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Innovative Use of Buckling Restrained Braces in Framed Structures

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ABSTRACT: Non-Buckling bracing is an innovative system, in which the buckling of the bracing is prevented and the energy is dissipated by plastic deformation under tension–compression cycles, with stable hysteresis. Comparative studies as well as completed construction projects confirm the advantages of Buckling Restrained Braced Frame system. Buckling-restrained braces show the same load deformation behaviour in both compression and tension and higher energy absorption capacity with easy adjustability of both stiffness and strength. Research and developments of various types of BRBs with different configurations are introduced. Buckling prevention in BRBs is achieved by jacketing a core of a steel plate with concrete, which is in turn encased in a steel tube. This will restrain the buckling of the core plate. A coating material is used between the concrete and the core in order to prevent transmission of axial force upon the onset of plastic deformation in the plate. In this manner the compression behaviour of the brace will be the same as that of its tension. It is observed that Non-Buckling bracings are effective in dissipating energy and controlling inter-storey drift.

KEYWORDS: Buckling-restrained braces, Damper, Hysteretic behaviour, Steel frame.

I. INTRODUCTION

Steel braces are used as an economic means of providing lateral stiffness to a steel structure. However, the energy dissipation capacity of a steel braced structure subjected to earthquake loads is limited due to the buckling of braces, which show unsymmetrical hysteretic behaviour in tension and compression, and exhibit substantial strength deterioration when loaded monotonically in compression or cyclically.



Fig. 1 Buckling Brace and Unbonded brace behaviour

If buckling of steel brace is restrained and the same strength is ensured both in tension and compression, the energy absorption of the brace will be markedly increased and the hysteretic property will be good [Fig. 1]. So the Buckling-



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Restrained Brace (BRB) is proposed. The capacity of resisting earthquake loads and energy dissipation of Buckling-Restrained Braced Frame (BRBF) is better than the frame with the installation of steel braces.

In earthquake-resisting braced frames, conventional steel bracings dissipate considerable energy by yielding under tension, but buckle without much energy dissipation in the compression range of cyclic loading. The Non-Buckling bracing system is an innovative, patented concept. In this, the two requirements to be met in the design of compression members, namely the axial strength to avoid material failure and flexural rigidity to avoid buckling, are provided by an axially loaded core and the sleeve surrounding it, respectively [Fig. 2]. The space between the core and the sleeve is filled with cement grout or any other inert filler. The bond between the core and the filler is broken to ensure that no part of the applied axial force is transferred to the sleeve. The projection of core beyond the sleeve is designed such that the core does not yield or buckle locally in this region.



Fig. 2 Non-Buckling bracings

As long as the sleeve has adequate elastic buckling strength under compression, the core can be subjected to a compressive strain well beyond the yield strain, without overall buckling of the strut. Recently, Non-Buckling bracing has been incorporated as an option in the earthquake-resistant design of multi-storeyed building. This paper presents the study carried out to understand the behaviour of buildings provided with Non-Buckling bracing systems under earthquake loading.

II. NON-BUCKLING BRACE BEHAVIOUR

In Non-Buckling bracing, the bracing force is transferred only to the core, which may consist of a single or double angle, plate or rod. Under cyclic loading, the central reduced portion of the core may yield under tension and compression during earthquake loading. Since the lateral deformation of the core has to be compatible with that of the sleeve, due to the inert filler between the core and the sleeve, the buckling of the core under compression is prevented by the sleeve. Since the sleeve does not experience any axial force, so long as its Euler buckling strength is greater than that of the core in Non-Buckling bracing can undergo considerable yielding, under both tension and compression, and absorb considerable energy, unlike conventional bracing [Fig. 3].







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III. LITERATURE STUDY

3.1 Jinkoo Kim et al, 2003

Energy dissipation capacity and earthquake response of steel structures installed with buckling-restrained braces (BRB) were investigated, and a straightforward design procedure to meet a given target displacement was developed. A formulation for optimum yield strength of BRB that maximize the equivalent damping ratio was derived, and nonlinear dynamic time-history analyses were carried out to investigate the seismic response of model structures with BRB. The analysis results show that the maximum displacements of structures generally decrease as the stiffness of the brace increases, and that the maximum displacement of the model structures designed in accordance with the proposed method corresponds well with the given target displacement.

3.2 Sabelli R et al, 2003

Buckling-restrained braces provide an effective means for overcoming many of the potential problems associated with special concentric braced frames. To accentuate potential difficulties with this system, numerical modelling and design assumptions were intentionally selected in this investigation to maximize predicted brace demands and the formation of weak stories. Nonetheless, the predicted behaviour is quite good, with significant benefits relative to conventional braced frames and moment resisting frames. Response appears to be sensitive to proportioning suggesting that further improvements in response may be obtained by better estimation of a structure's dynamic properties.

3.3 Tsutomu Usamiet al, 2003

In recent years, seismic damping devices are widely used in damage control design for bridge engineering as well as building engineering. Based on the design philosophy, damage is expected to concentrate in damping devices during severe earthquake, and correspondingly damage of main structures can be controlled. Among many types of damping devices, hysteretic damper shave been caught more and more attractions because the inelastic deformation capability of metallic substances represents an effective energy absorption mechanism for damping of engineering structures with low cost.

3.4 Richard J et al, 2004

A procedures for the design of buckling-restrained braced frames is presented. The procedure uses nonlinear time history analysis and optimization. Results from this procedure are compared to those from the commonly used equivalent lateral force procedure. Results are used to develop design curves and formulas for rapid determination of cross-sectional areas for buckling-restrained braces in each story. One interesting result is that the optimum variation of area from story to story is nearly linear for most cases studied. This result is not predicted by the equivalent lateral force procedure, and can only be discovered through optimization and nonlinear time history analysis.

3.5 Kanaji H et al, 2004

Failure pattern of each BRB are different. The parallel cross-type BRB and the existing-brace-modificationtype BRB broke by tension load. However the local buckling was found in the parallel-flat-type BRB. The cumulative plastic deformation ratio of the cross-type BRB shows larger value than those of others, which satisfy the design criteria. Several types of the weight saving BRBs are proposed and they show stable hysteretic properties. The crosstype BRB and the flat-plate-type BRB provide around 50% of the equivalent damping coefficient. That of the existingbrace-modification-type BRB is 37%. Frame tests indicate the cross-type BRB is better than the flat-plate-type BRB, because the latter difference in tension and compression strength causes the residual deformation of the lower beam.



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IV. DEVELOPMENT OF BRB



Fig. 4 Flow Diagram of Development of BRB

Above flow diagram [Fig. 4] shows the development of BRB in various stages.

V. CHARACTERISTICS OF BRB

- As indicated by the achieved ductility and stable, repeatable hysteresisloops, BRB can absorb significant amount of energy during cyclic loadings, such as an earthquake event.
- It can be observed that preventing buckling leads to similar strength and ductile behaviour in compression and tension, illustrating the envelope of the hysteresis curves, also referred as backbone curve. This curve is considered as an important basis of practical design.
- In accordance with the above observations, the beneficial cyclic behaviour of the steel material is extrapolated to element level and thus to the overall structural level: an extremely dissipative structure can be designed using BRBs.
- Experimental results prove the ductile, stable and repeatable hysteretic behaviour of structures built with BRBs. Depending on the configuration of braces, the building codes (e.g. AISC) in the United States allow the use of a behaviour factor (response modification factor) up to 8, that is comparable to special moment resisting frames. Thus, the seismic load applied to the structure is efficiently reduced, which results in smaller cross sections for the beams and columns of the braced frames, smaller demands on the connections and, most importantly, the loads on the foundation are drastically decreased.



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5.1 Inelastic Response of BRB



Fig-5 Inelastic behaviour of BRB

The above figure [Fig. 5] shows that BRB undergo both tension and compression action for behaving to the seismic forces in different directions.

VI. APPLICATION OF BRB

Initial research on BRB by Wakabayashietal was originally for areal building and thereafter, many other researchers focused on BRB and its practical applications. BRBs encased by reinforced concrete panels were employed in many hotels in Japan, such as the 26-story Raguza Tower Osaka.

One of the most widely used BRBs is the type, which is employed not only in Japan, on projects such as the Project of Harumi 1 Chome and the Passage Garden in Shibuya, Tokyo, but also in the US and Taiwan.

In order to upgrade the building's seismic resistance, unbonded braces were installed throughout the entire Taipei County Administration Building (TCAB). Several new design and retrofit projects in Taiwan have selected the double-Tee double-tube BRBs to improve the buildings seismic performances. To intentionally make the BRB's yield strength low to enhance energy dissipation, low-yield steels are employed in most of the cases in BRBs [Fig. 6].



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Fig. 6 Application of BRB

Although brace is very effective in providing both strength and stiffness to buildings, it buckles if the slenderness ratio is large. So buckling must be carefully considered in braced frame design.

VII. ADVANTAGES

Comparative studies as well as completed construction projects confirm the advantages of Buckling Restrained Braced Frame (BRBF) system. BRBF can be superior to other common dissipative structures with global respect to cost efficiency due to the following reasons:

- superior ductile and energy dissipative behaviour
- low seismic loads (due to high behaviour factor and usually increased fundamental period)
- easy-to-control structural behaviour
- smaller member sizes (columns, beams)
- smaller and simpler connections
- larger efficient plan area of the building, which also increases the real estate value
- lower demand on foundations specially, the arising tension loads are drastically decreased
- easy and fast erection providing significant time savings
- easy to adopt in seismic retrofitting
- easy post-earthquake investigation and replacement if needed

VIII. CONCLUSION

- From this study it is know that BRB shows the same load-deformation behaviour in both compression and tension and higher energy absorption capacity with good adjustability of stiffness and strength.
- Appropriate layout of the BRBs, the structure would reduce the peak displacement, and lower the overall structure of displacement.
- BRB is a good absorber energy component. It is very effectively for large-span spatial structure to improve anti-seismic and enhance safety of large-span spatial structure.
- Because of its good seismic behaviour, construction feasibility, and easy-replacement, BRBs become popular in high-rise buildings in Asia.
- So on future this study will be helpful in predicting valuable things about a Buckling-Restrained Braces(BRB).



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REFERENCES

- [1] AISC 341 Seismic Provisions for Structural Steel Buildings Chapter 16 March 9, 2005.
- [2] ASCE 7 Minimum Design Loads for Buildings and Other Structures.
- [3] AISC 341-05: Seismic Provisions for Structural Steel Buildings.
- Bonessio, N., Lomiento, G., Benzoni, G., (2011), "An experimental model of buckling restrained braces for multi-performance optimum design", Seismic Isolation and Protection Systems, Vol. 2.
- [5] Constantinou, M.C., Soong, T.T. and Dargush, G.F.(1998), "Passive energy dissipation systems for structural design and retrofit", MCEER Monograph, State University of New York, Buffalo, Newyork.
- [6] Dasse Design Inc. Cost Advantages of Buckling Restrained Braced Frame Buildings. San Francisco, 2009.
- [7] European standard EN 15129:2009: Anti-seismic devices.
- [8] EN1998-1:2005, Eurocode 8: Design of structures for earthquake resistance Part 1: General rules, seismic actions and rules for buildings, CEN.
- [9] Fujimoto M,Wada A, Saeki E,Watanabe A, Hitomi Y. A study on the unbonded brace encased in buckling restraining concrete and steel tube. Journal of Structural and Construction Engineering.
- [10] L. Calado, J. M. Proenca, A. Panao, E. Nsieri, A. Rutenberg, R. Levy: Prohitech WP5, Innovative materials and techniques, Buckling Restrained Braces.
- [11] L. Dunai(2011), Type testing of Buckling Restrained Braces according to EN 15129 EWC800.
- [12] Murakami E, Mitarai Y, Asayama N, Narihara H(1999), "Experiment on retrofitting of exiting brace improved to unbonded brace", Architectural Institute of Japan, Structural Engineering Section.