National Science Foundation

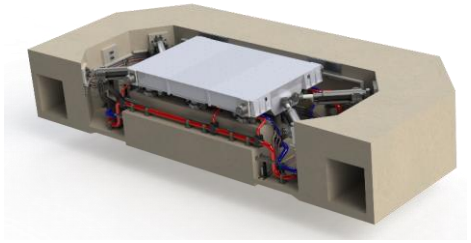
University of California at San Diego
NHERI
Natural Hazards Engineering Research Infrastructure

UC San Diego
JACOBS SCHOOL OF ENGINEERING
Structural Engineering

Converging Design Methodology

Multi-Objective Optimization of Resilient Structural Spines

Andre R. Barbosa, Oregon State University



NHERI@UC San Diego User Training Workshop

December 15-16, 2022
University of California, San Diego

Shake-Table Specimen Reuse Opportunity

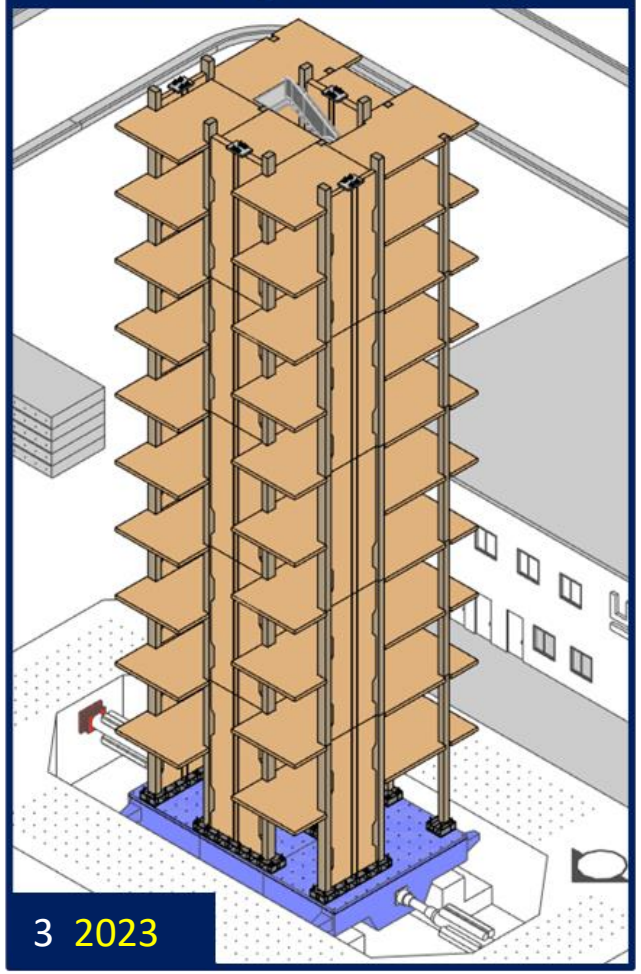
NSF TallWood Project | USDA-ARS

1 2017

USDA-ARS

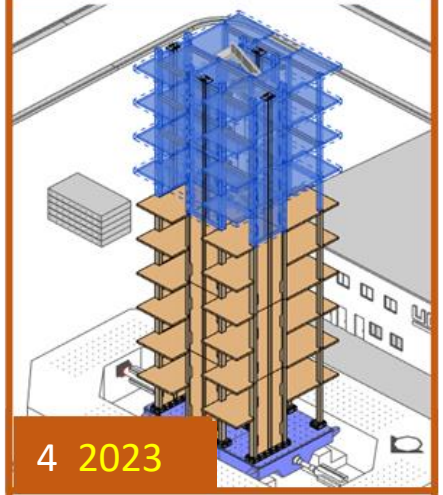
2 2022

NSF 10-story TallWood Project

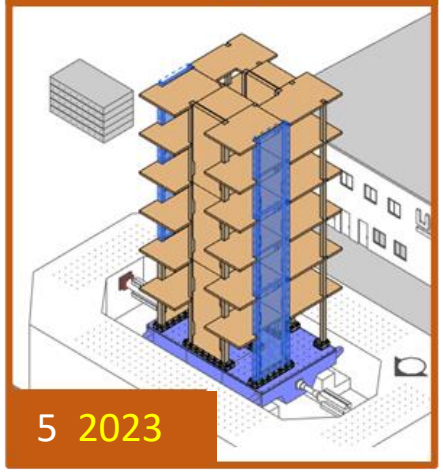


3 2023

NSF 6-story Project

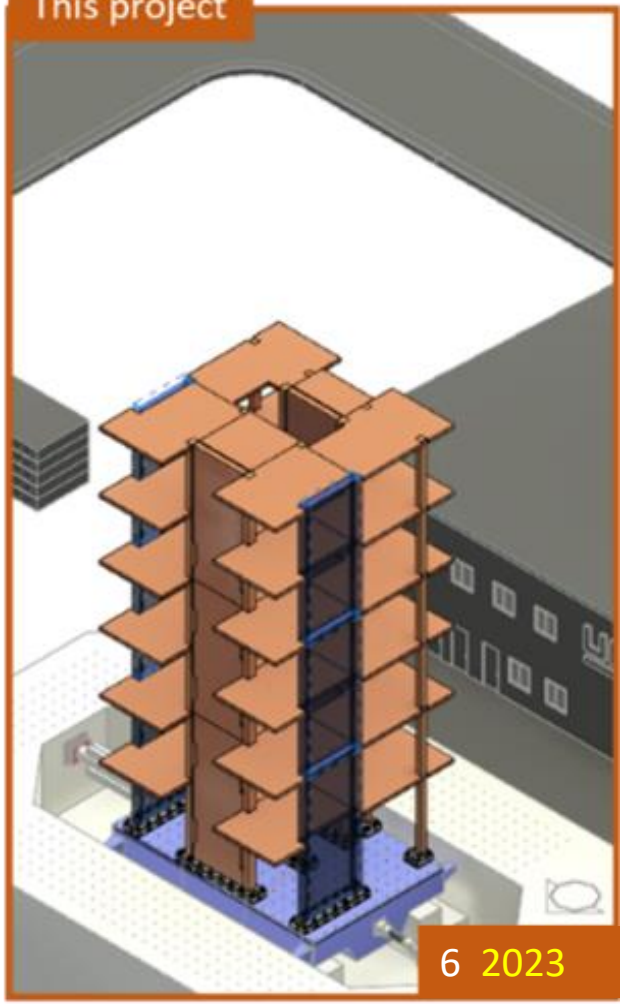


4 2023



5 2023

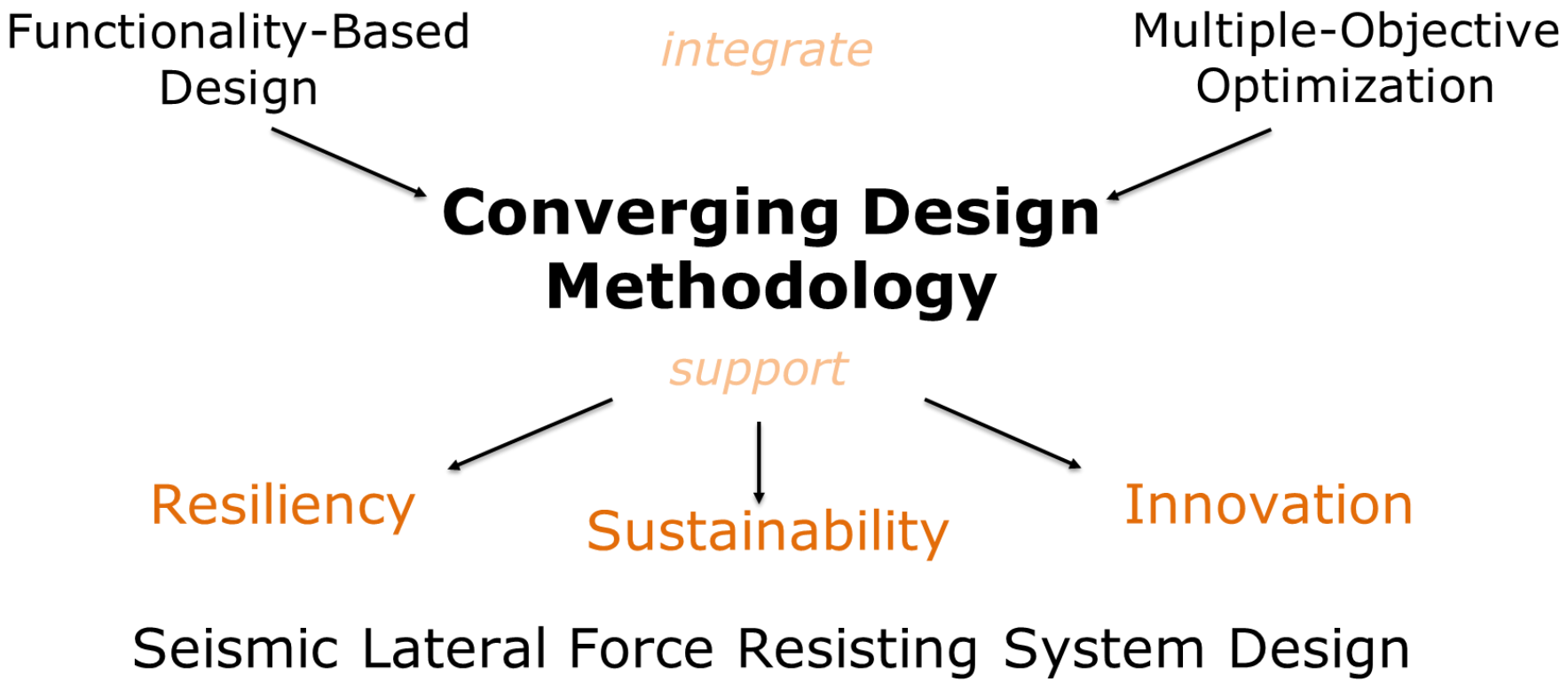
This project



6 2023

Overarching Aim:

Integrate functionality-based design and multiple-objective optimization into a single converging design methodology to support resilient, sustainable seismic designs of innovative lateral force resisting systems



IM 1: Define functional recovery and sustainability metrics

- quantification of uncertainty,
- design of innovative lateral force-resisting systems employing mass timber solutions

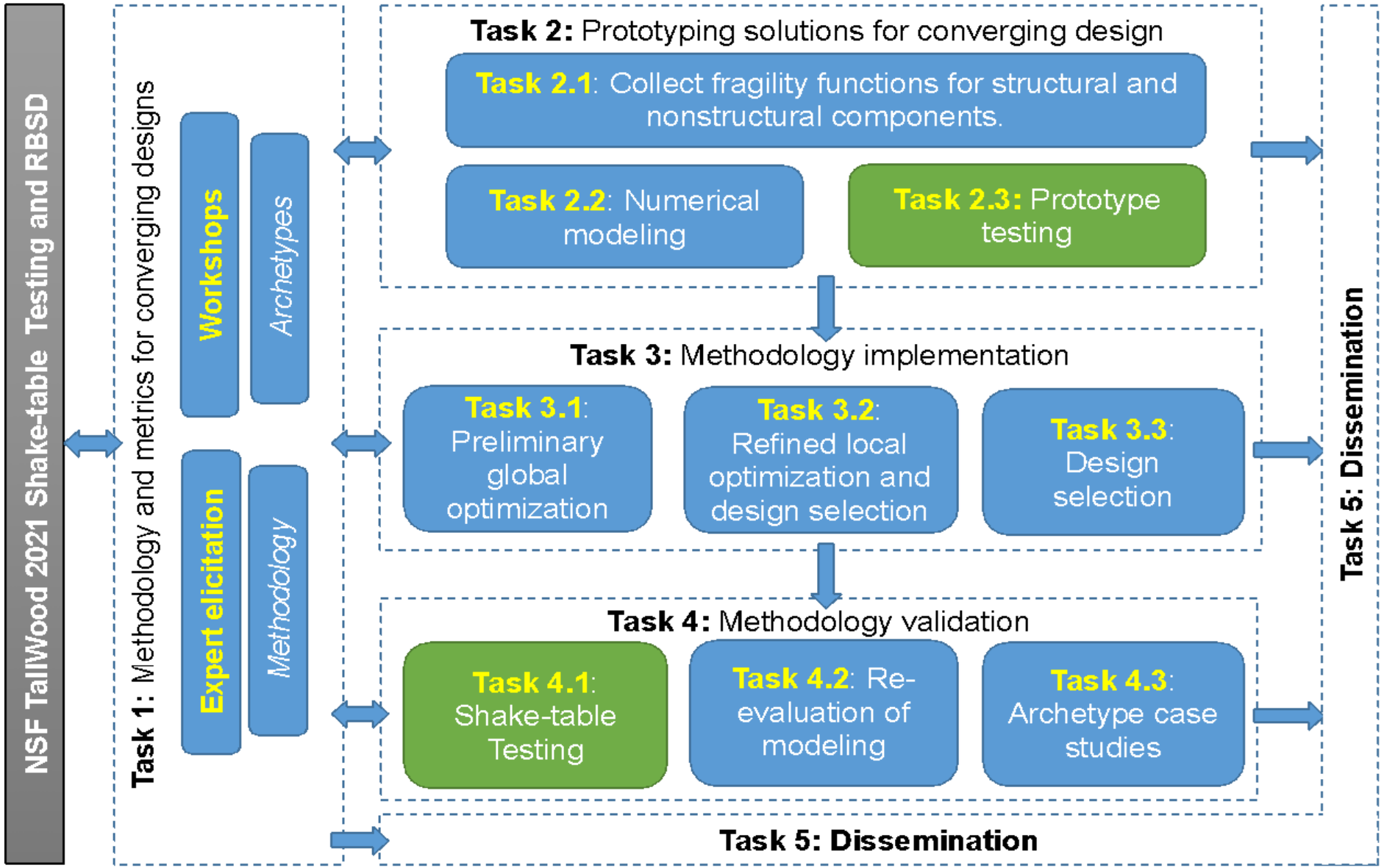
IM 2: Create and implement multi-objective optimization in a *converging seismic design methodology*

- Resiliency and sustainability goals integration in the design process

IM 3: Develop optimized seismic lateral force resisting systems

- Performance validation with 6-story test

Work Plan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Principal Investigators

Dr. Andre Barbosa
OSU

Office phone:
(541) 737-3052
Email:
andre.barbosa@oregonstate.edu

Dr. Arijit Sinha
OSU

Office phone:
(541) 737-6713
Email:
arijit.sinha@oregonstate.edu

Dr. Barbara Simpson
Stanford

Office phone:
(314) 941-2222
Email:
bsimpson@stanford.edu

Dr. Nathan Brown
PSU

Office phone:
(814) 863-9305
Email:
ncb5048@psu.edu

Dr. John van de Lindt
CSU

Office phone:
(970) 491-6697
Email:
jwv@engr.colostate.edu

Funded Students

Steven Kontra
OSU
Email: kontras @oregonstate.edu

Patricio Uarac
OSU
Email: uaracpip @oregonstate.edu

Jace Furley
CSU
Email: jace.furley @colostate.edu

Prashanna Mishra
CSU
Email: prashanna.mishra @colostate.edu

Other Members

Hossein Zargar
PSU
Email: szz188 @psu.edu

Dr. Tu Ho
OSU
Email: tu.ho @oregonstate.edu

Fernando Orozco
OSU
Email: gustavo.orozco @oregonstate.edu

Gustavo Araujo
OSU
Email: gustavo.araujo @oregonstate.edu

Project Collaborators

Dr. Shiling Pei
CSM

Email:
spei@mines.edu

Reid Zimmerman
KPFF

Email:
reid.zimmerman@kpff.com

Eric McDonnell
Holmes

Email:
eric.mcdonnell@holmes.us

Dr. Mark Fretz
UO

Email:
mfretz@uoregon.edu

Emily Dawson
Kaiser + Path

Email:
emily@kaiserpath.com

Project Advisory Committee

Design Optimization and Construction

William Silva
- Swinerton

Jonathan Heppner
- Lever Architecture

Alessandro Beghini
- SOM

Code and Regulatory

Amit Kumar
- City of Portland

Douglas Rammer
- Forest Products Lab

Siamak Sattar
- NIST

Phil Line
- AWC

Wood, Steel, & Concrete Industry

Patrick Farrell
- Freres

Scott Breneman
- Woodworks

Steve Pryor
- Simpson Strong-Tie

Glenn Bell
- Pankow Foundation

Daniel Cheney
- Boise Cascade

International Collaboration and Outreach

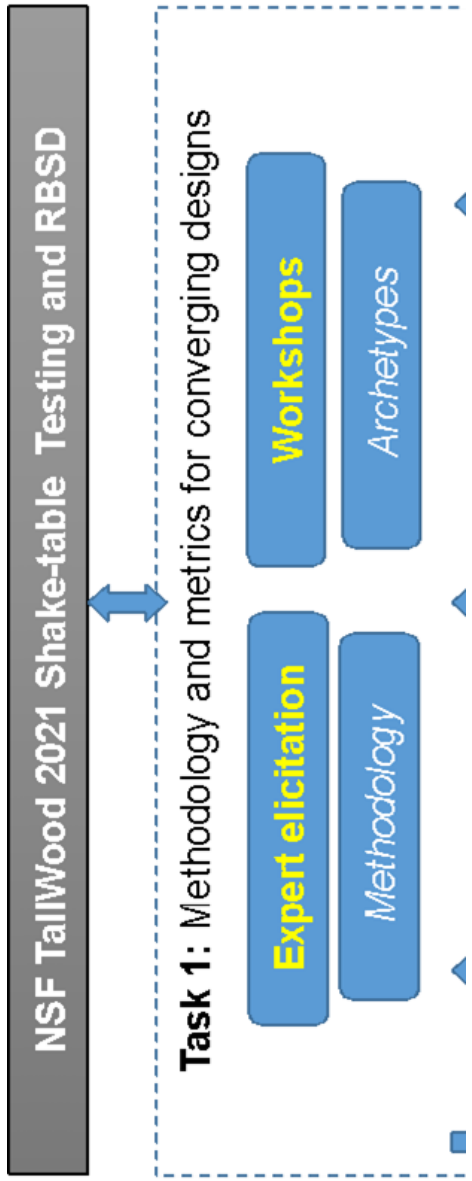
Thomas Tannert
- UBC, Canada

Masahiro Kurata
- Kyoto U, Japan

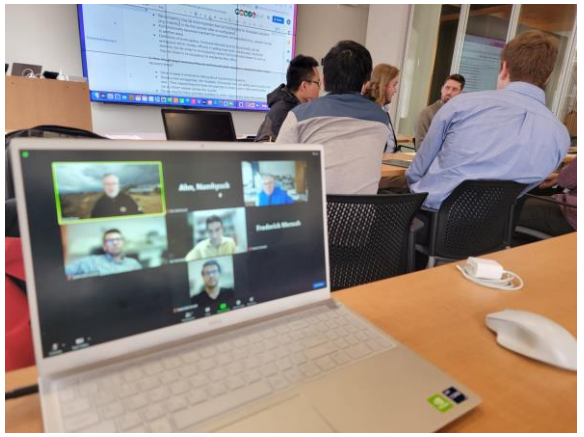
Alessandro Palermo
- UC, New Zealand

Massimo Fragiacomo
- U L'Aquila, Italy

Task 1 – Expert Elicitation



1. Functional Recovery Workshop 1 (April 2022), International Mass Timber Conference.

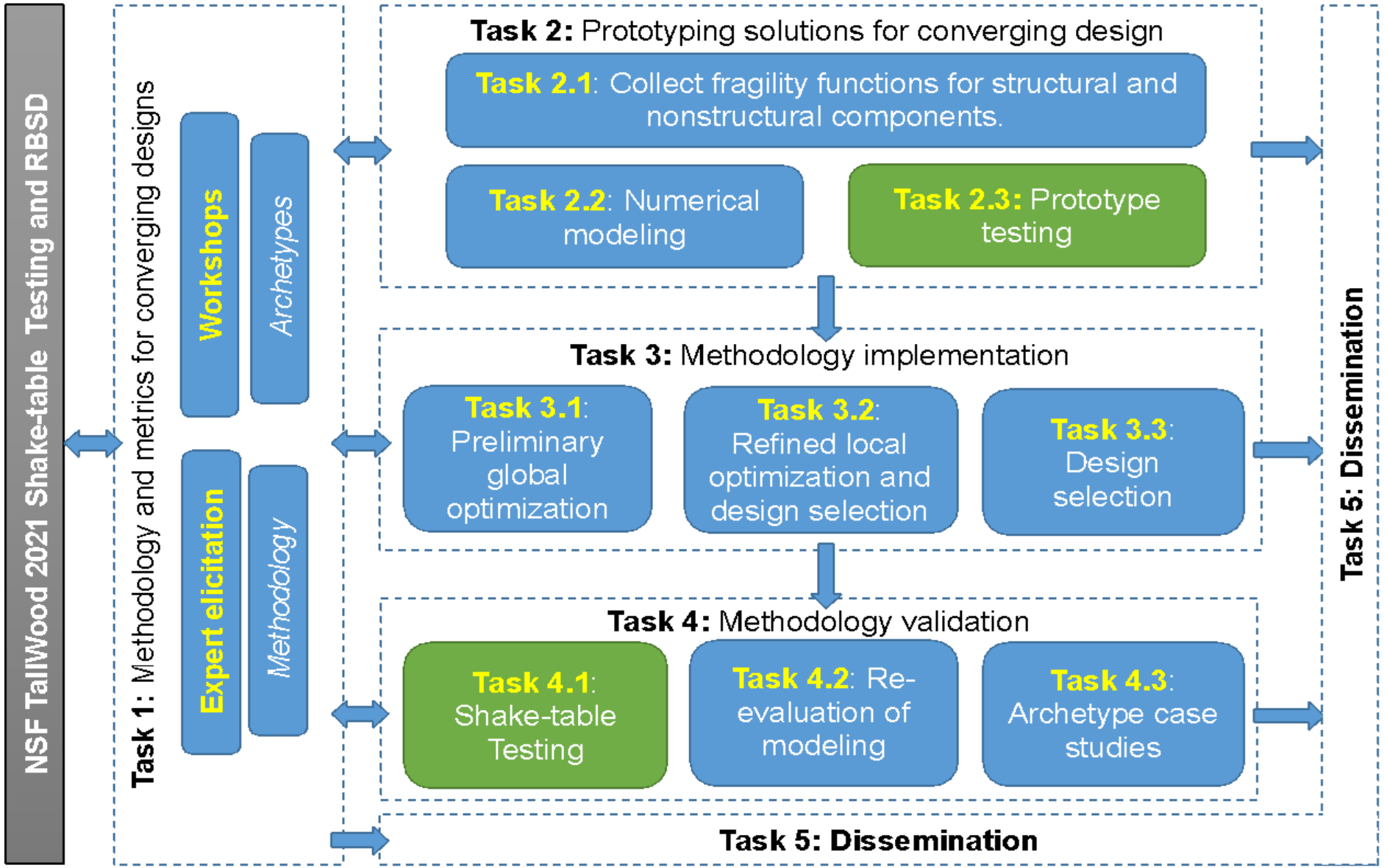


2. Sustainability Workshop (September 2022) held at the Forest Products Lab

SEI STRUCTURAL ENGINEERING INSTITUTE ASCE | SE2050 COMMITTING TO NET ZERO

3. ATC Functional Recovery Workshop (August 2022)
4. Sustainability Survey (February 2023)
5. Functional Recovery Workshop 2 (April 2023)
6. Sustainability Workshop 2 (TBD)

Task 2.3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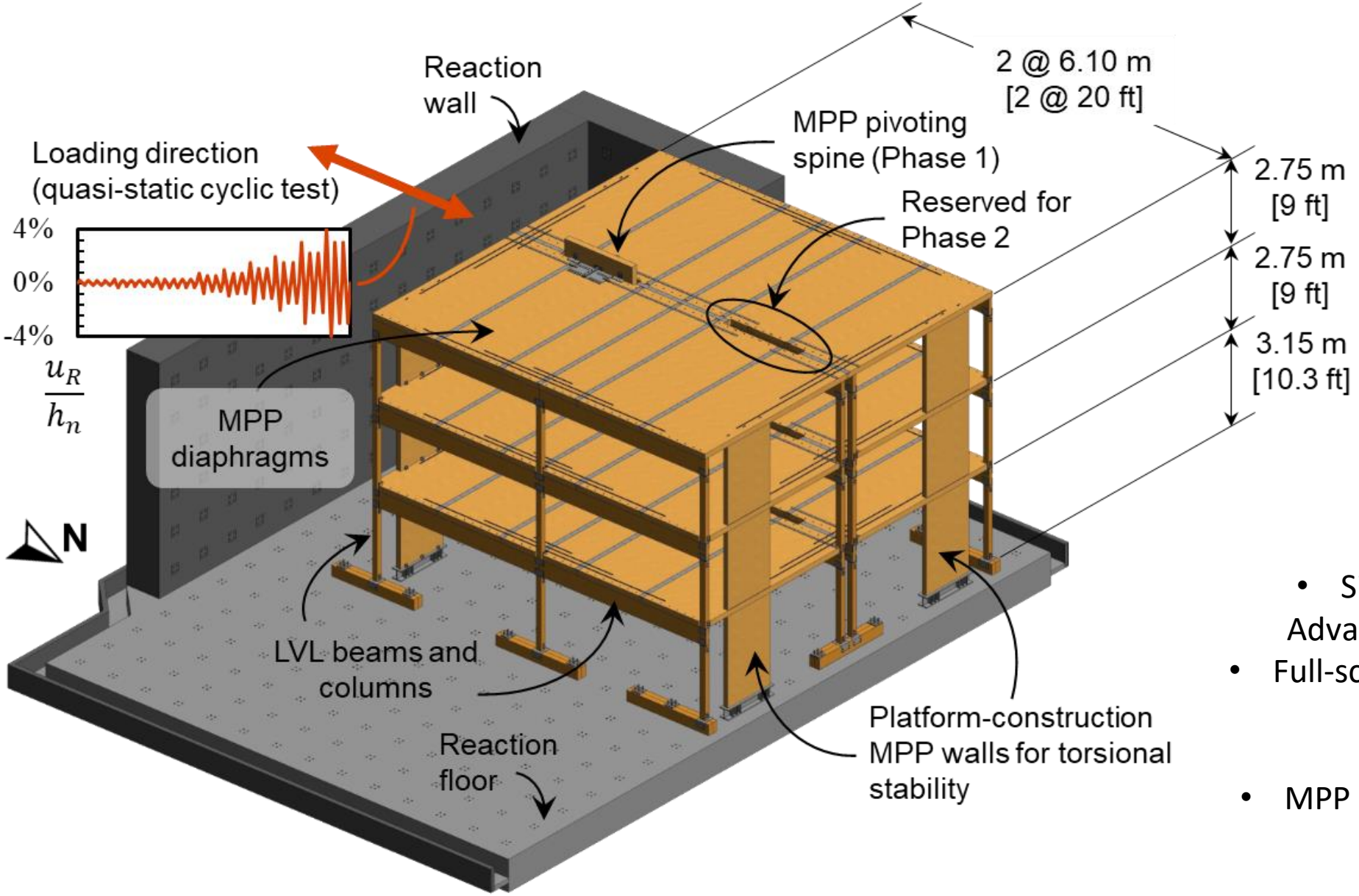
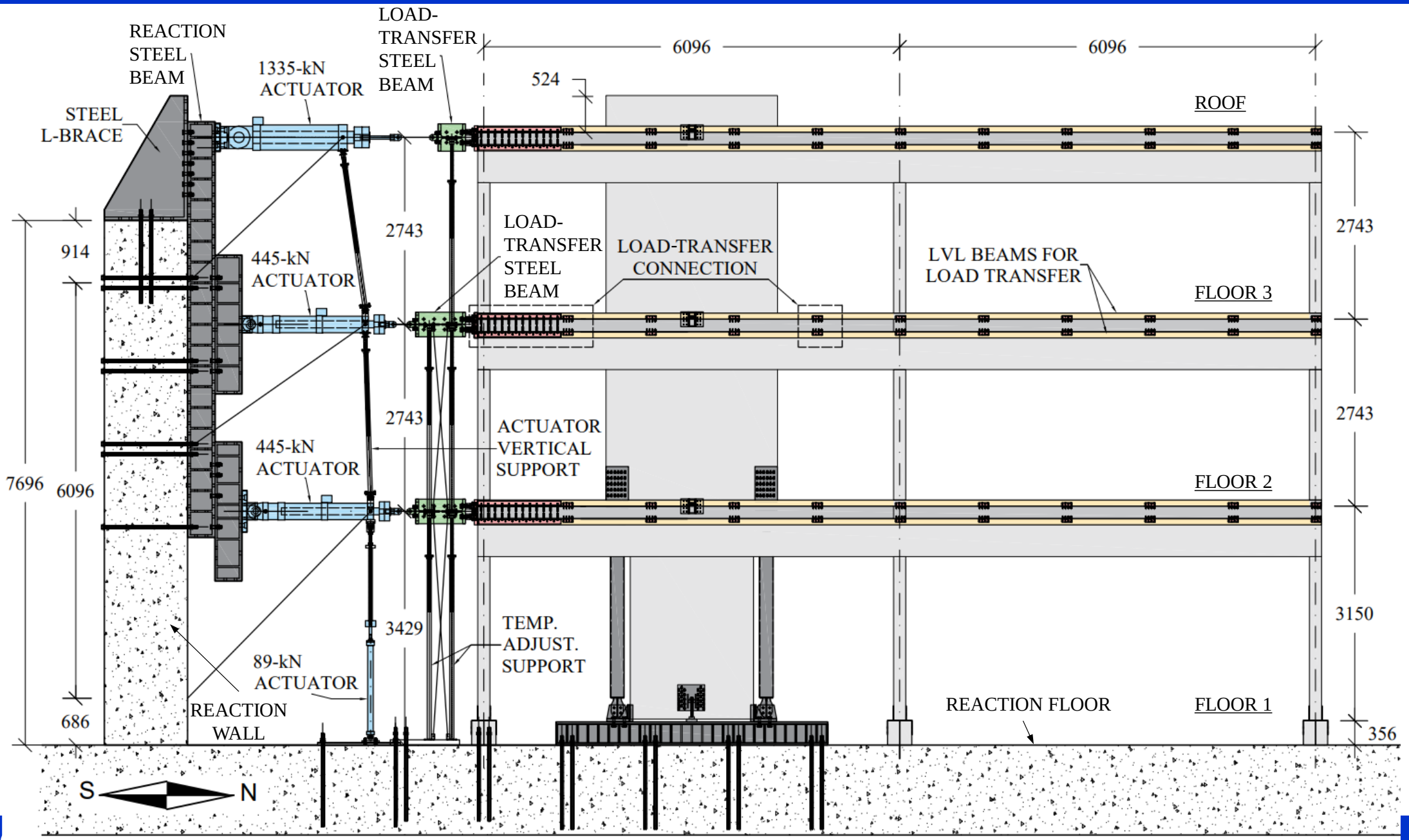
Task 2.3 – Prototype Testing (Phase I)

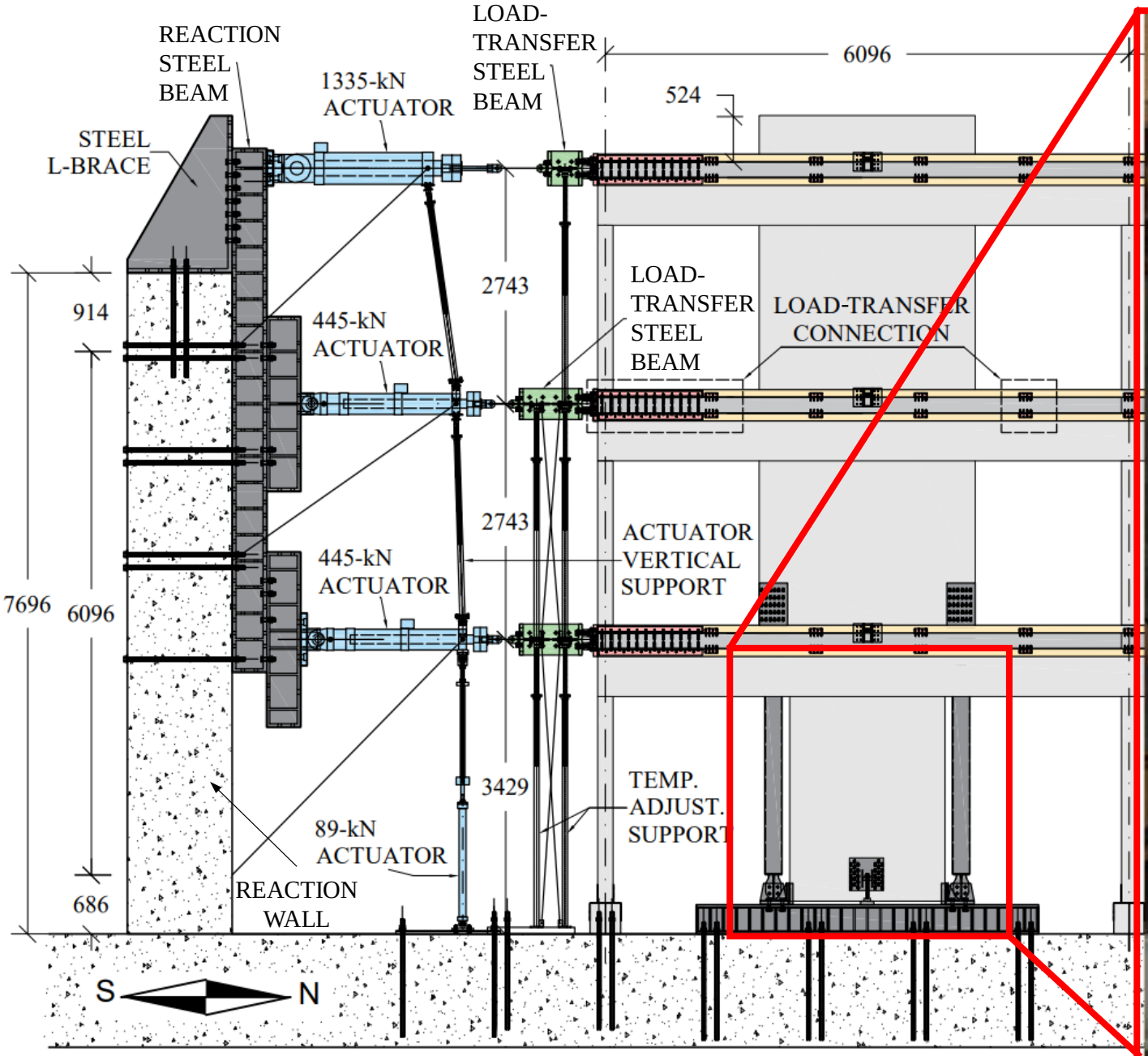


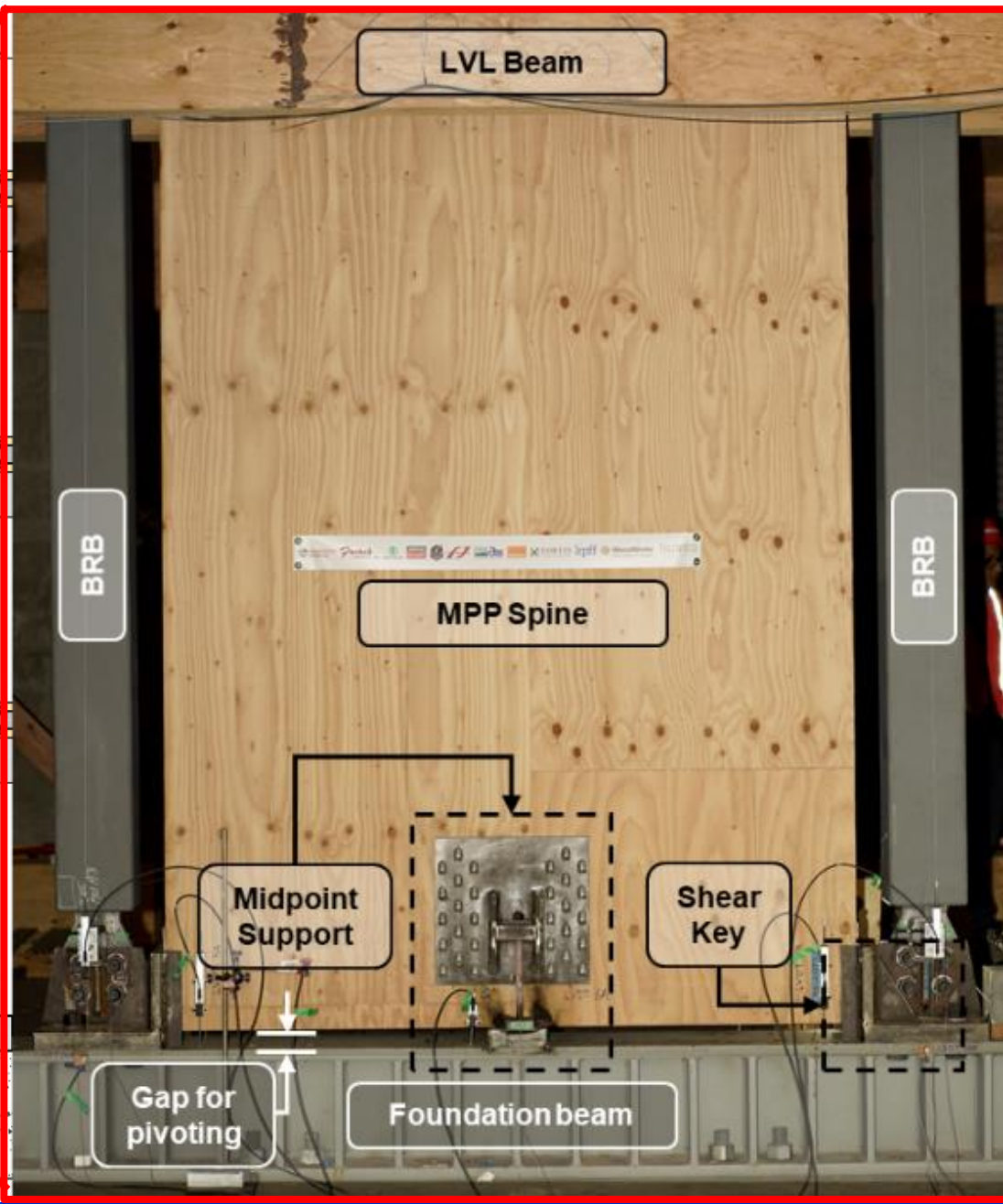
- Signature test at OSU's Emmerson Advanced Wood Products Laboratory.
- Full-scale 3-story mass timber building.
  - LVL gravity framing.
  - MPP one-way slabs.
- MPP wall with BRB energy dissipators.

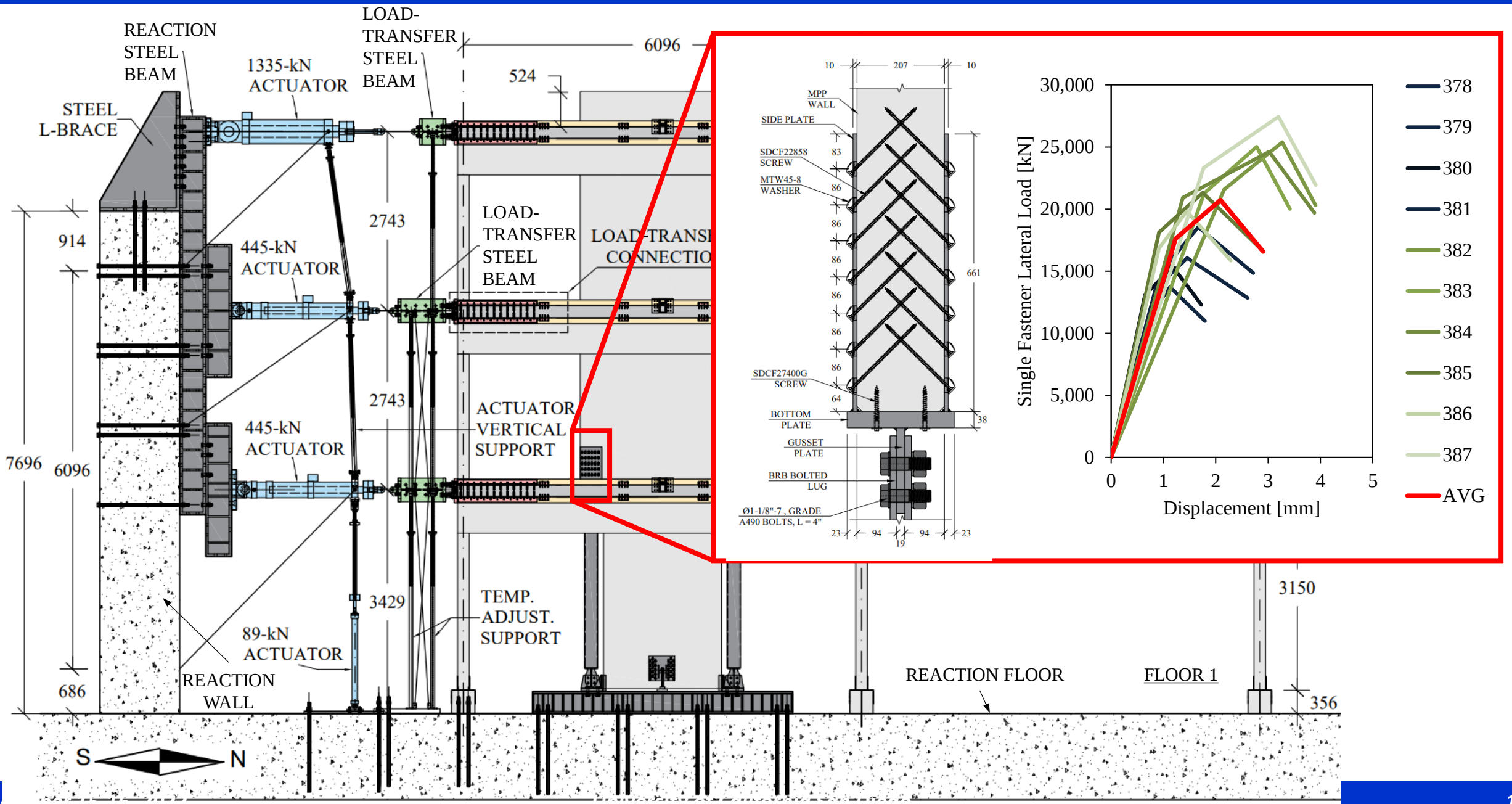
Experimental Setup: Elevation



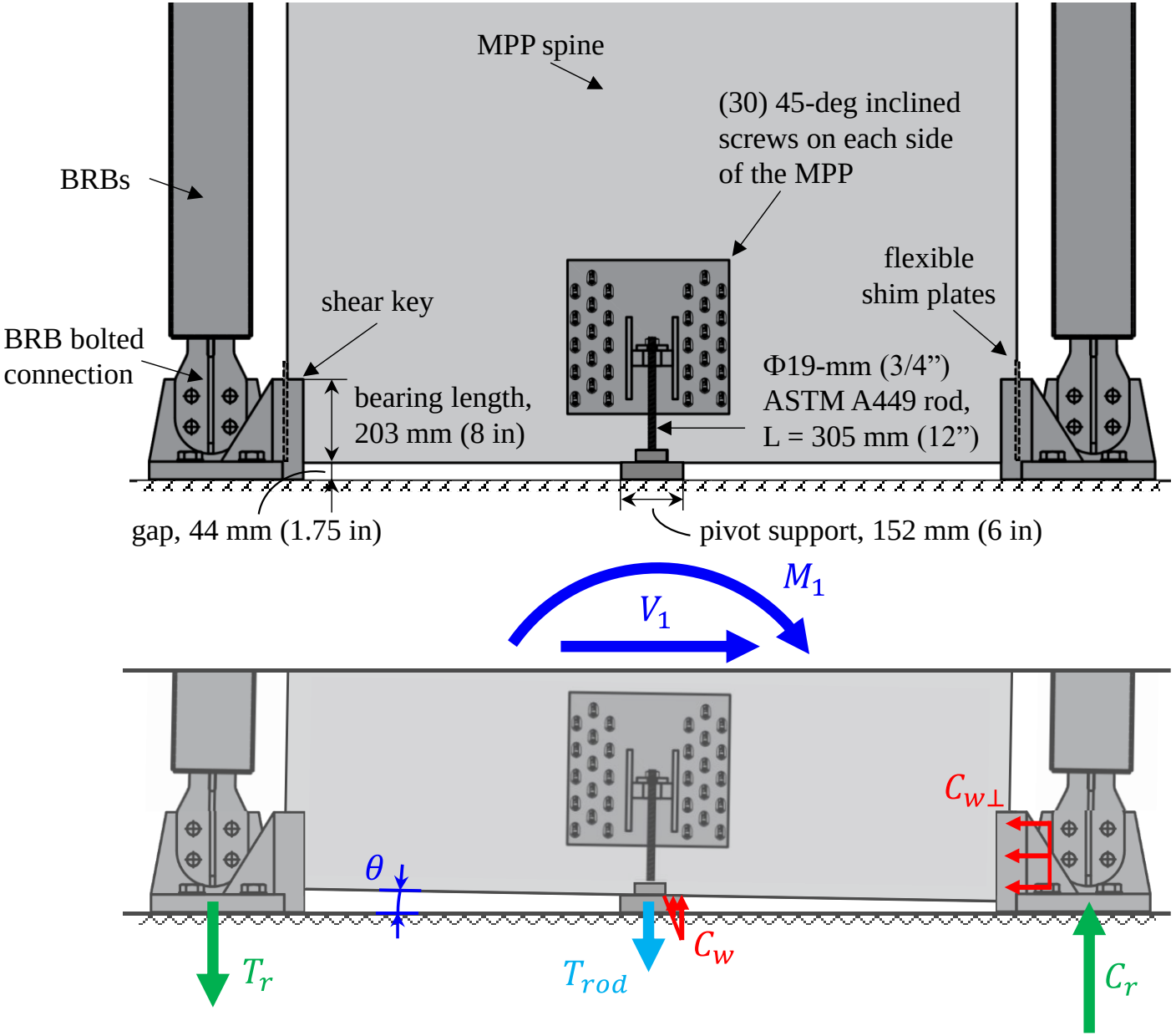
Experimental Setup: Elevation

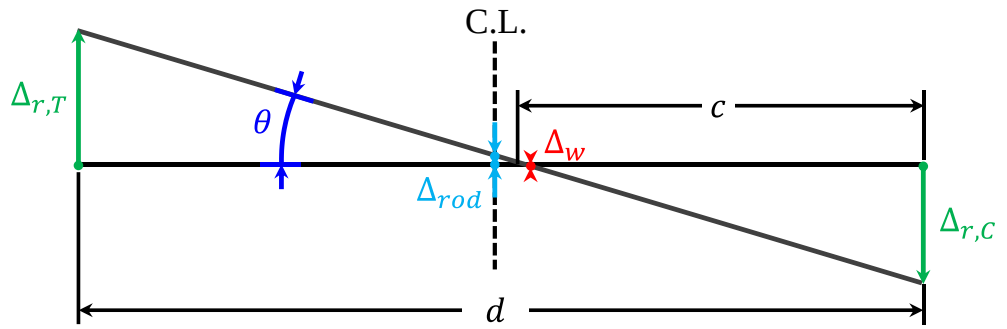




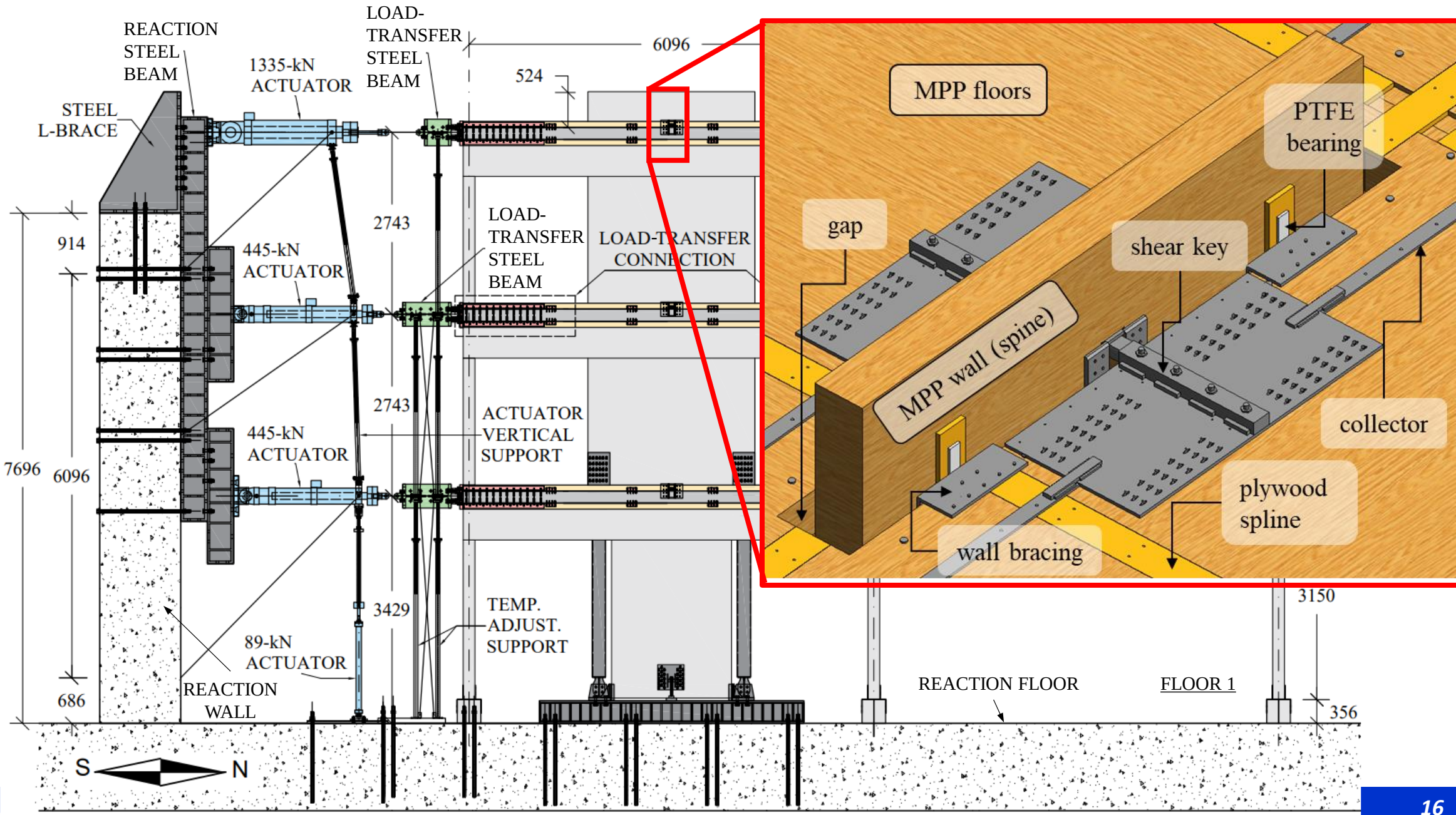

REACTION STEEL BEAM
1335-kN ACTUATOR
LOAD-TRANSFER STEEL BEAM
6096
524
STEEL L-BRACE
914
2743
LOAD-TRANSFER STEEL BEAM
445-kN ACTUATOR
2743
ACTUATOR VERTICAL SUPPORT
445-kN ACTUATOR
7696
6096
3429
TEMP. ADJUST. SUPPORT
89-kN ACTUATOR
686
REACTION WALL
REACTION FLOOR
FLOOR 1
3150
356
S
N
10
207
10
MPP WALL
SIDE PLATE
SDCF22858 SCREW
MTW45-8 WASHER
83
86
661
SDCF27400G SCREW
64
38
BOTTOM PLATE
GUSSET PLATE
BRB BOLTED LUG
Ø1-1/8"-7 , GRADE A490 BOLTS, L = 4"
23
94
94
23
19
Single Fastener Lateral Load [kN]
30,000
25,000
20,000
15,000
10,000
5,000
0
0
1
2
3
4
5
Displacement [mm]
378
379
380
381
382
383
384
385
386
387
AVG

Diaphragm-to-Wall Connection

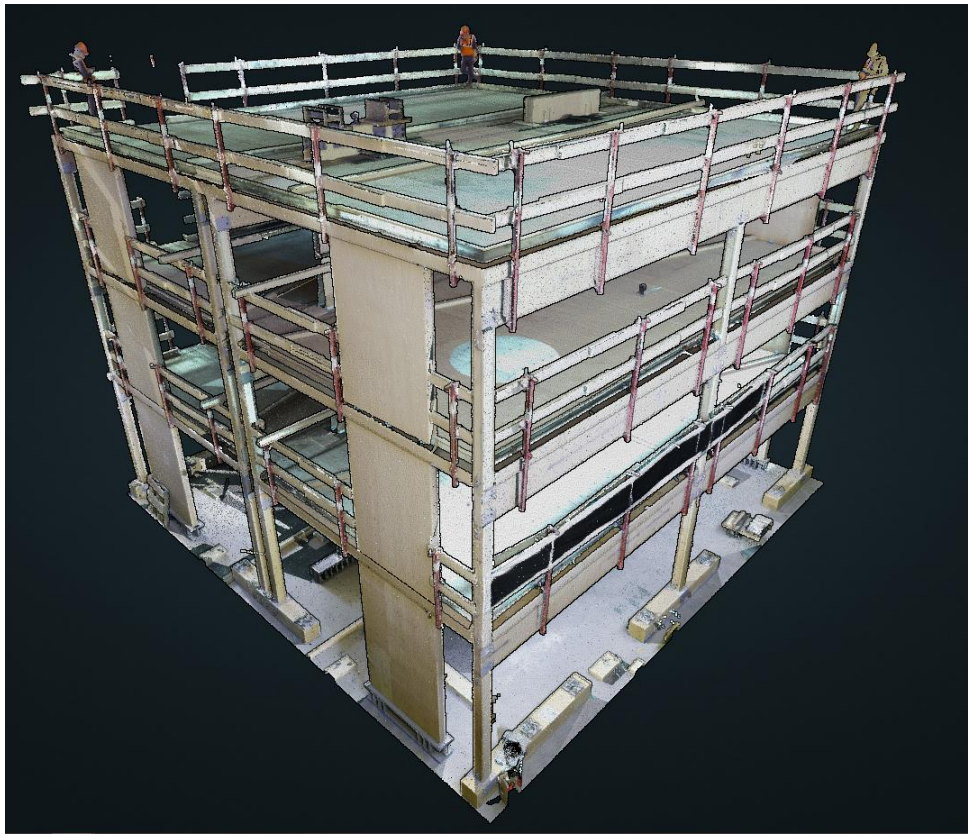




Experimental Setup: Elevation

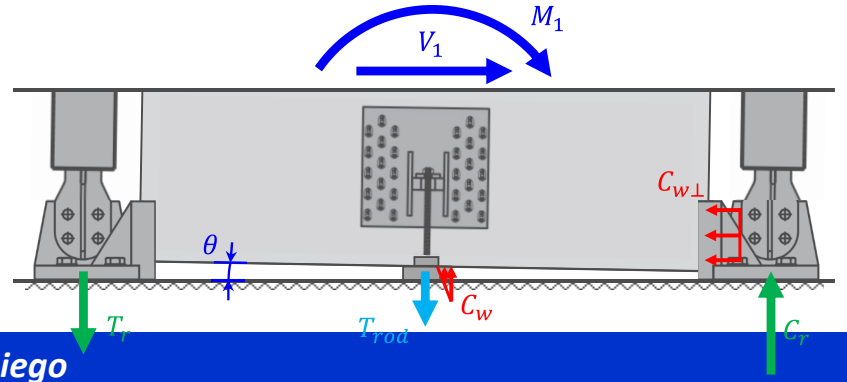


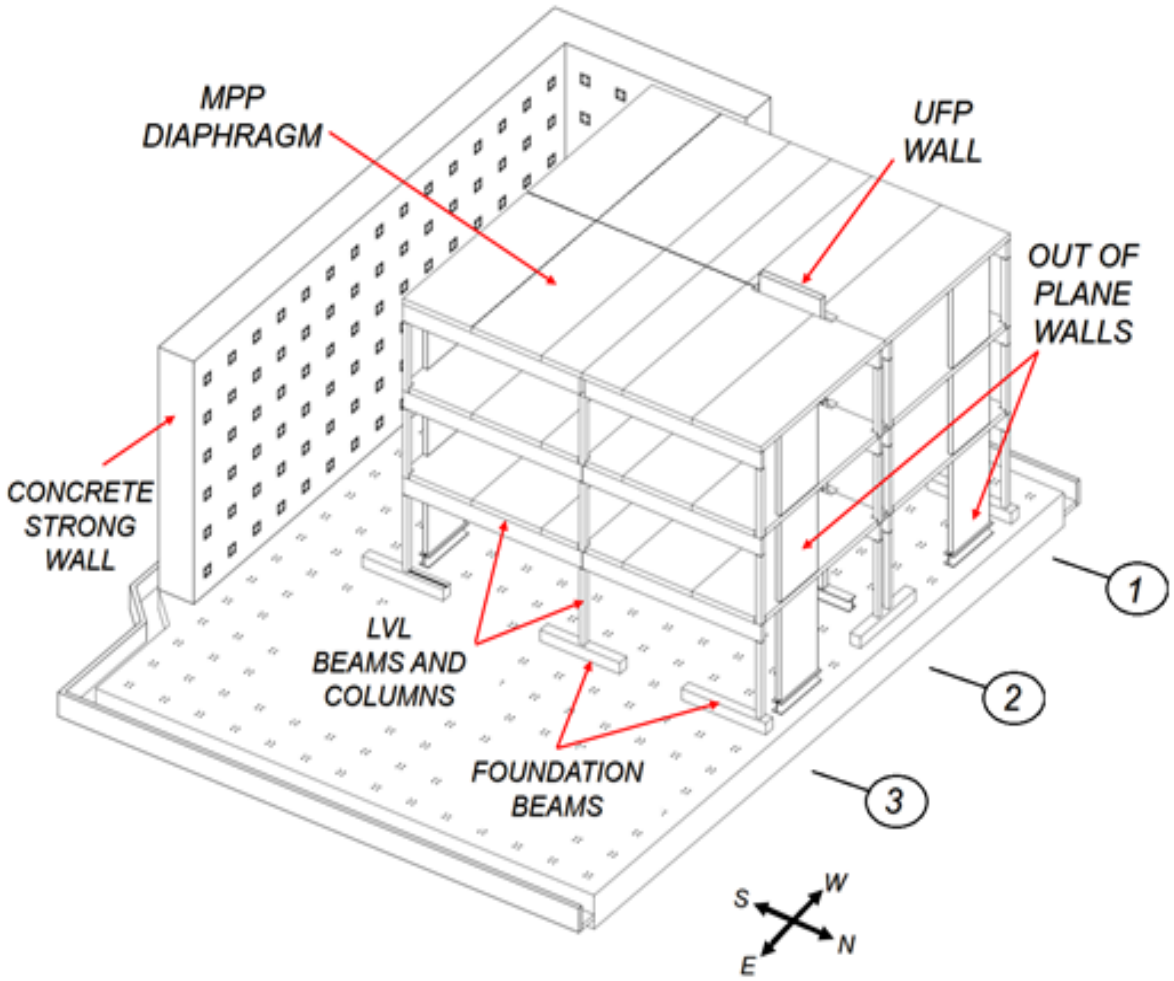
Documentation of As-Builts through Laser Scanning

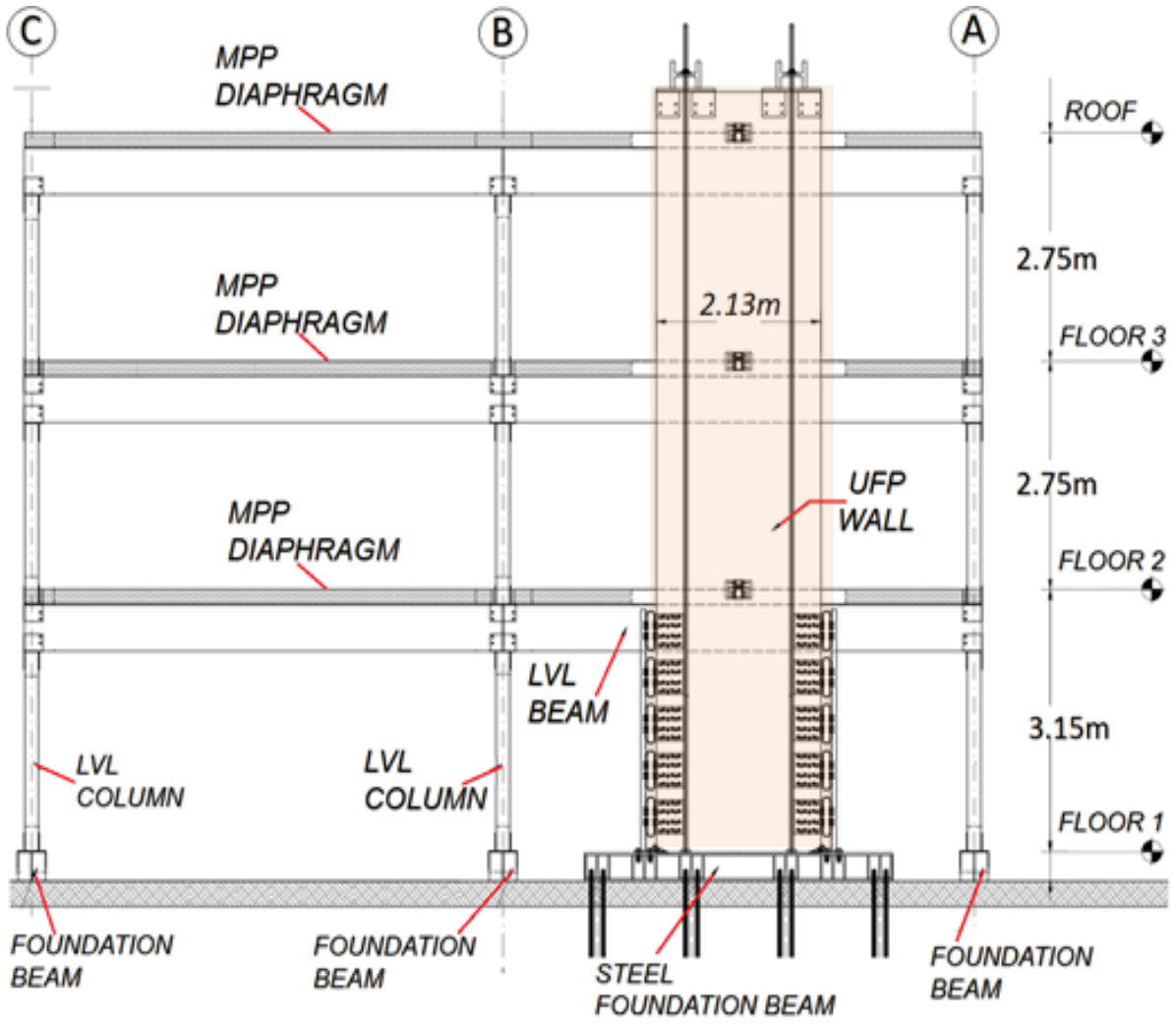


Potree Viewer: https://bit.ly/3Kpwqzc
Youtube video: https://www.youtube.com/watch?v=GheGriNTeSM&t=3s

Task 2.3 – Prototype Testing (Phase I)







Stay tuned: Testing January 12 and 13, 2023

Shake-Table Specimen Reuse Opportunity

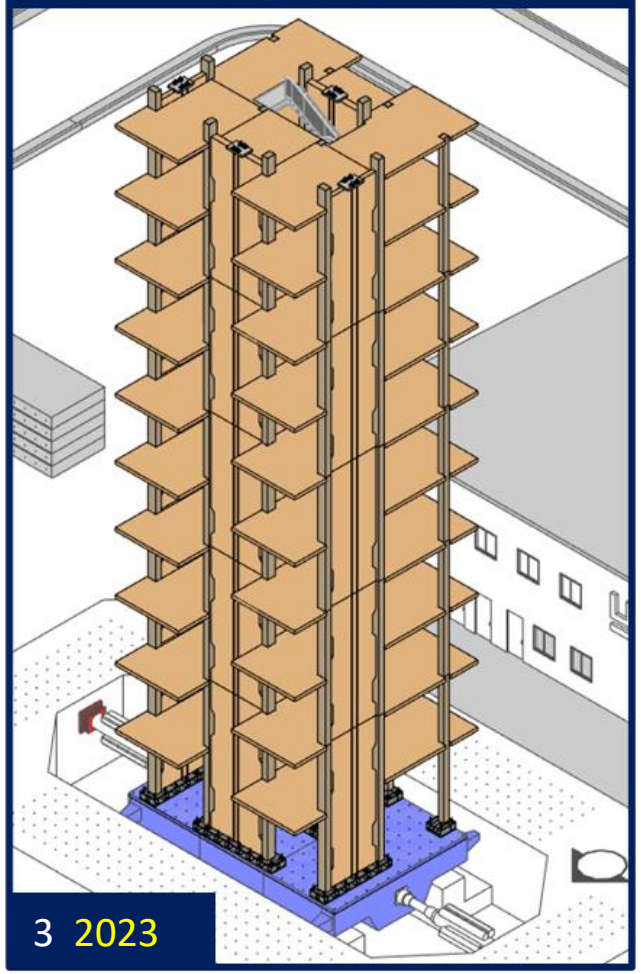
NSF TallWood Project | USDA-ARS

1 2017

USDA-ARS

2 2022

NSF 10-story TallWood Project



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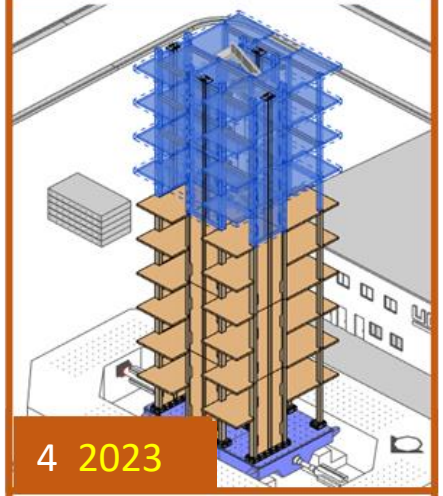
NSF 6-story Project



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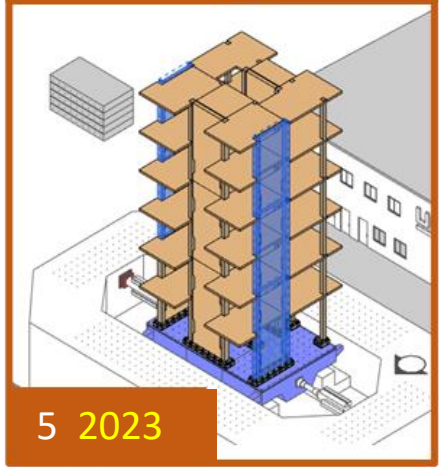
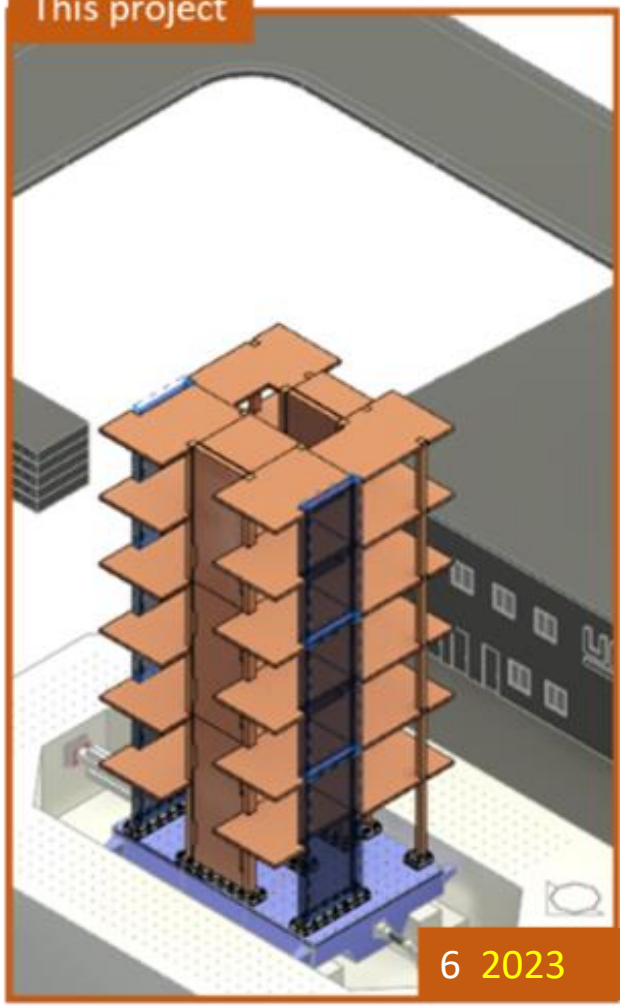


5 2023

This project



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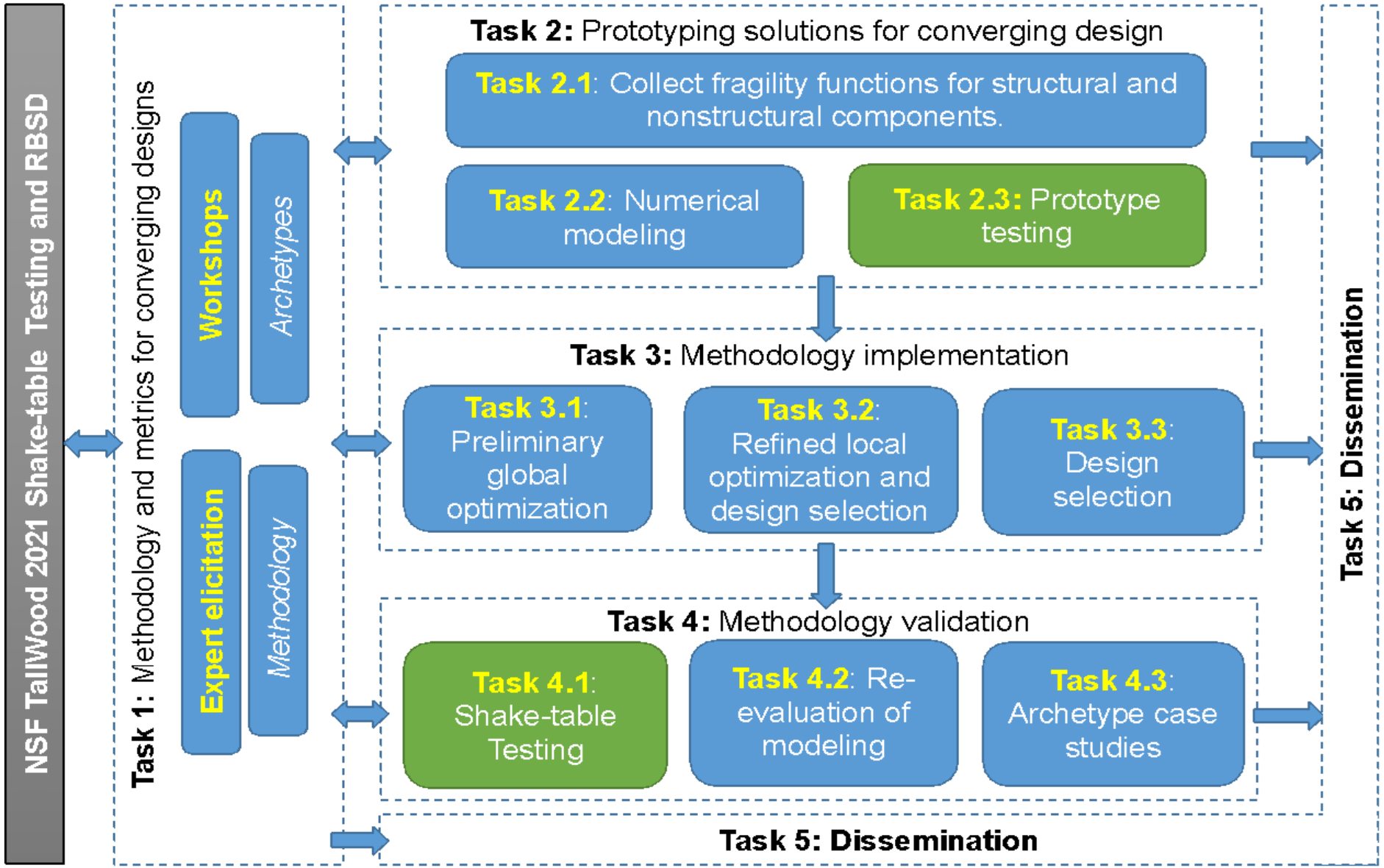
Task 2.3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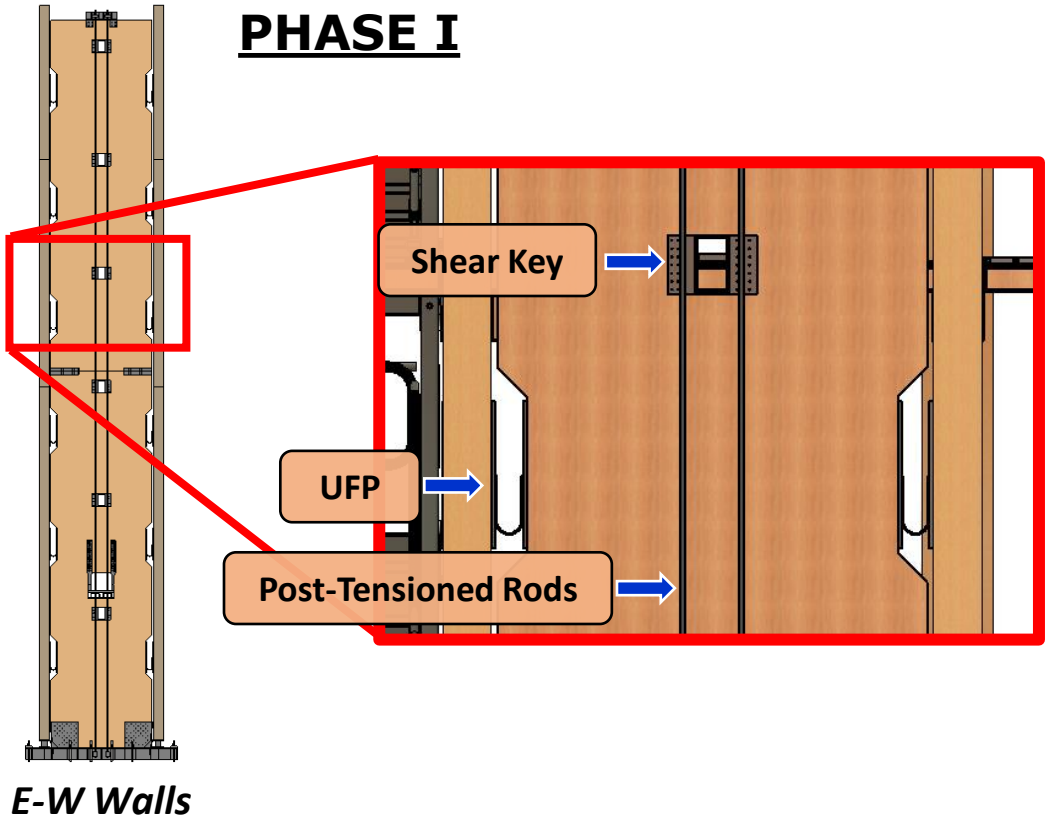
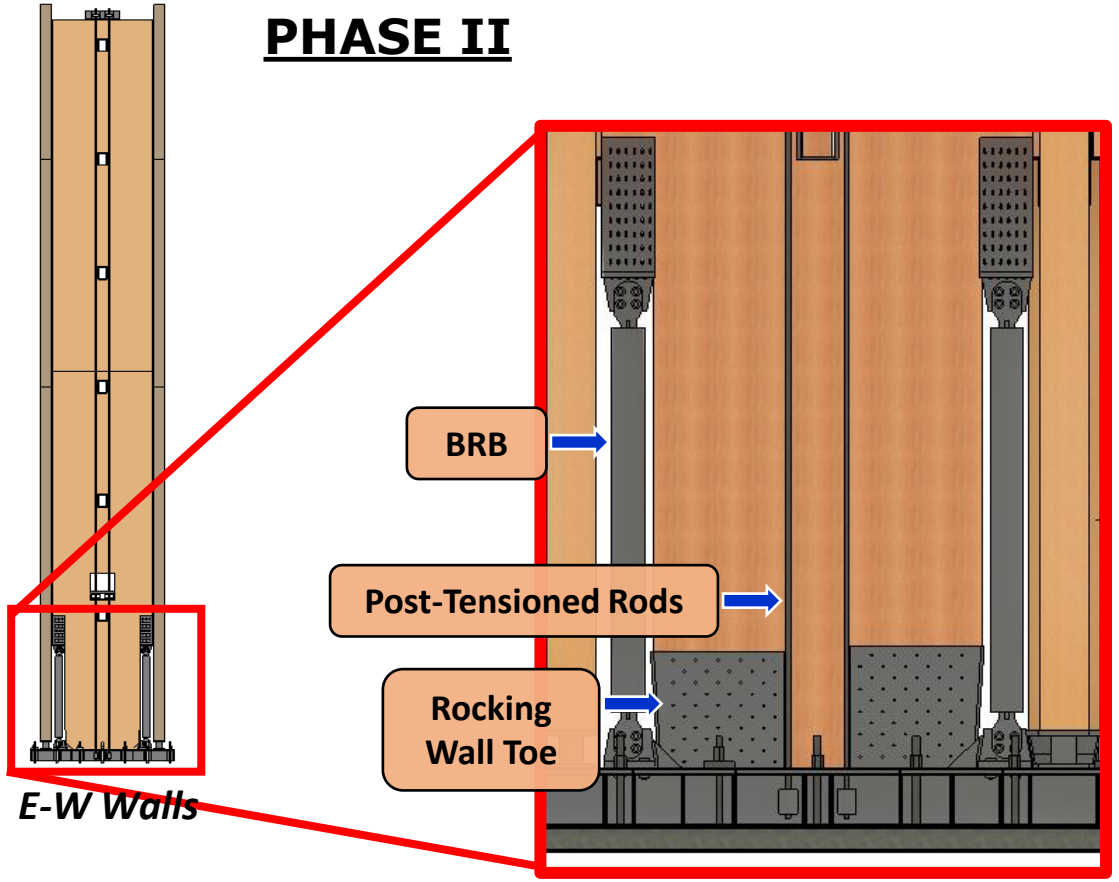
Shake-table testing will be conducted in three phases featuring:

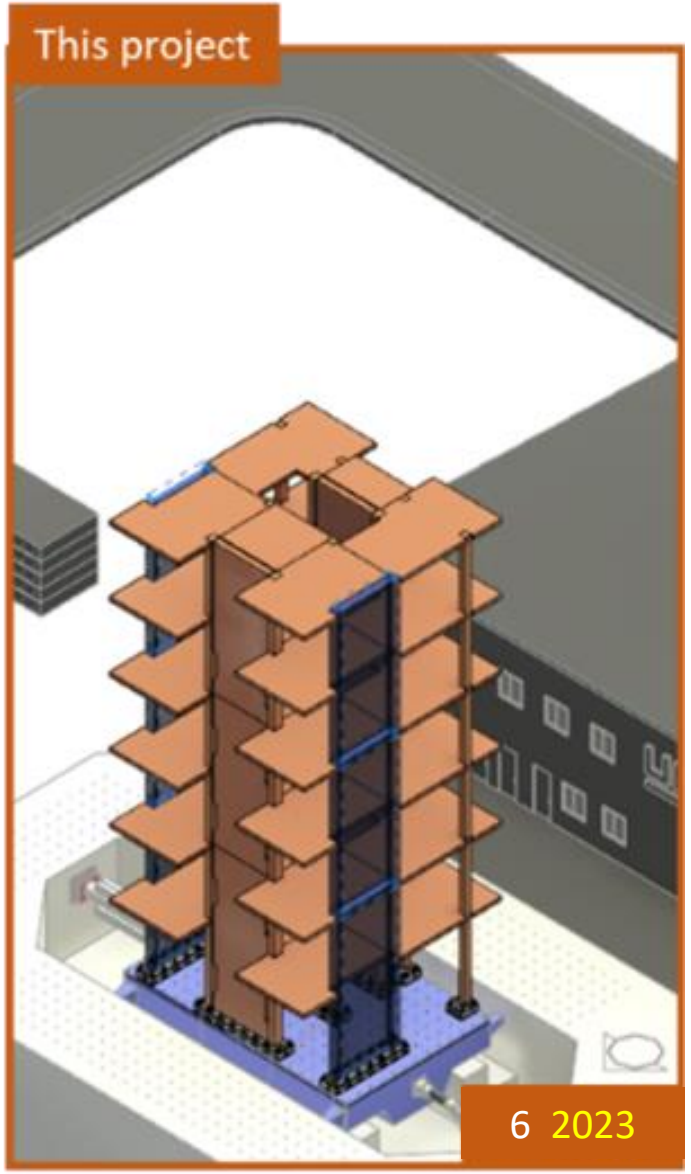
(1) Mass Timber Wall with U-Shaped Flexural Plates (UFP),
(2) Mass Timber Wall with Buckling Restrained Braces (BRB), and
(3) Steel Braced Frame with Innovative BRBs.





PHASE III

Courtesy of Steve Pryor @ Simpson Strong-Tie



Milestones

07/2017: Two-story Shake-table Test

08/2018: 3-story and 6-story Proposal Ideation

02/2019: USDA-ARS 3-story Proposal Submitted (Phases I and II)

10/2020: 3-story Designs Completed

12/2020: NSF 6-story Proposal Submitted (Phases I and II)

11/2021: NSF 6-story Kickoff Meeting

03/2022: NSF 6-story PAC Kickoff Meeting

04/2022: Functional Recovery Workshop

09/2022: Sustainability Metrics Workshop

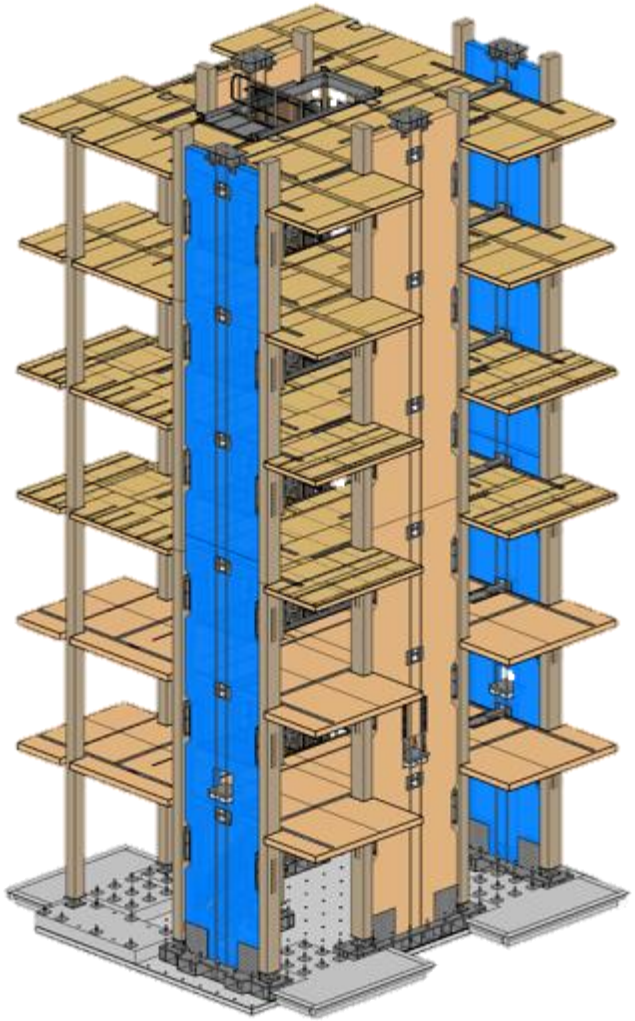
09/2022: Phase I Design Completed / Bids (UFP Wall)

10/2022: Contractor Meetings

10/2022: Phase III Ideation

11/2022: Phase II Design Completed / Bids (BRB Wall)

11/2022: Phase III Approved



Takeaways

- Timeline – things take time
  - Specimen re-use is possible but takes significant effort and collaboration
- Costs
  - 1 unit NSF to 3 units from additional sources (materials donations, etc.)
- Co-production:
  - (1) academic collaborators, (2) industry partners, (3) leveraging of other large projects makes these tests feasible
- Trust and Effective Collaborations/Partnerships is key.. Also takes time
- Future use of panels? the 10-story and 6-story structure shake-table will allow us to test demolition protocols and potential re-use of materials

National Science Foundation

Stay tuned…

Questions?

andre.barbosa@oregonstate.edu

Acknowledgments:

- This project is being executed under the National Science Foundation CMMI award numbers 2120683, 2120684, 2120692.
- Support from the TallWood Design Institute/USDA Agricultural Research Service Award 58-0204-9-165 are also acknowledged
- The findings, opinions, recommendations, and conclusions in this presentation do not necessarily reflect the views of others, including the sponsors.