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2006 IBC seismic design provisions

Significant improvements come from reorganization

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At first glance, the seismic provisions of the 2006 International Building Code (IBC), published by the International Code Council, look very different from those in the 2003 IBC. Most noticeable is how short the section has become. In the 2003 IBC, the seismic provisions extended from Section 1613 to 1623 and were 43 pages long. In the 2006 IBC, they are completely contained in one section, Section 1613, and are expected to be only 22 pages long.

The dramatic difference between the two codes can be attributed to the fact that the 2006 IBC references the American Society of Civil Engineers' Minimum Design Loads for Buildings and Other Structures (ASCE 7-05) for virtually all of the seismic design requirements. The provisions that remain in the 2006 IBC are not different from those in ASCE 7-05 (with the exception of two modifications) and are related to the local ground motion and soil parameters as well as the definitions of terms actually used within those provisions. Provisions regarding additions, alterations, and change of occupancy in an existing building have been relocated to Chapter 34.

It is expected that code users will welcome the straight forward approach the 2006 IBC uses to reference ASCE 7-05 for seismic provisions, especially because the optional approach used by the 2003 IBC to reference ASCE 7-02 was found to be confusing. Section 1613.1 of the 2006 IBC reads as follows:

1613.1 Scope. Every structure, and portion thereof, including non-structural components that are permanently attached to structures and their supports and attachments, shall be designed and constructed to resist the effects of earthquake motions in accordance with ASCE 7, excluding Chapter 14 and Appendix 11A.

ASCE 7-05 Chapter 14 is entitled "Material Specific Seismic Design and Detailing Requirements" and ASCE 7-05 Appendix 11A is entitled "Quality Assurance Provisions." Because these requirements are addressed specifically in other chapters of the 2006 IBC, they are excluded in 2006 IBC Section 1613.1 Scope.

The remainder of this article is dedicated primarily to discussing the seismic provisions of ASCE 7-05 because that is what the designer will be using. Only the discussion on Seismic Design Category refers back to the IBC, because seismic design category determination is still in the IBC. In the case of the 2003 IBC, if the simplified method was used, ASCE 7 was not used. This is no longer the case. The simplified method can only be found in ASCE 7-05. It is expected that the designer will have little need to refer back to the 2006 IBC for seismic design — perhaps only to Section 1613.6, which includes two modifications to ASCE 7-05. One modification is for the definition of flexible diaphragms (Section 1613.6.1)

Table 1: The latest editions of the commonly used materials standard are referenced in the updated ASCE 7-05.

Material	Referenced document
Structural steel	Standards developed by the American Institute of Steel Construction (AISC), as follows: • AISC 360 (2005) • AISC 341 (2005)
Concrete	Standards developed by the American Concrete Institute (ACI), as follows: • ACI 318 (2005)
Masonry	Standards developed by the ACI, the ASCE, and The Masonry Society (TMS), as follows: • ACI 530/ASCE 5/TMS 402 (2005) • ACI 530.1/ASCE 6/TMS 602 (2005)
Wood	Standards developed by the American Forest & Paper Association (AF&PA), as follows: • AF&PA National Design Specification (2005)

and the other modification is an exception applicable to seismically isolated structures (Section 1613.6.2).

Changes in the seismic design provisions of ASCE 7-05 were the subject of an earlier article published in the February 2005 issue of **Structural Engineer**. Only a few of the most significant changes are discussed here.

Reference standards

ASCE 7-05 became available in mid-November 2005. The traditional tan cover has changed to navy blue. The format, including typeface, resembles that of the 1997 Uniform Building Code, published by the International Conference of Building Officials. More importantly, it includes Supplement No. 1 to the white-covered edition published in late 2004. The supplement updates the referenced material standards to their latest editions (see Table 1).

Reformatting the provisions

The seismic provisions of ASCE 7-05 not only include substantive, technical revisions, but they have been reformatted completely and reorganized. The reorganization project was accomplished through a two-year effort funded by the Federal Emergency Management Agency through the Building Seismic Safety Council and the ASCE. The goal of this effort was to recreate the ASCE 7-05 seismic provisions so that they are user-friendly and can be understood and interpreted correctly and easily by an average engineer designing an average structure. By taking what used to be in one section (ASCE 7-02 Section 9.0) and expanding the material into 13 chapters and two appendices (ASCE 7-05 Chapters 11 through 23, Appendices 11A and 11B), the organization of the provisions became more transparent and understandable. Also, by expanding the provisions into chapters, the number of subsections is reduced. For example, ASCE 7-02 Section 9.14.7.3.10.6.2 (Structure Period) is Section 15.7.10.6.1 in ASCE 7-05.

One way to achieve the goal of making the seismic provisions easy to use was to relocate those provisions that are not frequently used to later sections. For example, most design engineers will not use the materials found in new Chapters 16 through 21, while all engineers will use the material found in Chapter 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. Also, a common complaint was that the ground motion maps took up too many pages and interrupted the flow of the provisions. The remedy was to relocate the seismic maps to Chapter 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 reference number within the text. In ASCE 7-05, they are referred to by their common names within the text and are all listed in one central location, Chapter 23. The reference documents listed in Chapter 23 are classified two ways, either as consensus standards or as other reference documents.

Ground motion maps

Maps showing the contours of 5 percent damped spectral response accelerations at 0.2-second and 1-second periods corresponding to the Maximum

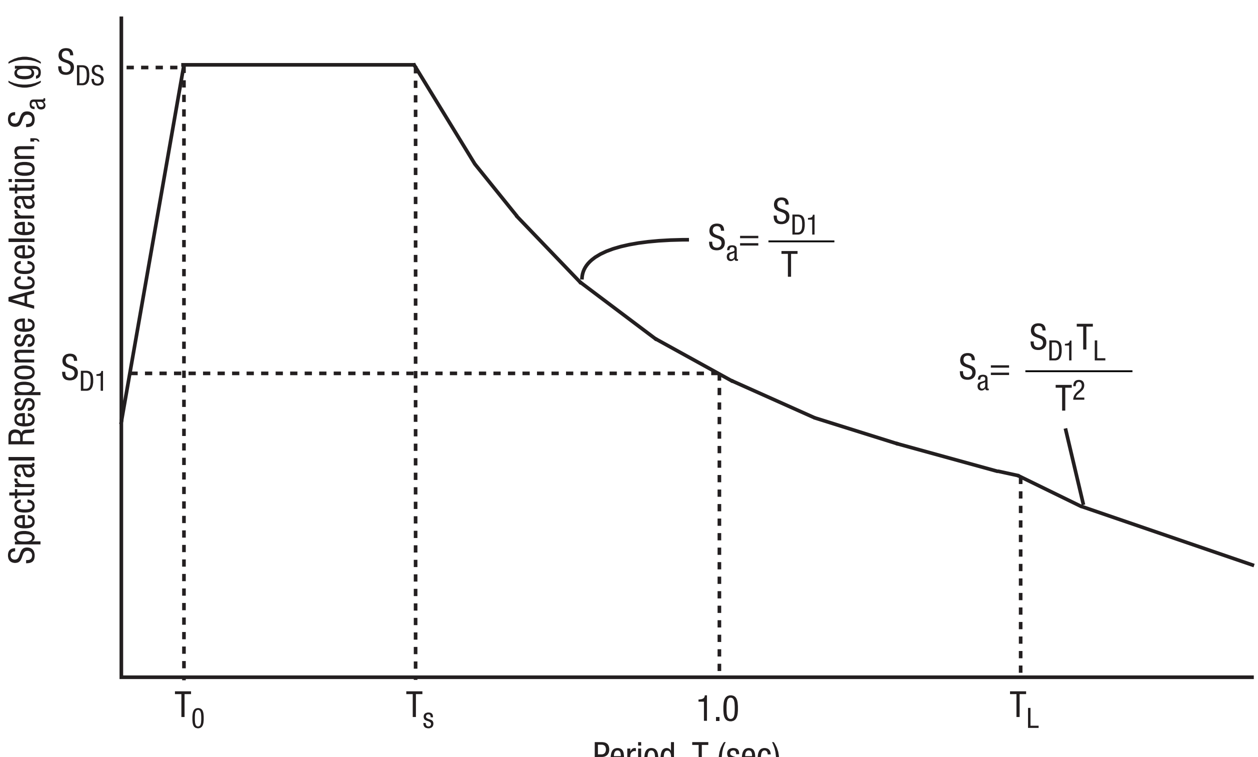

Figure 1: In ASCE 7-05, the constant velocity branch of the design spectrum terminates at the long-period transition period, T_L, beyond which a new constant-displacement branch starts.

Considered Earthquake (MCE) have been updated whereby Figures 1615(1) through (10) in the 2003 IBC are now replaced by Figures 1613.5(1) through (14) in the 2006 IBC. Besides including four additional enlarged maps for the New Madrid fault area and the Charleston, S.C., area, the new maps incorporate three major updates as follows:

1) The new maps are based on the 2002 U.S. Geological Survey (USGS) probabilistic maps, rather than the 1996 USGS maps that formed the basis of the 2003 IBC. This results in some changes in spectral acceleration values in some parts of the country.

2) A deterministic area is now included around New Madrid, which somewhat reduces the size of the high ground motion region near the New Madrid fault.

3) MCE maps now provide contours of varying spectral values in Puerto Rico and the Virgin Islands, as opposed to the older practice of assigning a single value to the entire region.

Design spectrum, Design base shear

In ASCE 7-05, the constant velocity branch of the design spectrum (see Figure 1) terminates at the new long-period transition period, T_L, where a new fourth branch to the design spectrum, proportional to $1/T^2$, starts. 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. One must locate one's site on this contour map to determine T_L, which ranges between 4 and 16 seconds, depending upon the location. It should be noted that the values of T_L are much larger than has been used traditionally by many engineers.

To be consistent with the new design spectrum discussed above, the following base shear equation for long-period structures (where $T>T_L$) is added in the equivalent lateral force procedure as follows:

$$C_s = \frac{S_{D1}T_L}{T^2\left(\frac{R}{I}\right)}$$

where C_s is the seismic response coefficient, S_{D1} is the design spectral response acceleration at the 1-second period, R is response modification factor, and I is the importance factor.

Determination of Seismic Design Category

The term "Seismic Use Group" (SUG) has been omitted from the 2006 IBC, and the SDC of a building is now determined directly from its Occupancy Category. The new tables defining SDC simply replace SUG I with Occupancy Categories I or II, replace SUG II with Occupancy Category III, and replace SUG III with Occupancy Category IV. The exception in 2003 IBC, which permitted the determination of SDC based on short-period ground motion alone, has been modified. The following three additional criteria have been included in the 2006 IBC's alternative SDC use qualifications to make it consistent with the same provision in ASCE 7-05 Section 11.6:

- the 1-second mapped spectral acceleration S_1 must be less than $0.75g$;
- in each of two orthogonal directions, the fundamental period of the structure used to calculate story drift must be less than the period, T_s, which marks the end of the constant-acceleration plateau of the design spectrum; and
- for buildings with flexible diaphragms, the distance between the vertical elements of the seismic force-resisting system must not exceed 40 feet.

Redundancy

The basic premise of the new redundancy provisions that have been adopted into ASCE 7-05 is that the most logical way to determine lack of redundancy 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.

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

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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 have been included in redundancy considerations 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 for any of the following situations:

- structures assigned to SDC B or C;
- drift calculation and P-delta effects;
- design of non-structural components;
- design of non-building structures that are not similar to buildings;
- design of collector elements, splices, and their connections for which the load combinations with over-strength of Section 12.4.3.2 are used;
- design of members or connections where the load combinations with over-strength of Section 12.4.3.2 are required for design;
- diaphragm loads determined using Equation 12.10-1; or
- structures with damping systems designed in accordance with Section 18.

Simplified design

The simplified design procedure has been revised completely and stands alone in Section 12.14. The procedure applies to structures in SDC B, C, D, and E, but is not permitted for structures where the design is typically drift-controlled. It was felt that the approach should be 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.

Conclusion

The 2006 IBC references ASCE 7-05 for virtually all of its seismic design requirements. This change represents a significant improvement to the seismic design provisions of the 2003 IBC and should make it remarkably easier to implement seismic design when using the 2006 IBC. ■

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