The Seismic Design Provisions of the 2003 Edition of the International Building Code

S. K. Ghosh, Ph.D.
President
S. K. Ghosh Associates, Inc.
Northbrook, Illinois

Susan Dowty, P.E., S.E.
Project Manager
S. K. Ghosh Associates, Inc.
Laguna Niguel, California

This article provides the reader with an overall perspective on the seismic design provisions of the recently published 2003 Edition of the International Building Code (IBC).

The user of the 2003 IBC will immediately notice that the seismic design provisions of Sections 1616 through 1623 look very different from those of the 2000 IBC[1] and that the sections are much shorter than before. The brevity is somewhat deceptive. It is a direct result of the fact that the 2003 IBC makes extensive references to the 2002 edition of the ASCE 7 Standard Minimum Design Loads for Buildings and other Structures.[2]

Seismic Design by ASCE 7-02

It is extremely important to note that the first exception to the requirement for seismic design in 2003 IBC Section 1614.1 exempts structures designed in accordance with ASCE 7-02 Sections 9.1 through 9.6, 9.13 and 9.14. This means that seismic design following the provisions of ASCE 7-02, rather than those of IBC 2003, is fully permitted by IBC 2003. ASCE 7-02 is organized such that Section 9, Earthquake Design, is divided into the subsections listed in Table 1. There are also the Supplemental Provisions of Appendix A, which consists of the following sections:

A.9.1 Purpose
A.9.3 Quality Assurance
A.9.7 Supplementary Foundation Requirements
A.9.8 Supplementary Provisions for Steel
A.9.9 Supplementary Provisions for Concrete
A.9.11 Supplementary Provisions for Masonry

Section A.9.1, Purpose, states, "These provisions are not directly related to computation of earthquake loads, but they are deemed essential for satisfactory performance in an earthquake when designing with the loads determined from Section 9, due to the substantial cyclic inelastic strain capacity assumed to exist by the load procedures in Section 9. These supplemental provisions form an integral part of Section 9."

Seismic Design by 2003 IBC

The 2003 IBC is organized such that the code includes all of the seismic design provisions, within the code itself, for structures that can be designed with the Simplified Analysis Procedure of Section 1617.5. In the case of more complex structures that do not qualify to be designed by the Simplified Analysis Procedure, they may be designed in accordance with 2003 IBC Sections 1613 through 1623.

Apart from items related to the Simplified Analysis Procedure, the decision was made to retain in the seismic sections of the code only the text, tables, and figures that are needed for the determination of the Seismic Design Category. For other subjects in 2003 IBC Sections 1613 through

1623, reference is made to ASCE 7-02 for code requirements. When addressing these subjects, it is necessary for the code user to work with the 2003 IBC and ASCE 7-02 side by side, because in some instances the 2003 IBC makes modifications to ASCE 7-02. Table 2 is provided for easy reference.

All of the above makes for a certain amount of potential confusion. A case in point is Section 1620, Earthquake Loads — Design, Detailing Requirements and Structural Component Load Effects. First, 2003 IBC Section 1620.1 refers the code user to ASCE 7-02 Section 9.5.2.6 for the requirements except in the case of structures using the Simplified Analysis Procedure. If the Simplified Analysis Procedure is used, all of the provisions are found in the 2003 IBC itself. This is not initially obvious unless the exception to 2003 IBC Section 1620.1 is read carefully, which states: "For structures designed using the simplified analysis procedure in Section 1617.5, the provisions of Sections 1620.2 through 1620.5 shall be used."

Unfortunately, only the title of 2003 IBC Section 1620.2 reflects that its applicability is limited to the Simplified Analysis Procedure. Second, there are modifications to ASCE 7-02 Section 9.5.2.6, which are given in 2003 IBC Sections 1620.1.1, 1620.1.2 and 1620.1.3. It is a good idea to mark these changes in the code user's ASCE 7-02 Section 9.5.2.6, as otherwise they may be overlooked.

Another case in point is Section 1617.2, Redundancy. This section refers the code user to ASCE 7-02 Section 9.5.2.4 for the requirements, except in the case of structures using the Simplified Analysis Procedure. The exception to this section reads: "Structures designed using the simplified analysis procedure in Section 1617.5 shall use the redundancy provisions in Section 1617.2.2." Section 1617.2.1 then proceeds to make important modifications to ASCE 7-02 Sections 9.5.2.4.2 (Seismic Design Category D) and 9.5.2.4.3 (Seismic Design Categories E and F). Section 1617.2.2, Redundancy (for use in the simplified analysis procedure of Section 1617.5), has two subsections: 1617.2.2.1 (Seismic Design Category A, B, or C) and 1617.2.2.2 (Seismic Design Category D, E, or F). Section 1617.2.2.2 is nearly, but not quite, identical to Section 1617.2.1. A code user, not privy to the background given above, is apt to wonder why the requirements of Section 1617.2.1 are repeated in Section 1617.2.2.2, and further why the two sets of requirements are slightly different here and there.

The National Council of Structural Engineers Associations (NCSEA) has submitted proposed code changes for intended inclusion in the upcoming Supplement to the 2003 IBC, which are aimed at removing much of the confusion discussed above.

Table 1. Seismic design requirements of ASCE 7-02.

ASCE 7-02 Section	Subject
9.1	General Provisions
9.2	Definitions and Symbols
9.3	(Intentionally blank)
9.4	Ground Motion, Seismic Design Category and Quality Assurance
9.5	Structural Design Criteria, Analysis and Procedures
9.6	Architectural, Mechanical and Electrical Components and Systems
9.7	Foundation Design Requirements
9.8	Steel
9.9	Structural Concrete
9.10	Composite Structures
9.11	Masonry
9.12	Wood
9.13	Provisions for Seismically Isolated Structures
9.14	Nonbuilding Structures

Table 2. Partial adoption of ASCE 7-02 by reference into IBC 2003.

2003 IBC Section	Subject	ASCE 7-02 Section referenced
1616.5	Building Configuration	9.5.2.3
1616.6	Analysis Procedures	9.5.2.5.1
1617.1	Seismic Load Effects, E and E_m	9.5.2.7
1617.2	Redundancy (2003 IBC Modifies ASCE 7-02)	9.5.2.4
1617.3	Deflection and Drift Limits	9.5.2.8
1617.4	Equivalent Lateral Force Procedure	9.5.5
1617.6	Seismic-Force-Resisting Systems (2003 IBC Modifies ASCE 7-02)	9.5.2.2
1618	Dynamic Analysis	9.5.6, 9.5.7, 9.5.8
1619	Soil Structure Interaction Effects	9.5.9
1620	Earthquake Loads – Design, Detailing Requirements and Structural Components Load Effects (2003 IBC Modifies ASCE 7-02)	9.5.2.6
1621	Architectural, Mechanical and Electrical Components (2003 IBC Modifies ASCE 7-02)	9.6
1622	Nonbuilding Structures (2003 IBC modifies ASCE 7-02)	9.14
1623	Seismically Isolated Structures (2003 IBC Modifies ASCE 7-02)	9.13

AMENDMENTS TO ASCE 7-02

It would appear from the above that the code user would find it easier to utilize the exception to Section 1614.1, and do seismic design by the requirements of ASCE 7-02, ignoring the remainder of Sections 1613 through 1623. This easy way out may not be to the user's best advantage, however. This is because by going all the way with ASCE 7-02, the user will not get to benefit from the amendments to ASCE 7-02 that have been introduced in IBC Sections 1613 through 1623. Some of these amendments are quite substantive. Discus-

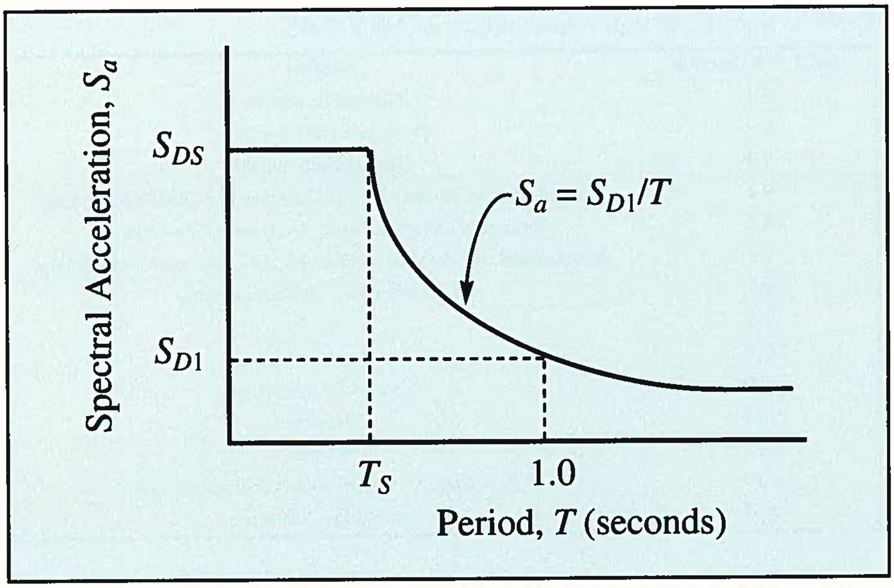

Fig. 1. Seismic design spectrum of the 2003 IBC.

sion here will be limited to arguably the most substantive amendment, which is to be found in the exception to IBC Section 1616.3, Determination of Seismic Design Categories.

Much attention has already been drawn[3] to the fact that the 2000 IBC requires the seismic design category of each structure to be determined twice: once based on the start-period design special response acceleration, S_{DS}, from Table 1616.3 (1), and a second time based on the long-period design special response acceleration, S_{D1}, from Table 1616.3 (2). The more severe of the two seismic design categories governs the design of the structure. The point has been made that it is unnecessary and wasteful to require that the seismic design category of a short-period structure be determined by long-period ground motion. The exception to 2003 IBC Section 1616.3 thus allows an important relaxation. The exception reads as follows:

The seismic design category is permitted to be determined from Table 1616.3 (1) (i.e., based on short-period design spectral response acceleration) alone when all of the following conditions apply:

1. The approximate fundamental period of the structure, T_a, in each of the two orthogonal directions determined in accordance with Section 9.5.5.3.2 of ASCE 7, is less than $0.8T_S$ determined in accordance with Section 1615.1.4,

2. Equation 9.5.5.2.1-1 of ASCE 7 is used to determine the seismic response coefficient, C_S, and

3. The diaphragms are rigid as defined in Section 1602.

The period, $T_S = S_{D1}/S_{DS}$, is the period at which the short-period or constant acceleration part of the design spectrum (see Fig. 1) transitions into the long-period or velocity-governed part of the spectrum. It is the dividing line between short-period and long-period response. By requiring in Item 1 above that T_a be less than $0.8T_S$, rather than T_S itself, the code is trying to minimize the possibility that because of imprecision in period determination, the above relaxation would be applied to structures having elastic fundamental period, T, that in fact is beyond the short-period range. In other words, it is trying to avoid the possibility that T might equal or exceed T_S, even though T_a is less than T_S.

Item 2 above requires that the upper-bound design base shear, as given by the constant acceleration or "flat-top" part of the design spectrum, be used in the design of a structure utilizing the above exception. This requirement is intended to impose a design force penalty on a structure for which T may equal or exceed T_S, while T_a is less than T_S.

Item 3 above makes the relaxation in question inapplicable to structures with flexible diaphragms because the

Table 3(a). Seismic Design Category of 2000 IBC vs. Seismic Performance Category of 1999 BOCA/NBC.

		1999 BOCA/ NBC	2000 IBC				
			Site class				
			A	B	C	D	E
Place	State	SPC	Seismic design category				
Hartford	Connecticut	C	A	B	B	C (B)	C
Washington	DC	A	A	A	B (A)	B	C (B)
Dover	Delaware	A	A	A	B (A)	B	C
Chicago	Illinois	A	A	A	B (A)	B	C (B)
Springfield	Illinois	B	A	B	B	C (B)	D (C)
Indianapolis	Indiana	B	A	A	B (A)	C (B)	D (B)
Lexington	Kentucky	B	A	B (A)	B	C (B)	D (C)
Louisville	Kentucky	B	A	B (A)	B	C (B)	D (C)
Baltimore	Maryland	A	A	A	B (A)	B	C (B)
Boston	Massachusetts	C	B	B	B	C	D (C)
Detroit	Michigan	B	A	A	A	B (A)	B
Kansas City	Missouri	C	A	A	B (A)	B (A)	C (B)
Springfield	Missouri	B	A	B (A)	B (A)	C (B)	D (C)
Albany	New York	C	A	B	B	C (B)	D (C)
Syracuse	New York	C	A	A	B (A)	B	C (B)
Cincinnati	Ohio	B	A	A	B (A)	C (B)	D (B)
Columbus	Ohio	B	A	A	B (A)	B	C (B)
Pittsburgh	Pennsylvania	A	A	A	A	B (A)	C (B)
Norfolk	Virginia	A	A	A	B (A)	B (A)	C (B)
Roanoke	Virginia	B	A	B	B	C (B)	D (C)
Charleston	West Virginia	B	A	A	B (A)	C (B)	C

flexible diaphragm may end up playing a decisive role in determining the elastic fundamental period of such a structure; and this period may be well in excess of the approximate fundamental period, T_a.

Tables 3(a) to 3(c), extracted from Reference 4, lists the major metropolitan areas of the United States where the user would benefit from the relaxation provided by the exception to Section 1616.3. The tables indicate, for a standard occupancy (Seismic Use Group I) structure in each metropolitan area, founded on Site Class A, B, C, D, or E, the seismic design categories: when the exception to Section 1616.3 does not apply (without parentheses), and when the said exception does apply (within parentheses). It should be quite apparent from the tables how advantageous the exception to Section 1616.3 quite often is. The reader is encouraged to consult Reference 5 for further information on seismic and other structural provisions of the 2003 IBC.

Table 3(b). Seismic Design Category of 2000 IBC vs. Seismic Zone of 1997 UBC.

		1997 UBC	2000 IBC				
			Site class				
		Seismic	A	B	C	D	E
Place	State	zone	Seismic design category				
Tucson	Arizona	2B	B	B	B	C	D (C)
Little Rock	Arkansas	2A	B	B	C	D (C)	D
Chico	California	3	B	C	D (C)	D	D
Fresno	California	3	B	C (B)	D (C)	D (C)	D
Sacramento	California	4	B	C	D (C)	D	D
Honolulu	Hawaii	2A	C	C	D(C)	D	D
Indianapolis	Indiana	1	A	A	B (A)	C (B)	D (B)
Wichita	Kansas	1	A	A	A	B (A)	B
Kansas City	Missouri	2A	A	A	B (A)	B (A)	C (B)
Billings	Montana	1	A	A	A	B (A)	B
Omaha	Nebraska	1	A	A	A	B (A)	B
Las Vegas	Nevada	2B	C	C	D (C)	D	D
Tulsa	Oklahoma	1	A	A	B (A)	B	C (B)
Eugene	Oregon	3	D (C)	D	D	D	D
Medford	Oregon	3	C	D (C)	D (C)	D	D
Houston	Texas	0	A	A	A	B (A)	B (A)
Spokane	Washington	2B	B	B	B	C (B)	D (C)

Table 3(c). Seismic Design Category of 2000 IBC vs. Seismic Performance Category of 1999 SBC.

		1999 SBC	2000 IBC				
			Site class				
			A	B	C	D	E
Place	State	SPC	Seismic design category				
Birmingham	Alabama	B	B	B	B	C (B)	D (C)
Huntsville	Alabama	B	B (A)	B	C (B)	C (B)	D (C)
Montgomery	Alabama	A	A	A	B (A)	B	C (B)
Little Rock	Arkansas	B	B	B	C	D (C)	D
Orlando	Florida	A	A	A	A	B (A)	B
Atlanta	Georgia	B	A	B	B	C (B)	D (C)
Macon	Georgia	B	A	A	B	C (B)	D (C)
Savannah	Georgia	C	B	B	C (B)	D (C)	D
New Orleans	Louisiana	A	A	A	A	B (A)	B
Shreveport	Louisiana	B	A	A	B (A)	B	C (B)
Jackson	Mississippi	B	A	A	B (A)	C (B)	D (B)
Charlotte	North Carolina	C	B	B	C (B)	D (C)	D
Greensboro	North Carolina	B	A	B (A)	B	C (B)	D (C)
Raleigh	North Carolina	B	A	B (A)	B	C (B)	D (C)
Wilmington	North Carolina	B	A	B	C (B)	C (B)	D (C)
Columbia	South Carolina	C	B	C	D (C)	D	D
Nashville	Tennessee	B	B	B	C (B)	D (C)	D (C)
Dallas	Texas	A	A	A	A	B (A)	C (B)
Houston	Texas	A	A	A	A	B (A)	B

CONCLUDING REMARKS

The 2003 IBC provides the user with two distinct options for seismic design purposes. Such design may be in compliance with the requirements of ASCE 7-02 Sections 9.1 through 9.6, 9.13 and 9.14, disregarding the provisions of IBC 2003 Sections 1613 through 1623. Or, the designer may choose to design by Sections 1613 through 1623 of the 2003 IBC, which adopts many of the provisions of ASCE 7-02 Section 9.1 through 9.6, 9.13 and 9.14 by reference, but in many instances with amendments that can be substantive. Although the first option may be easier and hence more attractive, the second option may very well be preferable because it enables the designer to take advantage of the amendments to the ASCE 7-02 provisions, some of which are quite beneficial.

REFERENCES

1. ICC, *International Building Code*, International Code Council, Falls Church, VA, 2000, 2003.
2. ASCE, *ASCE Standard: Minimum Design Loads for Buildings and Other Structures*, ASCE 7-02, American Society of Civil Engineers, Reston, VA, 2002.
3. Ghosh, S.K., "A Necessary Change in the Seismic Design Provisions of the 2000 IBC," PCI JOURNAL, V. 46, No. 4, July-August 2001, pp. 76-80.
4. Ghosh, S. K., *Impact of the Seismic Design Provisions of the International Building Code*, Structures and Codes Institute, Northbrook, IL, 2001.
5. Dowty, S., and Ghosh, S. K., *A Quick Start Guide to the Structural Provisions of the 2003 International Building Code*, International Code Council, Falls Church, VA, to be published in 2003.