# SEISMIC VULNERABILITY OF NON-SPECIAL BOUNDARY ELEMENT OF SHEAR WALL UNDER AXIAL FORCE REVERSALS

*2010 PEER Internship Program and NEES@Berkeley REU, University of California, Berkeley[1]*


**Cristian E. Acevedo (crienacepa@hotmail.com), Florida International University**

**Principal Investigator/ Mentor: Jack P. Moehle, Professor[1]**

**Graduate Advisors: Wael Hassan, PhD Candidate[1], Ahmet Can Tanyeri[1]**

**Research Partner: Ariel Creagh, The University of Texas at Austin**


## INTRODUCTION

The poor building performance observed in Chile after the February 2010 earthquake is questionable. It is not clear whether longitudinal reinforcement buckling of shear wall with non-special boundary elements (NSBE) was caused by compression, or yielding in tension followed by compression.

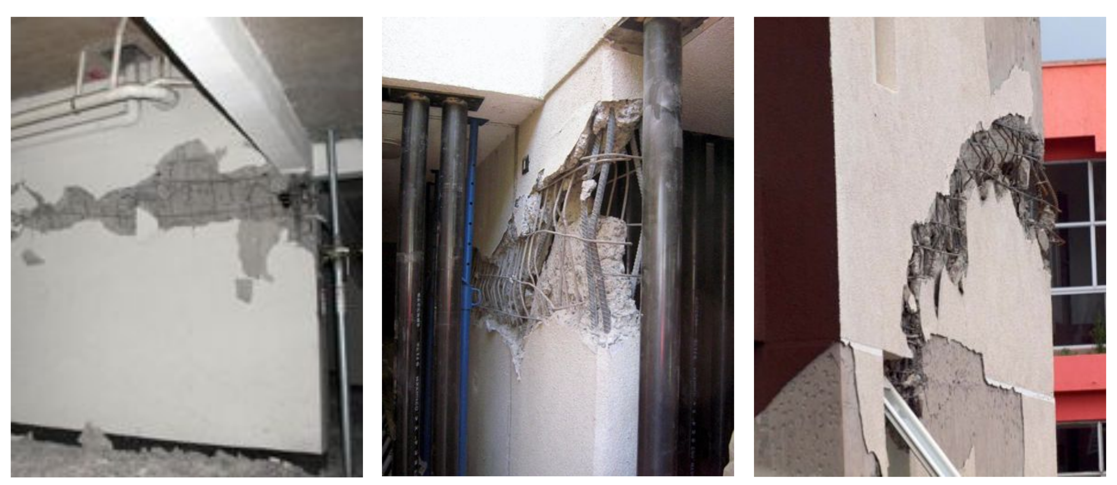


Figure 1. Buckling of Longitudinal Bars of Shear Wall with NSBE

High axial forces are triggered by earthquake lateral loads.

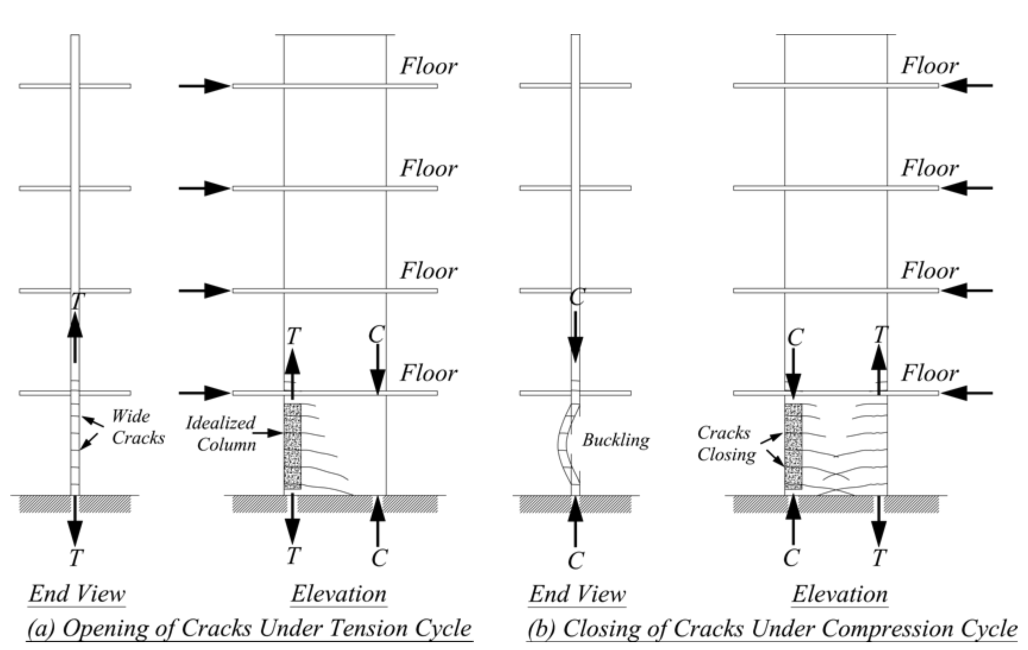



Figure 2. Earthquake Lateral Loads Inducing Axial Forces on Wall End-Region (Chai and Elayer, 1999)

***Research Importance***

- Understanding building failures is of concern since Chilean building code is similar to United States (U.S.) ACI Code.
- In the U.S. there are several buildings that are detailed with NSBE as permitted by ACI Code.
- No previous research has been done in the past to study the vulnerability of shear wall with NSBE under monotonic axial loading.

***Research Objectives***

- Study shear wall performance with NSBE under monotonic tensile and compressive axial loading.
- Provide a quick check on ACI 318-08 provisions for shear wall boundary elements.

## TEST SPECIMEN

Two NSBE specimens were designed and built according to ACI 318-08 provisions.

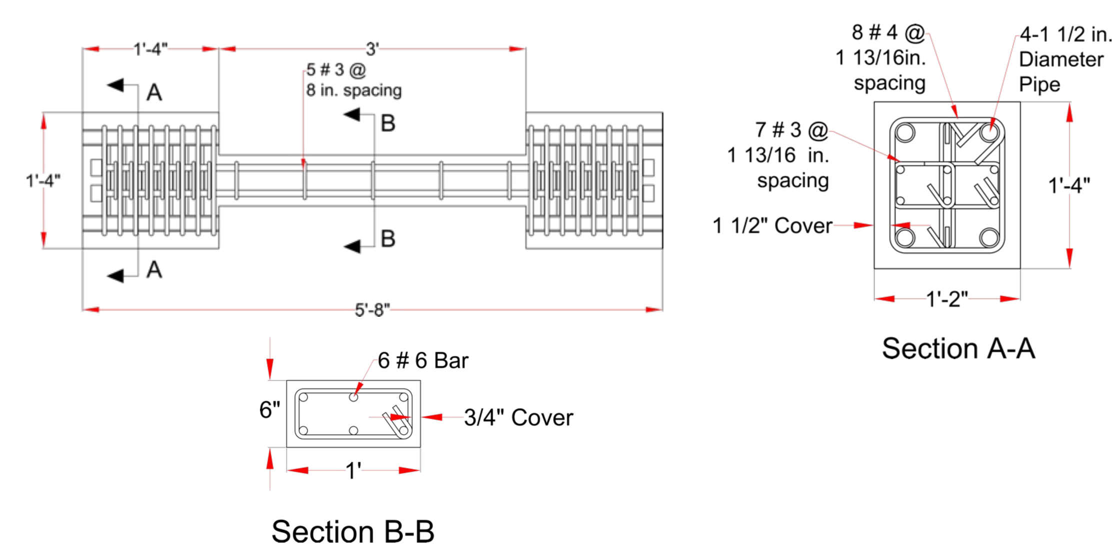



Figure 3. Specimen Design Details

Reinforcement Cage

Concrete Formwork

Concrete Pouring

Final Product

Figure 4. Specimen Construction

## TEST PROCEDURES

One specimen was subjected to compression only, while second was pulled in tension followed by compression.

***Tension Test***

- A hydraulic jack was used to pull specimen in tension to achieve 4% strain.
- Load was applied every 20 kips to keep track of crack development.

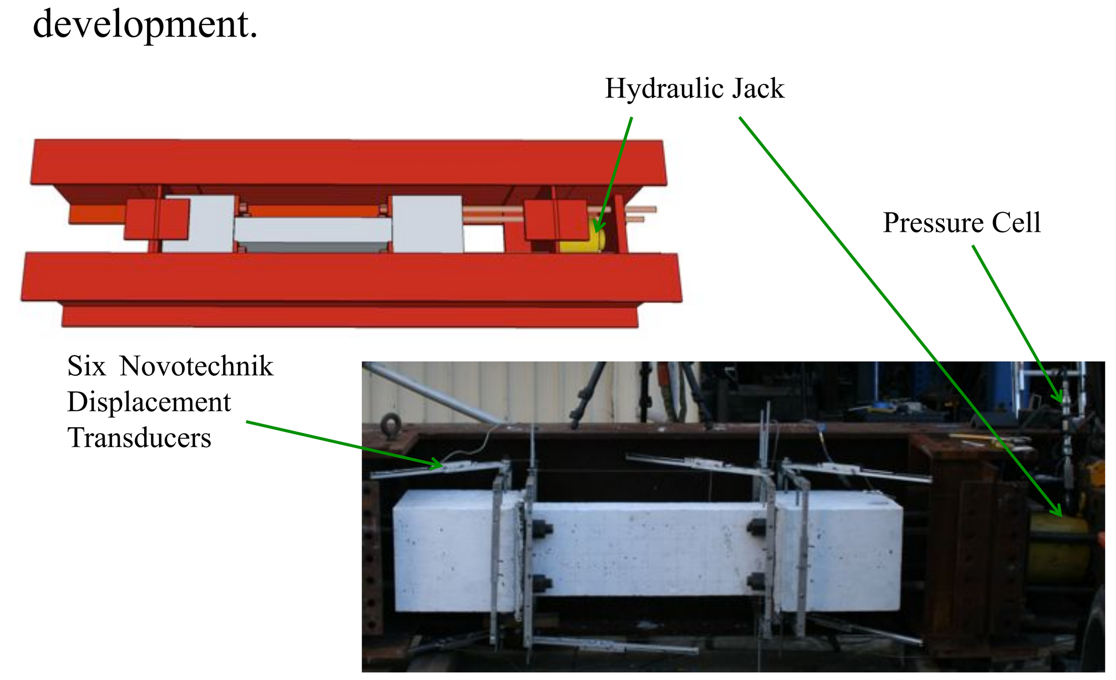



Figure 5. Tension Test Setup

## TEST PROCEDURES

***Compression Test***

- A Universal Testing Machine was used to load specimen in compression.
- Load was applied at a rate of 1042 lbs/sec.

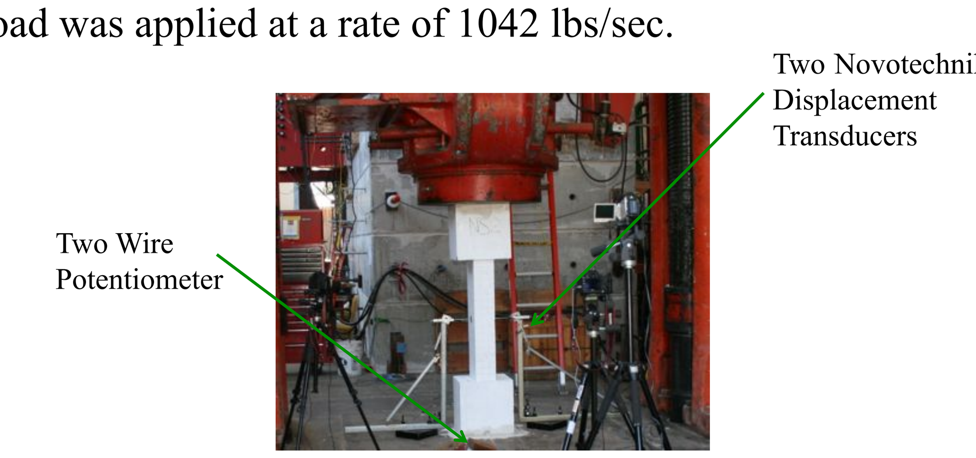
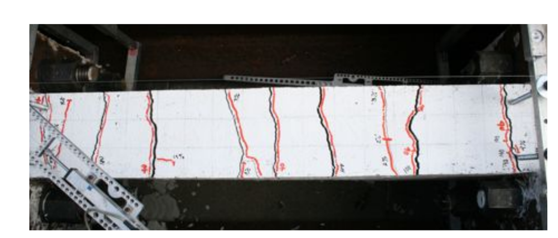



Figure 6. Compression Test Setup

## TEST RESULTS

***Tension Test Results***

- Major crack development was along transverse reinforcement.
- At 4% strain widest crack observed was 0.21 in.



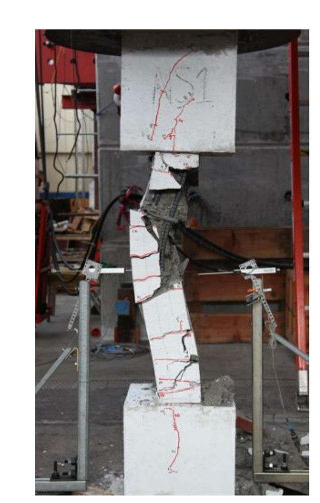
Plan View of NSBE 1

Side View of NSBE 1

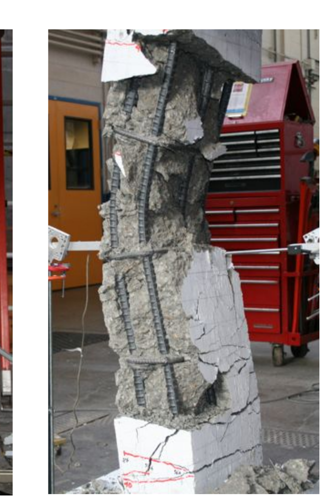
Figure 7. Crack Development at 4% Strain

***Compression Test Results***

- NSBE 1 maximum compression load was 115 kips.

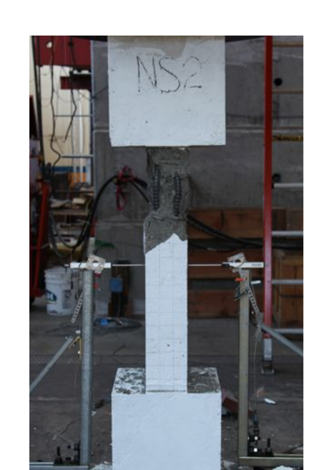


Significant Spalling



Global Buckling

Figure 8. NSBE 1



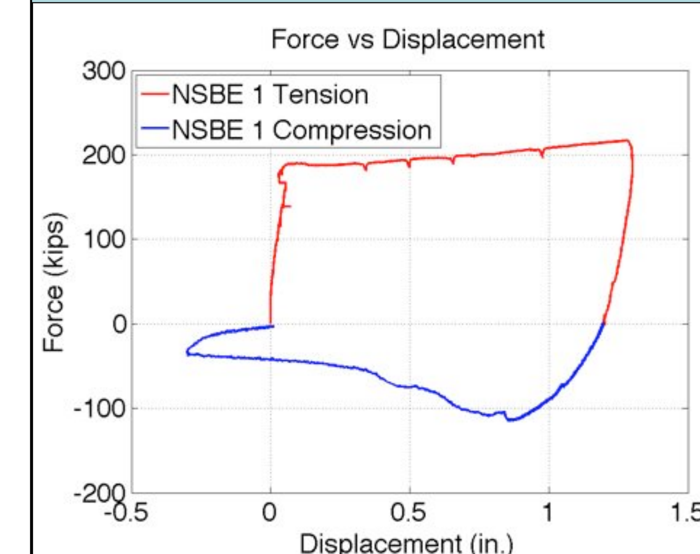
Non-ductile Behavior

Localized Buckling

Figure 9. NSBE 2

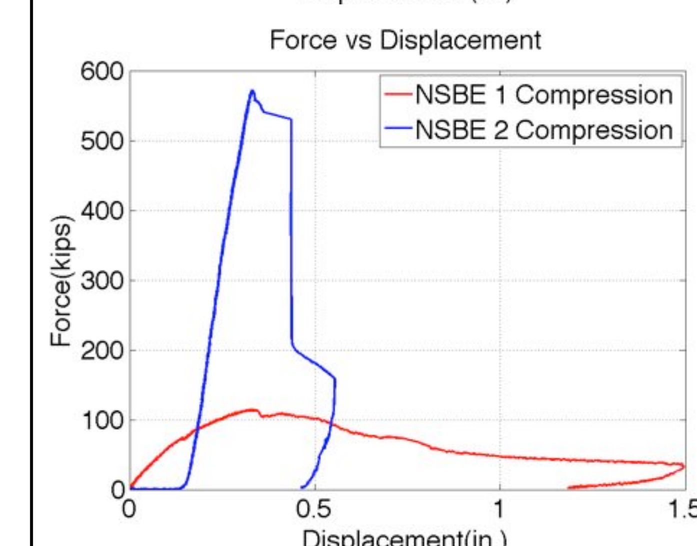
- NSBE 2 maximum compression load was 572 kips.
- Similar failure as seen in Chile.

## TEST RESULTS




***Graphical Representation of Data***

- Specimen subjected to tension became extremely weak in compression.




- NSBE 2 was five times stronger than NSBE 1.

## CONCLUSIONS

- Experimental results show that shear walls with NSBE have non-ductile behavior and are extremely vulnerable to axial force reversals.
- Results also suggest that most buildings in Chile failed locally due to compression, while others collapse due to axial force reversals.
- Revisions need to be made on ACI Code 318-08 provisions allowing the use of NSBE in buildings.

## REFERENCES


1. ACI Committee 318, *Building Code Requirements for Structural Concrete (ACI 318-08) and Commentary (ACI 318R-08),* American Concrete Institute, Farmington Hills, MI, pp. 349-356.
2. Chai, Y.H., and Elayer, D.T. (1999). "Lateral Stability of Reinforced Concrete Columns under Axial Reversed Cyclic Tension and Compression," ACI Structural Journal, American Concrete Institute, V. 96, No. 5, pp. 780-789.
3. EERI Special Earthquake Report (2010). *The $M_w$ 8.8 Chile Earthquake of February 27, 2010,* Earthquake Engineering Research Institute.


## ACKNOWLEDGMENTS


This research was supported by the Pacific Earthquake Engineering Research (PEER) Center as a part of the 2010 PEER Internship Program. Funding was provided by NSF Network for Earthquake Engineering Simulation (NEES) Grand Challenge Project. The author would like to thank Professor Jack Moehle, PhD Candidate Wael Hassan, and Ahmet Can Tanyeri for their mentorship, Erico for its generous donation of steel bars, and Ariel Creagh and the staff in Davis Hall and Richmond Field Station at the University of California, Berkeley for their support.


***For further information visit http://www.eqclearinghouse.org/20100227-chile/ and http://peer.berkeley.edu/.***