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Seismic Analysis of Diagrid and Buckling Restrained Braced Structural System

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ABSTRACT

Structural demands in high seismic zones require the use of strong lateral framing systems. Lateral load resistance of structure is provided by interior structural system or exterior structural system. The structure must have adequate strength and stiffness to resist smaller, frequent earthquakes with limited damage, but must also be able to sustain large inelastic cyclic deformations to economically assure safety and stability during large, infrequent earthquakes. The most frequently used lateral load resisting frames are the moment resisting frame (MRF) and the concentrically braced frame (CBF). Another prevalent structural system for today's buildings are diagrid structural system and Buckling Restrained Braced (BRB) system. Diagrid resist the lateral load by axial action of diagonal member provided on periphery of the structure and BRB structural system resist lateral load due to their significant ductility and energy dissipation capacity. Both system are used most effectively to reduce effect of lateral load on structure. The diagrid structures and BRB emerging as popular structural system in many developed countries of the world, but in India it is yet to gain importance.

In the present study, to study the effectiveness of diagrid and BRB structure over conventional structures comparative analysis has been carried out. The comparative analysis of results are in terms of story displacement, fundamental time period, story drift and base shear.

KEYWORDS: *Diagrid structural system, Buckling Restrained Brace, Time history analysis, Peak Ground Acceleration.*

I. Introduction

In recent years, the number of tall buildings being constructed has been rapidly increasing worldwide. Some buildings have been constructed with triangular exterior structural members, known as diagrid systems, which have been developed for structural effectiveness and architectural aesthetics. Diagrid system is also part of the bracing system, which originated from the conventional bracing system. The difference between conventional exterior-braced frame structures and current diagrid structures is that, for diagrid structures, almost all the conventional vertical columns are eliminated. This is possible because the diagonal members in diagrid structural systems can carry gravity loads as well as lateral forces due to their triangulated configuration in a distributive and uniform manner.

Another prevalent structural system for today's buildings is BRB structural system. Buckling restrained braced frames (BRBFs) are one of the seismic load resisting systems. A BRB consists of a steel core surrounded by a hollow steel section, coated with a low friction material, and then grouted with a specialized mortar. The encasing and mortar prohibit the steel core from buckling when in compression, while the coating prevents axial load from being transferred to the encasement, thus preventing strength loss and allowing for better and more symmetric cyclic performance. This structures have high stiffness and high ductility and it yields in both compression and tension. Hence the buckling is prevented in this type of structures. This structure provides a safe guard for a building under lateral loadings coming from earthquake forces and it can be moulded using parameters like storey drift and base shear.

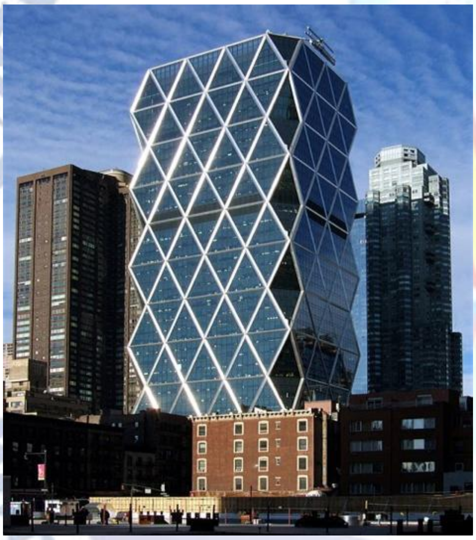

Fig.1: Diagrid building [Hearst Tower, New York]

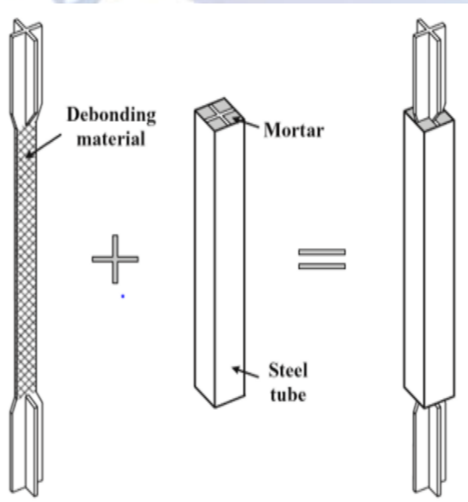

Fig.2: Buckling Restrained Brace (BRB)

Recently many researchers are putting efforts in developing different techniques to resist lateral load:

Kamath K. et al [13] showed that the performance of the diagrid structure is influenced by brace angle and aspect ratio. Kim Y. et al [15] carried out experimental study in which a new type of diagrid structural system node was proposed and tested cyclically for lateral loads such as earthquake and wind. Based on the test results, the cyclic performance for diagrid nodes is discussed with an emphasis on the hysteresis characteristics, welding methods, and failure modes. [3, 5, 12] studied the different types of geometric configuration of diagrid structure. [4, 6, 8, 9] investigated the seismic response of structure with BRB from that it is showed that maximum displacement of structure was decreased with increase in stiffness of the bracing. Naghavi M. et al [16] evaluated the seismic performance of structure with different patterns of BRB (i.e. diagonal, X, V and inverted V). Best performance was noted for V and inverted V pattern.

II. METHODOLOGY

The present study is to evaluate the comparative analysis of conventional, diagrid and BRB structural system. The structures are 36 m x 36 m in plan and story height is 3.6 m. Grade of concrete and steel is M30, A992Fy50. Vertical columns are provided at six meter spacing. All axial members are pin-connected. For beams, W 24 x 62 sections are used. Columns are of W 14 x 426 sections. For diagrid and BRB members steel tube of 400 x 400 x 25, 310 x 310 x 20 is used. The dead load and live load on floor slab are 4 kN/m2 and 2.5 kN/m2. Modelling and analysis is carried out using commercial software ETABs 2016. Seismic parameters considered are occupancy category II, site class D (stiff soil), importance factor 1, response reduction factor 8, strength reduction factor 0.9 as per ASCE 7-10. Time history analysis of all structures is carried out. The time history data are obtained from Strong-Motion Virtual Data Center (VDC) facilitated by The Consortium of Organizations for Strong-Motion Observation Systems (COSMOS), California. The selected records have a variety of PGA which is presented below:

Table 1: Ground motion Characteristics

Earthquake	Magnitude	PGA (m/s^2)
N California (1966)	5.7	0.12
Imperial County (1955)	6.3	0.71
NW California (1938)	6	1.40
Morgan Hills (1984)	6.1	3.05
Northridge (1994)	6.7	4.45

Design of BRB

The design and analysis of the Buckling Restrained Bracings (BRB) is not available in the Indian Standard (IS) codes as this technology is not yet used in India. The design of this bracing is based on the AISC 341-05: Seismic provisions for structural steel buildings, American Institute of Steel Construction. Modulus of elasticity, yield strength of steel and strength reduction factor are assumed to be 200,000 N/mm² and 250 N/mm² respectively. The core steel area for the buckling-restrained bracing members is determined based on the force in the bracing members from the analysis results in ETABs 2016**.** Following equation is used to obtain the core steel area for the buckling-restrained braces:

$$A_{core} = F_{BRACE}\Phi \times F_Y$$

where Fbrace is the axial force in the bracing member, Fy is yield strength of the brace steel material and Φ is the strength reduction factor, 0.9. Since the yielding portion of BRB has a substantially smaller cross section as compared to end section, most of the elastic and inelastic deformations take place therein. Considering this, the elastic axial stiffness (Kbr) of BRB is approximated as:

$$K_{br} = E \times 2\, A_{core} L_{br}$$

Where Kbr is elastic axial stiffness of brace, E is modulus of elasticity and Lbr is length of yielding member. Design properties i.e. core area and axial stiffness of elastic member of 10-story BRB structure is presented.

Table 2: Design properties of BRBs

tory	Core area (mm²)	Axial force (kN)	Axial stiffness (kN/m)
1	4520.1	1000	1286100.44
2	4066.6	915	1157109.13
3	3764.4	850	1071116.84
4	3555.5	800	1011680.17
5	3177.7	715	904188.36
6	3000.0	675	853606.48
7	2666.6	600	758759.42
8	2200.0	495	625978.09
9	1742.2	392	495723.43
10	1244.4	280	354087.35

Figure 1. shows the elevation view of 10 story diagrid and BRB structure.

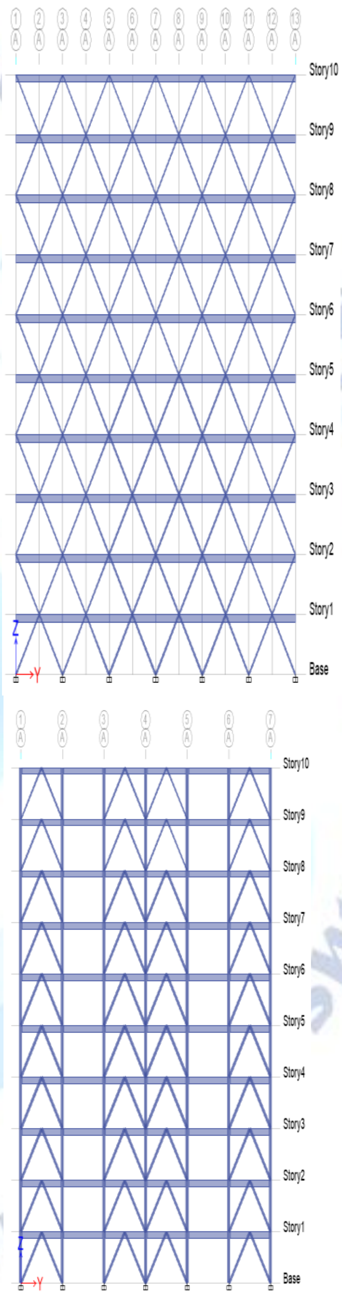

Figure 1: Elevation view of diagrid and BRB structure

III. RESULTS AND DISCUSSION

For analysis time history analysis has been carried out and the results are represented in the form of fundamental time Period, storey displacement, inter storey drift and base shear.

A. Fundamental Time Period

Fundamental time period of conventional, diagrid and BRB structure for 10-story, 20 -story, 30-story structure is shown here.

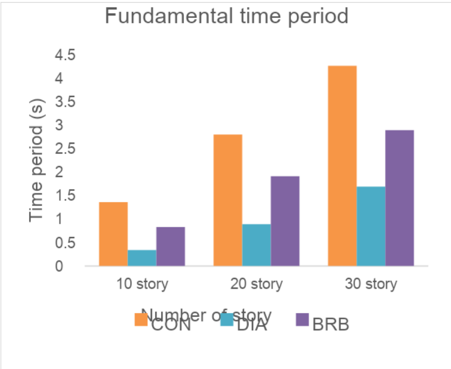

Figure 2: Fundamental time period

From results it is observed that time period of diagrid structure is less as compared to BRB and conventional structure. Since diagonal member of diagrid and core member of BRB sustain more lateral forces as compared to conventional structure. Generally time period depends on mass and stiffness of structure, but in this case mass of all structure is almost same, the difference is in time period due to the difference in stiffness of structure. Stiffness of diagrid structure is more as compared to conventional and BRB structure because of the connectivity of axial diagrid member on the periphery of the structure. As the height of structure increases time period of all structure also increases.

B. *Maximum Story Displacement*

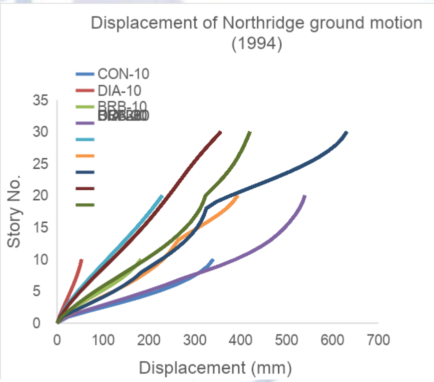

Figure 3: Maximum displacement of Northridge Ground Motion (1994)

From results it is found that displacement observed to be maximum for Northridge Ground Motion (PGA = 4.45 m/s²) for all structural system. It is observed that displacement of diagrid structure is very less as compared to conventional and BRB structure. Displacement of diagrid structure reduces up to 78 % (10-story) and for BRB structure up to 49 % (10-story) when compared with conventional structure. Response of diagrid structure is best as compared with conventional and BRB because diagrid structure consist of axial members on the periphery of the structure which stiffens the structure and sustain more lateral load. Further, it is seen that 91% increase in stiffness (10-story, diagrid structure) resulted in 86 % reduction in displacement as compared to conventional structure.

C. *Maximum Story Drift*

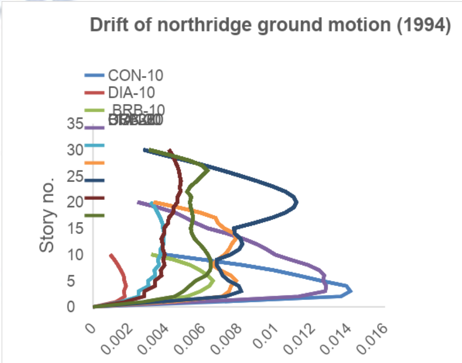

Figure 4: Maximum displacement of Northridge Ground Motion (1994)

From results it is observed that maximum drift is obtained for Northridge Ground Motion (PGA=4.45 m/s²) for all structural system.

It is observed that story drift is observed to be minimum for diagrid structure as compared to conventional and BRB structure. Drift of diagrid structure decreases up to 79 % (10-story) and for BRB structure up to 39 % (10-story) when compared with conventional structure. As the drift depends on the displacement of structure, similar response is observed as that of displacement. In diagrid structure less drift is observed because of its lateral stiffness of structure.

D. *Base Shear*

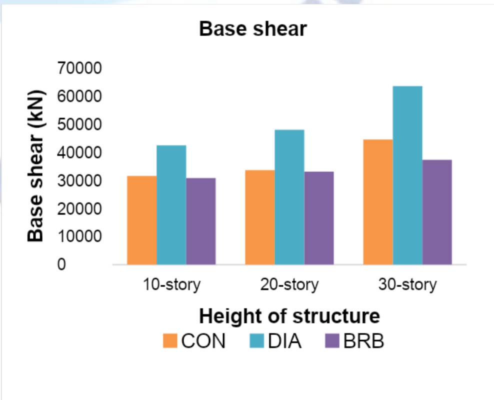

Figure 4: Base Shear

It is observed that base shear of diagrid structure is increased as compared with conventional structure. Base shear of diagrid structure is increased by 35 % (10-story), 24 % (20-story) and 43 % (30-story) as compared with conventional structure. It is seen that base shear of BRB structure is reduced by 3% (10-story), 14 % (20-story) and 17 % (30-story) as compared with conventional structure. Base shear of structure should be less, because structure having more base shear attracts more lateral forces, which results in damage to the structure. From the results it is seen that BRB structure is most effective than the diagrid structure as compared to conventional structure.

IV. CONCLUSIONS

This study presents the comparative analysis of conventional, diagrid and BRB structural system. The major objective of this work is to investigate the most effective lateral load resisting structural system. Following conclusions are drawn :

1. Due to higher stiffness of diagrid structure its fundamental time period is less as compared to conventional and BRB structure. Story displacement and story drift is maximum for conventional structure and minimum for diagrid structure.

2. Time period increases with the increase in height of structure. As the height of structure increases displacement, drift and base shear increases for all three structural systems.

3. As the Peak Ground Acceleration increases, displacement, drift and base shear also increase for all three structural systems.

4. Base shear of diagrid structure is maximum and for BRB structure it is observed to be minimum as compared with conventional structure. Hence, it is concluded that BRB structure is the most effective structural system.

REFERENCES

1. ANSI/AISC 341-05, "Seismic provisions for structural steel buildings", American Institute of Steel Construction, 2005, Chicago, IL.
2. ASCE 7-10, "Minimum design loads for buildings and other Structures", American Society of Civil Engineers, 2010, VA.
3. Baile V. and Bage A., "Comparative study of diagrid, simple frame and various bracing systems, International Journal of Innovative Research in Science, Engineering and Technology, Vol. 6, (2017), ISSN : 2347-6710.
4. Balling R., Balling L. and Richards P., "Design of buckling-restrained braced frames using nonlinear time history analysis and optimization", Journal of Structural Engineering, Vol. 135 (5), 2009, pp. 461-468.
5. Darbandsari S., Firoozi M. and Abadi N., "A comparative study on seismic performance of hexagrid, diagrid and tubular structural systems, Journal of Structural Engineering and Geotechnics, Vol. 7(1), 2016, pp. 55-65.
6. Deulkar W., Modhera C. and Patil H., "Buckling restrained braces for vibration control of building structure", International Journal of Recent Research and Applied Studies, Vol. 4(4), 2010, pp. 363-372.
7. ETABS: Structural Analysis Program, Computers and Structures, Berkeley, 2016, CA.
8. Field C. and Ko E., "Connection performance of buckling restrained braced frames", 13 World Conference on Earthquake Engineering, 2004, Paper No. 1321, Canada.
9. Ghowsi A. and Sahoo D., "Seismic performance of buckling-restrained braced frames with varying beam-column connections", International Journal of Steel Structures, Vol. 13(4), 2013, pp. 607-621.
10. Guerrero H., Escobar J. and Gomez R., "A study of the damping provided by Buckling-Restrained Braces (BRBs) within their linear-elastic response", Journal of Structures Congress, 2017, pp. 558-565.
11. Gunel M. and Ilgin H., "A proposal for the classification of structural systems of tall buildings", Journal of Building and Environment, vol. 42, 2007, pp. 2667-2675.
12. Jani K. and Patel P., "Design of diagrid structural system for high rise steel buildings as per Indian Standards", Structures Congress, ASCE, 2013.
13. Kamath K., Hirannaiah S. and Barbosa J., "An analytical study on performance of a diagrid structure using nonlinear static pushover analysis", Journal of Perspectives in Science, Vol. 8, 2016, pp. 90-92.
14. Kim J. and Choi H., "Behavior and design of structures with buckling-restrained braces", Journal of Engineering Structures, Vol. 26, 2004, pp. 693-706.
15. Kim Y., Jung Y. and Park S., "Cyclic behavior of diagrid nodes with H-Section braces", Journal of Structural Engineering, Vol. 136(9), 2010, pp. 1111-1122.
16. Naghavi M., Rahnavard R., Thomas R. and Malekinejad M., "Numerical evaluation of the hysteretic behavior of concentrically braced frames and buckling restrained brace frame systems" Journal of Building Engineering, Vol. 22, 2019, pp. 415-428