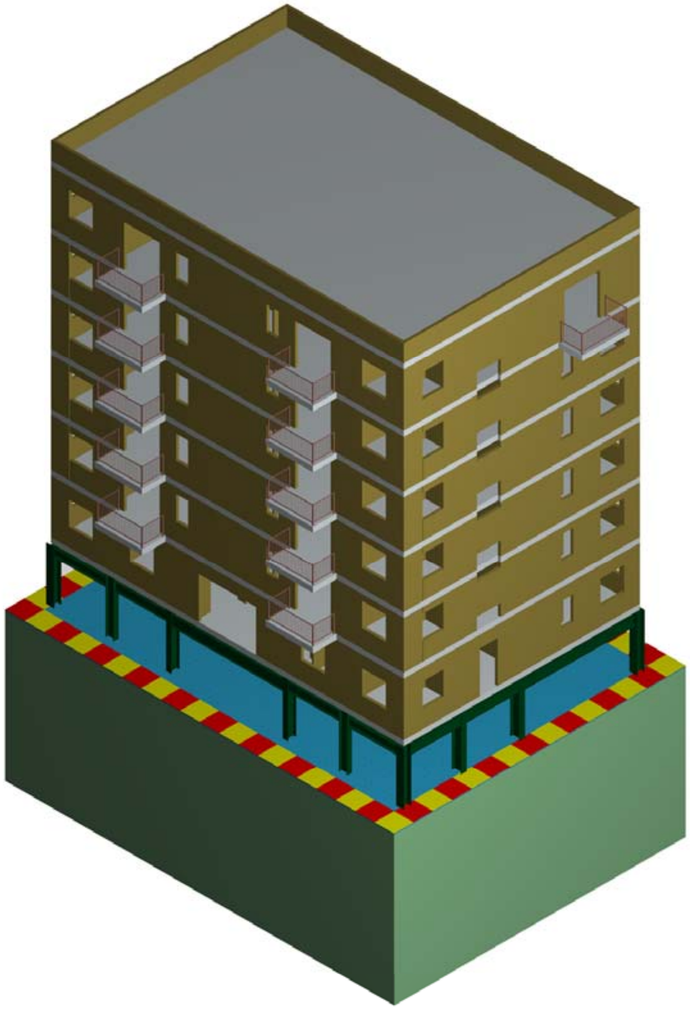
NEESWood Capstone - World’s Largest Shake Table Test of Mixed-Use Steel/Wood Light-Frame Structure



Fred Tai, P.Eng. Presenting on behalf of

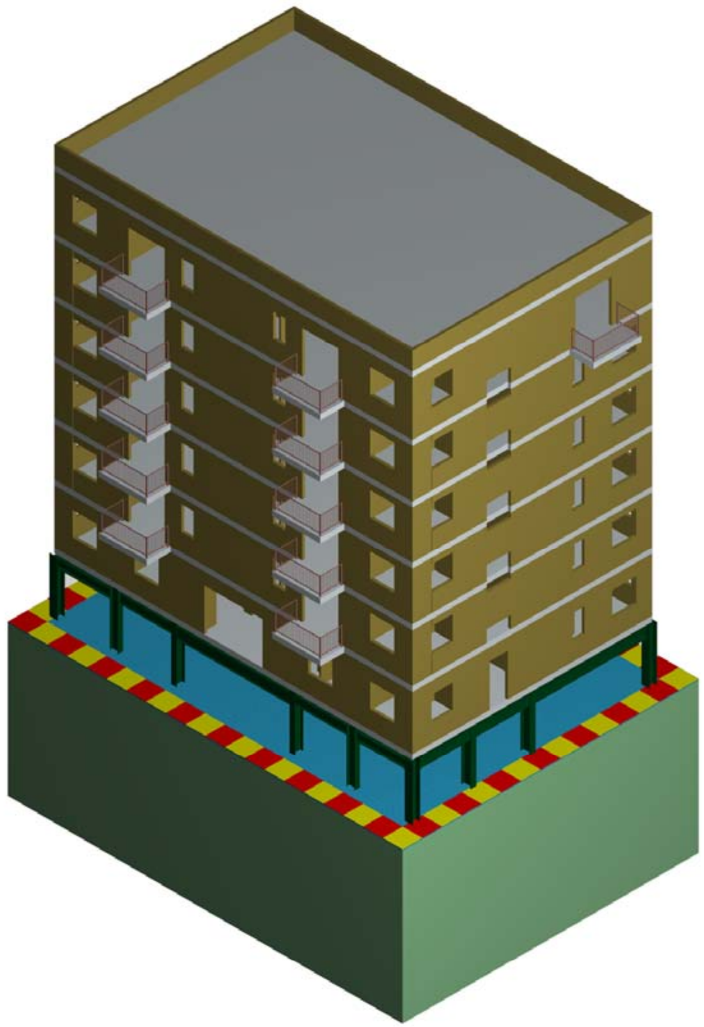
Steven E. Pryor, S.E., P.E.

International Director of Building Systems

Simpson Strong-Tie

Overview

- Largest building ever tested
- NSF grant
- Colorado State University
- Simpson Strong-Tie
- Purpose of the test is to understand how full-scale, multistory wood-frame buildings perform during large seismic events, using performance-based design



Project Objective and Team

SIMPSON Strong-Tie®

Project Background & Objective

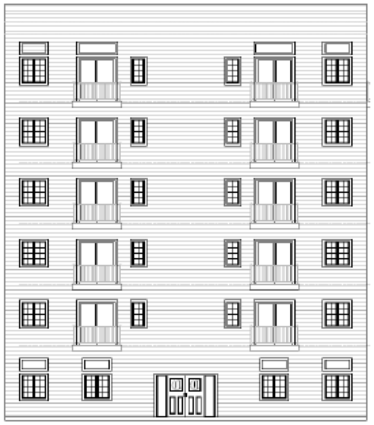
PBD for woodframe construction has roots in HUD's "Operation Breakthrough"

→ *Performance criteria resource document for innovative construction*, Report NBSIR 77-1316 National Institute of Standards and Technology, Washington, DC.

Woodframe PBD is in a position to fuel product innovation – the original intent of 1970's work

→ *Numerous industry sponsors and collaborators…and growing*
9 member practitioner advisory com.

The objective of the NEESWood project is the development of a new logical performance-based seismic design philosophy for mid-rise woodframe construction, thus enabling such construction to be an economic option in seismic regions in the U.S. and around the world



Project Objective and Team

SIMPSON Strong-Tie

The Project Team

NEESWOOD

"NEESWood: Development of a Performance-Based Seismic Design Philosophy for Mid-Rise Woodframe Construction"

www.engr.colostate.edu/NEESWood/

John van de Lindt

Colorado State University

Project Director
Software Development
PBSD
Education/Outreach
Benchmark Testing at UB
Component tests at CSU
Capstone tests in Japan

Andre Filiatrault

University at Buffalo — The State University of New York

Benchmark Testing at UB
Education/Outreach
PBSD
Capstone Tests in Japan

Rachel Davidson

University of Delaware

Societal Impact
Decision Making

David Rosowsky

TEXAS A&M ENGINEERING

PBSD
Numerical Modeling

Michael Symans

Rensselaer

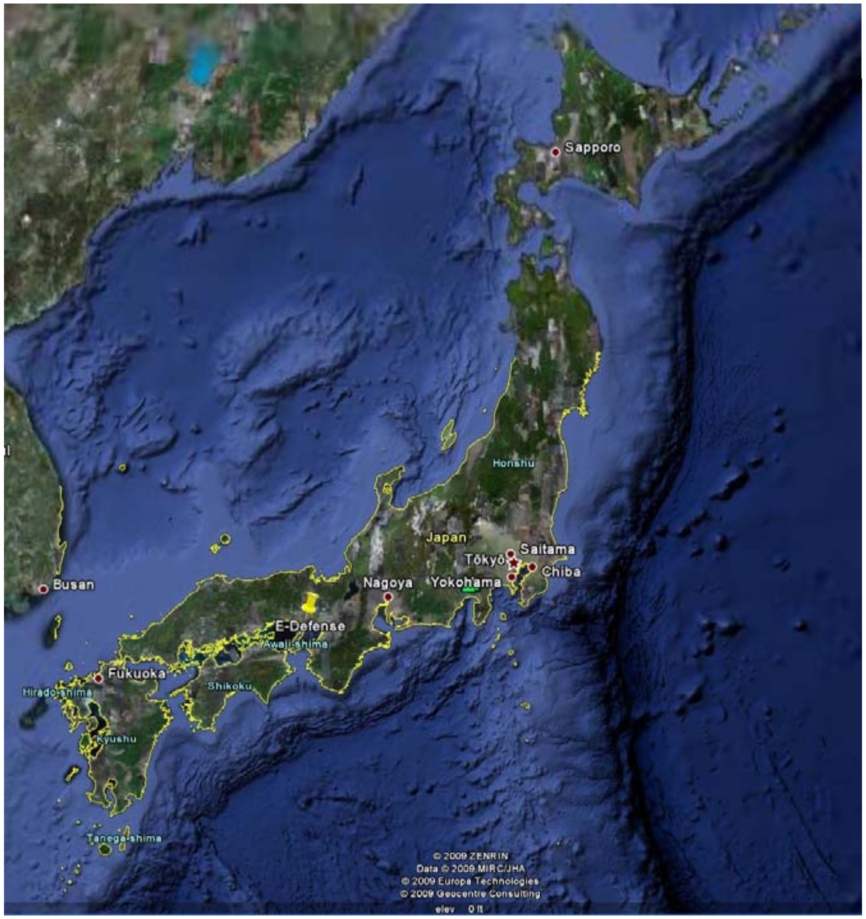
Seismic Protective Systems
Benchmark Testing at UB
Component Testing at RPI
Capstone Tests in Japan

Project Objective and Team

The Practitioner Advisory Committee

Kelly Cobeen, Cobeen & Associates
J. Daniel Dolan, Washington State University
Kevin Cheung, Western Wood Products Association
Steven Pryor, Simpson Strong Tie Company
Borjen Yeh, APA-The Engineered Wood Association
Philip Line, American Forest and Paper Association
Chikahiro Minowa, National Institute of Earth Science and Disaster Prevention-Japan
Rakesh Gupta, Oregon State University
Brian Knight, Axis Design Group

Miki, Japan


Sapporo
Honshu
Japan
Saitama
Tōkyō
Chiba
Busan
Nagoya
Yokohama
E-Defense
Awaji-shima
Fukuoka
Hirado-shima
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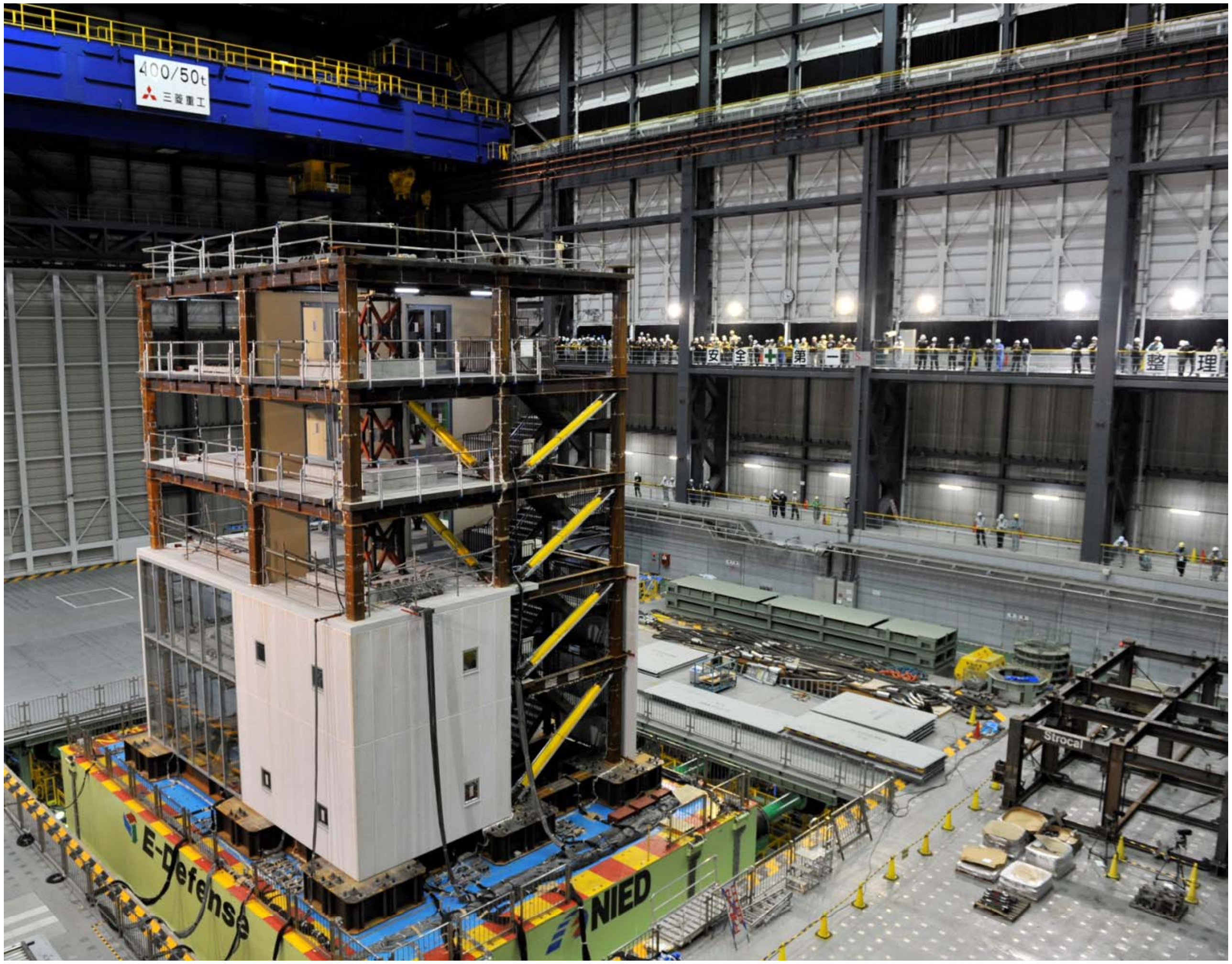
E-Defense
Kōbe
Ōsaka

E-Defense

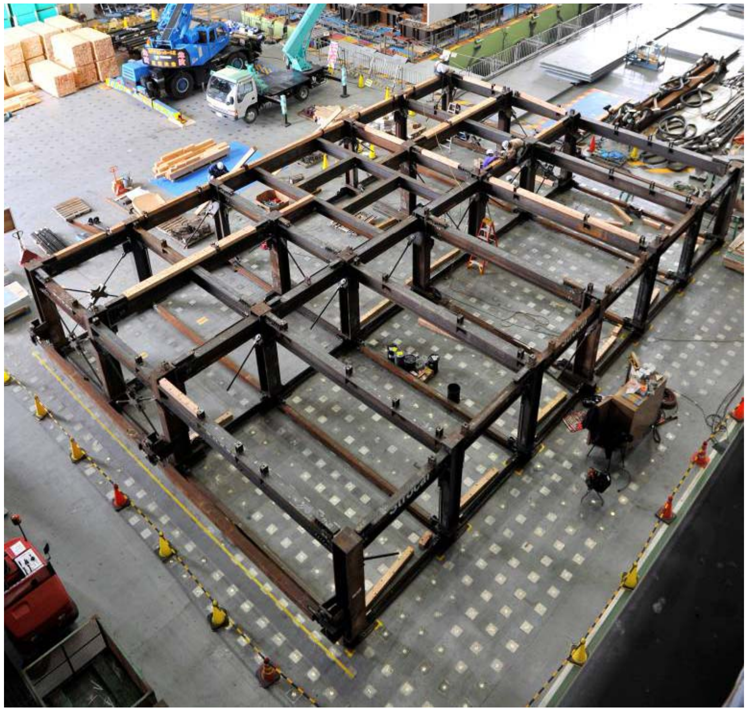
E-Defense Shake Table

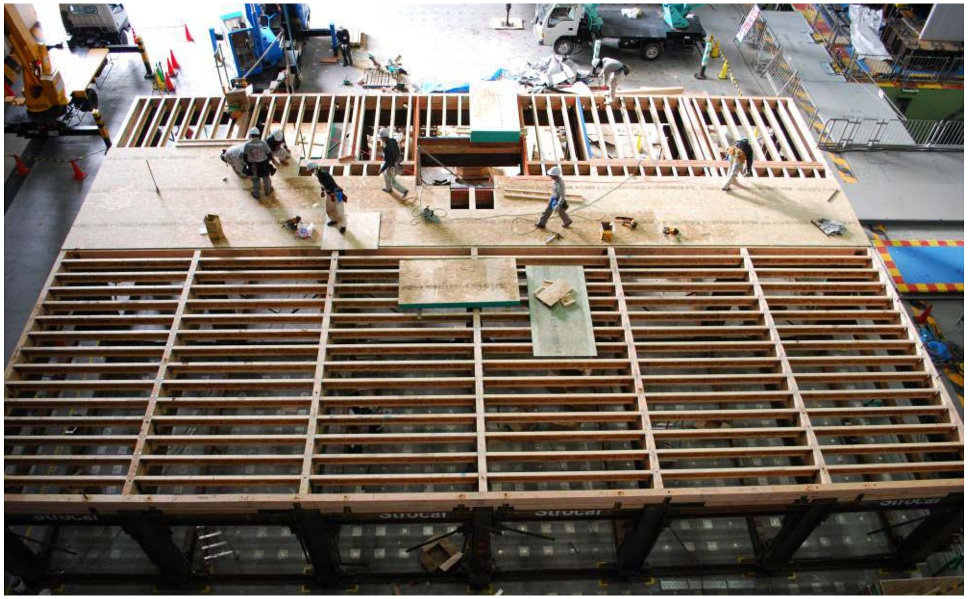


First Story Steel Special Moment Frame

Proprietary Simpson Prototype Steel Special Moment Frame…

- Lifting Truss to move building onto the table
- Braced frame for phase 2 testing

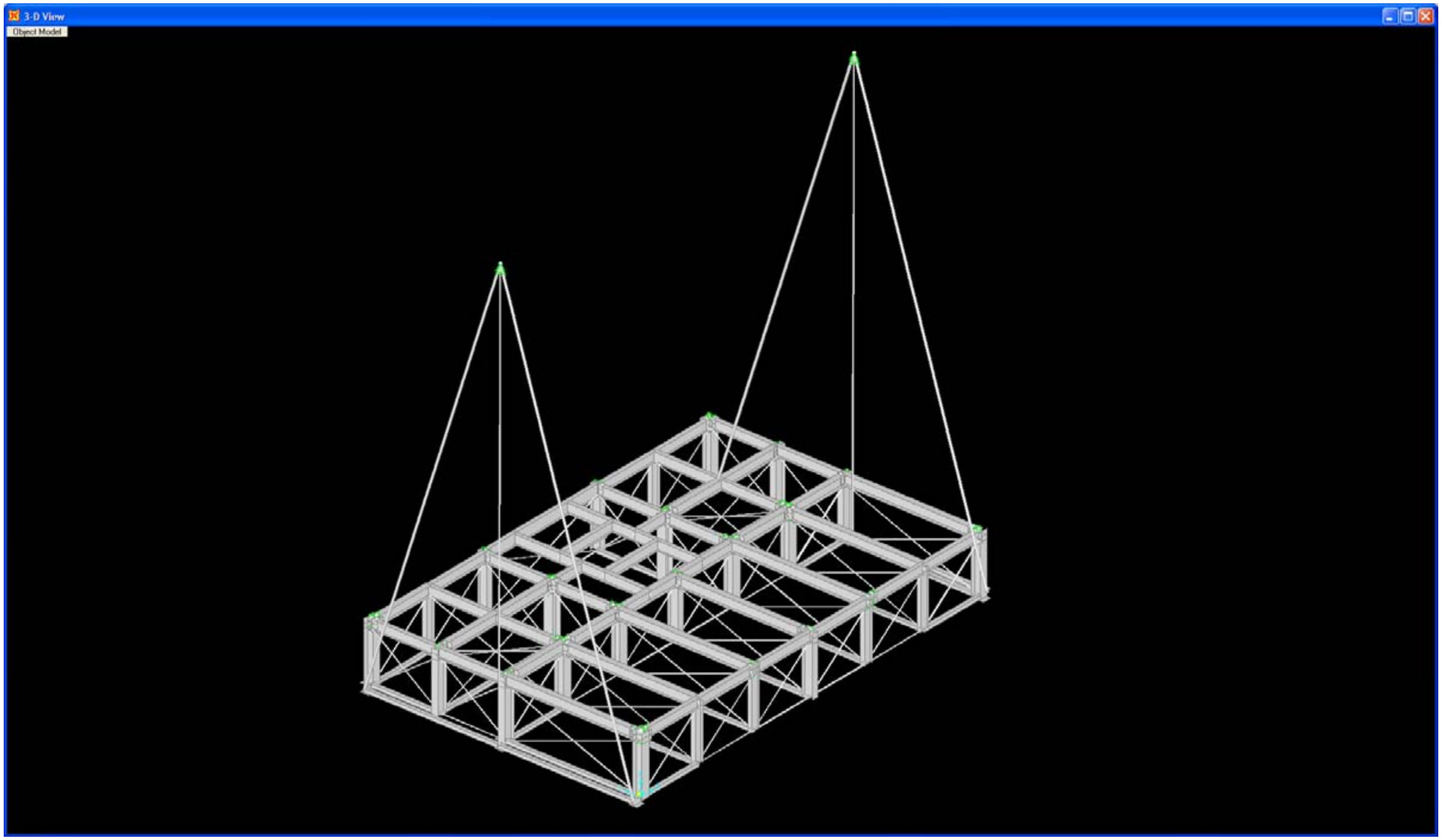




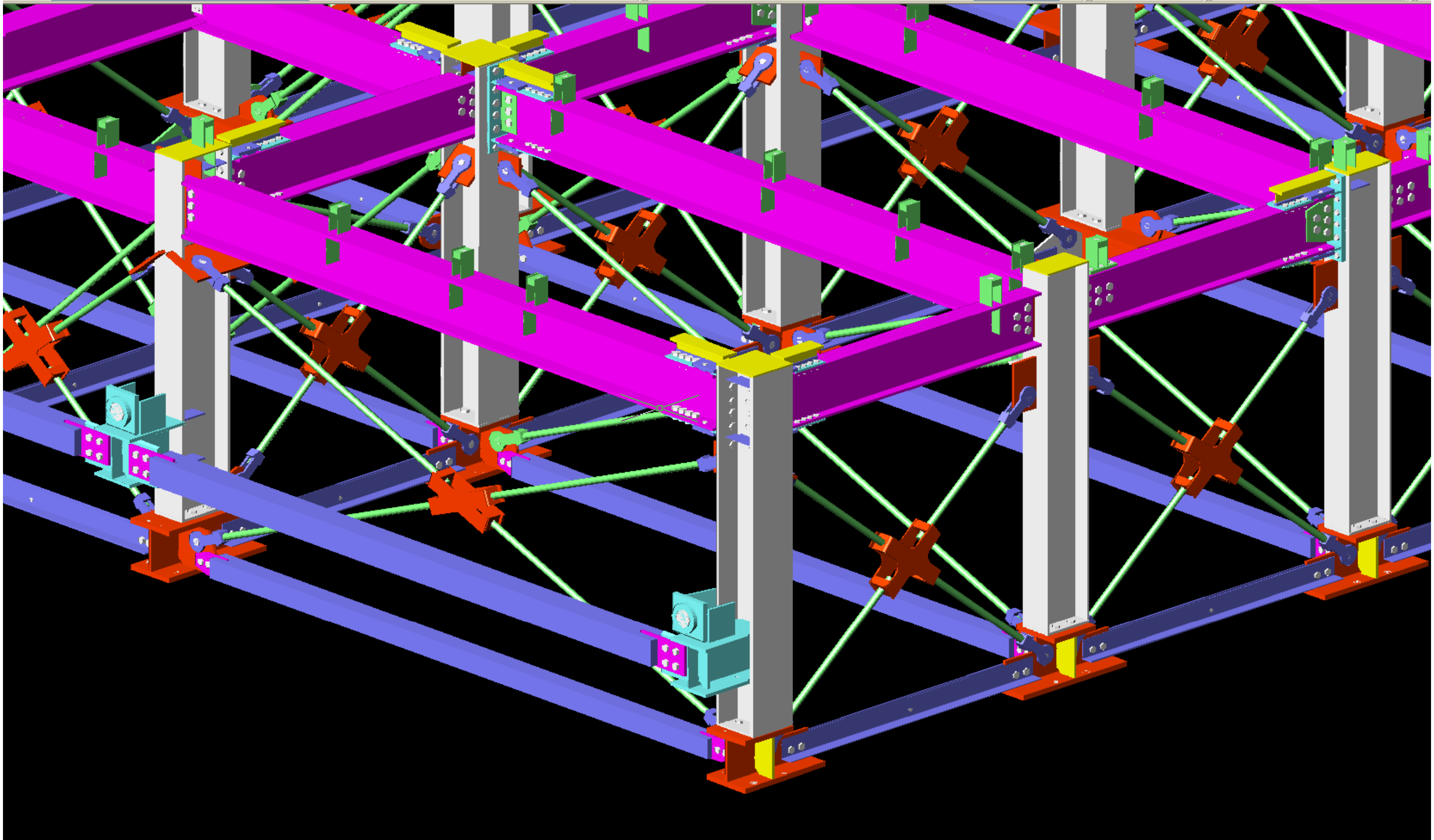
Prototype PR Steel SMF = Elastic Unbraced Beam

- Bolted shear tab: zero moment, axial and shear only
- Bolt on/off easily replaceable axial fuses transfer beam flange force to column

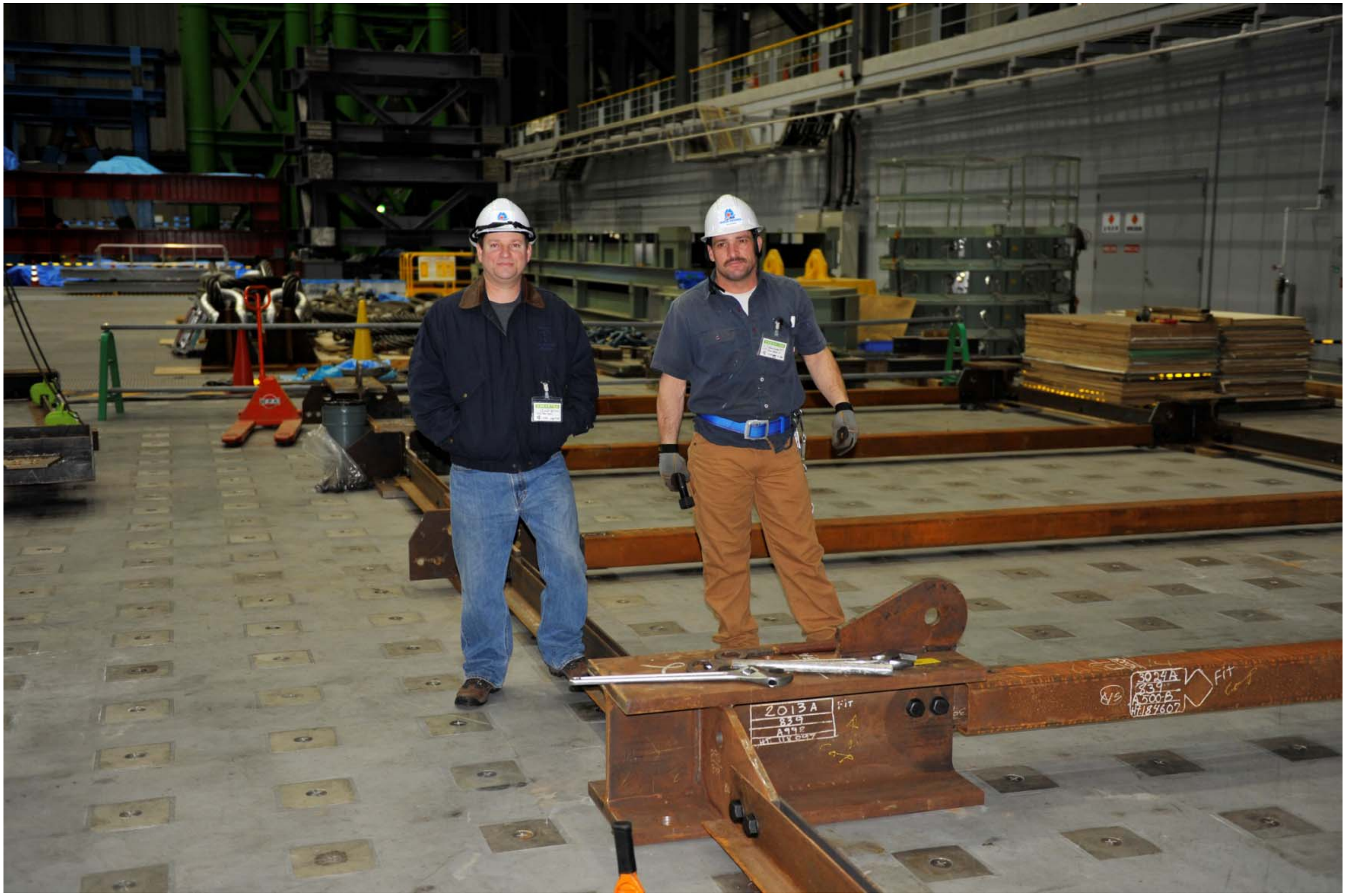
Truss ⇨ SMF ⇨ OCBF ⇨Truss



Truss ⇨ SMF ⇨ OCBF ⇨Truss

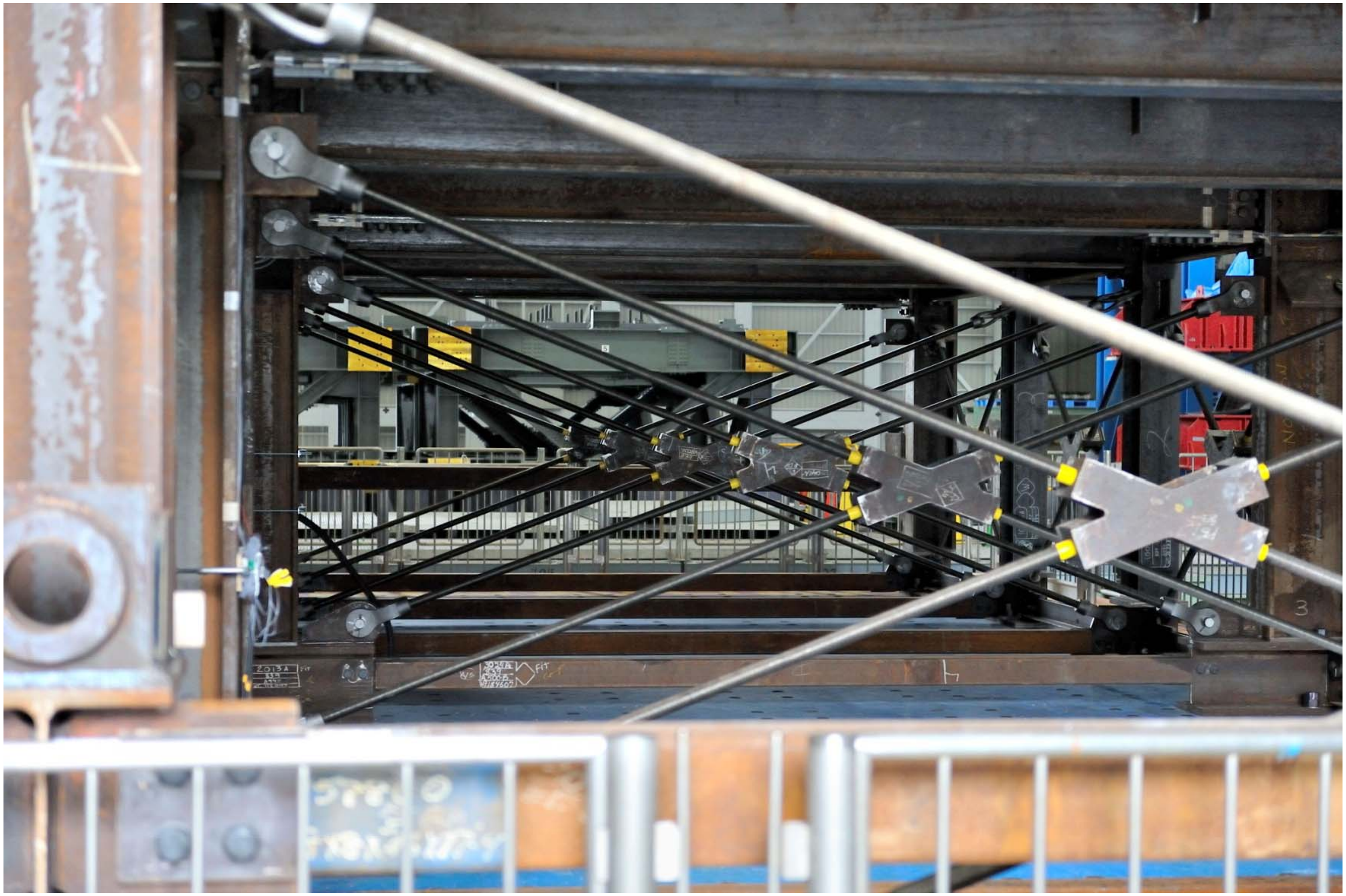


Construction Begins February 2009



Construction…

Truss ⇨ SMF ⇨ OCBF ⇨Truss



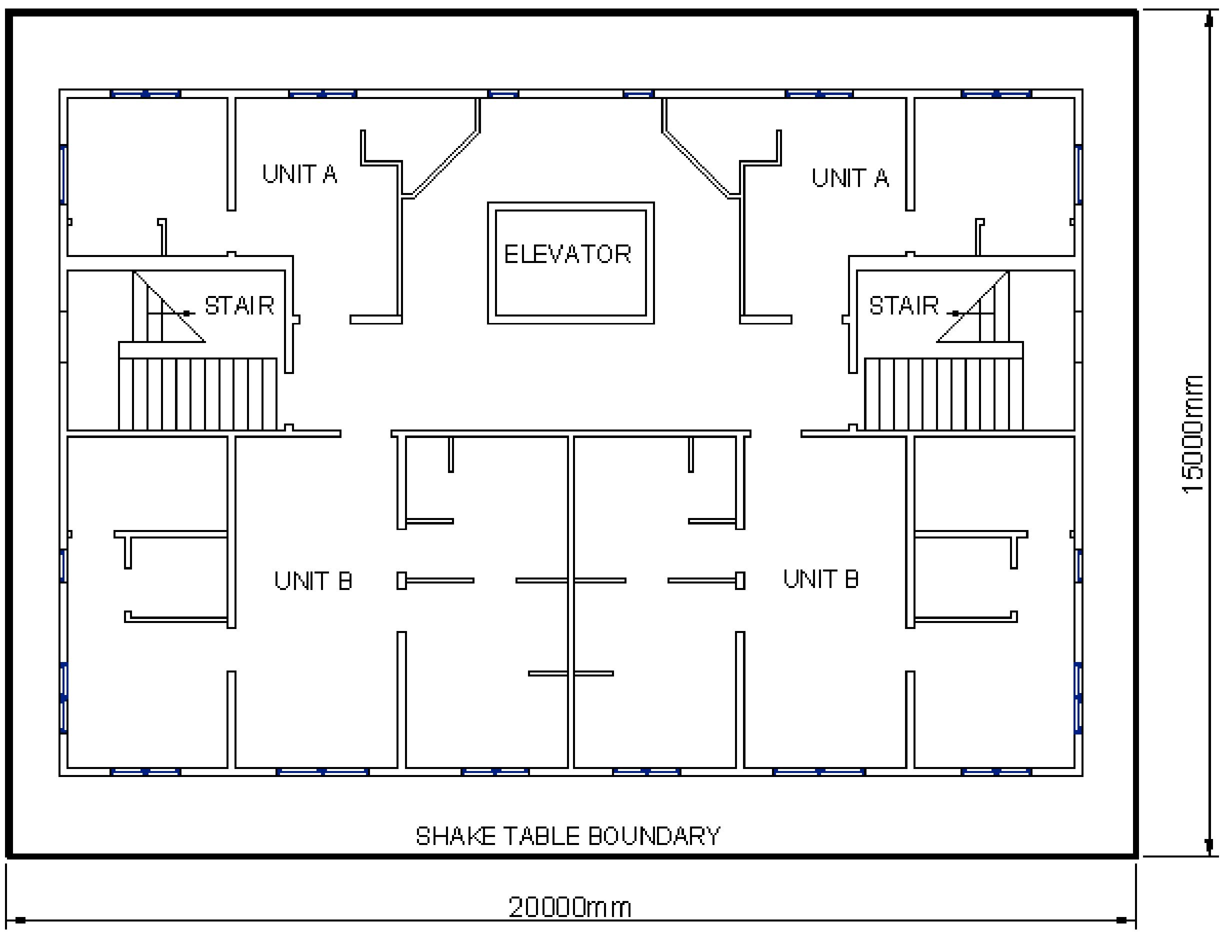
First Story Steel Special Moment Frame

Connection at wood-steel interface

Japanese “Customs”

Construction…

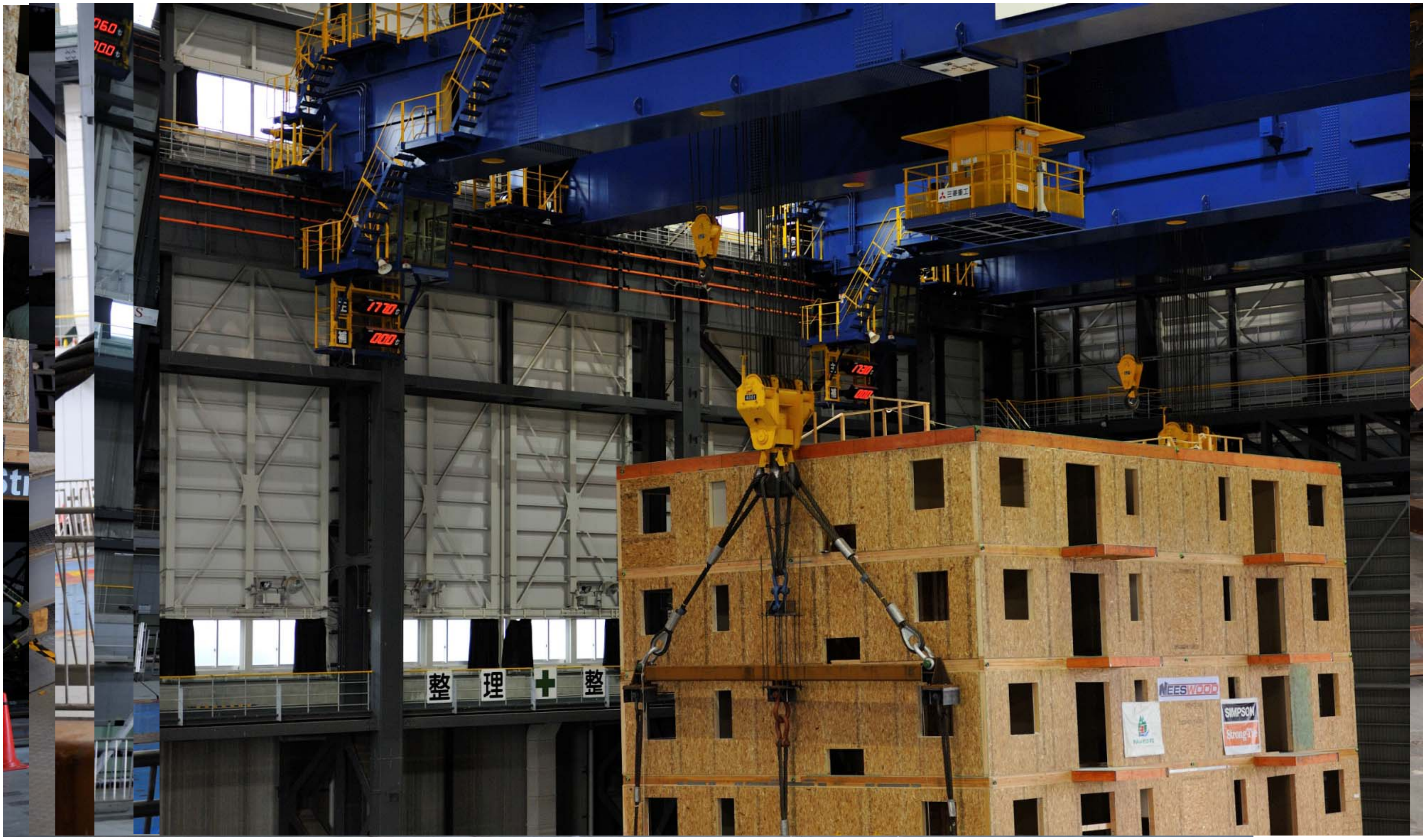
Floor Plan



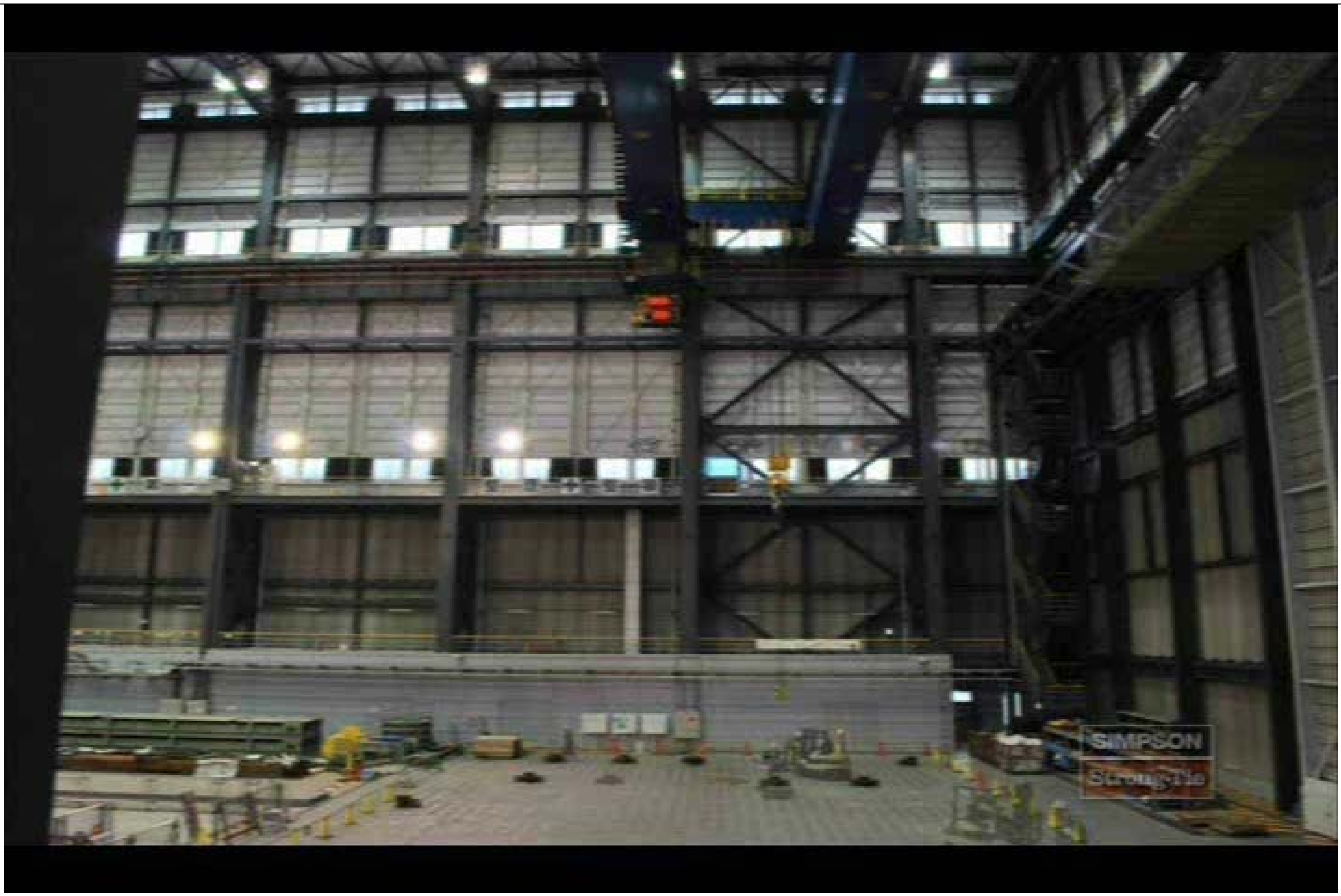
Second Story Floor Plan

Construction…

Move Onto Table…



Time Lapse Sequence



Basic Construction

- Walls
  - 2x6
  - Shear wall boundary members: multiple 2x6 stud packs
- Floors
  - 9.5" LP I-joist in ITS top flange hanger
  - GLB over walls for full bearing

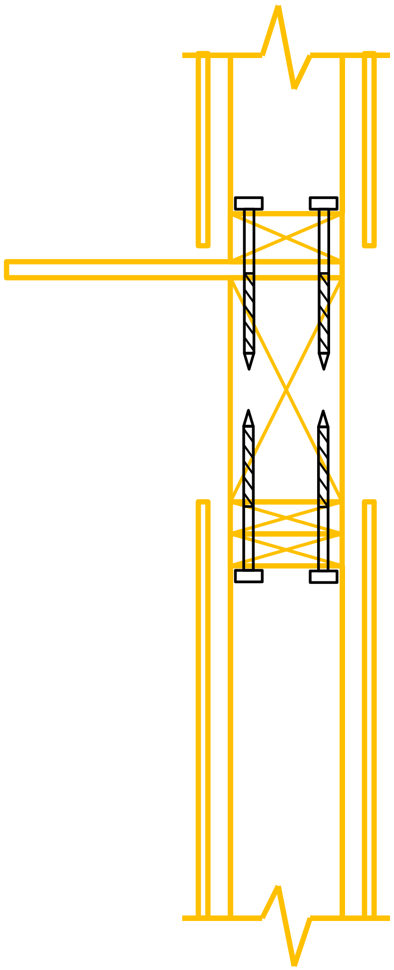
Bottom Story Shear Wall Chord

Basic Construction

- Overturning:
  - ATS rod system
  - TUD and CTUD shrinkage compensating devices
- Shear Transfer
  - Clips/Screws/straps/holdowns

Shear Wall / Floor Interface

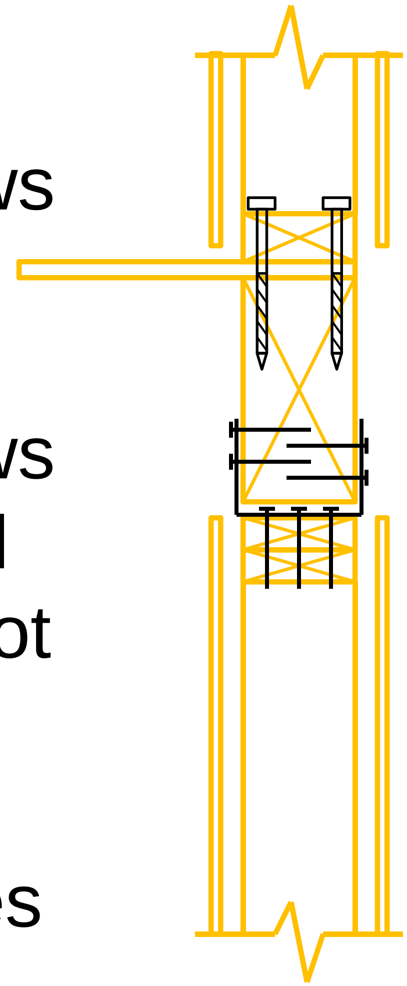
Shear Transfer Details



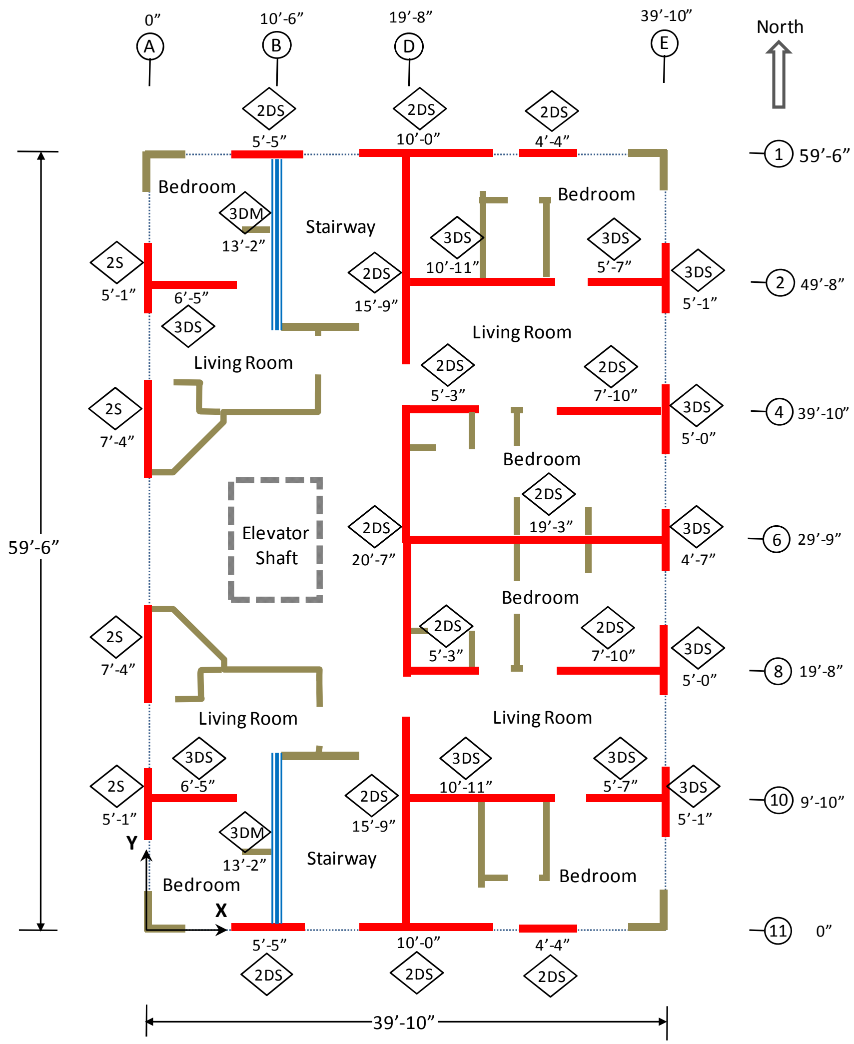
- 3x Sill Plates
- ¼”x6” SDS Screws

<u>Staggered</u>

- GLB
- ¼”x6” SDS Screws or custom channel
- Sheathing B.N. not shown for clarity
- Both methods leave dbl top plates open



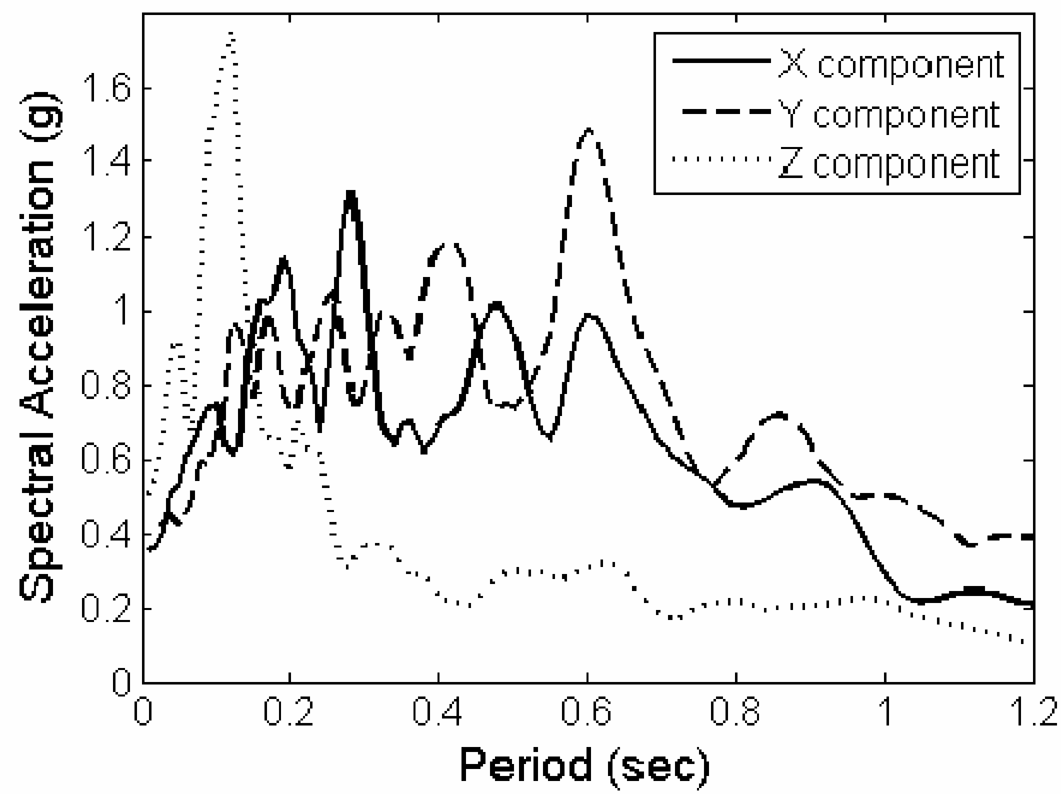
Second Floor Shear Wall Layout



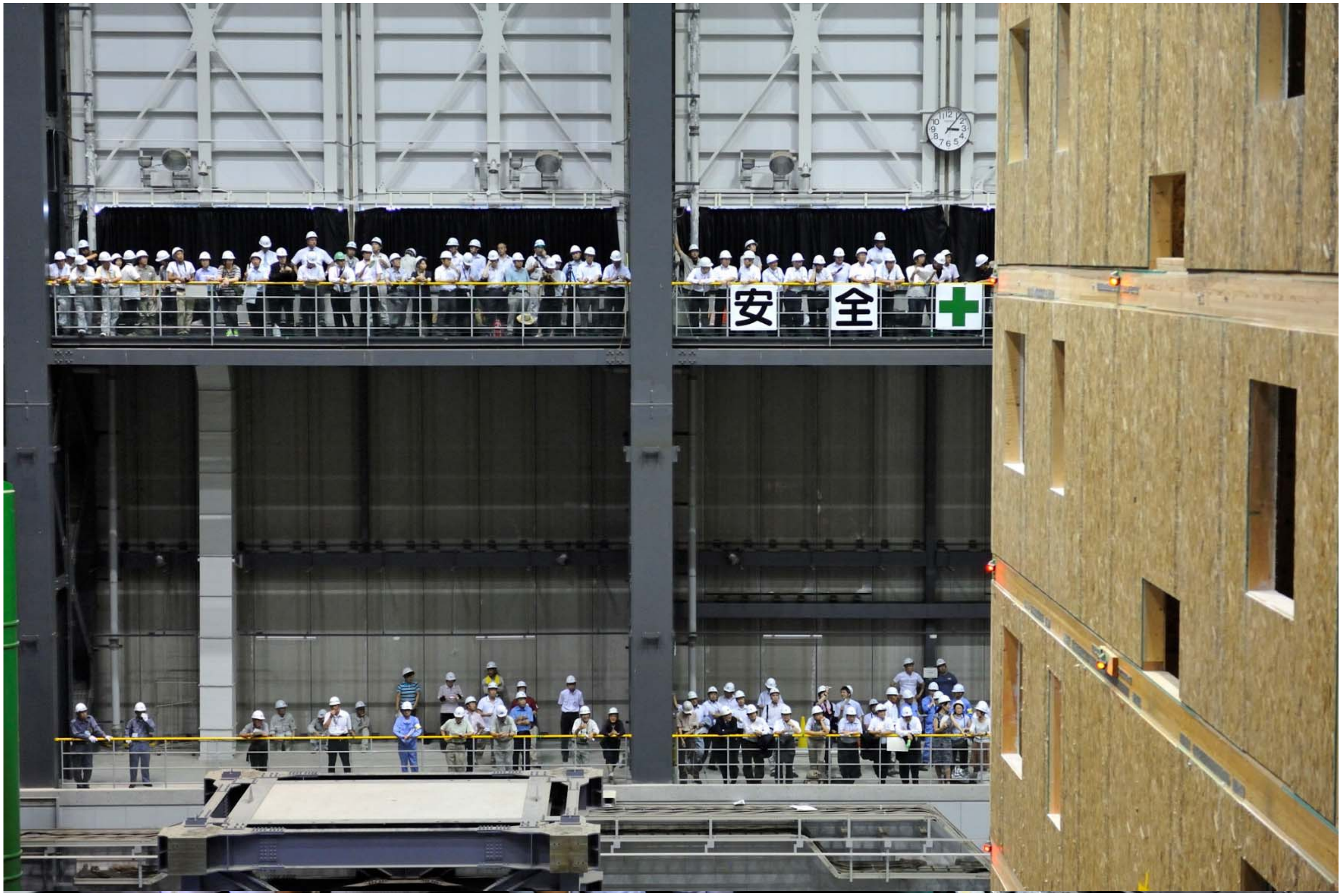
Unscaled Response Spectra

1994 Northridge, Canoga Park

Scale Factor for MCE: 1.8

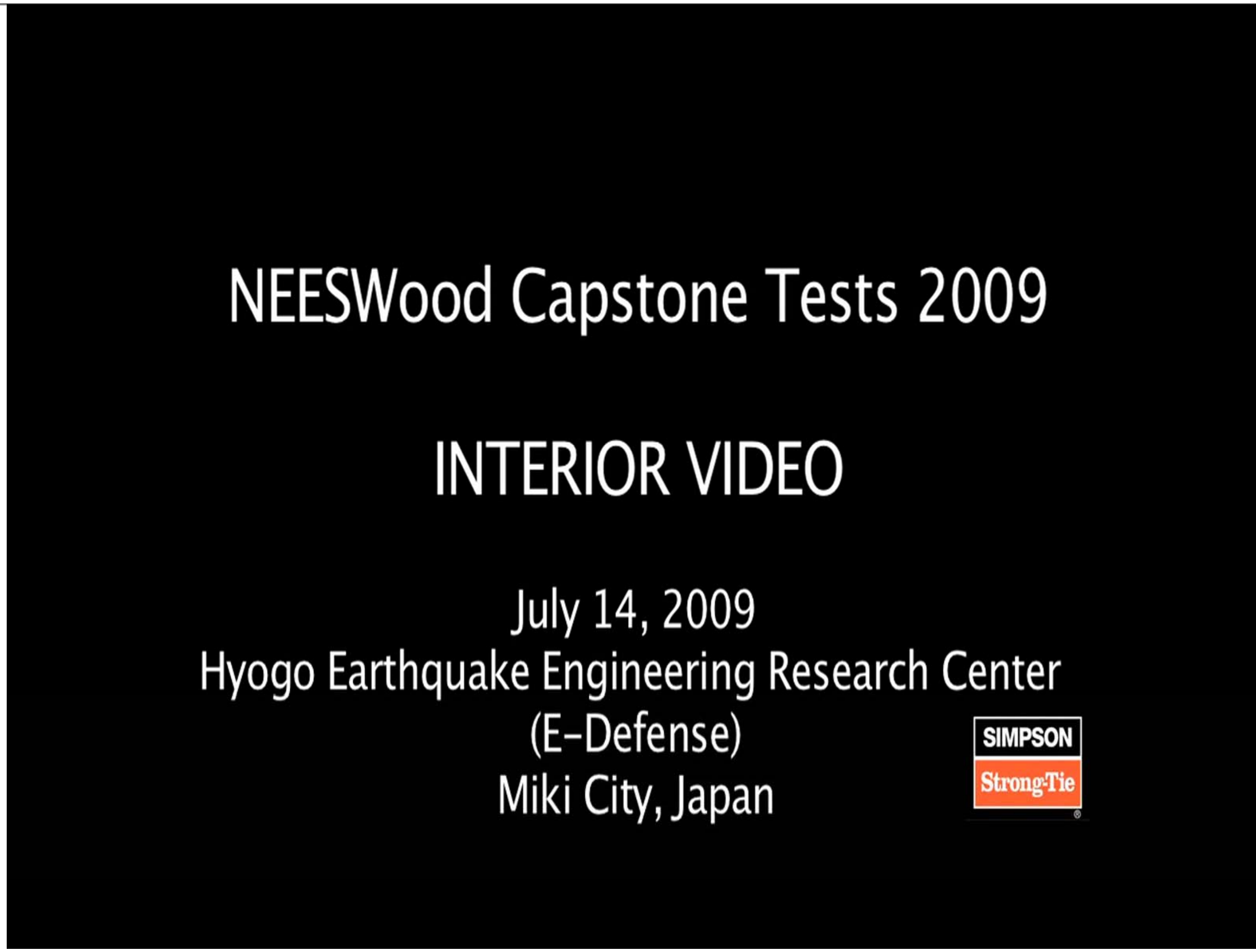


All Set – The BIG day…

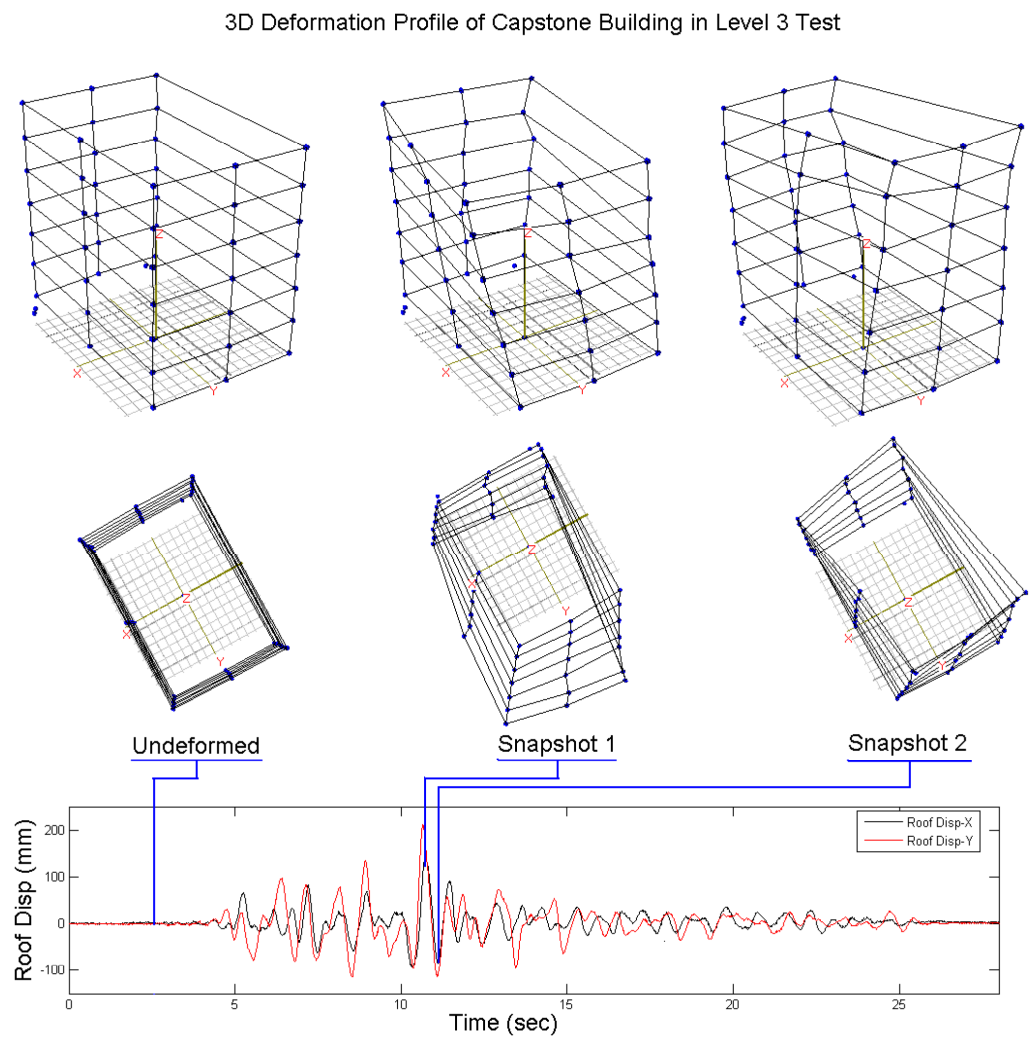


Test 5 (MCE): 180% Canoga Park

Test 5 (MCE): 180% Canoga Park



Results – Building Deformations



Results – Natural Period

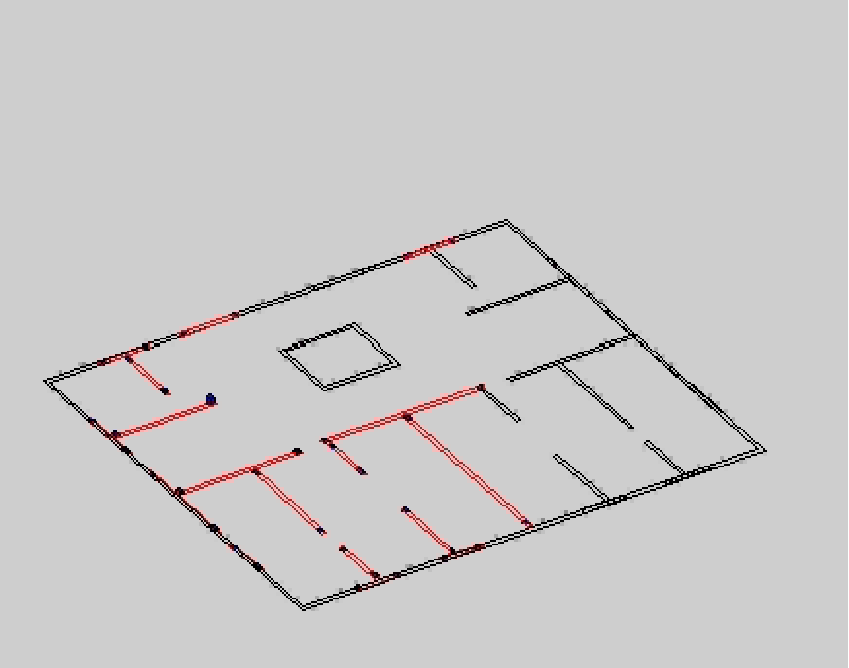
Test ID	Natural Period (sec)		
	X	Y	Z
White Noise	0.41	0.42	0.13
Test 3	Test Level 1-Seismic		
White Noise	0.41	0.42	0.13
Test 4	Test Level 2-Seismic		
White Noise	0.41	0.42	0.13
Test 5	Test Level 3-Seismic		
White Noise	0.47	0.49	0.14

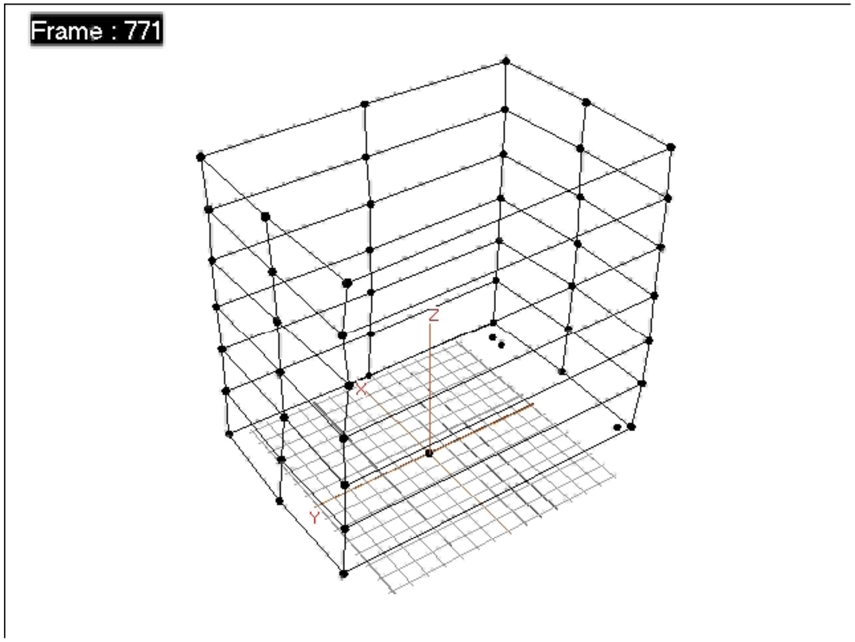
Results – Average Peak Interstory Drift

SIMPSON Strong-Tie®

Peak Inter-story Drift (%)	Test 3		Test 4		Test 5	
	X	Y	X	Y	X	Y
St1	0.26	0.44	0.49	0.77	0.84	1.12
St2	0.35	0.42	0.63	1.05	0.97	1.46
St3	0.29	0.54	0.64	1.02	0.89	1.64
St4	0.30	0.44	0.77	1.22	1.10	1.48
St5	0.36	0.46	0.64	1.14	1.00	1.88
St6	0.40	0.21	0.88	0.58	1.35	1.11

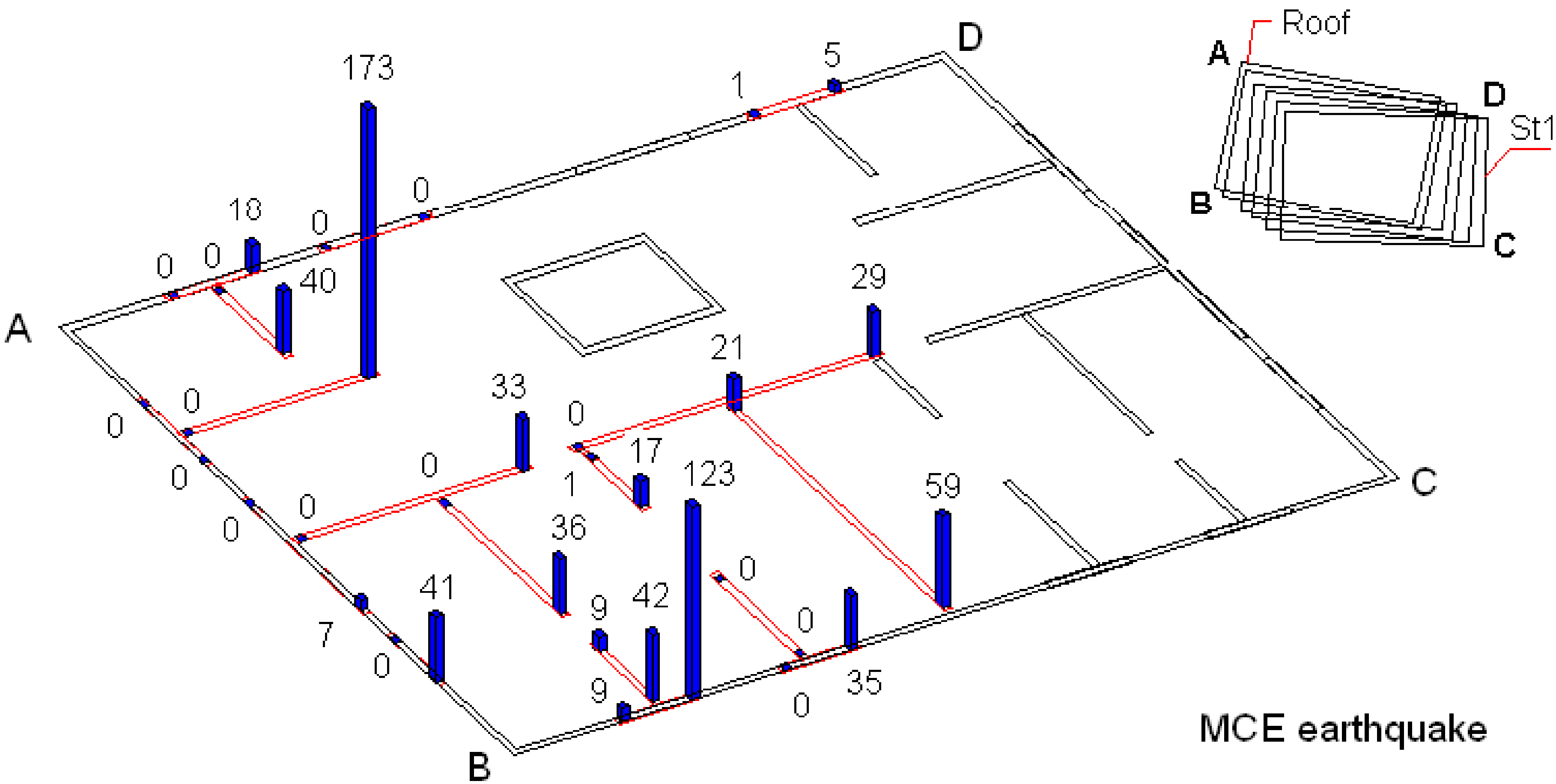
Results – Tie-down Forces and Bld'g. Deformation





Results – Tie-down Forces

Rod force distribution at time point of maximum uplift force (kips)



MCE earthquake

Results – Tie-down Forces in wall B1, Interior End

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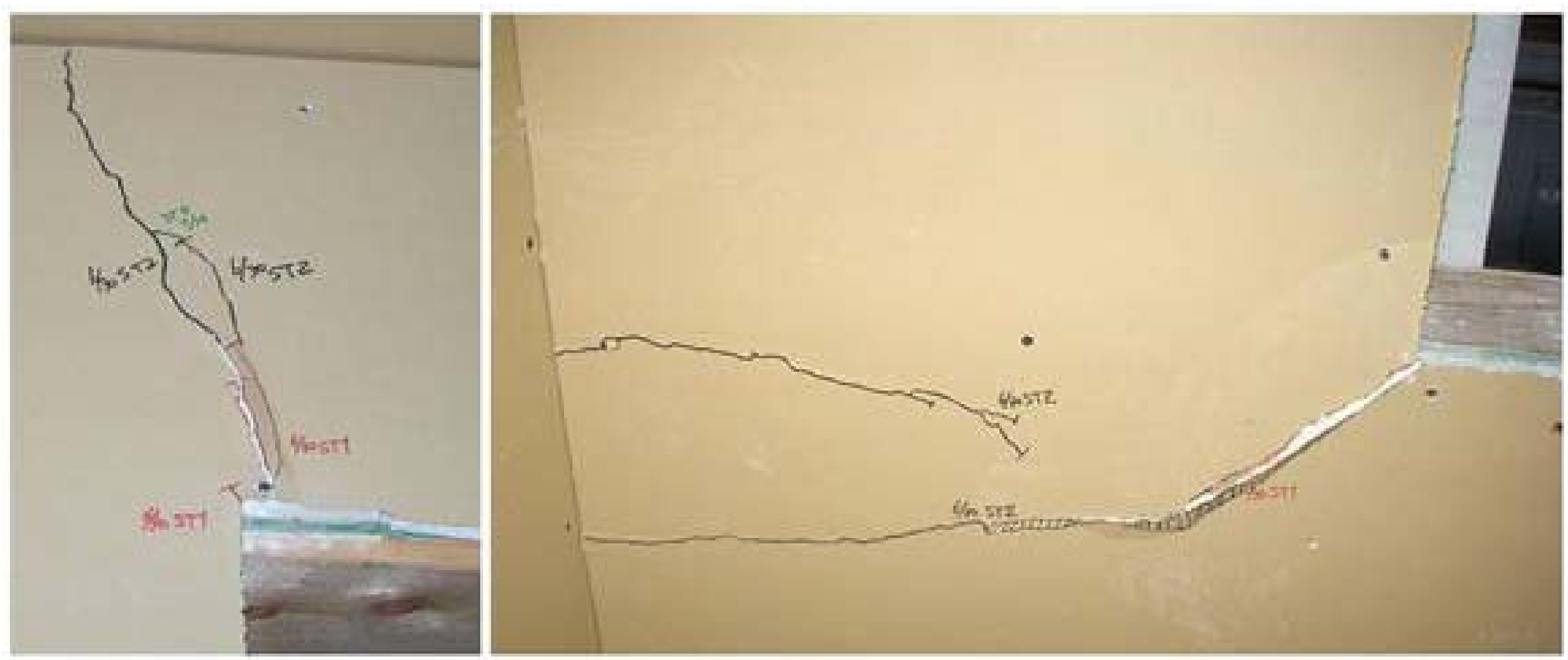
Test 5, 2%/50yr (MCE) Tiedown Forces (kips)		
Story	Measured	Design
1	173	169
2	117	120
3	72	78
4	39	42
5	13	17

- Design Demand developed from simple, stacked 5-story free-body diagram with wall shear forces taken from the 80^{th} percentile results of the nonlinear time-history analysis, $\sim 0.8 \times \Omega_0$

Typical Damage – Drywall Cracking at Corners

SIMPSON Strong-Tie



Little perspective

Acknowledgements…

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  - Staff of E-Defense
  - Maui Homes
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APEGBC Technical and Practice Bulletin

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Professional Engineers and Geoscientists of BC

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Structural, Fire Protection and Building Envelope Professional Engineering Services for 5 and 6 Storey Wood Frame Residential Building Projects (Mid-Rise Buildings)

Revised July 13, 2009

Questions?