COMMENTARY ON DESIGN OF SHEAR WALLS WITH OPENINGS
(APA RESEARCH REPORT 157)[1]

Subsequent to the development of APA Research Report 157, provisions for designing shear walls with openings have been incorporated in Sec. 2313.2.2 of the 1997 SBCCI Standard Building Code[2]. The provisions include shear capacity adjustment factors for designing shear walls with openings, which take into account partial composite action when determining shear resistance. The provisions include modifications [italics in (a) and (c) below] to the design method described in this report.

For shear walls containing window or door openings:

(a) *Tabulated values for Effective Shear Capacity Factor (SCF_{eff}) for the wall are based on the maximum height of any individual opening that occurs in the wall. If the wall area above or below openings is not sheathed, the tabulated values for SCF_{eff} are based on the maximum opening height which is the full height of the wall.*

In Report 157, the total area of individual openings in the wall is divided by the total area of the wall (including window and door openings), to calculate an Opening Area Ratio (α) which is used as one of the factors for determining a Shear Ratio F. F is used to calculate the allowable shear capacity for the wall in a manner similar to SCF_{eff}.

(b) The sum of the lengths of individual full-height shear wall segments, divided by the total length of the wall (including window and door openings), determines the percent of wall length containing full-height sheathing.

This same criteria is used in Report 157 to calculate the Wall Length Ratio (β), which is also used when determining a Shear Ratio F.

An important consideration is that the aspect (height/length) ratio of the full-height shear wall segments must comply with the provisions in the code (Sec. 2310.1.4 and Table 2310.1 of the Standard Building Code). Other model building codes have similar provisions for shear wall aspect ratio. If the aspect ratio of a wall segment exceeds the maximum value tabulated for vertical diaphragms (shear walls), then that segment should be excluded when determining the sum of the lengths of full-height wall segments. In the design example in Appendix B of Report 157, the aspect ratio of all full-height segments comply with the code requirements, thus all such segments were included when determining the percent of full-height sheathing.

(c) The Effective Shear Capacity Factor (SCF_{eff}) for the wall is based on the percent of wall length containing full-height sheathing, and the maximum height of wall openings as determined per (a) and (b) above. These factors and corresponding SCF_{eff} factors are listed in Table 2313.2.2 of the Standard Building Code. The allowable shear capacity for the wall is determined by multiplying *[(SCF_{eff}) x (code-recognized allowable unit shear for full-height shear wall segments)] x [sum of lengths of qualifying individual shear wall segments].*

In Report 157, the Opening Area Ratio (α) and the Wall Length Ratio (β) are used to calculate a Shear Ratio F. The allowable shear capacity for the wall is determined by multiplying (F) x (code-recognized allowable unit shear for the full-height shear wall segments) x (total length of the wall, including segments with window and door openings).

Because of the modifications to the design factors (in italics), the procedure in the Standard Building Code provides a more conservative design shear load for walls with openings. This can be demonstrated by comparing the design shear as determined by the Standard Building Code procedure with the design example shown in Appendix B of APA Research Report 157.

In accordance with (a) above, the maximum height of individual openings (e.g., doors) for the wall in the design example is (8 - 1)/8 = 0.875. The door height is greater than the maximum opening height of 5H/6 = 0.833H in Table 2313.2.2 of the Standard Building Code. The SCF_{eff} factor can be interpolated between 5H/6 and H.

In accordance with (b) above, the total length of qualifying full-height, fully sheathed wall segments for the wall in the design example is (4)(4) = 16 ft. The percent of wall that has full-height sheathing is 16/40 = 0.40 (40%). Only full-height, fully-sheathed wall segments that meet building code requirements for shear wall aspect (height/length) ratios should be considered when determining the percentage of wall length with full-height sheathing.

For the wall in the design example, with a maximum opening height of 7 ft and 40% of the wall with full-height sheathing, the Effective Shear Capacity Factor (SCF_{eff}) can be interpolated from Table 2313.2.2 of the Standard Building Code as follows: SCF_{eff} = [0.53] - [(7 - 6.667)/(8 - 6.667)][0.53 - 0.45] = 0.51. Therefore, the allowable shear capacity V = [(0.51)(200 +100)][16] = 2,448 lb, which is 89% of the shear capacity in the design example. Fastener size and spacing for the wall sheathing would be based on the **unadjusted** allowable design unit shear capacity (e.g., as required to develop 200 lb per ft for wood structural panels and 100 lb per ft for gypsum wallboard).

The design process also can be reversed, if the required shear capacity of the wall is known based on load calculations. In this case, using the appropriate tabulated value for SCF_{eff} based on the percent of full-height wall sheathing and the maximum height of the wall openings, and the total length of qualifying shear wall segments, it is possible to solve for the **unadjusted** allowable design unit shear capacity v = V / [SCF_{eff}][L].

To determine a conservative shear capacity for connections (bolts, nails, lag screws or steel connectors) to attach the base of qualifying full-height shear wall segments to the structure, the **unadjusted** allowable design shear capacity of the wood-sheathed shear wall segments is used. For the wall design example in Appendix B of Report 157, the connections at the base plate of the wall would be designed for a shear capacity [v][L] = [200 + 100][16] = 4,800 lb (e.g., 300 lb per ft).

Also implied in Sec. 2313.2.2 of the Standard Building Code is that hold-down connectors are required in accordance with Sec. 2313.2.1. These should be placed at the extreme ends of wall segments which are bounded by qualifying full-height shear wall segments. Using a similar conservative basis for determining the required hold-down capacity, as for wall base connections described above, the hold-down connector capacity is [(v)(L)(H)]/L = [v][H] = [200 + 100][8] = 2,400 lb at design load (wind). Tributary dead load of the structure may be sufficient to resist all or part of the design uplift force.
Similar design provisions for shear walls with openings have been proposed for incorporation in Chapter 23 of the 2000 International Building Code.

References Cited:

(1) Rose, J.D. and E.L. Keith, P.E. 1996. Wood Structural Panel Shear Walls with Gypsum Wallboard and Window/Door Openings. Research Report 157 (APA Form W250). APA -The Engineered Wood Association, Tacoma, WA 98411.

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