Innovations in Cold-formed Steel Design and Construction
Towards Tall, Fast, Dry, Multi-hazard Resilience

Amanpreet **Singh**[1, 2], Jiachen Zhang[3], Daniel Rivera[3], Mohammed Eladly[1, 2], Ruipu Ji[3], Thomas Gernay[1], Richard Emberley[4], Brian Meacham[5,6], Kara Peterman[7], Benjamin Schafer[1], Tara Hutchinson[3]

[1] Johns Hopkins University, [2] National Institute of Standards and Technology, [3] University of California San Diego, [4] California Polytechnic State University, San Luis Obispo, [5] Crux Consulting, [6] Meacham and Associates, [7] University of Massachusetts Amherst

University of California at San Diego NHERI Natural Hazards Engineering Research Infrastructure

INNOVATE CFS SEISMIC DESIGN DETAILING

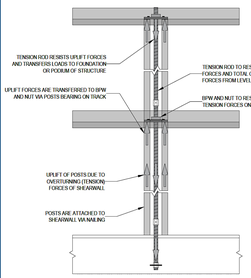
Towards Taller CFS-framed Buildings Beyond ASCE 7 and AISI S400

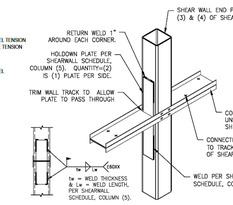
DESIGN BARRIERS

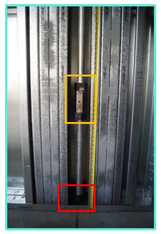
- 65ft height limit in SDC D,E,F restricts application
- Highest capacity steel sheet shear wall in AISI S400-15 creates structural limits
- High overturning moment demands lead to impractical chord stud design

ENGINEERING SOLUTIONS

- Steel sheet sheathed shear walls beyond AISI S400 capacities
- HSS columns and built-up stud packs as chord elements
- Multi-story details include hold-downs and tension tie-rods in orthogonal directions

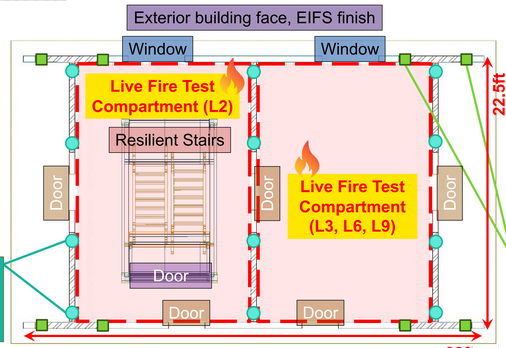






N-S Shear walls: Continuous tension tie-rod sandwiched between end posts

(West coast preference in construction)



E-W Shear walls: Hold-down or plate connected end posts

(East coast preference in construction)

EVALUATE FUNCTIONAL RECOVERY NEEDS

Integration of Nonstructural Components & Systems (NCSs)

NEED FOR UPDATE

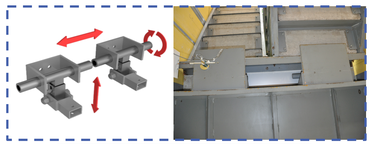
- FEMA P-58 limitations for fragility of CFS framing
- NCS fragility information based on expert judgement, reconnaissance reports, and decade+ old studies; not system-level experiments
- Missing newly developed resilient component options

OBJECTIVES

- Examine evolution of damage in a real building system under multi-directional seismic excitation
- Understand damage levels as function of engineering demand parameter
- Development of improved and accurate fragilities
- Improve downtime and financial loss estimates

Doors & Window Glazing

Fire Sprinkler System



Seismically Resilient Stairs

Building Envelope: Interior & Exterior Insulation Finishes

Flexible Gas Piping

ADVANCE VOLUMETRIC MODULAR CONSTRUCTION

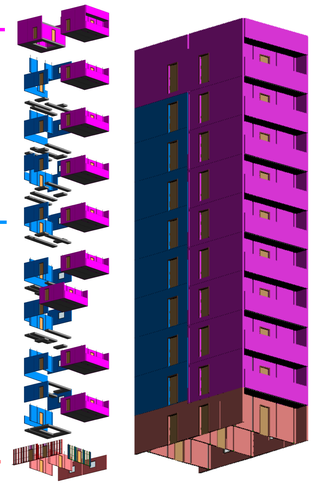
High precision, Low waste, Rapid construction

- Improved constructability in controlled environment leading to tighter building envelopes and higher energy efficiency
- Module strength/stiffness needs for damage-free transportation without significant weight increase

Volumetric Modular Units (nearly ready for use post-installation)

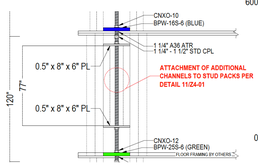
Panelized walls & floors (prefabricated elements, on-site connection)

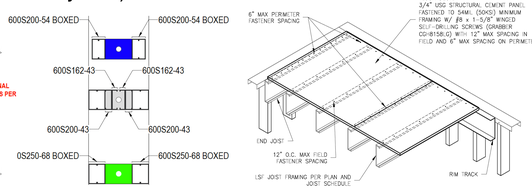
Stick-framed (conventional construction)



INNOVATIVE STRATEGY

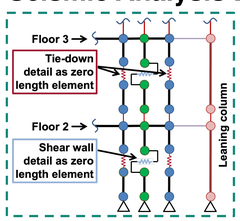
- Combined with dry floor solution (structural panel on joists) for fast construction



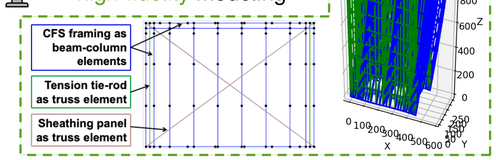


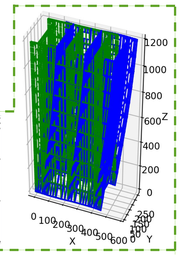
ENABLE MODELING FOR BUILDING DESIGN

Seismic Analysis Beyond ELF Procedure



- Phenomenological and high-fidelity modeling

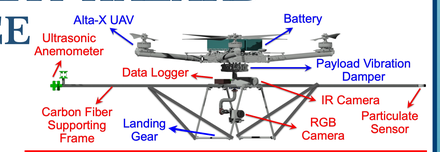




BUILD MULTI-HAZARD RESILIENCE

Alfred E. Alquist SEISMIC SAFETY COMMISSION · Cal OES GOVERNOR'S OFFICE OF EMERGENCY SERVICES

- Post-earthquake structural fire performance evaluation
- 60min duration burns using wood cribs and furniture
- Non-intrusive, real time remote sensing using UAV



July'24: Construction Begins
Mar'25: Seismic Test Program
May'25: Live Fire Test Program

Acknowledgements

The research presented is funded through the National Science Foundation (NSF) grants CMMI 1663569 and CMMI 1663348, project entitled: *Collaborative Research: Seismic Resiliency of Repetitively Framed Mid-Rise Cold-Formed Steel Buildings*. Support for the first author through the NIST Professional Research Experience Program is greatly appreciated. NSF travel award #2129782 for attending the NHERI Research Summit is gratefully acknowledged. Post-earthquake live fire testing is being undertaken with the support of California Seismic Safety Commission and California Governor's Office of Emergency Services agreement A211006635. The task of integrating modular volumetric construction concepts is supported through the Department of Housing and Urban Development, instrument no. RP-22-CA-005. The support of industry sponsors in this ongoing effort are greatly appreciated (see: cfs10.ucsd.edu/sponsors-partners/). Findings and opinions are those of the authors and do not necessarily reflect those of the sponsoring organizations.