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# Rapid Risk Assessment of Buckling Restrained Brace Frames with Focus on Residual Drifts

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# Project Goals

**Goal:** Expand P-58/SP3 risk analysis for BRBF buildings (without the user needing to create a nonlinear structural model).

- Extend the SP3 Structural Response Prediction Engine to predict nonlinear responses of BRBF buildings, without any needed structural modeling, with specific focus on residual drifts.
- Expand the *SP3 Fragility Database* to have a new family of CoreBrace BRBF fragilities; make these specific to the high-ductility of CoreBrace BRBFs and make them geometry-specific (132 new fragilities).
- Include these new developments in both the *SP3-Design* tool (for full detailed engineering evaluations) and the *SP3-RiskModel* (which supports rapid evaluations for single-building to large inventories).
- Use these new developments to create *Guidelines for Resilient Design of BRBF Buildings*.



# **Overview of Structural Modeling**

Designs from ATC-76 (NIST GCR 10-917-8)

- $\circ$  37 building design archetypes, with 19 in SDC D<sub>max</sub>
- 4 bracing configurations
- Used NIST Guidelines for Nonlinear Structural Analysis for Design of Buildings for the nonlinear modeling

Three primary model variants

- No gravity system (just the braces)
- With gravity system
- With backup frame (*not* designed as dual system)





# **Overview of Structural Modeling**



b. Long-period archetype heights (SDC Dmax)







The FEMA P-58 default residual drift model is slightly conservative for CoreBrace BRBFs (but only slightly).





The FEMA P-58 default residual drift model is slightly conservative for "bare frame" CoreBrace BRBFs (but only slightly).







The FEMA P-58 default residual drift model is slightly conservative for CoreBrace BRBFs (but only slightly).





## CoreBrace Fragility Comparisons

Comparison of new fragilities with standard FEMA P-58 fragilities (where the damage state is fracture of the brace requiring replacement)





# Example Repair Costs for an 8 Story BRBF in Long Beach, CA



# From Before: Modeling Results – Residual Drift





















# Resilient Design of BRBF Buildings

- In some cases, it is also desirable to make resilient design decisions without needing to run a full FEMA P-58 and SP3 risk assessment.
- We just completed *Resilient Design Guidelines for CoreBrace BRBF Buildings*, which will be available from CoreBrace.
- These Guidelines include simple look-up tables for strength and stiffness requirements needed for making your building resilient and including the effects of with/without a moment connected back-up frame (i.e. limiting residual drifts, repair costs, and building closure time).



# Resilient Design of BRBF Buildings





# Summary and Conclusions

- Previous residual drift models result in very conservative loss results.
- Inclusion of the gravity system can reduce residual drifts
- Inclusion of a moment resisting backup frame is extremely beneficial to the magnitude of residual drifts in the structure
- The default FEMA P-58 fragility for the BRBF is very conservative relative to the actual capacity of a CoreBrace BRB





# Example Design Sequence for an 8 Story BRBF in Long Beach, CA (No Backup Frame, with Gravity System)



### Resilient Design of BRBF Buildings

#### **Conceptual Design Needs to Meet Resilience Goals**

As detailed in an earlier section on resilience goals, there are several levels of resilient design, and the exact design requirements will depend on the level of resilience desired. Even so, the overall primary conceptual needs to make a building seismically resilient are as follows:

- **1)** Essentially no structural damage (i.e. no red tag and no damage that will inhibit building functionality).
- 2) Residual drifts low enough to not cause red tag and not require repair.
- **3)** Peak transient drifts low enough to prevent damage to non-structural drift-sensitive components that would inhibit building functionality.
- 4) Peak floor accelerations low enough to prevent damage to acceleration-sensitive components that would inhibit building functionality, or design of equipment anchorage to ensure that critical equipment functions after shaking.

The remainder of this section provides more conceptual detail on the specifics of controlling structural and non-structural damage, as well as thoughts on possible design restrictions and consideratons for resilient design.  Keep brace strains low enough to not have fracture and not need repair (easy with CoreBrace BRBFs).

2) Control residual drifts through use of a back-up frame or additional strength/stiffness.

 Possibly reduce design drift to prevent drift-sensitive nonstructural damage (same for any structural system).

4) Prevent acceleration-sensitive non-structural damage by either strengthening anchorages and/or controlling floor
acceleration demands (easier for BRBFs because PFAs are lower than elastic building).















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