Analysis of Knee-Braced, x-braced Moment Frame for Ductility Based Seismic Design

Eshanya Tongper Nongsiej, Karthiga N. Shenbagam, A. Mohanraj, and Kartik Kapoor

Abstract Multistory structures are the type of structures which are often subjected to seismic and wind effects simultaneously. The actual strength in the plan of multistory building is the regularity in planning, the type of materials, construction techniques used during constructions. The structure is mostly constructed to have adequate horizontal solidness to oppose the lateral loads caused by the seismic action and to control the parallel float of the structures. The steel supporting framework in strengthened solid edges is suitable for preventing horizontal powers. In this paper we are preparing and analysing a G + 20 with 3 m spacing of each floors. In this structure we will distinguish exposed casing and edges having X-type bracings or knee bracings at the corners. A three dimensional structure is taken, and 20 stories is taken with story tallness of 3 m. The bars and segments are intended to withstand dead and live load only. Seismic tremor loads are taken by bracings. The bracings are given just on the fringe sections. Analysis and design has been carried out using ETABS software, and the results are discussed.

Keywords Steel frame · X bracings · Knee · Moment resisting · Seismic

1 Introduction

Braced frame is type of a structural system commonly used in structures subjected to lateral loads such as wind and seismic loadings. The members in a braced frame are generally made of structural steel, which can work effectively both in tension and compression.

E. T. Nongsiej (✉) · K. N. Shenbagam · A. Mohanraj · K. Kapoor
Tamil Nadu, Sathyamangalam, India
e-mail: eshanyatongpernongsiej.ce18@bitsathy.ac.in

A. Mohanraj
e-mail: mohanraja@bitsathy.ac.in

K. Kapoor
e-mail: kartikkapoor.ce18@bitsathy.ac.in

T. G. Sitharam et al. (eds.), *Earthquakes and Structures*, Lecture Notes in Civil Engineering 188, https://doi.org/10.1007/978-981-16-5673-6_10

Beams and columns are the structural members that are constructed to carry vertical loads, and the bracing system are the structural members which carries lateral loads. The positioning of braces is found to problematic or very difficult due to the positioning of braces and its connections in a proper way with or without openings. Buildings adopting high-tech or post-modernist styles have responded to this by expressing bracing as an internal or external design feature.

To oppose lateral earthquake loads, braces or shear dividers are usually constructed in RC and Steel structures. RC structures with steel supporting elements were generally used as a retrofitting measure to strengthen earthquake-harmed structures.

2 Literature Survey

Vishwanatha et al. [1] proposed that the seismic performance of concrete and composite buildings for different parameters of vertical irregularities in buildings and composite columns are installed in the structure to increase the strength and fire resistance of the column and also to resist lateral forces. Finally, they concluded that the maximum storey drift and displacement will increase as the vertical irregularities increases.

Jingbo et al. [2] proposed the behaviour of steel concrete composite frame structure system under seismic loads. In this study four types of columns such as composite beam concrete filled square tubular column, Equivalent stiffness RC column and other two types are analysed under response spectrum analysis. And from the analysis of those columns and frame they come to a conclusion that in composite frames, the maximum storey drift angle is reduced by 18% and in composite we can achieve greater span and height, but in RC the columns must be enlarged to meet the desired bearing capacity.

Dhruvil [3] proposed the seismic analysis of tall building having different structural systems by using response spectrum method. The tall building comprises of shear wall system and shear wall combined bracing system. Their study is mainly based on the behaviour of the shear wall system under response spectrum analysis under varying storey height. From the study they suggested that for 15 storey building shear wall was recommended and for 25 stories shear wall and bracing combined and for 35 stories shear wall is recommended.

Rahul Pandey [4] proposed the response of the RCC, steel and steel concrete composite frame under earthquake loading. Comparative analysis of all the three is done based on the material, cost benefit and behaviour. The analysis is done in SAP 2000 software, and the behaviours are studied. They found that base shear is maximum in RCC frame. Base shear is reduced by 40% for composite frame and 45% for steel frame. Reduction in cost of composite is 33% and steel is 27%. RC frame has the least value of storey drift because of its high stiffness.

Prabhu Booshan [5] proposed that the behaviour of RCC and composite structures with different and various vertical irregularities were considered, and the structures were modelled and analysed using ETABS software. On comparing the results steel concrete composite structures' performance was better than that of RC structures.

Patil et al. [6] proposed that the behaviour of RCC and composite structure which has a soft storey was analysed using response spectrum method and equivalent static method in ETABS software. Those obtained results are compared, and they came to a conclusion that the storey drift reduces what parameter in composite structures, self-weight of the composite structure reduces, bending moment and shear force in composite columns are less when compared to RC columns. And they found that composite structures are exhibiting high ductility and lateral load resisting capacity greater than RC structures.

Chandak [7] proposed that the reinforced concrete buildings in structural walls and moment resisting frames were analysed using response spectrum method with the help of SAP 2000 software. The analysis is based on Indian standard code and two other codes such as Uniform Building Code and Euro Code. The main observation of his study is to find the difference in the response of the building based on the three codes. On successful analysis he found that IS Code method gives higher values of base shear. And IS method gives maximum displacement values when compared to other two methods.

Youcef et al. [8] proposed that the Seismic Performance of RC Building Using Spectrum Response and Pushover Analysis was carried out. This investigation is based on the Euro Code. They compared the storey drift, displacement, base shear using response spectrum and push over analysis. The modelling of the eight storey structure is done using ETABS software. The analysis of absolute displacements of a building using linear response spectrum was taken into account indirectly, and the nonlinear behaviour of structural elements by introducing the behaviour factor was considered; the nonlinear static analysis using pushover procedure was also done. The results showed a large difference between the two methods explain the results in detail.

Shirule et al. [9] proposed the response spectrum analysis of asymmetrical building. This study is based on the Indian Standard code on an asymmetrical building modelled in SAP 2000. After the performance of analysis was done, it is concluded that the provision of shear wall is necessary for asymmetrical building as it helps in the prevention of collapse and damage to the structure. It also decreases the storey drift (if it increases what happens) of the structure. And they also found that the IS code gives higher value of base shear when compared with Uniform building code.

Md. Akberuddin et al. [10] analysed the structure using Pushover Analysis. This method had been utilized to obtain the deformation capability of frame by inelasticity, and it is found that irregularity in height of the structure decreases the structure's performance level. This induces a decrease in the deformation or displacement of the structure, and the bare frame without irregularity has more lateral load carrying capacity compared to bare frames with vertical irregularity (i.e., the vertical irregularity decreases the flexure and shear demand). The lateral displacement of the structure is reduced with an increase in the percentage of irregularity.

Saisaran et al. [11] proposed a study on static nonlinear method i.e. push over analysis which utilizes to evaluate the deformations of the structure to evaluate the displacement force relationship or the capacity curve for a building or structural element. The analysis includes application of horizontal loads, in a recommended pattern, to the structure incrementally. There would be a progressive change in the slant of weakling bend with increment in the horizontal relocation of the building in which part of the structures. This is because of the progressive formation of plastic hinges in beams and columns throughout the structure.

Mindaye et al. [12] proposed that the seismic response of a residential G + 10 RC frame building structure has been investigated by equivalent static analysis and response spectrum analysis, and finally it was concluded that the results obtained from response spectrum analysis resulted in a more accurate for storey drift, displacements etc. The model created was analysed for different seismic zones in accordance with the Indian standard codes of practice as per I 1893:2002. The results predicted were further studied in a detailed manner for nonlinear seismic analysis.

Srikanth et al. [13] proposed that the responses of earthquake loadings for symmetric multi-storied structure were carried out by using equivalent static and response spectrum methods. It was finally concluded that the response of the structures obtained by static method was found to be much higher than that of response spectrum analysis. Hence response spectrum analysis gives a more accurate value, and it is reliable.

Ahirwar et al. [14] evaluated seismic loads on multistory RC framed structures, they considered three, five, seven and nine storey buildings, and each were analysed using seismic coefficient method, response spectrum method and modal analysis method. Seismic responses viz. storey shear and base shear were computed for all the four buildings, and the results were compared. The following conclusions were brought up from the above study: In both versions of codes IS: 1893–1984 and IS: 1893–2002, the seismic plan approach is to plan solid and flexible structure to deal with latency powers produced by quakes. The new version of IS: 1893–2002 plainly reflects that the seismic force configuration is much lesser than what can be normal from strong ground shaking. Seismic forces obtained from IS: 1893–2002 are relatively higher than that forces acquired by IS: 1893–1984. As per, IS: 1893–1984, when compared to response spectrum method and modal analysis method, the base shear value of seismic coefficient method would be higher. Modal analysis method gives higher values of lateral forces for upper storey.

Gottala et al. [15] proposed a similar investigation of static and dynamic seismic examination of a multi-story building that was done on a multi-storied encircled structure of nine storey. Direct seismic examination was completed for the working by seismic coefficient method and response spectrum method using STAAD-Pro as per 1893–2002-Part-1. A detailed examination was completed between the static and dynamic investigation, and the outcomes of the analysis, bending moment, nodal displacements and mode shapes were observed for beams and columns.

3 Methodology

The methodology includes the following:

1. Structure with a steel building of 20 storey's with its various structural and construction techniques. Its analysis methods and deign aspects.
2. Structure with a steel building of 20 storey's having knee bracings with its various structural and construction techniques. Its analysis methods and deign aspects.
3. Structure with a steel building of 20 storey's having X bracings with its various structural and construction techniques. Its analysis methods and deign aspects.

The analysis and the design of 20 storey's steel building and various types of bracings was done according to IS codal provisions for steel and concrete sections.

4 Modelling

For the analysis and design of the structure, ETABS software is used and the deign results and the various outputs are explained in detail.

The details of the structure are listed in Table 1.

Table 1 Structural details

Description	Values
Number of storey	20
Number of bays in X direction	9
Number of bays in Z direction	7
Storey height	3.5
X Direction width of bay	4
Z Direction width of bay	4.5
Grade of concrete	M25
Grade of steel	FE415
Live load	2 kN/m^2
Zone	V
Response reduction	5
Importance factor	1.5
Thickness of slab	110 mm
Steel bracing	As per IS 800 codal provisions-ISMB
Knee bracings	As per IS 800 codal provisions-ISMB

Earthquake loads are determined as per IS 1893:2016. Design of steel and concrete sections was done according to the limit state design, and the load combinations are considered which are determined with consideration to IS 800:2007 from Table 2.

5 Results

See Table 2, Figs. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10.

Table 2 Results of the structure with its performance level

Sl. no	Model type	V	D	Sa	Sd
1	Plane frame	521.54	0.128	0.165	0.997
2	X Bracings	2034.5	0.018	0.790	0.014
3	Knee Bracings	2027.4	0.024	0.796	0.019

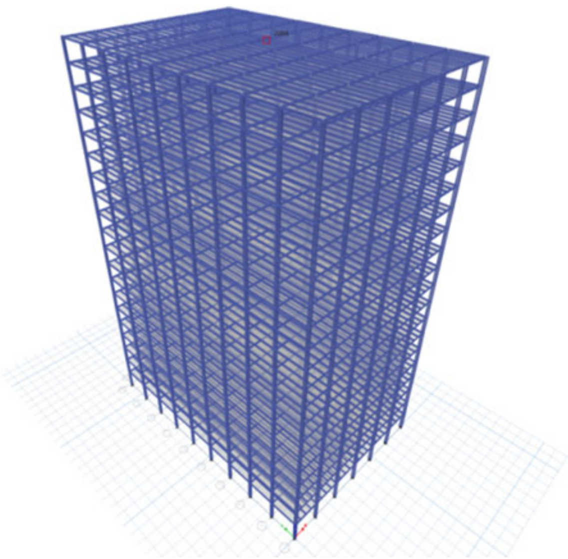

Fig. 1 Frame with loadings

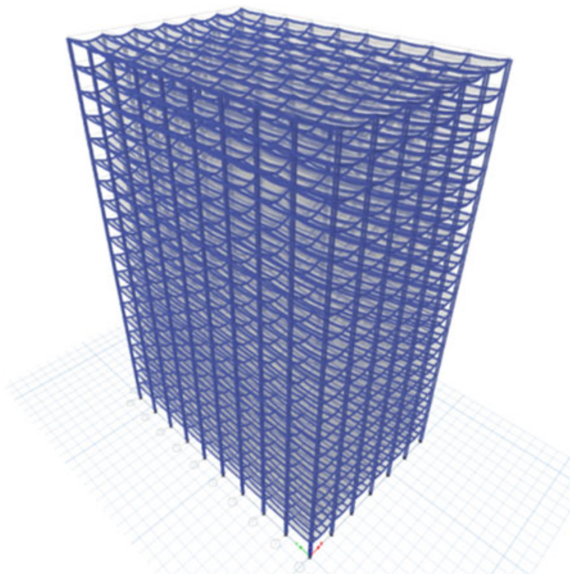

Fig. 2 Deflected shape of the building after analysis

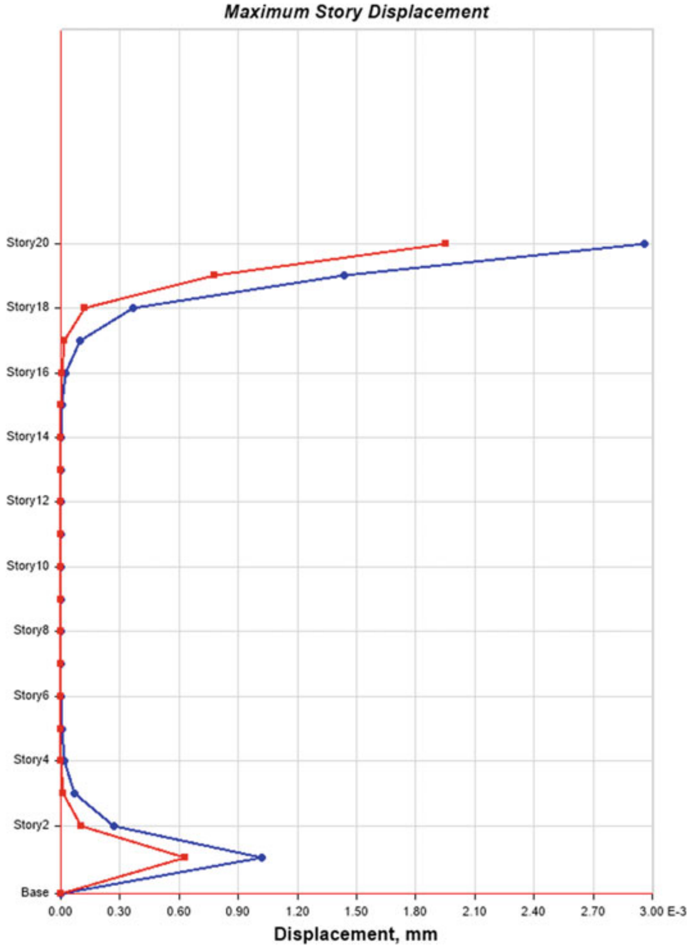

Fig. 3 Maximum storey displacement without bracings

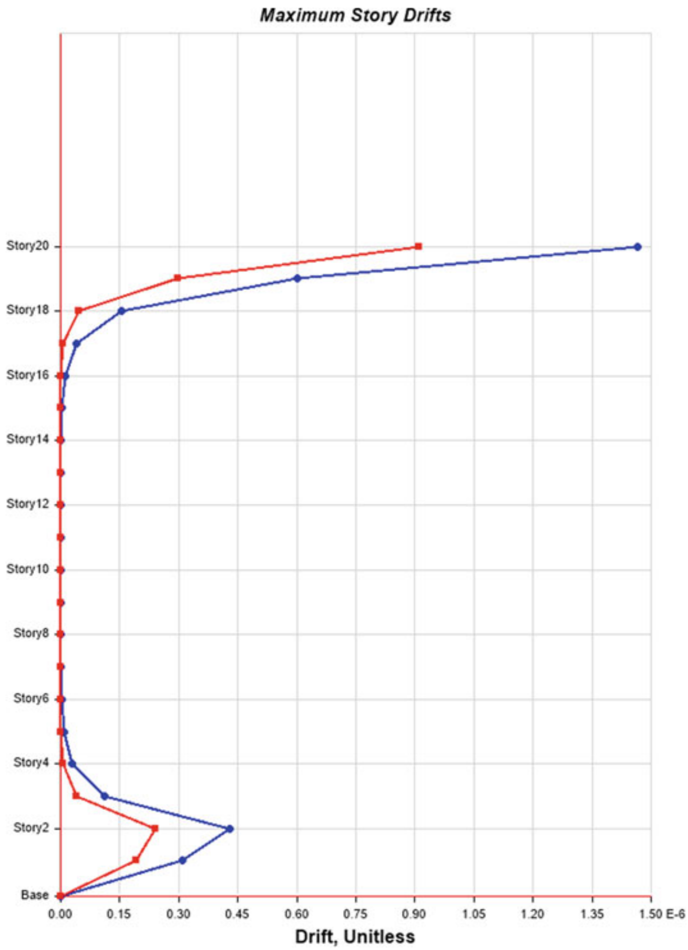

Fig. 4 Maximum storey drift without bracings

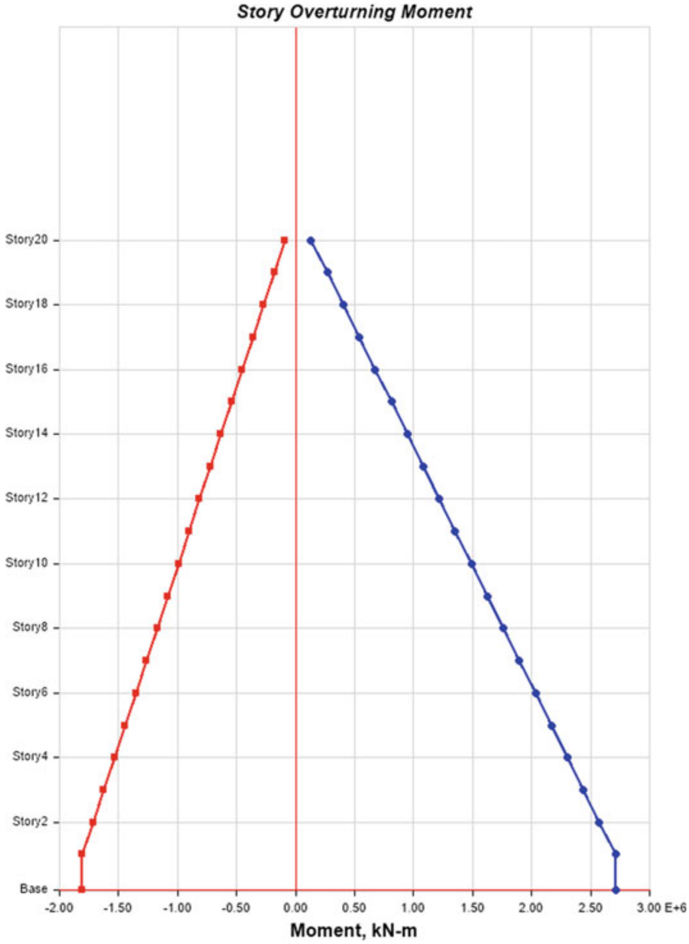

Fig. 5 Storey overturning momnet

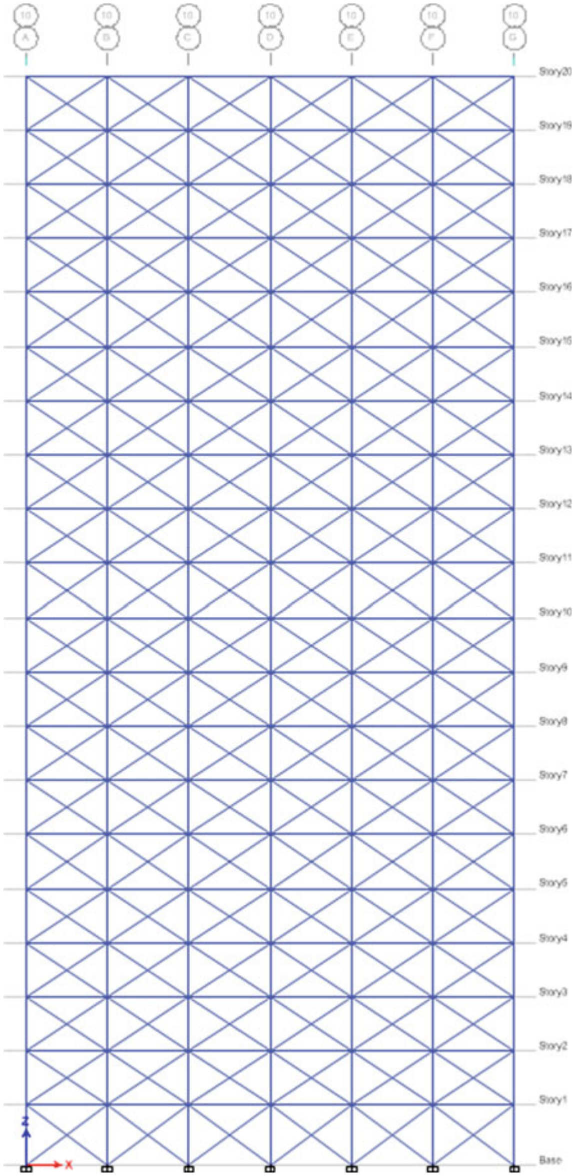

Fig. 6 Storey overturning momnet

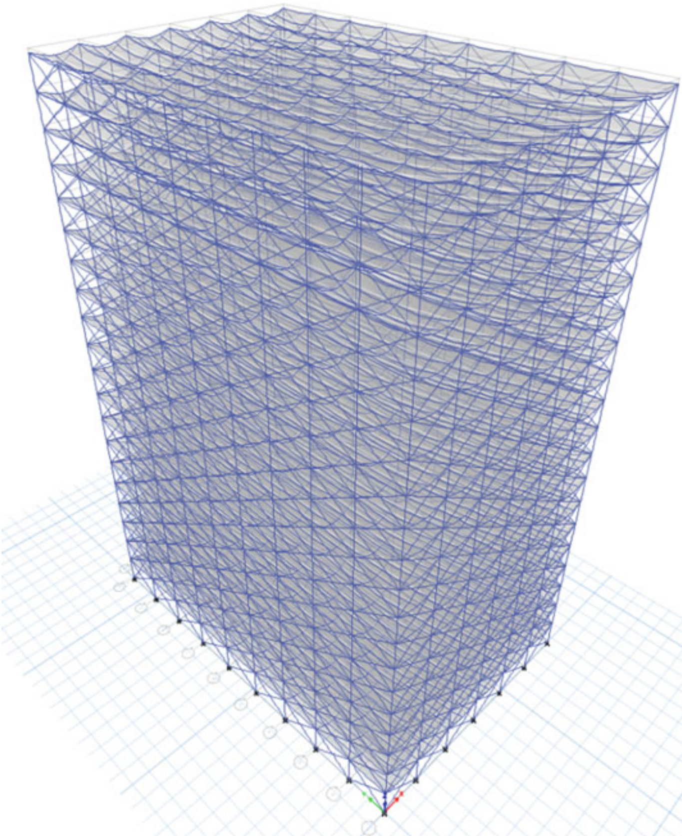

Fig. 7 Frame with loadings with X bracings

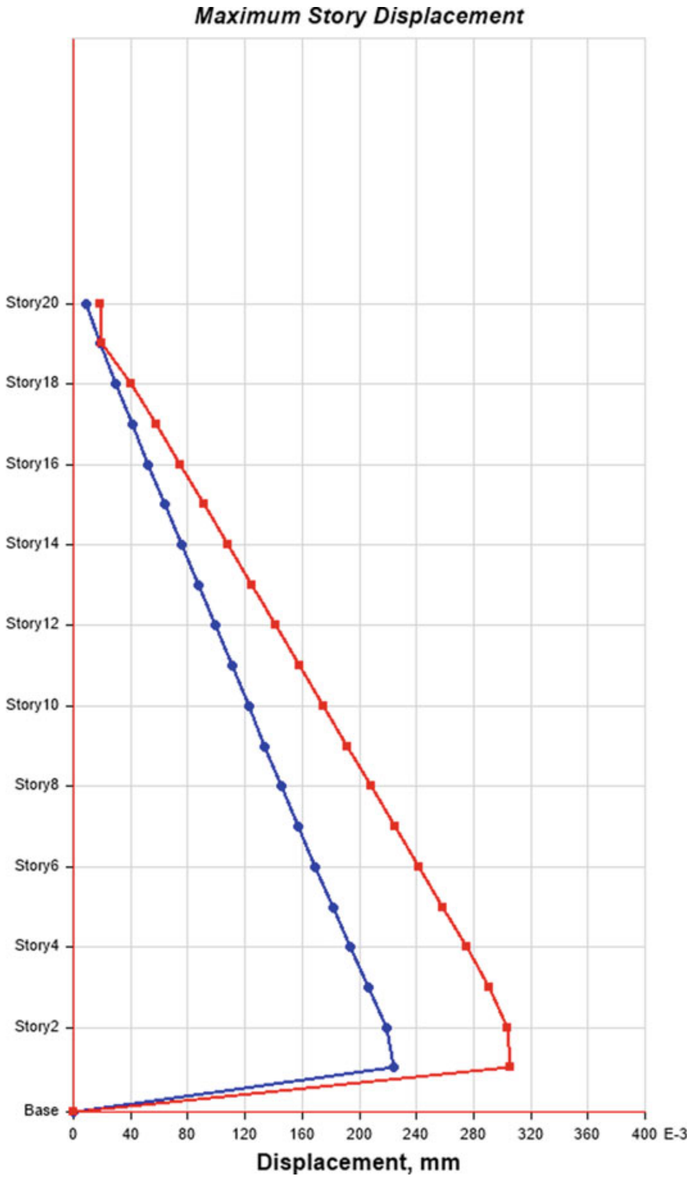

Fig. 8 Deflected shape of the building after analysis with X bracings

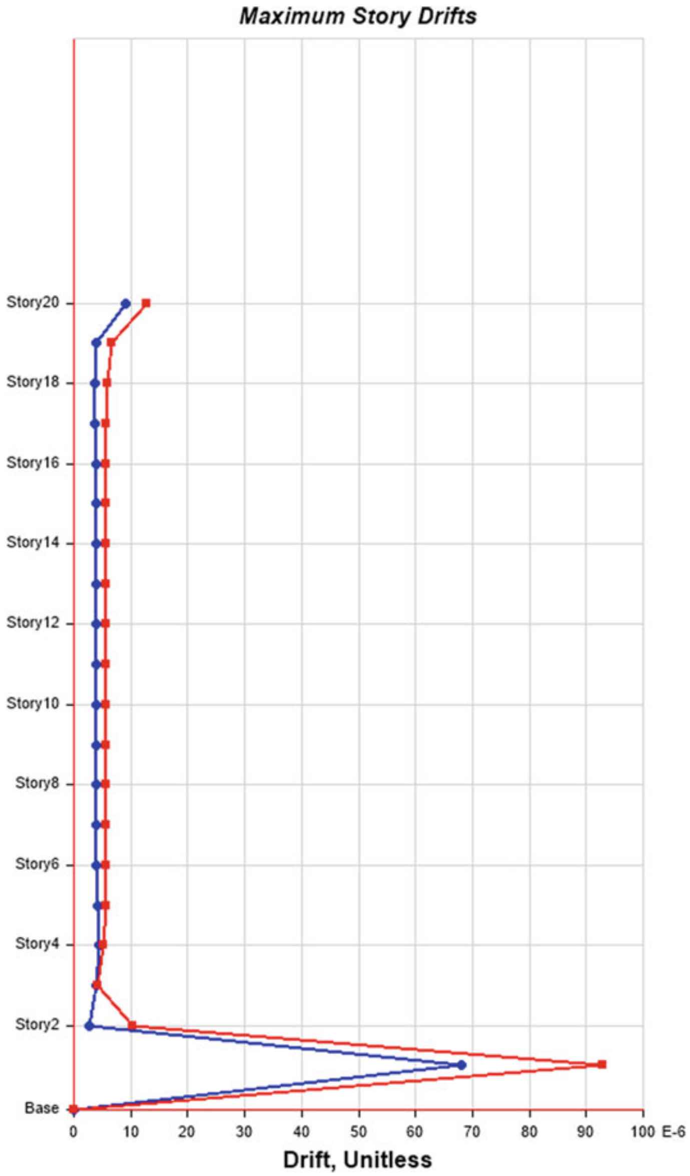

Fig. 9 Maximum storey displacement with X bracings

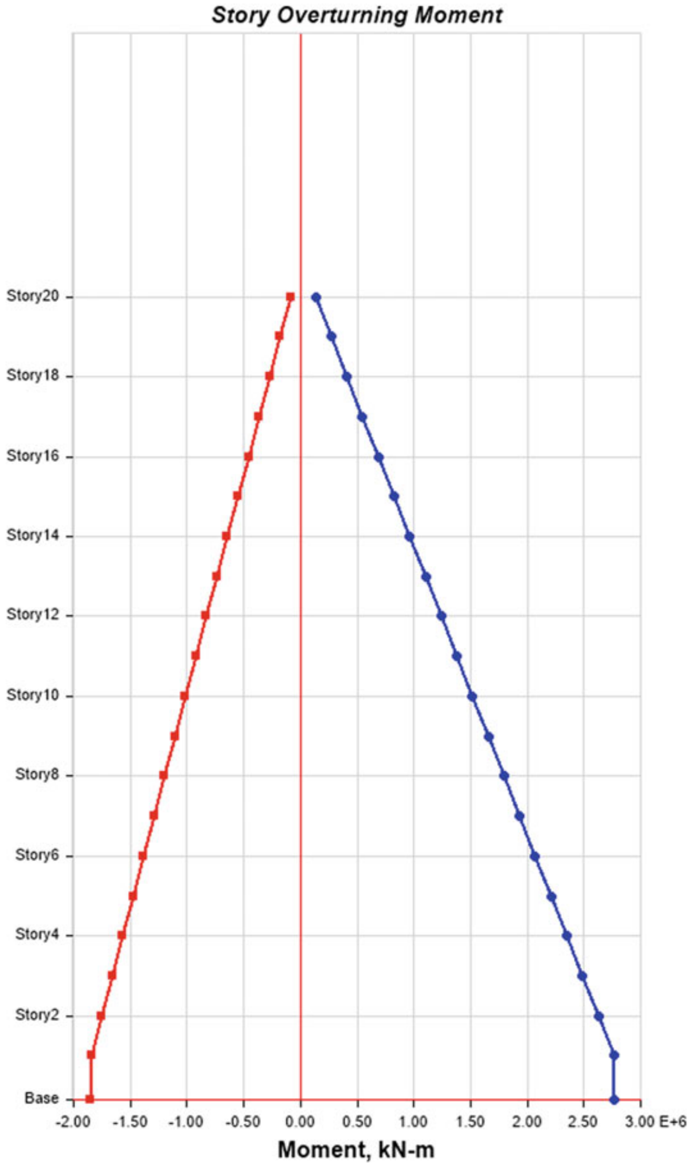

Fig. 10 Maximum storey drift with X bracings

6 Conclusions

The structural system with two types of bracing system for a twenty storey building has been analysed and designed.

And the conclusions of the research have been given below.

1. The drift in the storey without any bracing is nearly the same as specified in the IS 1893 codal provisions. With the use fob arcing systems out of X and knee bracing, X bracing is found to be more effective than knee bracing as there is significant reduction in the global lateral displacement in both X and Y directions.
2. After determining the performance of the structure with X and knee bracing, it was found that knee bracing is found economical as the overall capacity gets increased when compared to X bracing.

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