

Seismic Requirements for Wood Building Design – Recent Changes to ASCE 7 and IBC

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Introduction

Users of the 2006 *International Building Code (IBC)* will see changes in both format and content of seismic design requirements compared to the 2003 *IBC*. Notable changes for wood-frame buildings include an updated and expanded reference to *Minimum Design Loads for Buildings and Other Structures, ASCE 7-05* for earthquake loads and addition of 2005 *Special Design Provisions for Wind and Seismic (SDPWS)* and 2005 *National Design Specification® (NDS®)* for Wood Construction for design of wood-frame lateral force resisting systems (see 2005 *Special Design Provisions for Wind and Seismic (SDPWS)* in this issue of *Wood Design Focus*).

Analysis Procedures

Like the 2003 *IBC*, the Equivalent Lateral Force procedure in the 2006 *IBC* is obtained by reference to *ASCE 7*. Seismic design coefficients (R , Ω_o , C_d) for light wood-frame shear wall systems remain unchanged from those specified in 2003 *IBC*. However, new seismic design coefficients ($R = 1.5$, $\Omega_o = 1.5$, and $C_d = 1.5$) for cantilevered column systems (such as a wood pile supported structure where moment resistance is provided at the base) detailed in accordance with requirements for “timber frames” are included in *ASCE 7* Table 12.2-1. While “timber frames” is not a defined system, it is assumed that design in accordance with member and connection provisions of underlying wood reference standards such as the *NDS* is intended.

The simplified analysis procedure of 2003 *IBC* Section 1617.5.1 has been removed. An entirely new simplified procedure for bearing wall and building frame structures up to three stories in height replaces the 2003 *IBC* simplified analysis procedures. The new procedure, located in *ASCE 7* Section 12.14, includes several new limitations to ensure that the procedure is applied to a building with a “regular” layout. Similar to the 2003 *IBC*, designs in accordance with these new *ASCE 7* criteria need not calculate structural drift.

Determination of Seismic Design Category (SDC)

Determination of SDC in *IBC* Section 1613.5.6 has been revised to match criteria contained in *ASCE 7* Section

12.3.1. Special criteria for determination of SDC now extend to buildings with flexible diaphragms where the distance between vertical elements of the seismic force-resisting system does not exceed 40 feet. By including relatively small diaphragms that are flexible, determination of SDC, based on the mapped short-period spectral response acceleration parameter, S_s , will be more widely applicable to short-period wood-frame buildings. In many cases, consideration of the S_s only, will lead to determination of a lower SDC than would result if both S_s and S_1 (mapped 1-second spectral response parameter) were used. Assignment of a reduced SDC can be significant for engineered and prescriptive design of wood building systems. For example, engineered design of fiberboard shear walls and adhesive bracing systems, permitted in SDC A-C, are not permitted in SDC D. Design calculations such as those for amplification of torsion and redundancy as well as applicability of prescriptive requirements for wood-frame construction are triggered based on SDC assignment. Increased requirements and limitations are associated with higher SDCs.

Diaphragm Flexibility

Classifying diaphragm flexibility is based on reference to *ASCE 7*. However, expanded criteria for assumption of flexible diaphragm conditions are included in *IBC* Section 1613.6.1 as a modification to basic information in *ASCE 7* Section 12.3.1.1. In 2006 *IBC*, diaphragms are permitted to be idealized as flexible where constructed of wood structural panels with no more than 1-1/2 inches of nonstructural topping, or constructed of un-topped steel decking provided all of the following conditions are met:

- 1) vertical elements of the lateral-force-resisting system are light-framed walls sheathed with wood structural panels or steel sheets, and comply with allowable story drifts, and 2) cantilevered portions of wood structural panel diaphragms comply with Section 2305.2 of the *IBC*.

These new criteria, based on construction materials and compliance with design criteria, will often allow a dia-

phragm to be idealized as flexible for common wood-frame building configurations employing either wood structural panel diaphragm or diaphragms of un-topped steel decking.

Redundancy

Determination of the redundancy factor has changed significantly from its presentation in *2003 IBC* Section 1617.2.1. Criteria for calculation of the redundancy factor, (ρ), are obtained through *ASCE 7* Section 12.3.4.2 where the default value is $\rho = 1.3$ unless certain criteria are met:

“12.3.4.2 Redundancy Factor, ρ , for Seismic Design Category D through F. For structures assigned to Seismic Design Category D, E, or F, ρ shall equal 1.3 unless one of the following two conditions is met, whereby ρ is permitted to be taken as 1.0:

- a. Each story resisting more than 35 percent of the base shear in the direction of interest shall comply with Table 12.3-3, or
- b. Structures that are regular in plan at all levels provided that the seismic force-resisting systems consist of at least two bays of seismic force-resisting perimeter framing on each side of the structure in each orthogonal direction at each story resisting more than 35 percent of the base shear. The number of bays for a shear wall shall be calculated as the length of shear wall divided by the story height or two times the length of shear wall divided by the story height for light-framed construction.”

Reference to *ASCE 7* Table 12.3-3 in 12.3.4.2 (a) requires consideration of potential to introduce an irregularity or significant strength loss if an element is missing. This option requires calculations which can become complex for typical wood-frame shear wall buildings. Provisions in 12.3.4.2 (b) may provide a relatively quick method for determination of the redundancy factor for regular wood-frame shear wall structures when compared to 12.3.4.2 (a) and prior methods in *2003 IBC*. For light-frame construction, the number of bays for a shear wall is calculated as two times the length of shear wall divided by the story height. Or, expressed in terms of minimum wall length, the minimum length of wood structural panel shear wall must equal or exceed the story height to be considered as two bays (**Table 1**). Shear wall length for a given side may be made up of a single segment or multiple segments.

Horizontal Combination of Systems

ASCE 7 Section 12.2.3.2 includes new criteria for assignment of seismic design coefficients where different resisting systems are provided along independent wall lines in the same direction within the same story. New criteria permit use of the least value of R for structural systems in each independent line of resistance if all of the following conditions are met:

Table 1.—Number of bays for light wood-frame construction.

Sum of lengths, (ΣL), of shear wall segments on a side	Story height	$\frac{2(\Sigma L)}{\text{story height}}$
----- (ft) -----		
8	9	number of bays = 1.8
10	10	number of bays = 2.0
12	12	number of bays = 2.0

Table 2.—Application of horizontal combination rule to double-sided walls.^a

Side 1/Side 2	Design capacity ^b	Bearing wall, R	SDC limit
WSP/GYP	combined WSP/GYP	2	A – D
	WSP only	6.5	A – F
	GYP only	2	A – D

^a Single-side capacity (WSP only or GYP only) and combined capacity of double-sided wall (combined WSP/GYP) in accordance with *SDPWS*.

^b WSP = wood structural panel; GYP = gypsum wallboard.

“12.2.3.2.... 1) Occupancy Category I or II building, 2) two stories or less in height, and 3) use of light frame construction or flexible diaphragms...”

For many wood-frame buildings, these criteria will apply where interior and exterior walls consist of different bracing systems. Examples include house or hotel construction where exterior walls are often wood structural panel shear walls and interior walls or corridor walls are sheathed only with gypsum wallboard.

Application of horizontal combination criteria to double-sided wood-frame shear wall systems has the effect of requiring the least R where design is based on a combination of material strengths on each side of the shear wall as provided for in the reference standard (*SDPWS*). For a double-sided shear wall consisting of wood-structural panel exterior and gypsum wallboard interior, R = 2 is applicable where shear wall design is based on the combined capacity of both sides since R = 2 (associated with gypsum wallboard shear walls) is the least R contributing to the double-sided shear wall design capacity. For the same wall condition, when design is based on wood structural panel shear wall capacity alone, R = 6.5 is applicable. Example application of criteria is shown in **Table 2** where design capacity is based on either the 1) combined capacity, or 2) capacity of one side only.

Special Inspection

Provisions of *IBC* 1707.3 for periodic special inspection have been clarified for cases where wood-frame construction consists of relatively low unit shear capacity shear walls and diaphragms. When sheathing fastening is more than 4

inches on center, periodic special inspection of sheathing fastening as well as other fastening in the seismic force resisting system is not required. A fastening schedule of 6 inches on center is the typical construction case where the exception applies because standard wood-frame shear wall and diaphragm nailing schedules are at 2, 3, 4, and 6 inches on center. Although uncommon, a nailing schedule intermediate between 4 and 6 inches on center may be specified based on calculations.

Conventional Light-Frame Construction

Applicability of prescriptive provisions has been clarified in *2006 IBC*. Language added in *IBC* Section 2308.1 maintains consistency with scoping provisions in *IBC* Section 101.2 requiring use of the *International Residential Code (IRC)* for certain dwellings:

“2308.1 ...Detached one- and two-family dwellings and multiple single-family dwellings (townhouses) not more than three stories above grade plane in height with a separate means of egress and their accessory structures shall comply with the *International Residential Code*.”

This language directs users of the *IBC* to the *IRC* for prescriptive provisions for detached one- and two-family dwellings and townhouses within the scope of the *IRC*. When detached one- and two-family dwellings or portions of such dwellings, fall outside the limits set in the *IRC*, it is expected that design requirements of *IBC* will be followed. *IBC* Section 2308 prescriptive provisions remain applicable to other uses within the scoped limits of *IBC* Section 2308.2. Examples include one-story slab on grade buildings, school class rooms, and day care facilities. Like *IRC*, where portions of a building fall outside the limits of *IBC* Section 2308.2, design in accordance with the *IBC* is required.

Local Stresses in Fastener Groups

Appendix E for local stresses in fastener groups was introduced in the *2001 NDS* and remains unchanged in the *2005 NDS*. For connections loaded parallel to grain, such as a hold-down or tension splice, Appendix E gives one method to determine design capacity based on wood strength limit states of row tear-out, group tear-out, and

failure at net section. Procedures augment the general requirement for evaluating member stress at connections as well as specific placement criteria for bolt, lag screw, split ring, and shear plate connections. See *Wood Design Focus* Vol. 12, No. 4 “Is Your Wood Connection All Stressed Out? – It Needn’t Be!” for more details on Appendix E provisions.

Conclusions

The transition from *2003 IBC* to *2006 IBC* will introduce several improvements for seismic design of wood buildings. A significant format change is the removal of most seismic design content from *2006 IBC* coupled with the nearly exclusive use of *ASCE 7* as a reference for seismic design criteria. Technical changes tend to ease calculation requirements for compliance with seismic design criteria or facilitate the task of complying with existing requirements. Among these are the alternative simplified criteria, revised criteria for determination of seismic design categories, revised redundancy criteria, and revised criteria for determination of flexible diaphragms. The *IBC 2006* reference to *SDPWS* and *NDS* provides consensus criteria for ASD and LRFD design of shear walls, diaphragms, their members, and connections.

References

- AF&PA/SDPWS-05, 2005 Special Design Provisions for Wind and Seismic. American Forest & Paper Association, Washington, DC.
- AF&PA/NDS-05, 2005 National Design Specification (NDS) for Wood Construction. American Forest & Paper Association, Washington, DC.
- ASCE/SEI 7-05, Minimum Design Loads for Buildings and Other Structures, 2005 with Supplement 1. American Society of Civil Engineers, Reston, VA.
- IBC-03, International Building Code. International Code Council, Falls Church, VA.
- IBC-06, International Building Code. International Code Council, Falls Church, VA.
- IRC-03, International Residential Code. International Code Council, Falls Church, VA.

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