ASG Talk on Buckling Restrained Brace Frame Systems

Buckling Restrained Brace Systems: Some Home Grown Comments and Suggestions

Presentation to the ASG Meeting
07 November 2012 by:
Charles Clifton, The University of Auckland

THE UNIVERSITY OF AUCKLAND
FACULTY OF ENGINEERING

Scope of talk: this will very briefly cover

THE UNIVERSITY OF AUCKLAND
FACULTY OF ENGINEERING

- BRB testing at UofA
- Some comments on BRB design
- Some suggestions for enhancing self centering of BRB framed systems for low damage design

ASG BRBF talk 7 Nov 2012

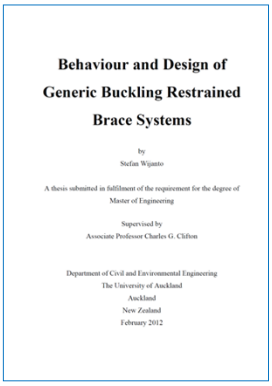
Experimental Tests on BRBs

THE UNIVERSITY OF AUCKLAND
FACULTY OF ENGINEERING

THE UNIVERSITY OF AUCKLAND
FACULTY OF ENGINEERING

Behaviour and Design of Generic Buckling Restrained Brace System

- By: Stefan Wijanto
- Supervisor: Associate Professor Charles Clifton
- Second Supervisor: Associate Professor John Butterworth
- Undertaken in 2011



Behaviour and Design of Generic Buckling Restrained Brace Systems

by
Stefan Wijanto

A thesis submitted in fulfilment of the requirement for the degree of
Master of Engineering

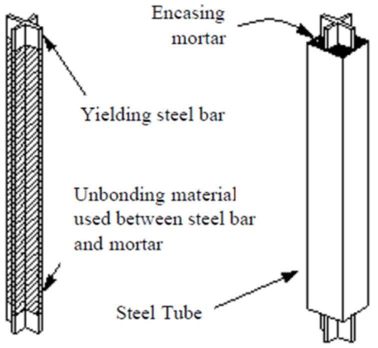
Supervised by
Associate Professor Charles G. Clifton

Department of Civil and Environmental Engineering
The University of Auckland
Auckland
New Zealand
February 2012

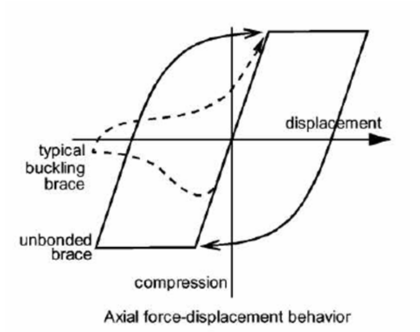
ASG BRBF talk 7 Nov 2012

THE UNIVERSITY OF AUCKLAND
FACULTY OF ENGINEERING

Buckling Restrained Braces System



(Clark et al., 2000)



(AISC, 2005)

ASG BRBF talk 7 Nov 2012

THE UNIVERSITY OF AUCKLAND
FACULTY OF ENGINEERING

Research Project

Background

- Earthquake impacts in New Zealand; emphasis on low damage solutions
- Widely applied in North America and Japan
- Subject to overseas patent laws

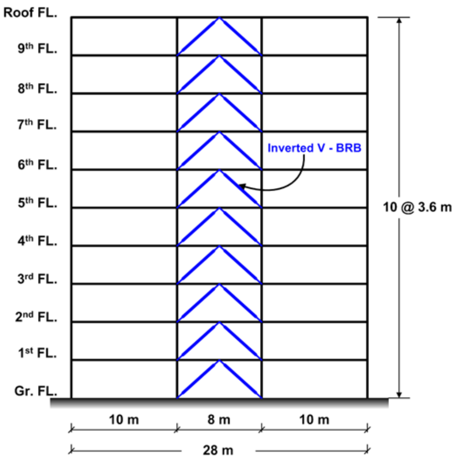
Objectives

- Development of a design procedure and application to a 10 storey building
- Determine the performance of the generic designed and developed BRB system through experimental testing; two end connection systems
- Some consideration of enhancing self centering of the BRBF systems

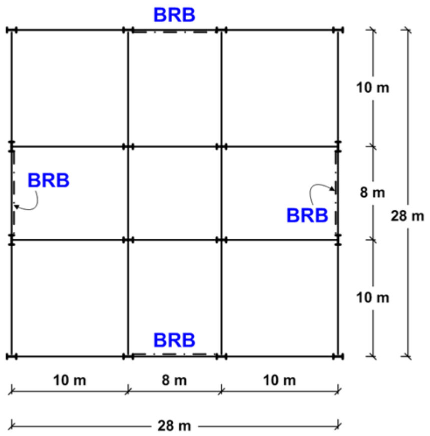
ASG BRBF talk 7 Nov 2012

THE UNIVERSITY OF AUCKLAND
FACULTY OF ENGINEERING

Case Study Model



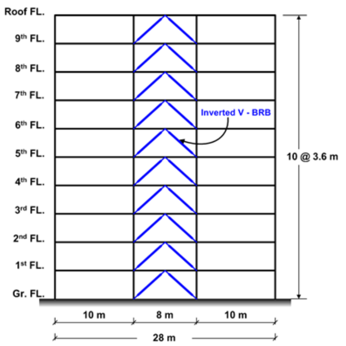
Building Section

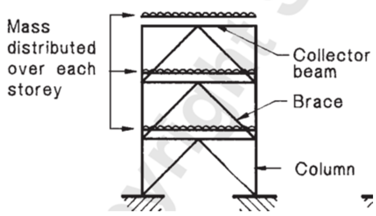


Typical Floor Plan

Questions considered

THE UNIVERSITY OF AUCKLAND
FACULTY OF ENGINEERING

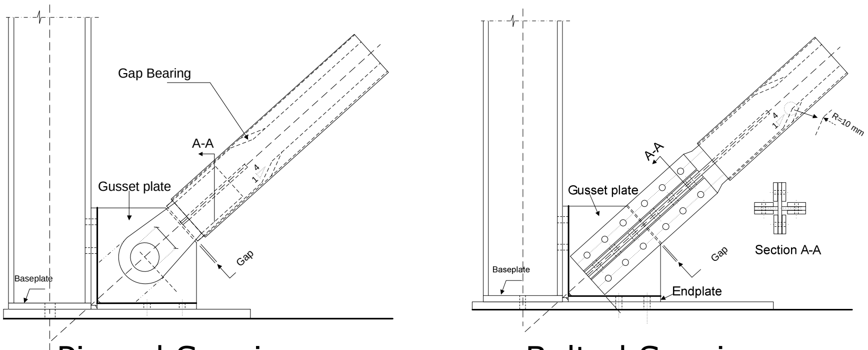




- Collector beam supported by brace or not for G&Q loading
- Semi-rigid connections between collector beam and column
- Type of connection between brace and frame
- Column base detail

Specimen Detailing

THE UNIVERSITY OF AUCKLAND
FACULTY OF ENGINEERING



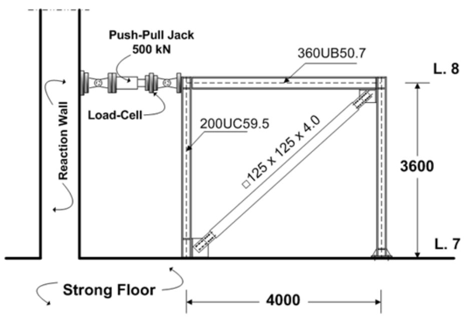
Pinned Specimen   Bolted Specimen

- Effect of each connection type on brace and frame performance
- Ensuring brace can resist moments developed with the bolted specimen

ASG BRBF talk 7 Nov 2012

Laboratory Test Model

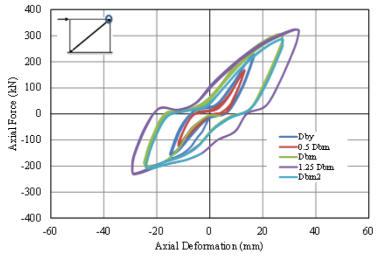
THE UNIVERSITY OF AUCKLAND
FACULTY OF ENGINEERING



- Brace comprised flat plate yielding element with *Densotape* separation from non shrink grout
- Detailing of cruciform and end connection detail to:
  - Ensure stability of overall brace between ends at gusset plates
  - Transfer in-plane end moments into restraining element
  - Confining yielding to core
  - Suppress member buckling of core

ASG BRBF talk 7 Nov 2012

BRB Dynamic Test



Key points:
- Design concept worked for brace and connections
- Slip in both connections must be suppressed with suitable detailing
- Strength and stiffness comparable in tension and compression
- Gusset plate induced moment resisted by restraining elements

7 Nov 2012

Design Considerations

THE UNIVERSITY OF AUCKLAND
FACULTY OF ENGINEERING

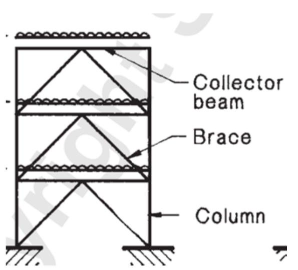
General Considerations

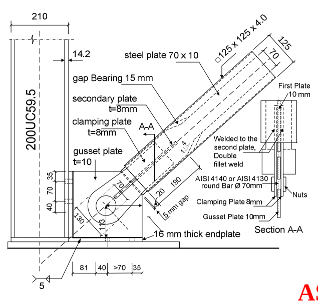
THE UNIVERSITY OF AUCKLAND
FACULTY OF ENGINEERING

- Use NZS 3404 Clause 12.12.2 with brace element slenderness ratio ≤ 30 for height limitations
- This corresponds to $\alpha_c' = 1.0$
- Use R4-76 capacity design procedure in conjunction with Wijanto's thesis and SCNZ guidance
- Model rotational stiffness in the bases in accordance with NZS 3404
- For V braced systems design the collector beam to carry 1.2G + 1.5Q simply supported
- Braces carry earthquake induced loads only

Connection Considerations

THE UNIVERSITY OF AUCKLAND
FACULTY OF ENGINEERING





- Collector beam to column connections use flush endplate design
- Mode 1 or 2 joint design
- Brace beam column connections can be bolted or welded
- Pinned ends must be designed as rotational pins (NZS 3404 Clause 9.5.2 with $k_p = 0.5$)
- Gusset plate connection must have out of plane stiffeners up to near edge of pin hole
- Bolted connections need space for bolt layout and full tensioning

Column Baseplate Connections

THE UNIVERSITY OF AUCKLAND
FACULTY OF ENGINEERING

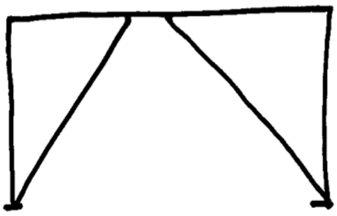
- High tension/compression forces
- May need shear key
- Adjust length of HD bolts to control stiffness
- Make these end connections rotationally elastic
- Don't want hinging in the columns at the column bases

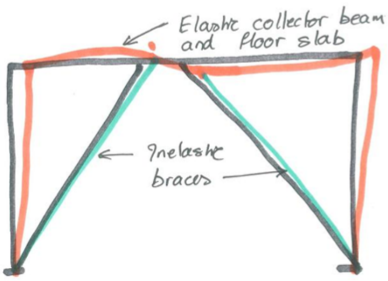
ASG BRBF talk 7 Nov 2012

Suggestion to Mobilise Floor Slab Out of Plane Strength and Stiffness

THE UNIVERSITY OF AUCKLAND
FACULTY OF ENGINEERING

- To enhance self centering
- With v-brace use an EBF configuration but with elastic beam
- Use floor slab stiffness (as seen in Chch eqs and now being quantified) to promote self centering

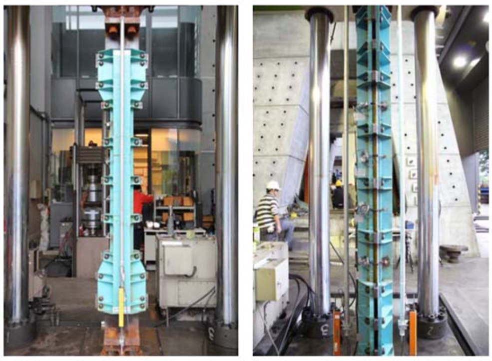


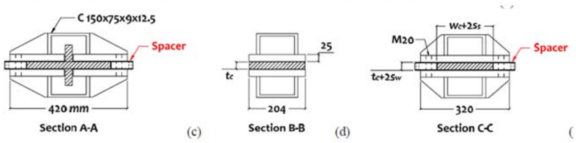


ASG BRBF talk 7 Nov 2012

15WCEE: BRB without filler material?

THE UNIVERSITY OF AUCKLAND
FACULTY OF ENGINEERING





A Type of Buckling Restrained Brace for Convenient Inspection and Replacement

An-Chien Wu & Pao-Chun Lin
National Center for Research on Earthquake Engineering, Taipei, Taiwan

Keh-Chyuan Tsai
National Taiwan University, Taipei, Taiwan

15 WCEE
LISBOA 2012

SUMMARY:
In this study, cyclic loading tests on three novel all-steel buckling restrained braces (BRBs) are conducted to investigate the high mode buckling phenomenon. The proposed BRB is composed of a steel core plate and two identical restraining members which restrain the core plate using shim spacers. The proposed BRBs can be visually inspected following a major earthquake. The two restraining members can be conveniently disassembled and the damaged core plate can be replaced if necessary. Tests confirm that the larger the applied axial compressive strain is, the shorter the high mode buckling wave length would develop. The weak-axis buckling wave length is about 12 times the core plate thickness when a core compressive strain of 3.5% is reached. Tests indicate that the proposed BRBs can effectively sustain large cyclic strain reversals. The high mode bucking wave length can be satisfactorily predicated using the proposed method.

Keywords: buckling restrained brace, restraining member, high mode buckling, wave length, local failure

1. INTRODUCTION

In contrast to the behavior of buckling braces, BRBs can be designed and fabricated to sustain yielding in both tension and compression (Watanabe *et al.* 1988). Therefore, BRBs have been increasingly adopted as hysteretic dampers to improve the earthquake resisting performance of the building and bridge structures (Uang *et al.* 2004, Tsai *et al.* 2008, Tsai and Hsiao 2008). A typical BRB has the core member encased by the buckling restrainer so that the failure of the core member cannot be easily detected. When the core member is subjected to the compression, the buckling restrainer must provide sufficient stiffness to prevent overall flexural buckling of the BRB (Watanabe *et al.* 1988). Lateral expansion increases the core member section due to Poisson effect under such compression. Thus, the clearance must be devised between the core member and the buckling restrainer to minimize the friction transferred to the restrainer (Watanabe *et al.* 1988, Wu *et al.* 2011). The clearance allows the core member to buckle first and the high mode buckling wave may form soon after the core member goes into the plastic range. The outward high mode buckling force is then produced at the crest of the high mode buckling wave (Wu *et al.* 2011, Lin *et al.* 2012). The restrainer local failure could occur due to the high mode buckling of the core member when the restrainer is not strong enough (Takeuchi *et al.* 2010, Lin *et al.* 2012). Takeuchi *et al.* carried out experimental and numerical analyses of mortar-filled BRBs to propose a criterion for the local restraint failure due to the core plate strong-axis buckling. Chou and Chen also presented the design recommendation for the sandwiched BRB to prevent the global and local buckling. Lin *et al.* provided the recommendation on the seismic design of thin BRB steel casing against local bulging failure.

Strong aftershocks could occur following the main shocks. In order to guarantee effective seismic performance of the buckling-restrained braced frames (BRBFs) which might experience multiple earthquakes and aftershocks during the service life, developing the technique for inspecting BRBs is warranted. Previous researchers have based on such concepts for BRBs in which the restrainers could be disassembled first for inspection of the core member (Takeuchi *et al.* 2010, Chou and Chen 2010).

ASG BRBF talk 7 Nov 2012