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EFFECT OF DIFFERENT BRACING SYSTEMS ON THE STRUCTURAL PERFORMANCE OF STEEL BUILDING

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ABSTRACT

The present study focuses on the study of the structural performance of steel building with different bracing systems. The effectiveness of various types of bracing system on the structure has also been investigated. For this study, a ten storied commercial steel building has been designed, and then analyzed under lateral loading. The structural performance of the steel building has been investigated using different types of bracing system such as crossed bracing, V-type bracing, and eccentric bracing. A comparative study has been done on story displacement, story drift, moments on beam between braced and un-braced structures at different floor level. From the study, it has been found that in case of crossed braced structure lateral displacement is reduced by 41% which is the largest one and thus significantly contributes to greater structural stiffness. Finally, it can be said that cross diagonally braced structure shows better structural performance among all the structures considered here under similar circumstances.

Keywords: *Steel Building, bracing system, story displacement, story drift.*

1. INTRODUCTION

Bracing is one of the most widely used lateral load resisting systems in multi-storied buildings. Bracing is a highly efficient and economical method of resisting horizontal force in a frame structure. Braced frame is a structural system, which is designed primarily to resist wind loads and earthquake forces. Braced frames can be an effective system for seismic retrofit due to their high stiffness. Braced frames are almost always composed of steel members. The beams and columns that form the frame carry vertical loads, and the bracing system carries the lateral loads. Braced frames reduce lateral displacement, as well as the bending moment in columns. Steel bracing is economical, easy to erect, occupies less space and has flexibility to design for meeting the required strength and stiffness. It allows obtaining a great increase of lateral 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.

A comparative study has been made by Tafheem & Khusru, 2013; Khusru & Tafheem,2014 to understand the effect of different types of bracing system on the structure. By considering both the economy and lateral stiffness, the chevron (V-type) bracing with angle section has been found the most suitable one for the building studied. Traditional chevron-braced (V- and inverted-V-braced) frames have been shown to have very undesirable post buckling behaviour characterized by beam flexure rather than truss action (Khatib et.al., 1988).

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 and columns, thus reducing the lateral stiffness of the frame. 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 primary focus of this study is to find the most effective bracing system for steel building under lateral loads and also to compare the structural performance between unbraced and different types of braced structures. To achieve this goal, a ten storied steel building has been designed, which is located in Dhaka, Bangladesh. All loads are applied according to Bangladesh National Building Code (BNBC). All the models have been developed for similar loading scenario using different braced conditions. Four building models have been created: one is unbraced structure and other three are braced structures; X-braced structure, V-braced structure and eccentric braced structure. A comparative study among all structural systems has also been done. Comparison of story displacement, story drift and moment of a beam for both braced and unbraced structures has been carried out.

2. METHODOLOGY

Ten storied steel building has been analyzed and designed using ETABS V.15.2 by following provisions and specifications as per Bangladesh National Building Code (BNBC), 2006. The dimension of the longitudinal direction is 90 feet and transverse direction is 45 feet. The height of the building is 100 feet (10ft of each story). There are six spans in long direction and three spans in short direction having 5inch slab. The building layout plan has been given in the following Figure 1.

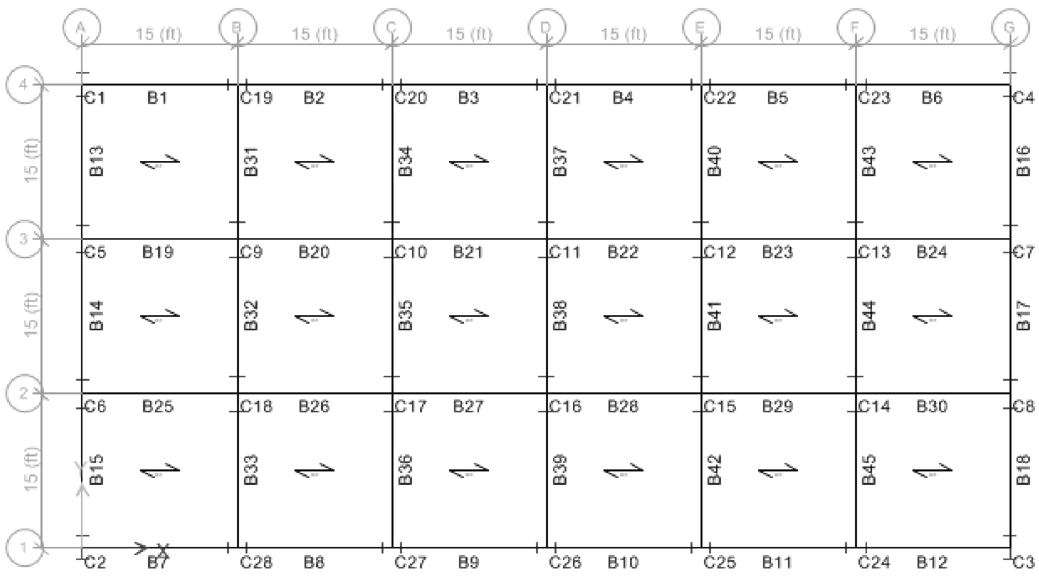


Figure 1: Column and Beam layout of the studied steel building

For simplification of study W24 section has been selected for corner columns, W18 for long direction exterior column, W27 for short direction exterior columns and W36 has been selected for interior columns. Table 1 shows the dimension of all columns.

Table 1: Column sections used in the model

COLUMN ID	Wide Flange Section
C1,C2,C3,C4	W24×370
C19,C20,C21,C22,C23,C24,C25,C26,C27,C28	W18×311
C5,C6,C7,C8	W27×539
C9,C10,C11,C12,C13,C14,C15,C16,C17,C18	W36×652

In case of beam design, W12 section has been used. Table 2 shows the dimension of all beams.

Table 2: Beam sections used in the model

BEAM ID	Wide Flange Section
B13,B14,B15,B16,17,B18,B31,B32,B33, B34,B35,B36,B37,B38,B39,B40,B41,B42, B43,B44,B45	W12×96
B2,B3,B4,B5,B8,B9,B10,B11	W12×152
B1,B6,B7,B12,B20,B21,B22,B23,B26,B27, B28, B29	W12×210
B19,B24,B25,B30	W12×230

All type of dead loads subjected to the structures are defined as per BNBC code. The super-dead loads are floor finish (FF), partition wall (PW) which act along with the self-weight.

Table 3: Dead load and live load

Name of Load	Value	Unit
Dead(FF and PW)	35	psf
Cladding Load	0.25	Kip/ft
Live Load	40	lb/ft^2

For the analysis, the wind and earthquake loading have been calculated as set forth by the provision of Bangladesh National Building Code (BNBC, 2006). According to the following Tables 4 and 5, different coefficients and parameters have been used for the wind (W) and earthquake (EQ) loading that have been applied to the structure.

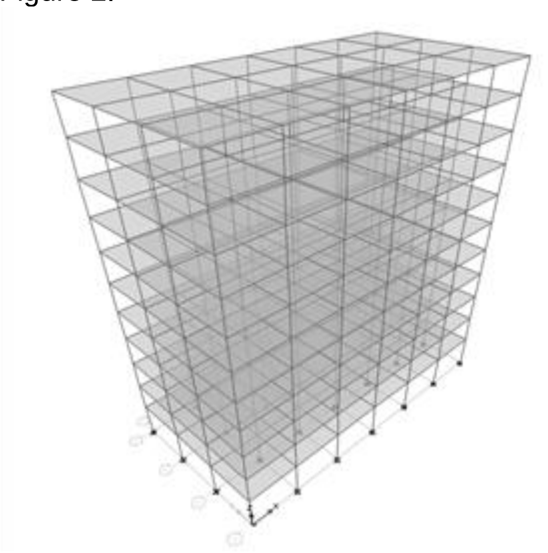
Table 4: Different coefficients taken into account for the calculation of seismic load

Name	Symbol	Value	Description
Seismic Zone Coefficient	Z	0.15	Zone 2 (Dhaka)
Structural Importance Coefficient	I	1	Standard occupancy Structure (Commercial-Office)
Site Coefficient	S	1.5	Soli profile type S3
Response Modification Co-efficient	R	12	Special Moment Resisting frame

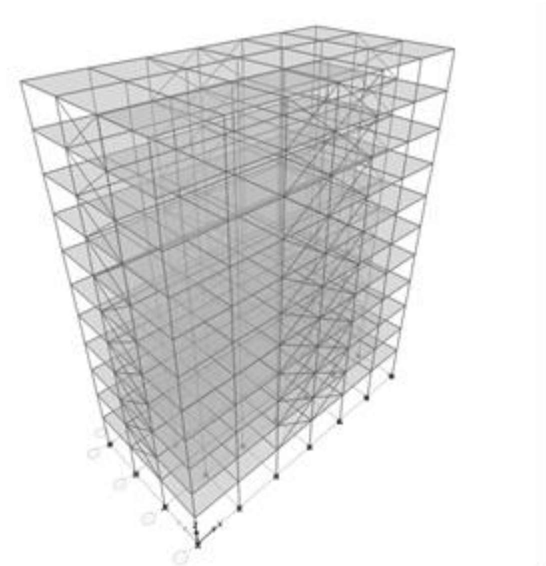
Table 5: Coefficients or parameters taken into account for the calculation of wind load

Name	**Symbol**	**Value**	**Description**
Terrain Exposure Category	A	---	Urban and sub-urban areas
Basic wind speed	V_b	210 km/hr	Dhaka city
Structural Importance Coefficient	C_I	1	Standard occupancy Structure

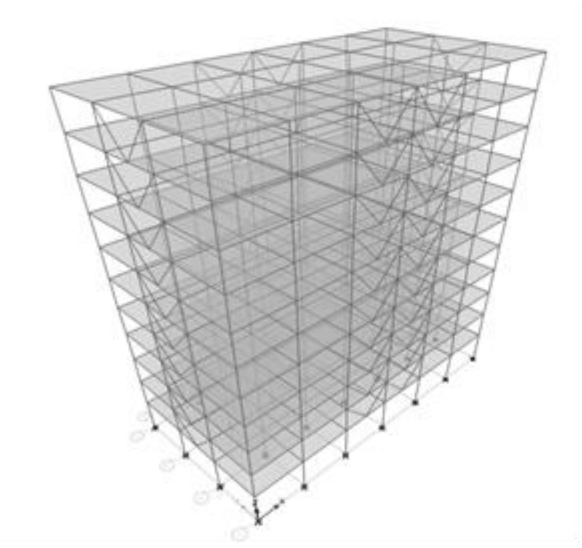
All structural models consist of same beam-column layout as architectural design are same for each. In the present study, one unbraced and three braced building structures such as X braced, V braced, eccentric braced structures have been modeled which are shown in Figure 2.



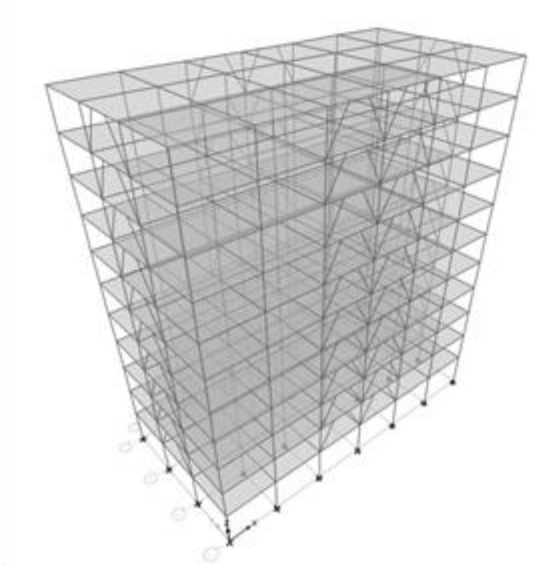
(a) Unbraced structure



(b) X-braced structure



(c) V-braced structure



(d) Eccentric-braced structure

Figure 2: Different types of braced and unbraced structures

3. RESULT AND DISCUSSION

All the displacement values of all 4 structures are plotted in Figure 3 and Figure 4 along both X-direction and Y-direction respectively.

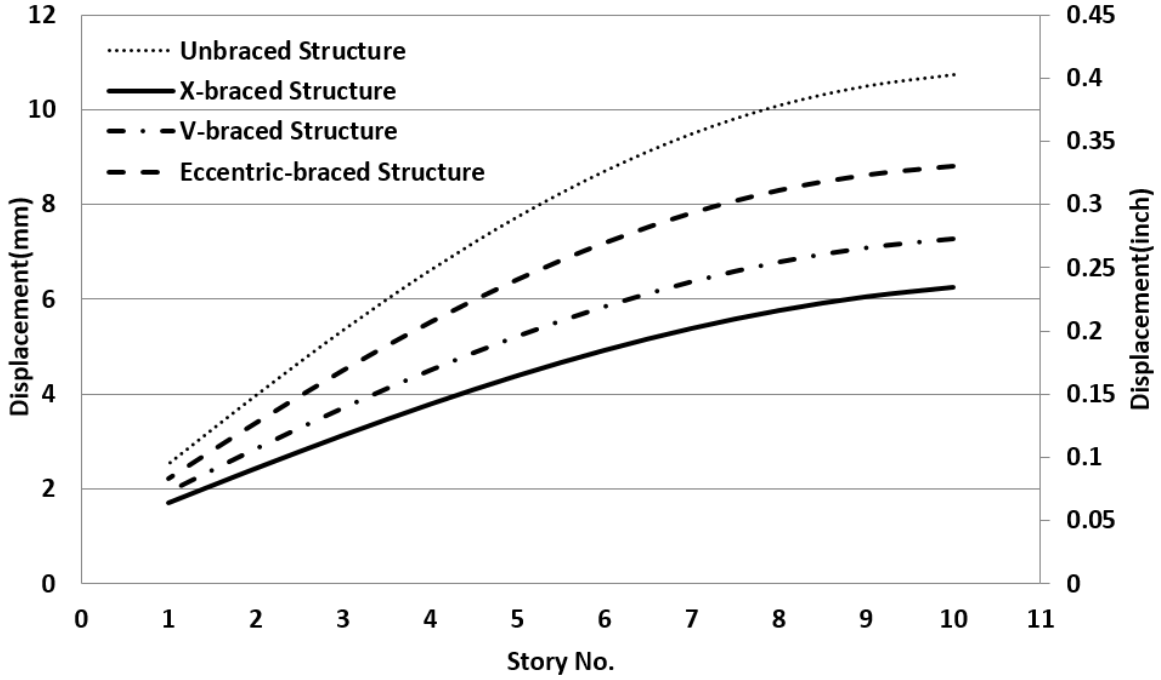


Figure 3: Displacement along X-direction for unbraced, X braced, V braced and eccentric braced structure

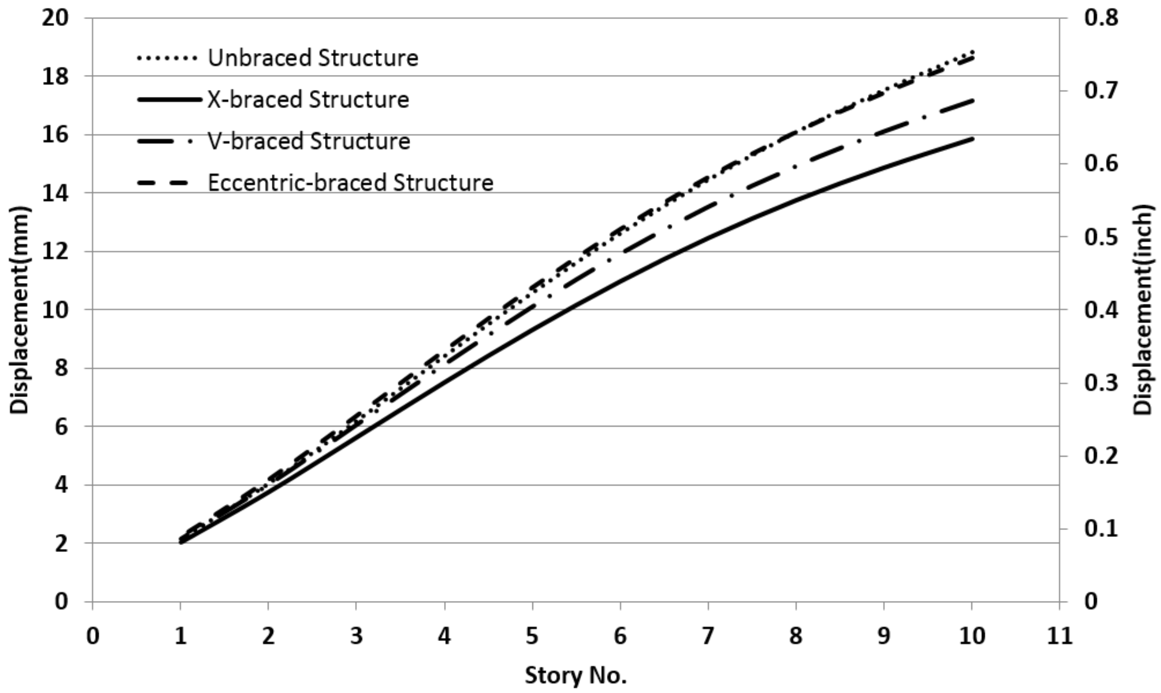


Figure 4: Displacement along Y-direction for unbraced, X braced, V braced and eccentric braced structure

From Figure 3, it is found that in X-direction and at the top floor the reduction in maximum displacement for X-braced structure is 41.7% while compared to unbraced structure followed by 32.2% for V-Braced structure and 17.9% for eccentric-braced structure. From Figure 4, it has been found that in Y-direction for roof (10th floor) the reduction in maximum displacement for X-braced structure is 15.6% in comparison to unbraced structure followed by 8.8% for V-Braced structure and 0.8% for eccentric-braced structure.

The drift values for all 4 structures are also plotted in Figure 5. It has been observed that at the 3rd floor the values of story drift are maximum in case of all structures and the reduction in story drift values for X-braced structure is 55.7% while compared to unbraced structure followed by 33.7% for V-Braced structure and 16.7% for eccentric-braced structure.

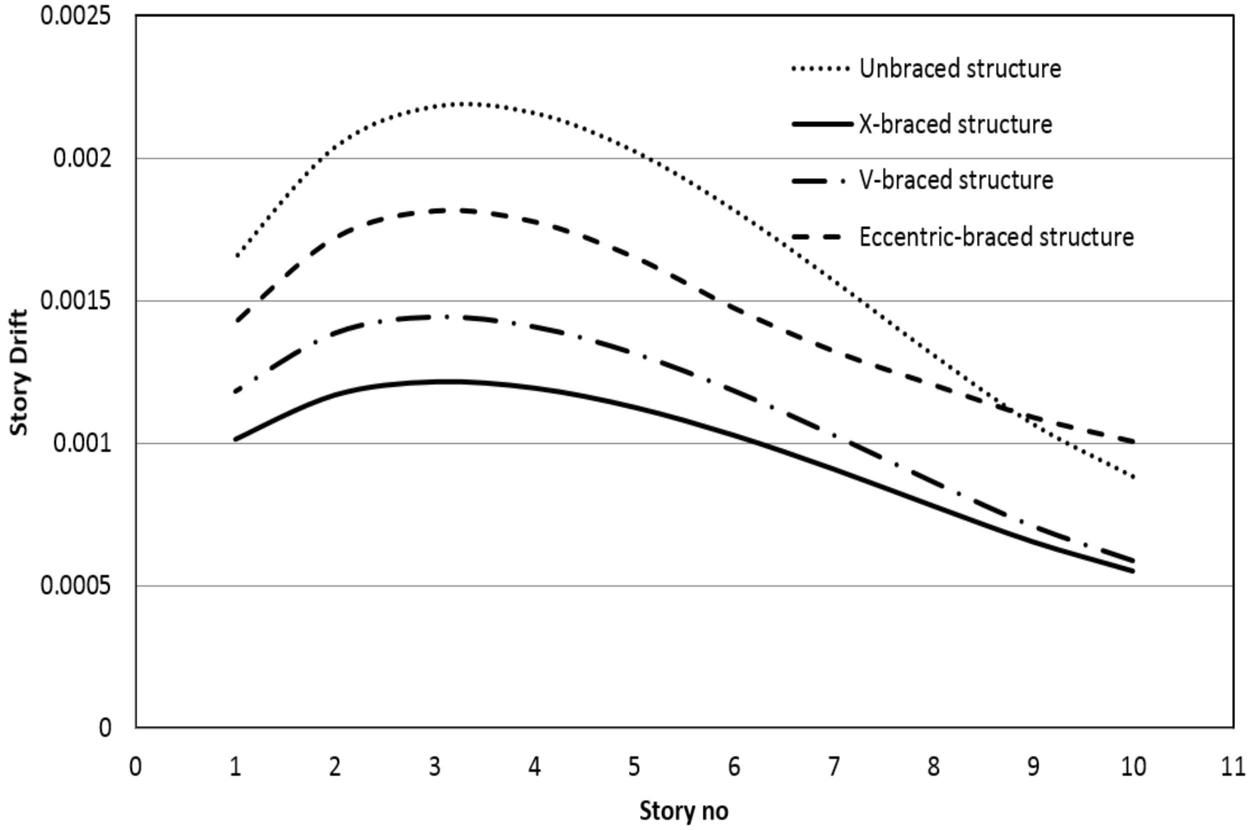


Figure 5: Story Drift of unbraced, X braced, V braced and eccentric braced structures

For the moment of a beam, the beam B13 has been considered and the highest positive or negative moment values of beam B13 were plotted in Figure 6. The moment value of the beam (B13) is lower in X-braced structure than other structures up to eighth floor and almost similar at ninth and top floor.

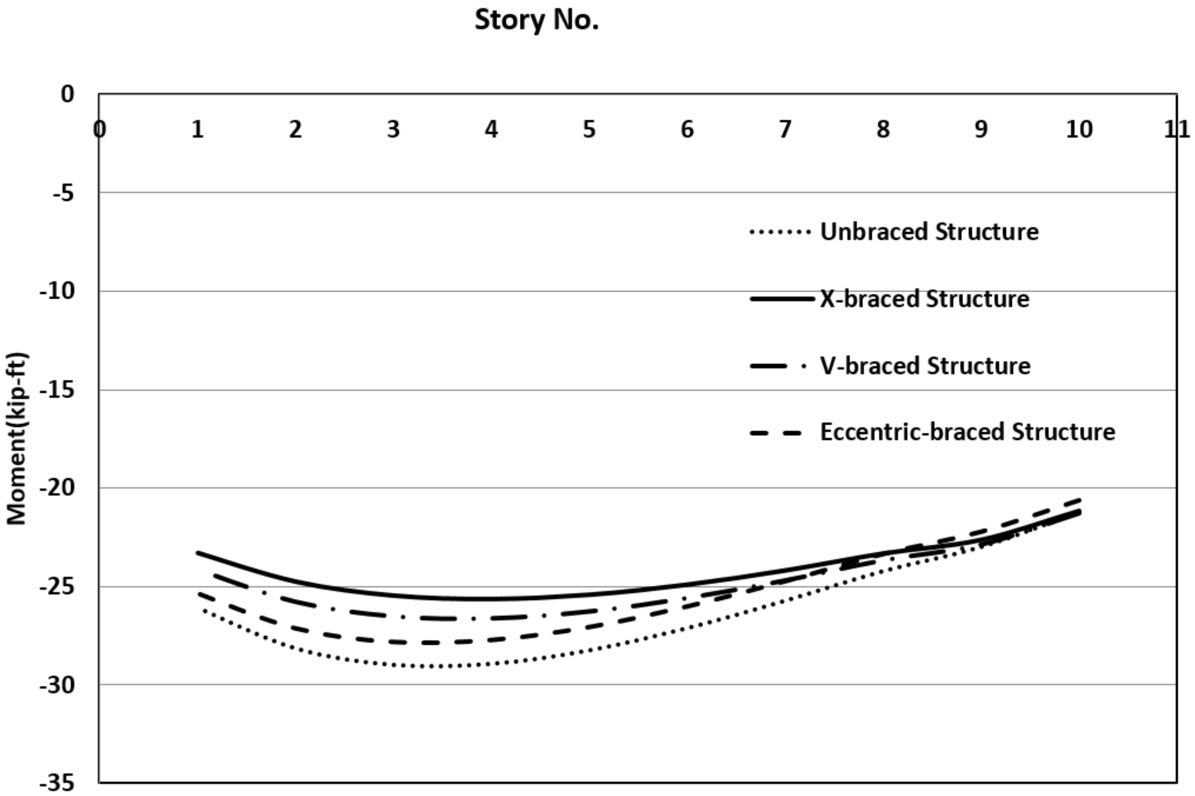


Figure 6: Moment of beam (B13) of Unbraced, X braced, V braced and Eccentric braced Structure

4. CONCLUSIONS

The findings of the present study are given below.

- In case of story displacement in X-direction, unbraced structure shows the maximum value of 0.422283 inch which is within BNBC limit. The maximum reduction in displacement value is 41.7% for X-braced structure in comparison to unbraced structure followed by 32.2% for V-Braced structure and 17.9% for eccentric-braced structure.
- In case of story displacement in Y-direction, unbraced structure shows the maximum value of 0.740774 inch which is within BNBC limit. The maximum reduction in displacement value is 15.6% for X-braced structure in comparison with unbraced structure followed by 8.8% for V-Braced structure and 0.8% for eccentric-braced structure.
- In case of story drift, unbraced structure shows the maximum value which is 0.002180. The maximum reduction in drift value is 55.7% for X-braced structure while compared to unbraced structure followed by 33.7% for V-Braced structure and 16.7% for eccentric-braced structure.
- In case of moment for beam (B13), maximum moment at 4th floor for X braced structure is lower than other three structures.

Among all models, braced structure has shown better resistance than unbraced structure. Finally, it has been found that among all the structures considered, X-Braced structure is the best option among all from the structural point of view.

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