

Low Damage Wall To Floor Connections For Seismic Resilient Timber Structures



QuakeCoRE DT2 Workshop

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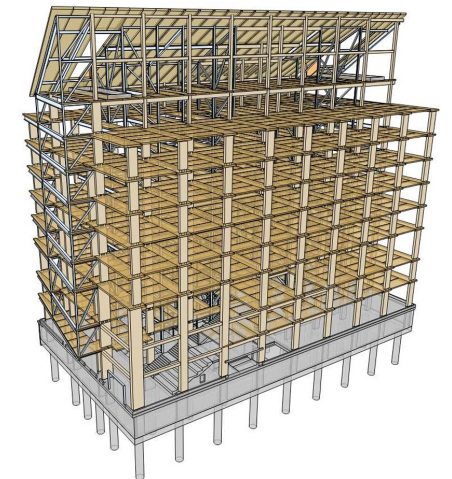
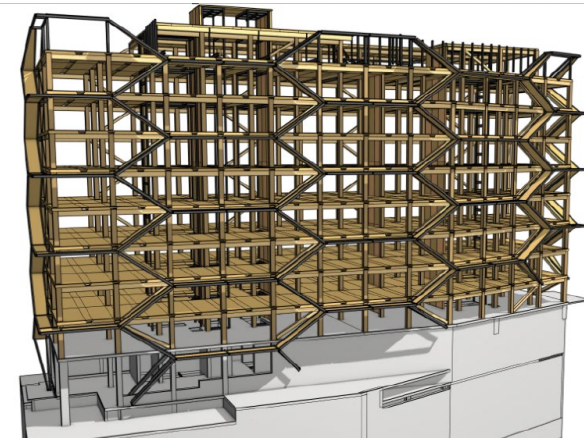


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NZ Centre for Earthquake Resilience
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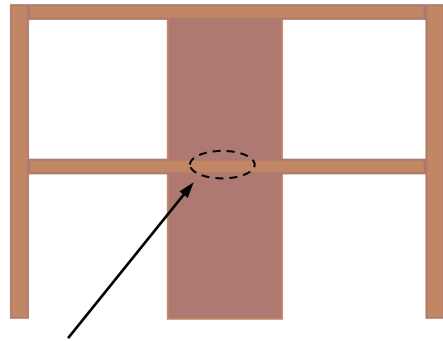
Why Mass Timber?

- ❑ Construction Time
- ❑ Structure Weight
- ❑ Variety and versatility of products including CLT, LVL, and Glulam
- ❑ Safety and durability (Fire, ...)
- ❑ Sustainability (material, construction waste, carbon-neutral construction, carbon emissions, reusable/re-cyclable)
- ❑ Architectural Finish

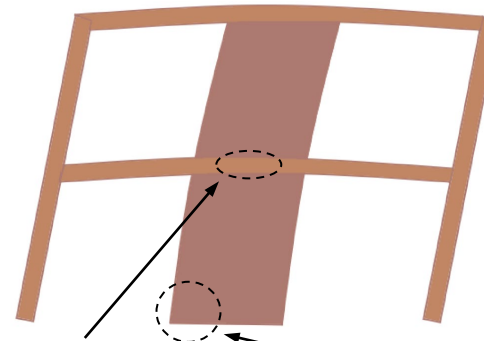


Wall-to-Floor Approaches (Balloon type):

Coupled Approach:



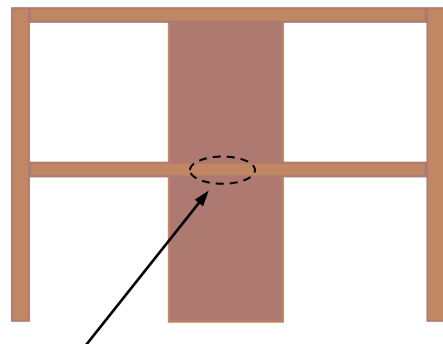
Floors (or beams) are integrally connected to the walls



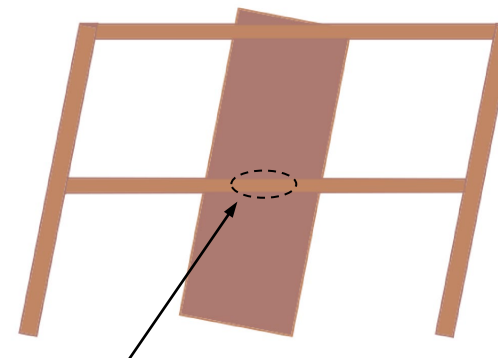
Floors and/or beams are damaged and seismic performance is compromised

Damage (for fixed-based walls) or gap opening (for rocking walls) causing vertical displacement incompatibility at the floor levels

De-coupled Approach:

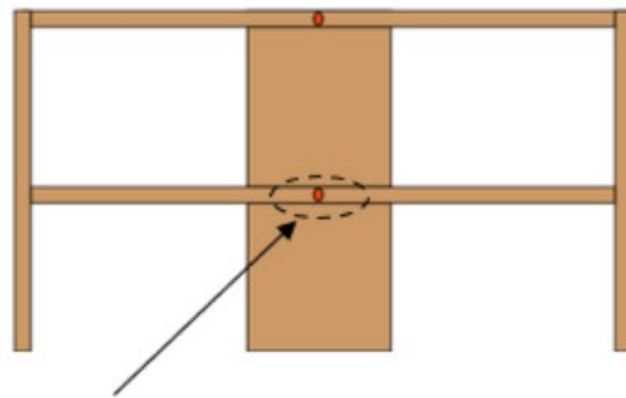


Floors (or beams) are isolated from the walls

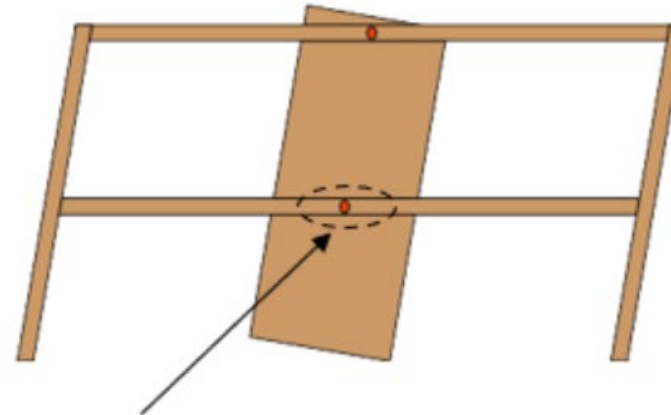


Damage to rigid/semi-rigid connections or use of special detailing which is complicated and costly and wall sections are not fully utilized

Objective: Low Damage Wall-to-Floor Connections

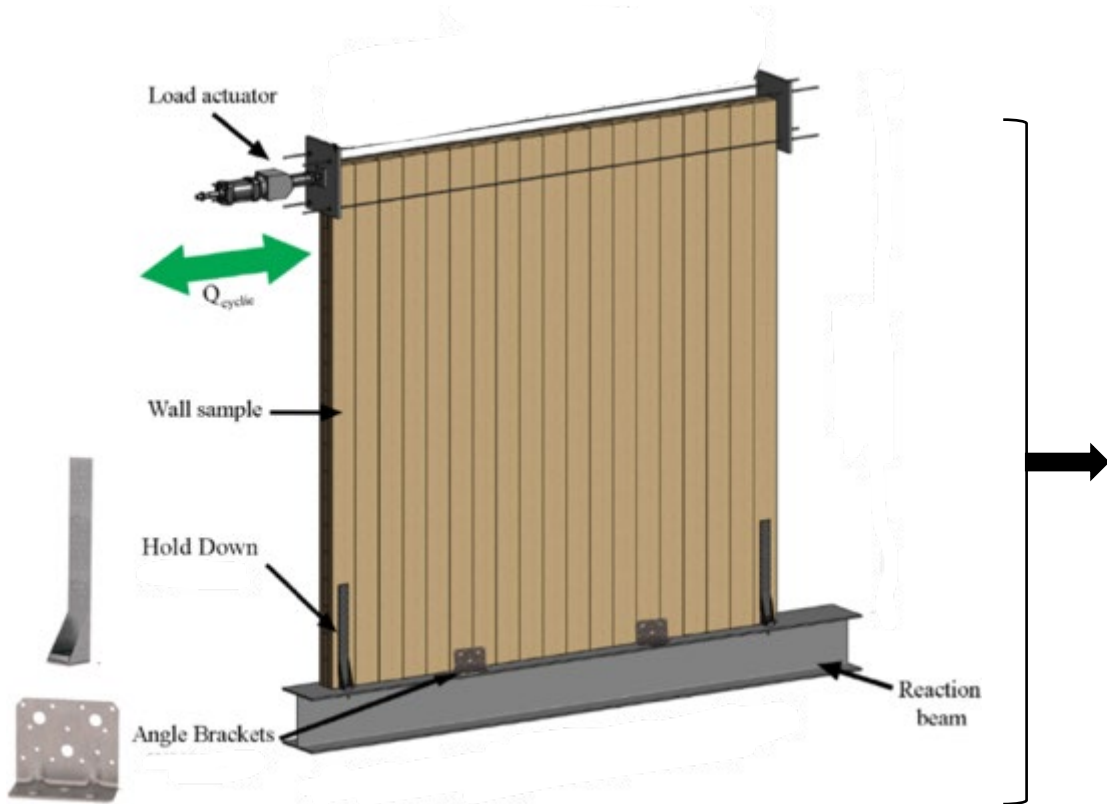
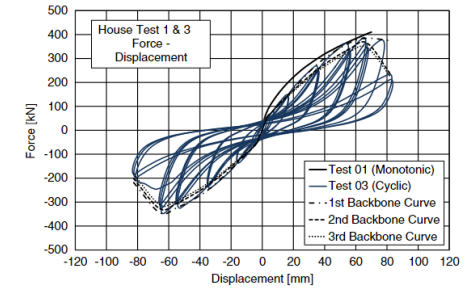


Resilient connections are used to connect wall to floors

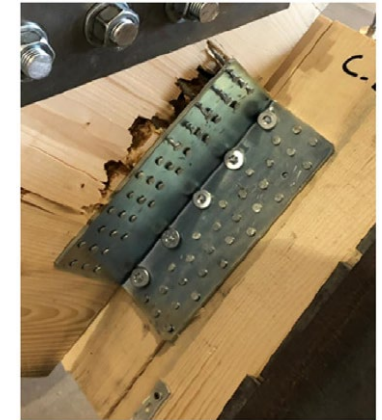
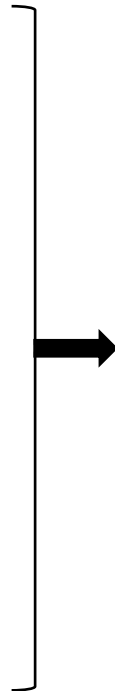
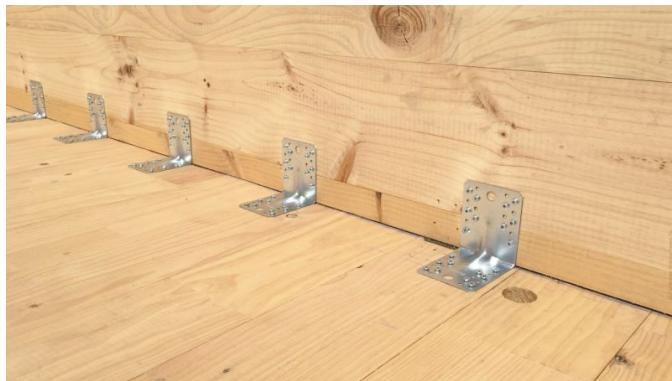
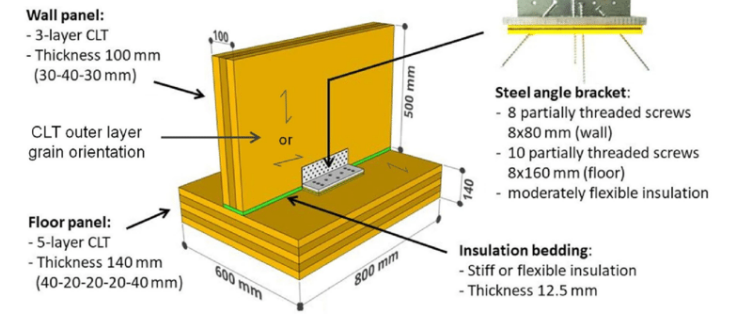


Floors are not damaged and the uplift demand is mitigated, accelerations are fully transferred, seismic energy is dissipated and wall sections are fully utilized

Conventional Detailing – Wall Base:



Conventional Detailing – at Floors:



Current Wall to Floor/Beam connection shortcomings

Undesirable Rigid/semi-Rigid Connection Failure Modes:



(a)



(b)



(c)



(d)



(e)

- Failure Mode (a), (b) and (c): Connection failure of plate or fasteners or both.
- Failure Mode (d), (e): Timber failure and tearing

Wall toe crushing:



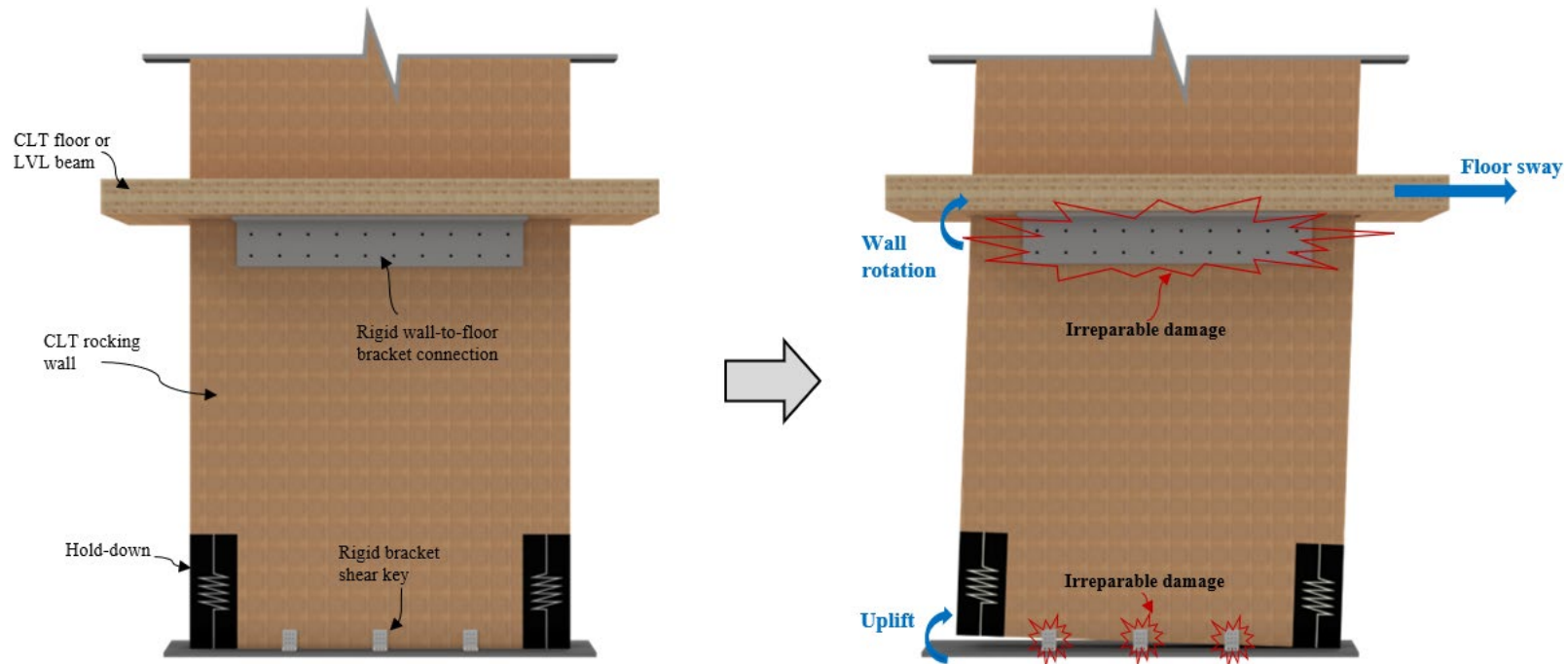
Slight compression deformation at the rocking wall corner



Chipping of wood at the rocking wall corner

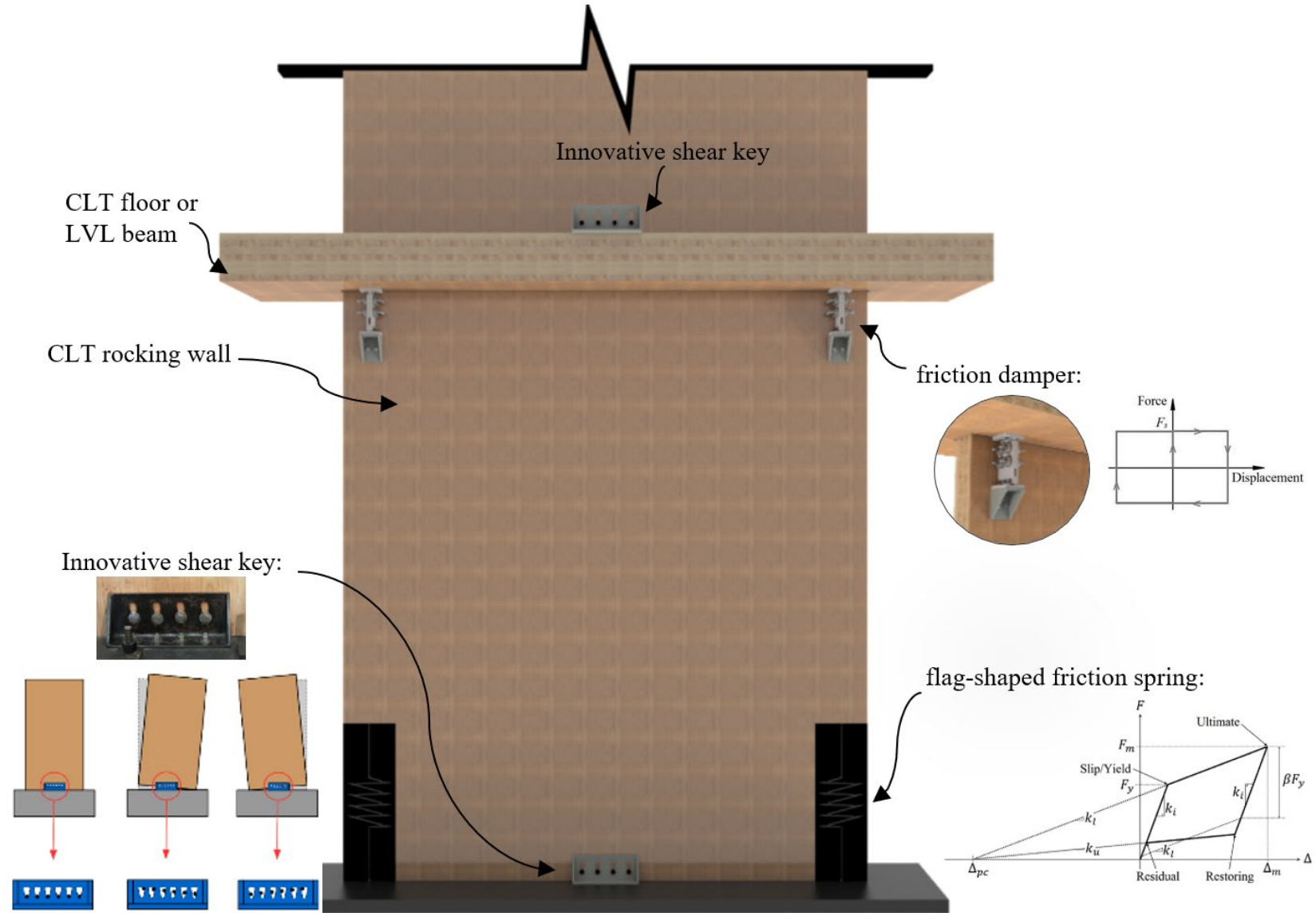


Current Shortcomings:



Current Concept:

- De-coupled rocking wall
- Addition of wall-to-floor shear key to allow safe uplift of the wall and swift interaction between wall and the floor.
- Implementing friction dampers at wall-to-floor to utilize the uplift displacement to dissipate energy.
- Flag-shaped friction spring hold-downs
- Eliminate bulky and expensive connections

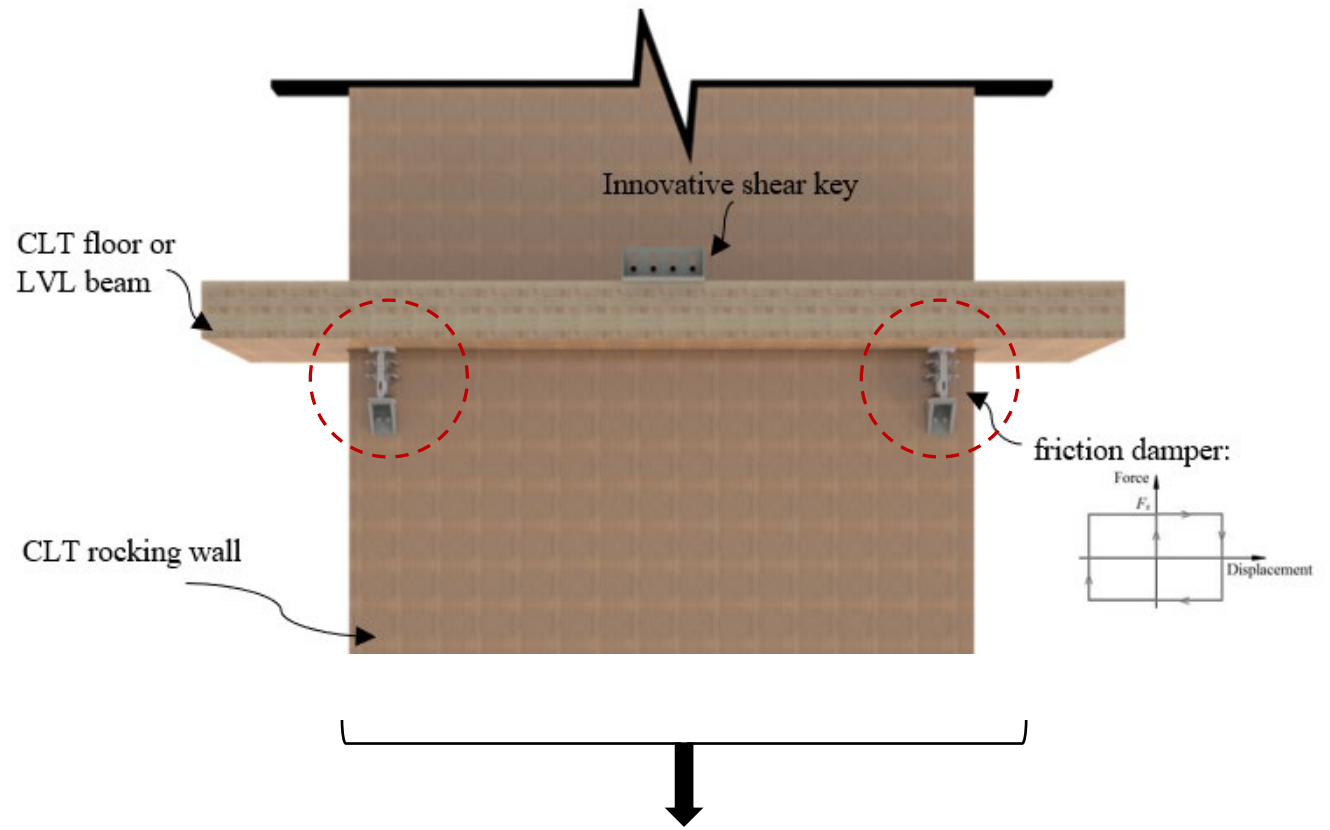


Tunable System:

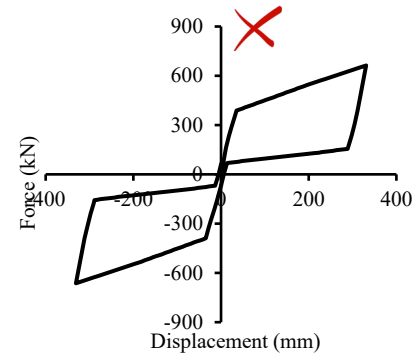
➤ Optimized Energy dissipation system

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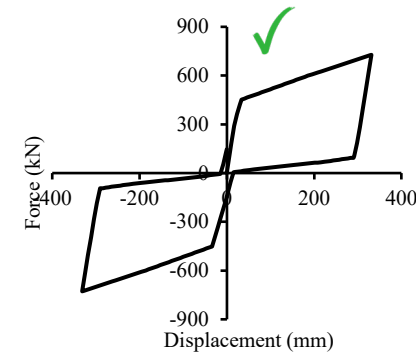
➤ Self-centring



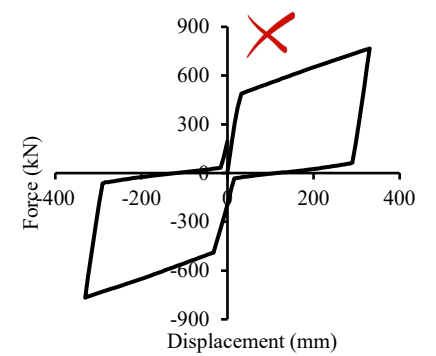
Energy dissipation system is not fully utilized:



Optimized Energy dissipation system:

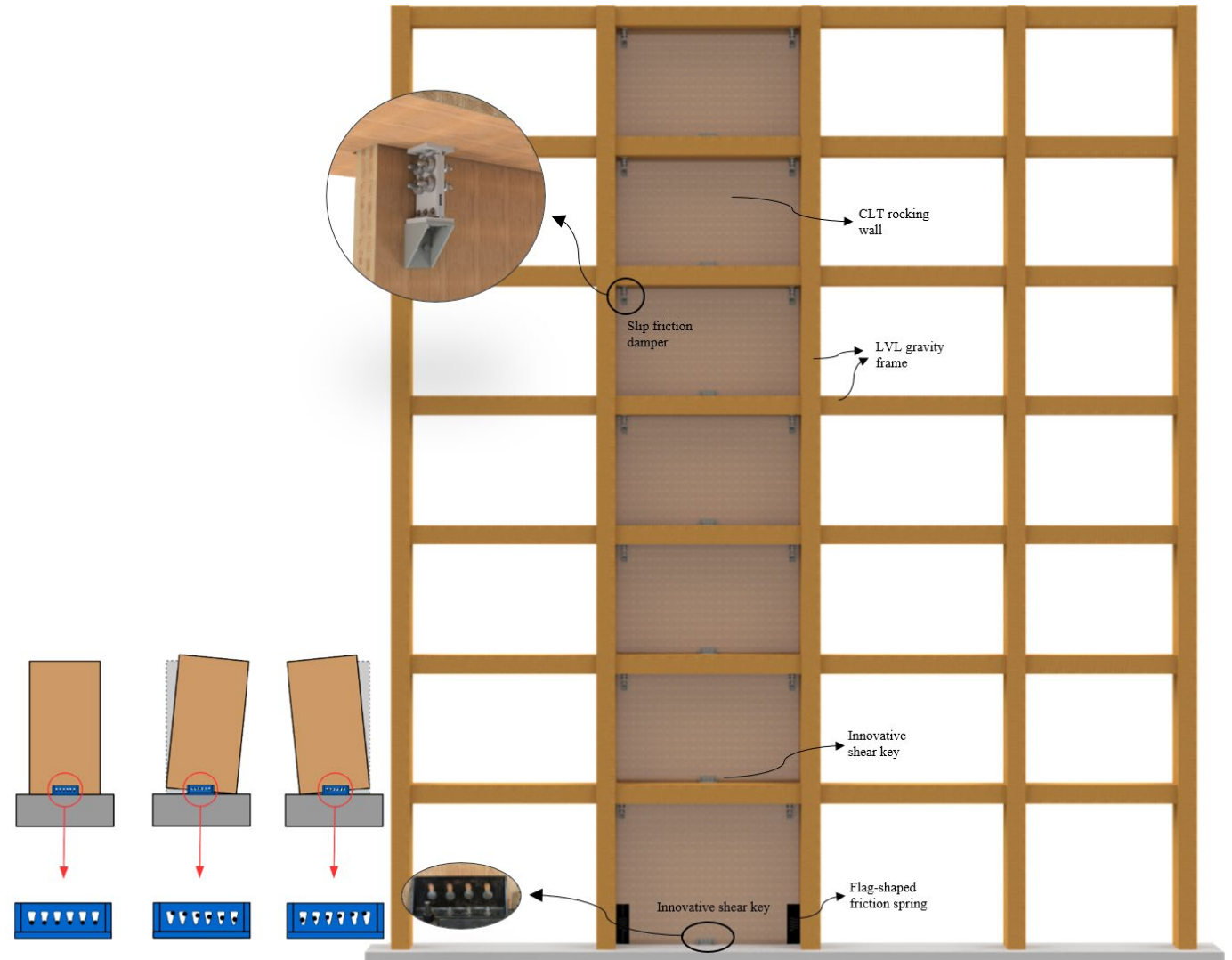
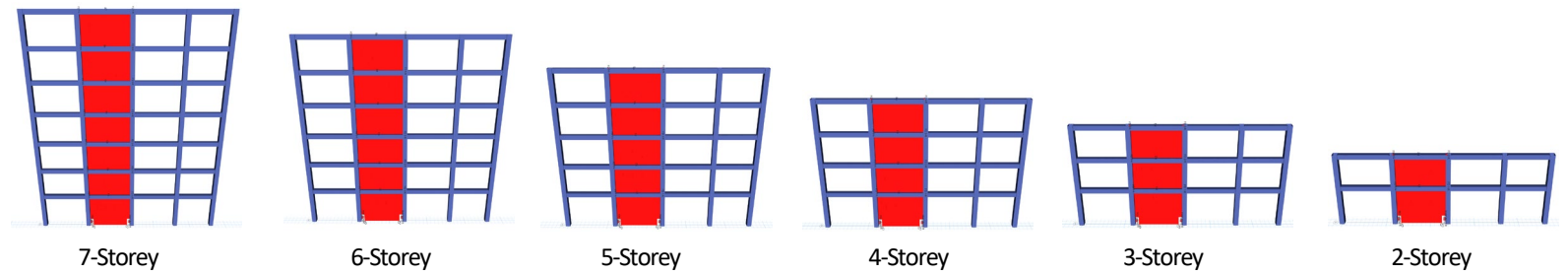
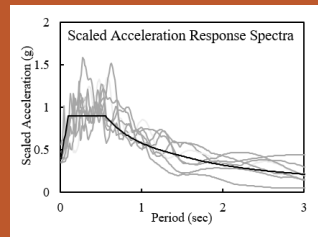


Excess Residual Force/Displacement:



Numerical Study:

- 6 Case study structures
- Non-linear Static and Dynamic Time History

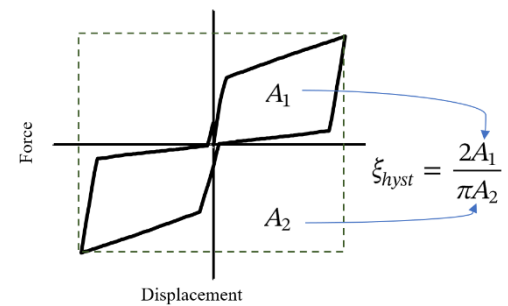
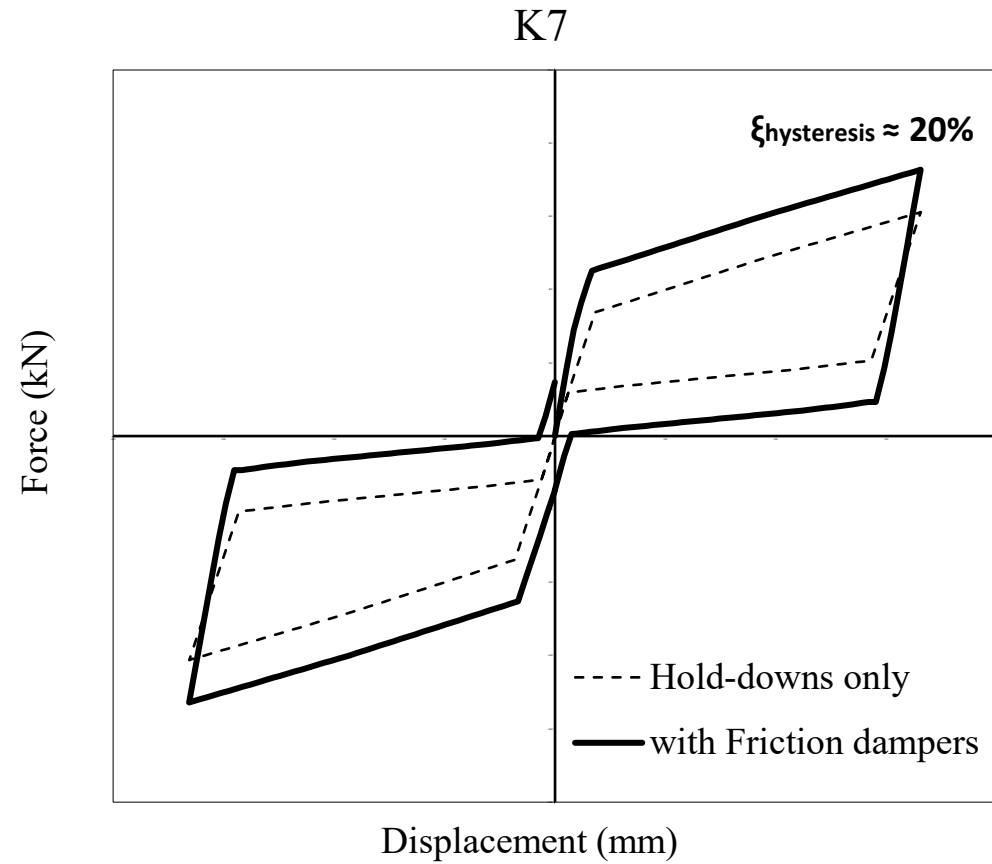


Numerical Result:

- High damping and efficient energy dissipation:

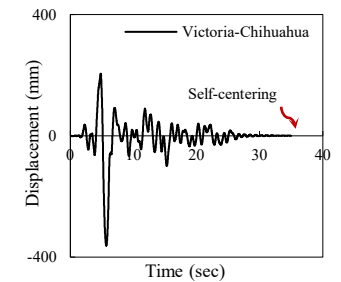
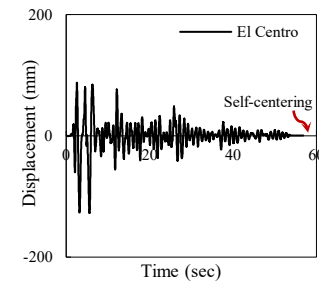
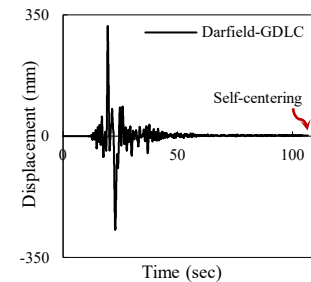
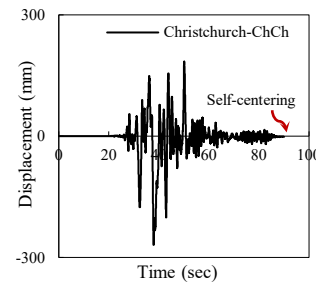
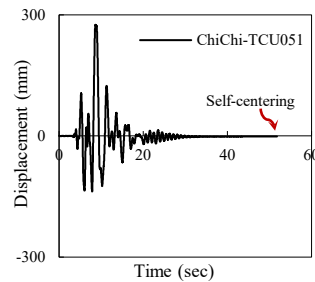
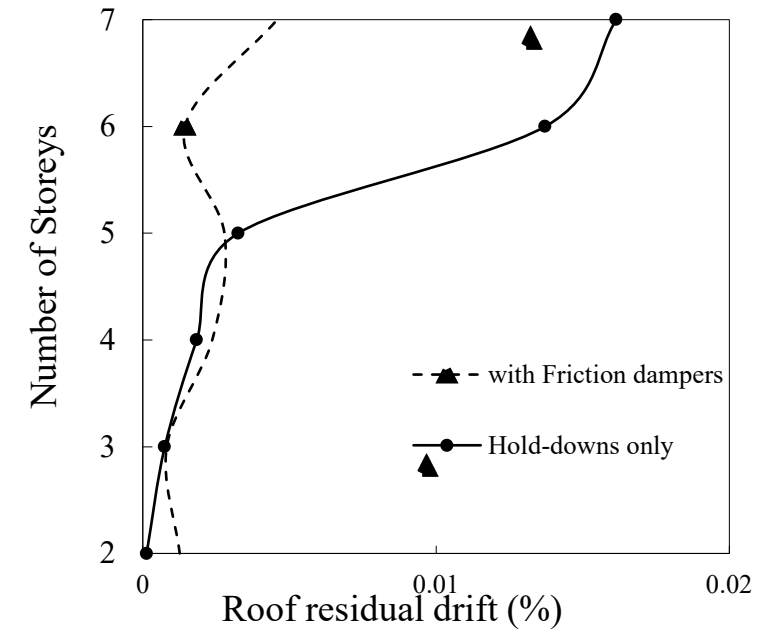
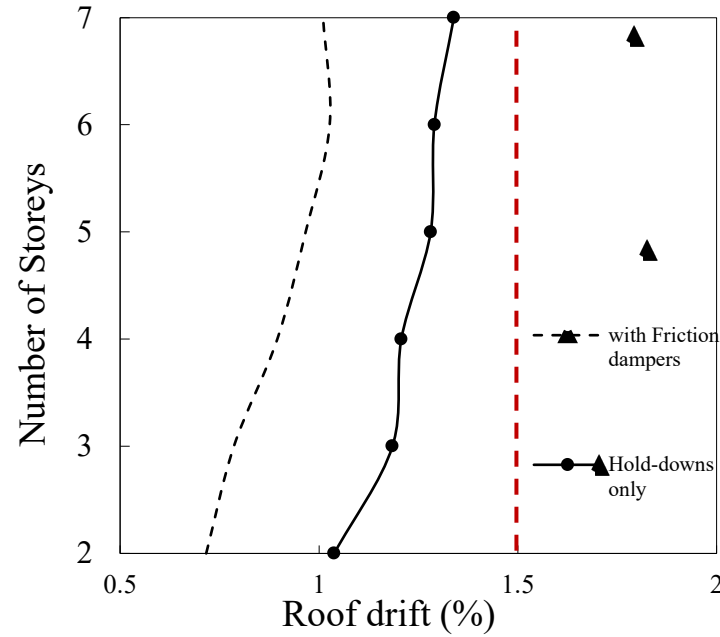
$\xi_{\text{hysteresis}} \approx 20\%$

- No yielding or damage to any of the devices or structural parts.



Numerical Result:

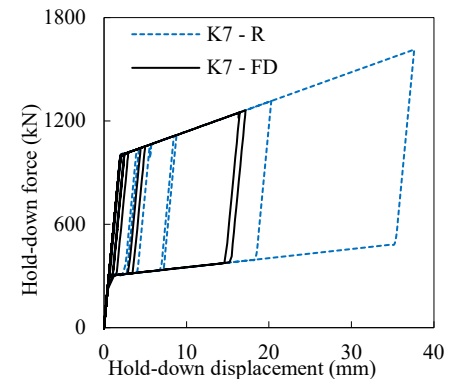
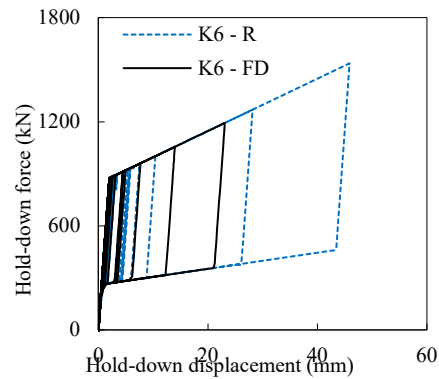
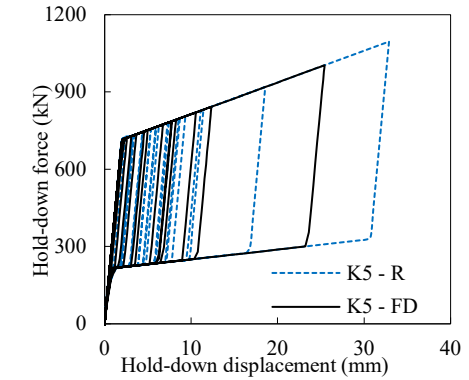
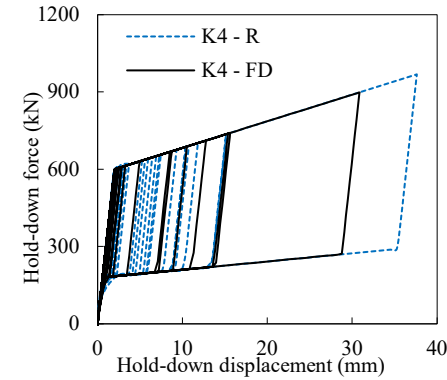
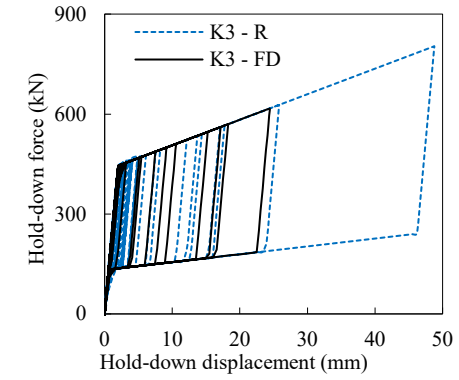
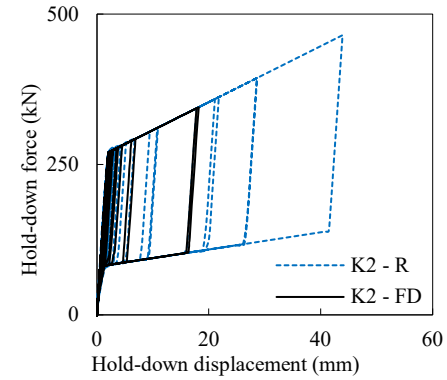
- Reduced roof drift on average $\approx 35\%$.
- Self-centring.
- Immediate Occupancy.



Numerical Result:

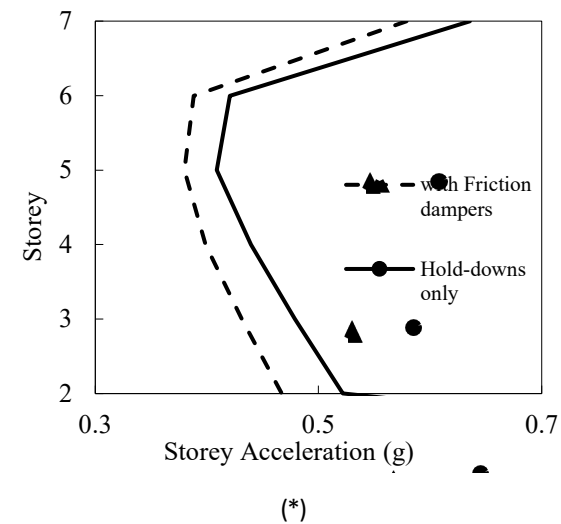
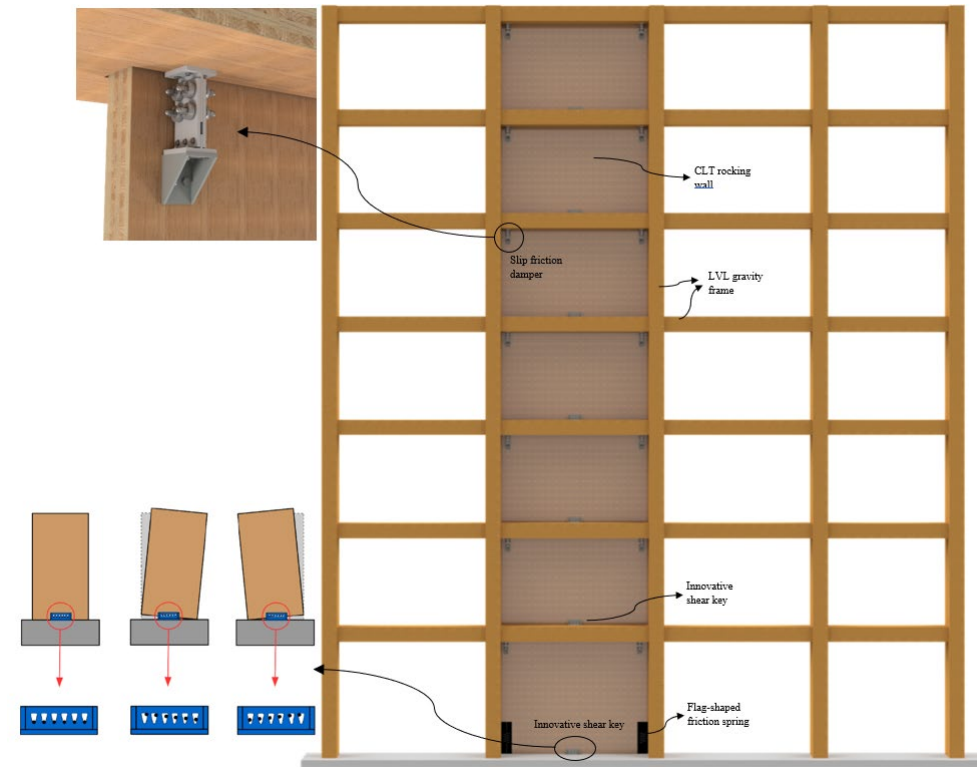
➤ Smaller Hold-downs required, on average:

- $\approx 40\%$ force demand reduction.
- $\approx 25\%$ displacement demand reduction.



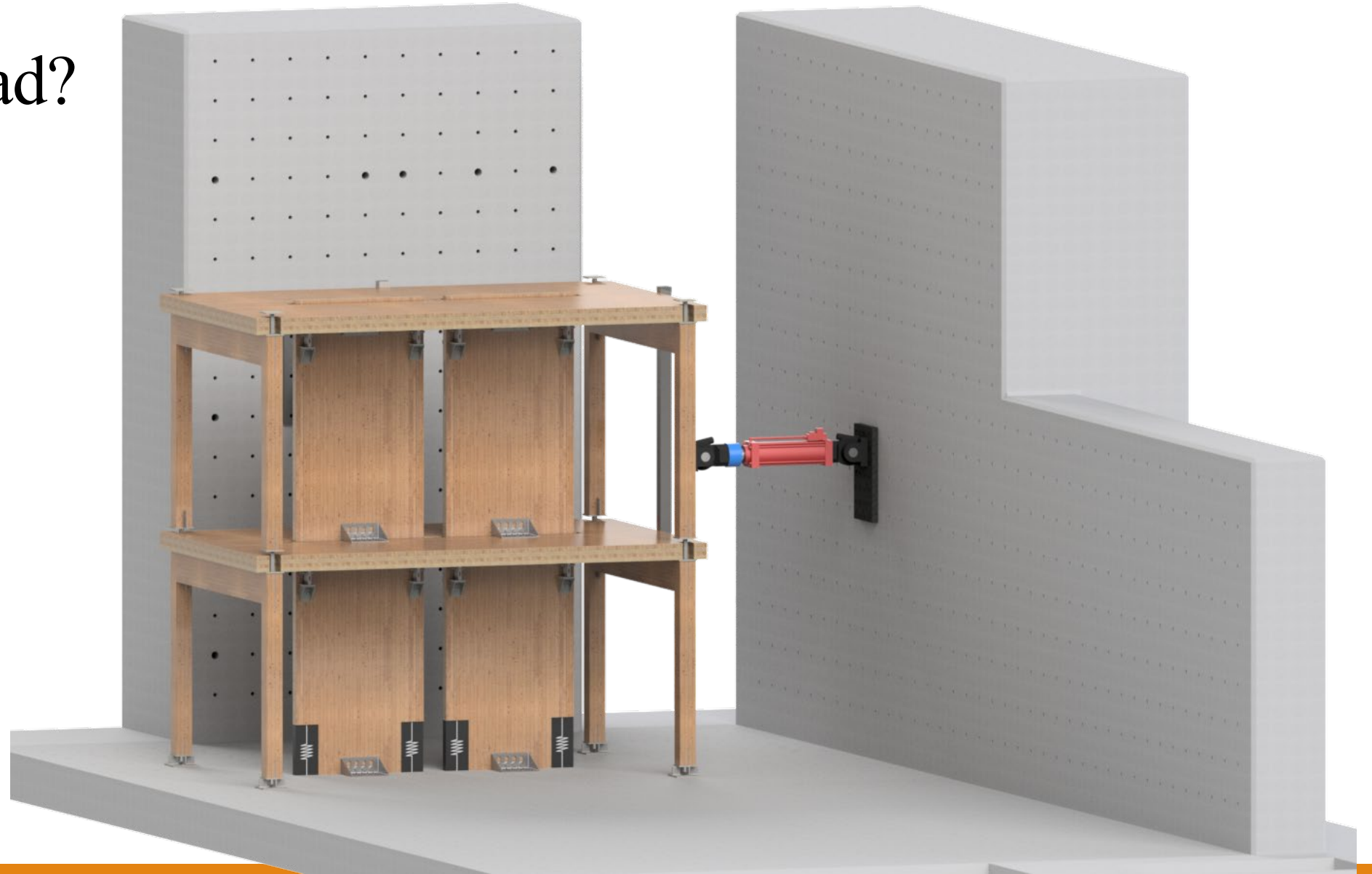
Numerical Result:

- Cost-effective and competitive Timber structure and construction.
- No yielding or damage to any of the devices or structural parts.
- Eliminate toe crushing
- Potential benefit on mitigating dynamic amplifications due to higher mode effects.
- Potential benefit on Non-structural members *
- Smaller Wall section.

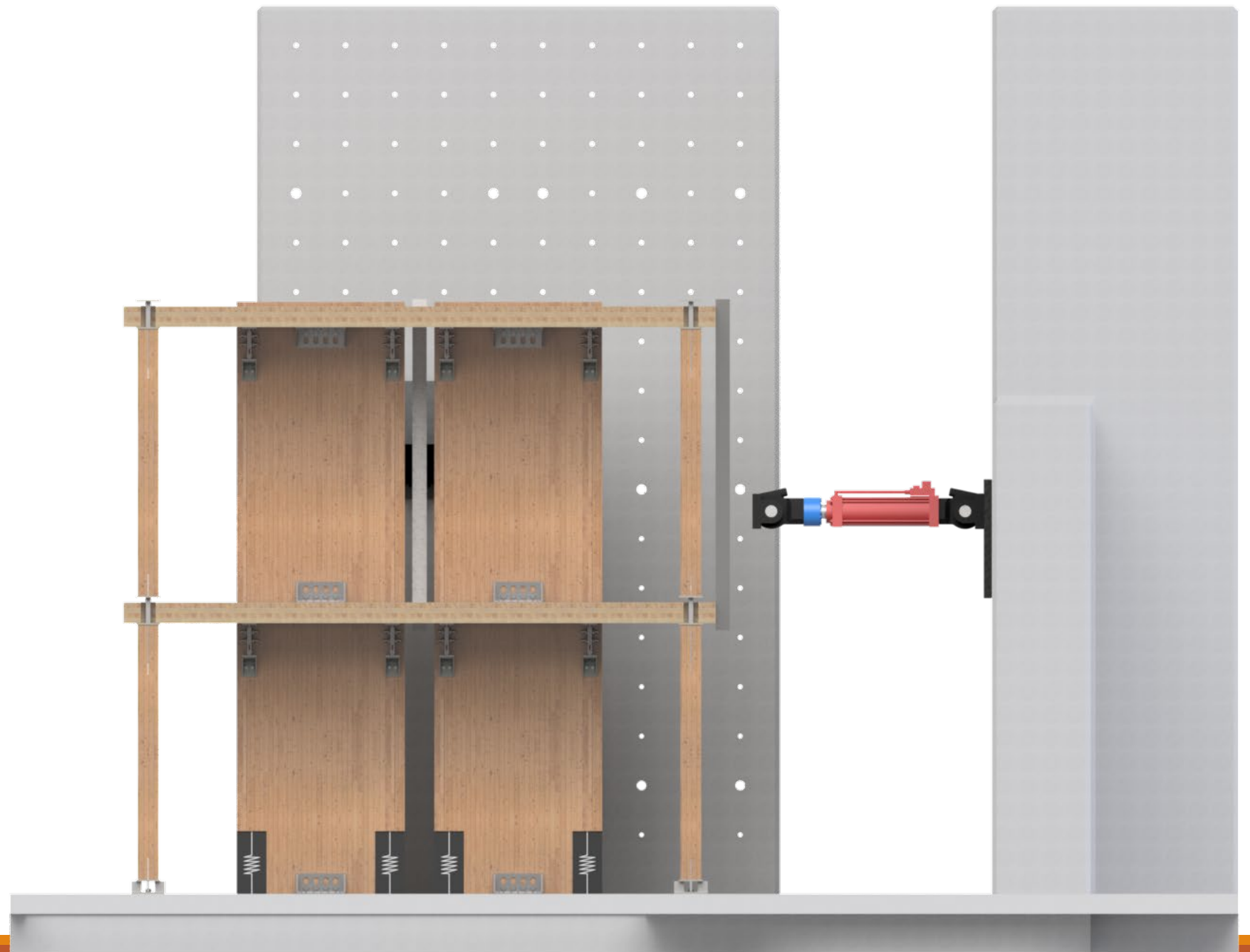


What's Ahead?

- ❑ Experimental Test:



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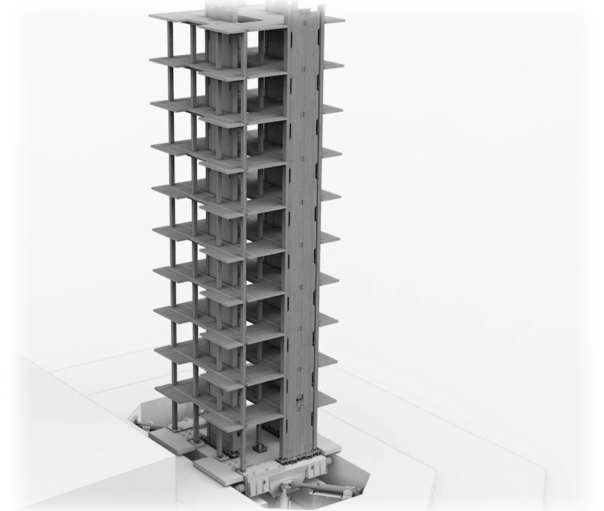


What's Ahead?

- ❑ Further improvements and investigation of the current system, as well as further exploration and potential innovative solutions for the Coupled approach.

Large-scale Building Seismic Test

- 3D Effects:
 - Torsional effects
 - Out-of-Plane effects
- Dynamic Effects
 - Second order – Higher mode effects
 - High Speed/Acceleration performance of shear-key and FDs
- Storey response:
 - Floor response & accelerations
 - Mitigating damage to non-structural members



Thank You



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