ABSTRACT: Wood construction has been traditionally utilized to reduce inertial demands in high seismic regions. Applications however are often limited to low-rise buildings of light-wood construction with distributed load bearing shear walls. Recent advancements in timber technologies are pushing mass timber systems into larger commercial scale markets where steel and concrete systems currently dominate the landscape. In high seismic regions, mass timber buildings currently lack code-defined lateral force resisting systems.

This paper presents a new concept of seismic force resisting system, known as the Heavy Timber Buckling Restrained Braced Frame. The system is intended, although not limited, for application to tall building timber construction, and is inspired by the unbonded brace technology today widely spread throughout Japan and the United States. In order to prequalify the system for future implementation in building codes, the paper first addresses component testing of a brace consisting of a steel core and a mechanically laminated glulam casing acting as the buckling-restraint mechanism. Test results are discussed and implementation at the system level in an archetype building is studied in order to assess overall system-level performance, constructability, and connection detailing.

KEYWORDS: buckling-restrained brace, heavy timber, braced frames, ductility, seismic design, component testing

1 BACKGROUND

In today’s market, designing code-based highrise buildings in high seismic regions of the United States inevitably means steel or concrete construction due to the absence of a codified timber-based lateral systems that provide reasonable ductility and height limits. The Heavy Timber Buckling Restrained Braced Frame (HTBRBF) project is a joint effort between practitioners, researchers and manufacturers to fill this gap at a system level, pioneering tall full-timber building solutions in regions of high seismicity.

Before addressing the system level ductility, a reliable ductile component capable of sustaining multiple cycles of seismic excitation is needed. For this purpose a Heavy Timber Buckling Restrained Brace (HTBRB) has been developed following the unbonded brace concept widely used in the steel industry, as well as the design philosophy based on a yielding “fuse” connected to elastic capacity-protected components. The HTBRB was designed consisting of three basic components: a steel core for inelastic deformations, a composite glulam casing for buckling restraint, and an air gap between those two. Figure 1 shows an exploded view of the brace assembly.

2 SCOPE OF RESEARCH AND TESTING

A three step process was implemented to evaluate the performance of the HTBRBF:

1. Component testing of the HTBRB to evaluate the stable hysteretic response of the braces, in collaboration with Star Seismic and the University of Utah.

2. Analytical evaluation of an archetype 12-story building (see Figure 2) to address performance at the system level, incorporating the component response from Item 1 above.
3. Evaluation of seismic performance factors to initiate the path towards codification of the system, following a FEMA P-695 methodology.

![Figure 2: 3D rendering of archetype 12-story analysis model.](image)

### 3 RESULTS

Preliminary results for the first two steps of the scope are included in this section. The HTBRB funded component physical testing is scheduled for January 2016. At a component level, the HTBRB has been designed to exhibit the stable and symmetrical hysteresis loops typical of an unbonded brace (refer to Figure 3). The objective of this test is to demonstrate the proof-of-concept for using a composite glulam casing to meet the acceptance criteria for conventional BRB’s as defined by AISC 341.

![Figure 3: Representative hysteretic loop for a BRB test specimen.](image)

At a system level, the model of the archetype exhibited a building response with typical dynamic characteristics for a system of its height (see fundamental modes in Figure 4), while meeting code limits of story drifts, as shown in Figure 5.

![Figure 4: Analysis model modal response.](image)

![Figure 5: Story Drifts under wind and seismic loads.](image)

As part of this second phase of system-level evaluation, conceptual level details for the HT-BRBF have been developed. See concept brace to column connections in Figure 6, where the ductile path is ensured by creating steel to steel connections inside the capacity-protected joint.

![Figure 6: Conceptual level braced frame details.](image)

### 4 CONCLUSIONS

The ongoing work of the Heavy Timber Buckling-Restrained Braced Frame project presented in this paper shows the successful first steps towards the codification of a new mass timber lateral system that will allow full-timber commercial building solutions in regions of high seismicity.

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### REFERENCES


