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Analytical Study on Effect of Buckling Restrained Bracing with Different Configuration Under Lateral Load on Steel Building

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ABSTRACT :

Buckling-Restrained Braces (BRBs) have become one of the most efficient earthquake-resistant structural systems and have been actively applied to seismic design and retrofit of building structures. It concludes that, BRB exhibits superior behavior and a better performance when it is compared with the OB system. From this analytical study we will observed that among various configuration, which type of BRB offers better resistance to the applied lateral loads. Different type of bracing system will use to analyze story drift, story displacement, roof displacement etc. with different bracing configuration for this study. ETABS software will use for analysis.

KEYWORDS – BRB, WIND ANALYSIS, STEEL STRUCTURE, ETABS

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INTRODUCTION

Many existing buildings do not meet the lateral strength requirements of current seismic codes due to various reasons which include; The design of the building according to gravity loads only, a)Subsequent updating of seismic codes and the intensity of seismic hazard in order to minimize the level of damage and repair costs after an earthquake, b)Modifications in existing buildings, c)Change in the building use and d)Strength deterioration due to aging or previous earthquakes. Such buildings are vulnerable to significant damageor collapse in the event of future earthquakes.

Various techniques have been used for seismic strengthening of RC buildings which can be classified into two main groups:

1. The member-level techniques
2. The structure-level techniques

The member-level techniques rely on section enlargement of the existing structural members by jacketing to improve flexural, axial and shear strength of these members; enhancements in ductility and stiffness are also attained. Jacketing can be performed by reinforced concrete, steel sections or fiber reinforced polymer sheets. In general, columns are regarded as the most critical structural members to be enlarged, as the failure of columns may lead to collapse. The jacketing technique may require evacuating the whole building and is labor-intensive due to the associated heavy demolition and construction works.

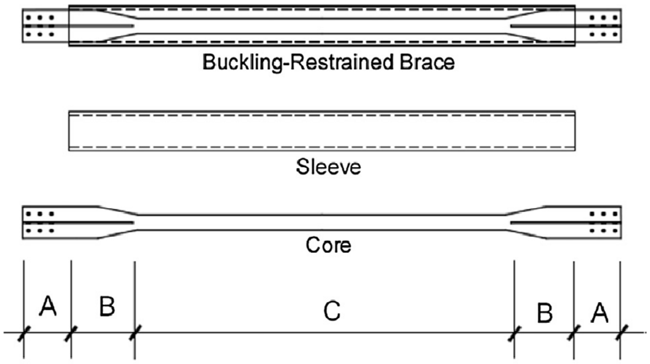
The structure-level techniques are mainly intended to reduce the demand on the existing structure by introducing new elements such as shear walls or conventional steel bracings.

Adding concrete walls by infilling certain frame bays with reinforced concrete is an efficient strengthening approach as long as the connection between the old concrete and the new ensures monolithic behavior. The main advantages of this technique are in improving the building lateral strength and in concentrating the construction work in few places of the building. However there are several disadvantages to this approach which include the need for new foundations or strengthening of the existing ones, the added new weight to the structure and the openings and lighting difficulties. Conventional steel braces have been used in seismic strengthening of RC buildings in areas of high seismicity. They can be more rapidly installed than other strengthening techniques and they do not add much weight to the structure. Buckling Restrained Braced Frame (BRBF) is a technically advanced type of Concentrically Braced Frame (CBF) that incorporates the effect of lateral forces subjected on to the structure.

1.1. What is BRB?

Buckling-Restrained Braces (BRBs) have become one of the most efficient earthquake-resistant structural systems and have been actively applied to seismic design and retrofit of building structures in regions with high seismicity.

BRB components which consist of a steel core and external jacket as shown in Figure 1.



A is the connection zone, B is the transition zone and C is the yielding Zone

Fig 1. Schematic diagram of the BRB components

The steel core is subjected to inelastic deformations under the effect of lateral loading and the external jacket serve in restraining buckling of the steel core element.

The steel core is divided into three segments:

- The yielding zone,
- The transition zone and
- The connection zone.

The yielding zone has a reduced cross section and is fully restrained to insure the occurrence of tensile and compressive yielding. The transition zones are the segments of the brace directly on either side of the yielding zone. These segments have larger cross-sectional area than the yielding zone but are similarly restrained. The connection zone is the portion of the brace that extends beyond the restraining components and is used to connect the brace to other structural elements of the frame. The steel core can be a rod, a single plate, or a built-up section and the external jacket can be made of steel tube filled with mortar. A gap between the steel core and the mortar must be set to ensure that the axial stresses are resisted by the steel core only and not by the jacket. De-bonding material, an important part of the system which separates the core and the filler, thus allowing the core to freely move and expand due to tension and shorten due to compression within the mortar. Various de-bonding material is epoxy resin, silicon resin, vinyl tapes, silicon rubber sheets, polythene film sheets, etc.Mortar, used as filler material between the steel tube and steel core to resist buckling stress. Other filler material such as reinforced concrete and grout can also be used as filler material. Uniaxial tests were conducted to three specimens of BRB with different filler materials and the results are shown in Figure 2, where filler material of specimen (a) is normal concrete, specimen (b) is aggregates and specimen (c) is lean concrete.

From the results, it can be concluded that normal concrete performs the best compared to the other filler materials. The research had also found that 25-30 MPa concrete was adequate in preventing local and global buckling of the flat plates.

There are three common configurations for BRB end connection with gusset plate is Bolted connection, Welded connection and Pin connection

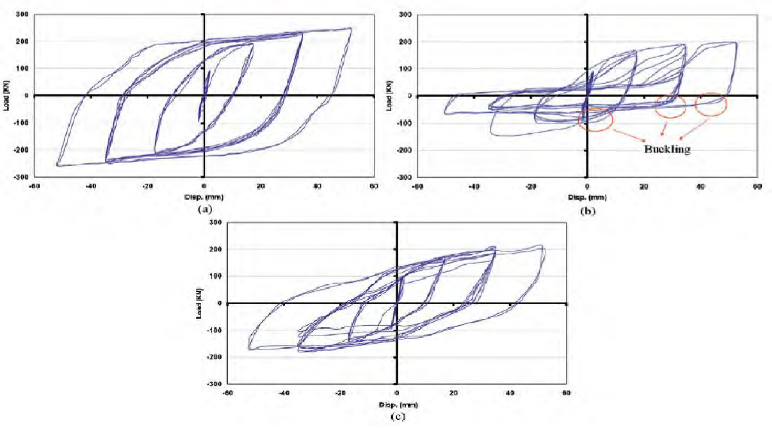


Fig 2 Comparison of hysteresis result between different types of filler material

1.2. Why BRB?

In a severe earthquake, the braces are subjected to extreme loading with repeated cycle of stress, which exceed the elastic limits of the brace. The braces will then yield in compression and tension to absorb and prevent the build-up of energy in the structure. The concept of BRB is shown in Figure 3

The bracing ability of conventional steel, in this case, is limited by its tendency to buckle due to the combination of compression force and the unbraced lengths of the steel core, which results in unsymmetrical hysteretic behavior as shown in Figure 4

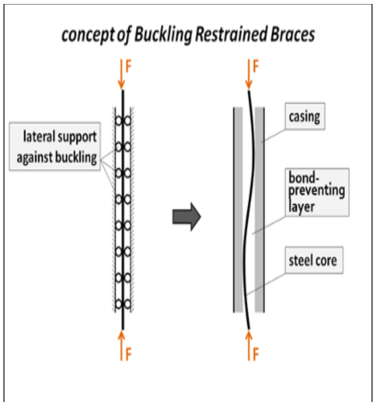


Fig. 3 Concept of BRB

After buckling occurs, the ability of the braced member to resist earthquake loading and to dissipate energy will be severely reduced. This also leads to complex design methods as the behavior of a buckled brace is very unpredictable.

Therefore, research has been focused towards finding a way to prevent the buckling of the brace, and to ensure that the same strength can be achieved by the brace in both tension and compression, which simplifies the design process.

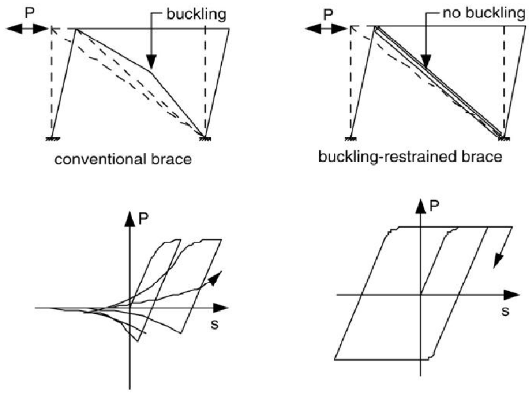


Fig 4 Behavior of conventional brace and BRB

Lateral loads can develop high stresses, produce sway movement or cause vibration. Therefore it is very important for the structure to have sufficient strength against vertical loads together with adequate stiffness to resist lateral forces. The brace which attempts to inhibit buckling under compression is called Buckling Restrained Brace (BRB).

Buckling restrained braces have full balanced hysteresis loops with compression and tension yielding behavior.

1.3. Objectives :

Buckling-Restrained Braces (BRBs) have become one of the most efficient earthquake-resistant structural systems and have been actively applied to seismic design and retrofit of building structures

The main objectives for present work is as follows :

- To study the various effect on performance of steel structure having BRB under different story height, using different bracing configuration system.
- To Analyze the inter story shear, roof displacement, story displacement, base shear, story drift and time period using BRB.
- Proposing the various configurations which have better performance.

RESEARCH METHODOLOGY & MODELING

Initially a building plan is selected and modeled in ETABS setting preliminary units, Dimensions, and codes according to Indian standards. Assigning preliminary sizes for columns, beams, slabs and BRB. Assign the fixed supports as required for the building. The diaphragms are added and are assigned to each floor of the building. Calculating loads such as dead, live and wind and loads as per IS 875-part1, 2, 3 1893 respectively.

1.1 Building Model

Table 1 model configuration

No. of stories	G + 15
Floor height	3 m
Total height of building	33 m
Plan area	24 m x 24 m
Slab thickness	100 mm
Concrete grade	M 25
Steel grade	Fe 250
Density of wall	20 N/m^2
Wall thickness	230 mm
Live load	3 KN/m^2
location	Ahmedabad
Basic wind speed	39 m/s
Terrain category	Class 2
Structure class	B
Risk factor k1	1.0
Topography factor k3	1.0
C_p	As per IS 875:1987

Calculation of BRB :

The BRBs are modeled by a truss element characterized by a cross-section with an equivalent area Aeq equal to

$$\mathrm{Aeq} = \frac{\mathrm{Ac}}{\frac{\mathrm{Lj}}{\mathrm{Lw}}\frac{\mathrm{Ac}}{\mathrm{Aj}} + \frac{\mathrm{Lt}}{\mathrm{Lw}}\frac{\mathrm{Ac}}{\mathrm{At}} + \frac{\mathrm{Lc}}{\mathrm{Lw}}}$$

Where,

L_c = The length of the yielding core

L_t = The length of the restrained non-yielding segment

L_j = The length of the unrestrained non-yielding segment

L_w = The length of the whole brace

A_c = The area of the yielding core

A_j = the area of the restrained non-yielding segment

A_t = the area of the unrestrained non-yielding segment

Area of yielding core,

$$A_c = \frac{V}{2\,\mathrm{fy}\cos\alpha}$$

Where,

V = shear force

F_y = yielding stress of the BRB's core

α = angle of inclination of the brace with respect to the longitudinal beam axis

$A_t = 2\ A_c$ ▪ $A_t = 2\ A_c$

$A_j = 3.33\ A_c$ ▪ $A_j = 3.33\ A_c$

In accordance with common application of BRBs, the length of the yielding core is supposed to be equal to 0.5 L_w in V type of bracing and 0.65 L_w in diagonal type of bracing.

$L_j = 0.65$ m

$L_t = 0.5\ (L_w - L_c - L_j)$

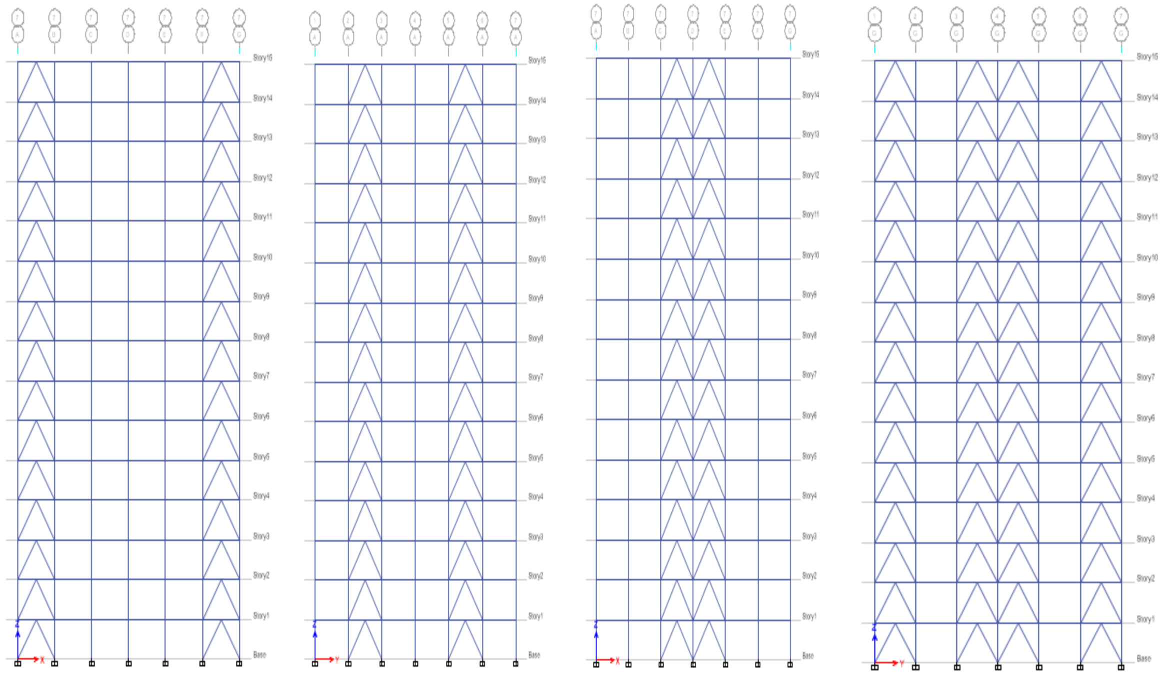
Fig shows the how bracing are provided in bays. Fig sows the providing BRBs in Inverted V type of bracing. Same as it provided in Backward, Forward, X and V type of BRB.

Type I : BRB in bay 1 & 6

Type II : BRB in bay 2 & 5

Type III : BRB in bay 3& 4

Type IV : BRB in bay 1,3,4 & 6



Type I **Type II** **Type III** **Type IV**

Fig 5 models with different bracing provision

2. Result and Discussion

The BRBs are modeled for the building with different configurations and comparison was made to propose the suitable configuration. Here in order to look at the benefit of BRB system in the lateral load conditions the comparison has been made and finalized that which type of system gives the better performances among all types of BRB.

1. Story Drift

From the Fig. 7 it can be observed that building without BRB shows more storey drift compared to the building with Inverted V types of BRB. From the above four different types of BRB model, type-4 showed to have less storey drift. It can also be observed that the storey drift at eleventh floor is maximum because of the more variation in the displacement.

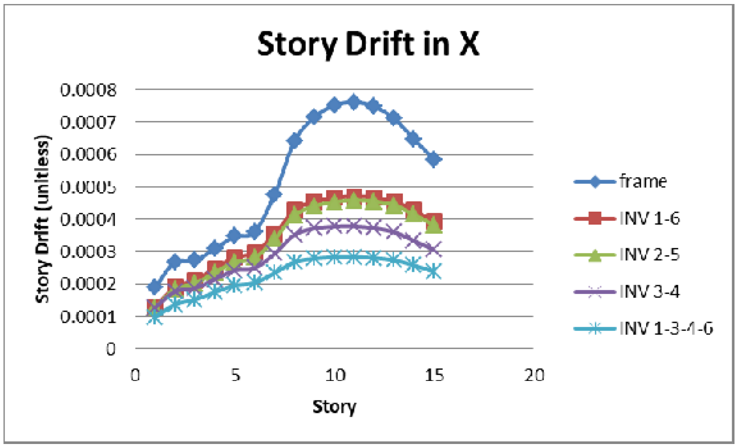


Fig 5 Story Drift in X

2. Roof displacement

In the fig it was observed that providing BRB in bay 3-4 is better than the providing it in 1-6 or 2-5. When BRB in 4 bays is used as better lateral support to the building, the displacement is more reduced as compare to any other type.

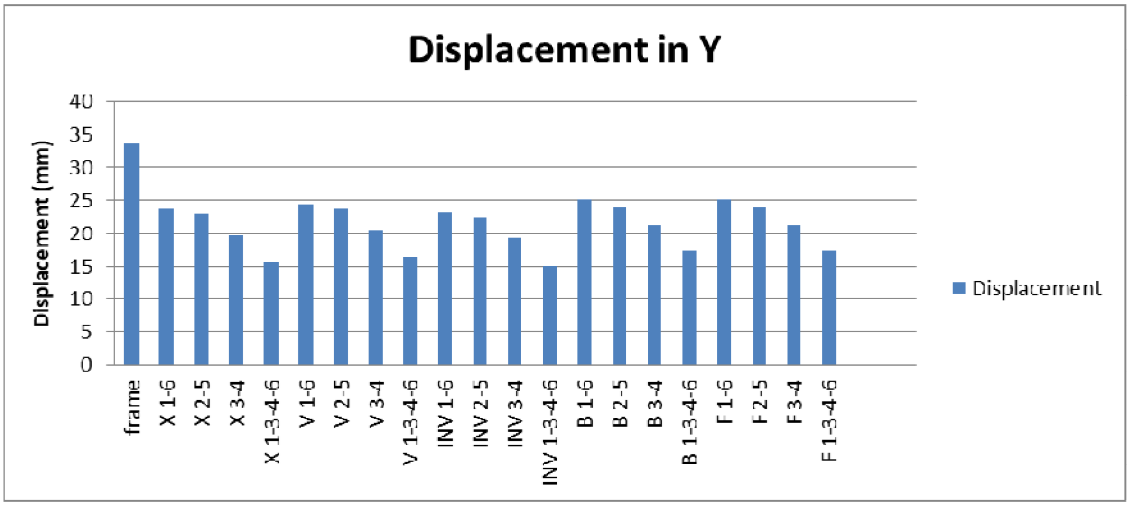


Fig 6 Roof Displacement in Y

CONCLUSION :

- The use of BRBs in two and four bay in each of the perimeter frames of the RC building results in a significant improvement.
- The storey displacement were decreased by 45% for providing BRB in two bays and decreased by 57% for providing BRB in four bays,
- The storey drift were decreased by 33% for providing BRB in two bays and decreased by 63% for providing BRB in four bays.
- In BRBFs, braces acts more effective in inverted V geometry than in any other form in steel structure.

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