Research article

Structural behavior of steel building with concentric and eccentric bracing: A comparative study

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ABSTRACT

Many existing steel buildings need to be retrofitted to overcome the deficiencies to resist the lateral loading. In the present study, a six storied steel building has been modeled and then analyzed due to lateral earthquake and wind loading, dead and live load. The performance of the same steel building has been investigated for different types of bracing system such as concentric (crossed X) bracing and eccentric (V-type) bracing using HSS sections. The performance of the building has been evaluated in terms of lateral storey displacement, storey drift as well as axial force and bending moment in columns at different storey level. The effectiveness of various types of steel bracing on the structure has also been investigated. More importantly, the reduction in lateral displacement has been found out for different types of bracing system in comparison to building with no bracing. From the present study, it has been found that the concentric (X) bracing reduces more lateral displacement and thus significantly contributes to greater structural stiffness to the structure.

Keywords: Bracing system, concentric and eccentric bracing, lateral storey displacement, storey drift.

1. Introduction

Steel braced frame is one of the structural systems used to resist lateral loads in multistoried buildings. Steel bracing is economical, easy to erect, occupies less space and has flexibility to design for meeting the required strength and stiffness. Braced frames are often used to resist lateral loads but braces can interfere with architectural features. The steel braces are usually placed in vertically aligned spans. This system allows obtaining a great increase of stiffness with a minimal added weight, and so it is very effective for existing structure for which the poor lateral stiffness is the main problem. Bracings are usually provided to increase stiffness and stability of the structure under lateral loading and also to reduce lateral displacement significantly.

The concentric bracings increase the lateral stiffness of the frame and usually decrease the lateral drift. However, increase in the stiffness may attract a larger inertia force due to earthquake. Further, while the bracings decrease the bending moments and shear forces in columns, they increase the axial compression in the columns to which they are connected. Eccentric bracings reduce the lateral stiffness of the system and improve the energy dissipation capacity. Due to eccentric connection of the braces to beams, the lateral stiffness of the system depends upon the flexural stiffness of the beams. The vertical component of the bracing forces due to earthquake causes lateral concentrated load on the beams at the point of connection of the eccentric bracings. EBFs have been used as this have a well-established reputation as high-ductility systems and have the potential to offer cost-effective solutions in moderate seismic region. (Viswanath K.G et.al., 2010) The only design loading parameter of importance is the maximum load likely to be experienced in its lifetime (Suresh P et.al., 2012). This paper explores the structural behavior of steel building for both braced (including eccentric and concentric type) and unbraced conditions under static and lateral loading. The results of static analysis have been presented and discussed in this paper. Finally a comparative study has been presented to assess the best structural performance of steel building under lateral loading. The main aim of the research work has been to identify the type of bracing which causes minimum storey displacement such contributes to greater lateral stiffness to the structure.

2. Problem modeling

For analytical application, a simple three dimensional steel building has been selected. The building considered for analysis is a six-storied steel building. The building consists of some secondary composite beams with 6.5 inch thick deck supported on steel beams and columns. The structural layout plan has been shown in figure 1.

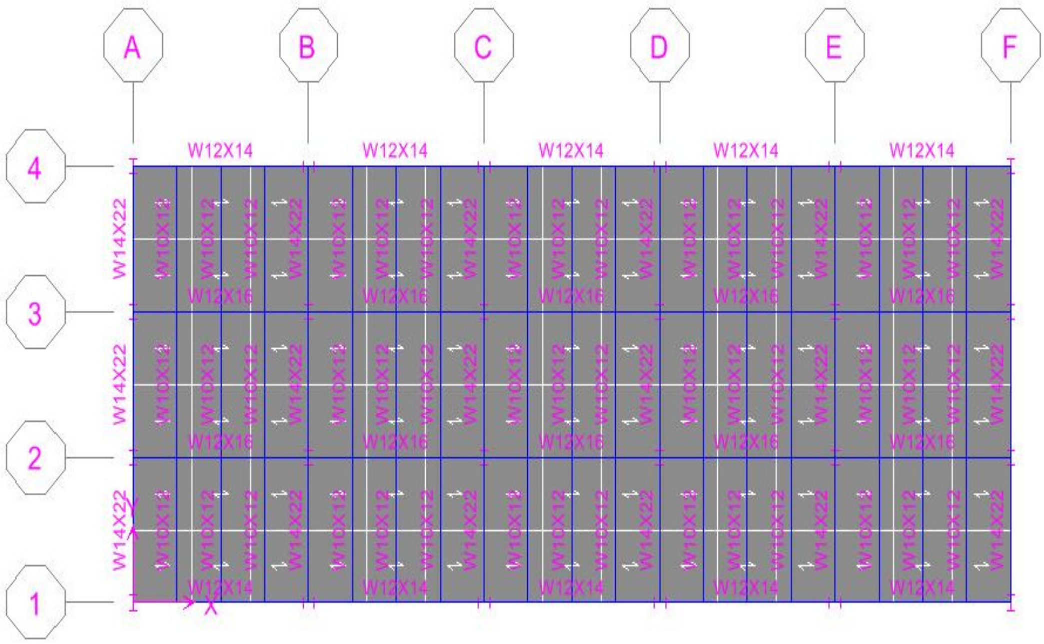


Figure 1: Layout plan of steel building

There are four frames consisting of columns and beams running along the building longitudinally. Transverse beams connect the four longitudinal frames. A three dimensional view of the steel building without bracing is shown in figure 2. In case of braced frame, all four external frames are braced by bracing systems placed only at corner panels and at middle panels along longitudinal direction. In this study two different structural bracing systems have been considered. They are the eccentric bracing for example V-type and another one is concentric X-type bracing which have been shown in figure 3.

Beams and columns have been designed with W steel sections and each bracing system has been analyzed using HSS section. For simplification of study same sections has been used for all bracing systems. For all steel members, 50 grade steel has been used. AISC-ASD method has been followed for member design.

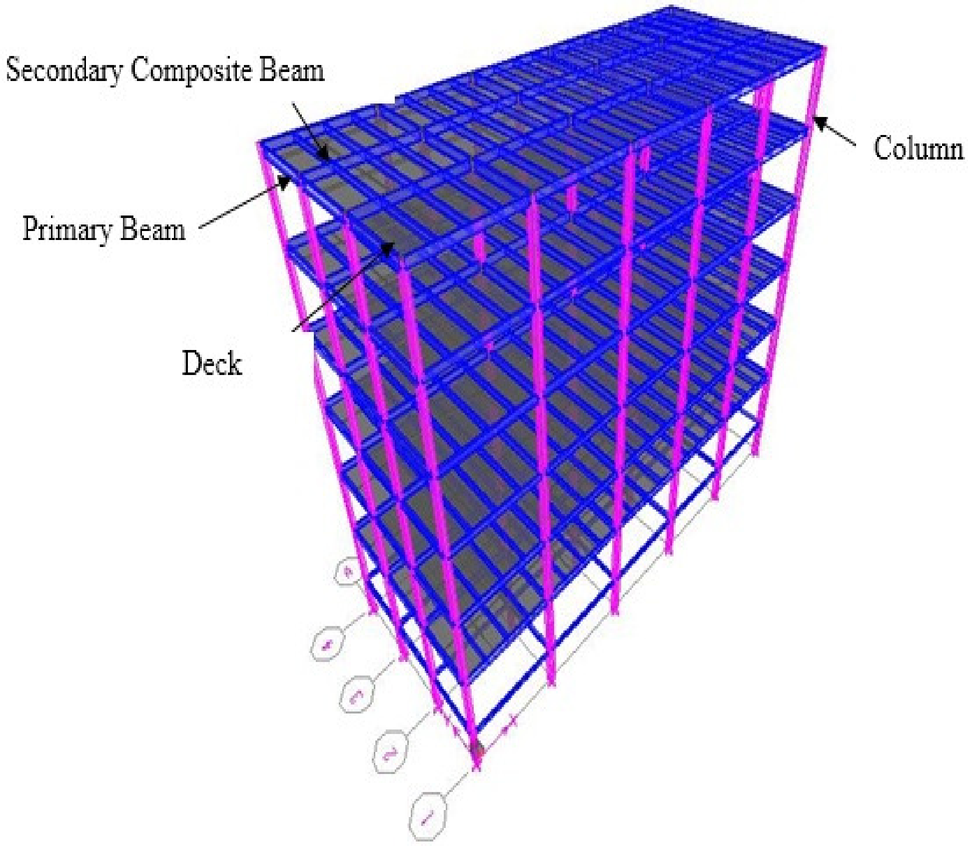


Figure 2: 3D view of steel building without bracing

The following table 1 represents a brief summary of key structural features. The building has been modeled using ETABS 9.6.0 software package and then a linear static analysis has been performed on the same structure for both concentric and eccentric type of bracing systems due to lateral loading considering project site located in Dhaka, Bangladesh.

Table 1: Key structural features

Name of parameter	Value	Unit
Number of stories	6	
Storey height	10	Feet
Total height of the structure	66	Feet
Length in long direction	75	Feet
Length in short direction	30	Feet
Column Section: Corner Exterior Interior	W 12×35 W 12× 40 W 12× 45	
Primary Beam Section	W12×14,W12×16,W 14×22	
Secondary Beam Section	W10×12	
Bracing	HSS 4×0.237	
Thickness of Deck	6.5	Inches

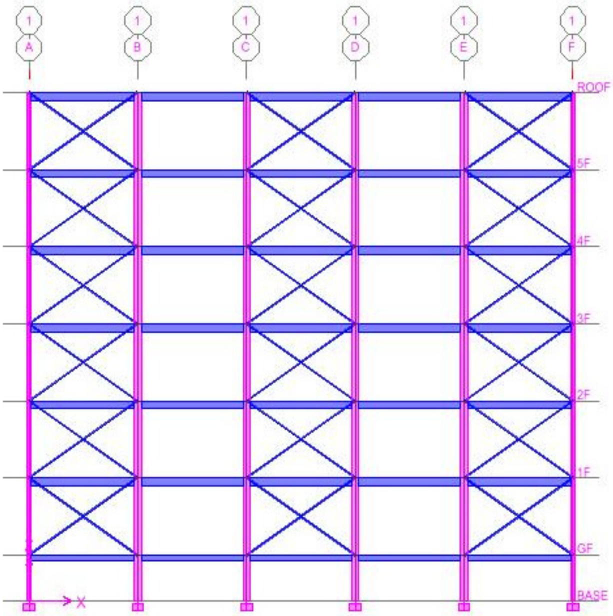


Figure 3a: Concentric bracing in long direction

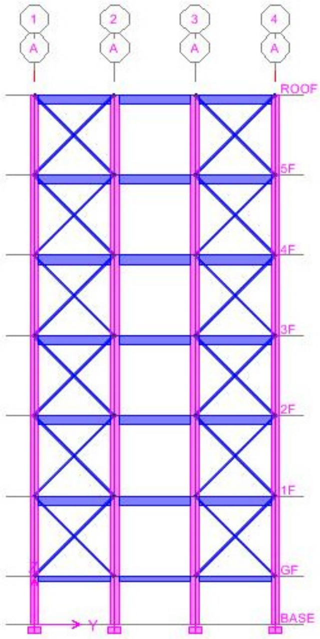


Figure 3b: Concentric bracing in short direction

For the analysis, the earthquake loading has been calculated as set forth by the provision of Bangladesh National Building Code (BNBC, 2006) and the applied wind load has been determined using ASCE 7-05 code. The steel building is analyzed with considering different load combinations as per AISC-ASD (Edwin H. Gaylord et. al.,1992).The applied loads on the structure are given in the following table 2.

Table 2: Applied loading on the structure

Type of load	Name of Load	Value	Unit
Super Dead Load	Partition Wall	25	Psf
	Floor finish	20	Psf
	Lime concrete on roof	30	Psf
Live load	Live load	40	Psf

3. Comparative studies

From the model of six storied steel building, data of different structural responses have been collected for both long and short direction due to lateral wind and earthquake loading. Then comparative studies have been made between the braced and unbraced structure.

3.1 Lateral storey displacements

The following figures 4 and 5 shows the variation of maximum lateral storey displacement with respect to different storey level in short and long direction respectively. The analyzed structure is subjected to super dead load, live load and code specified lateral wind and earthquake load.

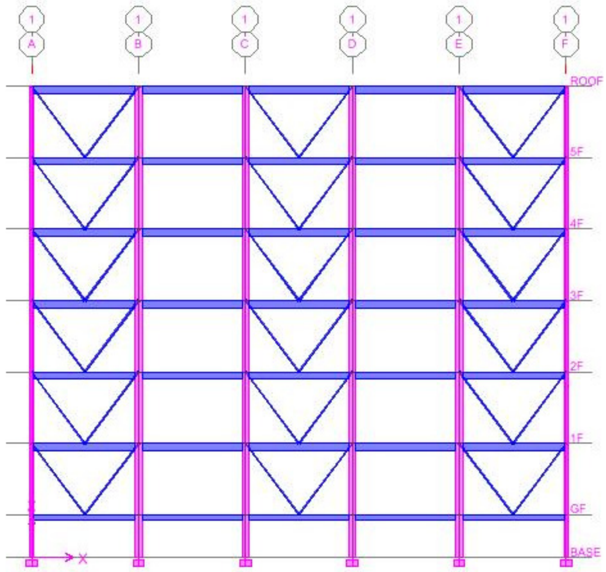


Figure 3c: Eccentric bracing in long direction

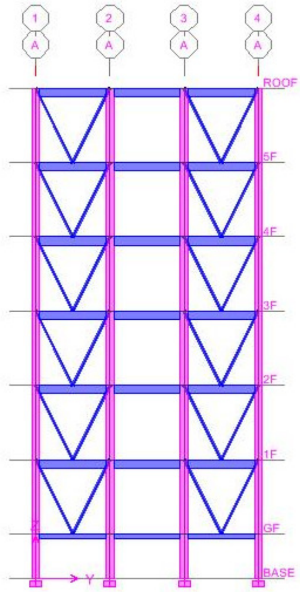


Figure 3d: Eccentric bracing in short direction

3.2 Storey Drifts

The variation of storey drifts in long direction with respect to different storey level for different braced and unbraced structure has been shown in the following figure 6.

3.3 Column axial forces

The variation of maximum axial forces (compressive) for both corner and exterior columns of external frame A at different storey level due to the combined effect of static and lateral loading has been shown in the following figures 7 and 8.

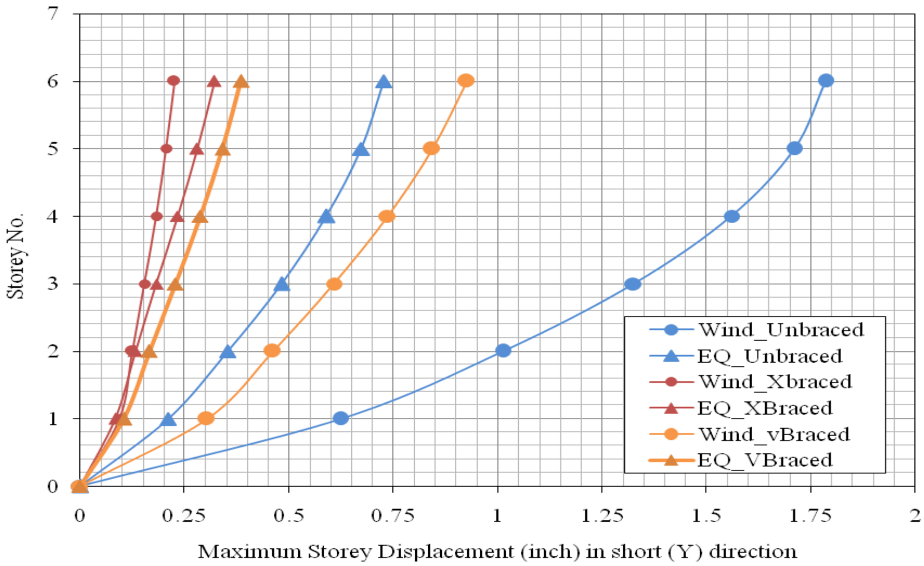


Figure 4: Lateral storey displacement in short direction

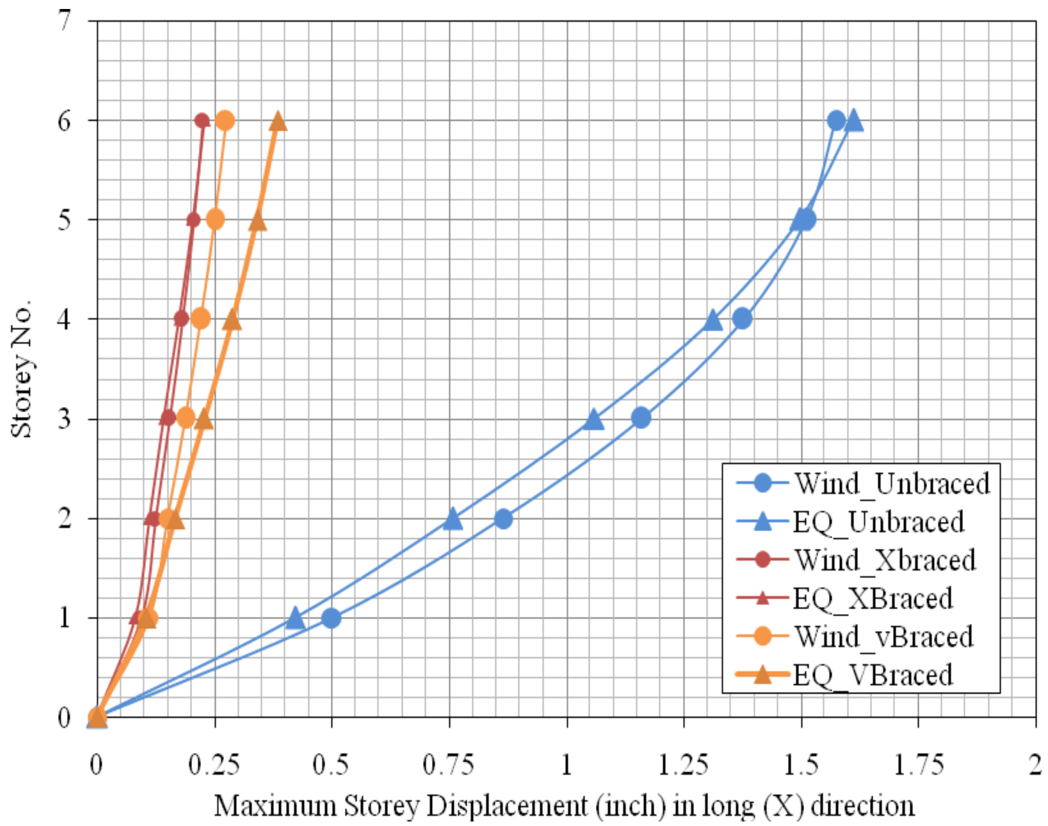


Figure 5: Lateral storey displacement in long direction

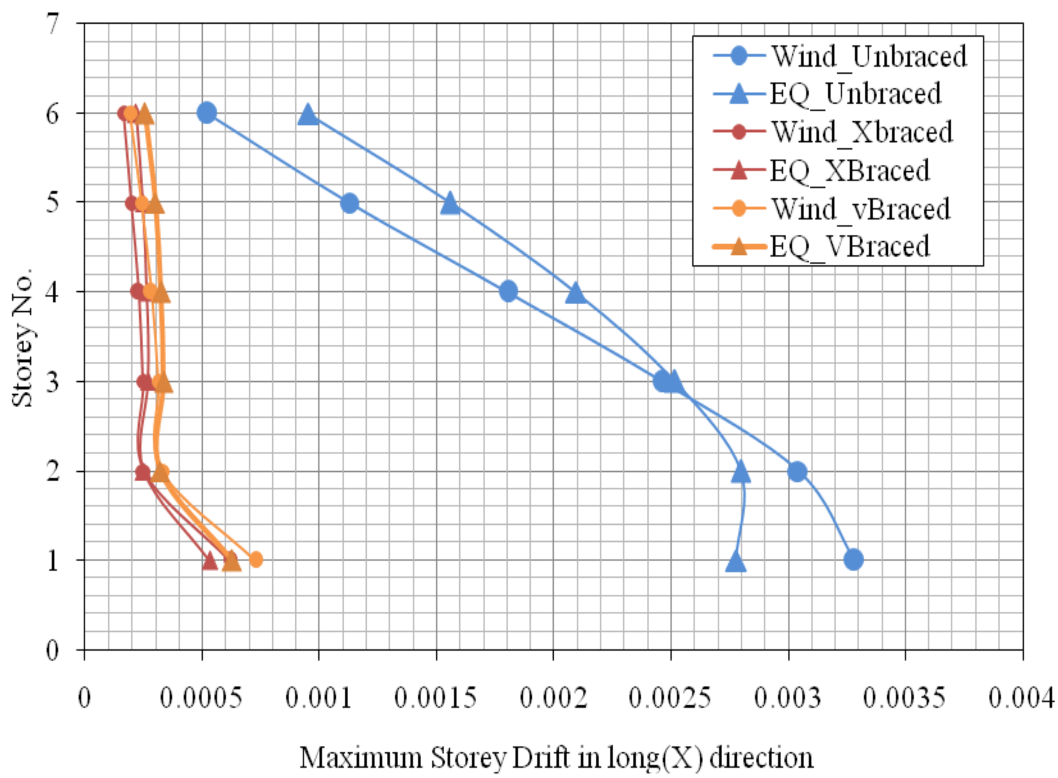


Figure 6: Storey Drift at different storey level in long direction

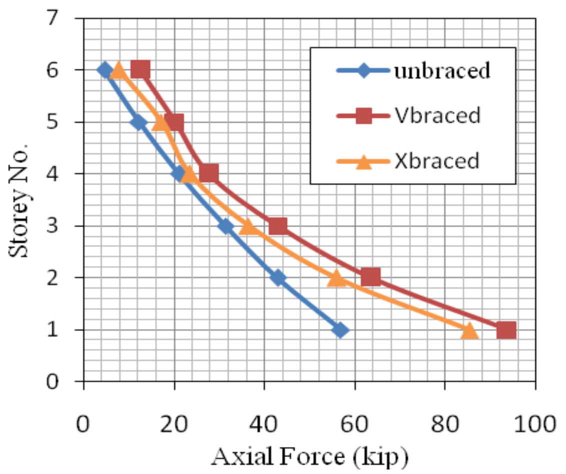


Figure 7: Axial forces in 1A-corner column

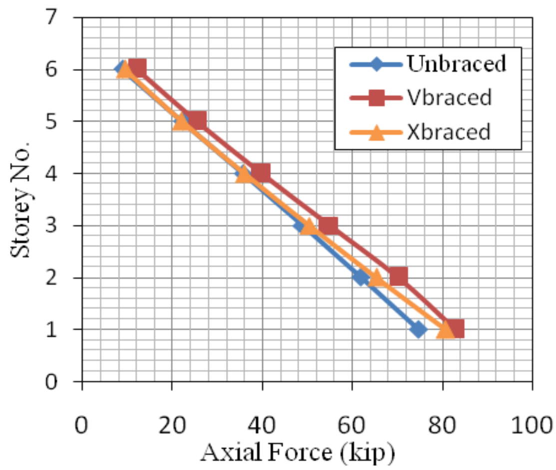
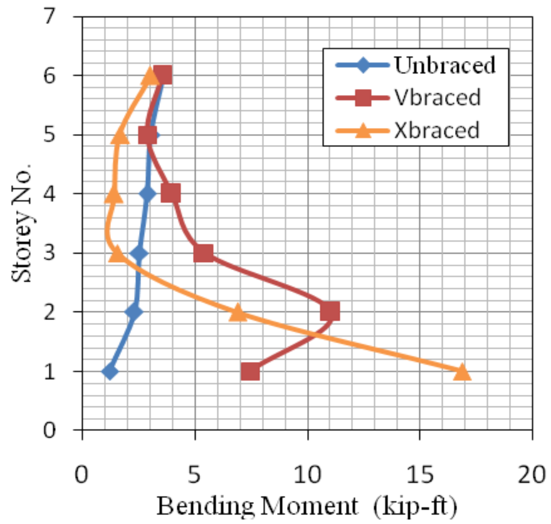


Figure 8: Axial forces in 2A-exterior column

3.4 Column bending moments

The variation of maximum bending moment for both corner and exterior columns of the same frame mentioned in axial force case at different storey has been shown in figure 9 and 10 respectively.



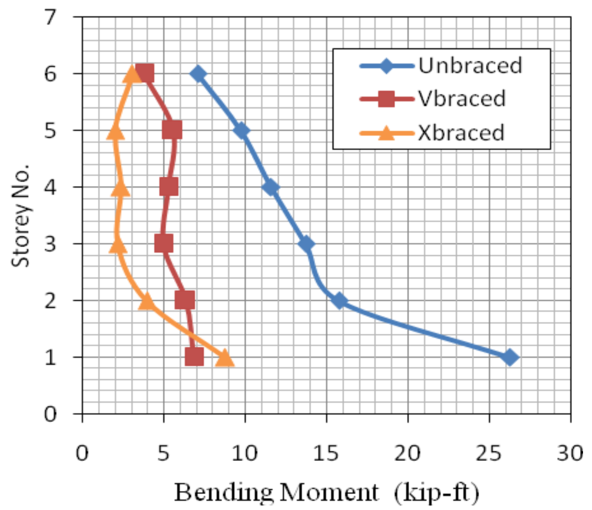


Figure 9: Bending moments in 1A-corner column **Figure 10:** Bending moments in 2A-exterior column

4. Discussions on obtained Results

After observing the storey displacement results from figure 4 to 5, it has been found that lateral storey displacement in long direction is greatly reduced by the bracing system. It has also been noted that concentric (X) bracing reduces storey displacement considerably. Therefore it can be said that concentric bracing provides greater lateral stiffness to the steel structure than eccentric (V) bracing. In case of wind load for short direction, concentric bracing system reduces 87% of the maximum lateral storey displacement whereas eccentric bracing reduces 48% at the top floor while comparing with the unbraced structure.

With reference to figure 6, it has been observed that the inter-storey drift in long direction is controlled well due to bracing system, but the influence of bracing system on inter-storey drift is reducing right from bottom to top when compared with unbraced structure. In braced structure, inter-storey drift is much less than that of unbraced structure at bottom floors. From figure 7 to 8, it has been found that maximum column axial forces at corner and exterior columns of external frame A in braced structure are high when compared with unbraced structure. It is also observed here that in corner column axial forces increases greatly from top to bottom in braced structure but no such significant variation is found in exterior column while they are compared with unbraced structure. From figure 9, it can be said that in the braced structure maximum corner column moments are very high at the bottom two floors of the structure and then drastically reduced up to top floor when compared with unbraced structure. From figure 10, it has been seen that the maximum exterior column moments are high in case of unbraced structure when compared with braced structure. In addition, it has been observed here that more column moments are developed in case of eccentric (V) bracing than concentric (X) bracing.

5. Conclusions

The following conclusions have been drawn based on the results obtained from present study

1. The concept of using steel bracing is one of the advantageous concepts which can be used to strengthen or retrofit the existing structures.
2. The lateral storey displacements of the building are greatly reduced by the use of concentric (X) bracing in comparison to eccentric (V) bracing system.
3. By considering lateral stiffness, the concentric (X) bracing has been found the most suitable one for the steel building studied under the present study.
4. The inter-storey drift is greatly reduced in presence of bracing system. As a result, it can be said that bracing system has more influence on the restriction to relative floor to floor lateral displacement.

6. References

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