EXPERIMENTAL STUDY ON PERFORMANCE OF BUCKLING RESTRAINED BRACINGS

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Abstract - *The moment-resisting frames are susceptible to large lateral displacements during severe earthquakes. In order to limit inter storey displacements, special attention is required in design so that potential problems due to geometric non- linearity and brittle or ductile fracture of beam-to-column connections are mitigated and excessive damage to non-structural elements is avoided. With this concern, seismic design requirements for braced frames changed considerably during the 1990s, and the concept of special concentric braced frames called the Buckling Restrained Bracing (BRB) system were introduced. Main advantage of BRB is its ability to yield both in tension and compression without buckling, thus obtaining a stable hysteresis loop. All-steel Buckling restrained braces (BRBs) are a newly developed variation of ordinary BRBS with enhanced characteristics in terms of weight and curing of the mortar core. Thus, it is evident that after comparison among all 5 steel BRBs which are with or without mortar of different core plate sizes, the plate section with 15 mm air gap is found to be the highly efficient structural bracing that can be incorporated in a structure to enhance its performance with more feasibility.*

Key Words: BRB, Hysteretic analysis, Energy Dissipation, All steel BRB, Earthquake

1. INTRODUCTION

Earthquakes causes environmental losses as well as losses of lives due to collapse of structures. During a severe earthquakes event, the main structural elements like beams and columns are seriously affected. When a building is subjected to seismic wave, large amount of energy is distributed within in the building and the level of damage sustained by the building depends on the dissipation of this energy. Therefore, a structural engineer has great concern in designing earthquake resisting system to dissipate energy effectively from the structure.

The Energy Dissipation System helps in reducing the dynamic response of the structures and they primarily reduce the damage in the components of a structure. These energy dissipating systems are categorized under Passive, Active & Semi-active systems. The bracing systems come under active energy dissipation systems and they dissipate energy in the vertical path as shear walls does. Bracings are widely used to stabilize the structure against the lateral loads generated due to wind, earthquakes etc. Buckling restrained braced (BRB) frame system is one such earthquake resisting system, which is much more efficient than conventional concentric braces.

1.1 Buckling Restrained Braces (BRB)

Buckling-Restrained Braces (BRB) is a relatively recent development in the field of lateral load resisting structures.

1.2 Components of BRB

The main components of BRBs consist of a steel core, which is encased by concrete. The space between the tube and brace is filled with concrete-like material and a special coating is applied to the brace to prevent it from bonding to the concrete. So that, the brace can slide with respect to the concrete-filled tube. The concrete filled tube provides the required confinement during cyclic loading. The main load resisting element in BRB is the steel core, and the overall buckling of the core steel is resisted by the restraining mechanism provided by the outer casing.

1.3 All steel BRBs

The conventional BRBs consist of a steel core encased in a mortar filled steel tube, which restraints the core plate from buckling in compression. However, these conventional BRBs suffer from heavy weight and curing problem of the mortar core. To overcome these inefficiencies, a new type of BRBs called All – Steel BRBs were introduced. The concept behind the new configuration is the same, but the unbounding agent is not mandatory in this type.

1.4 Mechanism of BRB

The behaviour of the BRB frame and a conventional braced frame are described in the hysteresis behaviour of the brace. BRB have a stable force-deformation curve during tension and compression cycle while concentric brace performs well during tension cycle and experiences buckling during the compression cycle. After the buckling of the brace, the brace loses its strength and leads to the fracture of the brace in the subsequent cycles. Low compression cycle capacity leads to the low energy dissipation and deformation ductility of the brace when compared to BRB. Numerous studies carried out showed that BRB is a reliable and practicable to conventional lateral load resisting systems.

1.5 Innovative use of BRBs

BRBs have been used on many types of structures throughout the world, as an economic method of seismic resistance in structures such as office buildings, hospitals, retail, car parks, multi-story residential, schools, religious, stadiums and arenas, as well as non-building and industrial structures. BRB can be used in buildings as well as in bridges as a structural fuse to dissipate seismic energy. Several research works are going in this field. Umami et al. (2005) studied the implementation of BRBs for the seismic upgrading of steel arch-truss bridges. The long-span Minato Bridge in Japan, was retrofitted by installing BRBs. BRBs were placed on the cross frames of the main tower and on the lower lateral bracings near the main tower.

1.6 Literature Review

The efficacy of buckling restrained braces thus becomes valid from the large body of knowledge literatures discussed below:

Sh.Hosseinzadeh et al. (2015) assessed the non-linear static and dynamic responses of all steel buckling restrained braces and suggested they could be used to retrofit4,8 and 12 storey frames with immediate occupancy performance level and the axial forces imposed on the first story columns of the retrofitted structure witnessed a maximum reduction of 18% compared to the non-retrofitted counterpart.

L.Di Sarno et al. (2010) performed comprehensive nonlinear static and dynamic analyses for an as- built and structures retrofitted with BRBs and found that the braced frame experienced higher period of elongation than bare frame and concluded that BRBs are effective to enhance ductility and energy dissipation of the sample structural system.

Chun Che Chou et al. (2010) conducted Sub-assemble tests and finite element analyses of sandwiched buckling restrained braces and demonstrated that the cumulative plastic ductility was significantly larger than the minimum required plastic ductility specified in AISC seismic provisions.

1.7 Objective

The objectives of the project work phase one are listed as follows:

1. To conduct a parametric study for different BRBs and verify the effects of the cross section of the core, material of the core and the spacing between the restraining material and the core with an air gap using Finite Element Analysis
2. To calibrate a hysteretic model for varied BRBs, that is found to predict, with fidelity, the brace force-displacement behaviour when exposed to cyclic loading.
3. To study the energy dissipation capacity of modelled BRBs
4. To propose a reliable, economical type of BRB that outweighs the performance and yield capacity of other BRBs.

2. GEOMETRY DETAILS

The finite element models of 5 BRBs are made as follows:

Different gap sizes (10mm, 15mm, 50mm) were introduced to assess the possibility of core buckling before achieving the ultimate axial displacements demand. The gaps were only included in the side directions of the core plate in order to force the buckling to form in the more critical out-of-plane direction. The models included the core plate of available thickness in India and tube as the restrainer while varying gap sizes were implemented.

Different shapes (Rectangular, I, Tube, Plate) of Standard Indian sections where used for the core and the restrainer was made to bound the core with an air gap of 10mm,15mm,50mm. hrs. Immersion in water, a previously dried sample of the coarse aggregate should not gain in weight more than 5%. Aggregates should be stored in such a way as to prevent segregation of sizes and avoid contamination with fines.

3. ANALYSIS INPUT

Axial deformations were restrained at one end of the assembly using pinned support. Axial displacements were imposed to the other end, following the cyclic quasi-static protocol suggested by AISC Seismic Provisions for Structural Steel Buildings [July 2016] for BRBs Based on the previous studies by Tremblay et al, the peak strain amplitude in full-length core braces typically fell in the range of 0.01 to 0.02 for common structural applications and peak deformation in the majority of the past test programs has been limited to that range. In this study, was set to 20 mm, which corresponded to the axial strain of 1% in the core and the core yielding displacement, was calculated as 4mm based on the material characteristics. Hence, the ultimate axial displacement demand of the brace during cyclic loading was determined as 2 = 40 mm (i.e. =11), which corresponded to 2% of the core strain. 17 The proposed BRBs where thus subjected to Non-linear cyclic analysis and the total deformation in X axis is calculated. The load-deflection curves where computed for each and every model to obtain the hysteresis loop.

Table 3.1 Material Properties

S.NO	Shape	Restrainer Dimension (mm)	Core Plate Area (mm2)	Length of BRB (m)	Air Gap (mm)	Load (kN)
1.	Rectangular without infill of Mortar	110mm x80mm x10mm	1416	3	10	557
2.	Rectangular with infill of Mortar	110mm x80mm x10mm	1416	3	25	588.09
3.	I Section	200mm x200mm x6mm	ISMB 150	2.5	50	427.3
4.	Tube Section	200mm x200mm x6mm	100 16	2.5	50	1462
5.	Plate Section	180mm x180mm x6mm	150 20	3	15	829.5

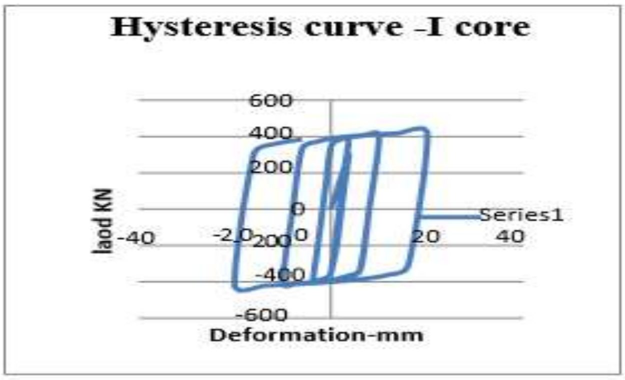
4. RESULTS AND DISCUSSION

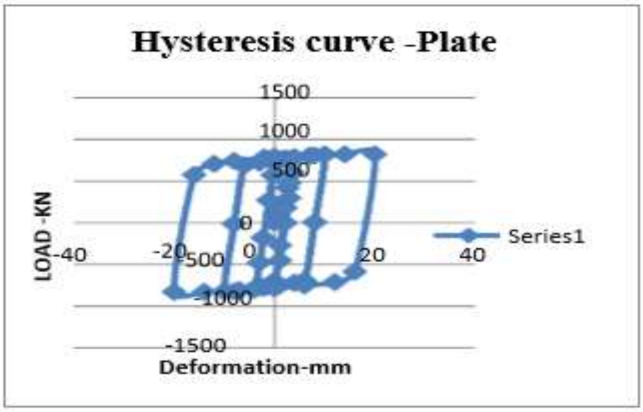
The hysteresis loop of each and every model is obtained by plotting the lateral load versus lateral deformation. These Bilinear curves are obtained by plotting P/Py along Y axis and along X axis. All curves are normalized with respect to yield lateral loads and yield lateral displacements.

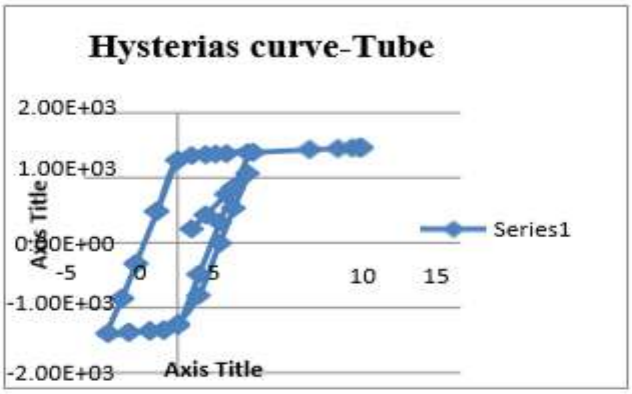
4.1. Hysteresis curves

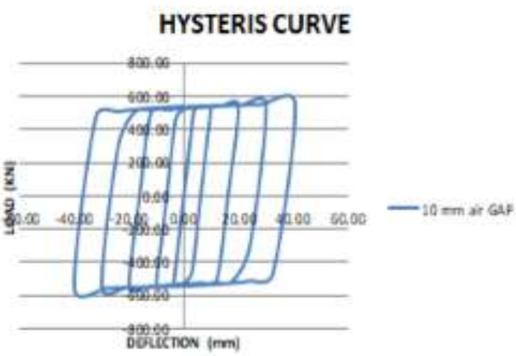
The following are evident from the hysteresis curves obtained:

1. The specimens with rectangular section gap size 10mm exhibit stable, ample hysteresis behaviour with good energy dissipation capacities and 25mm gap size with mortar fails to complete the cycles.
2. The specimens with gap sizes 50mm I sections has completed 10 cycles.
3. The specimens with gap sizes 15mm Plate sections has completed 10 cycles.
4. The specimens with gap sizes 50mm tube sections has not completed 10 cycles.









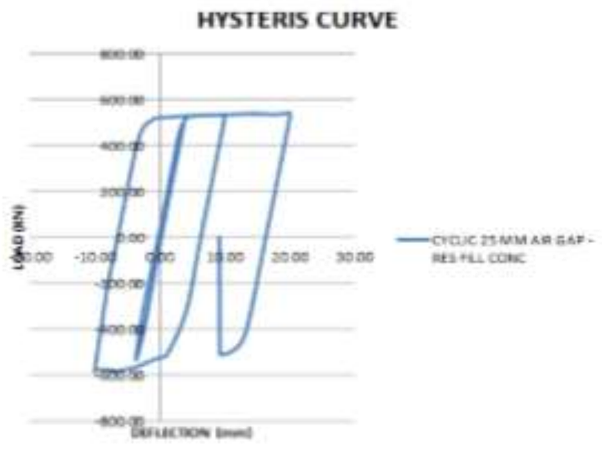


Fig. 4.1 Hysteresis and Bilinear curves for the modelled BRBs

4.2. LOAD CARRYING CAPACITY OF BRBs

ALL –STEEL BRBs:

Rectangular Section:557kN in 10 cycles at 10mm air gap
Rectangular section with mortar 25mm air gap 588.09kN in 5 cycles

Plate Section: Air gap 15mm /10 cycles load 829.5 kN

I section: Air gap 50mm /10 cycles load 427.3 kN

Tube: Air gap 50mm / 5 cycles load 1462 kN.

From the results comparing different sections of steel BRBs,

➢Tubular section takes place at 5 cycles with high load of about 1462.3 kN and it does not complete 10 cycles. Hence, this section takes high load which indicated the section.

➢Here, all other three sections such as I section, plate section and rectangular section have a complete run of 10 cycles.

➢The plate section is second best section for BRBs since it can withstand a load of 829.5 kN which is of 15 mm air gap.

➢Next to this, I section takes the position of better one where the failure takes place at 427.3 kN in 10 cycles with air gap of 15 mm.

➢Next in the line, rectangular section is considered for both air gap of 10 mm without mortar and with mortar of 25 mm air gap. In this, failure takes place at 557 kN in 10 cycles and at 588.09 kN in 5 cycles.

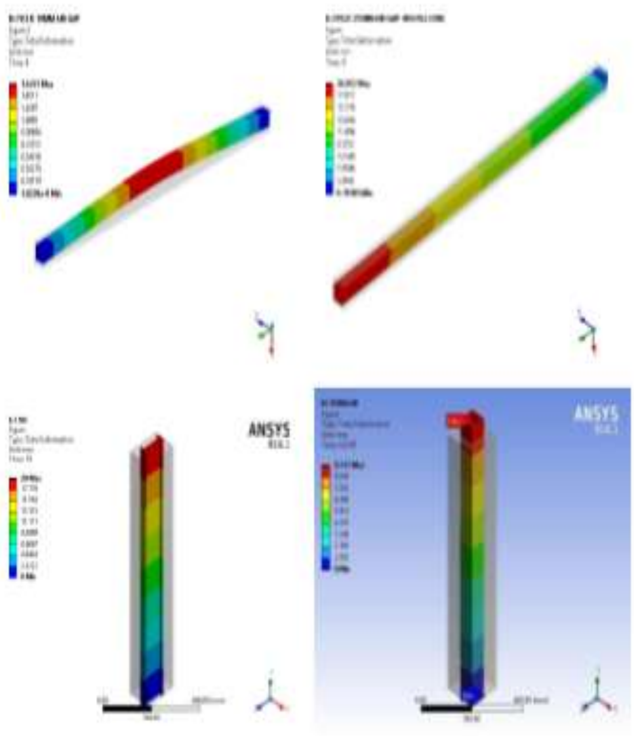


Fig. 4.2 Total Deformation of the I Section and Tube Section with 50mm Air gap

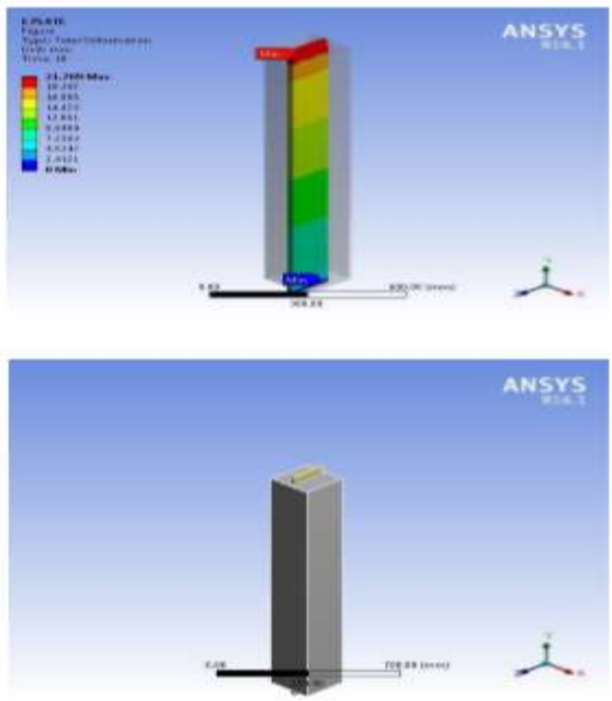


Fig. 4.3 Total Deformation of a BRB at Plate Section with 15mm Air gap

5. CONCLUSION

The parametric study on 5 proposed BRBs where carried out and a comparison of their behaviour is successfully studied. The hysteresis models for the proposed BRBs are computed and compared for efficiency. The energy dissipation capacity of BRBs is discussed in detail depending on the number of cycles and the occurrence of rupture of the sections. Thus, tube section with air gap of 50mm is found to be the most suitable form of steel bracings. This section of BRB is said to be the better option for steel bracings since it is found to be more economical and have the high ease of fabrication.

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