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NHERI TallWood 10-story Test Nonstructural, Part 2 of 4: Drift-Compatible Connections for Cold-Formed Steel Framed Exterior Walls

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ABSTRACT

Nonstructural exterior walls with cold formed steel (CFS) framing sustain extensive damage during earthquakes. Damage to these vertically distributed components is primarily caused by the differential drift between the floors of the structure. Exterior wall specimens will be built to evaluate detailing solutions to allow CFS walls with platform, bypass, and spandrel framing to accommodate structural drift without damage. Solutions to accommodate relative in-plane/out-of-plane movement at wall intersections are also proposed. This paper describes these solutions and specimens that will be used to validate that these solutions successfully accommodate seismic movement of exterior CFS walls attached to a mass timber structural system at an upcoming shake table test at UC San Diego.

Introduction

The seismic resiliency of buildings can be improved by preventing the downtime and economic losses caused by damage to nonstructural components. Nonstructural cold formed steel (CFS) framed walls often suffer extensive damage during earthquakes, causing significant economic losses and threats to human safety [1]. The primary cause of damage to CFS walls is the differential drift imposed by the connection of the walls to multiple stories. Therefore, industry practitioners accommodate drift by adding horizontal joints that allow CFS walls to move relative to the floors they are attached to [2]. While common in industry, very limited research has been conducted to confirm that these solutions effectively mitigate seismic damage. Furthermore, the joints cause a drift incompatibility at corners and intersections, so solutions that permit perpendicular walls to move laterally without impacting one another must also be found [2].

Three exterior wall specimens using drift-compatible joints will be included in the upcoming NHERI TallWood 10-story building test. An innovative feature of these specimens will be vertical joints that separate the movement of perpendicular walls and reduce corner damage. This paper, the second of four, describes the wall subassemblies, which will be used to evaluate the seismic performance of nonstructural exterior CFS-framed walls with various drift-compatible detailing solutions. The first paper gives a project and design overview and describes the curtain wall subassembly [3], while subsequent papers provide details of interior walls [4] and the stair system [5].

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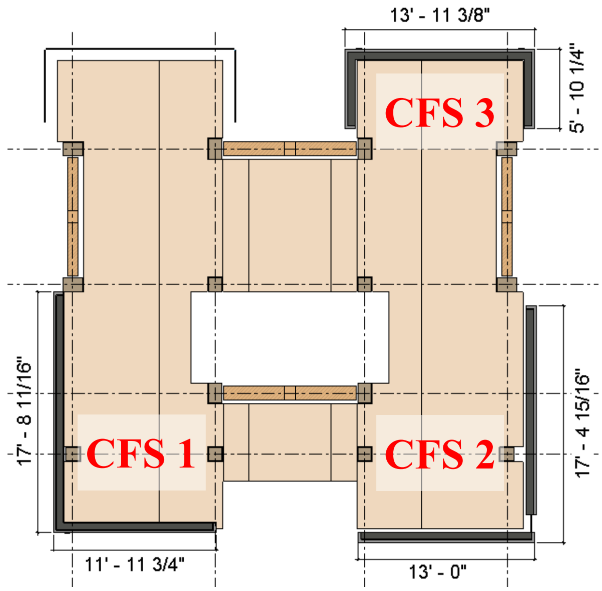


Figure 1. Plan View of Three Test Specimens

Testbed Structure

A full-scale, 10-story mass timber building with timber rocking walls will be built as part of the NHERI TallWood project. The building will be tested at the outdoor shake table at the University of California, San Diego in 2022. Timber rocking walls are able to sustain high drifts without damage [6], so this test represents an ideal opportunity to test drift-compatible connections for otherwise drift-sensitive CFS walls. Refer to the first paper in this series [3] for a more thorough description of the structure and the NHERI TallWood project.

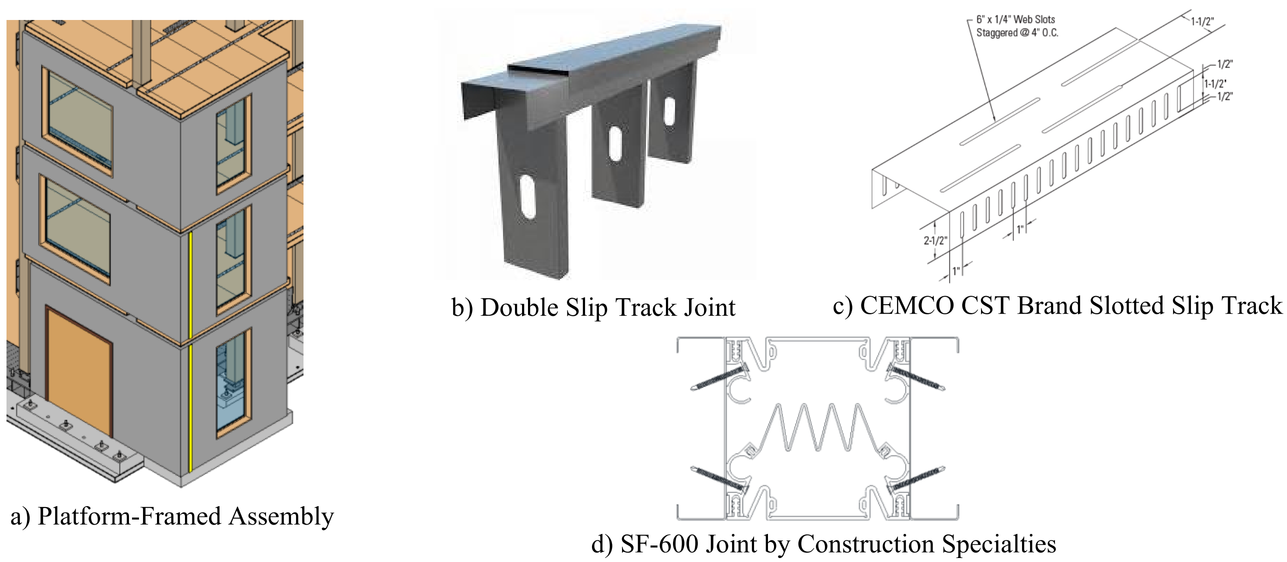
Description of Wall Specimens

Three exterior wall subassemblies will be built to examine the performance of drift-accommodating solutions for platform, bypass, and spandrel-framed CFS walls (denoted CFS 1, CFS 2, and CFS 3 in Fig. 1, respectively.) The subassemblies are distinct and disconnected and thus do not interact. The exterior and interior of the walls will be sheathed with fiberglass mat (except for CFS 2, see below) and gypsum panel sheathing, respectively, and the exterior of the walls will be finished with prefinished aluminum wall panels.

All three subassemblies use 18-gauge, 600S162 studs spaced 16 in. on center. Stud spacing was recommended by industry collaborators and verified using ASCE 7-16 nonstructural design provisions [3]. In order to better represent realistic wall construction, the wall subassemblies contain windows of varying size, operability, and glass type. Two window framing and attachment systems are used: a floating anchor system and a jamb receptor system.

CFS 1 – Platform Framing with Double and Slotted Slip Tracks

The first subassembly is L-shaped (Fig. 2a) and uses platform framing, where studs bear directly on the floor below and are connected to the floor above via an inverted "header" track. Drift is accommodated by including a slip joint at the header track. The first and third floors use double (nested) slip tracks (Fig. 2b) to accommodate in-plane seismic drifts, because damage is prevented when interior CFS partition walls, which are constructed similarly to platform-framed walls, were constructed with double slip tracks; however,



a) Platform-Framed Assembly

b) Double Slip Track Joint

c) CEMCO CST Brand Slotted Slip Track

d) SF-600 Joint by Construction Specialties

Figure 2. Platform-framed subassembly with double and slotted slip tracks.

increased damage occurs at wall intersections [6]. For comparison, the second floor uses CEMCO's CST Brand Slotted Slip-Track (Fig. 2c.) Slotted slip tracks have horizontal slots in their webs to permit horizontal movement and vertical slots in their flanges to permit vertical movement. Slotted slip tacks are easier to install and require less material than double slip track assemblies; however, slotted slip tracks may be more likely to suffer from binding.

To address the drift incompatibility at the corners, the first and second stories will use SF-600 corner joints by Construction Specialties, which is intended to separate the movement of adjoining walls. The joints provide 4 in. relative movement between perpendicular walls. The third story serves as a control specimen and use a typical, rigid joint at the intersection of the two walls. The corner of the third story is expected to suffer significant damage while the other two stories will accommodate in-plane drift without significant damage.

CFS 2 – Bypass Framing with Drift Clips

The second subassembly (Fig. 3a) is an L-shaped subassembly with bypass framing, wherein long studs span multiple stories outside of the diaphragm envelope. Damage in bypass-framed walls is typically concentrated at the clips used to attach studs to the structural system [7, 8]. Therefore, drift can be accommodated by connecting the studs to the floor diaphragm via a clip that is free to slide laterally. This will be accomplished using a DSSCB clip from Simpson Strong-Tie installed into standard U-track (Fig. 3b.) This connection resists out-of-plane loads while permitting in-plane movement of the clip withing the U-track.

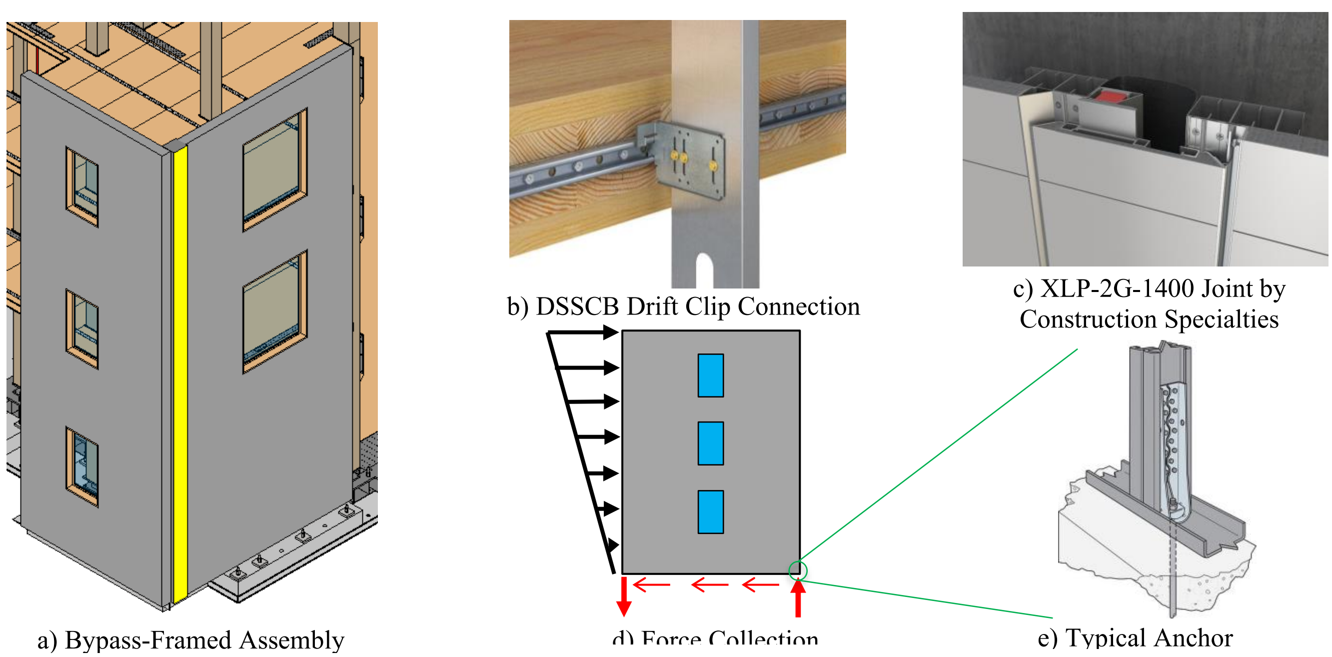


Figure 3. Bypass framed wall with drift clips.

Because the walls are continuous over three stories, this subassembly is expected to deflect much more than the other subassemblies. Thus, there is much greater potential for damage at the intersection of the two walls if nothing is done to mitigate the conflict. Therefore, the longer wall will include an XLP-2G-1400 by Construction Specialties, a 14 in. hinged joint oriented vertically along the height of the corner (Fig. 3c.) This joint is sized to allow 2.5% drift (about 11 in.) in each direction.

Because the drift clips do not resist in-plane seismic forces, the wall must collect shear forces over its entire height rather than transmitting them to the diaphragm at every floor (Fig. 3d.) Because of this, the exterior of the subassembly is sheathed with CEMCO's Sure-Board® Series 200 Structural Shear Panels for enhanced shear strength. Additionally, large anchors are used at the wall base to resist overturning forces (Fig. 3e.)

CFS 3 – Spandrel Framing with Nested Slip Tracks

The third subassembly, which uses spandrel framing, is C-shaped with two return walls (Fig. 4a.) Spandrel framing consists of bands of short studs rigidly attached around a floor diaphragm via rigid metal clips (Fig. 4c) and kicker studs (Fig. 4b.) Loads from the spandrel are transferred directly to the diaphragm to which it is attached. The space between spandrels can be filled with windows or infill studs. Drift compatibility is achieved by placing a double slip track (Fig. 2b) between the window and the spandrel above. At the base of the wall, the lowest spandrel cannot use a kicker stud, so it instead is anchored to the foundation using a moment-resisting connection (Fig. 4d.)

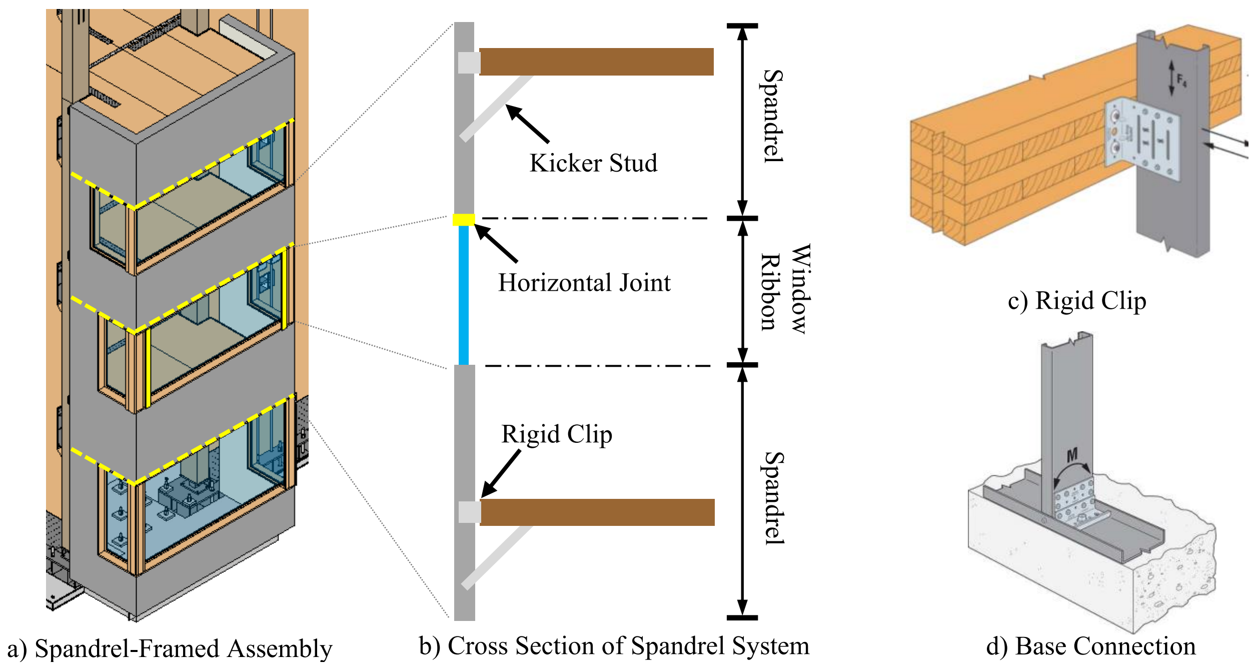


Figure 4. Spandrel framed wall with double slip tracks.

Spandrel framing is often used so that a "ribbon" of windows can extend around the entirety of the structure without unsightly interruptions. Thus, windows in this subassembly wrap around its corners (Fig. 4a.) The wall framing system is not present at window corners on the first and third floors, which will demonstrate whether typical window framing is flexible enough to permit perpendicular wall motion without damage. The second floor instead incorporates a SF-600 joint between perpendicular windows to separate their movement (Figs. 2d, 4a)

Conclusions

The proposed detailing solutions have the potential to reduce or eliminate damage to exterior, nonstructural CFS walls; however, the efficacy of these solutions remains unproven, and the problem of corner damage has not yet been solved. Testing wall specimens that incorporate drift-compatible details is intended to validate that those details – already used by industry professionals – successfully mitigate damage to exterior CFS walls. These specimens may uncover deficiencies in current construction practice and help identify advances that will improve the ability of exterior CFS walls to withstand seismic events without damage.

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References

1. Di Lorenzo G, De Martino A. Earthquake response of cold-formed steel-based building systems: an overview of the current state of the art. *Buildings* 2019; 9 (11): 228.
2. Kersh JS, Castle T. Designing for drift… Is lateral drift accommodation in exteriors really possible? *STRUCTURE Magazine* Jun. 2005; 20-23.
3. Wynn S, Ryan K, Roser W, Ji Y, Soroush S, Hutchinson T. NHERI TallWood 10-story Test Nonstructural, Part 1 of 4: Project Overview and Curtain Wall Subassembly. Proceedings of the 12th National Conference in Earthquake Engineering, Earthquake Engineering Research Institute, Salt Lake City, UT. 2022.
4. Ji Y, Ryan K. NHERI TallWood 10-story Test Nonstructural, Part 3 of 4: Cold-Formed Steel Framed Interior Walls. Proceedings of the 12th National Conference in Earthquake Engineering, Earthquake Engineering Research Institute, Salt Lake City, UT. 2022
5. Sorosh S, Hutchinson T.C., Ryan K. Pretest Overview of Shake Table Test Program of Steel Stairs with Different Connection Configurations in the NHERI Tall Wood Project. Proceedings of the 12th National Conference in Earthquake Engineering, Earthquake Engineering Research Institute, Salt Lake City, UT. 2022.
6. Hasani H, Ryan KL. Experimental Cyclic Testing of Reduced Damage Detailed Drywall Partition Walls Integrated with a Timber Rocking Wall, *Journal of Earthquake Engineering* 2021.
7. Wang X, Pantoli E, Hutchinson TC, Restrepo JI, Wood RL, Hoehler MS, Grzesik P, Sesma FH. Seismic Performance of Cold-Formed Steel Wall Systems in a Full-Scale Building. *Journal of Structural Engineering* 2015; 141 (10).
8. Schafer BW, Ayhan D, Leng J, Liu P, Padilla-Llano D, Peterman KD, Stehman M, Buonopane SG, Eatherton M, Madsen R, Manley B, Moen CD, Nakata N, Rogers C, Yu C. Seismic Response and Engineering of Cold-formed Steel Framed Buildings, *Structures* 2016; 8: 197-212