Lateral Response of Cold-formed Steel Framed Steel Sheathed In-line Wall Systems Detailed For Mid-rise Buildings

Amanpreet Singh | University of California San Diego

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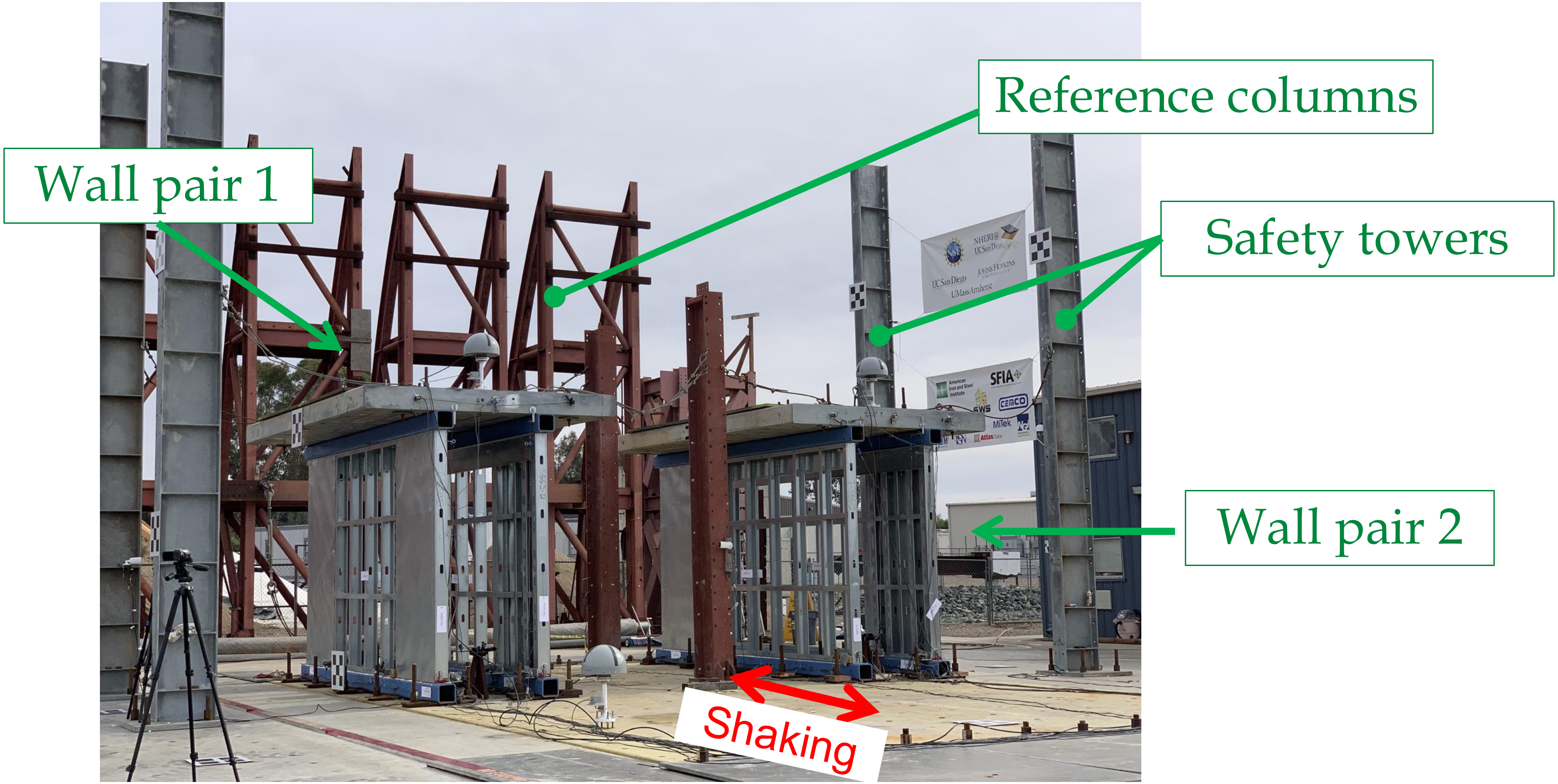
Wall-Line Tests: *Experiment Objectives*

NHERI@ UC San Diego

- Characterize dynamic performance of CFS framed walls subjected to in-line earthquake motions
- *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 *holdown* systems
- Compare *symmetrical and unsymmetrical* walls
- Examine lateral load sharing between shear walls placed in-line with gravity walls

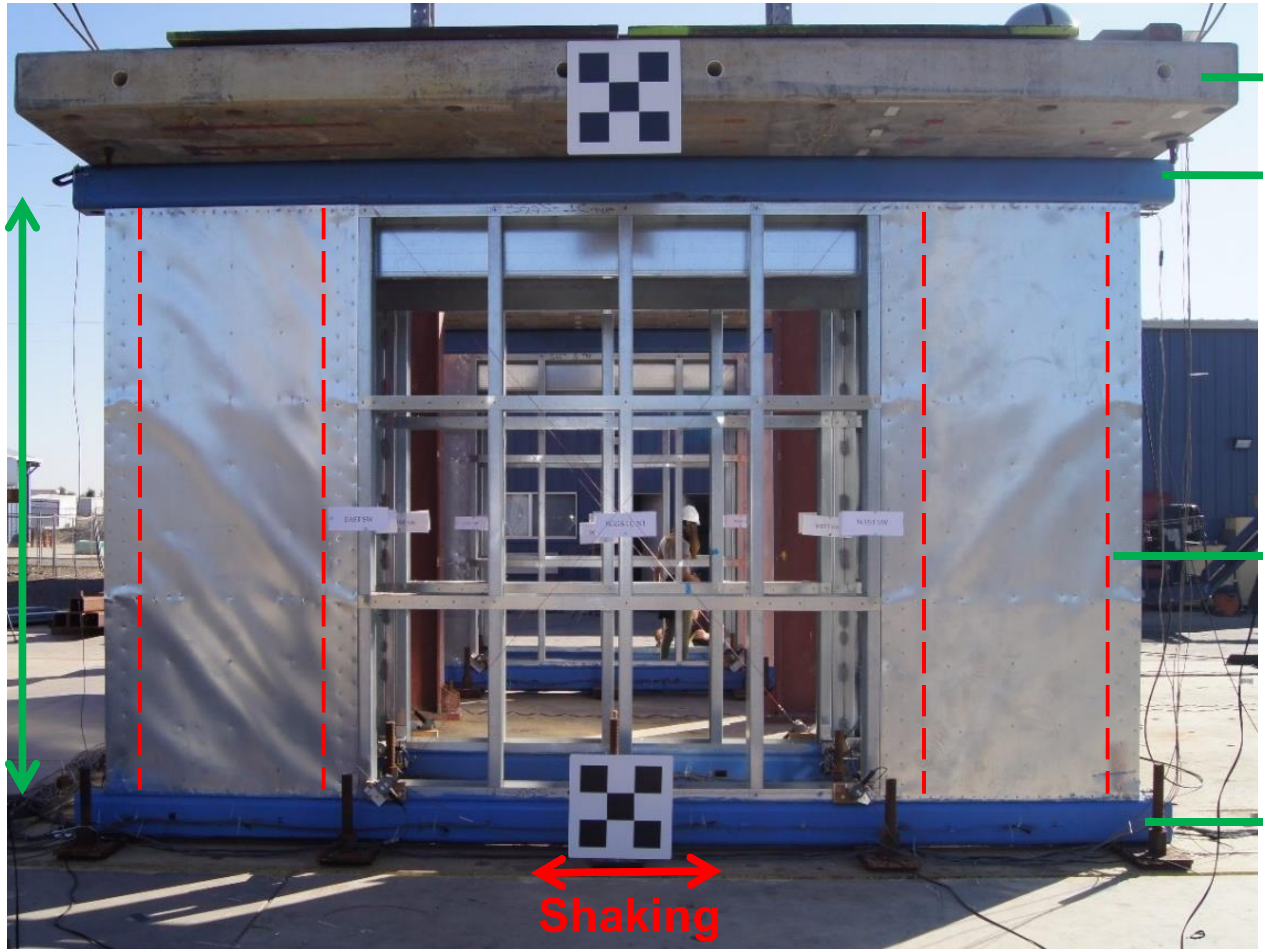
In total, 16 unique configurations; blend of dynamic (shake table) and quasi-static reversed cyclic (displacement control) testing regimes

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



Test Setup: *SGGS-1 specimen (baseline)*

9 ft



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

Top transfer HSS beam

Locations of tension
tie rods

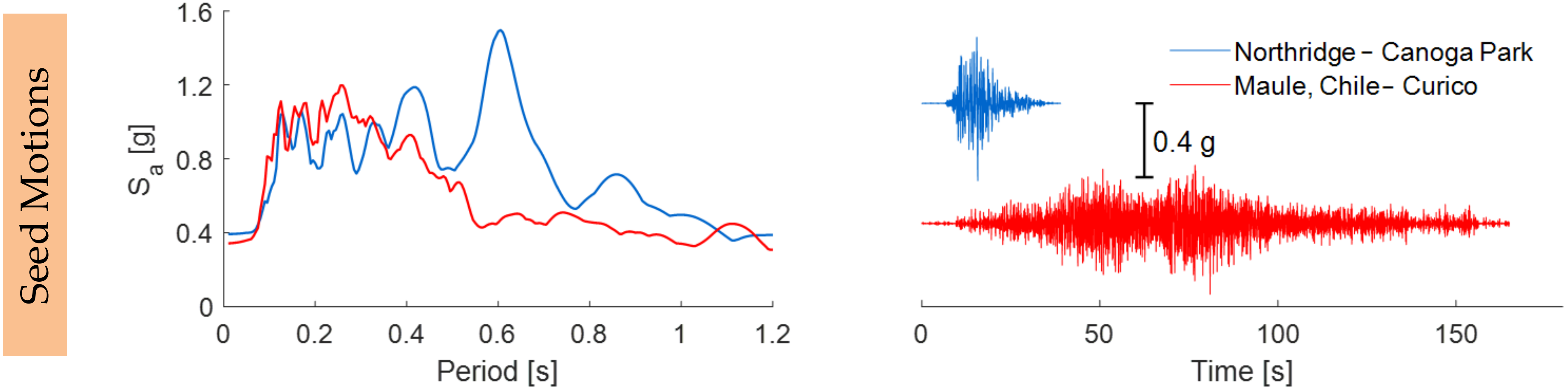
Bottom transfer HSS beam

4 ft	4 ft	4 ft	4 ft	
Shear	**G**ravity	**G**ravity	**S**hear	**-1** (Type I)

Naming convention

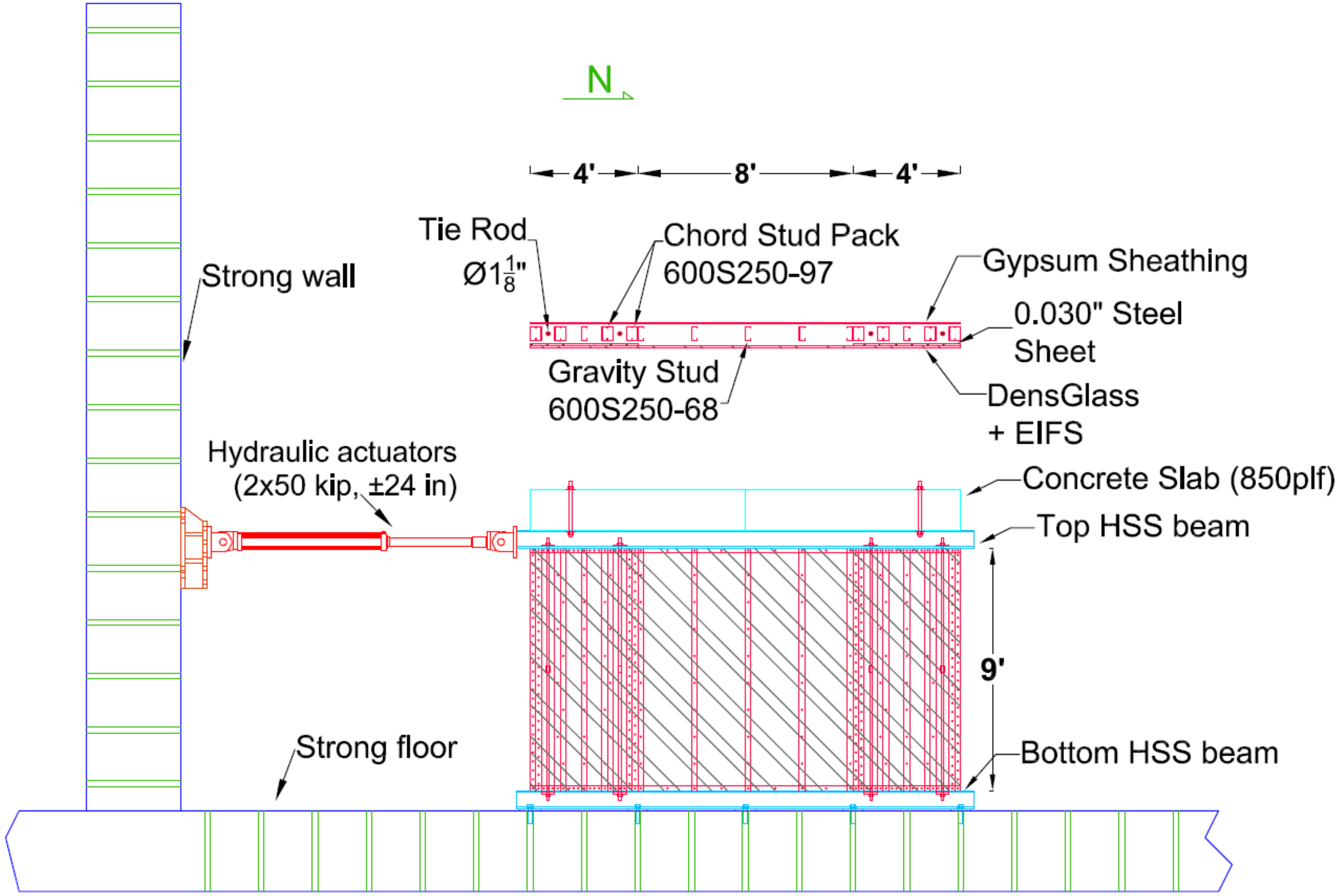
Test Protocol: *Shake table tests*

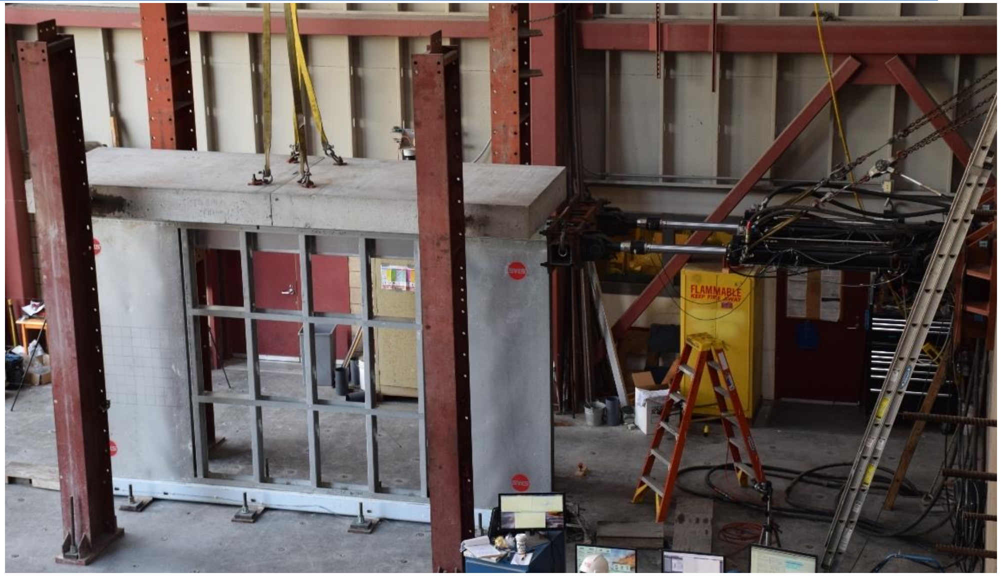
- Scaled ground motions (increasing intensity)
  1. Elastic Level
     - 1994 Northridge – Canoga Park
     - 2010 Maule, Chile – Curico
  2. Quasi-elastic Level
     - 1994 Northridge – Canoga Park
  3. Design Level
     - 1994 Northridge – Canoga Park
  4. Above Design Level (optional)
     - 1994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

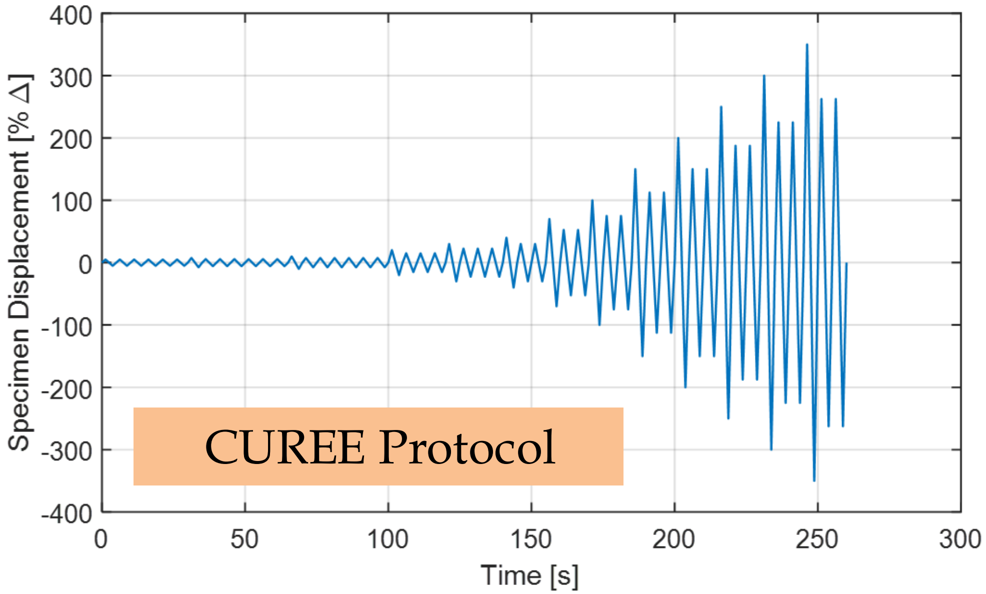


- Low-amplitude white-noise base excitation tests
  - Before & after each EQ tests (duration: 4 minutes)
  - Amplitude: 1.5% *g* & 3% *g* RMS
- Static monotonic pull over for post-peak behavior (for select specimens)

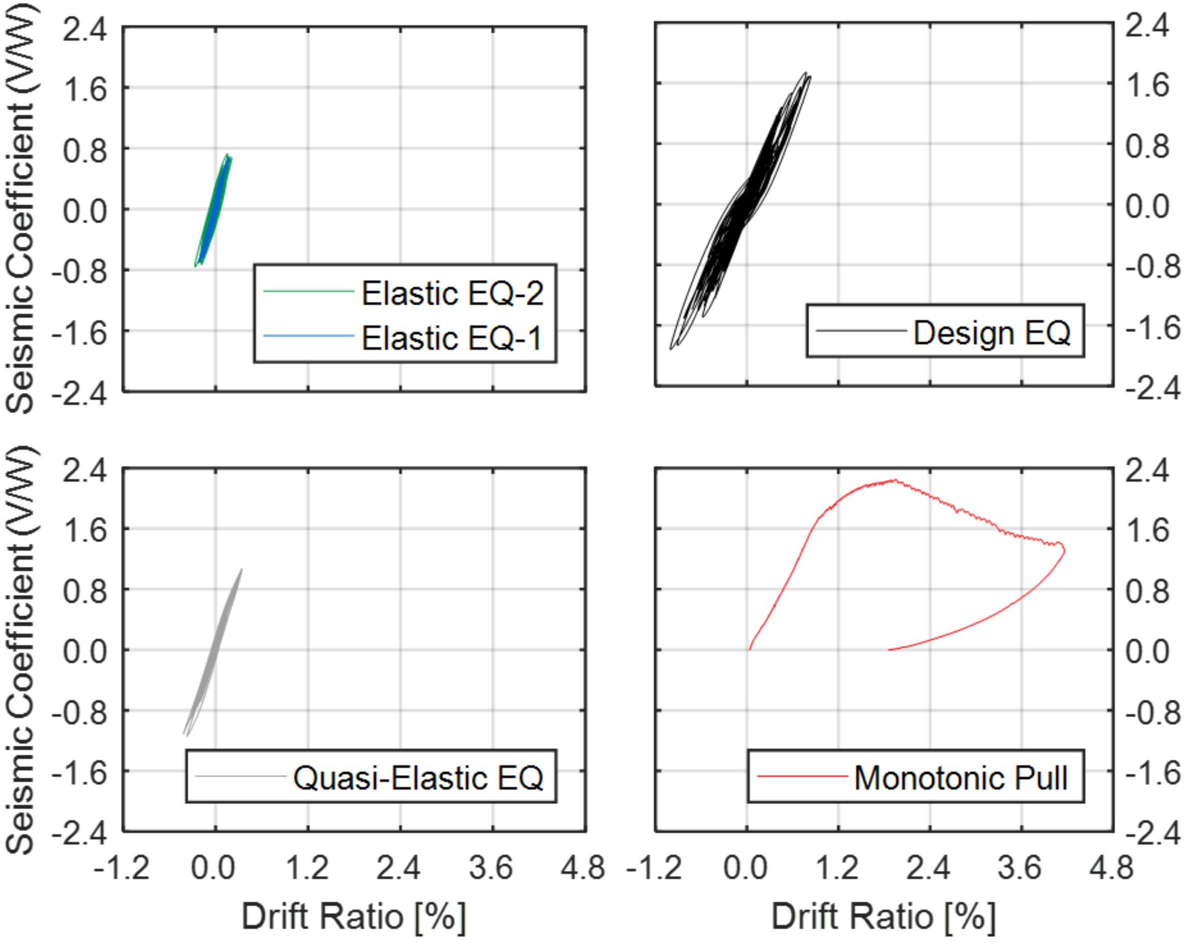
Test Setup and Protocol: *Quasi-static tests*

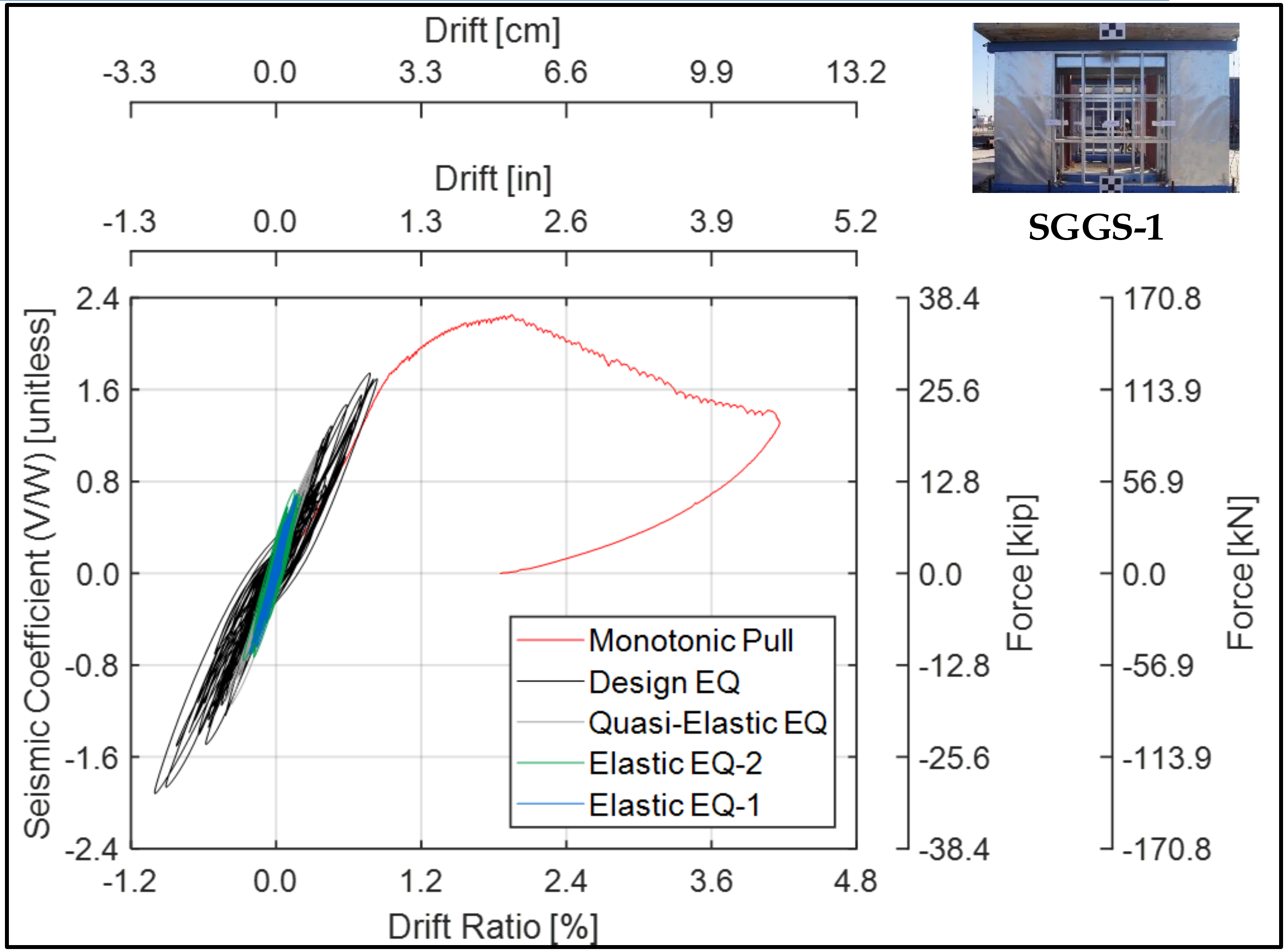






Force-Displacement Response: *SGGS-1 (baseline)*

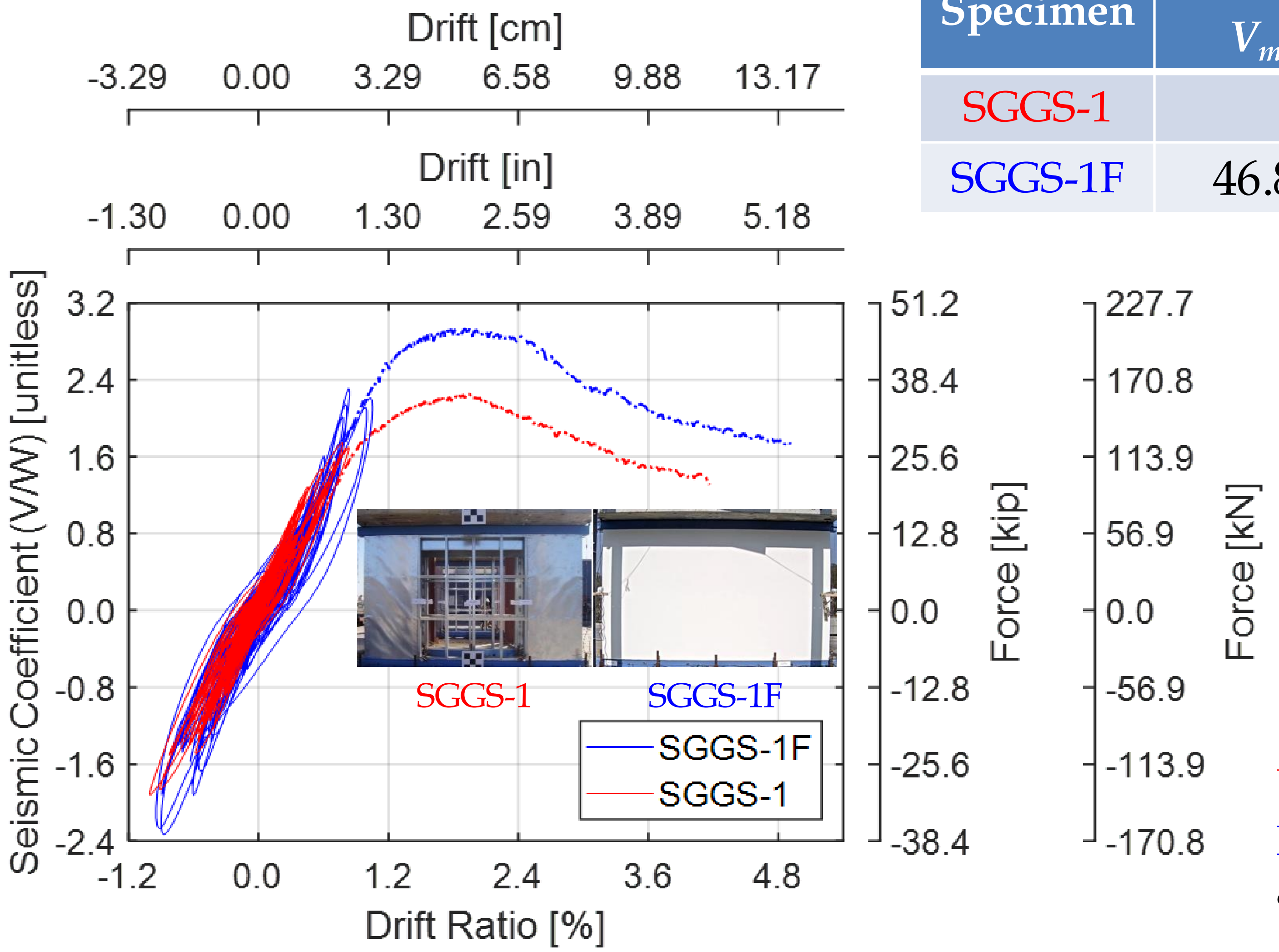




Specimen	Strength, V_{max} [kip]	Drift, $\delta_{V_{max}}$ [in] (%)	Initial Stiffness, k_e [kip/in]	Secant Stiffness, k_{sec} [kip/in]
SGGS-1	36.0	2.11 (1.95%)	47.4	17.1

Comparison: Finished vs Unfinished

Specimen	Peak Strength, V_{max} [kip]	Drift, $\delta_{V_{max}}$ [in] (%)	Initial Stiffness, k_e [kip/in]
SGGS-1	36.0	2.11 (1.95%)	47.4
SGGS-1F	46.8 *(↑30%)*	2.05 (1.90%)	116.8 *(↑150%)*

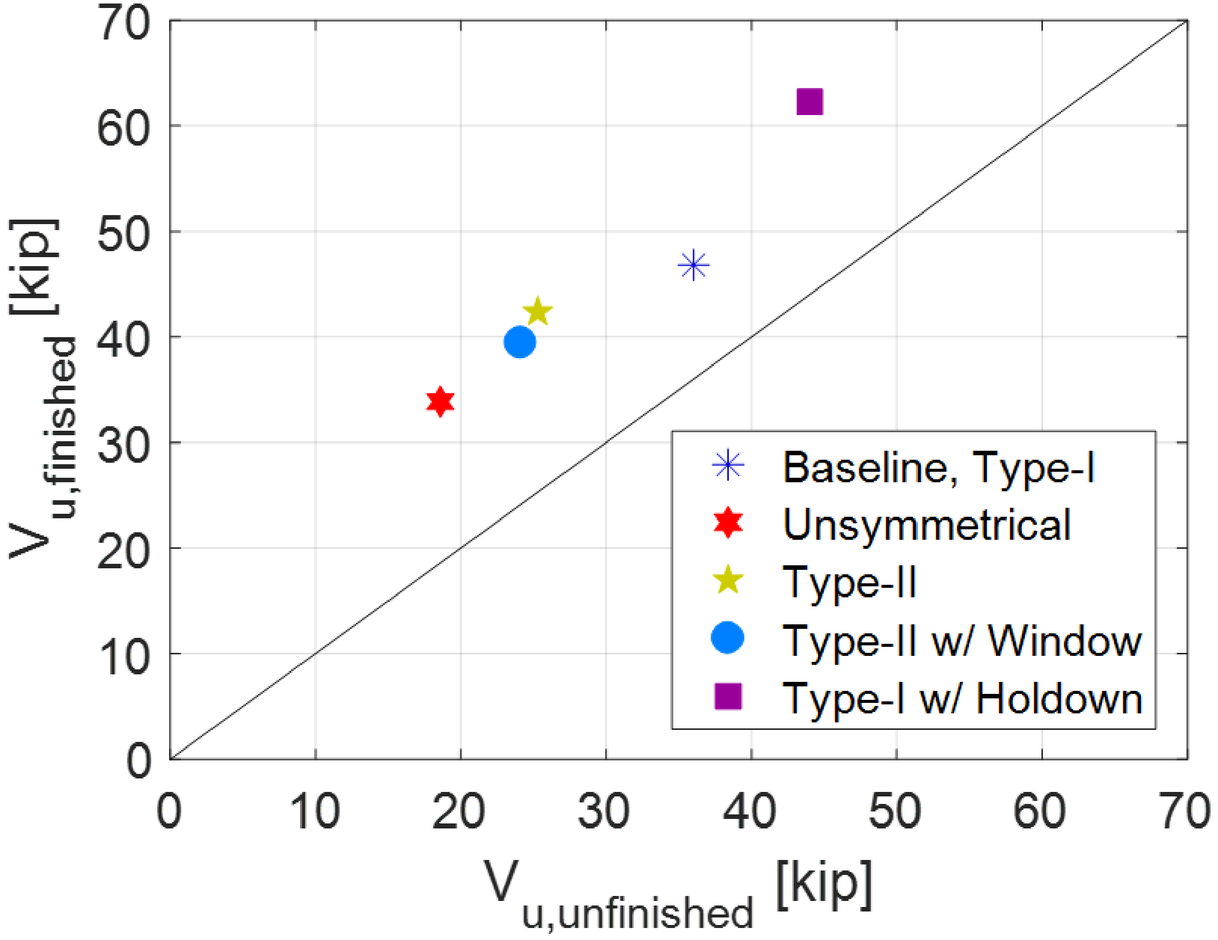


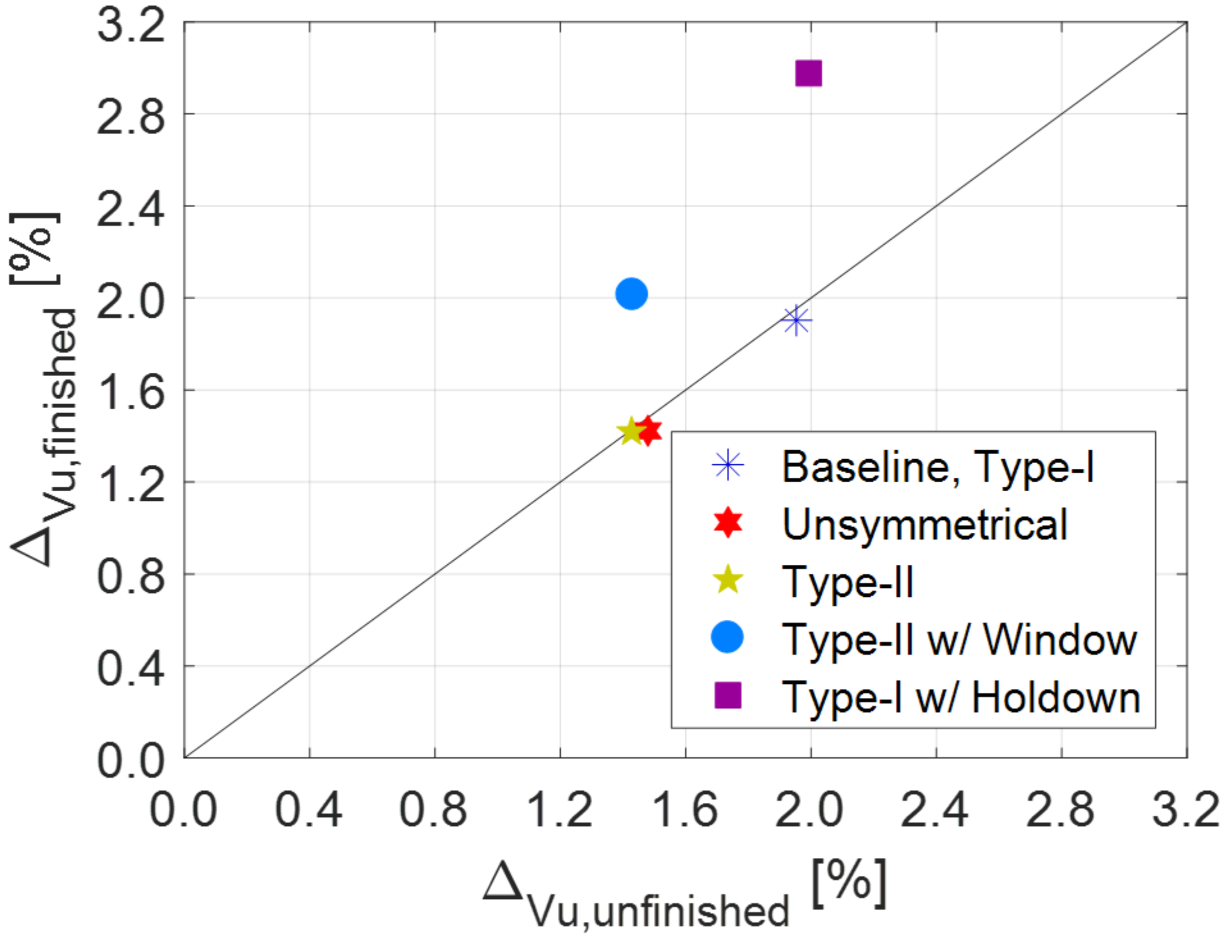
- **Strength** increase
- **Initial stiffness** increase
- No negative effect on **drift at strength**

Unfinished = Wall framing

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

Effect of Finish Application

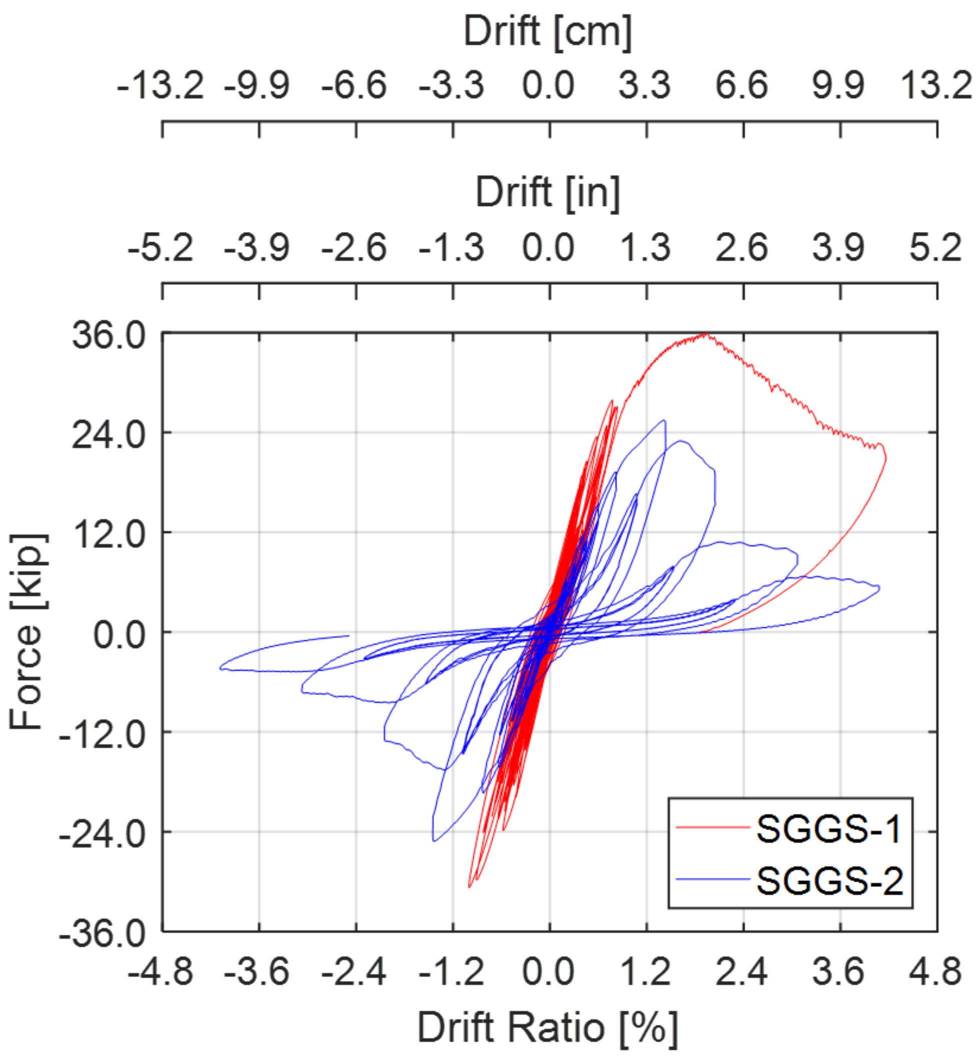




$$V_{u,finished} = 1.01 \times V_{u,unfinished} + 930\,plf$$

- **Strength** increase (additive strength model)
- No negative effect on **drift at strength**

Comparison: Type-I vs Type-II Wall Systems



Specimen	Strength, V_{max} [kip]	Drift, $\delta_{V_{max}}$ [in] (%)	Initial Stiffness*, k_e [kip/in]
SGGS-1	36.0	2.11 (1.95%)	47.4
SGGS-2	25.5 (↓30%)	1.53 (1.41%)	25.9 (↓45%)

- **Strength** decrease, but not 50% as suggested by code
- **Initial stiffness** decrease
- Lower **drift at strength**

SGGS-1 SGGS-2

Type-I = anchorage at each end of wall segment

Type-II = anchorage at ends of wall

Concluding Remarks: Observations

- Symmetry: Unsymmetrical wall with one 4ft shear wall segment
  - ~50% ⬇ in strength and stiffness
  - Aligning with conceptual design perspective
- Window Opening & Window Framing:
  - Negligible effect on strength or stiffness
  - Drift capacity not effected
  - Damage to adjacent stud packs concerning
- Tension Tie-Rod/Holdown detailing:
  - Strength ☝20%-30% with holdowns
  - Similar initial stiffness
  - Tension rods offer advantages: easy installation and continuous floor-to-floor system
- Finishes: EIFS and Gypsum boards
  - Strength ☝30%-80% = 930*plf*
  - Initial stiffness ☝1.5x-3x
  - Period elongation < 10% (QE)
  - Damping ~ ☝50%
  - No derogatory effect on drift capacity
- Anchorage Detailing: Type-II wall
  - ~30%-35% ⬇ in strength, not 50% as suggested by code
  - Initial stiffness ⬇ 30%-45% with tie-rods anchorage at ends of wall

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