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Peng Li, S.E. CASp.
Senior Engineer
Department of Planning, Building, and Code Enforcement
City of San Jose, California

Re: UCSD Shake Table Test

Dear Sir:

DCI Engineers recently assisted UCSD with a shake table test for a CFS 6 story building. The test was intended to show how this type of building would perform during a design level seismic event. The following is a description of the building and how it was developed.

The floor plan was developed to represent a typical residential double loaded corridor layout. It was sized to be as large as possible and still fit on the UCSD shake table. The structure was ballooned framed with cold formed steel (CFS) walls and floors. The lateral system consisted of Sure-Board Series 200S diaphragms spanning between Sure-Board series 200 shearwalls. A standard Zone 4 tie-down system was utilized at the ends of each shearwall along with standard CFS compression studs. Standard gypsum board was provided on the non-shear walls. In order to capture all of the mass that would be typical for a building like this, steel mass plates were added to all of the floor levels and the roof. Each of the mass plates was bolted down at only two locations so that their mass could be captured in the shake table test but they would not add additional strength or stiffness to the floor diaphragms. These plates were sized to represent mass that would occur in a typical fully finished building from floor toppings, finishes, exterior stucco, etc. These finishes were not provided on the test building both for ease of construction and to provide better clarity on the behavior of the structural systems.

The final mass of the building and seismic forces were independently checked by UCSD. The mass was also confirmed by reviewing the shipping weight for all of the CFS.

The buildings lateral design was based 2012/2015 CBC design requirements for the materials used and the USGS ground motion for downtown Los Angeles. The Sure-Board series 200 screw attachment and the rod tie-down system were designed to resist this force based on code allowable values. The CFS compression studs and rods at the ends of the shearwalls were designed for omega level forces as required by ASCE 7-10 for an R=6.5.

The building was subjected to multiple shake tests. The test runs were 25%, 50%, 100% and 150% of design level events. A ground motion was selected which would represent an earthquake typically found on a fault in California. The earthquake was scaled to represent the above indicated percentages. The 150% ground motion was the maximum and represented the earthquake that would be the design basis under the current CBC.

After each earthquake the building was inspected for damage. All cracks and permanent wall displacements were noted. The damage for the 150% earthquake was very minor and was much less then what we would be predicted by the current CBC. Damage included some cracking of exterior walls and minor buckling of rim tracks. This is particularly interesting since the building was subjected to multiple lower level earthquakes before being subjected to the design level event.

It is DCI's opinion that the high performance was related to the following two key factors:

1. The balloon framing for the walls provides a more direct load path for the building shear to transfer loads down to the ground (shake table).

2. The compression post and rod tie-down systems seems to provide a high degree of seismic resilience, which is not adequately incorporated in the determination of the R-factor of 6.5. This is particularly true because the compression post and rods are designed for omega level forces. While this force amplification is a somewhat arbitrary code requirement and not based on explicit research, it does seems to reduce the level of damage you might see in a typical building at the ends of the shearwalls.

Based on the positive results of the shake table test DCI would have no concerns designing CFS buildings with Sureboard shearwalls up to seven or even eight stories.

Sincerely,
DCI Engineers

Harry Jones II PE, SE
Principal