NONLINEAR ANALYSIS OF WOODFRAME SHEAR WALLS

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ABSTRACT :

This paper presents various analytical techniques available to consulting engineers in the seismic evaluation of woodframe lateral load resisting walls. Analytical models with varying degrees of complexity were utilized for this purpose. These included the CASHEW and SAWS computer programs (developed as part of the CUREE-Caltech woodframe project), along with SAP2000 (commercially available nonlinear finite element program). The SAP2000 model incorporated frame elements for the wood studs, shell elements for the wall sheathing, and nonlinear link elements for the sheathing-to-stud fasteners. More testing on various types of fasteners is recommended since fasteners dominate the dynamic response of woodframe shear walls and buildings. Plywood shear walls with and without stucco and drywall wall finishes were considered in the analyses. The paper provides verification of the analytical models with the results from shear wall tests performed as part of the woodframe programs of the City of Los Angeles – University of California, Irvine (CoLA-UCI), and CUREE. SAP2000 is effective in the determination of the target displacement and strength capacity for the walls. Nonlinear finite element analysis allows the user the flexibility to model shear walls with openings, various sheathing panel configurations, and various boundary conditions such as wrap-around sheathing at wall ends. A good match was found between the analytically determined and experimentally measured quantities. This paper provides details of the analytical model and compares results to experimental data. The analytical methods described can be used in the post-earthquake evaluation of damaged wood buildings or in the seismic design of new buildings.

KEYWORDS: Nonlinear analysis, woodframe, shear wall, stucco, drywall

1. OBJECTIVES

The aim of this study is summarized as follows:

1. Create a structural model to estimate woodframe wall response.

2. Include wall and ceiling returns in the structural model.

3. Use test data and analysis tools that became available in the last decade to model connectors and walls.

2. TEST SPECIMENS

Test specimen numbers 5 and 7 of CUREE report EDA-07 (2005) were chosen, mainly due to their consideration of the ceiling returns and wall corner details. Test specimens were 16 feet long and 8 feet high, and represented one story tall walls. The walls had two window openings, each 4 feet wide and 3 feet high. The wall sheathing consisted of ⅞ inches thick stucco on one side of the wood stud framing and ½ inches thick gypsum wallboard (drywall) on the opposite side of the framing. Furring nails connected the stucco sheathing to the framing, and 5d cooler nails connected the drywall sheathing to the framing.

Extra top plate and nailing are provided for the ceiling return. Extra corner stud and nailing are provided at wall ends. Illustrations of the test specimen are provided in Figures 1, 2, and 3.

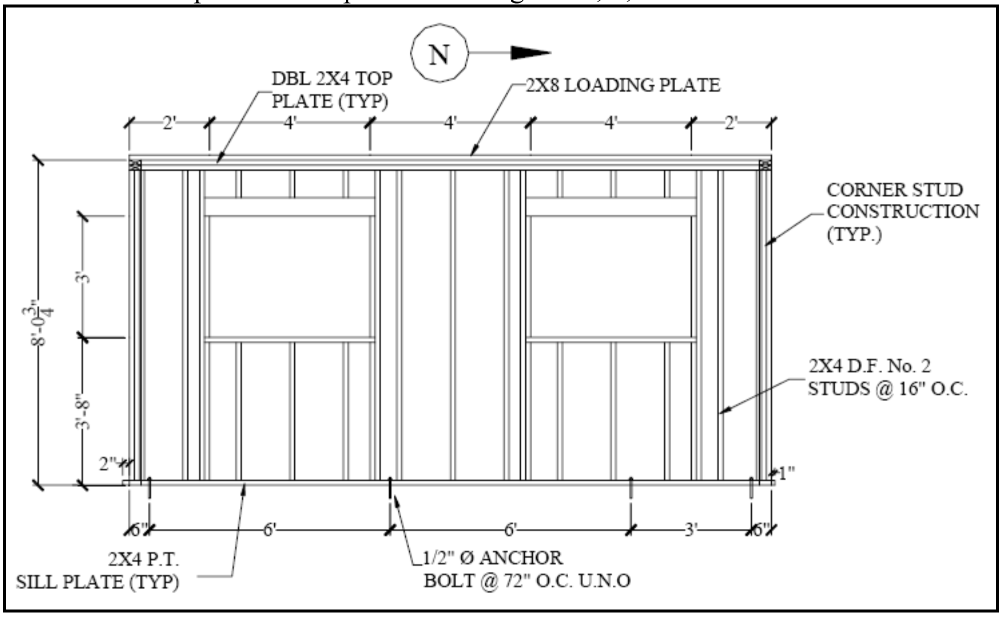

Figure 1 Test specimen (CUREE EDA-07)

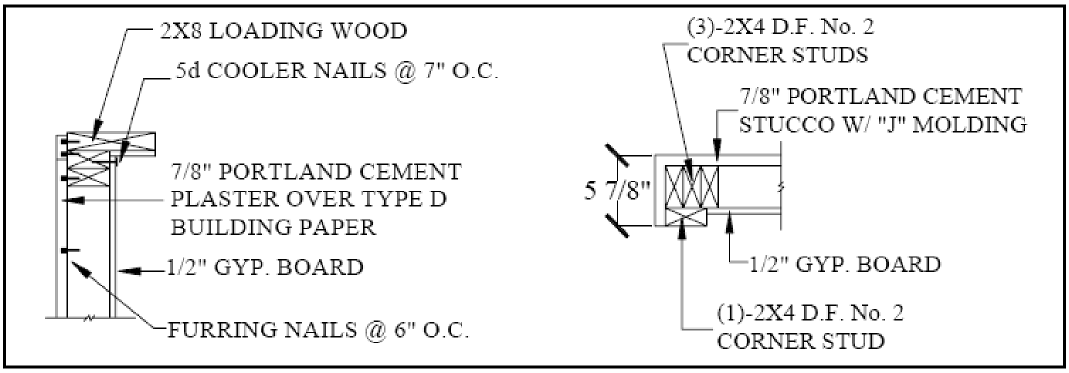

Figure 2 Test wall construction details: wall-top ceiling return and wall-end corner detail (CUREE EDA-07)

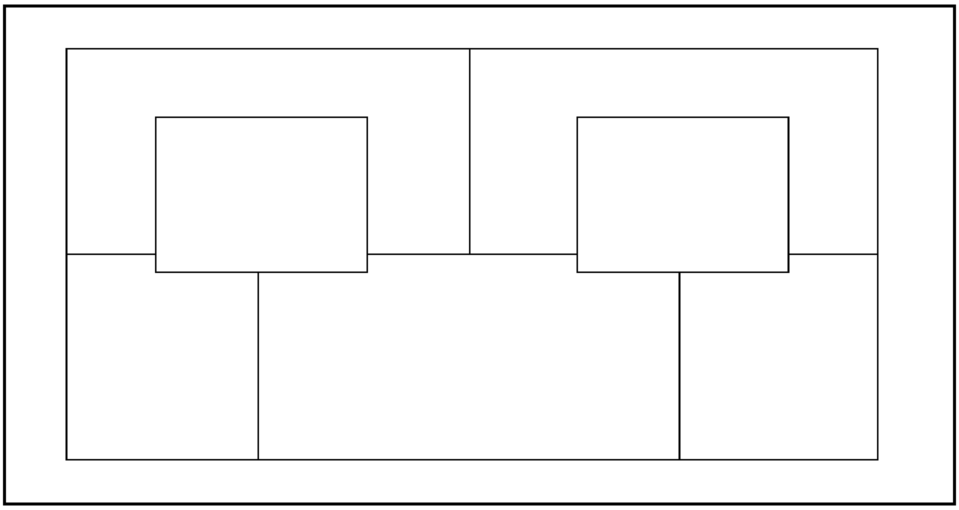

Figure 3 Gypsum wallboard panel configuration (CUREE EDA-07)

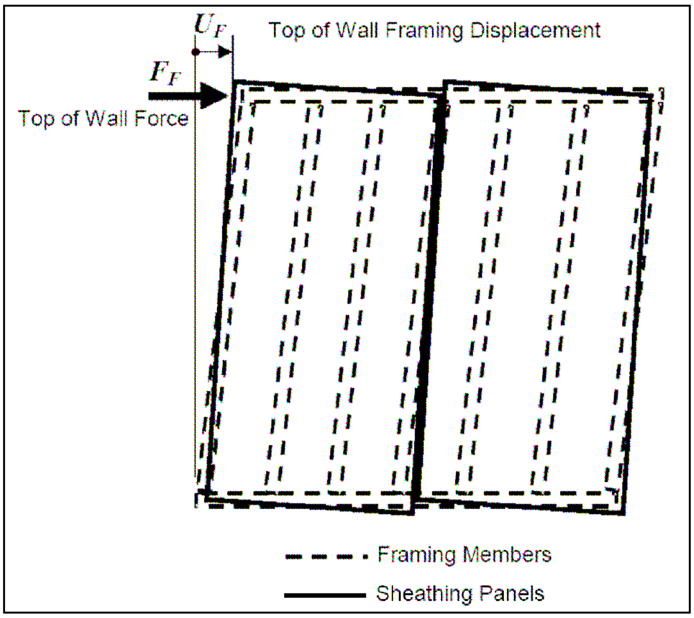

Figure 4 Deformed woodframe wall (CUREE W-08)

3. STRUCTURAL ANALYSIS MODEL

A structural analysis model was created in the finite element program SAP2000 as shown in Figure 5. Shell elements were used to model the sheathing materials as shown in Figure 6 for drywall and Figure 7 for stucco. Frame elements were used to model the wood studs as shown in Figure 8. Vertical studs are pinned at top and bottom to mimic the shear deformation of the sheathing relative to the framing members as illustrated in Figure 4. Nonlinear link elements were used to model the load versus deformation property of the fasteners (Figure 9).

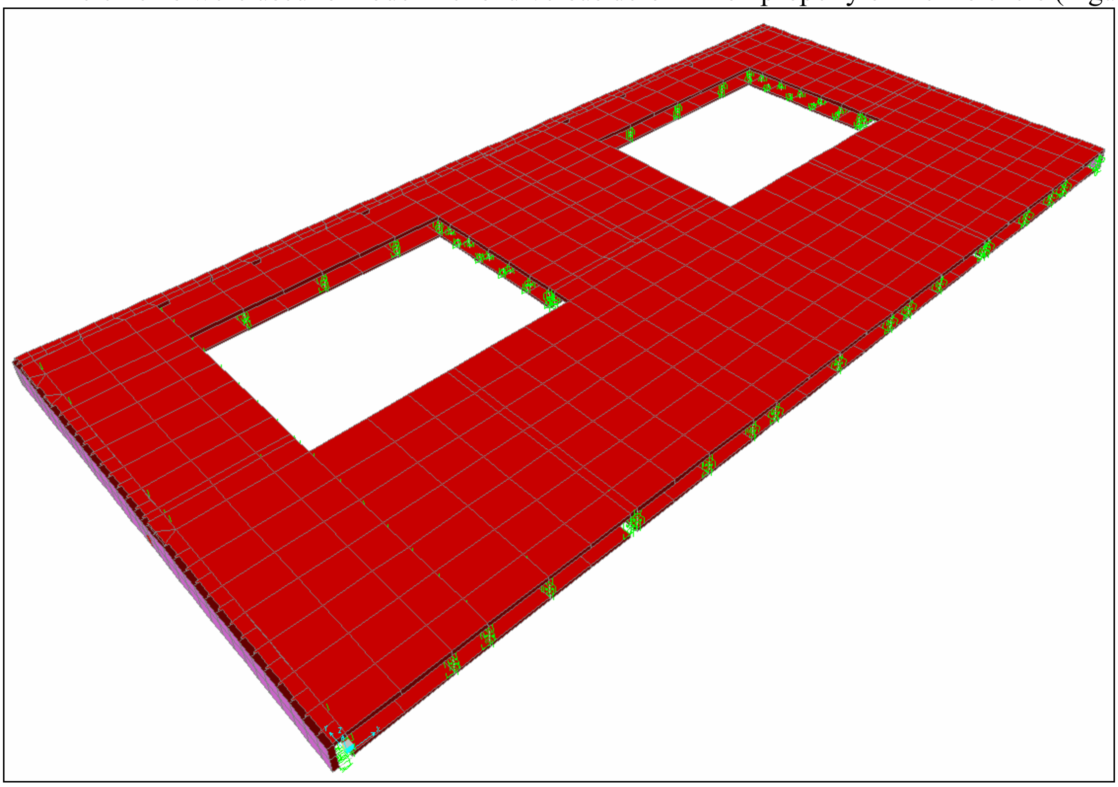
Figure 5 Structural analysis model in SAP2000

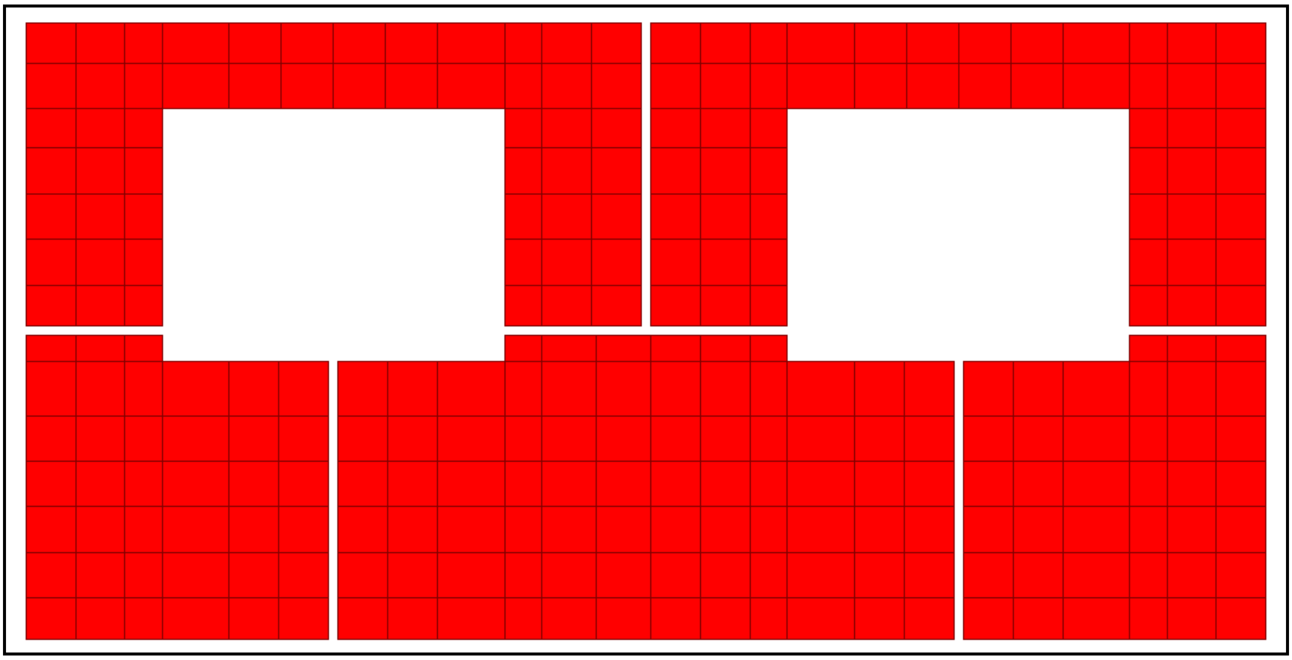

Figure 6 Gypsum wallboard configuration and shell elements in SAP2000

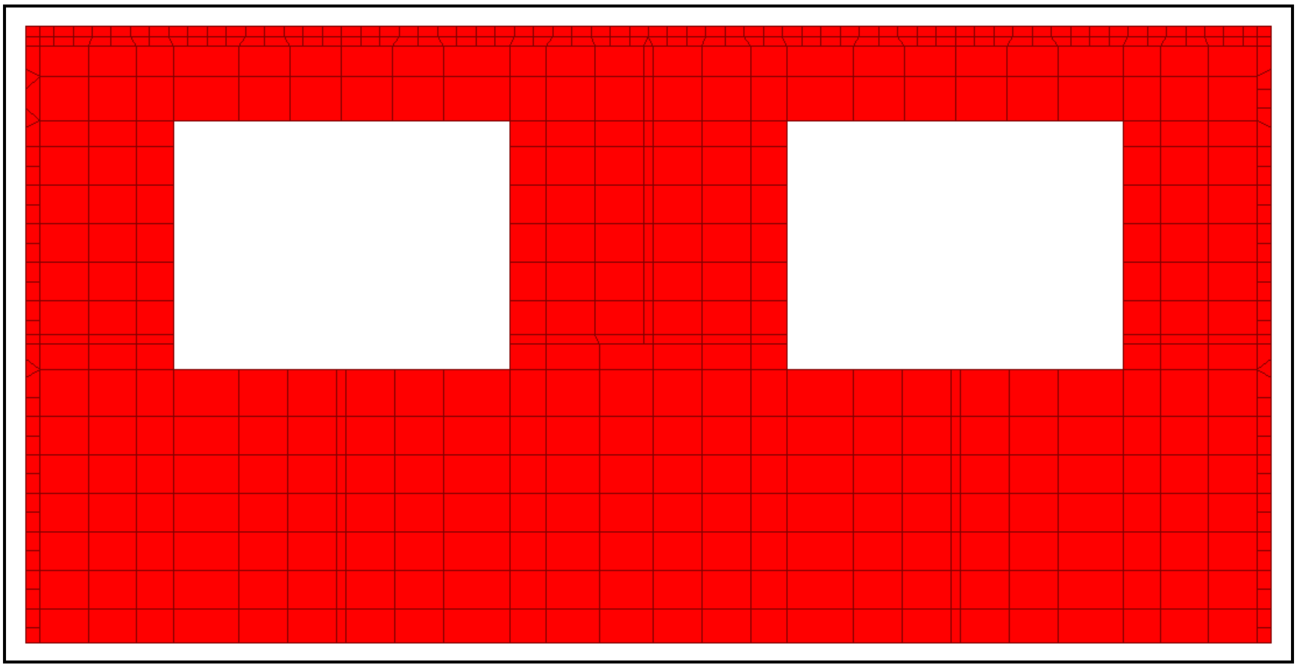

Figure 7 Stucco shell elements in SAP2000

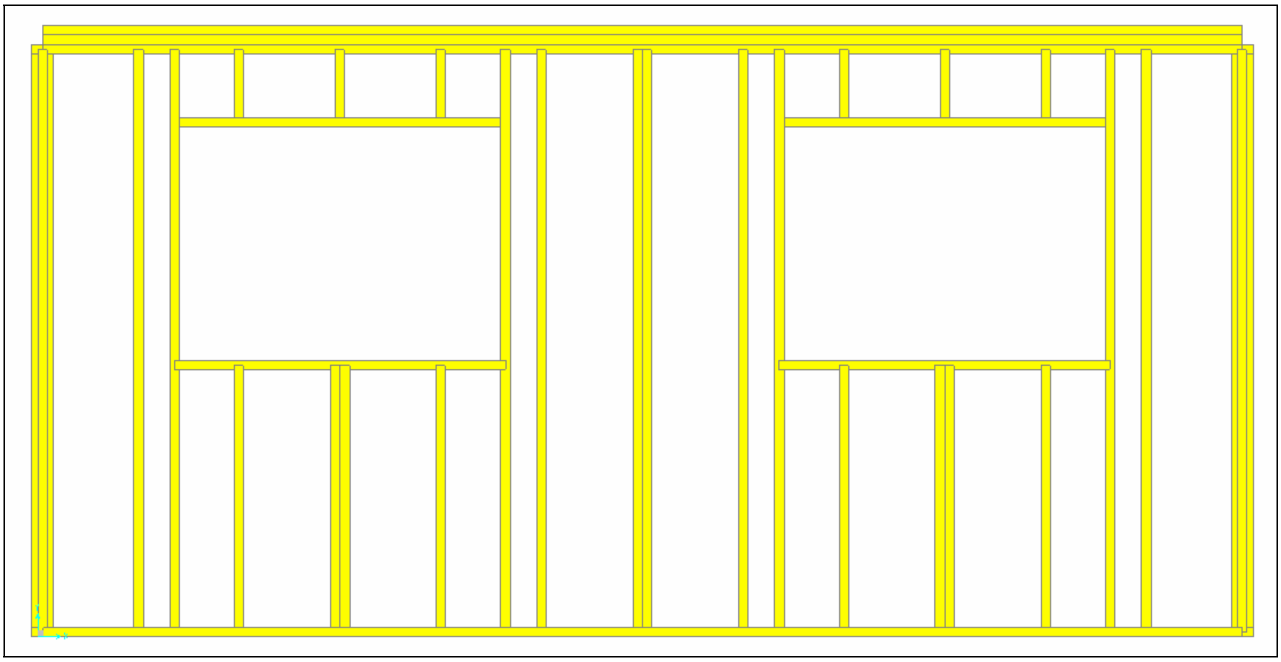

Figure 8 Frame elements (wood studs) in SAP2000

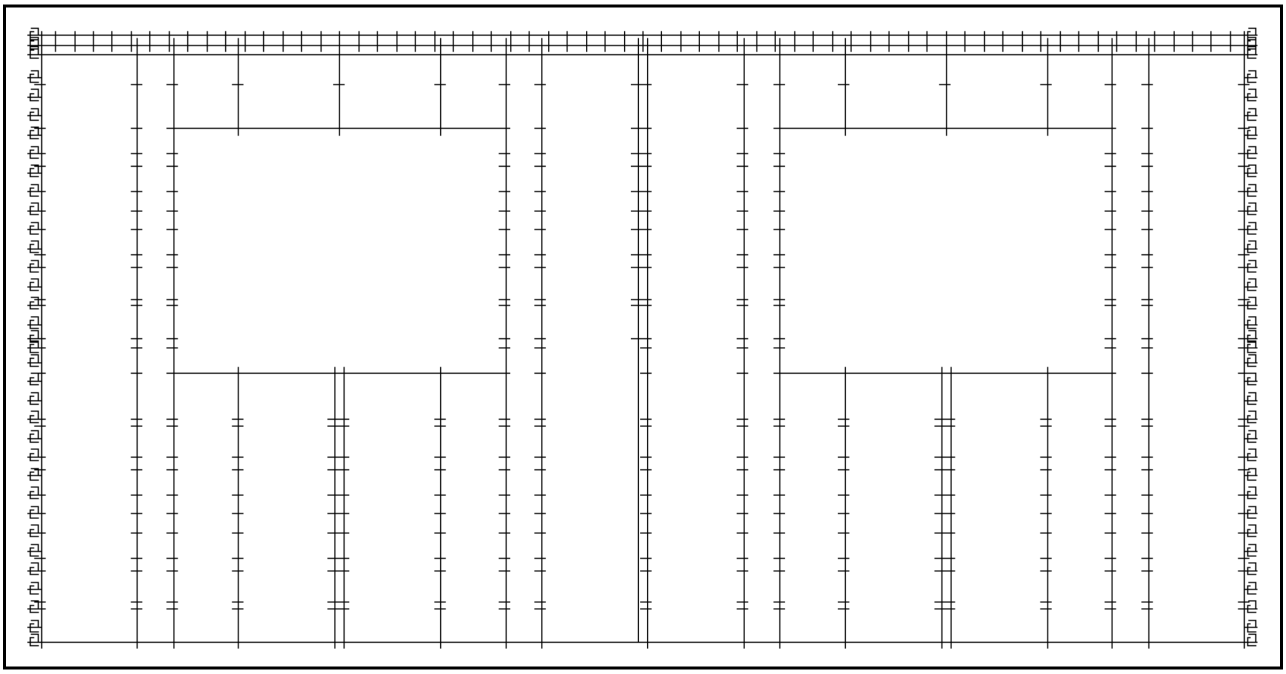

Figure 9 Link elements (fasteners) in SAP2000

Figure 10 shows the typical deformed shape of the gypsum wallboard panels when a horizontal load is applied along the top of the woodframe wall. Figure 11 compares the load versus deformation response of the wall between the computer model output and the two test results.

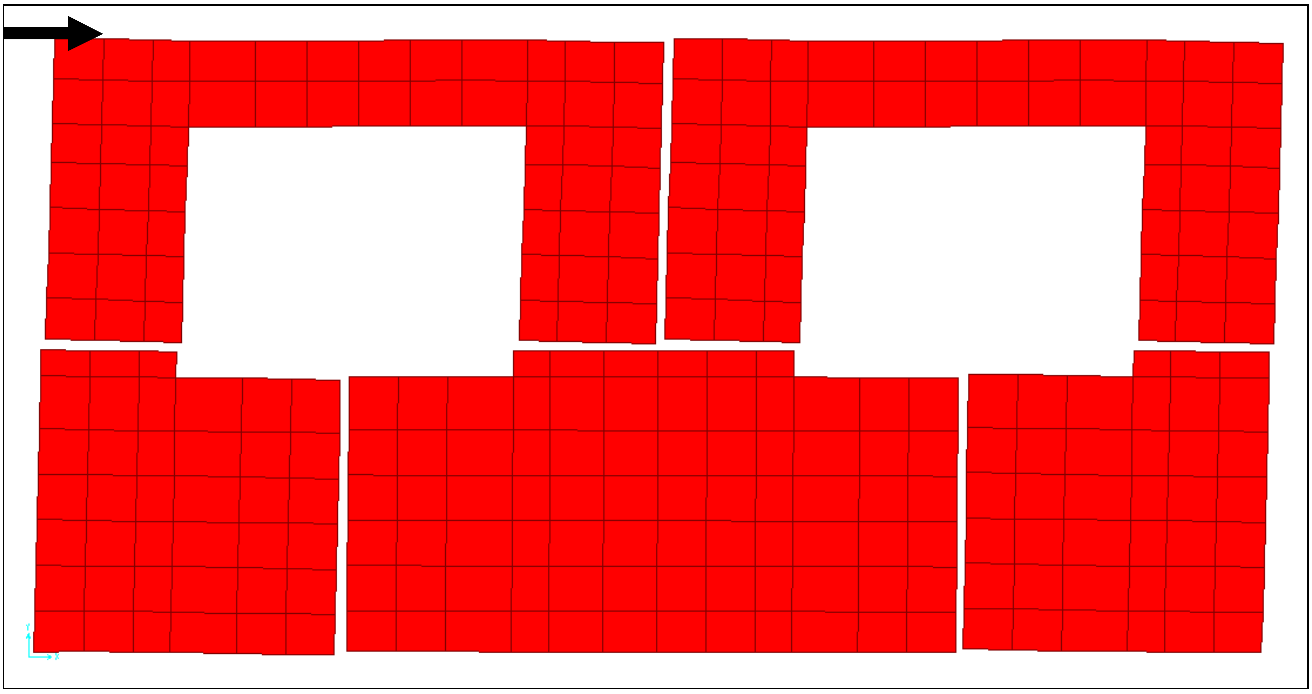

Figure 10 Deformed shape of gypsum wallboard panels

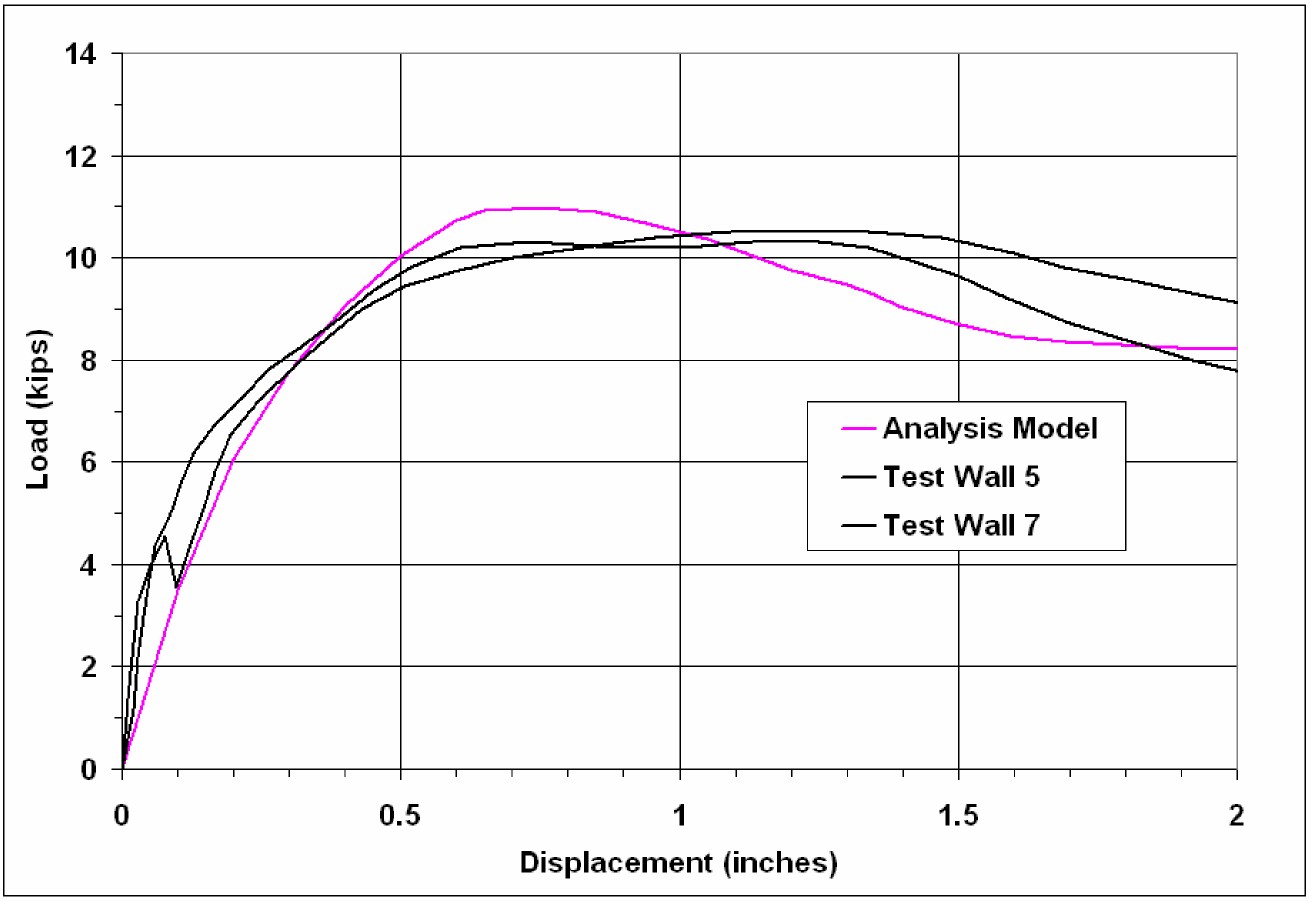

Figure 11 Response comparison

4. CONCLUSIONS

The conclusions are listed as follows:

1. Analysis results concur with experimental data. A good match was obtained between the model and the test force-deformation envelope curves.

2. The analytical model has the flexibility to include sheathing panels with any shape and configuration around window and door openings in the wall. Wrap-around corners at wall ends and ceiling returns can be modeled. Multiple layers of sheathing on same or opposite sides of the framing can be modeled as well.

3. Shell elements in the finite element program can display stress contour output that helps identify locations and magnitudes of high principal stresses and corresponding cracking in the sheathing.

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