

**SEISMIC EVALUATION OF STRENGTHENING OF SOFT STOREY BUILDING
CONSIDERING EQUIVALENT DIAGONAL STRUTS****Abdul Juned Siddiqui*, Prabhat Soni, Aslam Hussain**

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ABSTRACT

The term soft storey explain one level of a building that is significantly more flexible than the stories above it. And to counter the effect of soft storey equivalent diagonal struts are used. The frames with unreinforced masonry can be modelled as equivalent braced frames by replacing infills with equivalent diagonal strut. Equivalent Static method of analysis is a linear static procedure, in which the response of building is assumed as linear static manner. The analysis is carried out as per IS: 1893-2002 (Part 1).

In this work G+5 storey (six storey) building is taken in which floor wise (changing soft storey position from first to six storey) soft storey is analysis and its contribution in the behaviour of the structure is examined. Soft storey is more flexible as above storey and we will conclude by getting best geometry in seismic zone; thereby geometry of the building shall be optimized by considering 4 building plan for seismic zones-II. The main objective of this thesis is to investigate the effective building frame with different geometry to withstand under seismic parameters. The investigation is to be carried out by conducting-

- (a) Modelling of building frames considering different geometries
- (b) Analysis of frames considering seismic parameters
- (c) Critical study of results in term of moments, forces and deflections

KEYWORDS: Seismic forces, Soft story, Infill, optimization, axial force, displacement, etc.

INTRODUCTION

Since the presence of a soft storey which has less rigidity than other storeys and if this fact was not taken into consideration it causes the construction to be affected by the earthquake. Because the columns in this part are forced by the earthquake more than the ones in the other parts of the building. Studies conducted suggest that walls increase the rigidity at a certain degree in the construction

A construction is divided into two parts from the point where there is a soft storey of the constructions with equal rigidity between the storeys; the displacement of the peak points at the moment of a earthquake causes the other building with a soft storey to get damaged because the construction with a soft storey cannot show the same rigidity. Reinforced concrete frame buildings have become common form of construction with masonry infills in urban and semi urban areas in the world. The term infilled frame denotes a composite structure formed by the combination of a moment resisting plane frame and infill walls. The infill masonry may be of brick, concrete blocks, or stones. Ideally in present time the reinforced concrete frame is filled with bricks as non-structural wall for partition of rooms because of its advantages such as, thermal insulation, durability, cost and simple construction technique.

Many such buildings constructed in recent times have a special feature - the ground storey is remains open, which means the columns in the ground storey do not have any partition walls between them. This types of structures (Fig. 1.2) having no infill masonry walls in ground storey, but having infill masonry walls in all the upper storeys, are called as Open Ground Storey (OGS) Buildings. This open ground storey structure is also termed as structure with 'Soft Storey at Ground Floor'. They are also known as open first storey building (when the storey numbering starts with one from the ground storey itself), pilotis, or stilted buildings. Open first storey is now a day's unavoidable feature for the most of the urban multi-storey buildings because social and functional needs for parking, restaurant, commercial

use etc. are compelling to provide an open first storey in high rise structure. Parking has become a necessary feature for the most of urban multi-storeyed buildings as the population is increasing at a very fast rate in urban areas leading to crisis of vehicle parking space. Hence the trend has been to utilize the ground storey of the building itself for parking purpose.

P.B. Kulkarni et. al. (2013) Masonry infill walls are mainly used to increase initial stiffness and strength of reinforced concrete (RC) frame buildings. It is mainly considered as a non-structural element. In this paper, symmetrical frame of college building (G+5) located in seismic zone-III is considered by modeling of initial frame. With reference to FEMA-273, & ATC-40 which contain the provisions of calculation of stiffness of infilled frames by modeling the infill panels are modeled as a equivalent diagonal strut method.

Lee and ko (2007) found that three 1:12 scale 17-story RC wall building models having different types of irregularity at the bottom two stories were subjected to the same series of simulated earthquake excitations to observe their seismic response characteristics. The first model has a symmetrical moment-resisting frame (Model 1), the second has an infilled shear wall in the central frame (Model 2), and the third has an infilled shear wall in only one of the exterior frames (Model 3) at the bottom two stories.

Sivakumaran (1990) developed a method of analysis for the earthquake response of multi-storey mono-symmetric buildings founded on flexible foundations. The analysis also includes the sway ($P-\Delta$) effects.

Mahdi Modirzadeh et. al (2012) found that seismic resiliency of new buildings has improved over the years due to enhancements in seismic codes and design practices. However, existing buildings designed and built under earlier codes are vulnerable and require a performance-based screening and retrofit prioritization. The performance modifiers considered are soft story, weak story, and the quality of construction, which are collated through a walk down survey. The building evaluation is performed through a pushover analysis, and performance objective are obtained through initial stiffness of the pushover curve.

Danay (1976) analysed asymmetric multi-storey buildings with varying cross-section. The basic structural component is a rectangular thin panel bounded between floors and vertical edges. Its behaviour is governed by the conventional axial, bending and shear assumptions of beam theory.

El-Hawary (1994) investigates the importance of including the effects of the flexibility of the horizontal diaphragms when using the P-delta method of analysis, especially when considering the loads applied to intermediate frames on trusses that are not part of the lateral force resisting system. Analyses were conducted for structural systems with a variable number of stories, number of bays and diaphragm stiffnesses and supported by rigid jointed plane frames or vertical trusses.

GEOMETRY DETAIL & MODELLING

This thesis deals with comparative study of behaviour of soft storey building frames considering geometrical configurations under earthquake forces. This problem is associated with the soft story buildings considering geometrical and seismic parameters.

The framed buildings are subjected to vibrations because of earthquake and therefore seismic analysis is essential for these building frames. The fixed base systems are analyzed by employing different building frames in seismic zones by means of STAAD.Pro software. The responses of the same building frames are studied and the evaluation of the best geometry which satisfy one of the seismic zones is carried out

Following cases has taken in to consideration for the study:-

CASE- 1 Bare frame without equivalent diagonal struts

CASE-2 Equivalent diagonal struts at centre of structure

CASE-3 Equivalent diagonal struts at centre of structure

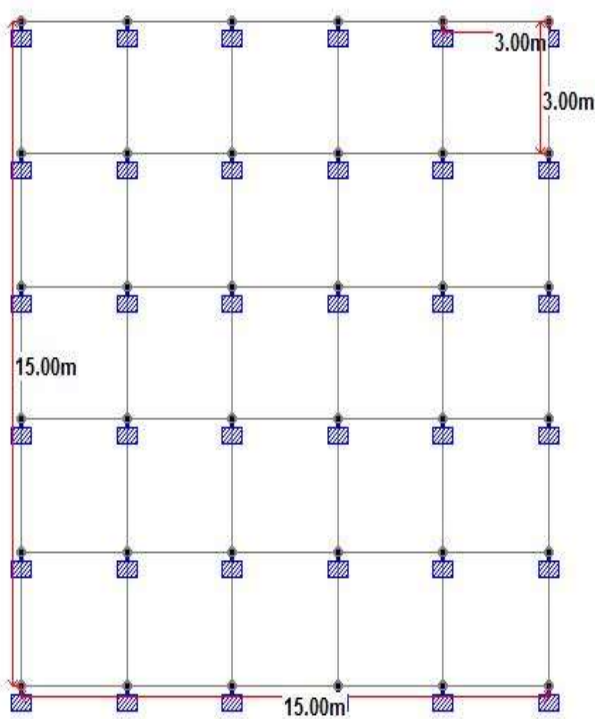


Fig. 1: Structure plan of geometry

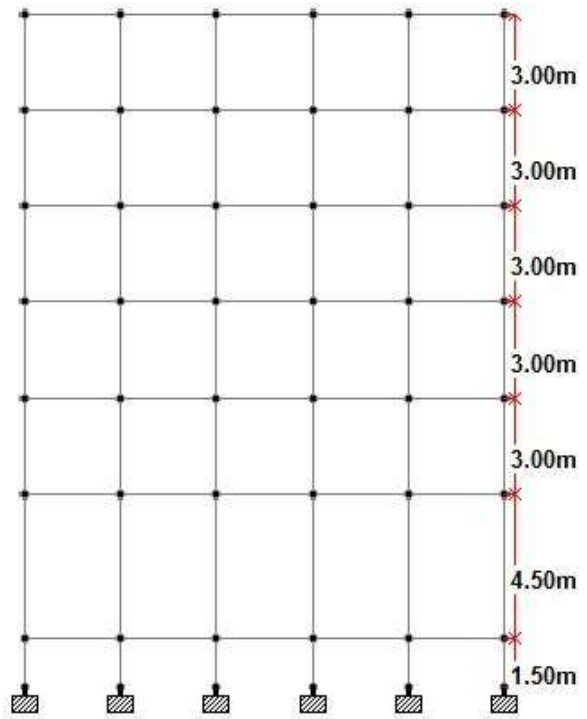


Fig. 2: Soft storey at first storey of 4.5 m

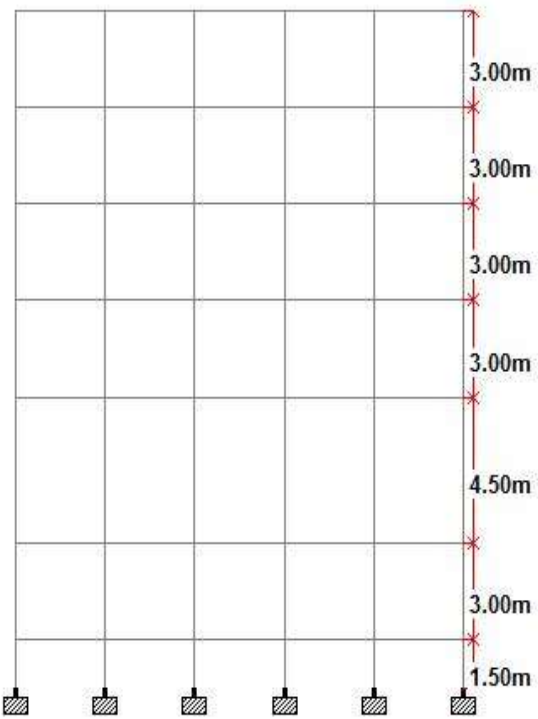


Fig. 3: Soft storey at second storey of 4.5 m

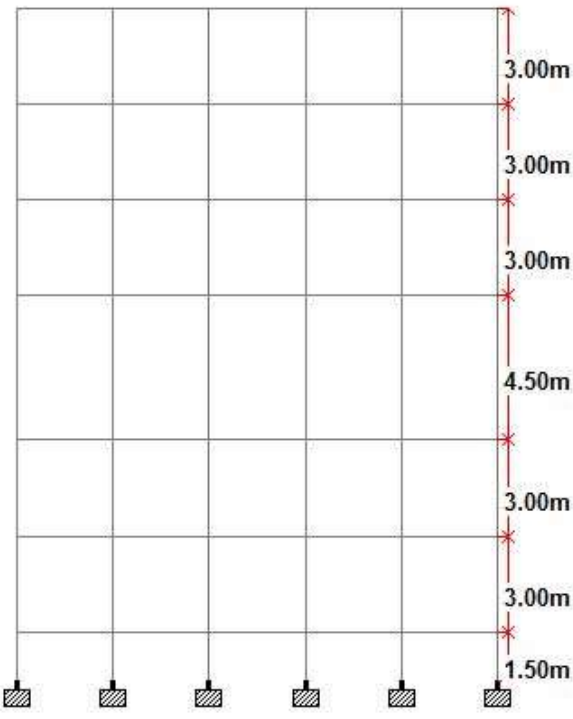


Fig. 4: Soft storey at third storey of 4.5 m

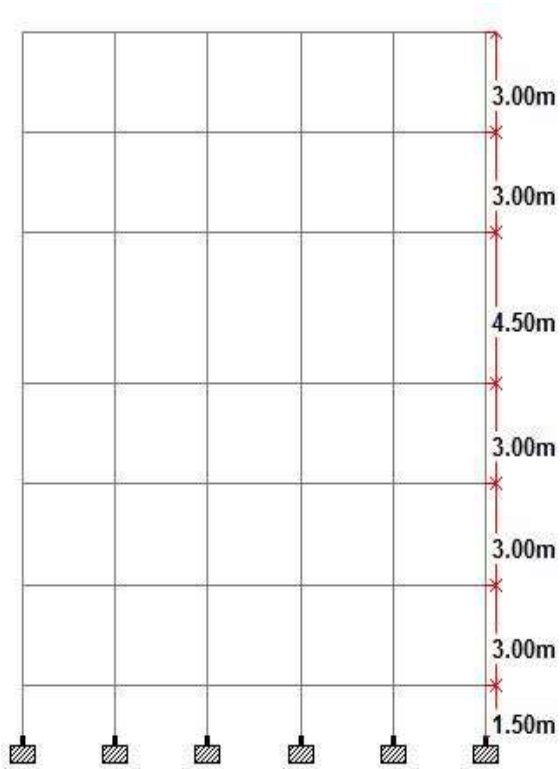


Fig 5: Soft storey at second storey of 4.5 m

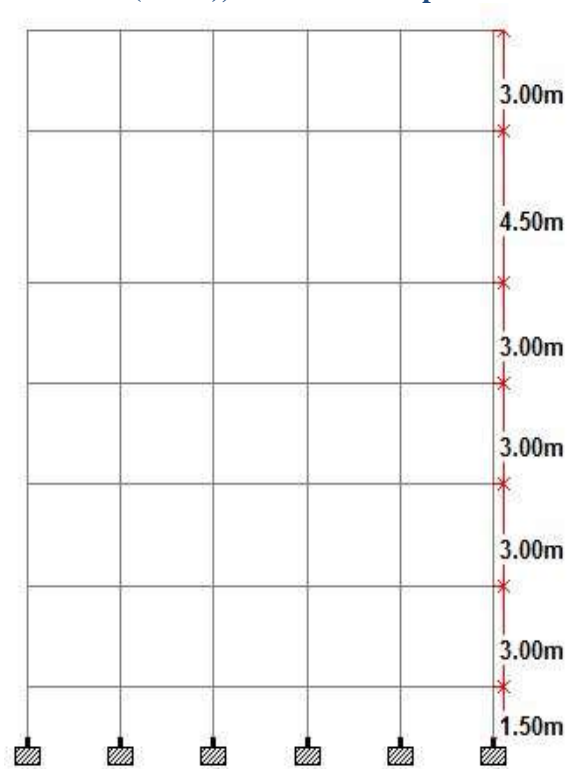


Fig 6: Soft storey at third storey of 4.5 m

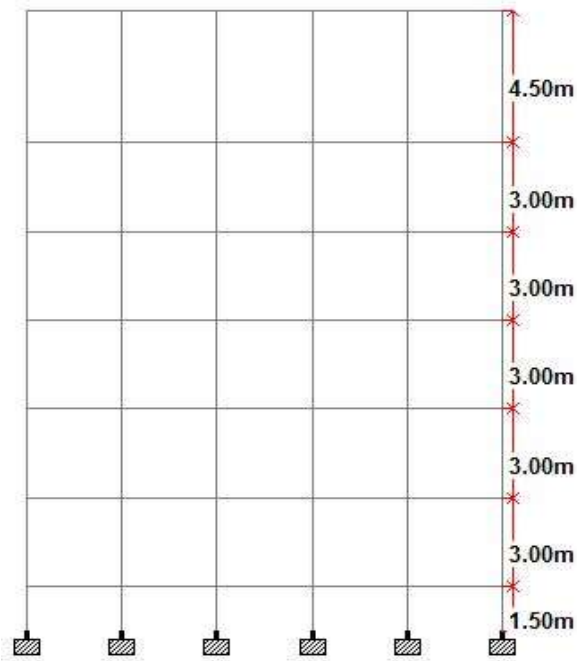


Fig 7: Soft storey at sixth storey of 4.5 m

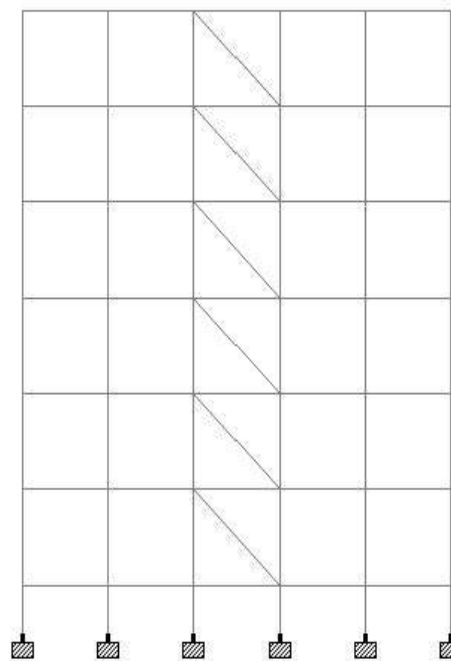


Fig 8: Front view with equivalent diagonal struts at centre

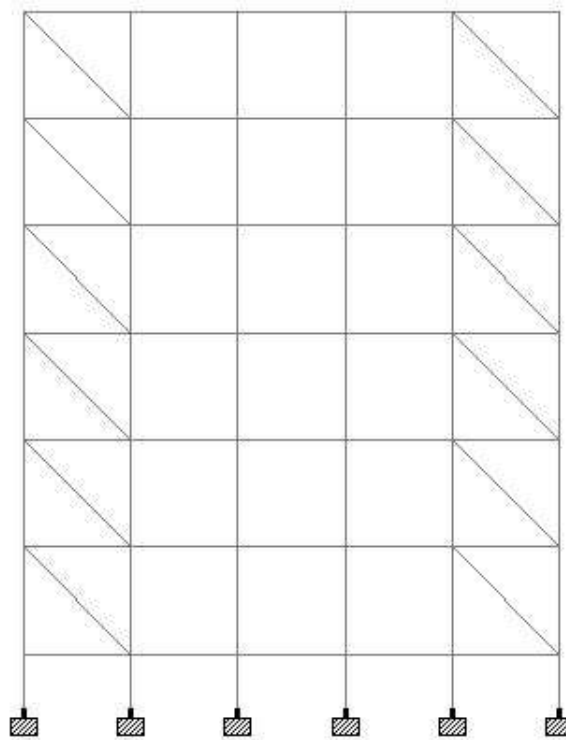


Fig 9: Front view of bare frame with equivalent diagonal struts at corner

RESULTS & DISCUSSION

Maximum Displacement

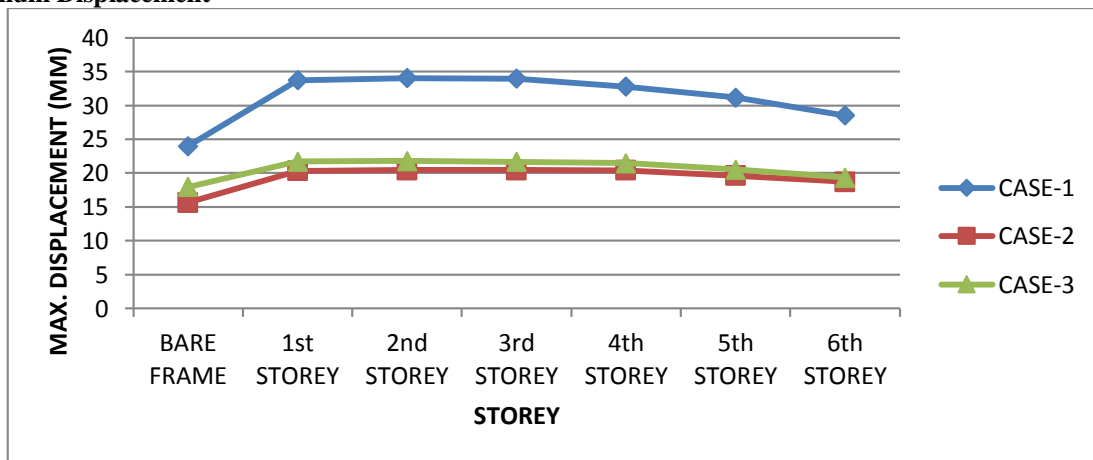


Fig. 10: Maximum displacement in zone-II of X direction

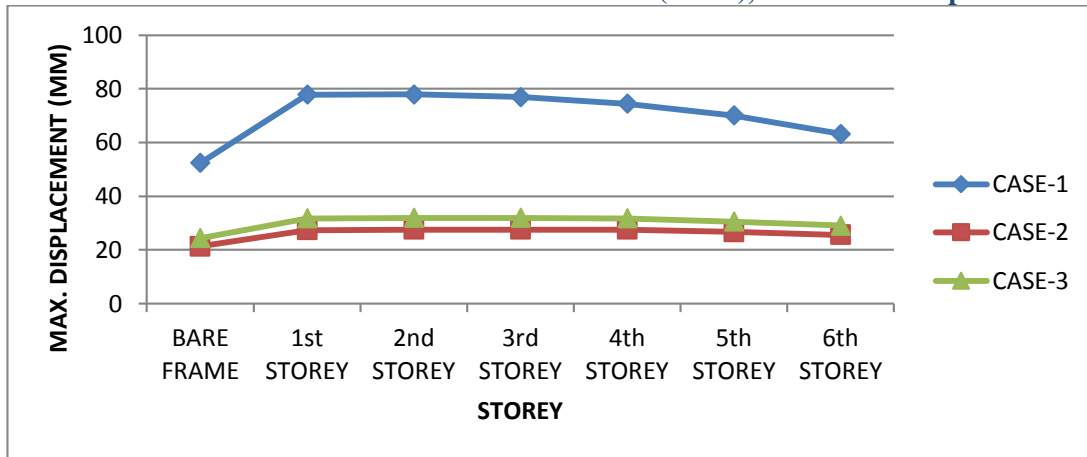


Fig. 11: Maximum displacement in zone-II of Z direction

Beam Forces

Maximum Bending Moment

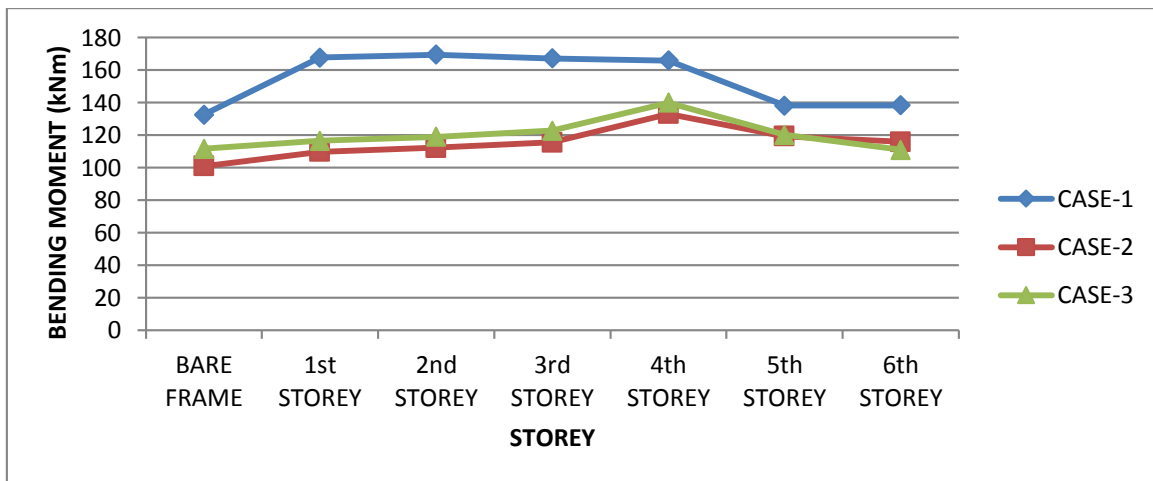


Fig. 12: Bending moment (kNm) in beam in X direction

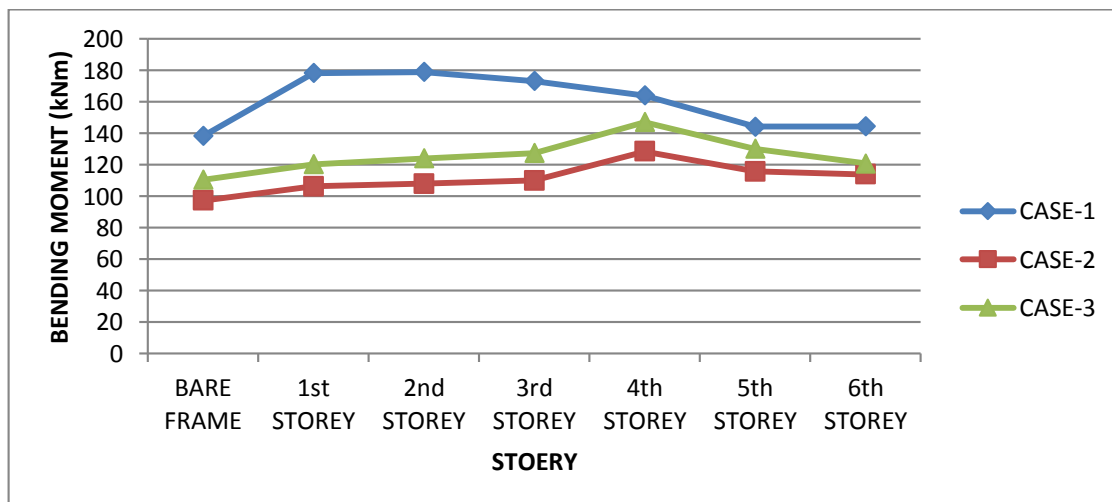


Fig. 13: Bending moment (kNm) in beam in Z direction

Shear Force

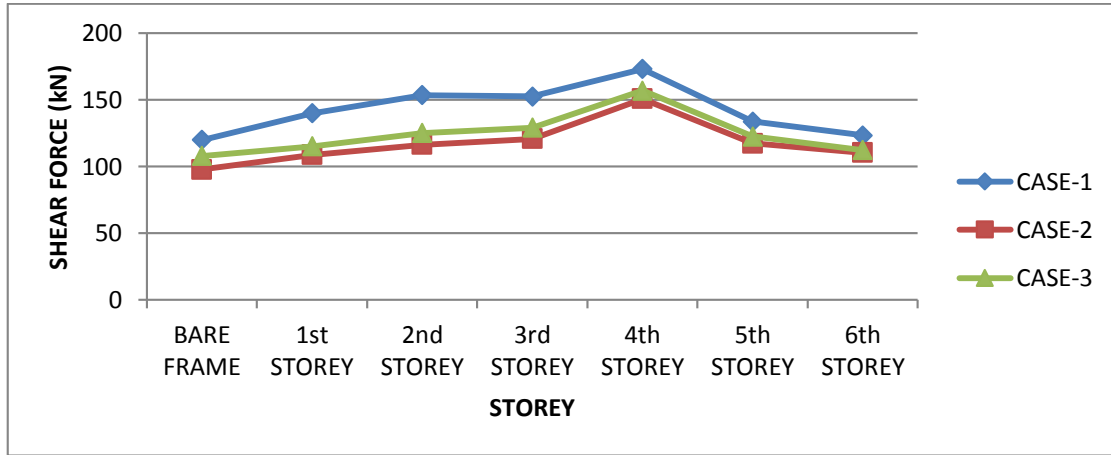


Fig. 14: Shear force (kN) in beam in X direction

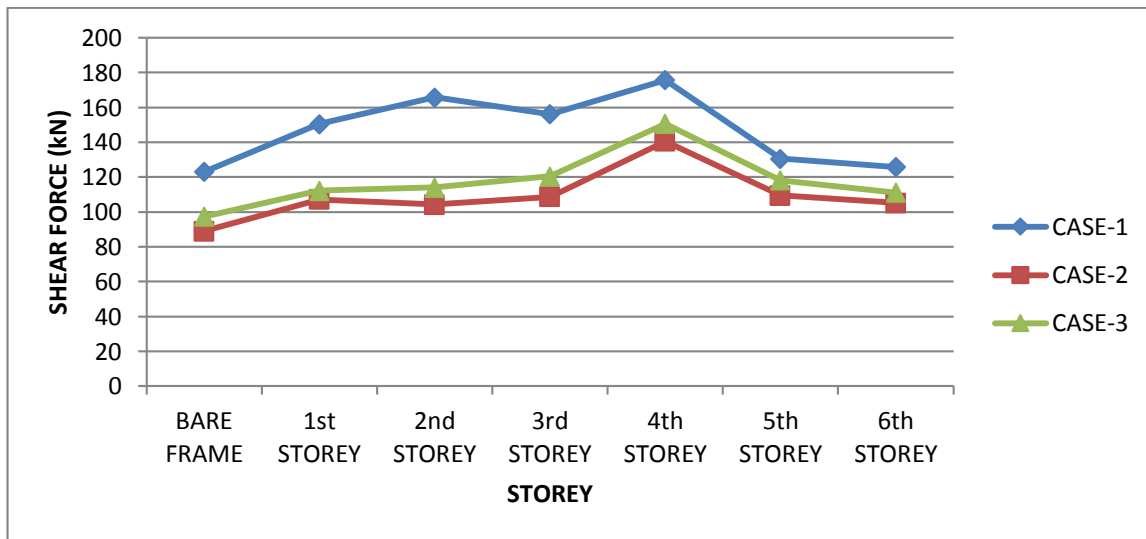


Fig. 15: Shear force (kN) in beam in Z direction

Storey Displacement

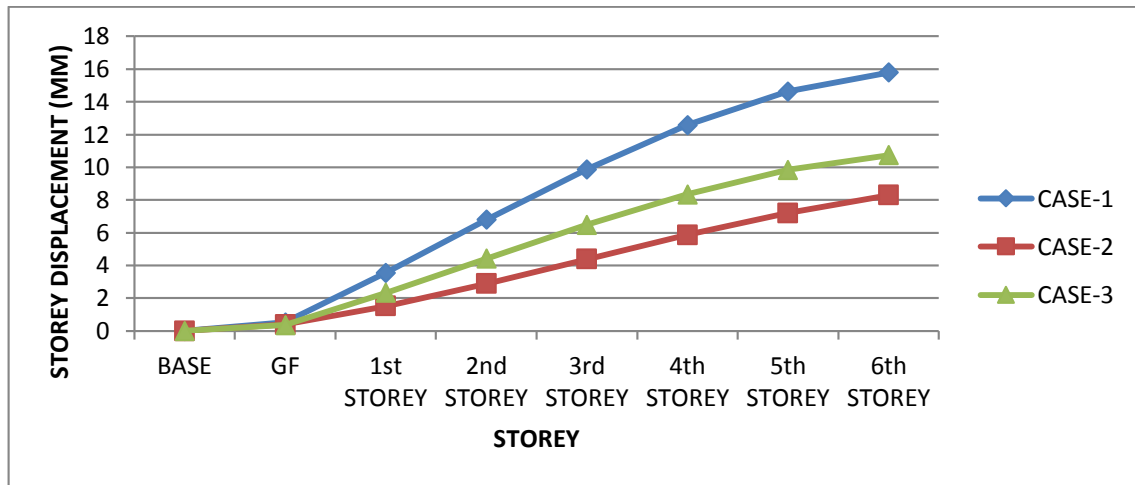


Fig. 16: Storey displacement (mm) in bare frame in zone-II of X direction

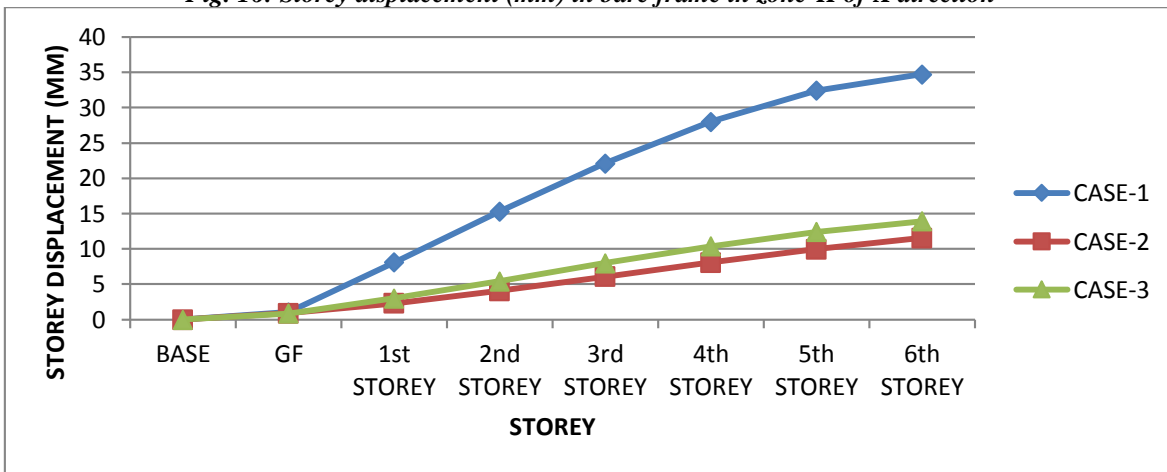


Fig. 17: Storey displacement (mm) in bare frame in zone-II of Z direction

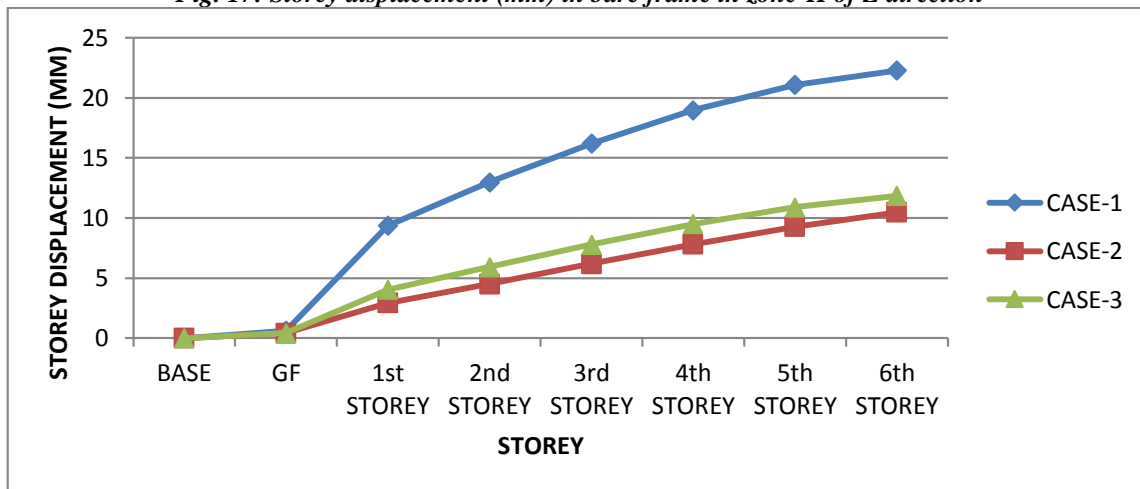


Fig. 18: Storey displacement (mm) in 1st storey soft in zone-II of X direction

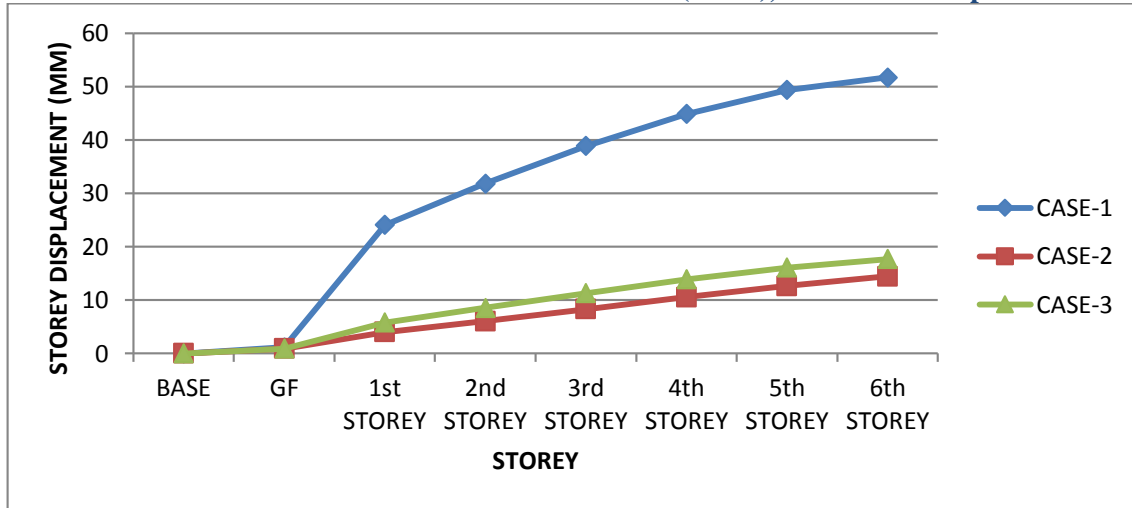


Fig. 19: Storey displacement (mm) in 1st storey soft in zone-II of Z direction

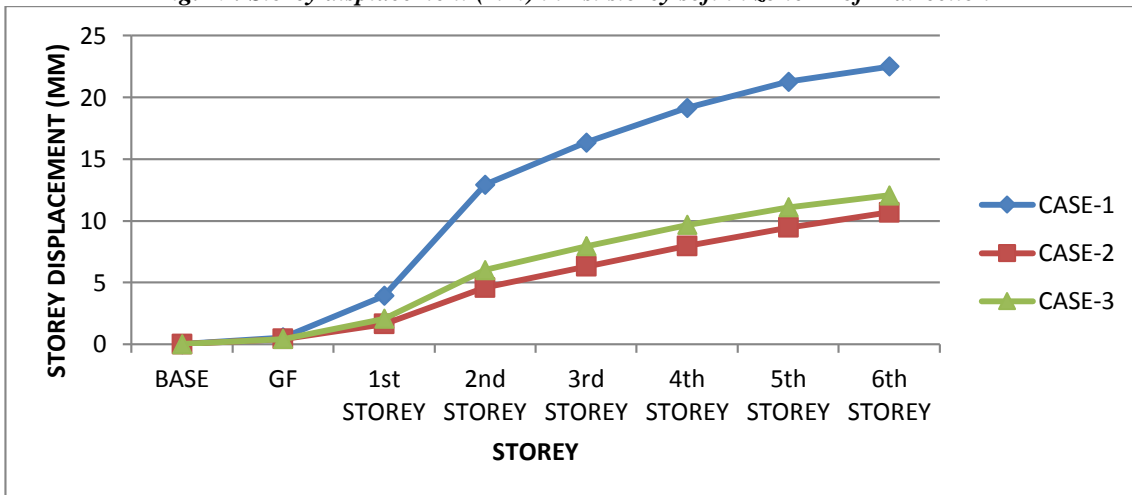


Fig. 20: storey displacement (mm) in 2nd storey soft in zone-II of X direction

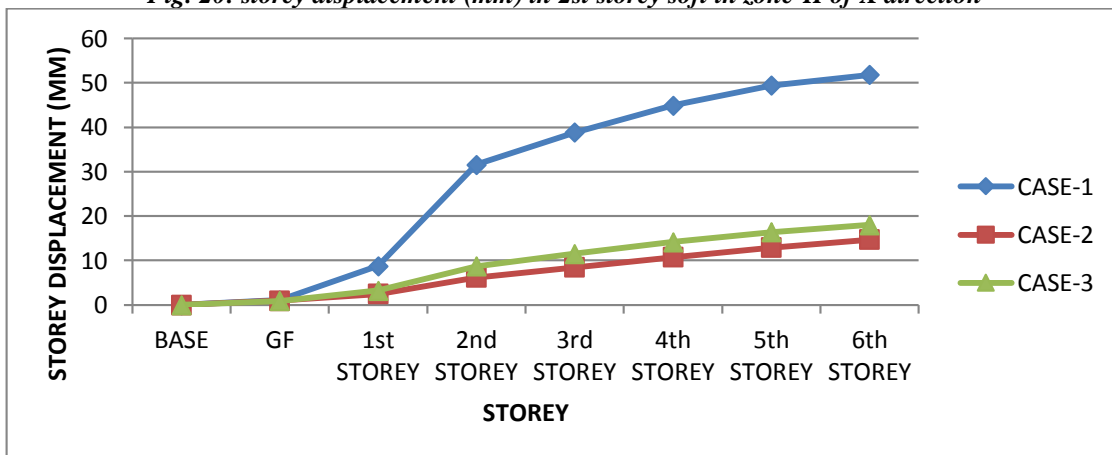


Fig. 21: Storey displacement (mm) in 2nd storey soft in zone-II of Z direction

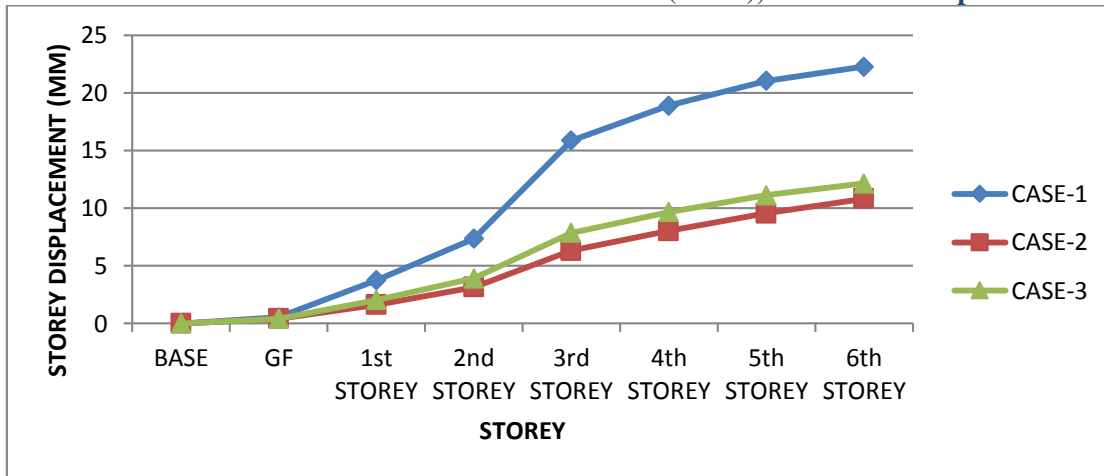


Fig. 22: Storey displacement (mm) in 3rd storey soft in zone-II of X direction

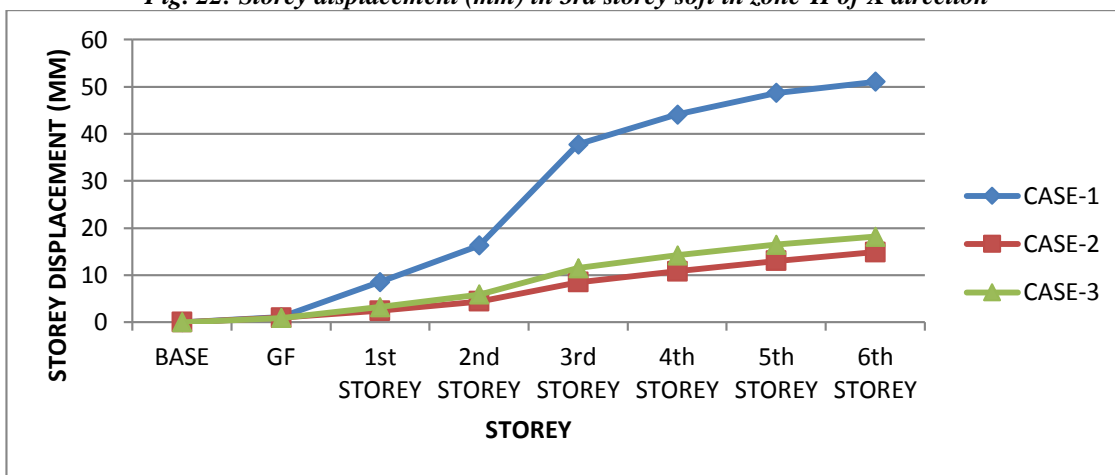


Fig. 23: Storey displacement (mm) in 3rd storey soft in zone-II of Z direction

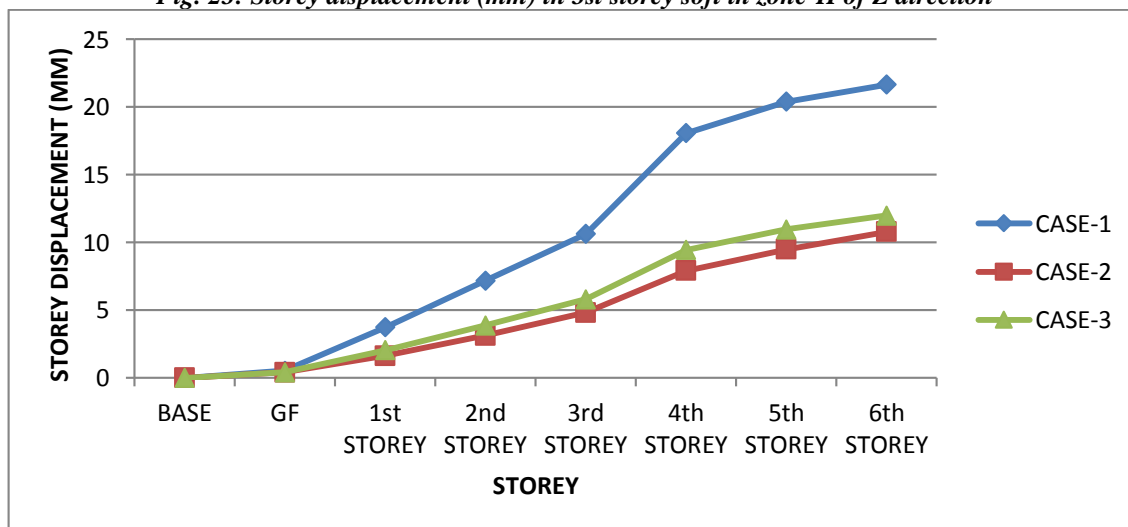


Fig. 24: Storey displacement (mm) in 4th storey soft in zone-II of X direction

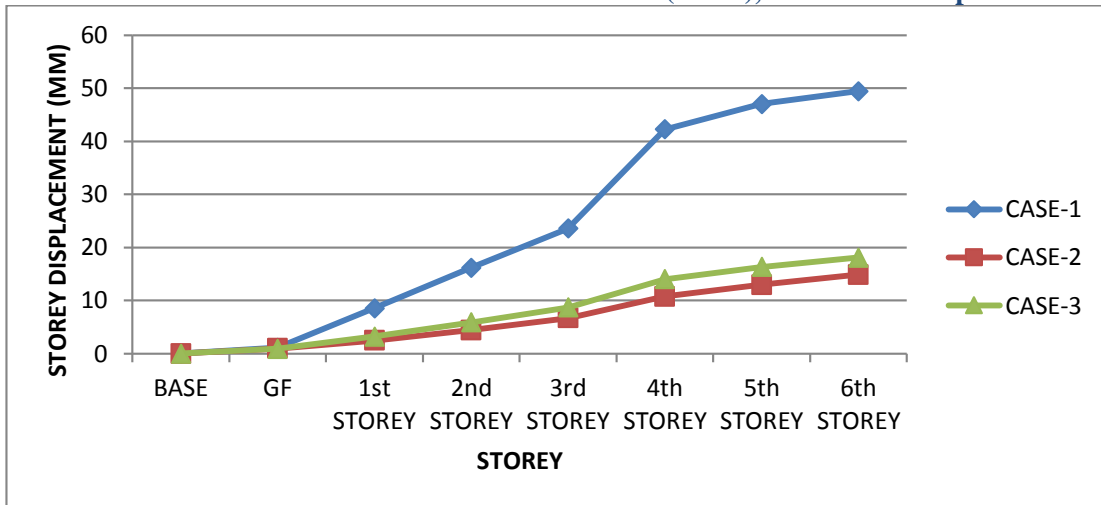


Fig. 25: Storey displacement (mm) in 4th storey soft in zone-II of Z direction

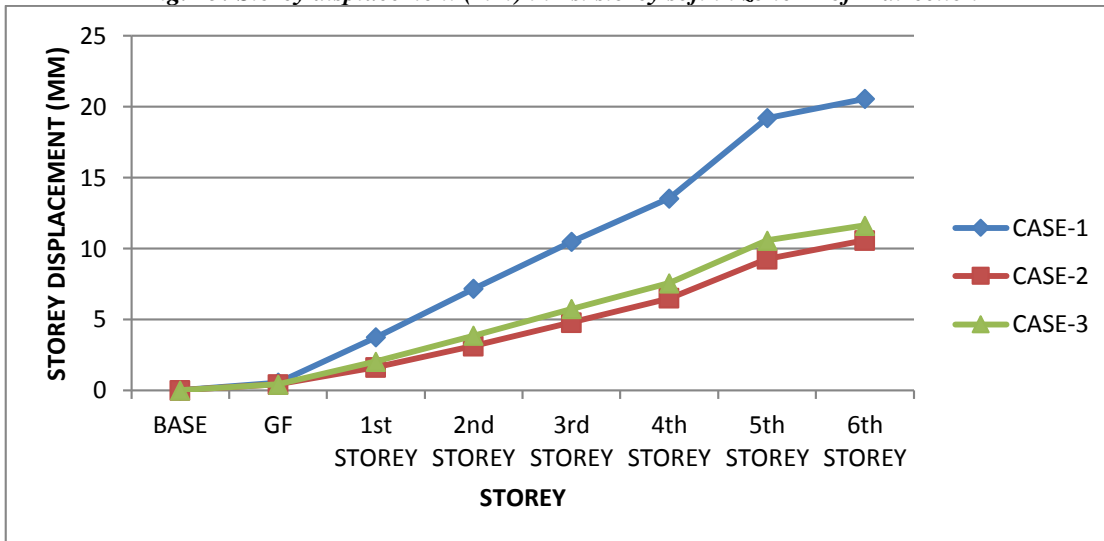


Fig. 26: Storey displacement (mm) in 5th storey soft in zone-II of X direction

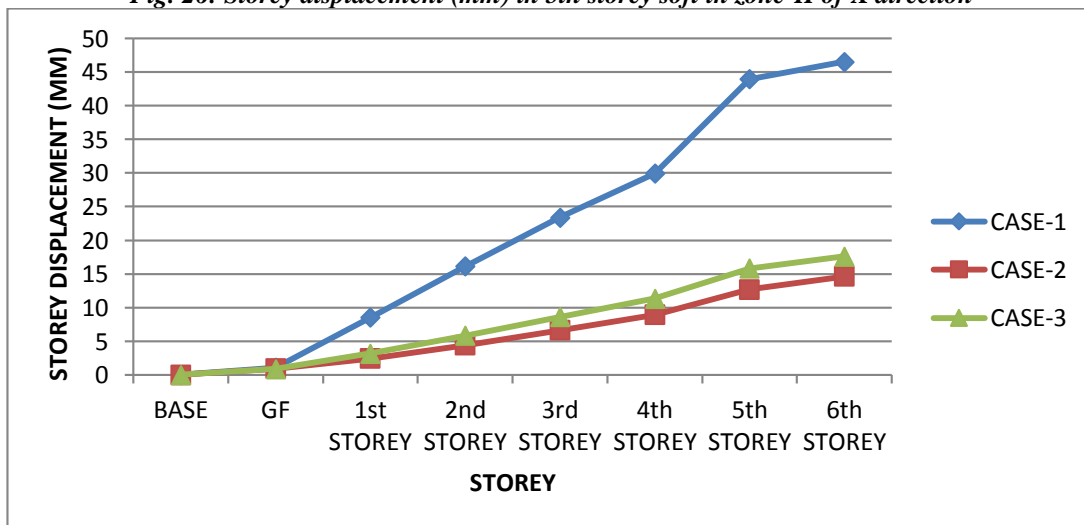


Fig. 27: Storey displacement (mm) in 5th storey soft in zone-II of Z direction

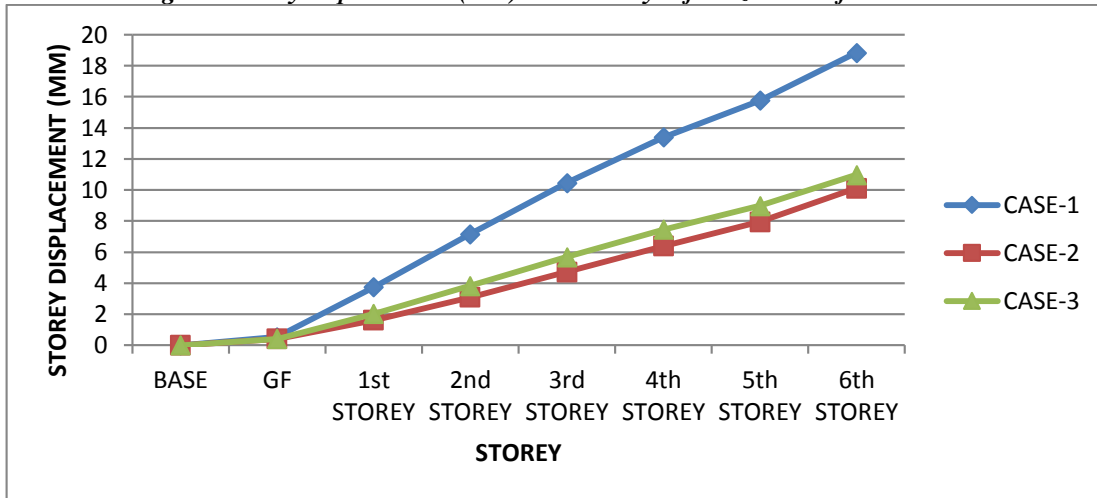


Fig. 28: Storey displacement (mm) in 6th storey soft in zone-II of X direction

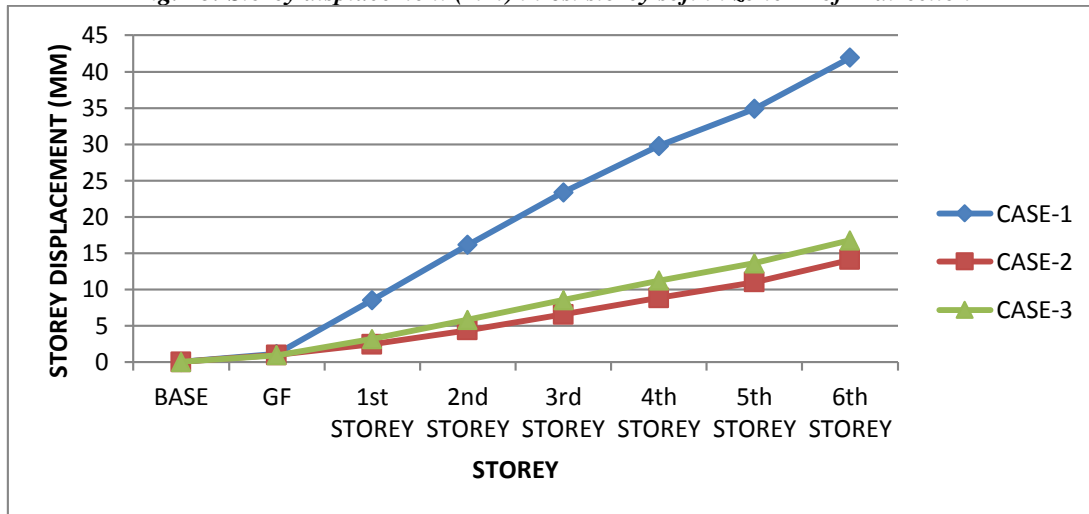


Fig. 29: Storey displacement (mm) in 6th storey soft in zone-II of Z direction

Axial Force

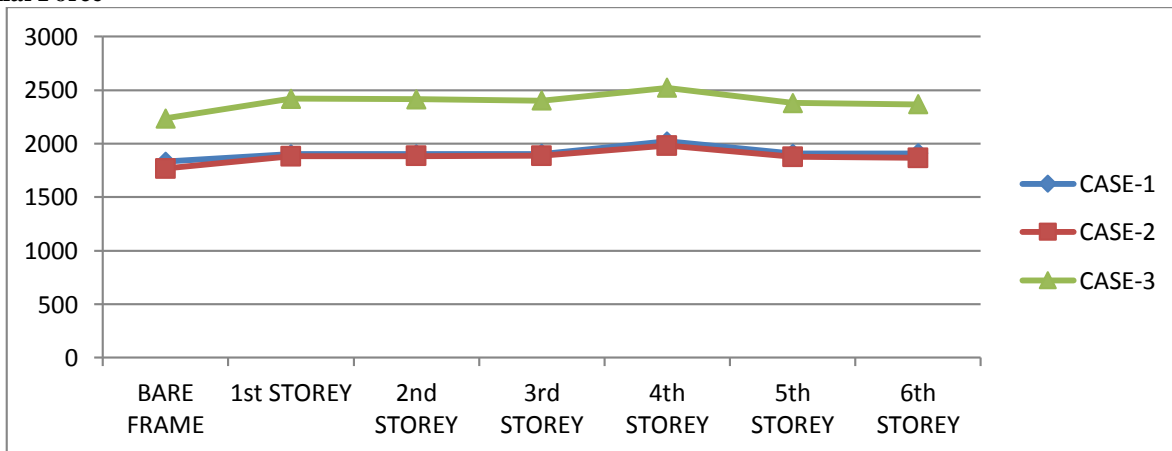


Fig. 30: Axial force (kN) in column in zone-II

4.5 Storey Drift

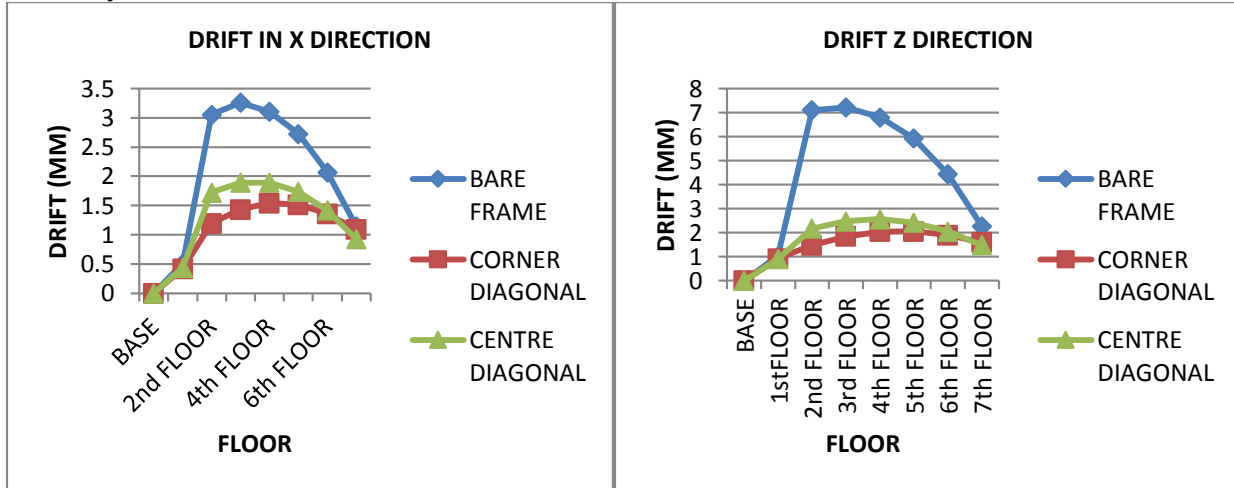


Fig. 31: Drift (mm) in without soft storey structure in zone-II

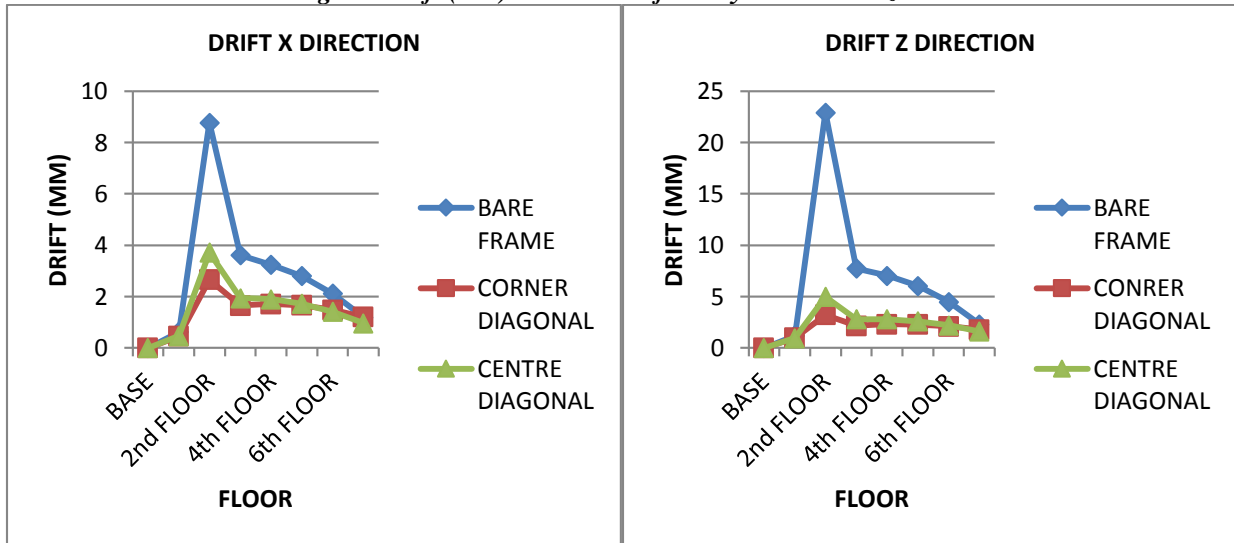


Fig. 32: Drift (mm) in 1st storey soft in zone-II

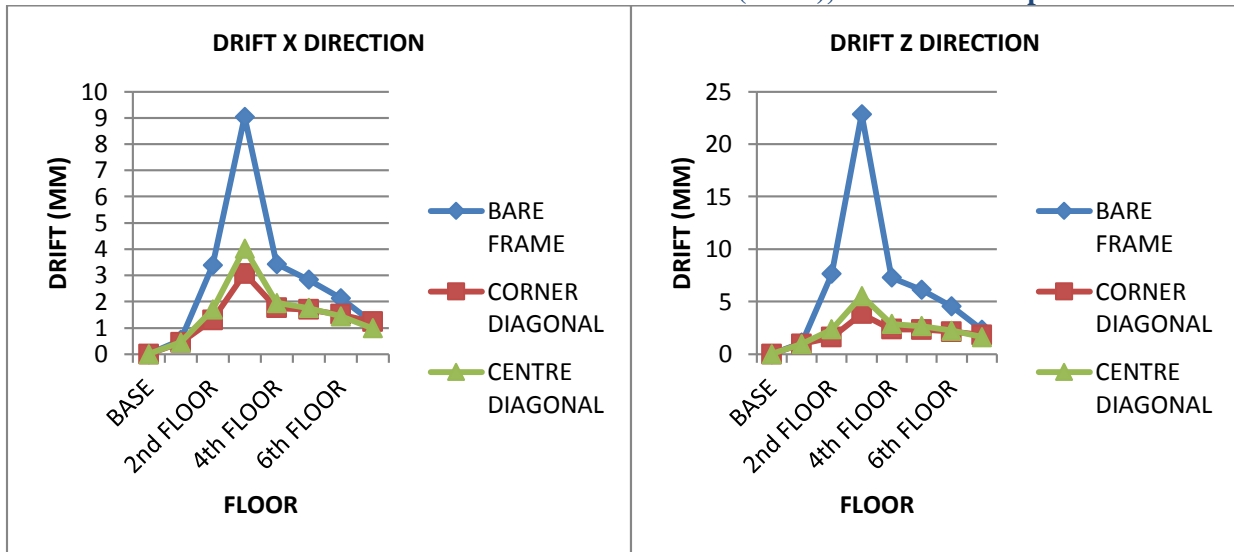


Fig. 33: Drift (mm) in 2nd storey soft in zone-II

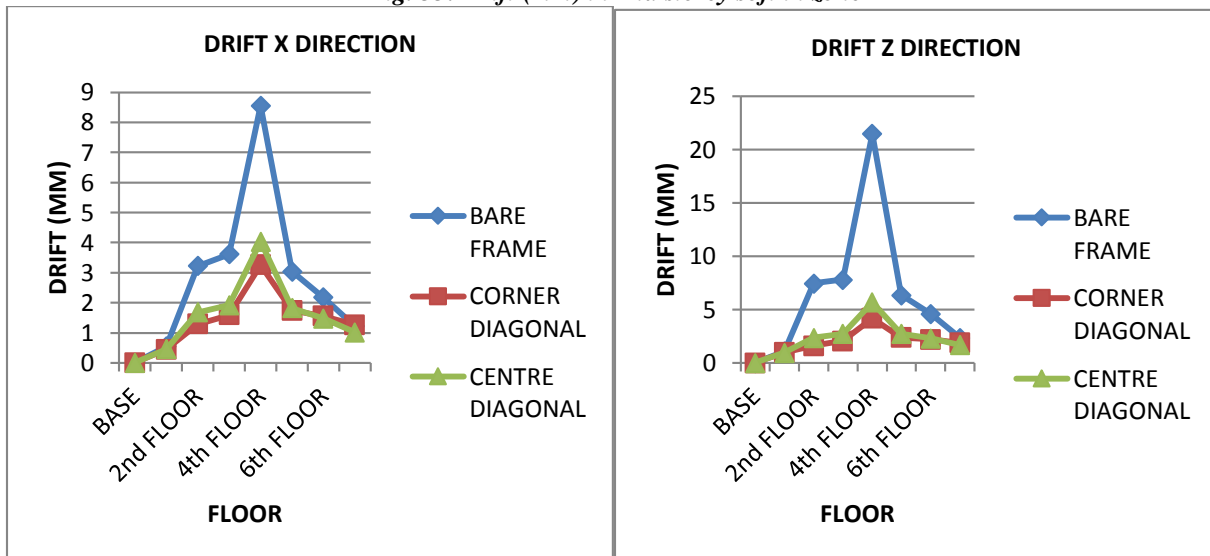


Fig. 34: Drift (mm) in 3rd storey soft in zone-II

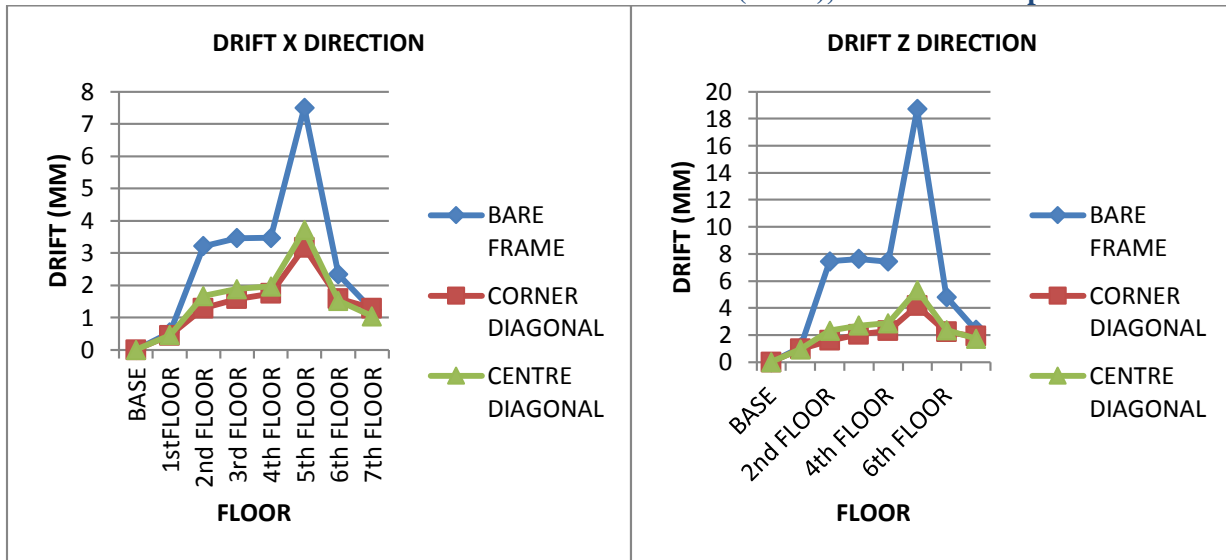


Fig. 34: Drift (mm) in 4th storey soft in zone-II

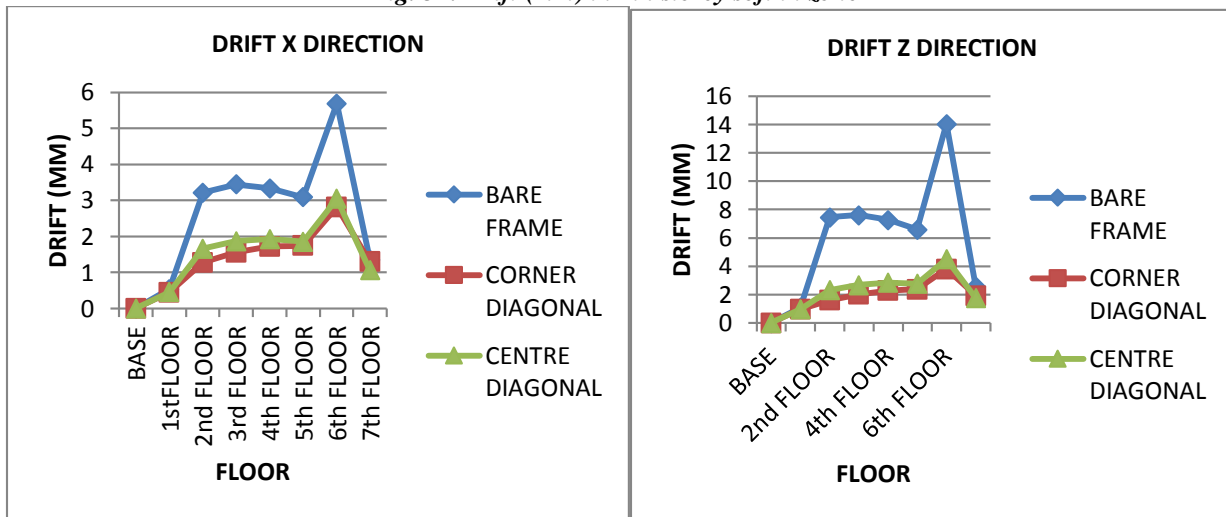


Fig. 35: Drift (mm) in 5th storey soft in zone-II

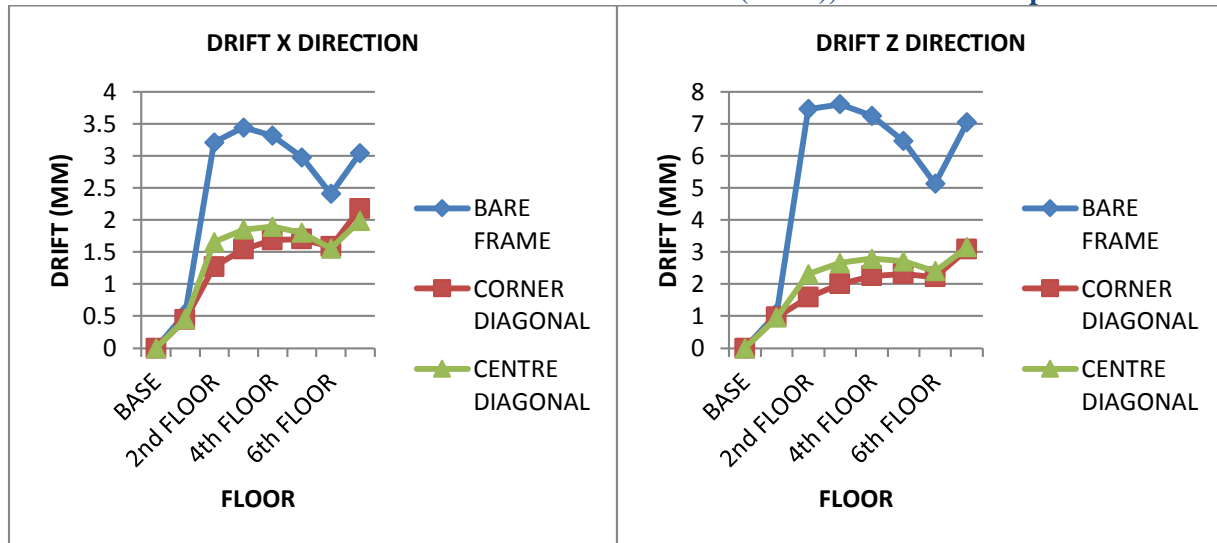


Fig. 36: Drift (mm) in 6th storey soft in zone-II

CONCLUSIONS

Following are the salient conclusions of this study-

1. Considering maximum moment, it is seen that soft storey at 4th storey is critical in both X direction and Z direction for all CASES of buildings. So it can be concluded that soft storey at fourth floor must be avoided. And maximum moment is seen in CASE-1 (bare frame without equivalent diagonal struts) and minimum is seen in CASE-2 (equivalent diagonal struts at corner) in both direction.
2. Considering shear force maximum shear force is seen in CASE-1 (bare frame without equivalent diagonal struts) and minimum is seen in CASE-2 (equivalent diagonal struts at corner) in both direction. And soft storey at 4th storey is critical in both X direction and Z direction for all CASES of buildings. So it can be concluded that soft storey at fourth floor must be avoided.
3. Considering maximum displacement, maximum displacement is seen in CASE-1 (bare frame without equivalent diagonal struts) and minimum is seen in CASE-2 (equivalent diagonal struts at corner) in both direction. In X direction CASE-2 and CASE-3 (equivalent diagonal struts at centre) is almost equal and in Z direction displacement is reduced more than half of bare frame these results can be seen in table and graph.
4. Considering maximum axial force, it seen that maximum is in CASE-3 and CASE-2, CASE-3 have almost same. And from table and graph it is observed that 4th storey is critical in all cases.
5. Considering storey displacement, maximum storey displacement is seen in CASE-1 (bare frame without equivalent diagonal struts) and minimum is seen in CASE-2 (equivalent diagonal struts at corner) in both direction. Z direction have maximum storey displacement in comparison to X direction. In 6th storey graph of is linear in all CASES.
6. Considering storey drift, maximum storey drift is seen in CASE-1 (bare frame without equivalent diagonal struts) and minimum is seen in CASE-2 (equivalent diagonal struts at corner) in both direction. While providing equivalent diagonal struts it will dynamically reduce the storey drift.

From above observation it can be concluded that considering all the parameters, 4th storey is critical in all CASES. CASE-1 (bare frame without equivalent diagonal struts) is most critical frame among them and CASE-2 (equivalent diagonal struts at corner) is efficient one. Means while providing equivalent diagonal struts at corner will reduces moment, shear force, displacement storey displacement and storey drift. Equivalent diagonal struts provide better stiffness to the building.

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