Examination of Slip Behavior in Drywall Partition Walls

Preliminary Report of Bidirectional Subassembly Tests at Lehigh University: Phase I of Nonstructural Testing

Experiments conducted as part of NSF Grant No. CMMI-1635363 and 1635227, "Collaborative Research: A Resilience-based Seismic Design Methodology for Tall Wood Buildings"

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Acknowledgments

This material is based upon work supported by the National Science Foundation under Grant Nos. CMMI-1635363, and 1635227. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the National Science Foundation.

The authors are grateful to the following companies that donated materials and supplies needed to construct the partition walls, including Clark Dietrich, Trevdan Building Supply, United States Gypsum Company, Kempf Company, and G&S Fastening Systems. Duggan and Marcon generously provided the wall fabrication service at the NHERI Lehigh Facility. Finally, the authors are especially indebted to Ken Loush of Eastern Exterior Wall Systems Inc, who coordinated the entire effort.

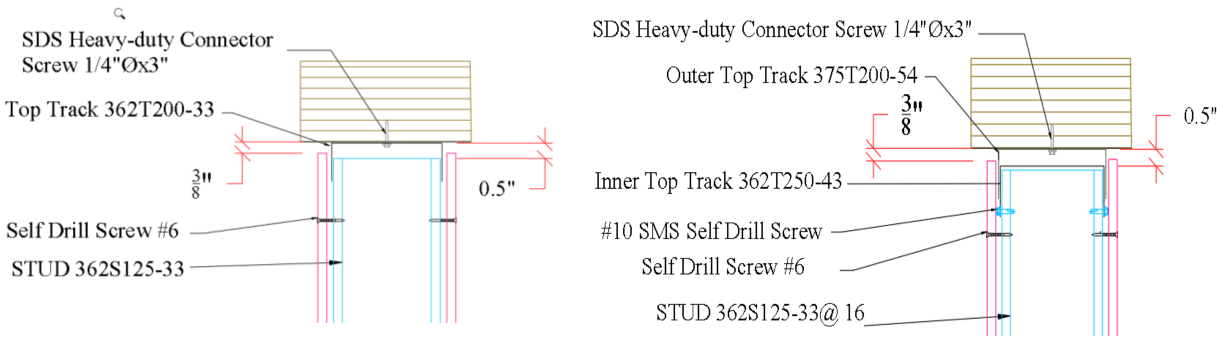
Abstract

Preliminary observations of Phase I testing of a subassembly of nonstructural drywall partition walls integrated with cross-laminated timber (CLT) rocking walls are reported. In this phase, the slip behavior of two straight drywall partition walls (without return walls) – one with conventional slip-track detailing and the other with telescoping detailing – was examined. These drywall partition walls were tested under a bidirectional loading protocol, which allowed for systematic evaluation of the effect of out of plane drift on the in-plane resistance of the drywall partition walls. Preliminary conclusions are that the telescoping detailing performs better since it eliminates damage to the framing, such as detachment of end studs that causes bending of the end studs and damage to the track. Moreover, the out-of-plane drift had a negligible effect on the in-plane resistance.

Introduction

Drywall partition walls are drift sensitive components, which are susceptible to damage at low shaking intensities. In contrast, buildings with post-tensioned cross-laminated timber (CLT) rocking walls as a lateral load resistant system can sustain large drift demands with little damage (Buchanan et al. 2008; Ganey 2015). Thus, drift-induced damage in drywall partition walls needs to be reduced to achieve overall seismic resiliency. Damage reduction is proposed using two details that attempt to isolate the drywall partition walls from the inter-story movement.

Previous studies have shown that drywall partition walls with slip-track connection detailing can endure higher drifts compared to the full connection when return walls are not present; however, these drywall partition walls are susceptible to detachment of boundary studs from the walls (Davies et al. 2011). Another alternative for the top connection of the drywall partition wall is the track-within-a-track deflection assembly (referred to hereafter as telescoping). This detail is used mainly for absorbing the vertical deflection of the diaphragm, but it has also been suggested for lateral movement (Applied Technology Council 2012). However, to the authors' knowledge, this connection detail has not been tested for the seismic-induced drift so far. Figure 1 shows the connection detailing at the top for both types of drywall partition walls.



Slip track connection | Telescoping connection

Figure 1: Slip track and telescoping connection detailing

The most critical parameter yet to be scrutinized is the behavior of interior drywall partition walls under bidirectional loading. To the authors' knowledge, drywall partition walls have not been tested bi-directionally under systematic quasi-static loading, which can provide better information about their damage states.

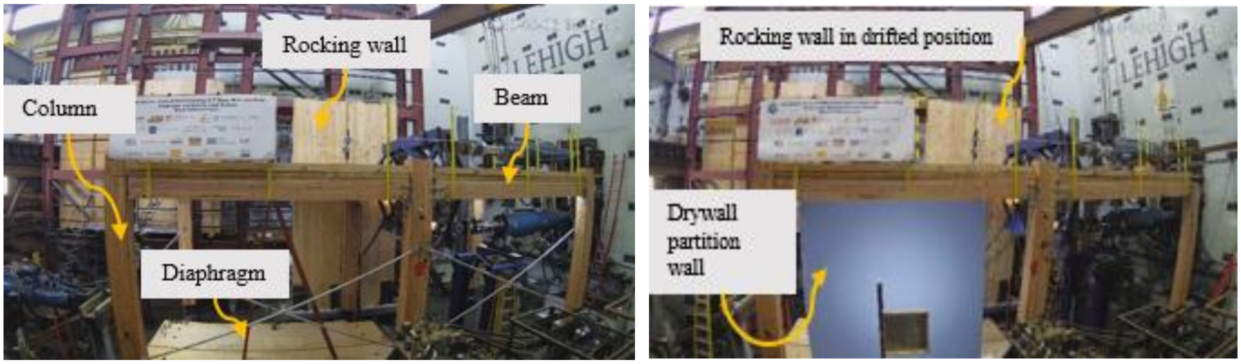
Test Objective

Two straight drywall partition walls, one with conventional slip track detailing and the other with telescoping detailing, were built within a post-tensioned CLT rocking wall subassembly at the National Hazards Engineering Research Infrastructure (NHERI) Lehigh Equipment Facility (EF). The overarching objective is to investigate the seismic performance of drywall partition walls integrated with the rocking wall subassembly. The specific objectives of Phase I testing are 1) to evaluate the relative seismic and slip performance of the walls with telescoping detailing and conventional slip-track detailing, and 2) to assess the influence of out-of-plane loading on the in-plane resistance of the walls.

Experimental Program

Testbed Structure

The testbed structure was a single-story, 2-bay by 1-bay CLT post-tensioned rocking wall system with gravity framing. For simulating a realistic specimen, the structure dimensions were 30 ft. by 15 ft., and floor-to-floor height was 12.5 ft. The rocking wall system was composed of two five-ply CLT panels with dimensions of 20 ft. x 5 ft. x 6.75 in., and connected by U-shaped flexural plates (UFP) for energy dissipation (Figure 2). The first-floor diaphragm was built from three-ply CLT panels, and the base diaphragm was built from five-ply CLT panels. The connection of the wall and collector beam was designed to isolate the diaphragm from the vertical movement of the rocking walls (Clay et al. 2019).



(a) (b)

Figure 2: (a) Testbed structure; (b) testbed structure with drywall partition walls subjected to 5% drift

Test Specimen Detail

The test specimen consisted of two 12 ft. long and 12.5 ft. high of drywall partition walls constructed between CLT diaphragms. The first wall used a slip-track top connection detail. In this detailing, the drywall is connected only to the studs, and there is not any connection between the stud and the top track (Figure 1(a)). The other wall used a telescoping connection detail, which uses two sets of tracks at the top of the wall. One track nested in the other track without any connection between the two tracks. However, studs are connected to the inner track (Figure 1(b)). The base of both walls was fully connected to the tracks. Both walls used institutional detailing, which specifies gauge 33 studs spaced 16 in. o.c. Figure 3 shows the whole setup of the test.

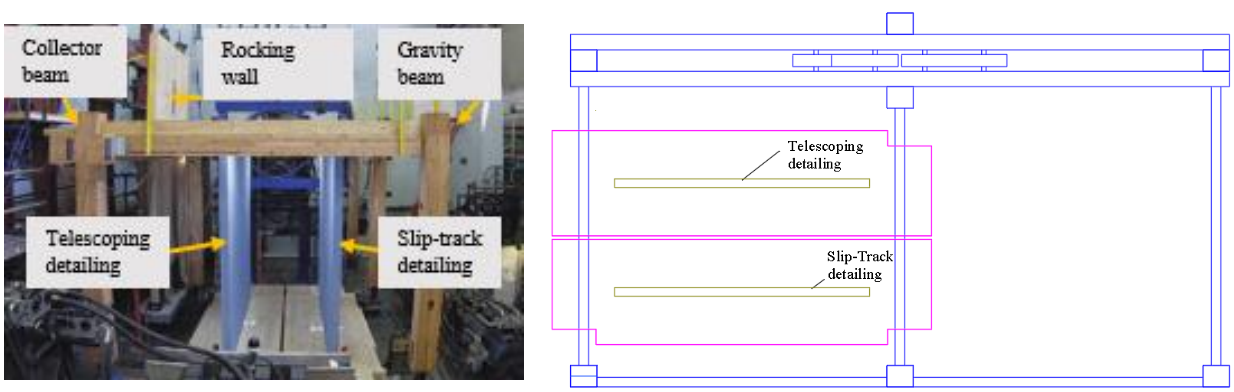
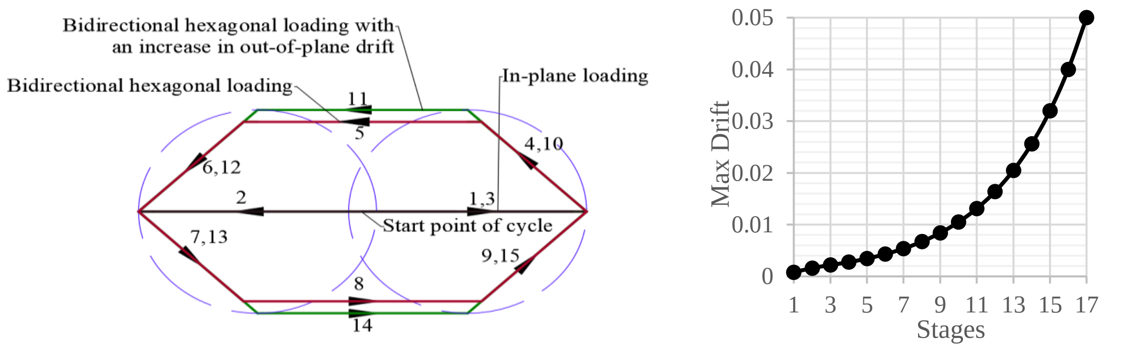


Figure 3: (a) Drywall partition walls installed between CLT diaphragms; (b) position of drywall partition walls in the structure

Loading Protocol

A cyclic drift loading protocol has been used for this test, through which the drift amplitudes are increased in each stage. The loading protocol specified a bidirectional path of movement, with three sub-cycles in each stage: in-plane, bidirectional hexagonal, and bidirectional hexagonal with an increase in out-of-plane drift (Figure 4(a)). The magnitude of peak in-plane drift is increased in each stage, as shown in Figure 4(b). This loading protocol was designed to evaluate the effect of the out-of-plane drift on the in-plane resistance of the drywall partition wall.



(a) (b)

Figure 4: (a) Path of movement of bidirectional load step; (b) peak in-plane drift amplitude in different stages

Preliminary Results

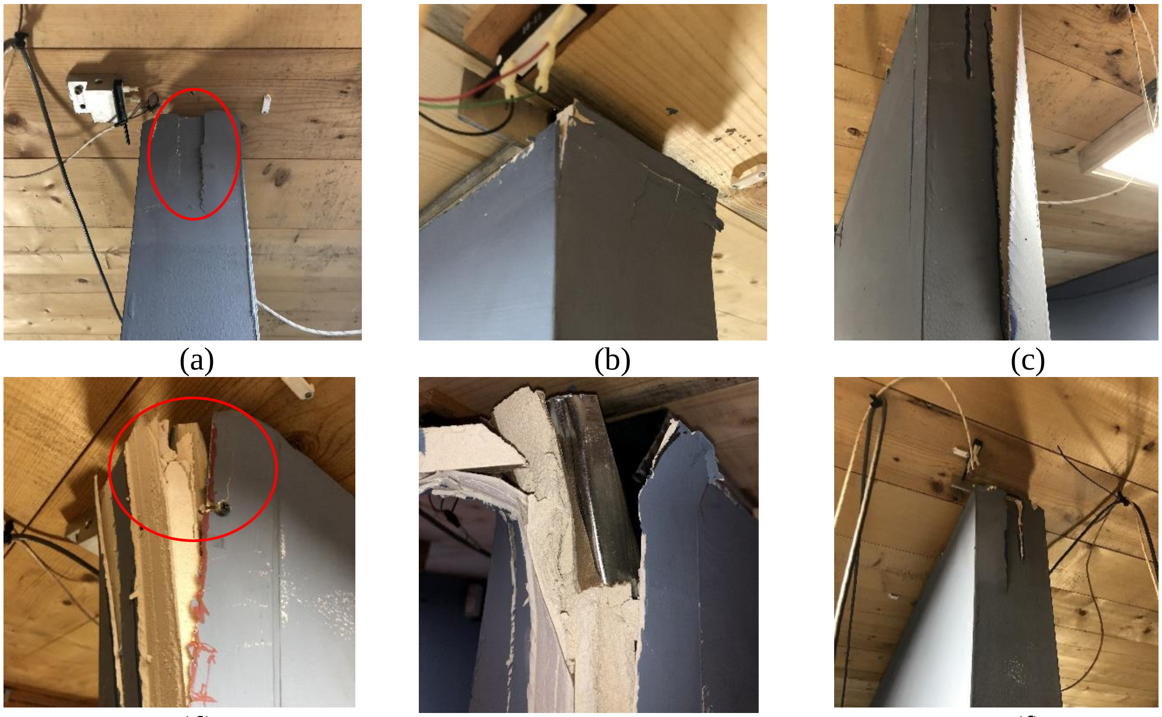
The seismic performance of the drywall partition walls was preliminarily evaluated through observation of the damage mechanisms (Figure 5). After each cycle, the damage to the partition walls was assessed, and a damage description recorded. Corner beads at the end of both walls started to lightly detach at around 0.46% drift (Figure 5(a)). This damage occurs because the entire wall below the top track tends to remain stationary, while the top track tends to move with the top diaphragm (natural behavior of slip-track). Since fire regulations permit only up to half-inch gap at the top of the gypsum (Gypsum Association 2018), while the top track leg length is 2 in. for both types of detailing, the top track hits the gypsum at the top of the wall ends.

The detachment of corner beads increased with increasing drift. Light warping of the gypsum was observed at 0.67% drift (Figure 5(b)), and the corner bead opened significantly at 0.84% in the slip-track connected wall (Figure 5(c)). Coincident with this observation at 1.26 in. displacement, the resisting force increased significantly. Since the stud leg is 1.25 in., the authors believe that the considerable opening in the corner bead is due to the stud not returning to its nested track in the slip-track connected wall. Bending of the end stud was observed at 2.56% drift in the slip-track connected wall (Figure 5(d)). At a drift of 3.2%, the damaged end stud in the slip-track connected wall bent the leg of the track (Figure 5(e)), which was coincident with a considerable increase in the resisting force. While all of this damage progressed in the wall with the slip track connection, the wall with telescoping detailing showed only minor damage at the top end of the wall (Figure 5(f)).

The post-test inspections suggest that the framing of the wall with telescoping detailing remained damage-free during the test (Figure 6(a)). However, the stud and track of slip-track detailing suffered damage due to the detachment of end studs from the track (Figure 6(b)).

Hysteresis Response of Drywall Partition Wall

Figure 7 shows the hysteresis loops of the walls with slip-track connection (Figure 7(a)), and telescoping detailing (Figure 7(b)). The hysteresis loops show that both walls developed approximately similar forces because both walls have slip behavior at the top. Moreover, the hysteresis loops suggest that the out-of-plane drift of the drywall partition does not affect the in-plane force of the wall considerably. The slip track wall hysteresis loops exhibited a few sudden increases in the force, which coincided with the occurrence of damage to the framing of this wall mentioned earlier.



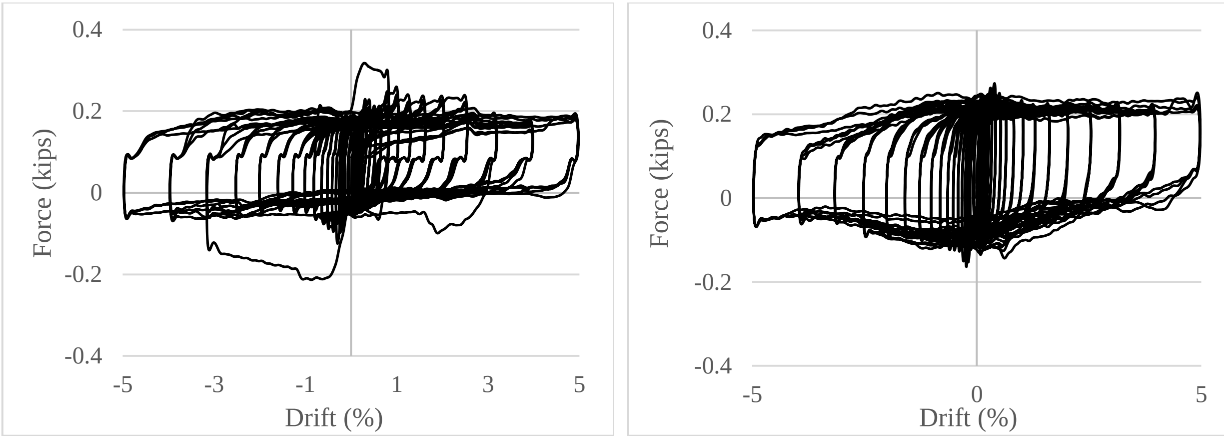
(a) (b) (c)

(d) (e) (f)

Figure 5: (a) Light detachment of corner bead at wall ends (0.46% drift, slip track); (b) light warping of gypsum (0.67% drift, slip track); (c) significant opening in the corner bead (0.84% drift, slip track); (d) end stud bending (2.56% drift, slip track); (e) track leg bent (3.2% drift, slip track); (f) light detachment of corner bead at wall ends (1.64% drift, telescoping)

(a) (b)

Figure 6: Post-test inspection after removal of gypsum board: (a) damage in the wall with telescoping detailing; (b) damage in the wall with a slip track connection



(a) (b)

Figure 7: Force vs. displacement hysteresis of drywall partition walls: (a) slip track detailing; (b) telescoping detailing

Moreover, the hysteresis loops of the entire subassembly are shown in Figure 8. Since the drywall partition walls had slip behavior, they contributed less than 1% to the whole subassembly force. It is worthwhile to mention that the structural subassembly suffered almost damage. The CLT rocking wall was protected at the toes with steel armoring; therefore, visible damage was limited to crushing of the concrete base beneath the toes of the rocking wall.

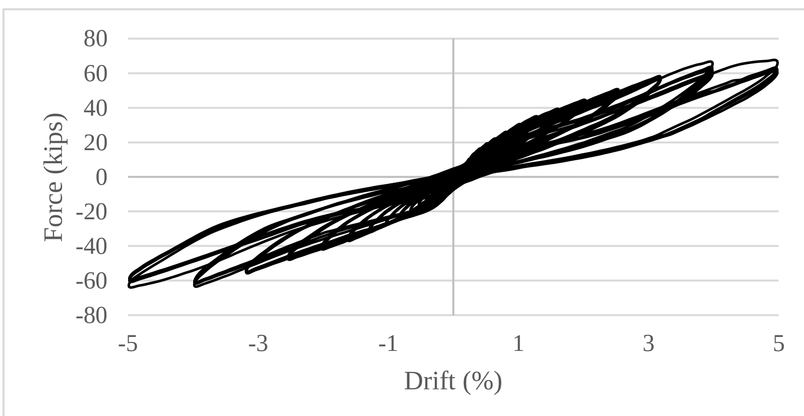


Figure 8: Hysteresis loops of the entire subassembly in the in-plane direction

Conclusion

Bidirectional quasi-static experiments of drywall partition walls integrated into a CLT rocking wall subassembly were performed at the NHERI Lehigh EF as part of a project to develop a resilience-based seismic design methodology for tall wood buildings. Compared to a traditional slip track connection detail, telescoping detailing was observed to eliminate damage to drywall partition walls that is caused by the separation of the end studs from the track at large drifts. Moreover, the out of plane drift did not affect the in-plane resistance. Furthermore, since both walls have slip behavior, the resisting force of the walls was insignificant compared to the force of the CLT rocking walls.

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