National Science Foundation

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

UC San Diego JACOBS SCHOOL OF ENGINEERING Structural Engineering

Modular Test Bed Building (MTB2): A Reconfigurable Shared-Use Equipment Resource for use by Researchers at LHPOST6

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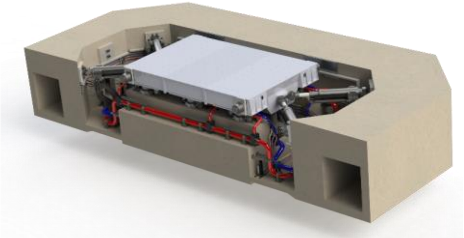

NHERI@UC San Diego User Training Workshop

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

Making it Happen: Team

- University of California San Diego & University of Utah
- Industry Partners

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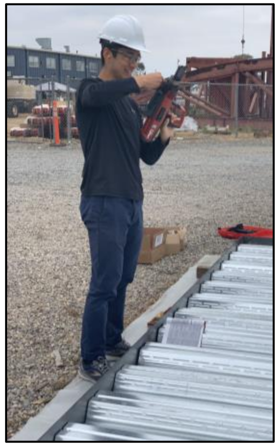
Gilberto Mosqueda

Michael Morano



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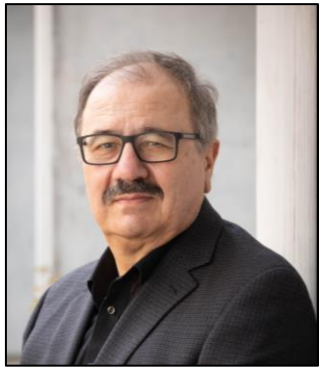

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THE RESILIENT SEISMIC SOLUTION

http://chei.ucsd.edu/MTB2/index.html

Additional Industry Partners

SME STEEL

NUCOR®

AMERICAN INSTITUTE OF STEEL CONSTRUCTION
AISC
FOUNDED 1921

HILTI

Atlas Tube

LeJEUNE
BOLT COMPANY

ASBURY STEEL

VERCO DECKING, INC.
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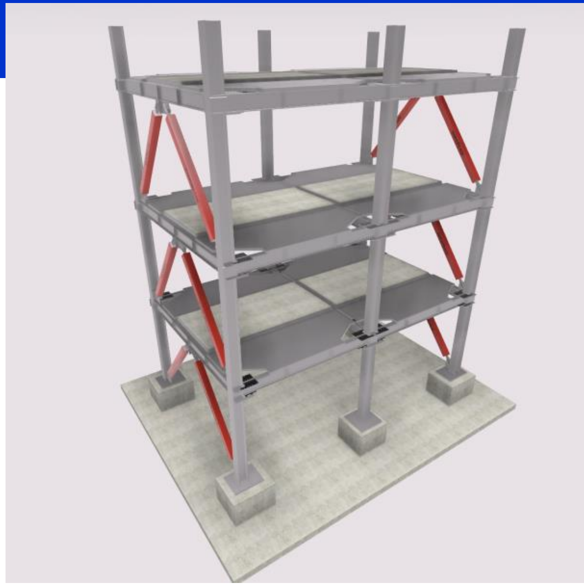
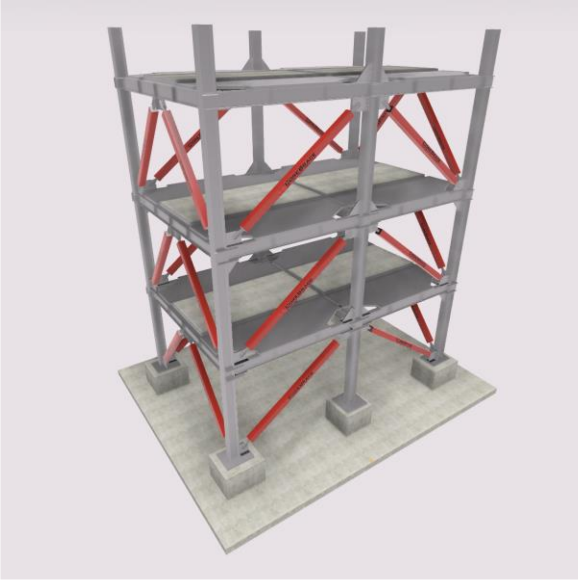
Design Scope

- **Community-available building for NHERI users:**
  - New infrastructure to contribute to NHERI@UC San Diego & shared-users of NHERI EF
  - First structure to be tested on newly upgraded LHPOST6
- **Evolution:**
  - Community input via NHERI workshops
  - Inception from prior research & proposals to investigate NCSs
  - Partnership amongst Academe & industry
- **Unique features:**
  - Designed to be reconfigurable & reusable with low-cost replaceable nonlinear fuse elements and simple removable floor system
  - Enabling low-cost testing of components & systems under simulated dynamic 3D loading
  - Provide a *vehicle to deliver seismic loads & displacements* to elements of interest

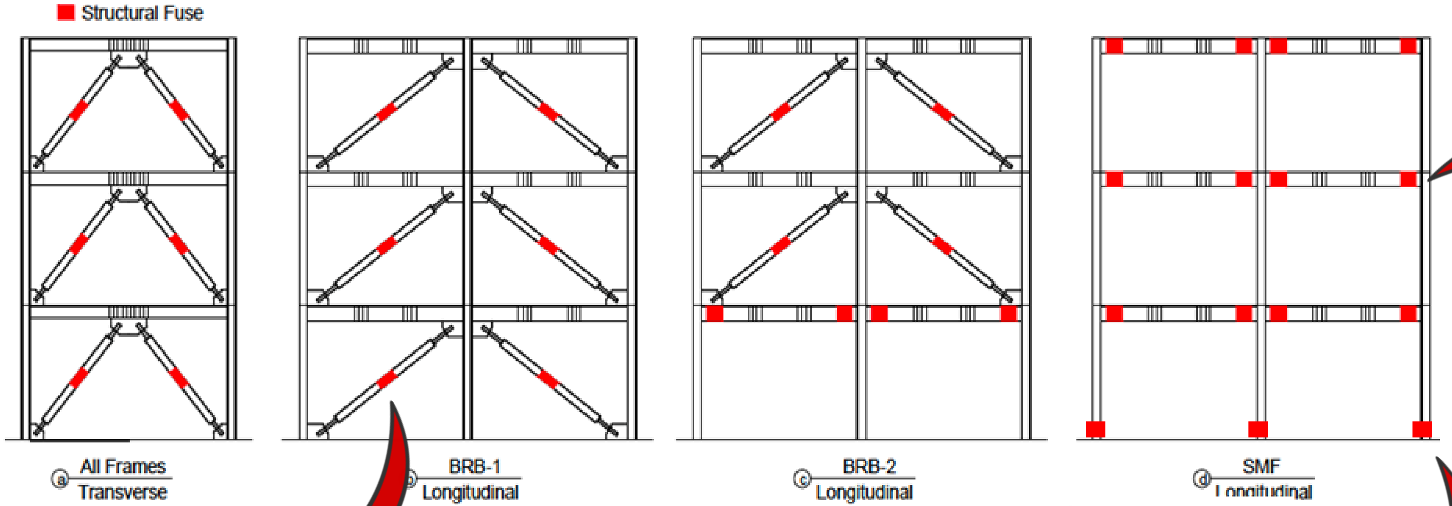


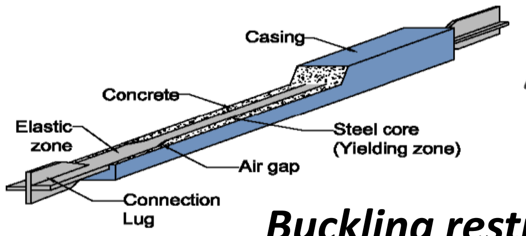


Design Features

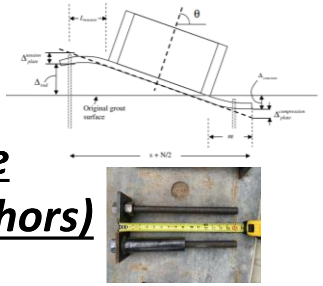
Reconfigurable 3-D full-scale three-story steel building designed to accommodate a wide range of seismic behavior of buildings:

1) Moment frame behavior with **shear fuse** type plastic hinges
2) **Compliant base** to alleviate moment demands at beam joints (coupled with 1)
3) Braced frame behavior with **buckling restrained braces** (BRBs) at built-in gusset plates at joints

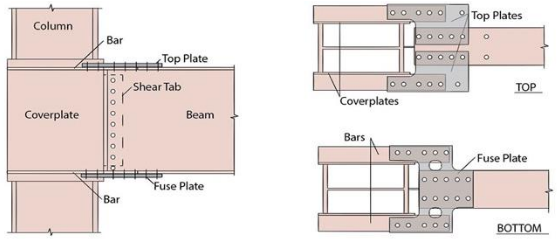




<u>Buckling restrained braces</u>

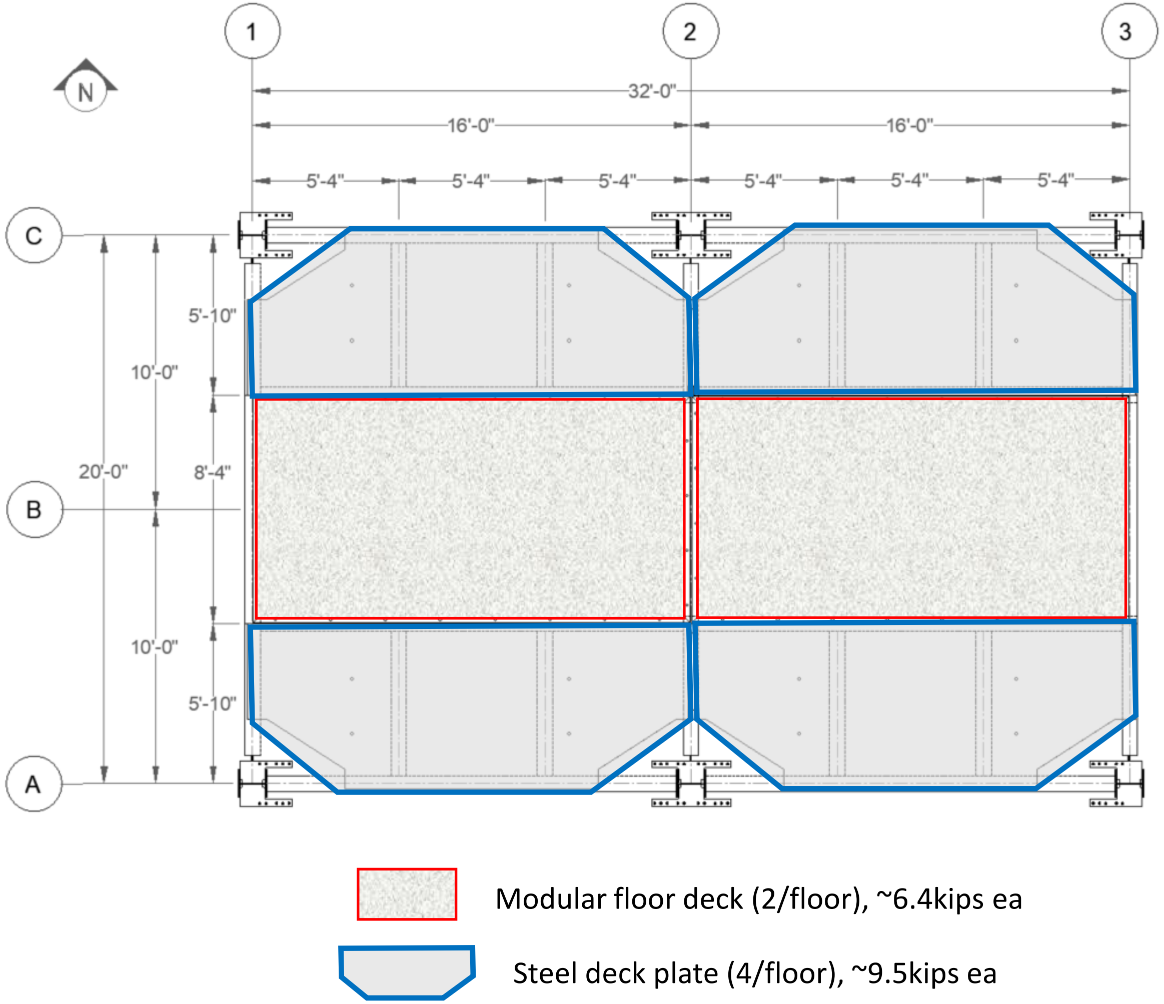


<u>Compliant base (stretch-length anchors)</u>



<u>Special moment frame joints (shear fuses)</u>

- All-hot rolled steel framing system
- Simple floor plan, accommodate geometry directly atop LHPOST
- Simple foundation footprint, straight-forward tie-down to LHPOST6
- Modular nonlinear fuse components
- 3-stories (can be extended)
- Modular diaphragm (attach to; remove and adapt)
- Readily de-erected and stored



Modular diaphragm: steel plate + concrete deck

Weight Distribution

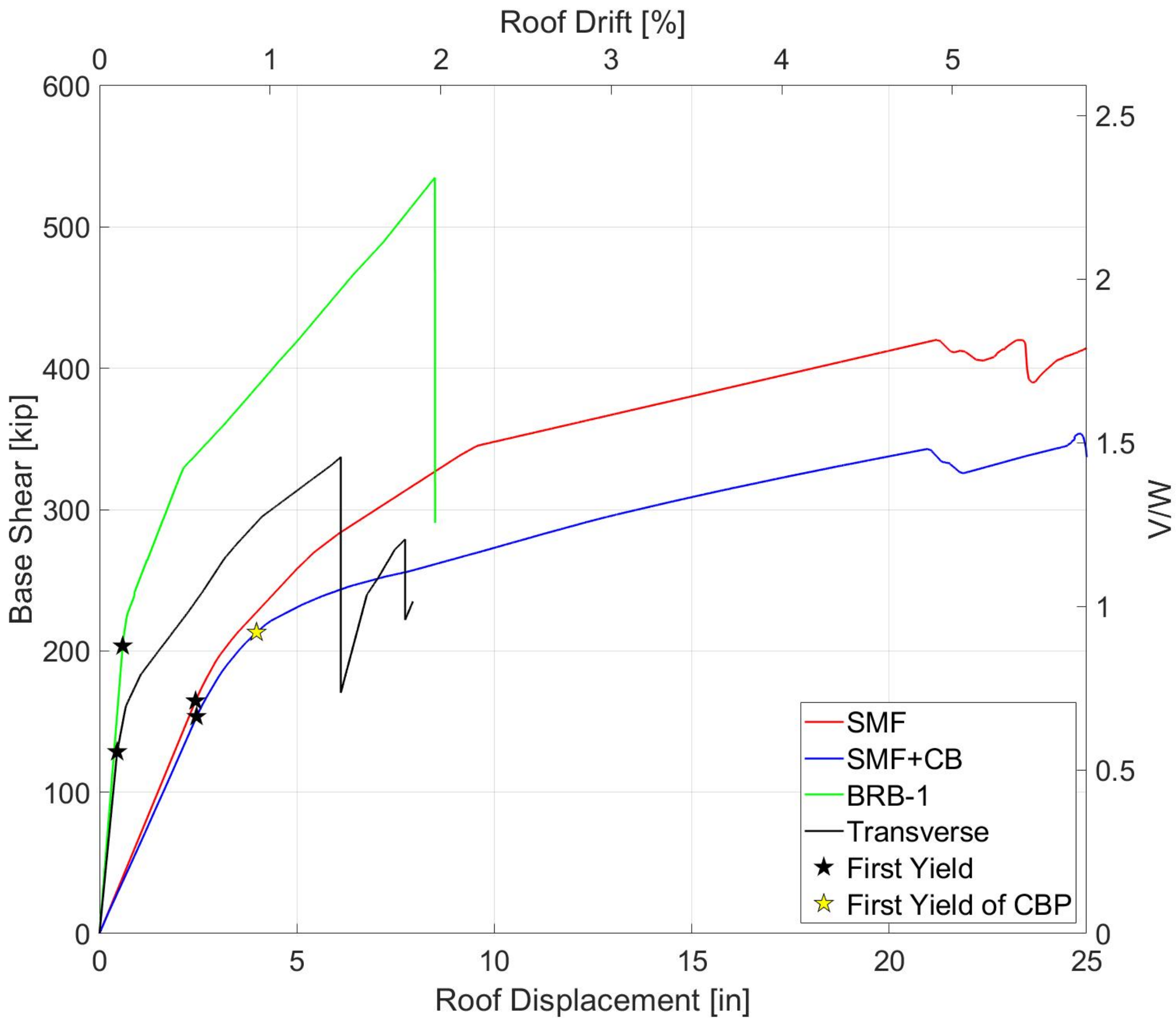
Item	Longitudinal LFRS: BRB-1	Longitudinal LFRS: SMF/SMF+CB
Transverse LFRS [k]	13.2	13.2
Longitudinal LFRS [k]	20.5	2.5
Steel Plate [k]	113.2	113.2
Modular Deck [k]	38.4	38.4
Columns + BP [k]	28.2	28.2
Beams [k]	17.9	17.9
Structural System [k]	**231.4**	**213.4**
Footings [k]	81.6	81.6
Total Weight [k]	**313**	**295**

MTB² Performance Range (NL Pushover Behavior)

Features of behavior

- Softer, ductile SMF response
- Softer, post-yield SMF+CB response
- Stiffest, strongest configuration BRB-1
- Consistent elastic stiffness in all BRB configurations
- ~2% roof drift capacity (@BRB PL = 2.5% ε_a)
- ~4% roof drift capacity (@SMF PL = 0.05r)

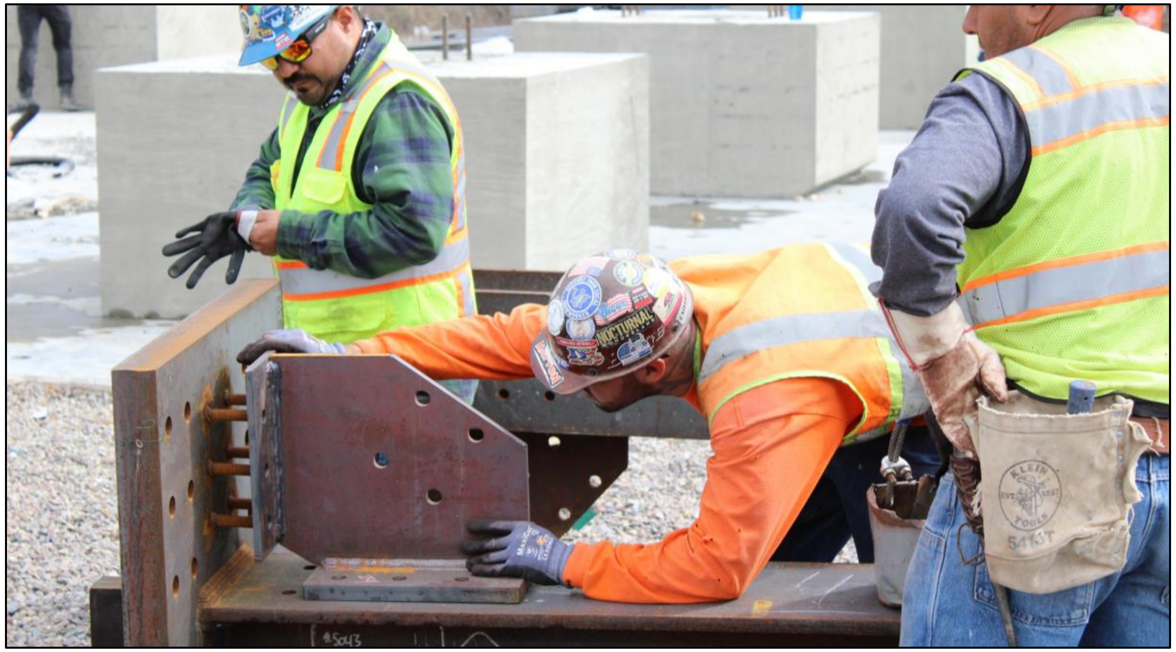
- Gradual fuse-fuse (floor-floor) progression of yielding



ETabs FE Model NL Pushover results

Erection of MTB^2

- Erection of MTB^2 on the UCSD staging slab
  - Oct – Nov 2021 (BRB-1, 50% bolt-up)
- Erection on Shake Table
  - May 2022
- Outcome:
  - ~2days for erection
  - ~1.5days for de-erection



Modular Testbed Building (MTB²)
NHERI@UC San Diego LHPOST6

Configuration SMF+CB versus BRB1
1994 Northridge Earthquake, Rinaldi Receiving Station
EQ Scale Factor: 1.00X, 1.00Y, 1.00Z

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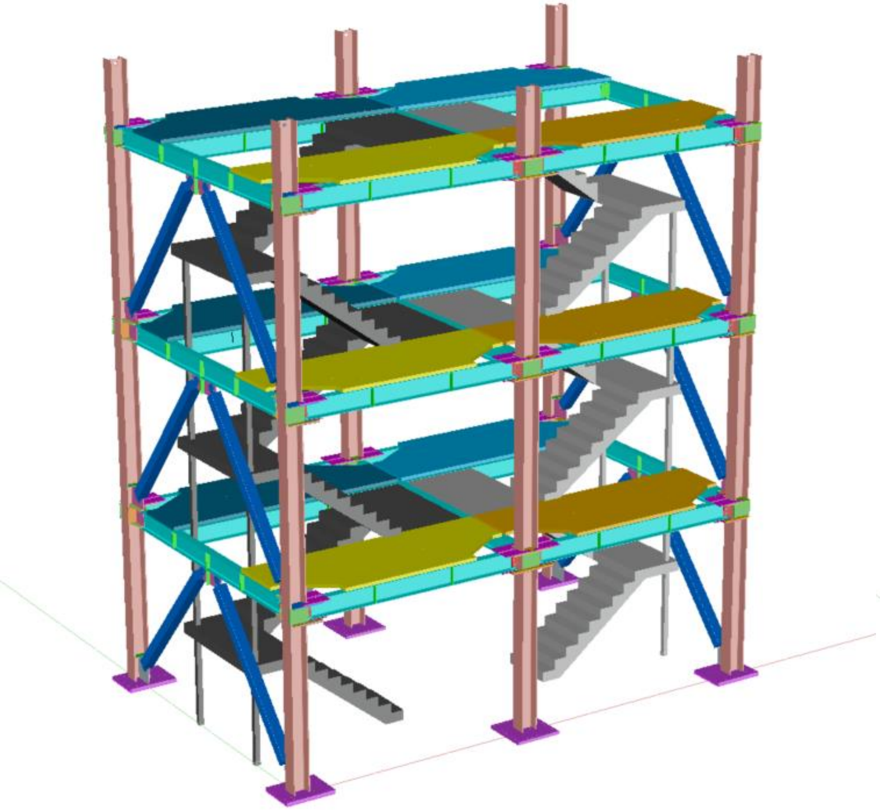
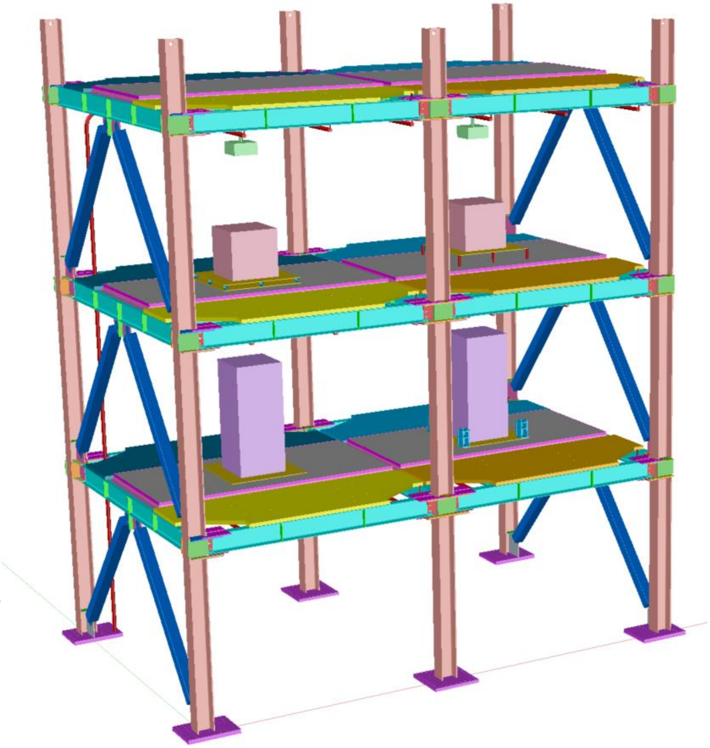
Current Status

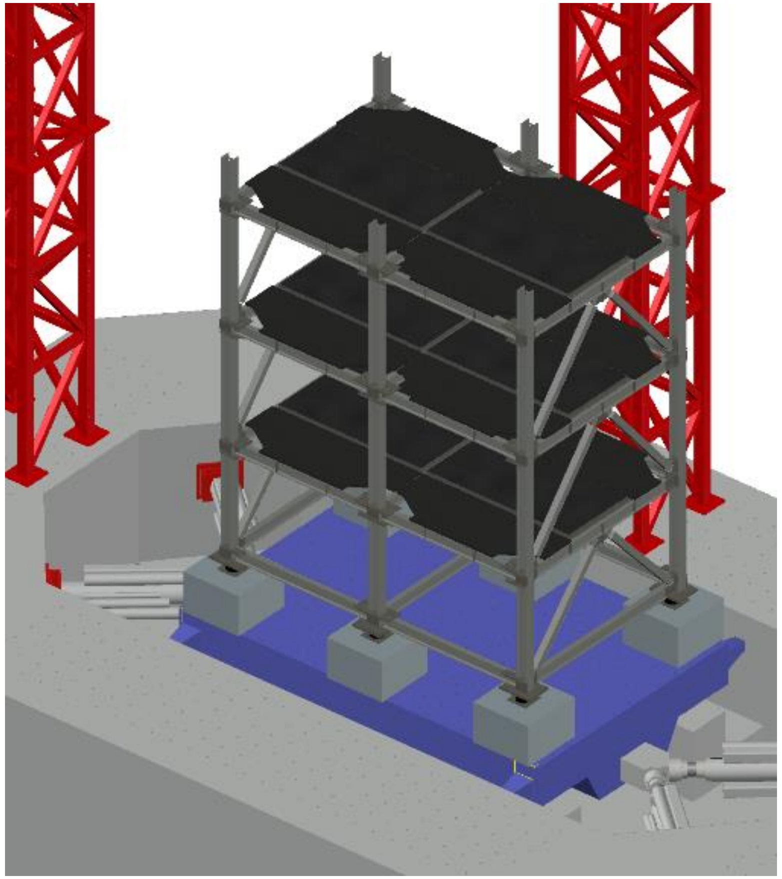
- MTB^2 is intended to be a community resource
- Data analysis
- Papers
- Preparation of data for publication on DesignSafe
  - Design drawings for different configurations
  - Data from experimental program
  - Numerical models
  - Jupyter Notebooks

Future Research Opportunities with MTB^2

- Test nonstructural components and systems
  - Vertically spanning, e.g. stairs, cladding, elevators
  - Floor-mounted, hung (suspended)
- Protective systems (seismic solation, damping)







Information for Future Users

- BRBs, Fuse Plates, Anchors and Hardware are Consumables

- Procuring and managing erection and de-erection ~$60-70k

- Modifications to existing frames need to be substantiated by detailed Non-linear analysis
  - New loading histories
  - Changes in structural elements (beams, columns, connections, footings, additional stories etc.)
  - Changes to magnitude or distribution of floor mass