7-05 the constant velocity branch terminates at the new long-period transition period, T_L .



of spectral acceleration (S_a) versus the elastic fundamental period (T), has changed in ASCE 7-05. In ASCE 7-02, the spectrum consisted of three branches. First, between the zero period ($T = 0$) and the constant acceleration portion, the spectral acceleration ramps up linearly to period T_o . Second is the “flat-top” or constant-acceleration part of the spectrum, ranging up to the transition period (T_c), which governs the seismic response and design of short, stiff structures having short periods of vibration. Third is the “descending branch” or constant-velocity part of the spectrum (proportional to the inverse of T), which governs the seismic response and design of taller, more flexible structures having periods longer than T_c .

In ASCE 7-05 (see Figure 1), the constant velocity branch terminates at the new long-period transition period (T_L), where a new fourth branch to the design spectrum starts, proportional to $1/T^2$. This is the constant-displacement part of the design spectrum that will govern the seismic response of structures with periods in the range beyond T_L . The period T_L is given on new contour maps for all 50 states. A designer must locate the structure’s site on this contour map to determine T_L , which ranges between 4 seconds and 16 seconds, depending upon the location. Note that the values of T_L are much larger than have been used by many engineers in the past.

This change will be significant in determining slosh height in tanks and the design seismic forces of longer-period buildings. Because the designs of many tall buildings have assumed displacement cutoff periods of 4 seconds or less, the impact of this change could be significant for high-rise buildings.

Redundancy — The 2003 NEHRP Provisions Update Committee took it upon themselves to revisit the effect of redundancy in buildings. If the lack of redundancy is “... when the failure of a component is equivalent to the failure of the entire system,” as stated

by Vitelmo V. Bertero, professor emeritus at University of California at Berkeley the most logical way to determine such lack is to check whether a component’s failure results in an unacceptable amount of story strength loss or in the development of extreme torsional irregularity. This is the basic premise of the new redundancy provisions adopted into ASCE 7-05.

In ASCE 7-05, the redundancy factor (ρ) is equal to either 1.0 or 1.3, depending upon whether or not an individual element can be removed (deemed to have failed or lost its moment-resisting capabilities) from the lateral-force-resisting system without causing the remaining structure to suffer a reduction in story strength of more than 33 percent or creating an extreme torsional irregularity (Plan Irregularity Type 1b).

Braced frame, moment frame, and shear wall systems have to conform to redundancy requirements. Dual systems are included also, but in most cases are inherently redundant. Shear walls with a height-to-length ratio greater than 1.0 are included in redundancy considerations. This requirement usually will result in having to use a reasonable number of shear walls to reduce the force in collector elements to a manageable level. Shear wall systems were added to the requirements to help ensure that an adequate number of wall elements are included or that the proper redundancy factor is applied.

ASCE 7-05 adds a new user-friendly feature of conveniently listing when ρ , may be taken as 1.0. New Section 12.3.4.1 reads

as follows:

12.3.4.1 Conditions Where Value of ρ is 1.0. The value of ρ is permitted to equal 1.0 for the following:

1. Structures assigned to Seismic Design Category B or C.
2. Diaphragm and P-delta effects.
3. Design of non-structural components.
4. Design of non-building structures that are not similar to buildings.
5. Design of collector elements, splices, and their connections for which the load combinations with over strength factor of Section 12.4.3.2 are used.
6. Design of members or connections for which the load combinations with over strength factor of Section 12.4.3.2 are used.
7. Diaphragm loads determined using Equation 12.10-1.
8. Structures with damping systems designed in accordance with Section 18.

Design base shear — The following base shear equation for long-period structures (such that $T > T_L$) is added in the equivalent lateral force procedure to be consistent with the new design spectrum discussed above:

$$C_v = \frac{S_{D1} T_L}{T^2 \left(\frac{R}{I} \right)} \text{ for } T > T_L$$

Base shear by the new equation is inversely proportional to the square of the

Table 1: The expanded table of contents for the reorganized seismic requirements of ASCE 7-05 minimizes the number of subsections.

Section 11	Seismic Design Criteria
Section 12	Seismic Design Requirements for Building Structures
Section 13	Seismic Design Requirements for Nonstructural Components
Section 14	Material Specific Seismic Design and Detailing Requirements
Section 15	Seismic Design Requirements for Non-building Structures
Section 16	Seismic Response History Procedures
Section 17	Seismic Design Requirements for Seismically Isolated Structures
Section 18	Seismic Design Requirements for Structures with Damping Systems
Section 19	Soil Structure Interaction for Seismic Design
Section 20	Site Classification Procedure for Seismic Design
Section 21	Site-Specific Ground Motion Procedures for Seismic Design
Section 22	Seismic Ground Motion and Long Period Transition Maps
Section 23	Seismic Design Reference Documents
Appendix 11A	Quality Assurance Provisions
Appendix 11B	Existing Building Provisions

fundamental period, which is consistent with the constant-displacement part of the design spectrum.

Load combinations using seismic loads — New Section 12.4 was added to clarify the load combinations and appropriate load factors that are to be used with seismic loads. It has been observed that many engineers have been using the vertical earthquake term incorrectly. The new section should eliminate this problem.

Simplified design — In a significant development, the simplified design procedure has been revised completely and added as a stand-alone Section 12.14. The procedure applies to structures in Seismic Design Categories B, C, D, and E, but is not permitted for structures where the design is typically drift-controlled. The approach was limited to certain structural systems to avoid problems that may arise from omitting the drift check for drift-controlled systems (steel moment frames for example). The simplified procedure is allowed for bearing wall and building frame systems, provided that several prescriptive requirements are followed, which result in a torsion-resistant regular layout of lateral-force-resisting elements.

Seismic design category — There is an important change in the procedure for seismic design category determination in

ASCE 7-05 Section 11.6.1.1. The seismic design category now is permitted to be determined on the basis of short-period ground motion (S_{DS}) alone when all of the following conditions apply:

1. The approximate fundamental period of

the structure (T_a) in each of two orthogonal directions is less than $0.8T_s$, where T_s is the period at which the “flat-top” part of the design spectrum transitions into the descending branch;

2. The fundamental period of the structure (T) in each of two orthogonal directions, used to calculate the story drift, is less than or equal to T_s ;
3. The upper-bound design base shear, corresponding to the short-period plateau, is used in the design of the structure; and
4. The diaphragm is rigid, or for diaphragms that are flexible, the distance between vertical elements of the seismic force-resisting system does not exceed 40 feet.

Architectural, mechanical, and electrical components — The shallow anchor provision, which required use of $R_p = 1.5$ when the depth-to-diameter ratio of anchor bolts is less than 8, was replaced by referencing the anchorage provisions of the American Concrete Institute (ACI 355.2, 2001, Evaluating the Performance of Post-Installed Mechanical Anchors in Concrete).

Updated material reference standards — ASCE 7-05 updates many of the reference standards (now referred to as reference documents) to the latest edition. With respect to materials standards, Table 2 lists

Table 2: The updated ASCE 7-05 lists the reference documents and editions for the most commonly used materials standards.

Material	Referenced document
Structural steel	Standards developed by the American Institute of Steel Construction (AISC), as follows: - AISC Allowable Stress Design (1989, including Supplement No.1, 2001) - AISC Load and Resistance Factor Design (1999) - AISC Seismic (2002)
Concrete	Standards developed by the American Concrete Institute (ACI), as follows: - ACI 318 (2002)
Masonry	Standards developed by ACI, ASCE, and The Masonry Society (TMS), as follows: - ACI 530/ASCE 5/TMS 402 (2002) - ACI 530.1/ASCE 6/TMS 602 (2002)
Wood	Standards developed by the American Forest & Paper Association (AF&PA), as follows: - AF&PA National Design Standard (2001)

the reference documents and editions for the most commonly used materials standards.

Current plans call for development of a Supplement 1 for ASCE 7-05 — available in the Fall of 2005 — that will incorporate the 2005 editions of the material standards.

New seismic-force resisting systems —

Two new seismic-force resisting systems were added to the R-values table (Table 12.2-1 Design Coefficients and Factors for Seismic Force-Resisting Systems) — ordinary and intermediate precast shear walls; and prestressed masonry shear walls. Adding ordinary and intermediate precast shear walls to the list of R-values, Table 12.2-1, makes it consistent with ACI 318-02 provisions. Ordinary precast shear walls are permitted only in SDC A and B. Use of intermediate precast shear walls is permitted as part of seismic-force-resisting systems in SDC D, E, and F, provided the building height does not exceed 40 feet. This is an indirect way of permitting lateral-force resisting tilt-up walls in SDC D, E, and F, which typically would not conform with the special detailing requirements of ACI 318-02, Section 21.8.

Adding prestressed masonry shear walls to the R-values, Table 12.2-1, makes it consistent with ACI 530/ASCE 5/TMS 402, 2002 edition. These systems are permitted only in SDC A and B and are assigned an R-value of 1.5 because data have shown that the behavior is essentially stiffening degrading linear elastic with little ductility and energy dissipation.

Modal analysis procedure — The old modal analysis procedure now is referred to as “modal response spectrum analysis” in ASCE 7-05, Section 12.9. Much of the text in this section was deleted because it was deemed unnecessary since commercially available software used by structural engineers implements these mathematical procedures.

Non-building structure design requirements — The design coefficients table was split into two tables: one for structures similar to buildings (Table 15.4-1 Seismic Coefficients for Non-building Structures Similar to Buildings), and the other for structures not similar to buildings (Table 15.4-2, Seismic Coefficients for Non-building Structures NOT Similar to Buildings). Also, references to the applicable design and detailing requirements in other sections and reference documents have been added to the two tables.

The design coefficients table for non-building structures in ASCE 7-02 prescribed design coefficients for non-building structures similar to buildings that were the same as those for corresponding structural systems in the design coefficients table for building structures, except that less restrictive height limitations were prescribed in the case of non-building structures. This inconsistency is corrected in ASCE 7-05. In addition, some structural systems may be used in non-building structures similar to buildings with less restrictive height limitations if lower specified R-values are used.

Structures with damping systems — A new section on structures with damping systems (Section 18) is added to ASCE 7-05. The provisions found in this section are the same as those added as a new chapter in the 2003 NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures.

Site classification and site-specific ground motion procedures — Two new sections (Sections 20 and 21) were added to clarify procedures for determining site classification and site-specific ground motions. Separate procedures are provided in Section 21 for site response analysis and ground motion hazard analysis.

Conclusion

As with all of the codes and provisions that guide structural engineers' design calculations, the standard that governs how to determine seismic loads — ASCE 7 — has undergone significant organizational and content changes in the 2005 edition. These updates were made to improve how structural engineers establish and apply seismic loads. ■

S.K. Ghosh, Ph.D., is president of S.K. Ghosh Associates Inc., a structural, seismic, and code consulting firm located in Palatine, Ill. He can be contacted at skghosh@aol.com. **Susan Dowty, S.E.**, is project manager at S.K. Ghosh Associates Inc., and served as editor for the ASCE 7-05 seismic reformatting project. She can be contacted at dowtyskga@cox.net. **Robert Bachman, S.E.**, is principal at R.E. Bachman Consulting Structural Engineers and was chair of the ASCE 7-05 Seismic Task Committee. He can be contacted at rebachmanse@aol.com.