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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http://chei.ucsd.edu/MTB2/index.html
Additional Industry Partners

- SME STEEL
- NUCOR
- ASBURY STEEL
- HILTI
- LeJEUNE BOLT COMPANY
- VERCO DECKING, INC.
- Atlas Tube

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

\textbf{Buckling restrained braces}

\textbf{Compliant base (stretch-length anchors)}

\textbf{Special moment frame joints (shear fuses)}
Design Features

- 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

Weight Distribution

<table>
<thead>
<tr>
<th>Item</th>
<th>Longitudinal LFRS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BRB-1</td>
</tr>
<tr>
<td>Transverse LFRS [k]</td>
<td>13.2</td>
</tr>
<tr>
<td>Longitudinal LFRS [k]</td>
<td>20.5</td>
</tr>
<tr>
<td>Steel Plate [k]</td>
<td>113.2</td>
</tr>
<tr>
<td>Modular Deck [k]</td>
<td>38.4</td>
</tr>
<tr>
<td>Columns + BP [k]</td>
<td>28.2</td>
</tr>
<tr>
<td>Beams [k]</td>
<td>17.9</td>
</tr>
<tr>
<td>Structural System [k]</td>
<td>231.4</td>
</tr>
<tr>
<td>Footings [k]</td>
<td>81.6</td>
</tr>
<tr>
<td><strong>Total Weight [k]</strong></td>
<td><strong>313</strong></td>
</tr>
</tbody>
</table>

Modular diaphragm: steel plate + concrete deck

Modular floor deck (2/floor), ~6.4kips ea
Steel deck plate (4/floor), ~9.5kips ea
**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% $\varepsilon_a$)
- ~4% roof drift capacity (@SMF PL = 0.05$r$)
- Gradual fuse-fuse (floor-floor) progression of yielding
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:
  - ~2 days for erection
  - ~1.5 days 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
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 isolation, 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