Numerical Simulation and Benchmarking Study of Reinforced Concrete Shear Walls

Iman Talebinejad[1], Payman Tehrani[1], Natalie Doulgerakis[1], Andrew Whittaker[2]

[1] SC Solutions, Inc.; [2] State University of New York at Buffalo

A numerical modeling approach for reinforced concrete shear walls subjected to cyclic loading is proposed and benchmarked against experimental data. The response of the shear wall including its initial stiffness, peak shear strength, and hysteretic behavior is a function of various parameters including the concrete compressive strength and steel reinforcement mechanical properties as well as the concrete elastic modulus and tensile strength. While the first two parameters can be directly established from test data, the concrete modulus and tensile strength are estimated from empirical relationships available in the literature and standards.

The proposed modeling approach implements concrete modulus and tensile strength values calculated based on data available in the literature for the shear-controlled low-aspect ratio shear walls. The concrete material model accounts for concrete crushing in compression and concrete cracking in tension. The post-cracking response of the concrete known as tension-stiffening is considered using a bilinear stress-strain curve. Steel reinforcement is simulated using a hysteretic material model that captures yielding, strain hardening and post-peak softening of the steel rebar. It also incorporates an unloading-reloading rule that considers the Bauschinger effect, i.e., the reduction of the yield stress during the cyclic reversals. The proposed modeling approach uses composite layered shell elements to simulate the core and cover concrete as well as the vertical and horizontal reinforcement.

Pushover and cyclic analyses are performed to validate that the aforementioned numerical approach for shear wall modeling can predict the failure mechanism, peak shear strength and hysteretic response of the wall. The numerical model adequately predicts the expected tri-linear shear response of the wall subjected to a monotonic in-plane lateral load. The gradual formation of cracks and the extent of the wall region with fully opened cracks are reproduced with the numerical model showing reasonable agreement with the experimentally observed cracked region. Additionally, a good agreement is observed between the experimental and numerical values of vertical reinforcement strain at the peak shear strength of the wall. The finite element-predicted shear strength value also corresponds well to the shear strength values predicted by equations in the literature and building codes. The hysteretic shear response of the wall presented as the shear force-drift ratio is in good agreement with the experimental data. The favorable comparison between the numerical and experimental results confirms that the proposed numerical approach is appropriate to simulate reinforced concrete shear walls subjected to seismic loading.