Preliminary Analysis of a “Strongback” System

NEES: Collaborative Developments for Seismic Rehabilitation of Vulnerable Braced Frames

Co-Principal Investigator: Stephen A. Mahin, UC Berkeley
Student Investigator: Barbara G. Simpson, UC Berkeley
NEES@Berkeley Laboratory, University of California, Berkeley
Affiliated Principal Investigator: Charles Roeder, *Affiliated Co-Principal Investigators:* Jeffrey Berman, Dawn Lehman, University of Washington

ABSTRACT

Conventional braced frames have a tendency to form soft or weak stories, concentrating damage in a few stories while the rest of the frame contributes little to the structure’s ability to dissipate energy. A two-story one-bay “strongback” (SB) retrofit was tested under quasi-static cyclic loading conditions to assess the SB system’s ability to alleviate this soft or weak story behavior. The SB system employs an elastic mast that runs over the height of the structure, forcing similar drift demands in adjacent stories; thus engaging multiple stories in an imposed linear mode. The test utilized braces arranged in a “lambda” configuration, comprised of a buckling restrained brace (BRB) acting as an energy dissipating “fuse” and two HSS braces acting as a strong truss, or “mast,” intended to spread interstory drifts over the entire frame height. Results show that the SB test was effective in limiting a soft or weak story mechanism and the “strongback” imposed nearly uniform drifts in each story throughout the duration of the test. Calibrated numerical results were able to capture the general response of the frame, including fracture of the BRB.

MORE INFORMATION

Simpson, B., Mahin, S., & Lai, J. (2015). *Experimental Report: Performance of Vulnerable and Retrofit Braced Frames under Quasistatic Cyclic Loading.* PEER Report, Pacific Earthquake Engineering Research Center, University of California, Berkeley, CA

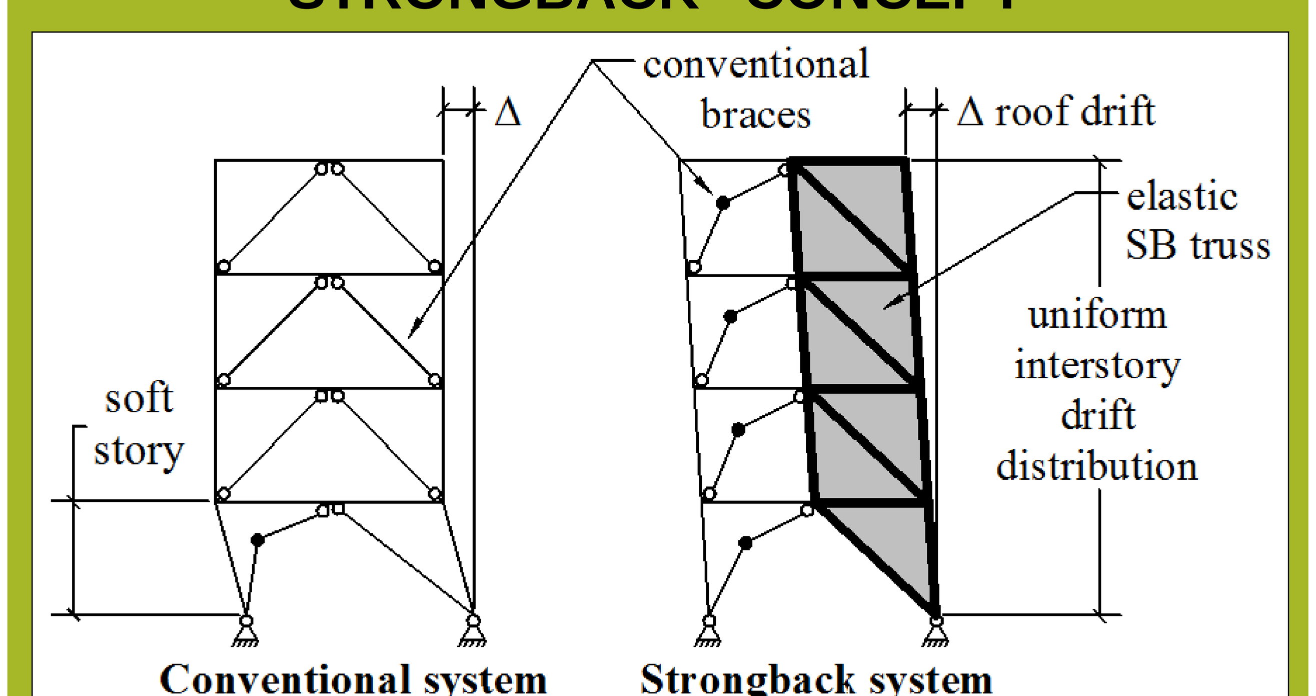
CONCLUSIONS

The third in a series of three tests examined a retrofit “strongback” strategy intended to mitigate the weak-story behavior seen in two previous test specimens. The strongback was designed to impose a uniform drift distribution over the entire frame height, engaging both stories so that damage would not concentrate in a particular story. The “strongback” retrofit (NCBF-B-3SB) was successful in completing the loading protocol required for testing a BRB frame intended for new construction. The SB system had sufficient displacement capacity to satisfy basic code requirements and was successful in mitigating soft- or weak-story behavior.

The strongback concept has been implemented in practice by Tipping Structures in a building in Berkeley, CA with better “architectural compatibility at a lower cost” than a conventional braced frame (Panian & Bucci, 2015), but a more complete economic estimate of construction and loss after an earthquake may provide invaluable information about the economic viability of using this system in practice.

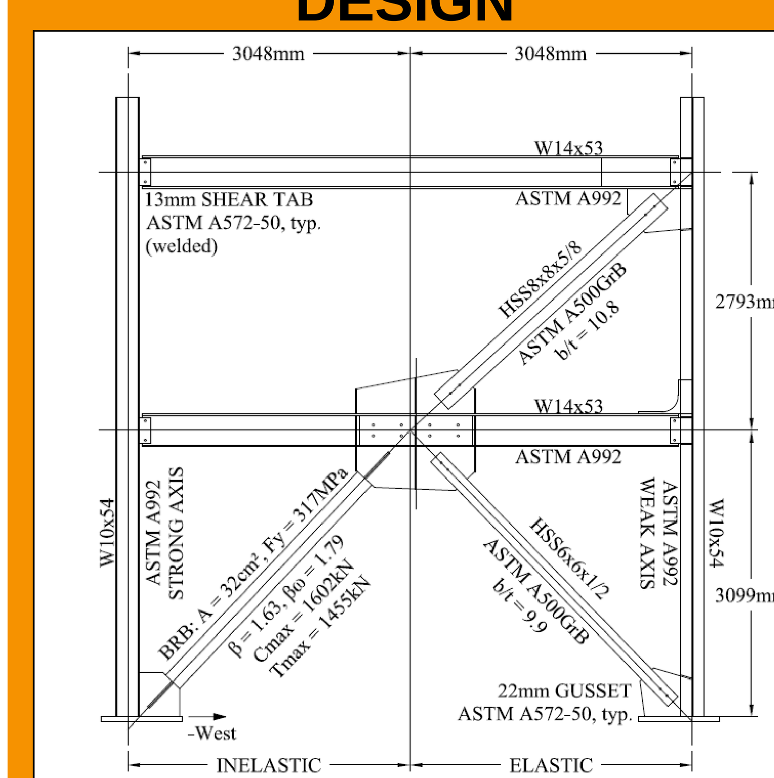
The numerical models show that the general behavior of the experimental tests can be created in relatively simple OpenSEES models. However, while these OpenSEES models appear to adequately capture overall experimental behavior, there are still many failure modes that fiber model are unable to predict. Further refinement of the fiber model can be done to improve the model’s prediction of local buckling, fracture, and post-fractured BRB behavior. Finite element modeling may be necessary to capture localized failures that cannot be predicted by fiber models, including local buckling of the BRB casing and connection failures.

“STRONGBACK” CONCEPT



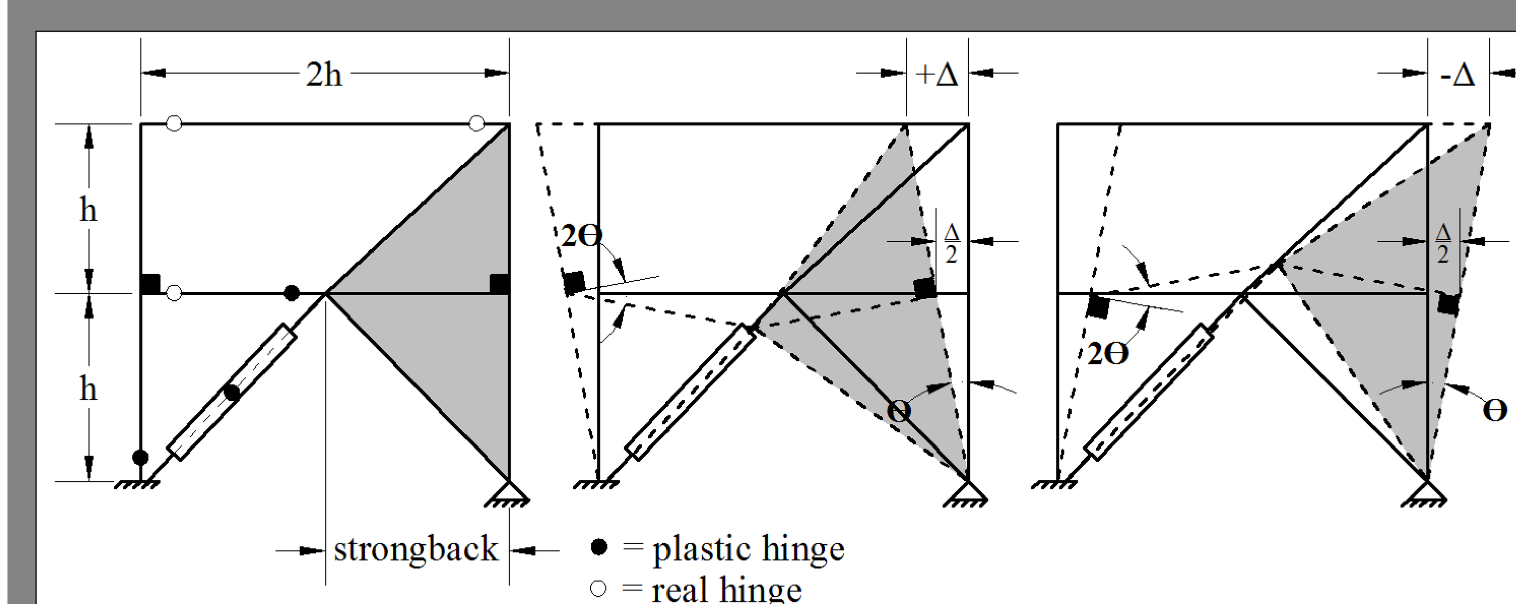
THE SOFT STORY PROBLEM.

SCHEMATIC DESIGN



A POSSIBLE RETROFIT STRATEGY.

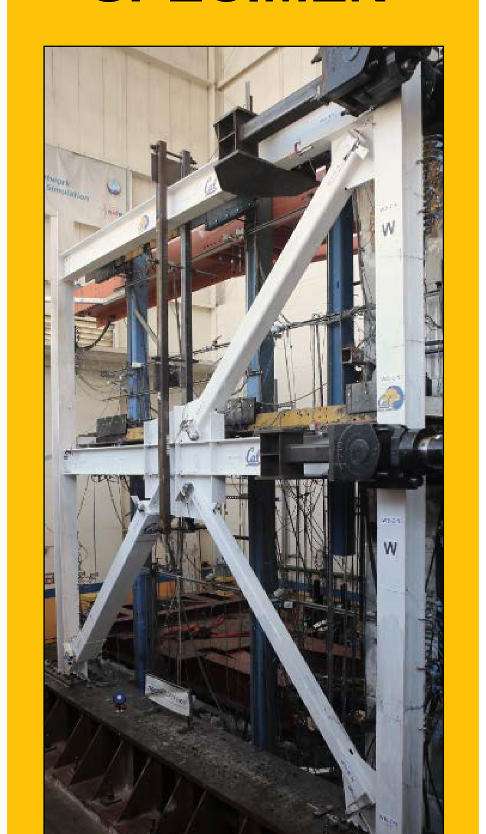
KINEMATICS & THE COLLAPSE MECHANISM



RIGID BODY MOTION AND THE ENGAGEMENT OF BOTH STORIES.

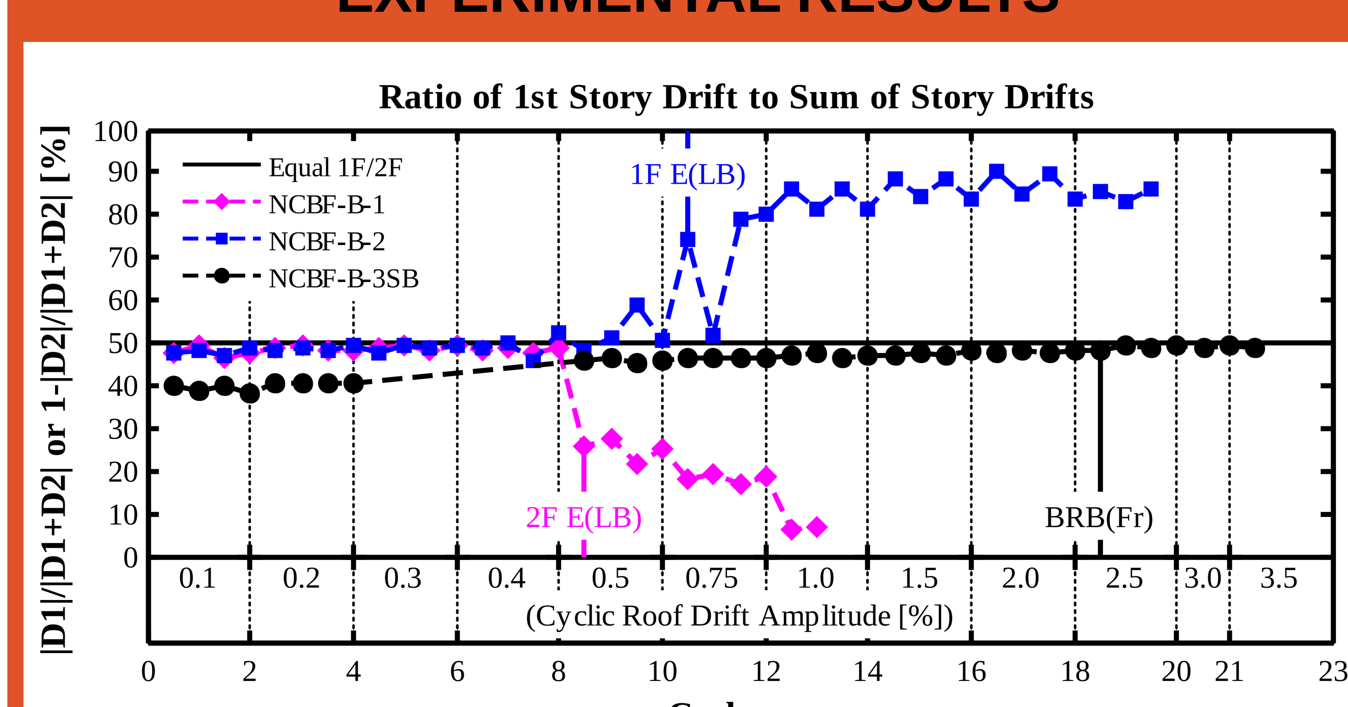
FULL-SCALE TSTING.

EXPERIMENTAL SPECIMEN

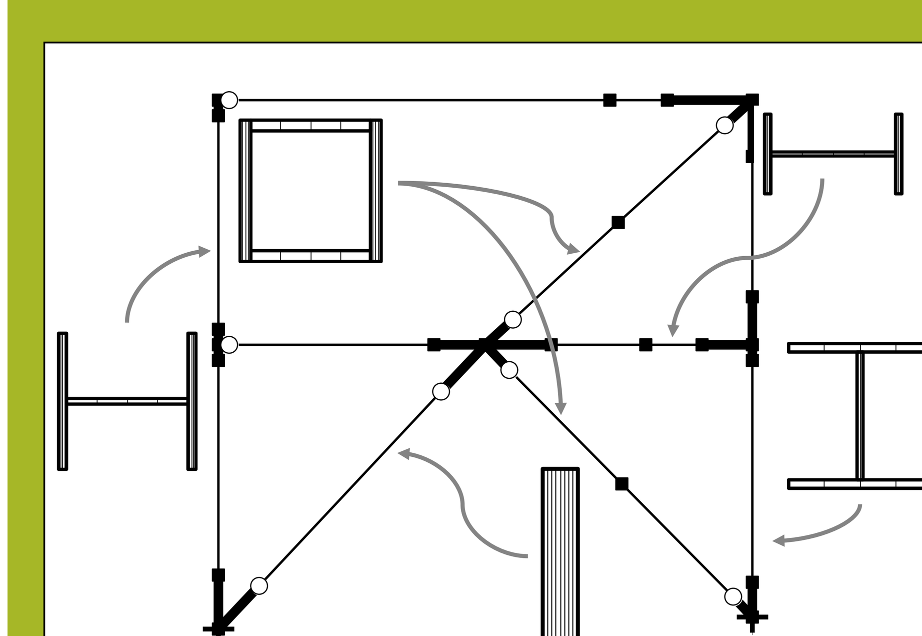


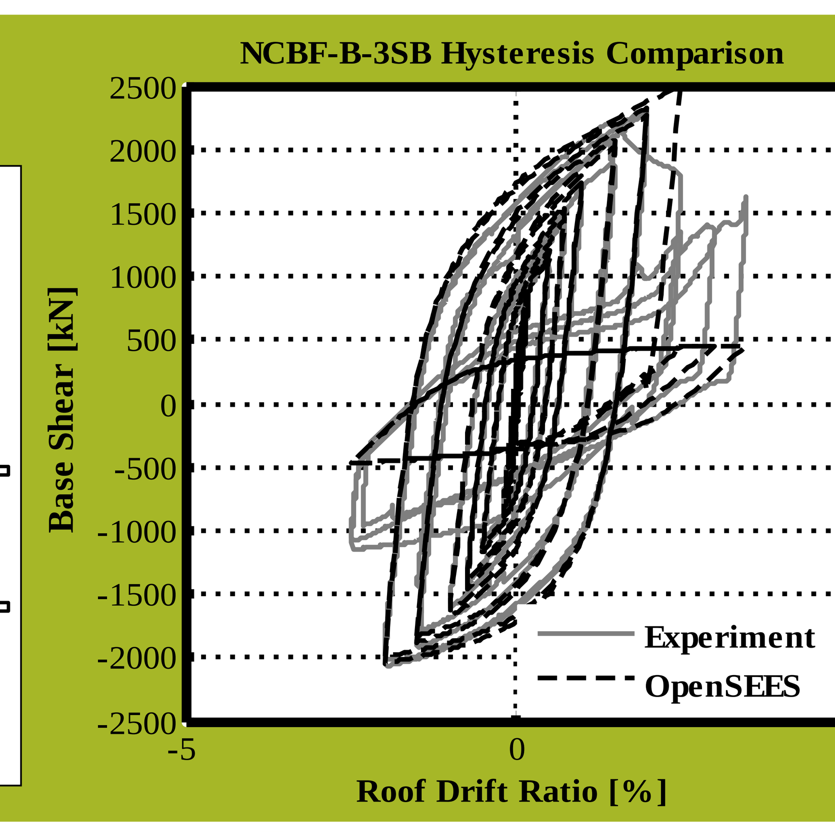
SUCCESSFUL MITIGATION OF A SOFT STORY.

EXPERIMENTAL RESULTS



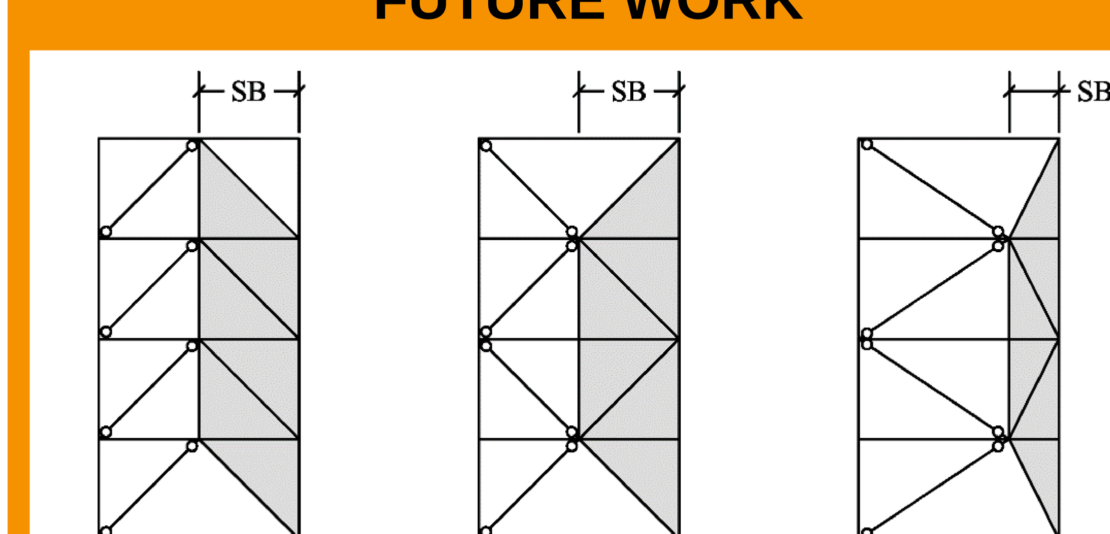
NUMERICAL CALIBRATION





ALTERNATIVE CONFIURATIONS.

FUTURE WORK



PROFESSIONAL PRACTICE.

IMPLEMENTATION & CONSTRUCTION

TIPPING STRUCTURES, BERKELEY, CA

ACKNOWLEDGEMENTS

This project would not have been possible without the substantial contributions of Schuff Steel and StarSeismic who donated the steel fabrication and the BRB. The author would further like to thank Prof. Stephen Mahin, the co-PI and advisor for this project, whose advice and feedback was indispensable. This research is supported by National Science Foundation (NSF) under grant number CMMI-1208002: Collaborative Developments for Seismic Rehabilitation of Vulnerable Braced Frames. The overall Principal Investigator for this project is Prof. Charles Roeder of the University of Washington, Seattle. The findings, opinions, and recommendations or conclusions in this paper are those of the author alone and do not necessarily reflect those of the National Science Foundation.

This project was made possible with support from:

PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

UC Berkeley ▪ Caltech ▪ OSU ▪ Stanford ▪ UC Davis ▪ UC Irvine ▪ UC Los Angeles ▪ UC San Diego ▪ USC ▪ U Washington

peer.berkeley.edu