SEISMIC PERFORMANCE OF CONCRETE SPECIAL BOUNDARY ELEMENT

2010 PEER Internship Program & NEES Grand Challenge Project
PEER Laboratory at UC Berkeley

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INTRODUCTION

February 2010, a magnitude 8.8 earthquake struck South Central Chile. Of the reinforced concrete structures, 50 were severely damaged, 4 of which were partially or totally collapsed. Chilean concrete design uses shear walls as the main lateral force resisting system, and they were a critical part in the failure of these buildings. However, the failure mechanism stumped engineers. One proposed theory suggested that because of commonly used T-shaped shear walls, the boundary elements of the web section were subject to both tension and compression with reversals of the ground motion. The intention of this research was to provide evidence of the effect tensioning a boundary element has on buckling failure.

Figure 1 & 2: Failure of shear walls after Chilean earthquake

- Chile uses American building codes
- A few differences exist and codes are loosely enforced
- Damage seen in shear walls without boundary elements
- Shear walls detailed according to ACI 318-08 Section 21.9.6.4 appeared to have no damage

Figure 3 & 4: Typical damage seen in shear walls after February earthquake

SPECIMEN CONSTRUCTION

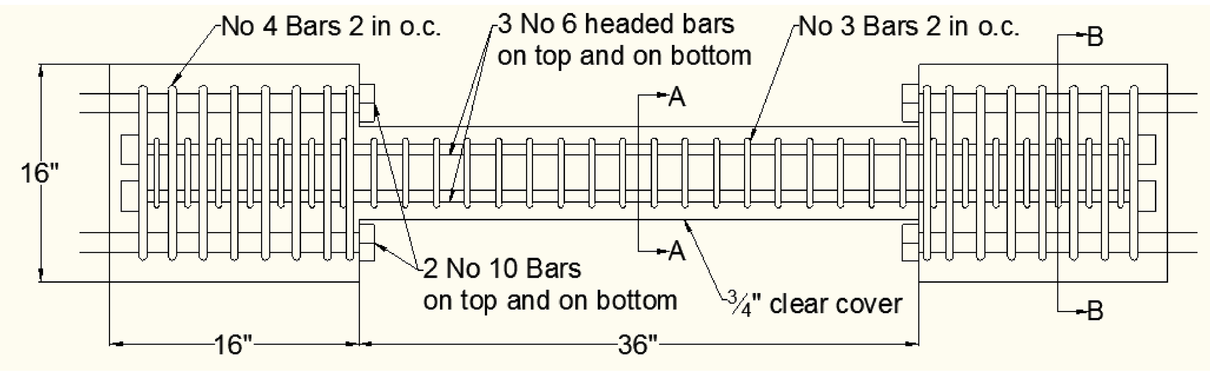


Figure 5: Design of special boundary element with tension heads

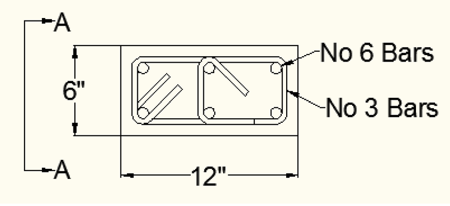


Figure 6: Cross-section of test specimen

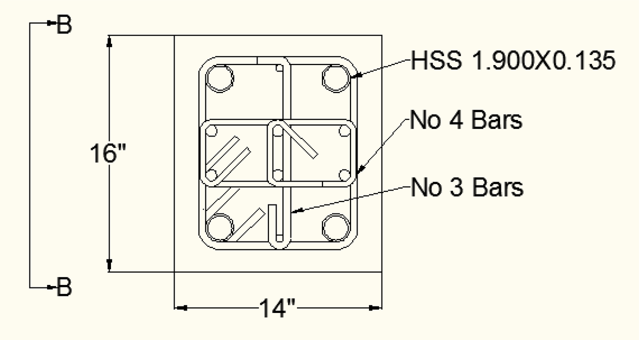


Figure 7: Cross-section of tension head

TEST PROGRAM

Figure 8: "Big Press" 4,000 kip capacity compression machine

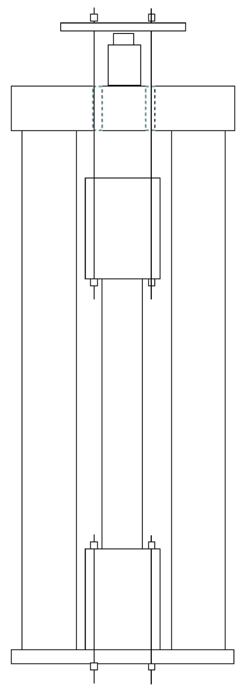


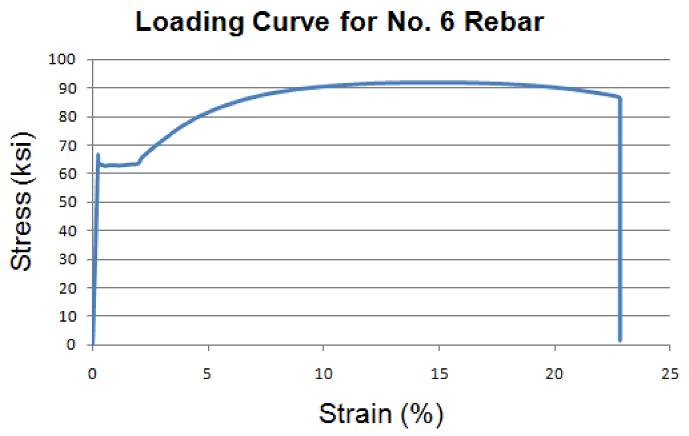
Figure 9: Design of tension test with 300 kip capacity hydraulic jack

SPECIMEN 1: Loaded in tension and compression

SPECIMEN 2: Loaded in compression only

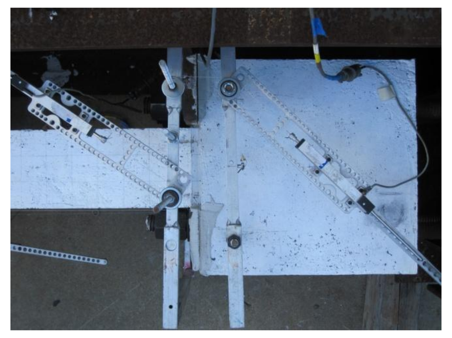
Tension:
- Loading rate controlled manual at roughly 1.5 kip/s
- Stopped at increments of 20 kips until yield where loading continued in increments of strain until 4% strain

Compression
- Loading rate at roughly 1.0 kip/s until total failure



Compressive strength tests for 6x12 concrete cylinders

Cylinder	S1	S2
1	5765	5959
2	5418	6097
3	5832	6094



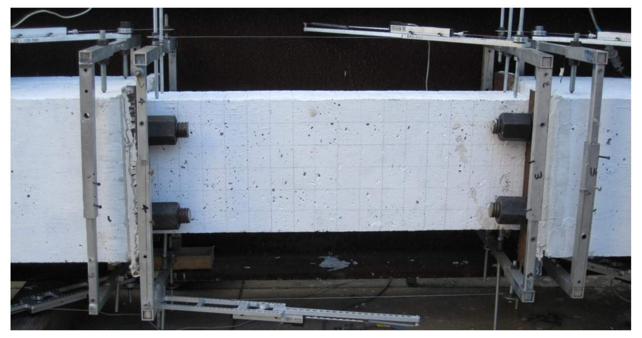
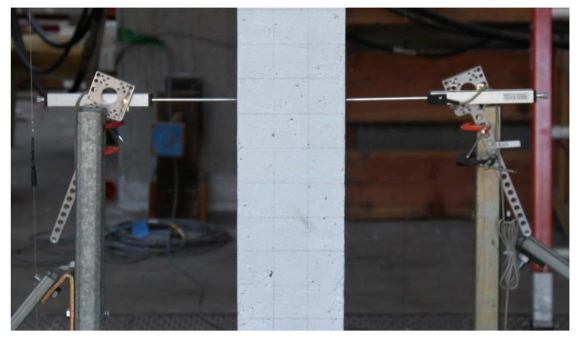
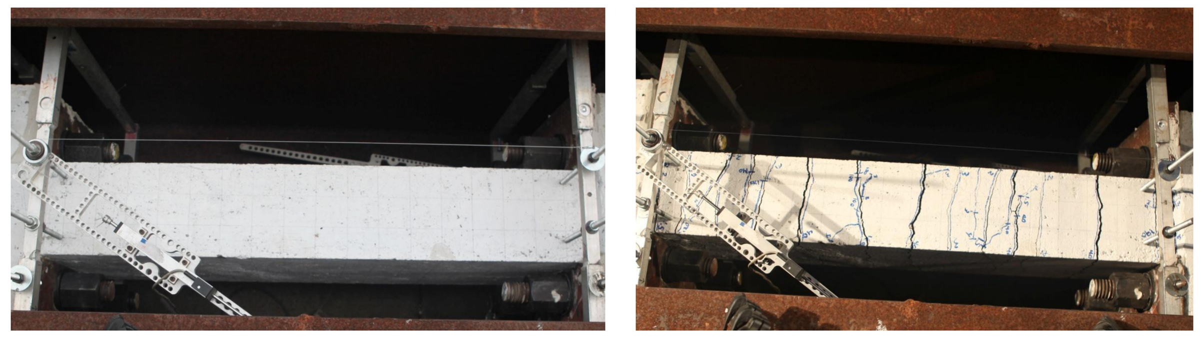


Figure 10, 11, & 12:
Instrumentation to measure displacements
- Spring loaded Novotechniks connected to removable brackets
- Wire potentiometers



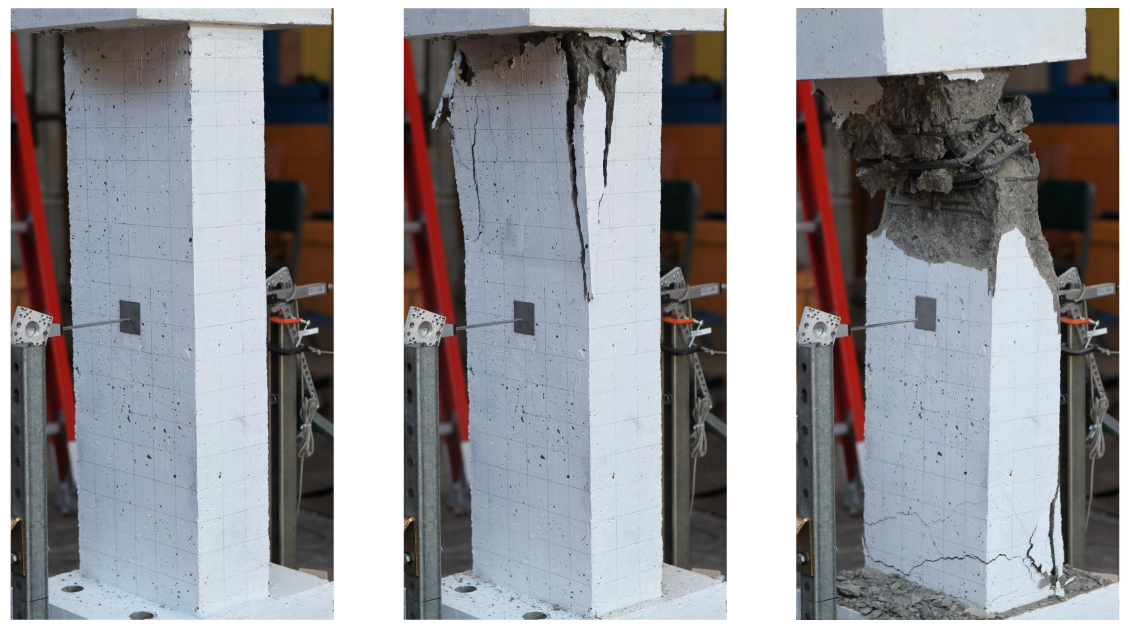
RESULTS

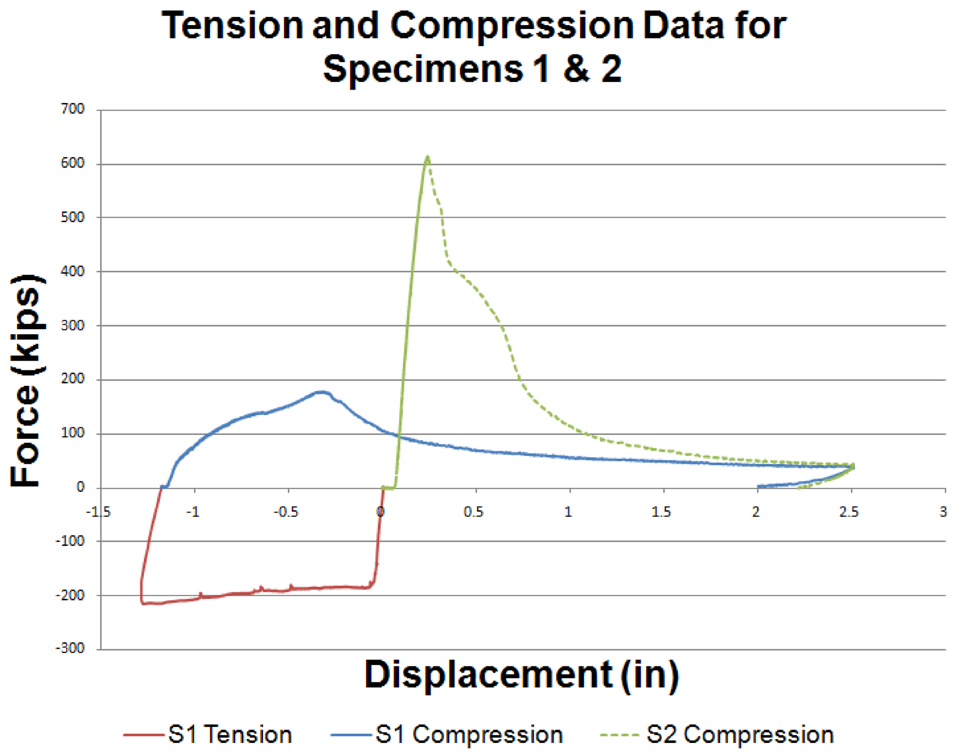
S1 TENSION



S1 COMPRESSION

S2 COMPRESSION





CONCLUSION

S1 ANALYSIS

- Development of cracks present in the planes of transverse reinforcement due to stress concentrations and decreased clear cover
- Tension loading plateaus at a yield strength of approximately 183 kips, 20 kips larger than the anticipated yield strength of the rebar , can be attributed to strain hardening

- After pre-tensioning, all the compressive load was carried by the elongated rebar
- Buckling of the yielded rebar within the cracks caused uneven contact of the separated concrete, crushing the concrete on the right side
- Instability allowed global buckling of the cross section at 170 kips

S2 ANALYSIS

- Virgin column placed in pure compression took loading until 600 kips
- Explosive spalling of the concrete and global buckling developed in a short amount of time
- Unable to declare the failure ductile as anticipated

A special boundary element subjected to tension prior to compression can only tolerate less than a third of the load capacity of a virgin boundary element. Although a more ductile failure was seen in the pre tensioned case, this drastic decrease in compression capacity is alarming. Continued analysis will take place with emphasis on Euler buckling and critical buckling load. With the following information, further research is needed: investigation under what conditions boundary elements are vulnerable to extreme tension, most probable strains likely to develop, and performance under multi-cycle loading.

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FURTHER INFORMATION

For additional information about the grand challenge project please visit:
http://peer.berkeley.edu/grandchallenge/.