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Buckling Restrained Braces (BRB) – A Review

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Abstract - *Civil engineering structures are subjected to enormous cyclic forces during a seismic event. Many of the structural failures in buildings during strong earthquake shaking have indicated that sustainable strength and stable energy dissipation capability are most desirable to maintain inter story drifts and overall structural displacements within tolerable levels. So earthquake action brings a greater concern in the structural design of buildings which is situated in earthquake prone areas. Steel bracing are the common type which mainly used to resist the lateral loads acting during a seismic activity. Conventional type of lateral load resisting systems are concentrically-braced frames (CBFs) and eccentrically braced frames (EBF). Buckling Restrained Braces(BRB) are recent developed structural system which has a stable energy dissipation property. Main advantage of BRB is its ability to yield both in tension and compression without buckling, thus obtaining a stable hysteresis loop. The BRB brace placed in a concentric frame is termed as BRBF system.*

Key Words: stable energy dissipation, concentrically-braced frames, Buckling Restrained Braces(BRB), inter story drifts, hysteresis loop

1.INTRODUCTION

Earthquakes causes economic losses as well as losses of lives due to collapse of structures. During a severe earthquake 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. So a structural engineer has great concern in designing earthquake resisting system to dissipative energy effectively from the structure.

The primary function of an energy dissipation element is to reduce the damage in main structural components. Bracings are widely used to stabilize the structure against the lateral loads generated due to wind, earthquakes etc. Main drawback of conventional bracing is the degradation of brace strength under compression due to buckling of the brace. BRB is an effective solution for this problem. Buckling restrained braced frame system is one such earthquake resisting system which is much more efficient than conventional concentric braces.

2. BUCKLING RESTRAINED BRACES(BRB)

Buckling-Restrained Braces (BRBs) are a relatively recent development in the field of lateral load resisting structures. The early invention on BRB started in 80's and its testing took place in mid-80's. during 90's it was implemented in Japan and because of its good response, this technology was transferred in US in 1998 whose testing and simulation took place in 1999 and then safely implemented in important projects after 2000. In 2000, the first BRB system is applied in North America as a primary lateral resisting system at UC Davis. The figure 1 shows the various stages in the development of BRB. The concept of BRB was first conceptualized by Wakabayashi a Japanese engineer. The first buckling-restrained brace that was made up of flat steel plate sandwiched between reinforced concrete panels.

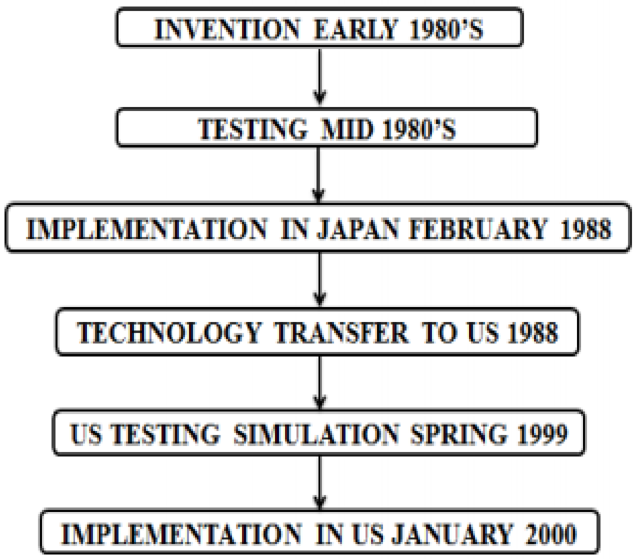

Fig -1: Timeline of BRB system development

The main component of BRBs consists of a steel core, which is encased by concrete which is shown in figure 2. The space between the tube and brace is filled with a 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.

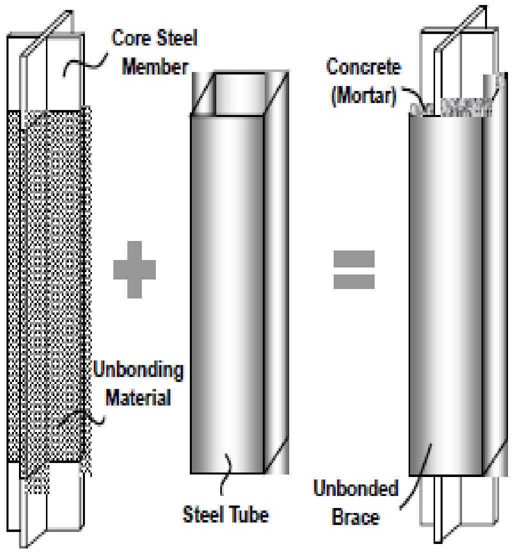

Fig -2: Schematic of buckling restrained brace

The basic behaviour of conventional braced frame and BRBF system is shown in the figure 3. BRB shows a symmetry in the response during the action of lateral loads and BRB is designed in such a way that the buckling during the compression cycle is avoided. Figure 4 shows 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 losses 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 the BRB. Watanabe et al. (1988) conducted experiments on five BRBs to investigate the effect of the strength of the steel tube on the strength of the steel core. The results suggested that, in order to prevent buckling of BRBs, the steel tube must have an elastic buckling strength greater than the yield strength of the steel core (or $P_e \geq P_y$). In order to prevent global buckling, the ratio of P_e/P_y must be greater than 1.5.

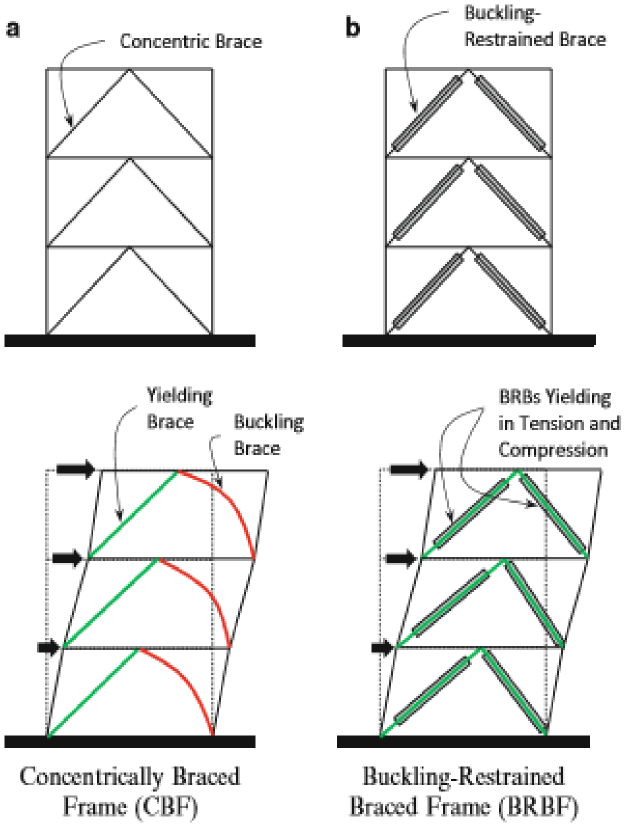

Fig -3: Behaviour of brace

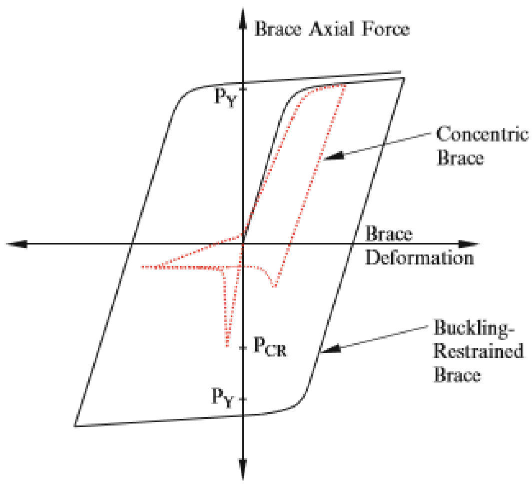

Fig -4: Hysteresis plot for buckling-restrained brace and concentric brace

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. Usami et al. (2005) studied the implementation of BRBs for the seismic upgrading of steel arch-truss bridges. The long-span Minato Bridge in Japan, which was retrofitted by installing BRBs. BRBs were placed on the cross frames of the main tower and on the lower lateral bracing near the main tower.

2.1 Advantages

BRBs offer the following advantages

- Simple modelling of its cyclic behaviour for inelastic analysis
- It can be easily connected to the structural system by means of a bolted or pinned connection to gusset plates
- Stable hysteretic behaviour and high energy dissipation capacity
- Limited sensitivity to environmental condition changes
- Design flexibility in the selection of both stiffness and strength of the whole structural system of a building
- Does not usually require structural members and foundation strengthening.
- It yields in both tension and compression
- It is easy to adopt in seismic retrofitting
- BRB act as a structural fuse and during a seismic event damage is concentrated in the BRB element. The BRB element can if necessary be replaced after a major seismic event.
- Depending on the configuration used, BRBF's can give lower foundation loads than comparable shear wall systems.

2.2. Disadvantages

However, BRBs have some disadvantages

- Lack of recentering mechanism
- Lack of criteria for detecting and checking damaged braces
- Ductility properties strongly affected by the geometry and material type of the yielding steel core segment
- Further studies regarding the reliability of brace connections to the frame are required.

2.3. Innovative uses for BRBs

BRBs have been used on many types of 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 [3][4]. Some of them are shown below.

Fig -5: Osaka International Convention Centre, Japan

Fig -6: Casad Dam, Bremerton, WA, US

Fig -7: Wallace F. Bennett Federal Building, Utah

3. LITERATURE REVIEW

A review of literatures is presented below summarizing the various work done by different scholars and researchers on BRB.

Symans M. D et al (2008) "Energy Dissipation Systems for Seismic Applications: Current Practice and Recent Developments": This paper mainly discusses about the current practice and recent developments in the application of passive energy dissipation systems for seismic protection of structures. Most commonly been used devices for seismic protection of structures include viscous fluid dampers, viscoelastic solid dampers, friction dampers, and metallic dampers. Basic principles of energy dissipation systems, descriptions of the mechanical behaviour and mathematical modelling of selected passive energy dissipation devices, advantages and disadvantages of these devices are also discussed in these paper.

Gaetano Della Corte et al(2009) "All-steel" buckling-restrained braces for seismic upgrading of existing reinforced concrete buildings: This paper discusses about a new type of BRB that is all steel BRB. In all steel type BRB the restraining unit is made of steel instead of concrete filled tube. Five BRB specimens were tested according to the AISC loading protocols. All steel BRB shows excellent response and it act as a structural fuse. Even when undesired failure modes occurred, RC frames equipped with BRBs showed superior performance over bare RC frames. All steel type have certain advantages over conventional BRB i) economical and ease of fabrication ii) easily detachable after damage iii) cost effective since pouring and curing of concrete is eliminated.

W. N. Deulkaret al (2010) This paper presents the study of Buckling Restrained Braces (BRB), its analysis, design, modeling and its application in steel building frame. Nonlinear time history analysis of 5-story 2D frame is carried using software, SAP 2000 under El Centro earthquake. The response parameters used to evaluate structural performance are natural time period, story interstory drift, displacement, axial forces and story shear. Five different types of BRB configuration are studied and the correct behavior of BRB is evaluated. It is observed that BRB can be modeled by keeping the area of central core equal to or less than half of end offset area and length of yielding central core equal to 1/3 of total length of brace. Based on the study, new brace configuration is proposed which controls joint displacement over the unbraced and BRB configurations studied

T. Usami et al (2011), Low-Cycle Fatigue Tests of a Type of Buckling Restrained Braces: in this paper the fatigue life of steel BRB is studied. Twelve BRB specimens divided into two series as welded BRB and toe finished BRB were tested under constant and variable loading. The toe-finished method can effectively improve the fatigue performance of BRBs with relatively small strain amplitudes. But the BRB's fatigue performance is affected by the in-plane gap width between filler members and the restraining member.

Fatih Sutcu et al, "Seismic retrofit design method for RC buildings using buckling-restrained braces and steel frames" This paper discusses the evaluation of seismic retrofit of building with BRB. A typical five-story RC school building in Turkey, was selected for the upgradation. The results were confirmed by nonlinear time-history analysis using high-intensity seismic waves. The building retrofitted with BRB shows relatively reduced story drift when compared to the original building and the building with CBs.

Tsutomu Usami, Hanbin Ge and Xiao-Qun Luo, Experimental and analytical study on high-performance buckling restrained brace dampers for bridge engineering: In this paper they have studied the use of BRB in steel bridges. When compared to seismic dampers in building, the main disadvantage in bridge engineering structures is that they are subjected to large number of forces. So it requires high performance dampers. The experiment conducted on five BRB specimens shows that they can be used effectively in steel bridges and it satisfies the overall buckling condition.

Jose et al (2014) Application of BRB in 50 storey building: this paper describes the use of BRB in a high rise building. Here the BRB is combined with the ductile core wall. Response spectrum analysis is carried out for design basis earthquake and non-linear time history analysis for credible earthquake. Modelling and analysis are done ETABs and PERFORM 3D software packages. The results indicate that BRB is effective in reducing base shear and controlling the deformations.

Tsutomu Usami (2015), A new seismic performance upgrading method for existing steel bridges using BRBs: In this paper a novel method for seismic upgradation of steel bridge is presented. The paper deals with the retrofitting of steel bridges without replacing the existing steel braces in the bridge. The bare H section was strengthened using BRB and experimentally investigated the properties. BRBed sections were capable to dissipate large amount of energy.

Zhe Qu et al (2015) "Seismic responses of reinforced concrete frames with buckling restrained braces in zigzag configuration": Here in this paper a new buckling restrained braced frame system was proposed which was featured by the zigzag configuration of BRB. Experimental tests were conducted to establish realistic numerical models of the brace connections in the proposed system. With these numerical models, a nonlinear dynamic analysis of a prototype building was conducted to investigate the seismic behaviour of the new braced frame system. The results show that the BRB in the new system are efficient in reducing the responses of the building, even if the nonlinearity of the brace connection is considered. Furthermore, the strength demands for the brace connections are significantly influenced by higher modes of the system after the braces yield.

Sh Hosseinzadeh (2016) Seismic evaluation of all steel buckling restrained braces using finite element analysis: this illustrates the study on finite element analysis of ten BRB specimen with varying gap size between the steel core and restrainer. 10mm air gap found to be very effective in dissipating energy. Bi linear FE derived back bone curve of the effective BRB were used to retrofit three 4,8,12 story frames. Static pushover curves of the frames shows that all steel BRB shows a more ductile behaviour compared to the conventional x bracing. Also the response modification factor for BRB was greater than the x bracing because of the ductility factor.

Ramiro Bazaez et al (2016)"Cyclic behaviour of reinforced concrete bridge bent retrofitted with buckling restrained braces", This paper illustrates the use BRB as a structural fuse for retrofitting RC bridge bents to increase their stiffness and strength, and to dissipate seismic energy through hysteretic behaviour while the bridge piers remain elastic. The results of the three large-scale experiments successfully demonstrated the effectiveness of utilizing BRBs for achieving high displacement ductility of the retrofitted structure, while also controlling cracking and plastic hinge formation in the columns and the cap beam. The lack of damage and inelastic behaviour of the RC components in BRB implies that no additional retrofit is needed of the RC column and the RC bent beam. Since no damage was observed in the gusset connection the BRB can be easily replaceable after a major earthquake event, allowing a minimal interruption of service for the bridge. BRBs as SFs can be designed and can be effective in improving seismic behaviour of building as well as bridges.

4. CONCLUSIONS

Based on the review presented shows that BRB can be effectively used as seismic resisting system. Among other conventional braced frame system Buckling Restrained Brace behaves more effectively when it is subjected to a seismic force. Its characteristic feature of stable energy dissipation without buckling is effective in resisting lateral loads. It acts as a structural fuse in bridges and buildings

REFERENCES

[1] Jose A Sy, Naveed Anwar,(2014) Application of BRB in 50 storey building, International Journal On High Rise Buildings March 2014 Vol 3 No 1, 81-87

[2] Gaetano Della Corte, Mario D'Aniello, Federico M. Mazzolani "All-steel" buckling-restrained braces for seismic upgrading of existing reinforced concrete buildings 2009 bologna

[3] K. S. Robinson, "Advances in design requirements for Buckling Restrained Braced frames" NZSEE Conference 2014

[4] M. D. Symans, F. A. Charney,A. S. Whittaker, "Energy Dissipation Systems for Seismic Applications: Current Practice and Recent Developments", ASCE 2008.

[5] Ramiro Bazaez, Peter Dusicka "Cyclic behaviour of reinforced concrete bridge bent retrofitted with buckling restrained braces", Engineering Structures 119 (2016) 34–48

[6] Sh Hosseinzadeh, B. Mohebi, "Seismic evaluation of all steel buckling restrained braces using finite element analysis", Journal of Constructional Steel Research 119 (2016) 76-84.

[7] Tsutomu Usami, Zhihao Lu, "A Seismic upgrading method for steel arch bridges using buckling restrained braces", Earthquake engineering struct. Dyn 2005

[8] T. Usami , H.B. Ge and A. Kasai ," Overall Buckling Prevention Condition Of Buckling- Restrained Braces As A Structural Control Damper", The 14th World Conference on Earthquake Engineering October 12-17, 2008, Beijing, China

[9] Tsutomu Usami, Chunlin Wang, and Jyunki Funayama, "Low-Cycle Fatigue Tests of a Type of Buckling Restrained Braces", Procedia Engineering 14 (2011)

[10] Tsutomu Usami , "A new seismic performance upgrading method for existing steel bridges using BRBs" SECED Conference: Earthquake Risk and Engineering towards a Resilient World 9-10 July 2015, Cambridge UK

[11] W. N. Deulkar, C. D. Modhera & H. S. Patil "Buckling Restrained Braces For Vibration Control Of Building Structure" IJRRAS, September 2010

[12] Xie, "State of the art of buckling restrained braces in Asia." Journal of Constructional Steel Research, vol. 61, pp. 727–748, 2005.

[13] Zhe Qu , Shoichi Kishiki , Yusuke Maida , Hiroyasu Sakata , Akira Wada, "Seismic responses of reinforced concrete frames with buckling restrained braces in zigzag configuration", Engineering Structures 105 (2015) 12–21