Enhancing Light-Frame Shear Wall Performance with Elastomeric Adhesives

A test program study.

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Modern elastomeric adhesives can potentially transform the realm of light-frame wood (LFW) construction, offering a cost-effective solution to increase strength, stiffness, and energy dissipation under lateral loads induced by earthquakes and wind. LFW shear walls are integral to the lateral force-resisting system, providing a primary source of stiffness and strength to the structure by transferring loads to the foundation. The current model of shear walls dissipates energy through plastic deformation of the sheathing-frame connections, resulting in nail yielding, nail withdrawal, and sheathing edge tearing. Investigators found that conventional adhesives, including water-based, solvent-based, and polyurethane-based (PU), can significantly improve shear walls' strength and stiffness. However, concerns about volatile emissions, lack of durability, and brittleness limit their application in LFW structures. On the other hand, silyl-modified polyether (SMP) are modern adhesives gaining interest in construction for their moisture-curing, isocyanate-free, UV-stable, chemically resistant, and high flexibility properties. This article demonstrates the efficiency and cost-effectiveness of SMP adhesive in improving the seismic performance of shear walls through an experimental program.

Polymer adhesive base	Index	Elongation (%)	Shear strength (psi)	Shear stiffness (kips/in)	Curing days
Silyl-modified polyether	SMP	991	300	2.34	3
Polyurethane	PU	70	780	7.65	7

Table 1 Mechanical properties of the used adhesives

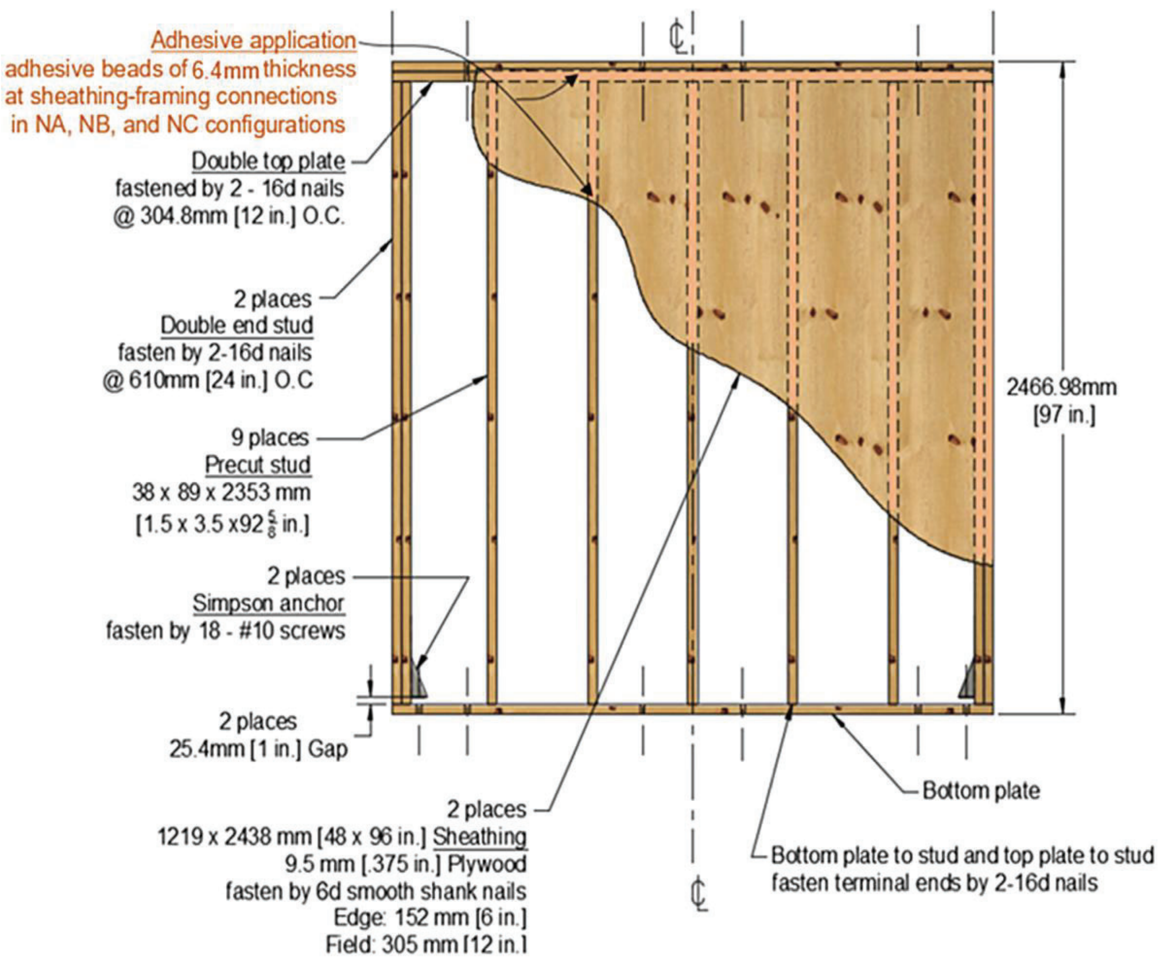

Figure 1 Schematic of the test specimen

Materials and Methods

The researchers fabricated three configurations of 8 × 8 feet LFW shear wall specimens (see Figure 1), which consist of 2 × 4 nominal Douglas-Fir frames and 3-ply plywood sheathing of 4 × 8 feet and 3/8 inch thickness. The reference configuration (R) used the minimum standard of nailing specified in the Special Design Provisions for Wind and Seismic (SDPWS). The construction applied an adhesive bead thickness of approximately 0.25 inches of PU and SMP adhesives at the sheathing-frame connections to make the two adhesive configurations. Table 1 shows the mechanical properties of these two adhesives. The adhesive cost in each specimen was less than 21 US dollars, corresponding to a 15% increase in the total material cost. To evaluate the seismic capacity performance, the researchers tested the specimens under lateral cyclic loading simulating ordinary ground motions.

Results and Discussion

Force-displacement relationships

The researchers developed hysteresis loops and corresponding envelope curves from the cyclic loading tests (see Figure 2). The R configuration initially demonstrated linear loops but ultimately exhibited a nonlinear response due to nail deformation and hysteretic pinching. Pinching occurs when the hysteretic cycles pass closer to the horizontal axis due to nail slippage. The PU configuration showed a linear response of all the loops. The drop in the load capacity at a small displacement explains its brittleness. The SMP configuration had linear loops at the early primary cycles. Then the nonlinear loops dominated yet showed no signs of degradation at higher displacement relative to the PU configuration. The shear resistance of the continuous adhesive bonding between the sheathing and framing decreases the pinching in the hysteresis responses in both PU and SMP configurations.

Performance analysis

The performance parameters, including maximum load strength, elastic shear stiffness, and energy dissipation, show that the SMP adhesive increases the energy dissipation by 100%, strength by 150%, and stiffness by 15% compared to the R configuration (see Figure 3). The higher elongation of the SMP adhesive allowed the sheathing to translate and rotate with less constraint and resulted in a cohesion failure in the wall specimen. Comparatively, the relatively high shear strength and low elongation of conventional PU adhesive caused a premature failure in the substrate and reduced energy dissipation.

Comparison to design standards

Shear wall design shall comply with the allowable story drift (Δ) specified in the ASCE 7 standards based on the seismic risk category to maintain structural integrity and life safety. For LFW residential housing, the drift limit of an 8 feet wall is 2.5% of the wall height translating to 2.4 inches. The displacement corresponding to the first drop below 80% of the maximum load determines the ultimate displacement (Δ_u). The R configuration had a Δ_u of 3.2 inches, exceeding 2.4 inches of the SMP configurations and 1.1 inches of the PU configuration. Thus, increasing the strength and stiffness of shear walls using the SMP adhesive slightly reduced the seismic deformation, which reduced damage while still leading to the most energy dissipation (see Figure 3) among the three configurations. On the other hand, the R configuration would require heavy construction (i.e., additional wood materials of ~20 US dollars based on the current market) to achieve an equivalent strength (i.e., 12,000 lbs) of the SMP configuration.

Conclusion

This experimental program demonstrated that modern elastomeric adhesives like SMP significantly improve light-frame shear

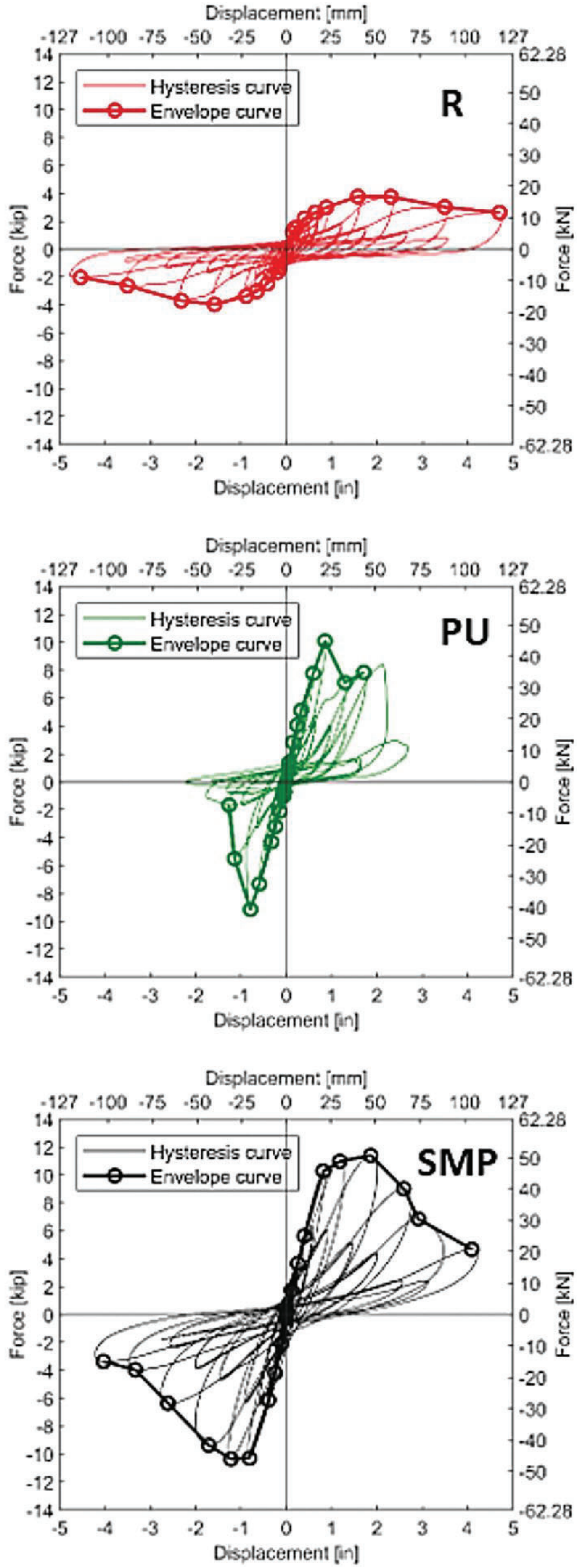

Figure 2 Force-displacement hysteresis

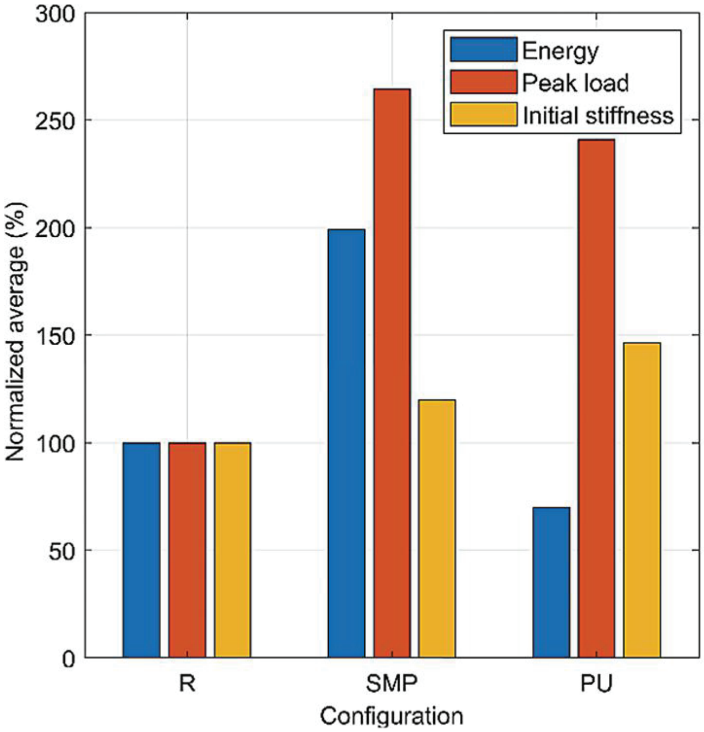

Figure 3 Normalized results of the reference configuration

walls' wind and seismic performance by providing a constant source of strength, stiffness, and energy dissipation. Using SMP adhesive can lead to cost savings and efficiently reduce the risk of damage during seismic and high wind events. The continuous adhesive bond between wood members significantly reduces pinching in the hysteresis responses of shear walls. It also decreases drift to meet the allowable story drift criteria, thus benefiting nonstructural components by mitigating damage caused by large displacements. SMP adhesive results in twice the energy dissipation of the conventional nail shear walls. The more ductile failure observed in the SMP specimens proves its ability to change the brittle failure observed in conventional adhesive research, making SMP adhesive a cost-effective solution to enhance the seismic performance of LFW structures. The promising experimental results motivate the researchers to further quantify the building system's performance and response parameters following the Federal Emergency Management Agency (FEMA P-695) methodology. The quantification will establish global seismic performance factors for the SMP application as a new seismic force-resisting system proposed for inclusion in model building codes. Overall, the SMP adhesive represents a promising solution for construction professionals seeking to optimize project safety and efficiency.▪

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