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Comparative Study of Buckling Restrained Braces and Conventional Braces in a Medium Rise Building

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Abstract: ***Earthquake forces on the structures are great concern for the engineers. To minimize the effects of Earthquake and lateral forces on the structure, bracing system is one of the systems which play an effective role in resisting the lateral forces in buildings. New type of bracing system, called Buckling Restrained bracing system, has many advantages over conventional bracing, hence can be employed in the structure. In present study, comparative analysis between conventional bracing systems and buckling restrained bracing system is done. For comparison, ten story concrete reinforced building which is located in seismic zone IV and soil type is II as specified in IS 1893-2002 is analyzed using a commercial software ETABS v2015. Inverted V braces are used for both the buildings. For the analysis, Response Spectrum analysis is done and the various parameters such as story drift, story forces and story displacements have been evaluated and compared. It is concluded from this study that buckling restrained bracing can reduce the effect of lateral forces on a building compared to conventional bracing***

Keywords: Buckling restrained braces, response spectrum analysis, ETABS v2015, story drifts, conventional bracing

1. Introduction

1.1 General

Lateral displacements on structural buildings have been of great concerns for engineers. In order to minimize the effect of earthquake and wind forces, special diagonal members, called braces, have been used successfully. However, these members when subjected to compressive forces exhibit buckling deformation and show unsymmetrical hysteretic behavior in tension and compression. 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 simplified. These requirements motivate researchers and engineers to develop a new type of brace, the buckling-restrained brace (BRB). The concept of the BRB is simple, restraining the buckling of the brace so that the brace exhibits the same behavior in both tension and compression.

The main characteristic of a BRB is its ability to yield both in compression and tension without buckling. A BRB is able to yield in compression because it is detailed and fabricated such that its two main components perform distinct tasks while remaining de-coupled. The load resisting component of a BRB, the steel core, is restrained against overall buckling by the stability component or restraining mechanism, the outer casing filled with concrete. The typical view of Buckling Restrained Brace is as shown in Fig. 1

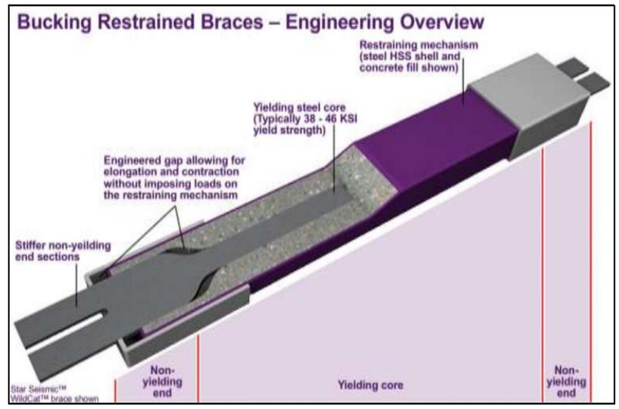

Figure 1. Buckling restrained brace.[2]

Bonding of the steel core to the concrete is not allowed to ensure that the BRB components remain separate and composite action not allowed to takes place. The BRB brace is placed in a concentric braced frame and becomes a buckling-restrained braced frame (BRBF) system. The braces are typically used for structures where seismic activity may be encountered, regardless of whether wind or seismic loads govern the design of the structure. Thus the core in Buckling-Restrained Braces can undergo considerable yielding, under both tension and compression, and absorb considerable energy, unlike conventional bracing as in Fig. 2

Testing performed on BRBs has suggested that BRBs may be capable of withstanding multiple seismic events without failure or loss of strength. Though the construction of the BRB appears to be simple, poor design of a BRB can result in casing buckling, connection failure, and poor BRB performance, so it is important to incorporate only fully tested products manufactured at facilities with personnel who are trained in BRB manufacturing and incorporate rigorous quality procedures.

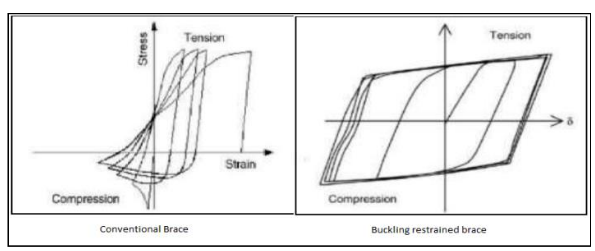

Figure 2. load tests on braces.[3]

The rapid expansion of the use of the BRB in all types of projects has occurred due to the clear cost savings of the overall system and the simplicity of design and erection. Many cost studies have been performed comparing BRBF frames to

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Eccentrically Braced Frames (EBF) and ductile Concentrically Braced Frames (CBF). The majority of the savings found was due to the smaller, simpler gusset plates, but there were also significant savings on beams, columns, and foundations.

The concept of buckling-restrained braces was introduced about thirty years ago in Japan by Nippon Steel Corporation. The idea behind a buckling-restrained brace is to fabricate a structural element that is able to work in a stable manner when subjected to compressive deformations. Because, braces are normally able to behave in a stable manner when subjected to tensile forces, a buckling-restrained brace is capable of dissipating large amounts of energy in the presence of multiple yield reversals.

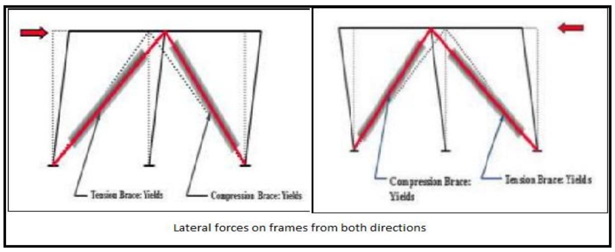

Figure 3. effect of lateral force. [2]

The above figure [Fig. 3] shows that BRB undergo both tension and compression action for behaving to the lateral forces in both directions.

1.2 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 behavior.
- Low seismic loads (due to high behavior factor and usually increased fundamental period).
- Larger efficient plan area of the building, which also increases the real estate value.
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- It yield in both tension and compression
- It is easy to adopt in seismic retrofitting
- Braces can be designed for controlled strength and stiffness
- BRBs are lightweight, compact elements which can be designed and detailed with a variety of end connection configurations (pinned, welded, bolted)
- Damage in a seismic event 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

1.3 Need of Buckling restrained brace

Based on many research studies, it is proven that in high seismic zones common RCC buildings are failed to perform up to the desired life span of the structure. To get rid over this problem, bracing system is now a day looks better option. It not only stabilizes the structure but also gives more stiffness to it.

This modified brace called Buckling-restrained brace have much more advantages over conventional braces, such as it is very cost effective, higher stiffness value, low maintenance, easy replaceable, and many more. Keeping these points into consideration, this research work leads to study of behavior of BRB frame structure with commercial software ETABS v2015.

2. Model and analysis:

This study is concerns about comparative study between two similar buildings with BRB and conventional bracing systems. Building is located in seismic zone IV soil type is considered as of type II. Detailed description about the building and its components is as follows:

- Plan area = 20x20 m
- Beam size = 0.3x0.45m
- Column size = 0.45x0.45m
- Slab thickness =0.15m
- Live load = 2kN/m
- Floor Finish = 1.5kN/m
- Seismic zone IV
- Steel brace ISMB450
- Buckling restrained brace BRB.5
- Grades: Fe415, M30, Fe250

Both Buildings are classified as Building A for conventional bracing and building B for BRB bracing. Bracing patterns in both buildings are same as in middle bay in X-direction there is inverted V type brace and in 2nd, 3rd bay of Y-direction there are forward and backward braces respectively. Plan and elevations for both buildings are ideal except the bracings used as shown in Fig.4 & 5.

For the conventional bracing system, ISMB450 section is used in the building. Properties of this I section is as defined in the Indian codal provisions. Properties of Buckling restrained which is taken from Star Seismic provisions are as follows:

- Total weight of BRB = 8.247 kN
- Total depth = 304.8mm
- Total width = 203.2mm
- Area of yielding = 32.3 cm^2
- Length of yielding = 4.2672m
- Length of Elastic segment = 1.7162m

Response Spectra analysis is performed for both buildings. Mass source is defined for dead, live, floor finish and wall loadings. Different load cases are formed for dead, live, floor finish, wall and earthquake (EQx & EQy) loadings. Also there is special load case for response Spectra as RSx & RSy formed for zone IV generated Response Spectra.

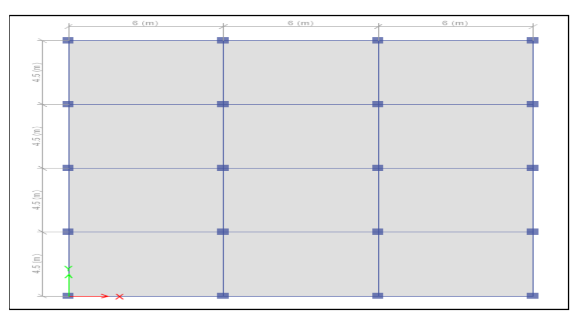

Figure 4. Plan of building

Numbers of bays in X & Y directions are different in the building as three bays in X-direction and 4 bays in Y-direction. All columns and beams in the building are same throughout all the stories.

By the Response Spectrum Analysis, earthquake forces in X & Y direction are applied on the building and the behavior of both the buildings, i.e. with conventional and buckling restrained braces, are obtained.

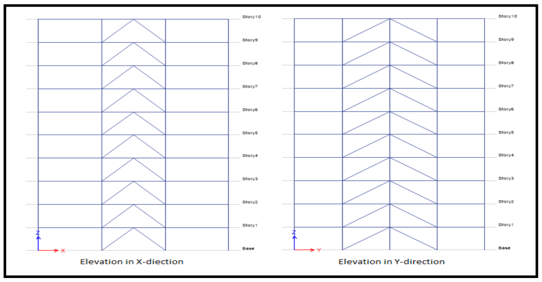

Figure 5. Elevation of building

3. Results and discussions

3.1 Results

From the Response Spectrum analysis which performed over both the buildings, following results are obtained. They are compared together to get the brief idea about the pro and cons in the results obtained. For parametric study, three main results are analyzed which are story forces, story drift and story displacement as follows:

3.1.1 Story forces

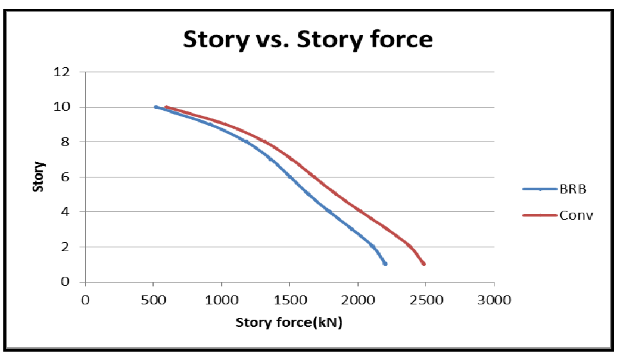

Figure 6. Story vs. story forces

3.1.2 Story drifts

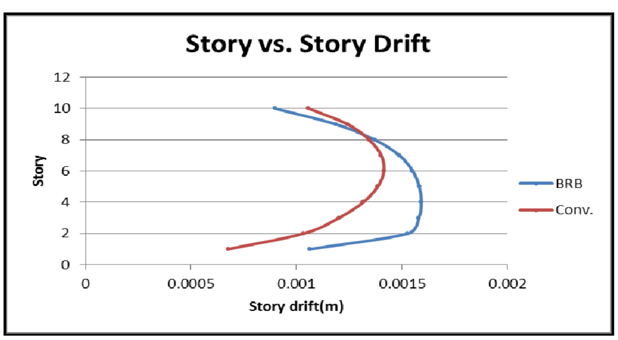

Figure 7. Story vs. story drift

3.1.3 Story displacements

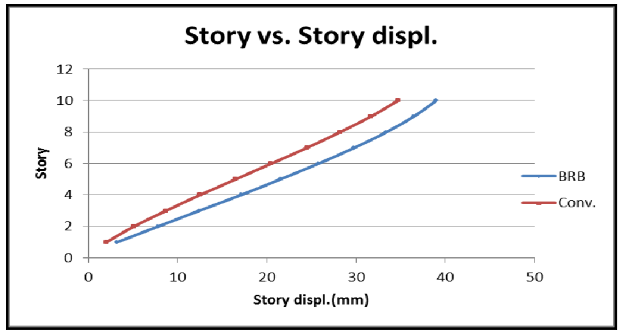

Figure 8. Story vs. Story displacement

For above graphs, on Y-axis there is number of story and on Y-axis there are story force, story shear and story displacement. For all the above three results blue line indicates the response of building with buckling restrained brace and red line indicates the response of building with conventional brace. As the plan of the building is square, the response of building in X & Y direction is nearly same. Hence in this study we are taking into considerations the response in only one direction, i.e. in X- direction.

3.2 Discussion

The response of both buildings under earthquake loading is analyzed and considering the parametric study of above results, certain discussion is made out as follows.

For the story vs. story forces plot, building with buckling restrained brace shows reduced values of story forces at base as compared to building with conventional bracing. This shows the utility of the building in an earthquake event will be more useful for building with buckling braces than conventional braced building. The building with BRB is safe as compared to the building with conventional bracing system.

For the story vs. story drift plot, buildings with buckling restrained brace shows higher value of story drift at the base compared to building with conventional bracing system. But the story drifts inverses as the increase in the height of the building. At top story, story drift is more in BRB building than conventional brace building. This shows that drift in BRB building decreases as the increase in the height of the building. Behavior of the story drift in both buildings is similar.

It is assumed that the story displacement in the structure should be small to make the structure stiffer. For contrary to this, building with BRB has more story displacement than conventional bracing building. This makes the structure less stiff than the building with conventional bracing. This factor will plays an effective role in an earthquake event as this will avoid the brittle failure of the structure and will provide more time period for the failure of the structure. In short it BRB building will takes more time for failure than conventional braced building.

4. Conclusion

From the comparative study between both the buildings and from the analysis of results of various parameters, it is concluded that in the seismic events the Buckling restrained brace building shows better performance over the building with conventional bracing. BRB reduces the story forces in the building which provides the stability of the building. Hence the use of BRB is considered safer than the conventional bracing in the building.

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