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Design of SIP Shear Walls with Openings

Three methodologies for Wood Frame Shear Wall design are provided in the American Wood Council (AWC) Special Design Provisions for Wind and Seismic (SDPWS-2015). These are (a) Individual Full-height Wall Segments (segmented), (b) Force-Transfer Shear Walls and (c) Perforated Shear Walls (PSW).

The Segmented shear wall is a well-established method of analysis and is applicable to virtually any form of wood shear wall including SIPs. It assumes that only the full-height segments in the wall line resist the lateral forces. Resistance of each full-height segment is summed together to determine resistance of the entire length of the shear wall and the resulting resistance is generally considered to be a conservative estimate. A downside of this method is that it requires a hold-down at each edge of each full height segment as well as at both ends of the wall. For example, a wall that is 20 feet in length with three different openings along the length of the wall, such as for windows or doors, would require eight hold-downs and the installation of hold-downs is labor intensive and adds cost to a project.

The Force-Transfer methodology was first published in the McGraw-Hill Wood Engineering and Construction Handbook in 1989. This methodology was substantiated by an extensive joint research study conducted by the FPL, APA and the University of British Columbia. It is an engineering mechanics-based methodology that requires rigorous engineering calculations. This method requires the use of additional framing members and blocking, typically 2x dimension lumber, framed into the wall around the openings during construction to transfer lateral shear forces. Due to the need to add additional 2x lumber framing members around the openings in the construction of the wall it is not generally applied in the design of SIP walls.

Another method to relate the shear load for a light framed wood wall with openings to the shear load of a fully sheathed wall was developed by researchers in Japan in 1994. They determined an empirical equation to relate shear capacity and sheathing area ratio based on scaled tests. This method is referred to as the Perforated Shear Wall (PSW) method and was adopted into the design provisions for wood frame shear walls in the SPDWS and is referenced in the International Building Code (IBC).

The PSW method is often a preferred method for the design of wood framed shear walls as it is based on simplified calculations and only requires the use of hold-downs at each end of a wall. Compared to the example for the segmented design method above, a wall that is 20 feet in length with three different openings along the length of the wall, a wall designed using the PSW method would only require two hold-downs instead of eight resulting in easier and less costly construction. While the PSW is widely recognized for the design of light frame wood shear walls, its use for the design of other wood framed wall systems such as SIPs has been questioned by design professionals and building code officials citing the lack of supporting test data.

In order to address this concern, the USDA Forest Products Laboratory (FPL), in conjunction with other organizations, undertook two research studies of SIP shear walls with openings. The first was conducted at the NAHB Home Innovation Research Labs (HIRL). The goal of this study was to conduct a preliminary evaluation of the applicability of the PSW method to SIP shear walls. This study consisted of tests of three multiple segment SIP walls under simulated seismic loading that contained various sized door and window openings. Each wall was 20 feet in length with hold-downs installed at each end of the walls. The tests were conducted in accordance

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with the general provisions of ASTM E2126-11 Standard Test Methods for Cyclic (Reversed) Load Test for Shear Resistance of Walls for Buildings (CUREE Method).

The results indicated that multiple segment SIP shear walls with openings followed the overall trend predicted by the perforated shear wall method for both strength and stiffness. The details of this study are reported in FPL-RP-682, *SIP Shear Walls - Cyclic Performance of High-Aspect-Ratio Segments and Perforated Walls.* While the results of this study were positive it was determined that a follow-up study should be conducted to evaluate a broader range of wall opening configurations to substantiate these results.

The second study undertaken at the FPL involved testing seven different multiple segment SIP wall configurations to further evaluate the effect of openings on lateral resistance. Each wall was 20 feet in length and the wall openings in this study were representative of doors and ranged in width from 2 feet to 12 feet. Walls were constructed with 4-foot or 8-foot wide full-height panels interconnected with block splines. As with the HIRL study hold-downs were placed at the ends of the walls on the outside of the double end posts.

For each wall configuration, three replicates were tested. All walls were tested by displacing the top of the specimen in accordance with the CUREE cyclic protocol (Method C, ASTM E2126-11). The test results for any of the SIP wall configurations evaluated showed that the PSW method gave conservative results for all strength ratio predictions. Therefore, based on these configurations, applying the PSW approach to SIP walls with openings was determined to be appropriate for both stiffness and strength. The details of this study are provided in FPL-RP-704, *Performance of Structural Insulated Walls Under Seismic Loading.*

All three of the SPDWS methodologies for the design of shear walls with openings permit the use of wall segments with aspect ratios up to 3.5:1 for blocked wood structural panel walls, but the nominal sheer capacity must be adjusted by the aspect ratio factor for wall segments having aspect ratios greater than 2:1. The FPL study discussed above (RP-704) confirmed that SIP walls are equivalent to blocked wood structural panel walls for aspect ratios up to 3:1. Therefore a SIP shear wall designed using any of the SPDWS methodologies can have wall segments with aspect ratios up to 3:1 when applying the shear capacity limitations for segments with aspect ratios exceeding 2:1.

Both of these FPL reports can be downloaded at no charge from the FPL website (fpl.fs.fed.US) from the SIPA website (www.sips.org).

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