CFSRC summer symposium

Seismic Behavior of Cold-Formed Steel Framed Steel Sheathed Wall Systems Detailed for Multi-story Buildings

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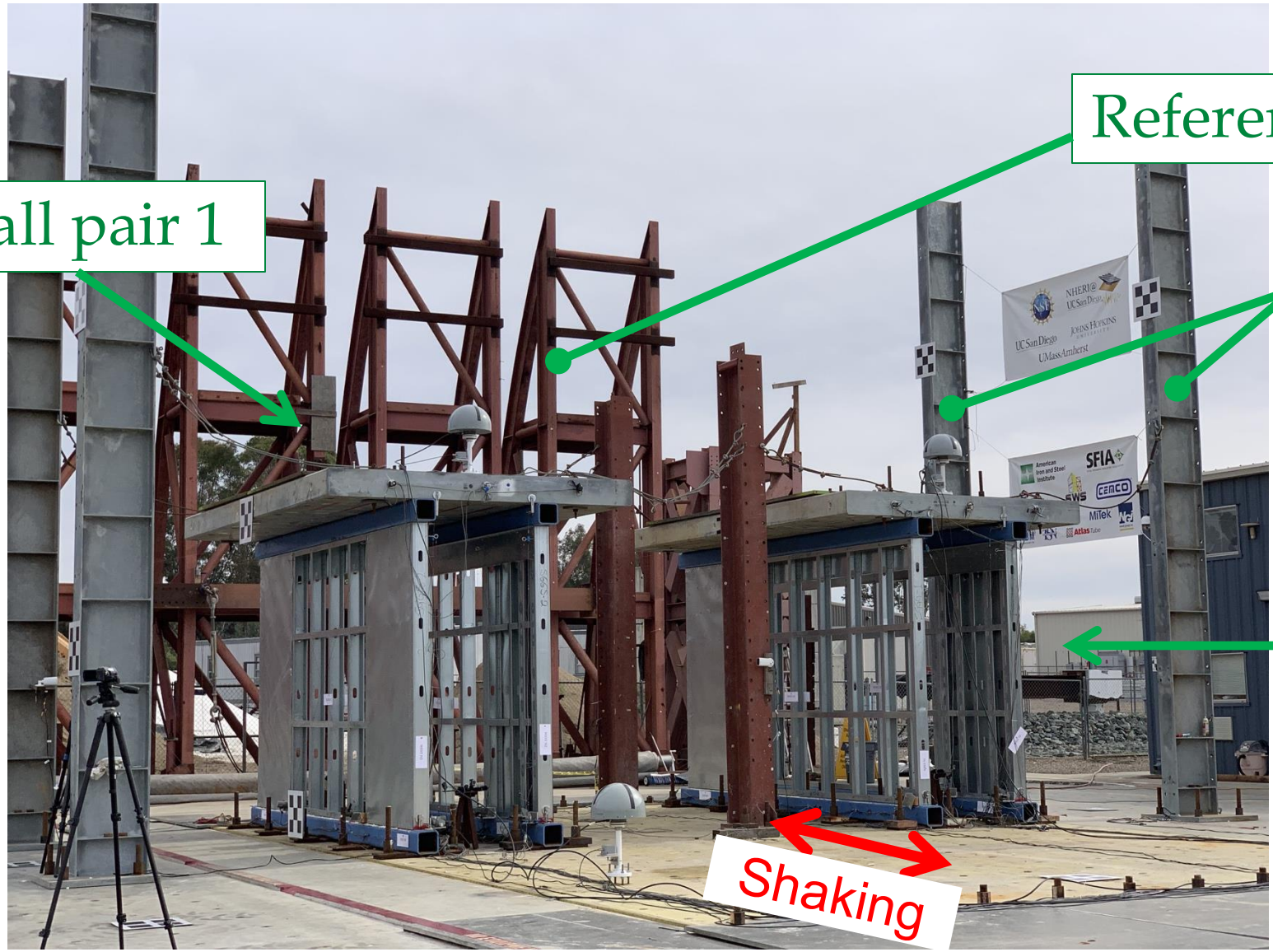
Wall-Line Tests: *Experiment Objectives*

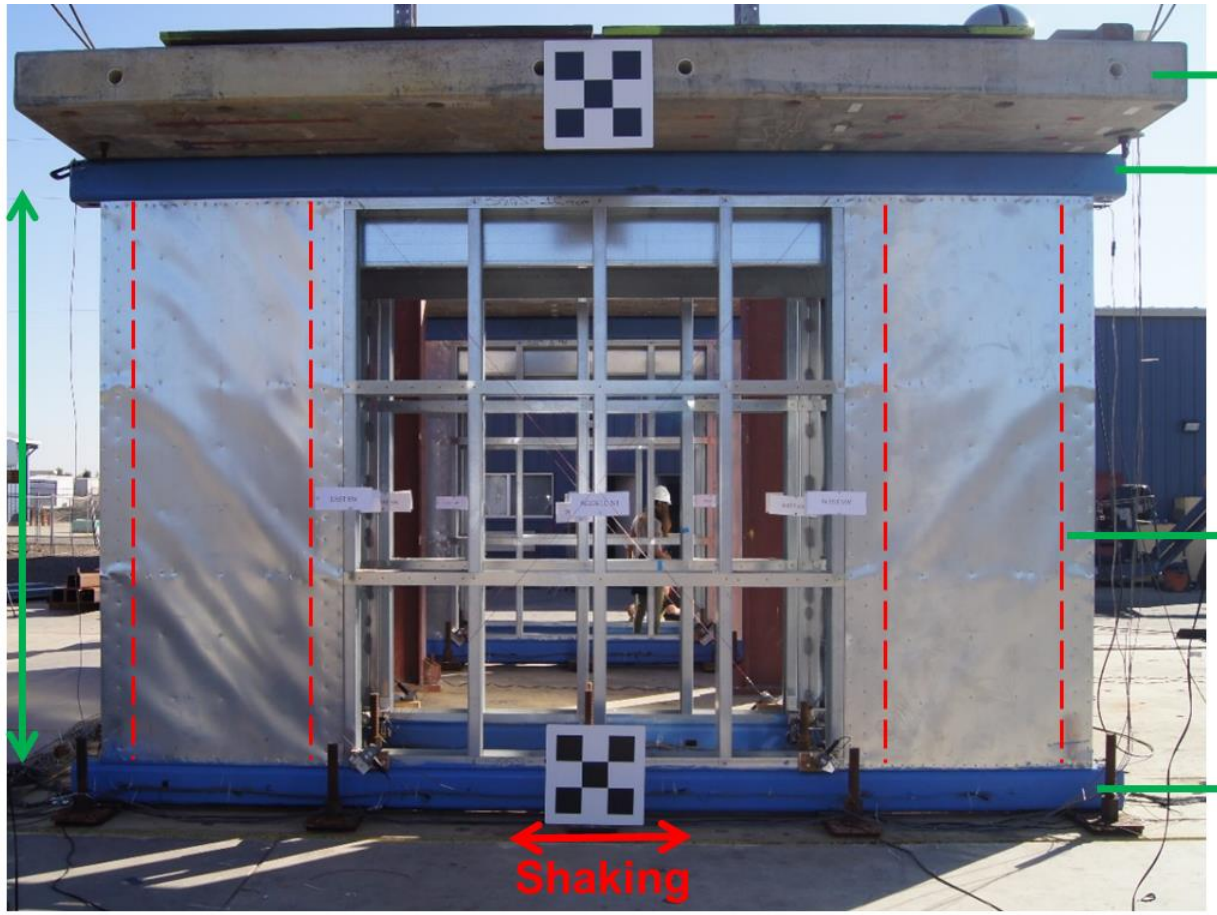
NHERI@ UC San Diego

- Characterize dynamic performance of Cold-Formed Steel framed walls subjected to in-line earthquake motions of increasing intensity:
  - *Effect of finishes* and *effects of openings* on wall behavior
  - *Comparison of Type I and "Type II"* walls
  - Compare *steel tension tie-rods* assembly versus *hold-down* systems
  - Compare *symmetrical and unsymmetrical* walls
- Examine lateral load sharing between shear walls placed in-line with gravity walls
- In total, 18 test specimens; blend of dynamic (shake table) and quasi-static (inertial-induced displacement control) testing regimes

Test Setup: *Shake table tests (NHERI@UCSD)*



Framing Details (e.g. SGGS-1)



Seismic Weight = 1000plf/wall
Concrete slab + trench plates

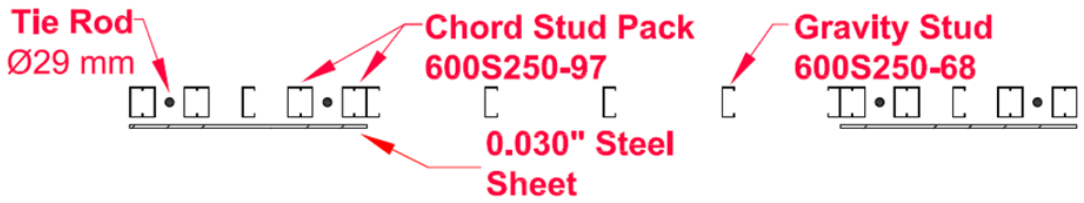
Top transfer HSS beam

Locations of tension tie rods

Bottom transfer HSS beam

- Chord stud packs: 600S250-97
- Tracks: 600T250-97
- Gravity studs: 600S250-68
- Sheet thickness: 30 mil
- #12 screws @ 2”/12” o.c.
- Tension tie rod Ø1 $^{1}/_{8}$ "

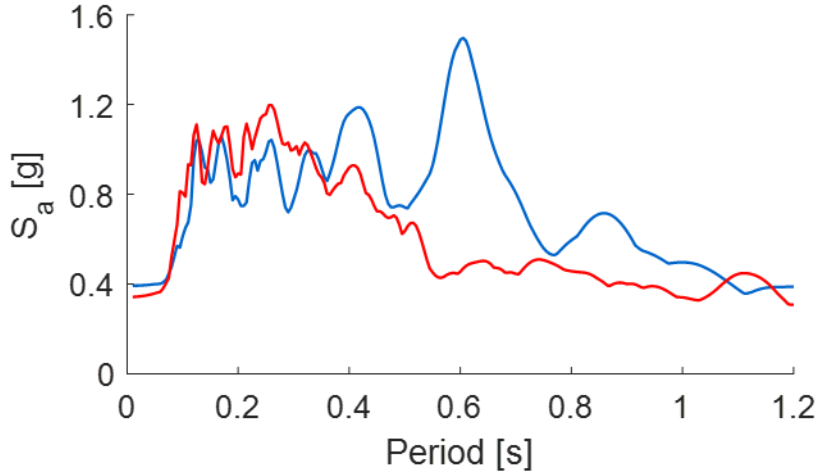
-1 (Type I)

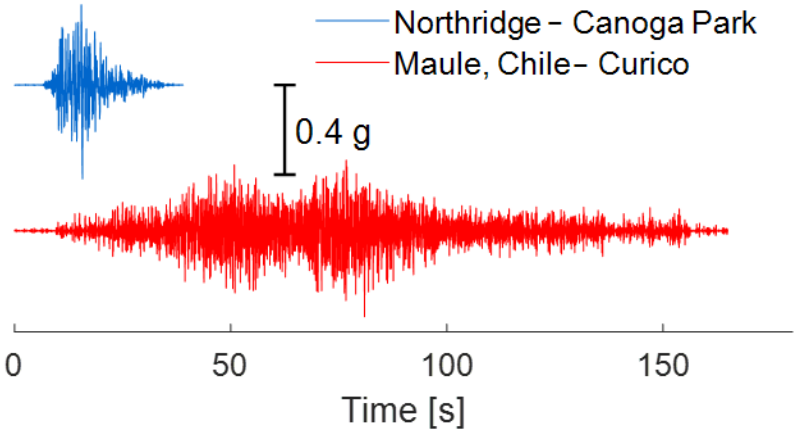


Test Protocol: *Shake table tests*

- Scaled ground motions
  1. Elastic Level
     - 1994 Northridge – Canoga Park
     - 2010 Maule, Chile – Curico
  2. Quasi-Elastic Level
     - 1994 Northridge – Canoga Park
  3. Design Level
     - 1994 Northridge – Canoga Park
  4. Above Design Level (optional)
     - 1994 Northridge – Canoga Park

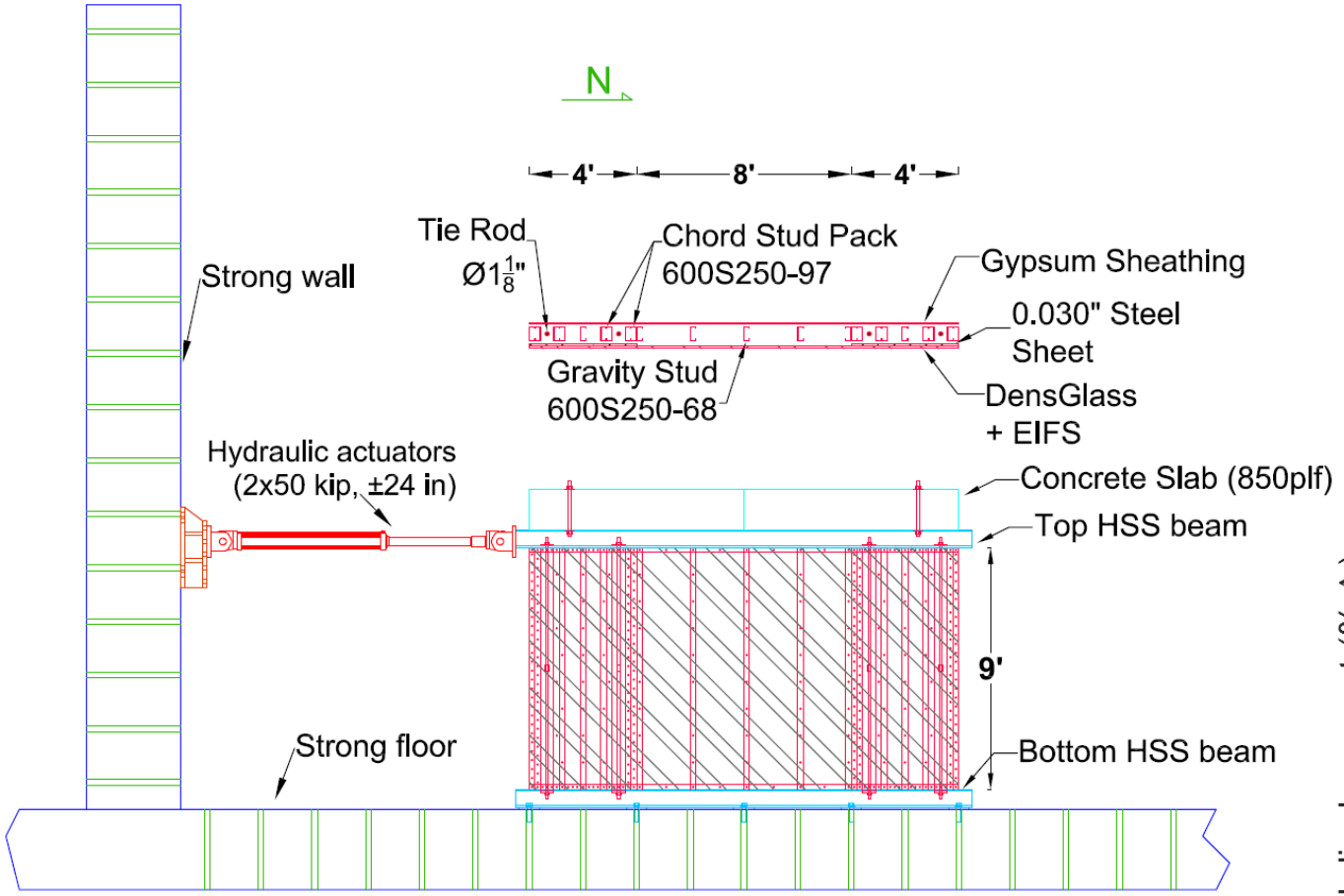
Seed Motions

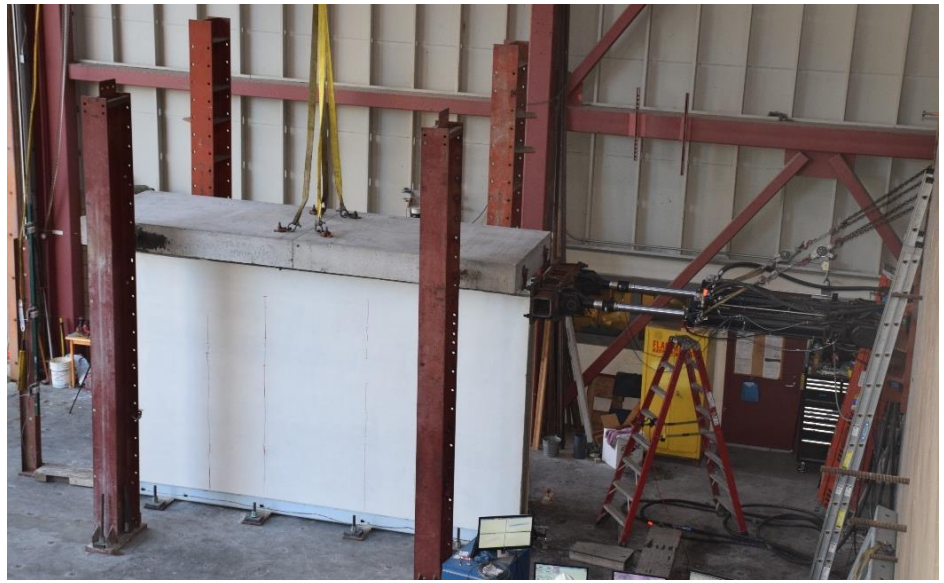


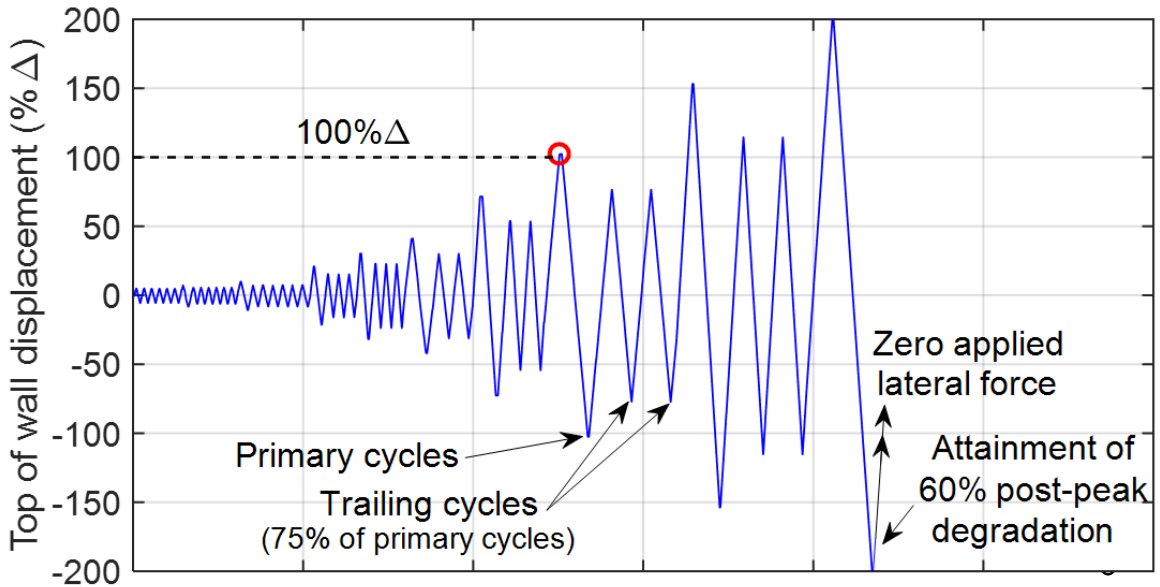


- Low-amplitude white-noise base excitation tests
  - Before & after each EQ tests (duration: 4 minutes)
  - Amplitude: 1.5% *g* & 3% *g* RMS
- Static monotonic pull over for post-peak behavior (select specimens)

Test Setup and Protocol: *Quasi-static tests*



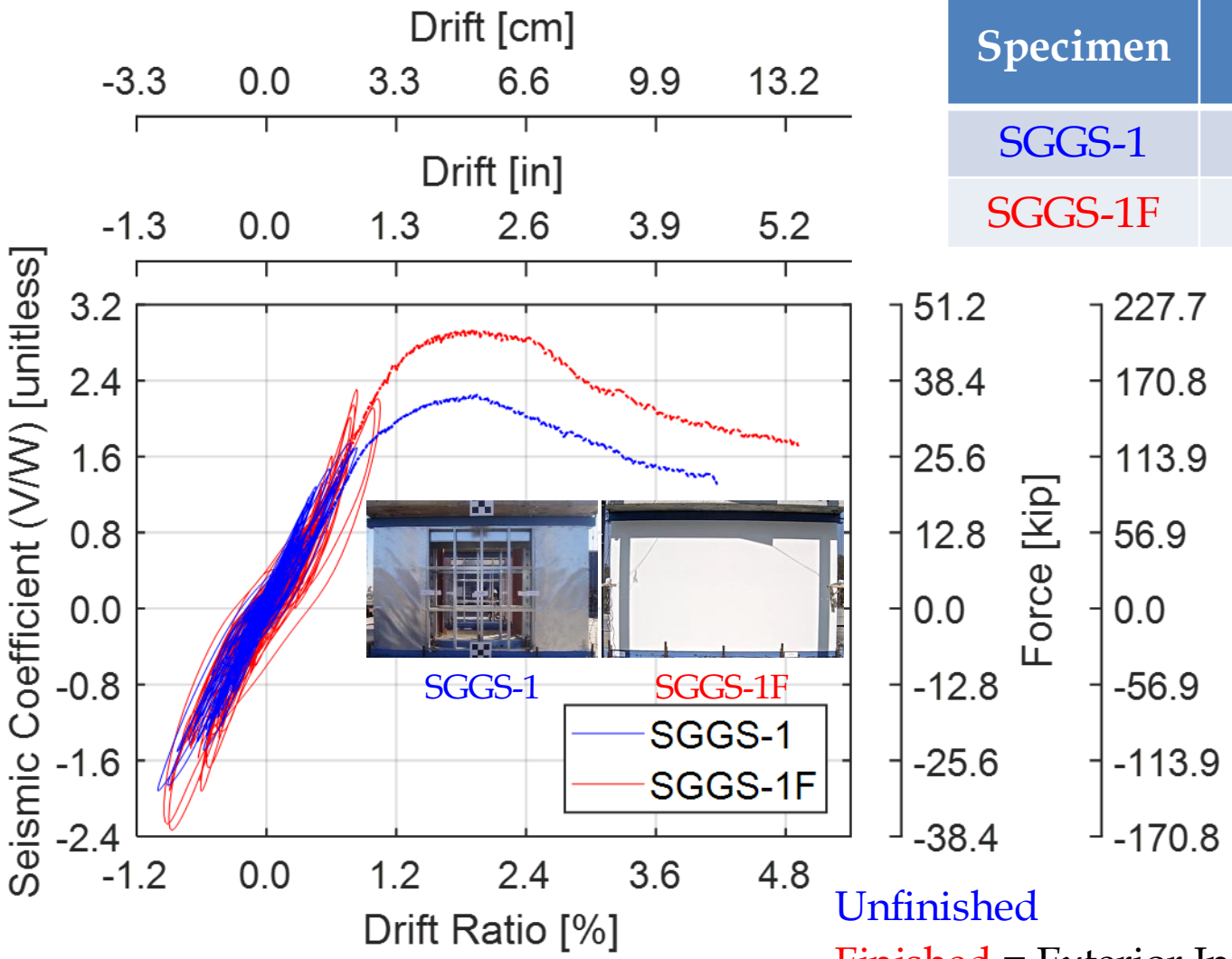


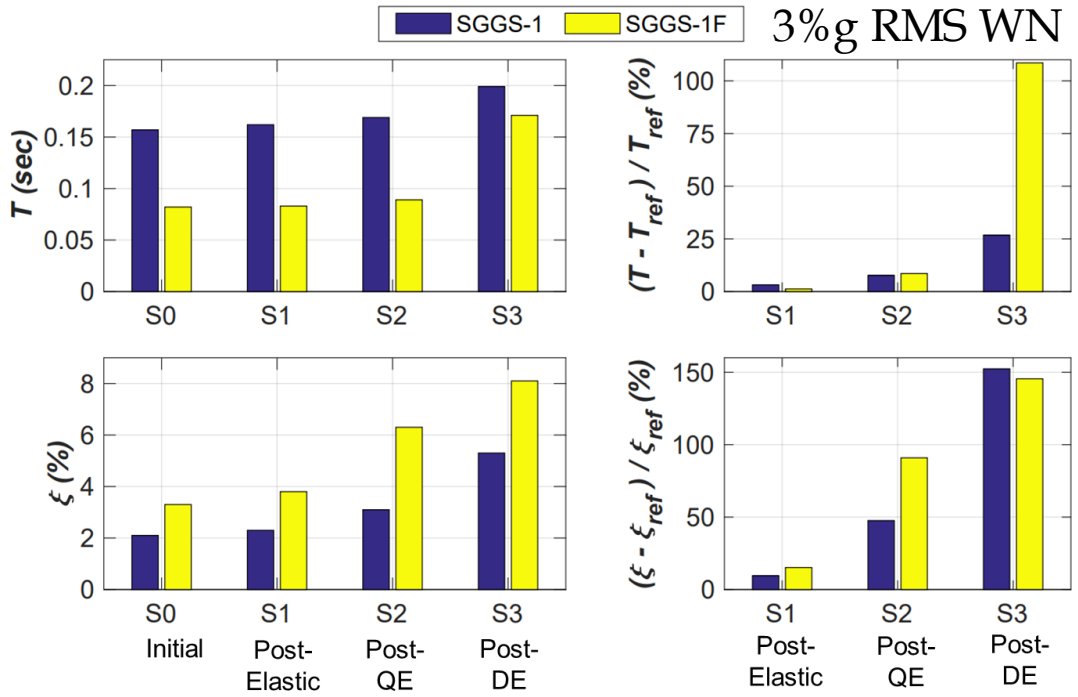


CUREE Protocol (Krawinkler et al. 2001)

Effect of Finish

Specimen	Strength, V_u [kip]	Drift, Δ_{Vu} [in (%)]	Elastic Stiffness, K [kip/in]
SGGS-1	36.0	2.11 (1.95%)	47.4
SGGS-1F	46.8	2.05 (1.90%)	126.2





Unfinished

Finished = Exterior Insulation Finish System (EIFS) and gypsum panels on interior face on wall framing

Typical Damage Characteristics (*e.g. SGGS-1F*)

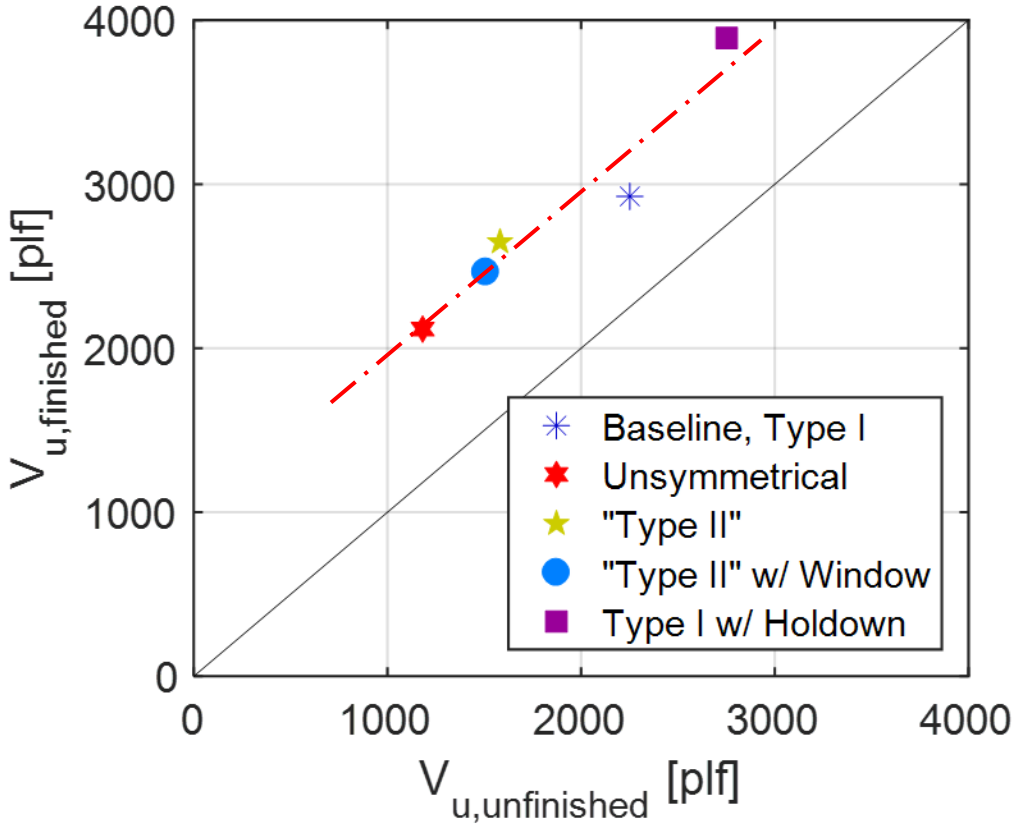
Damage reported at 5% drift ratio

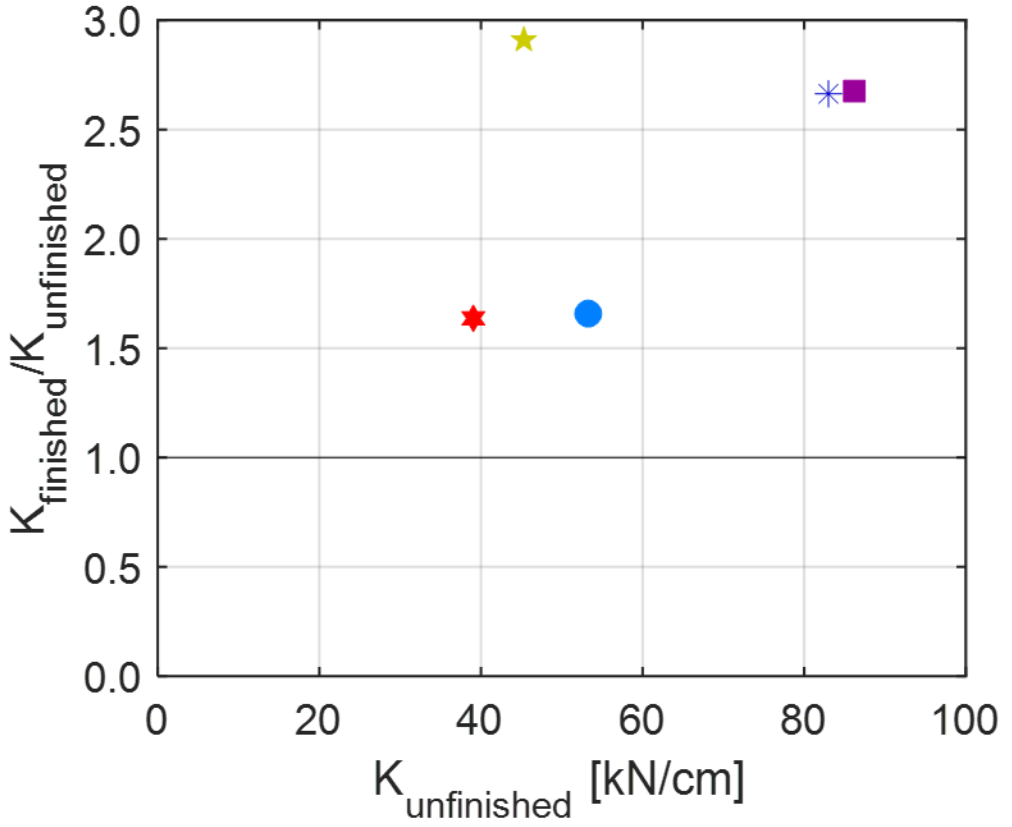
Separation of finish layer from steel sheet with screw pull through

Shear buckling of steel sheet

Extensive damage to Gypsum boards

Effect of Finish: *Strength & Stiffness*

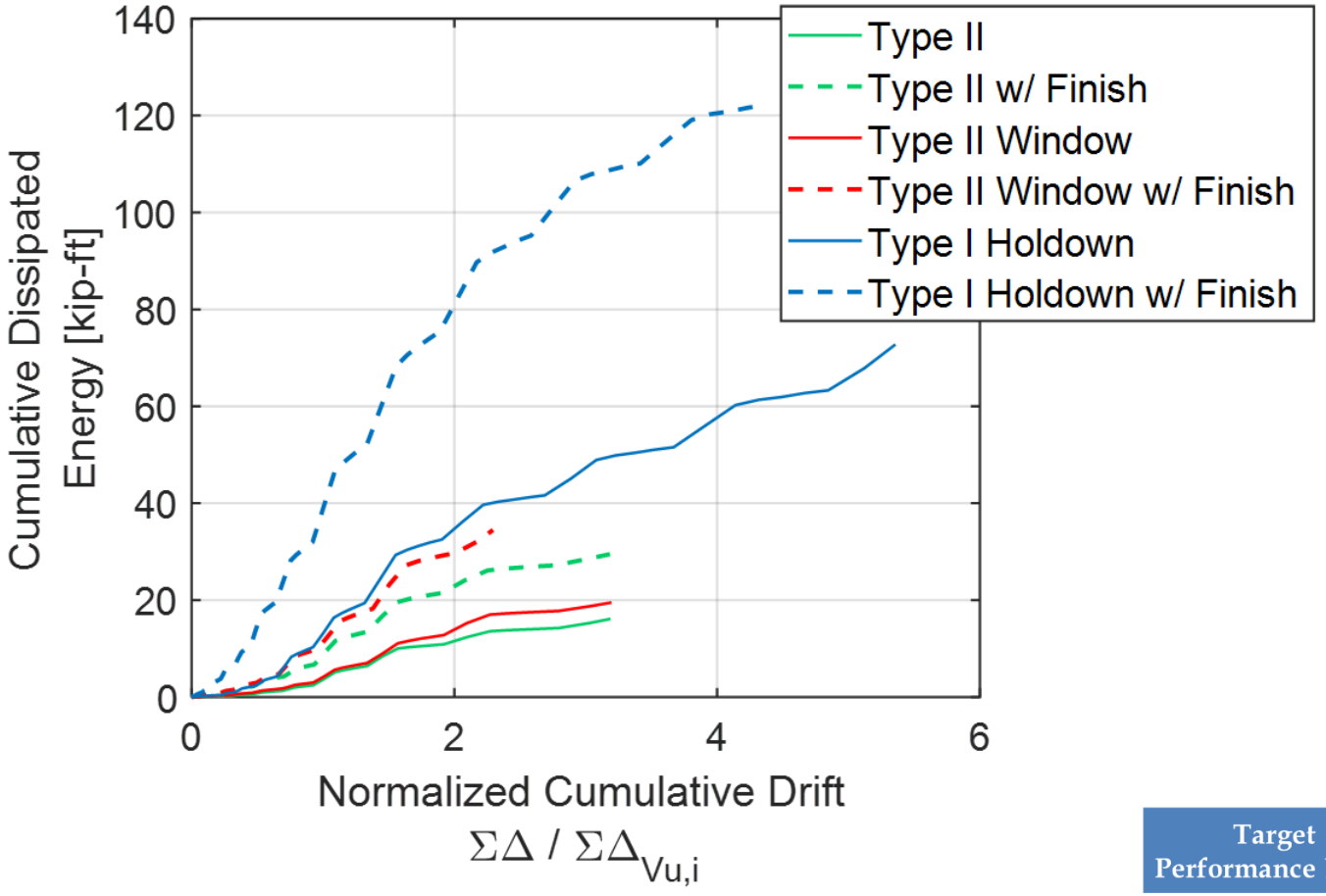


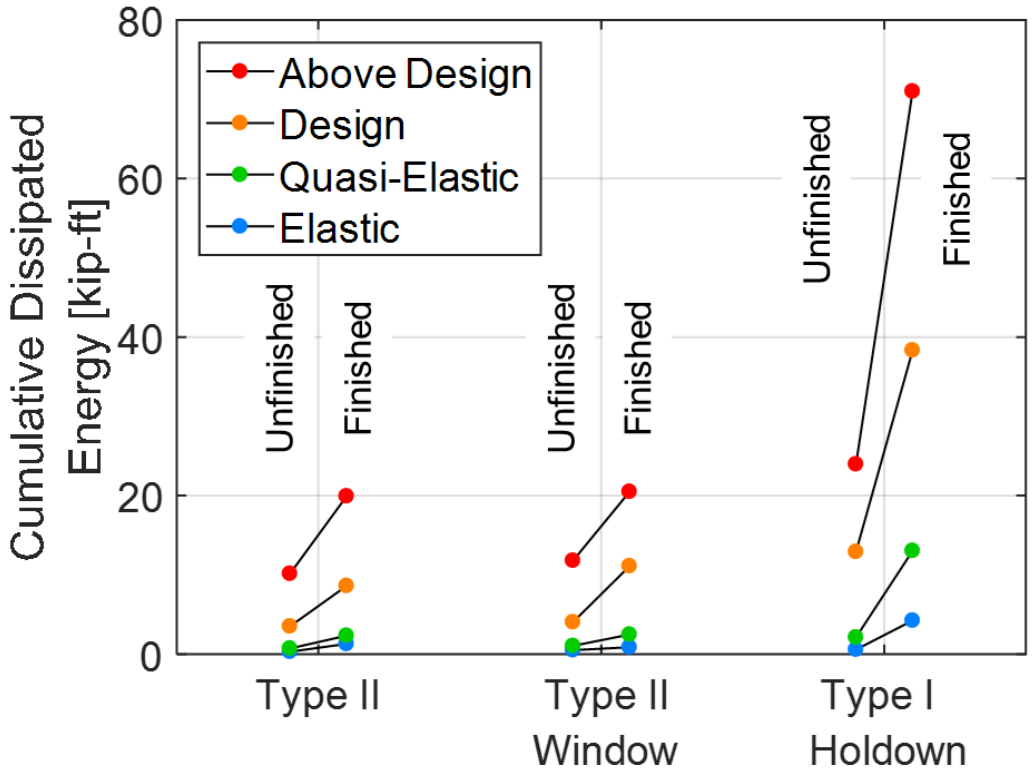


$$V_{u,finished} = 1.01 \times V_{u,unfinished} + 1006\,plf$$

- **Strength** increase (additive strength model)
- **Elastic stiffness** increase: 1.6x-2.9x

Effect of Finish: *Hysteretic Energy Dissipation*



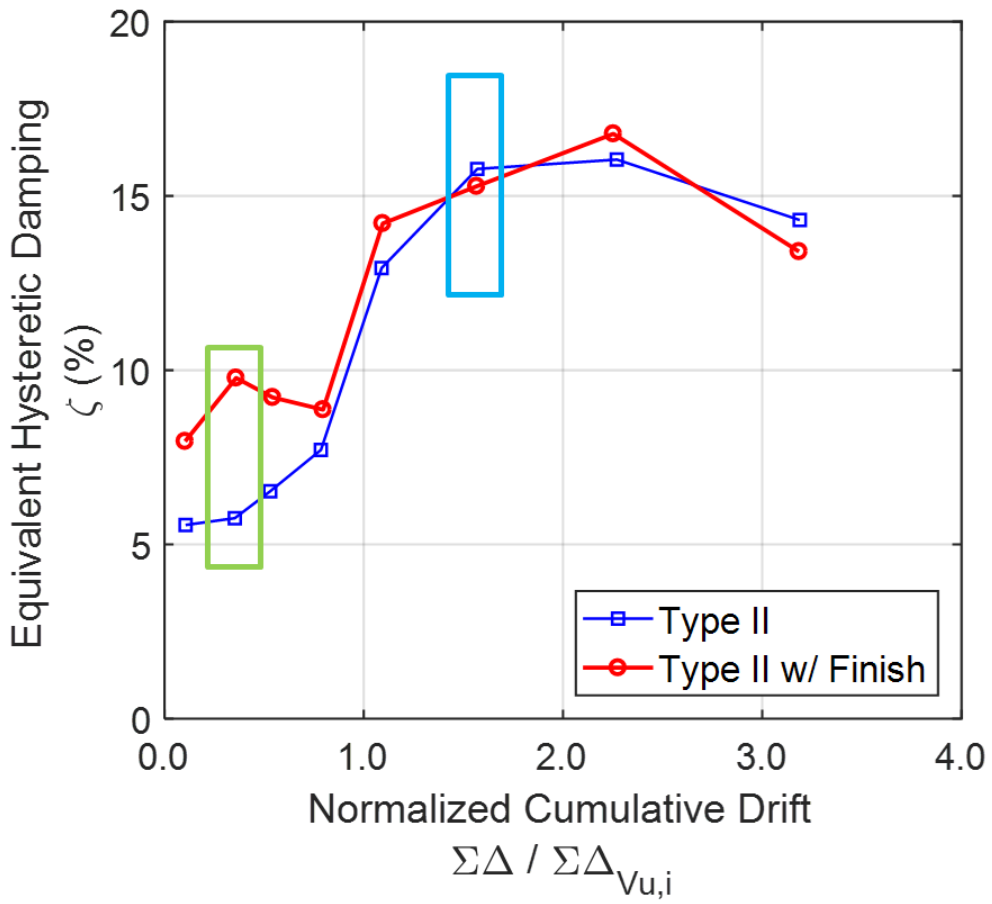


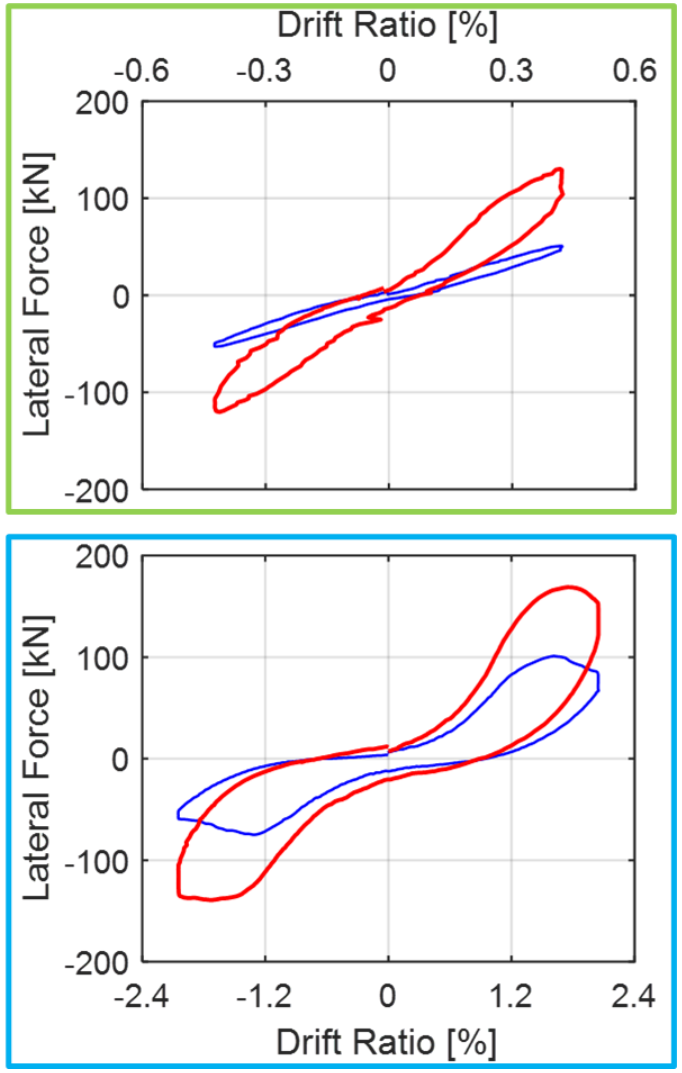
- **Energy dissipation** 2-3 times higher

$\Sigma\Delta_{Vu,i}$: Average cumulative drift at specimen strength

Target Performance Level	Response Characteristics	Strength Target, V_{target} (% V_u)	Drift Target, Δ_{target} (% Δ_{V_u})	Damage
Elastic	Linear	20%–40%	~20%	Minimal damage
Quasi-elastic	Essentially linear	60%–70%	30%–40%	Minor (cosmetic) damage
Design	Nonlinear	Near peak strength	75%–95%	Moderate damage
Above Design	Noticeable pinching	< 20% strength deterioration	125%–150%	Continued damage, uncompromised structural integrity

Effect of Finish: *Equivalent Hysteretic Damping*





- **Hysteretic damping** higher for finished specimens till specimen strength

$$\zeta = \frac{A_{loop}}{2\pi FmaxDmax}$$

$\Sigma\Delta_{Vu,i}$: Average cumulative drift at specimen strength

Concluding Remarks: Observations

- Finishes: EIFS and Gypsum boards
  - Strength ☝ 1006*plf*
  - Initial stiffness ☝1.6x-2.9x
  - Period elongation < 10% (QE)
  - Damping ~ ☝50%
  - 2-3x energy dissipation till above design performance level
  - No derogatory effect on drift capacity
  - Consistent with physical damage observations

Sponsors and Collaborators