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A Study on Seismic Performance of Multi-storied Eccentrically Braced Steel Frame Structure

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ABSTRACT

The moment resisting frame system is one of the largely used structural systems but shows significantly large lateral displacements when compared to concentrically braced frame systems. Concentrically braced frame systems proved to be the one that reduces lateral displacement but with the cost of reduced energy dissipation capacity of the joints. Eccentrically braced frame simultaneously serves both purposes i.e. increases ductility to the joint while reducing lateral displacement. In this research paper, the seismic performance of a G+10 steel building is studied for several arrangements of eccentric bracings incorporated in a moment-resisting frame. An appropriate number of models are created and analysed using SAP2000. Their seismic performances are evaluated using the Indian standard code (IS: 1893 part 1-2016 and IS: 800-2007). A set of bracing eccentricities ranging from 0.2m to 1.4m is adopted in the non-linear time-history analyses. The obtained results are also discussed for the best suitable arrangement of bracing, eccentrically placed in a moment-resisting frame subjected to seismic load considering inter-storey drift, lateral displacement capacity, energy dissipation and etc. The best suitable arrangement of bracing is further analysed with incremental dynamic analysis to obtain IDA-curve.

INTRODUCTION

In this research, a G+10 story steel buildings designed as per IS 800:2007. The designed building is a Moment Resisting Frame (MRF), in which there is no particular arrangement to resist lateral loading. This MRF is compared with Different types of Concentric Braced Frames (CBF) and further compared with different Eccentric Braced Frames (EBF) with different eccentricities ranging from 0.2m to 1.4m from each side of beams. A total of twenty-two structures are analyzed and the best structure is chosen.

The structure is analyzed on CSI software SAP2000 v22.0.0. A total four-time history graph is chosen to analyze the seismic effects on the structures. Seismic analysis is a part of structural analysis, it is used in the calculation of the response of the building over different earthquakes. Seismic forces are caused due to movement of tectonic plates. In India major earthquakes originated from the Himalayan range. In this paper, the dynamic analyses of Moment Resisting Frame (MRF), Concentric Braced Frames (CBF) and Eccentric braced Frames (EBF) [2] are carried out. MRF system can dissipate seismic energy efficiently but it shows large lateral displacement as it lacks lateral stiffness [3]. To make Structure laterally stiff CBF are introduced but due to low joint ductility, it cannot dissipate energy efficiently. To overcome this problem EBF is introduced, which is a hybrid of MRF and CBF. EBF [4] are laterally stiff as well as it dissipates energy efficiently. In this paper, the best suitable forms of eccentric bracings are explored and compared. Storey drift, base shear and dissipated energy are computed for the comparison. The present research work is focused on Fast Nonlinear Analysis (FNA). FNA analysis solves uncoupled modal equations. Ritz vector is used instead of eigenvectors. As per the CSI knowledge base [7], the Ritz vector is more efficient in the calculation of the equation of equilibrium.

For the sake of simplicity single brace section is applied to all the structures, and their behavior is analyzed. This deviates from the real scenario of the structure as it is uneconomical. The eccentricity of the bracing in EBF is increased from 0.2m to 1.4m with an increment of 0.2m. For better results increment should be small. There are many types of bracing system are available, but only four types of bracing systems are considered in this research (X braced frame, V braced frame, Inverted V braced frame, Diagonal braced frame).

LITERATURE REVIEW

R. Yahyapour and S.M. Seyeedpoor (2021)
In this paper, the authors aim to study the seismic behavior of knee-braced steel frames using nonlinear static and dynamic analyses. structures with four different types of knee braces (top knee, x-knee, chevron knee and double knee braced frames) at heights of 5, 10, 15 and 20 storey are designed. Far- Fault and Near-fault time history are used for the analysis. Incremental dynamic analysis has been applied to analyze the results. using IDA results in the far-fault area, the x-knee braced frame demonstrates the best performance.

Abbas Rouhi and Hamed Hamidi (2021)
Performance-based Plastic Design (PBPD) method considers the inelastic behavior of the structure for the seismic design that follows a pattern in which a pre-selected yield mechanism is defined for each type of structural system. Despite the general adequacy of this method, there is a further need to improve this method against forwarding directivity. In this paper, attempts have been made to improve the conventional PBPD method to consider the effect of forward-directivity. To this end, the energy modification factor (γ) was modified by recalculating ductility demand μ and ductility reduction factor Rμ of 3-, 6-, 12-, and 18-story EBF structures.

Tengfei Li, MingzhouSu, Yan Sui and Lei Ma (2021)
Real-time Hybrid Simulation (RTHS) is a new, economical, and reliable seismic testing technology for structural analysis. Nowadays many RTHS is widely used for analysis. Authors have applied the RTHS to the structure of a high-strength steel frame with Y-shaped eccentric braces (HSYE). The Open Fresco test platform and x PC-Target with an adaptive feed-forward delay compensator was used to real analyze real-time loading. Before conducting the RTHS, to compensate for the initial delay, the method of adding an adaptive stage before the seismic acceleration record was proposed.

S.RezSalimbahrami and M.Naghipour (2021)
This paper represents the numerical study of Ductile Elements in the Seismic Performance of Steel Frames with the eccentrically braced frame using ANSYS and Open Sees. This ductile element includes a ring with a box around it as a dissipater that increases the ductility and energy dissipation of structures during the earthquake loading. Flexural plastic hinges are defined which delays the non-linear phase of other members.

MusadAiedQissab Al-Janabi and CemTopkaya (2021)
In this research paper, the authors compared the results of two guidelines namely AISC 341 and EC8. Both the guideline is for the design of Eccentrically Braced Frame.The European provisions (EC8) were developed mostly based on the research works conducted in the US. Even though there are certain differences in the amount of lateral force reduction and distribution of member over-strength among the stories.

Li Shen, Li Rong-Rong, Wang De-Fa, Pan Xiu-Zhen and Guo Hong-Chao
Shen et al. 2021, have carried out In this research paper, Y-shaped eccentrically braced frame is used. Here the authors focused on the response modification factor (R) and displacement amplification factor (Cd). R should be selected such that building performance is reasonable without compromising the economy of the structure. Keeping the importance of R, the structures with different stories (4, 8, 12, and 16 stories) and link lengths (700, 900, and 1100 mm) were designed via the performance-based seismic design method.

METHODLOGY

Modeling and Analysis of the Building- The building is modeled using software SAP2000 version 22.0.0. This software works on the principle of finite element analysis. The structural components of the building consist of the beam, column, slab and braces which is the most important component for seismic analysis. The structures which do not influence the structural behavior of the building are not considered. Beams along the X-axis are fixed jointed with the column and beams along Y-axis are pinned jointed as the beams are jointed with the web of the column and the web cannot transfer moment. The material of the floor slab is reinforced concrete and the strength of the concrete is M30. The floor slabs act as a diaphragm to ensure the rigidity of the slabs. Diaphragms ensure the integral action of all vertical load resisting elements and are modeled as a four nodded thin shell with six degrees of freedom on each node.

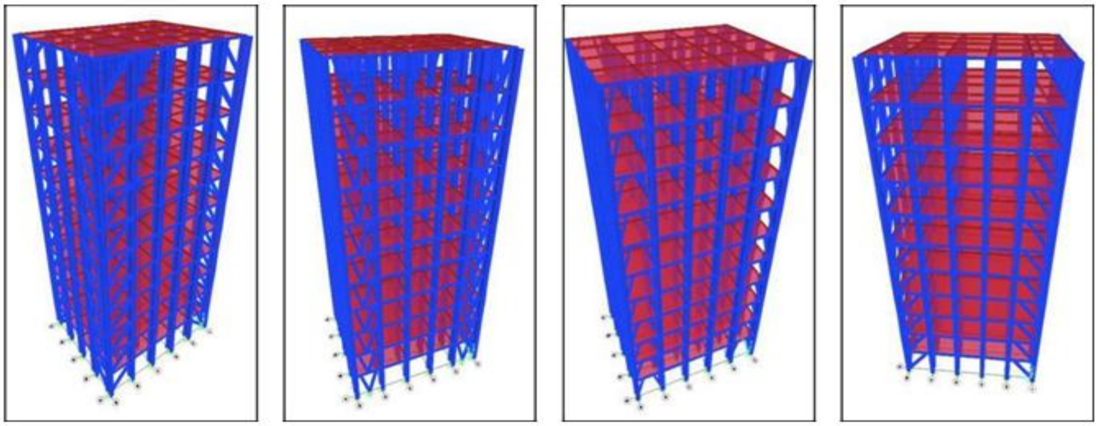

Figure 1 Model of building generated in SAP2000

Analysis of the building- Seismic analysis is done with the reference of standard code. In India, IS1893-2016 is the latest code of practice for the analysis of the seismic behavior of the structure. As per IS 1893-2016 there are two methods of analysis of the building.

- Equivalent Static analysis
- Dynamic analysis

Equivalent static analysis. The seismic weight of the building is calculated by the summation of the weight of each storey lumped at the floor level. Base shear is calculated when the seismic weight of the building is multiplied by the design horizontal acceleration coefficient. The formula for the calculation of design horizontal co-efficient is shown in IS 1893- 2016 part-1. Then the base shear is distributed to each storey level. Dynamic Analysis. There are two types of analysis in dynamic analysis of structure (Response spectrum analysis and Time history analysis). In this research paper, we will discuss Time history analysis. Time history analysis is a function of ground displacement parameters with some fixed interval of time. Here parameter is referred acceleration or ground velocity or ground displacement with time. Four different Indian time history functions are considered for dynamic analysis of structure as shown in Table 4. The graph of all time history functions is shown in Fig. 6. The first function is the Bhuj earthquake [4] ground time history which was recorded by IITR, Ahmadabad. Its hypo central distance is 293Km and its depth is 16km. the second function is Chamoli Earthquake.

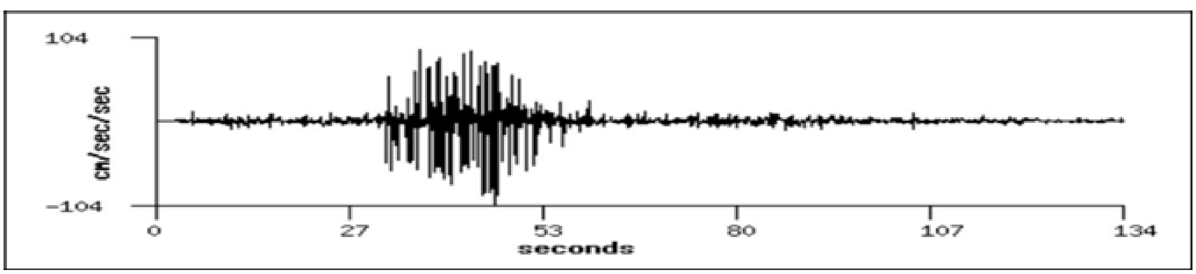

Figure 2 Time history plot of Bhuj

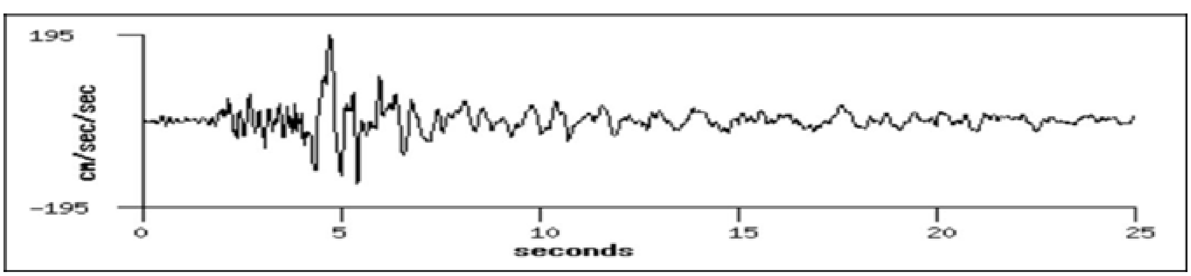

Figure 3 Time History plot of Chamoli

RESULT

For the analysis of the building, we have taken four different types of time history functions and every four functions are applied in both the directions of Cartesian planes.

Lateral displacement

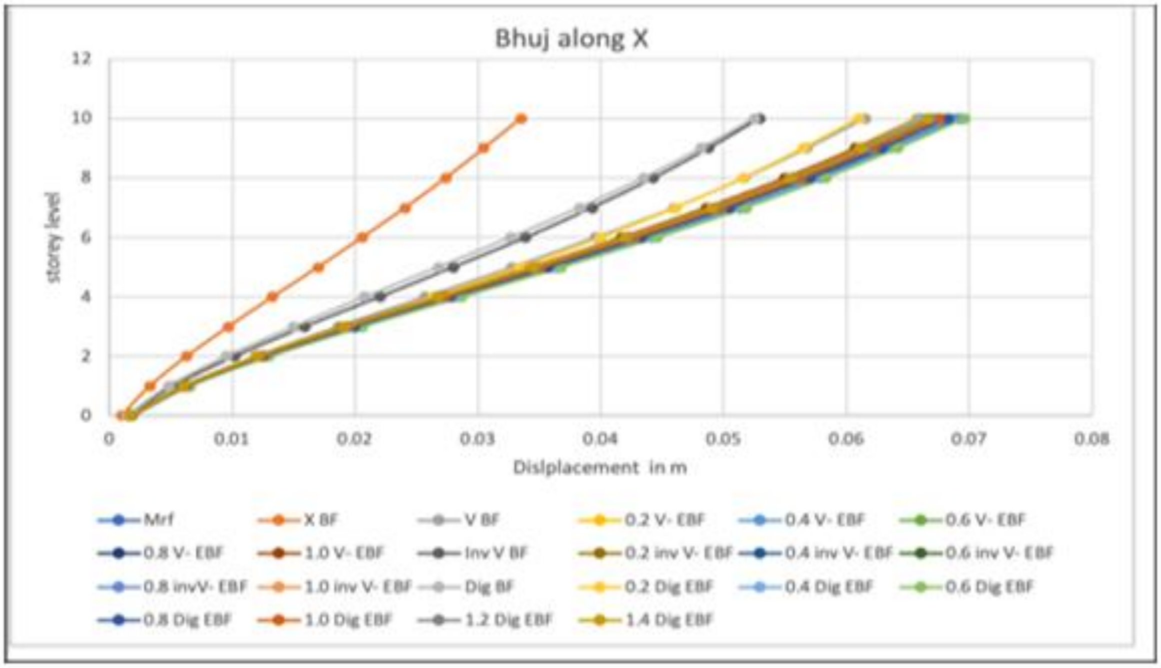

Figure 4 Lateral displacement of floors along X-axis for Bhuj Earthquake

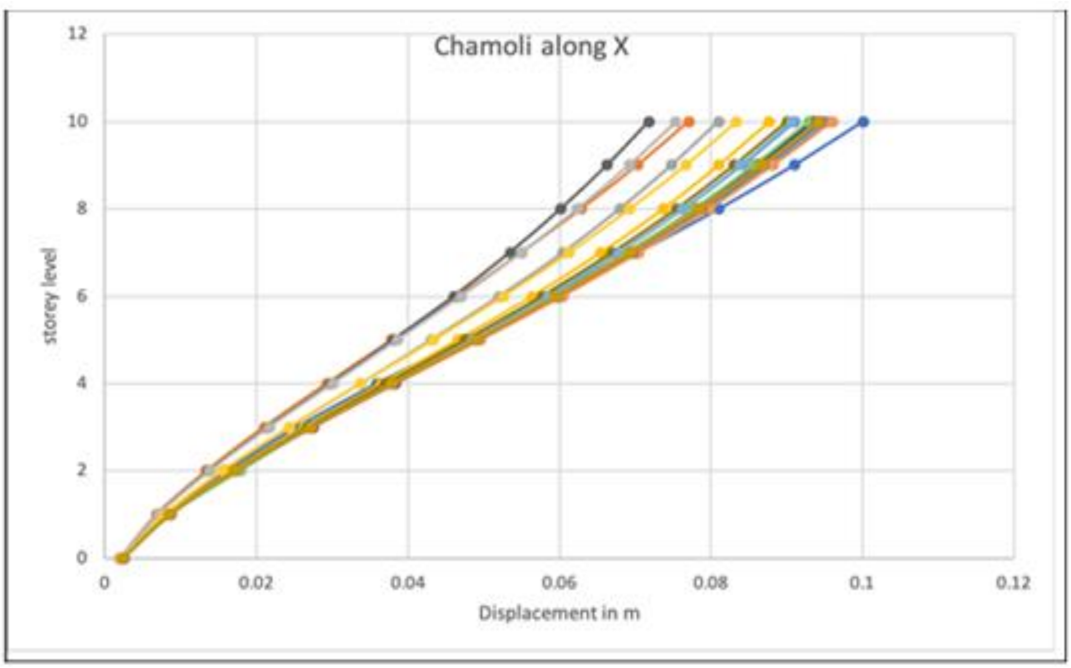

Figure 5 Lateral displacements of floors along X-axis for Chamoli Earthquake

Base Shear

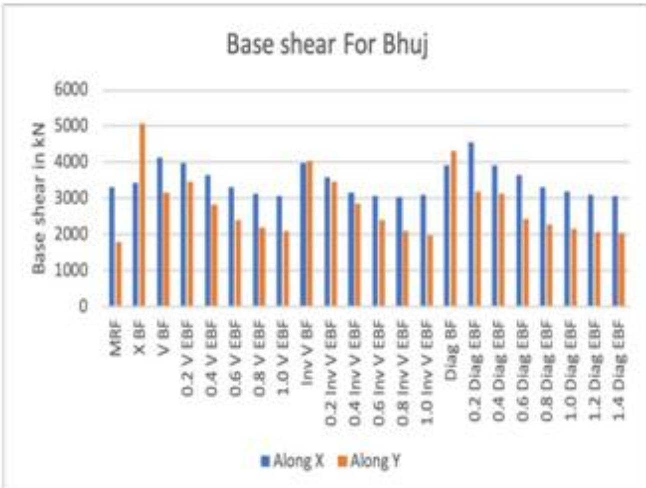

Figure 6 Base shear for Bhuj

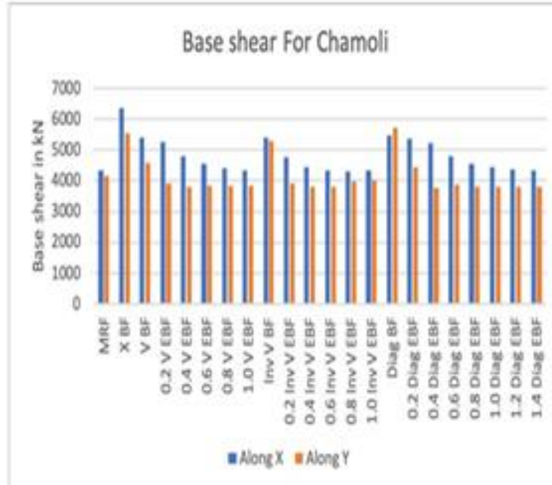

Figure 7 Base shear for Chamoli

CONCLUSION

The non-linear time-history analyses of steel-framed structures are carried out by considering different types of framing systems. Following are the main conclusions from the study:

- The X-CBF structure shows the best performance in terms of storey drift and lateral displacement among all 22 models while the MRF system shows the worst performance.
- In terms of storey drift, Diagonal Eccentric braced frame shows the best performance. The results of storey drift show that X-CBF has the highest stiffness, and MRF has the lowest Stiffness.
- In terms of energy dissipation, the results of 0.2m-Dig-EBF are in between MRF and X-CBF. A diagonally braced frame with an eccentricity of 0.2m, is performed most efficiently as the structure is stiff as well as it can dissipate energy due to ductile joints.
- A designer should consider Diagonal-Eccentric Braced Frame as it is laterally stiff like CBR and it dissipates seismic energy like Moment resisting frames. So EBF structures show better performance than MRF and CBF.

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