DEPT. CIVIL AND ENVIRONMENTAL ENGINEERING, IIT TIRUPATI

SUMMER INTERNSHIP REPORT

DESIGN PROCEDURE TO ELIMINATE SOFT STORY EFFECTS IN OPEN GROUND STORY BUILDINGS.

SUPERVISOR

DR. ROMANBABU OINAM

Assistant Professor

Dept. Civil and Environment Engineering

SUBMITTED BY

BOMMIN BAM (CE18B030)

10-10-2021

ACKNOWLEDGEMENT

I sincerely want to offer my heartful gratitude towards my internship mentor; Prof. Dr. Romanbabu Oinam, for giving me an opportunity to work on the subject and for guiding me throughout the internship process.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The paper talks about the mechanism, the impacts of soft story in structures in metropolitan cities and others during seismic exercises. A typical residential building of 'G+4' floors with soft ground floor, is seismically assessed using the ETABS software. Response spectrum analysis method is opted for analysing seismic activities on the building, in ETABS. For the purpose of determining seismic forces and parameters, **IS 1893:2016** was used. Results of the analysis is shown for critical parameters. Different techniques for the reduction of soft story effect on the building is discussed. The building implemented with the soft story reduction technique is also analysed using the software. Comparison between the results of analysis for building with soft story and building with modifiers for reduction of the former. Conclusion and remarks are evaluated.

INTRODUCTION

Soft first story is a commonplace component in the cutting-edge multi-story developments in metropolitan India. However multi-storeyed structures with delicate story floor are innately helpless against breakdown because of seismic tremor, their development is as yet far reaching in the non-industrial nation like India. Utilitarian and Social need to give vehicle parking spot at ground level and for workplaces, open stories at various degree of construction out of sight the notice against such structures from designing local area. Therefore, retrofitting in those structures is a must to avoid disintegration of structure during earthquake. Design procedure to mitigate such effect have been discussed in the study.

SOFT STORY MECHANISM

A soft story building is a multi-story working in which at least one stories have windows, wide entryways, huge unhindered business spaces or different openings in places where a shear divider would typically be needed for solidness as an issue of designing plan for seismic tremor and others. A typical soft story building is a high rise of at least three stories situated over a ground level with huge openings, for example, a parking structure or series of retail organizations with huge windows and structures developed on the slanting grounds, for the most part in the hilly regions. Soft story may also exist in the intermediate floors, floors which are soft due to structural designs.

The Indian seismic code IS 1893 (Part1): 2016 classifies the structures have a soft story if that level is under 70% as firm as the floor promptly above it, or under 80% as hardened as the average of the firmness of the three stories above it.

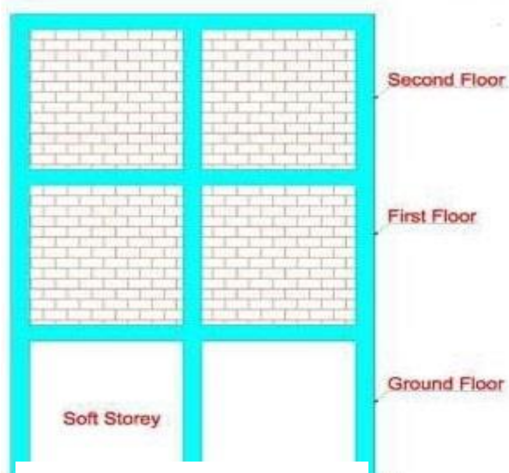


Fig.1. A basic soft story

Soft story structures are defenceless against breakdown in a moderate to extreme tremor in a phenomenon known as soft story breakdown. The insufficiently propped level is generally less impervious to lateral seismic tremor movement than the encompassing floors, so a disproportionate amount of the building's overall side-to-side drift is focused on that floor. In this way, the floor turns into a flimsy spot that is less ready to withstand the pressure due to which the structure may suffer damage or complete failure, which in turn results in the collapse of the entire building.

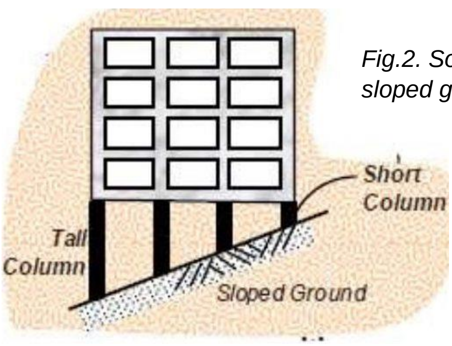


Fig.2. Soft story building in a sloped ground.

Fig.3. An example of a soft story building.

SOFT STORY

EFFECT IN OPEN GROUND FLOOR BUILDINGS

1. <u>OPEN GROUND FLOOR BUILDINGS</u>

The soft level or floor in the soft story buildings, accounts to be a weak element in the perspective of seismic forces. During an earthquake motion, the soft story behaviour is based on the criteria that the ground motion will look for all possible weakness in the structure. This weakness may be a sharp variation in the stiffness, ductility or in the strength parameters. These variations result in the poor distribution of masses throughout the floor. With the variation of lateral stiffness in vertical direction, the building is more susceptible to structural damages.

The soft story configuration is possible in by different arrangement in the building. It is illustrated in figure-4. One such arrangement is the combination of open ground floor and the masonry fill at other top floors. This arrangement is shown in figure 4(a). The presence of walls in upper stories makes them much stiffer compared to the bottom stories. This makes the upper stories to behave like a single block. Another arrangement is the provision of longer columns at the bottom floor and another with smaller ones, as shown in figure 4(b). Figure 4(c) shows a soft story arrangement where the columns are arranged in a discontinuous manner.

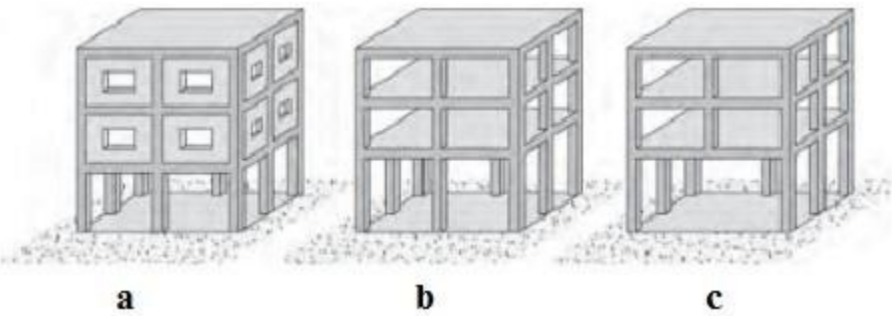


Fig.4.

- **<u>SEISMIC VULNERABILITY OF COLUMNS OF RC FRAMED BUILINGS WITH SOFT GROUND FLOOR</u>**

Earthquake produces low –high waves which vibrate the base of structure in various manners and directions, so that lateral force is developed on structure. In soft story buildings, the stiffness of the lateral load resisting systems at the soft stories is quite less than the stories above or below. Due to which there will be a displacement between the stories known as inter story drift. if abnormal inter-story drifts between adjacent stories occur, the lateral forces cannot be well distributed along the height of the structure. This situation causes the lateral forces to concentrate on the storey (or stories) having large displacement(s). Such building act as an Inverted Pendulum which swing back and forth producing high stresses in columns and if columns are incapable of taking these stresses or do not possess enough ductility,they could get severely damaged and which can also lead to collapse of the building.

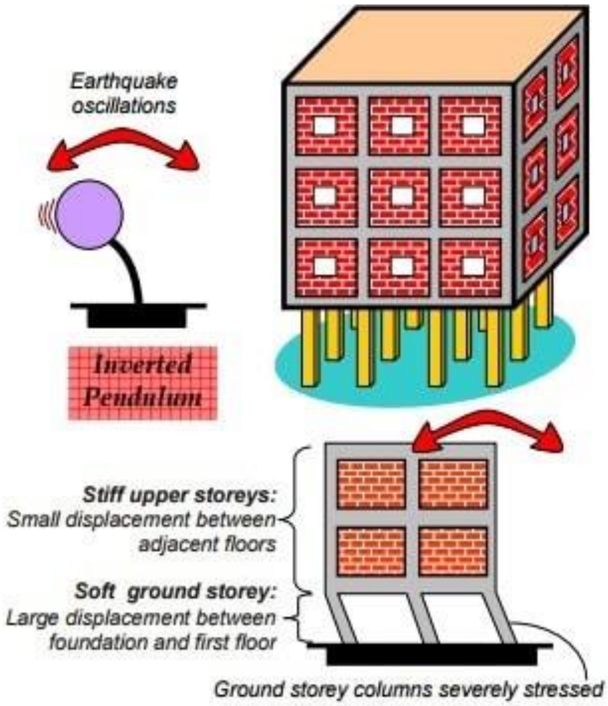


Fig.5. Effect of Earthquake on soft story buildings.

- **METHOD OF SEISMIC ANALYSIS**

RESPONSE SPECTRUM ANALYSIS:

Earthquake response spectrum is the most popular tool in the seismic analysis of structures. There are computational advantages in using the response spectrum method of seismic analysis for prediction of displacements and member forces in structural systems. The method involves the calculation of only the maximum values of the displacements and member forces in each mode of vibration using smooth design spectra that are the average of several earthquake motions. Response spectra are curves plotted between maximum response of SDOF system subjected to specified earthquake ground motion and its time period (or frequency). Response spectrum can be interpreted as the locus of maximum response of a SDOF system for given damping ratio. Response spectra thus helps in obtaining the peak structural responses under linear range, which can be used for obtaining lateral forces developed in structure due to earthquake thus facilitates in earthquake-resistant design of structures.

Usually, response of a SDOF system is determined by time domain or frequency domain analysis, and for a given time period of system, maximum response is picked. This process is continued for all range of possible time periods of SDOF system. Final plot with system time period on x-axis and response quantity on y-axis is the required response spectra pertaining to specified damping ratio and input ground motion. Same process is carried out with different damping ratios to obtain overall response spectra.

- **SEISMIC ANALYSIS OF OPEN GROUND FLOOR BUILDINGS USING ETABS SOFTWARE**

SEISMIC PROPERTIES

Seismic zone	V
Seismic intensity	Very severe
Zone factor	0.36
Soil type	Medium
Response reduction factor	5
Importance factor	1
Damping ratio	5%
Reduction percentage for live load	25%

GENERAL PROPERTIES

Type of structure	G+4 RC Framed structure
Moment resisting frame	SMRF
Plan dimension (metre)	20×15
Building type	Residential
No. Of bay in x & y direction	4×3
Width of bay in x & y direction (metre)	5
Height of each floor (metre)	3

MEMBER PROPERTIES

Size of column	(310×450) mm
Size of beam	(240×375) mm
Thickness of slab	127 mm
Thickness of shear wall	254 mm
Bracing section	ISLB600

MATERIALS PROPERTY

Grade of concrete	M20, M25
Grade of steel	HYSD415, HYSD500
LIVE LOAD INTENSITY	
Slab	2 KN/m^3
Floor finish	1 KN/m^3
INDIAN STANDARD CODES	
IS 1893:2016	Seismic analysis
IS 456:2000, IS 875:1987, IS 800:2007	Dimensions and loads for RC structure and rebars

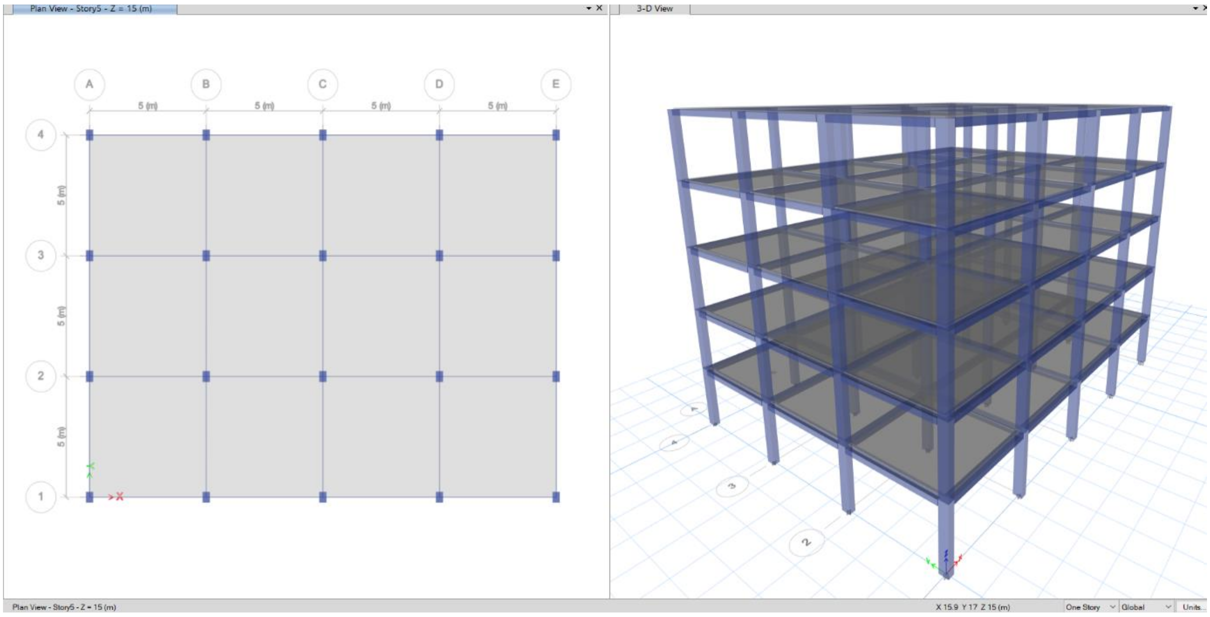


Fig.6. MODEL STRUCTURE WITH DIMENSIONS.

The followings are the parameters that are critical for seismic analysis of the soft story buildings:

a) ***Storey displacement:*** For seismic design it is important to estimate, maximum lateral displacement with respect to the base or foundation of the structures due to severe earthquake for several reasons. Storey displacement is the absolute value of displacement of a storey with respect to ground, under the action of lateral forces.

b) ***Inter storey drift:*** It is the difference between the roof-floor or floor-floor displacements of any given storey as the building sways during the earthquake, normalized by the storey height.

c) ***Storey stiffness*****:** It refers to the rigidity of a structural element. This means the extent to which the element is able to resist deformation or deflection under the action of applied force.

d) ***Base shear:*** It is an estimate of the maximum expected lateral forces that will occur due to seismic ground motion at the base of structure.

RESULTS

1. Maximum story displacement.

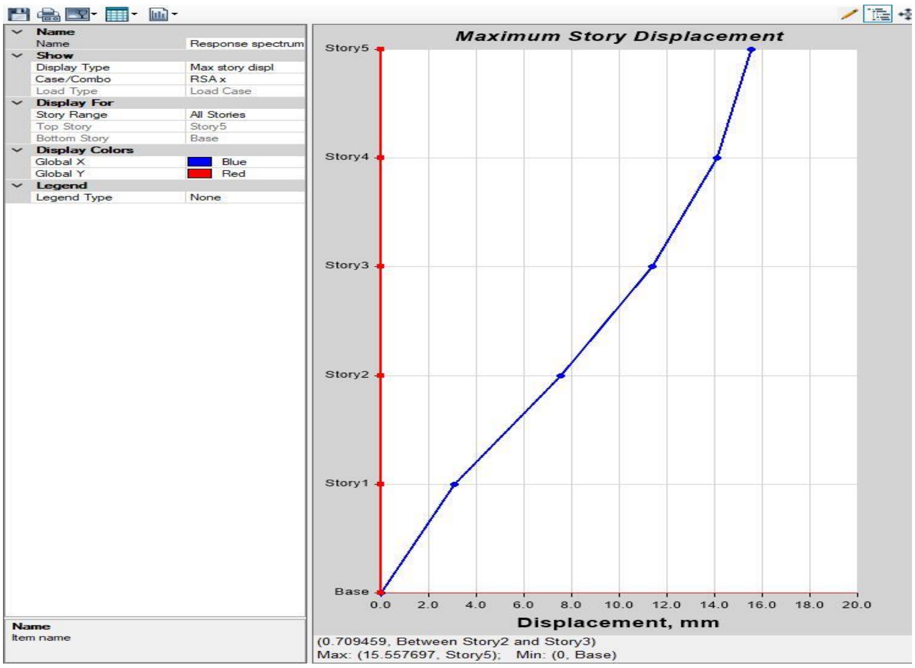


Fig.6.A

2. Maximum story drift.

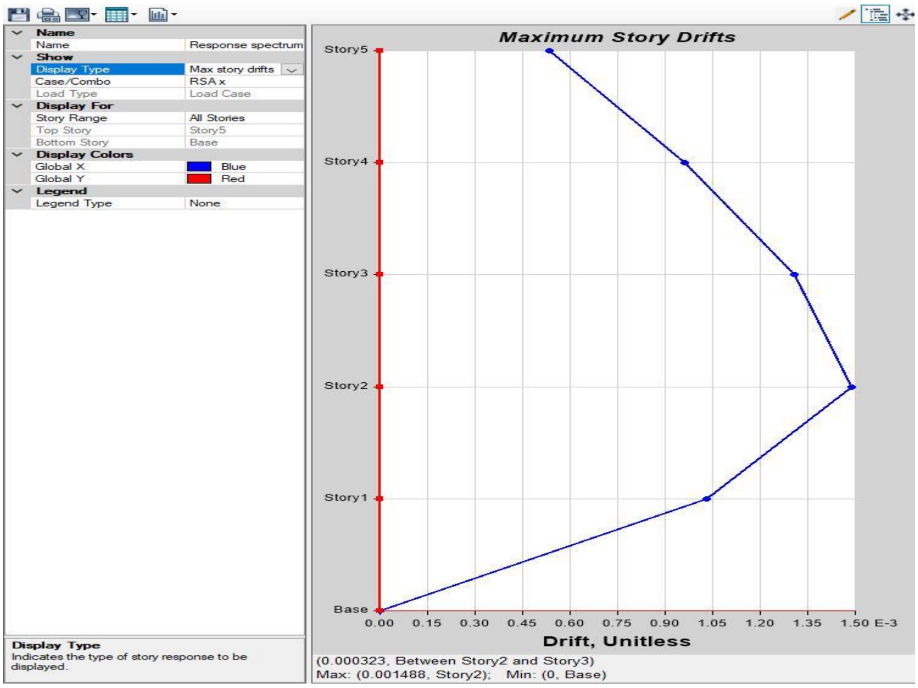


Fig.6.B

3. Story shear.

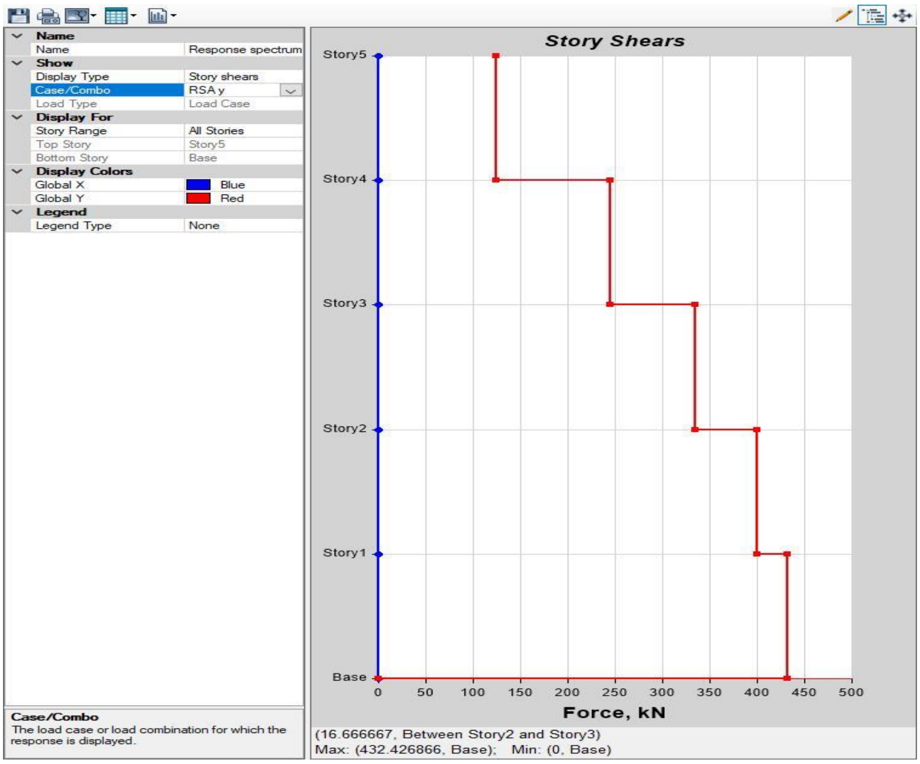


Fig.6.C

4. Story stiffness.

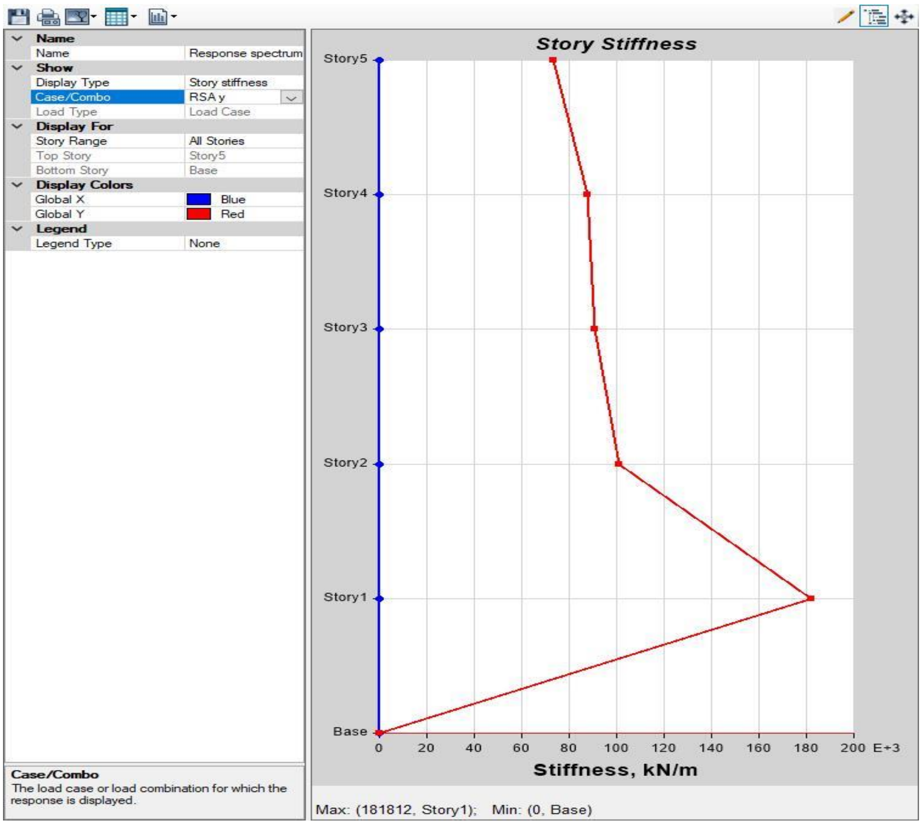

Name
Name
Response spectrum
Show
Display Type
Story stiffness
Case/Combo
RSA y
Load Type
Load Case
Display For
Story Range
All Stories
Top Story
Story5
Bottom Story
Base
Display Colors
Global X
Blue
Global Y
Red
Legend
Legend Type
None
Case/Combo
The load case or load combination for which the response is displayed.
Story Stiffness
Story5
Story4
Story3
Story2
Story1
Base
0 20 40 60 80 100 120 140 160 180 200 E+3
Stiffness, kN/m
Max: (181812, Story1); Min: (0, Base)

Fig.6.D

METHODS FOR MITIGATING SOFT STORY EFFECTS

1. **Shear walls**

   Soft story effects on the buildings can be minimized by providing shear walls along the height of the building, from the ground floor till the top. The arrangement and position of the shear walls are done according to the aesthetic preference of the owner/constructor. Shear walls provide better transmission of lateral loads to the vertical frame sections, which in turn increases the stiffness and rigidity of the building. With the provision of shear walls, there is a decrease in maximum story displacement and lesser story drifts during seismic tremors. The results are shown below. Generally, they are positioned at the ends of the building with no openings, around lift shafts and stair wells. In the paper, the shear walls are placed at the centre of each half of the building. But this is rarely practical as it occupies a lot of space. Therefore, the positioning is done for assessment purposes only.

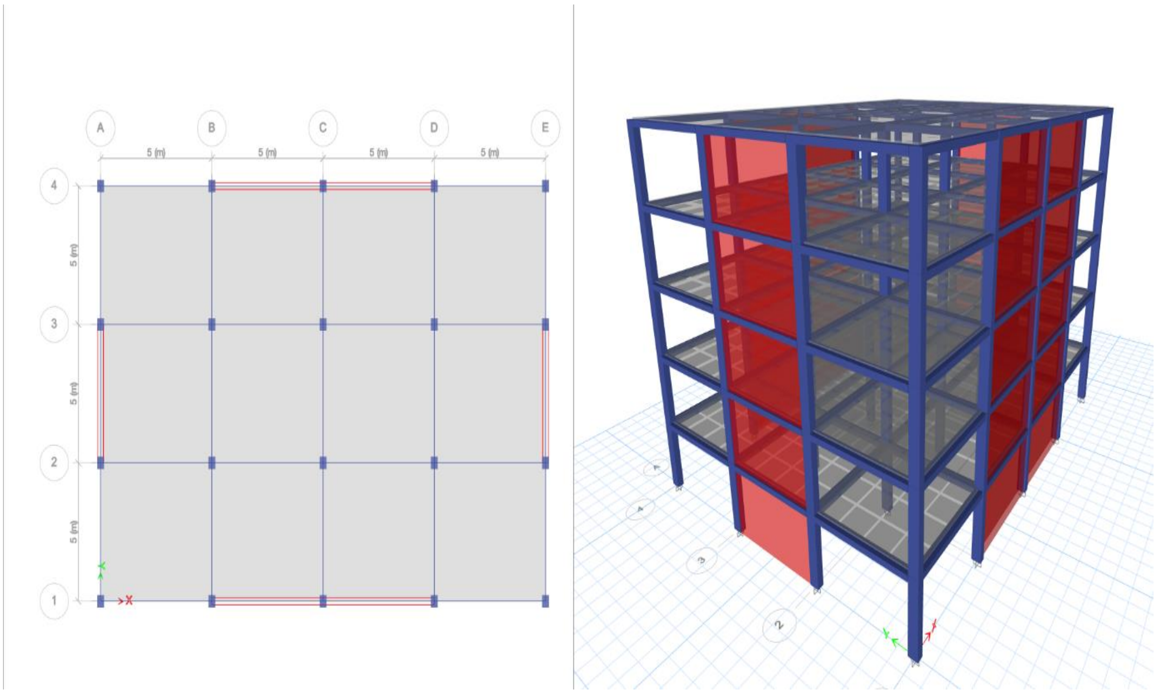


Fig.7. Model with shear walls

a. Maximum story displacement

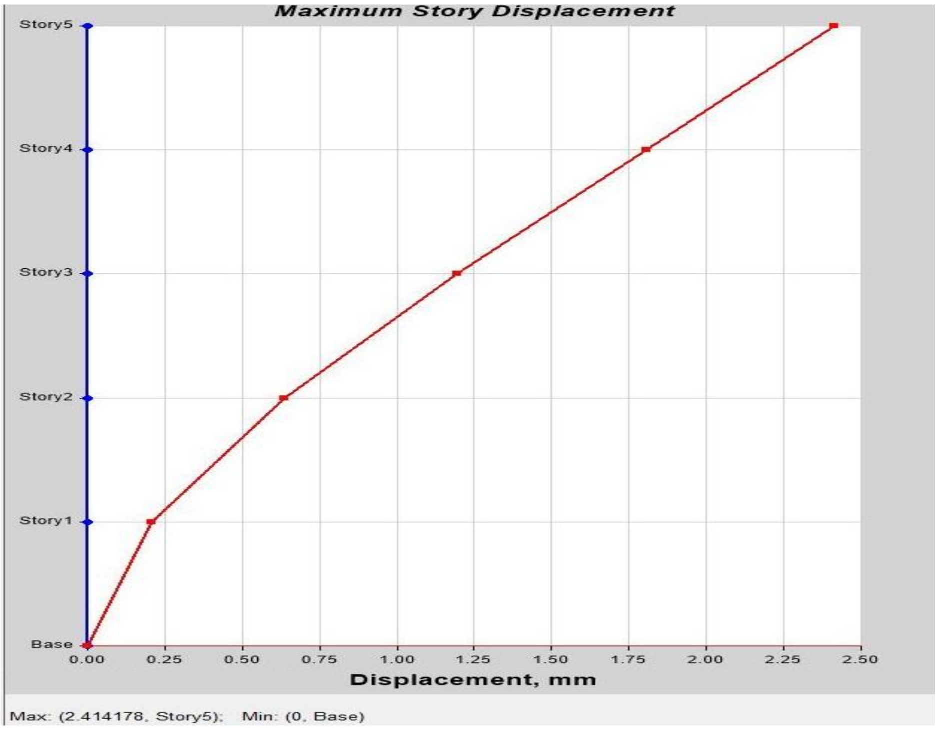


Fig.7.A

b. Maximum Story drift

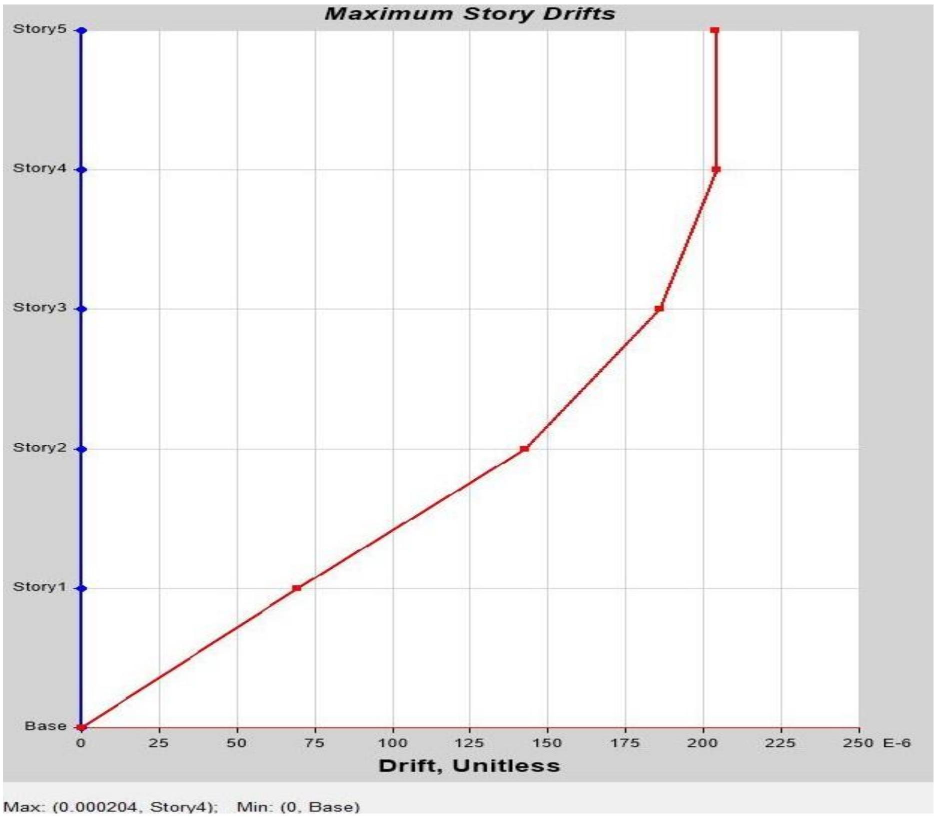


Fig.7.B

c. Story shear

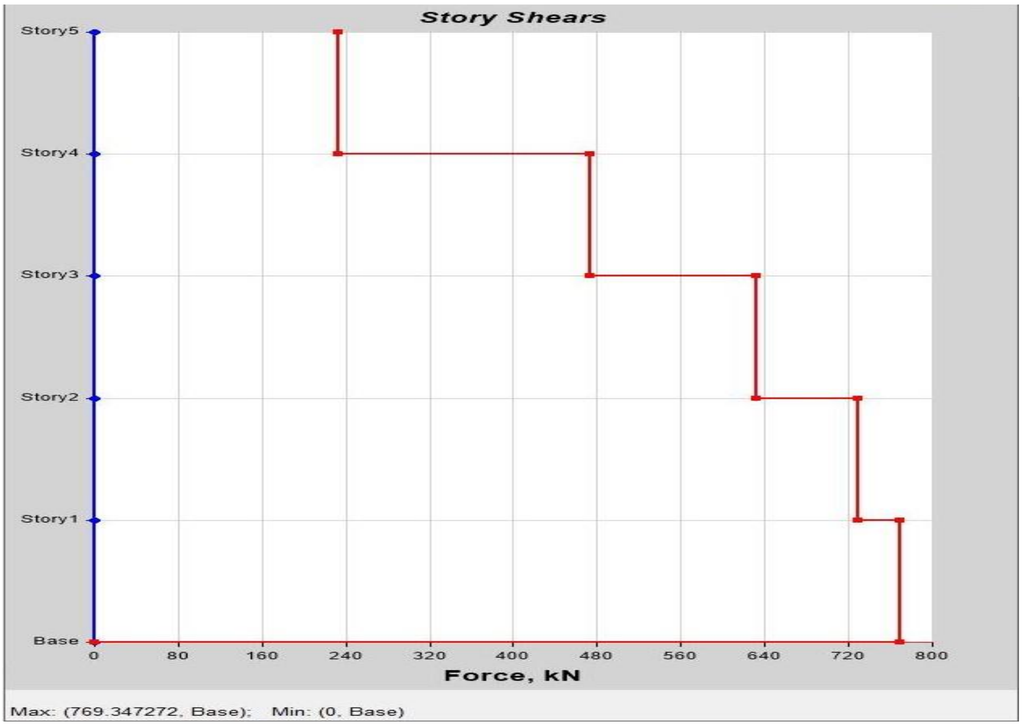


Fig.7.C

d. Story stiffness

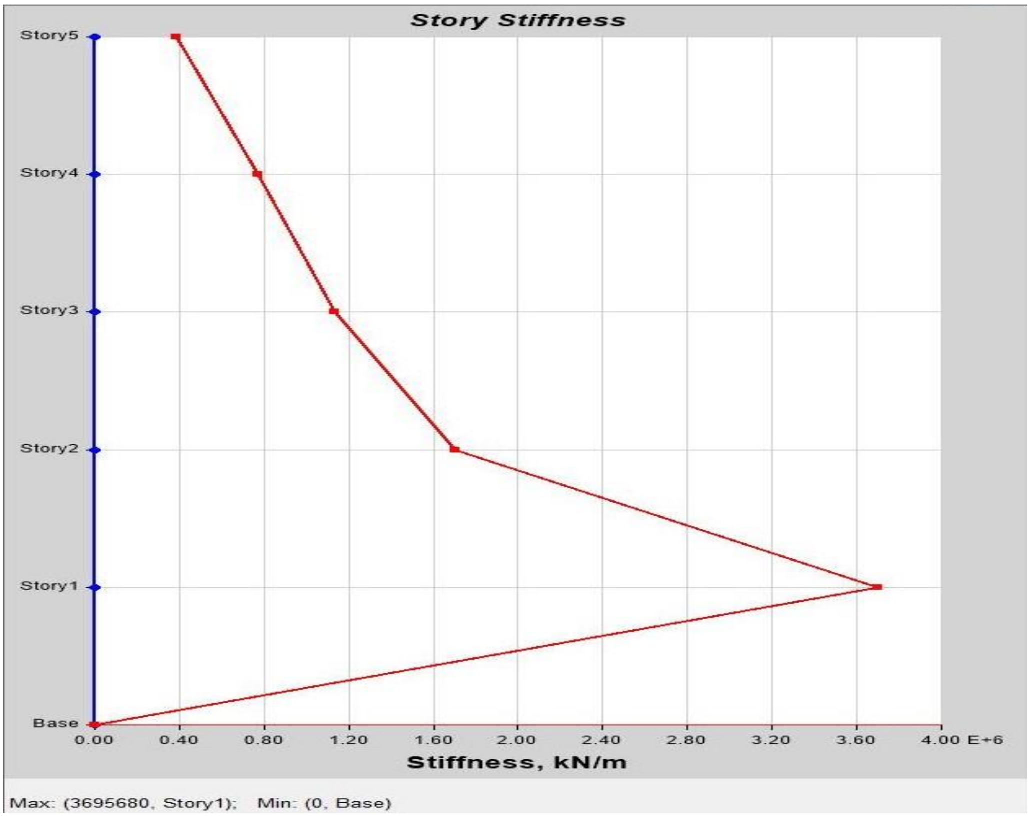


Fig.7.D

2. Steel bracing system

Steel braces are effective structural systems for buildings subjected to seismic or wind lateral loadings. Steel bracing retrofit systems have the advantage of distributing the inelastic demand up the height of the structure, increasing the total strength, stiffness and energy dissipation of the existing bare frame. With the help of the retrofitting, the brittle failure mechanism of the frame can be eliminated by setting the design drift. Secondly, the desired deformed shape and the required capacity of the frame can be obtained. The positioning of the bracing systems is similar to that of shear walls.

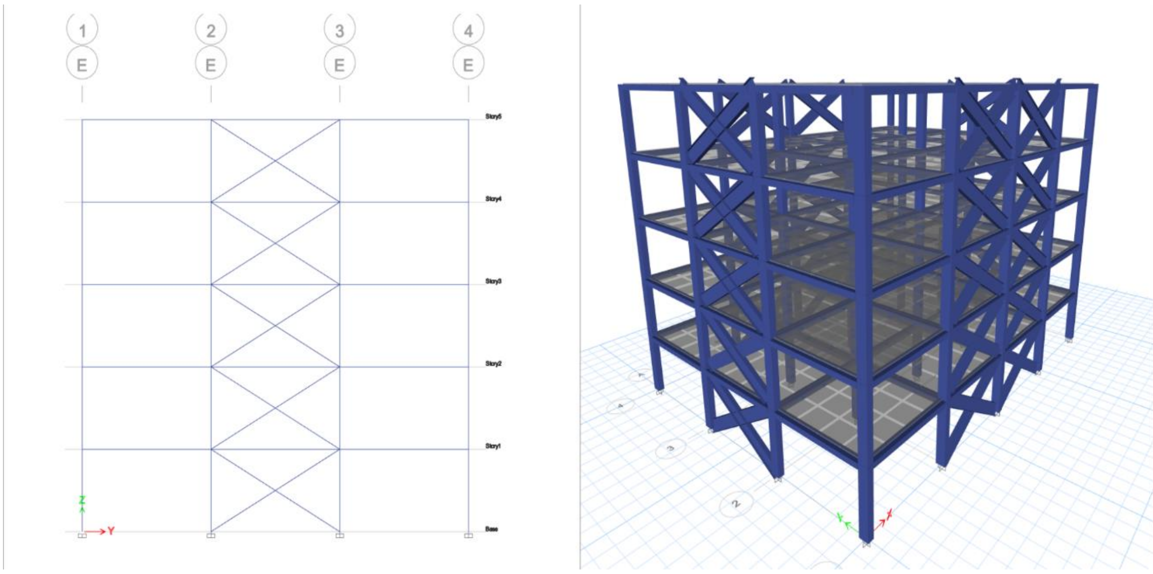


Fig.8.Model with steel bracing system.

a. <u>Maximum story displacement</u>

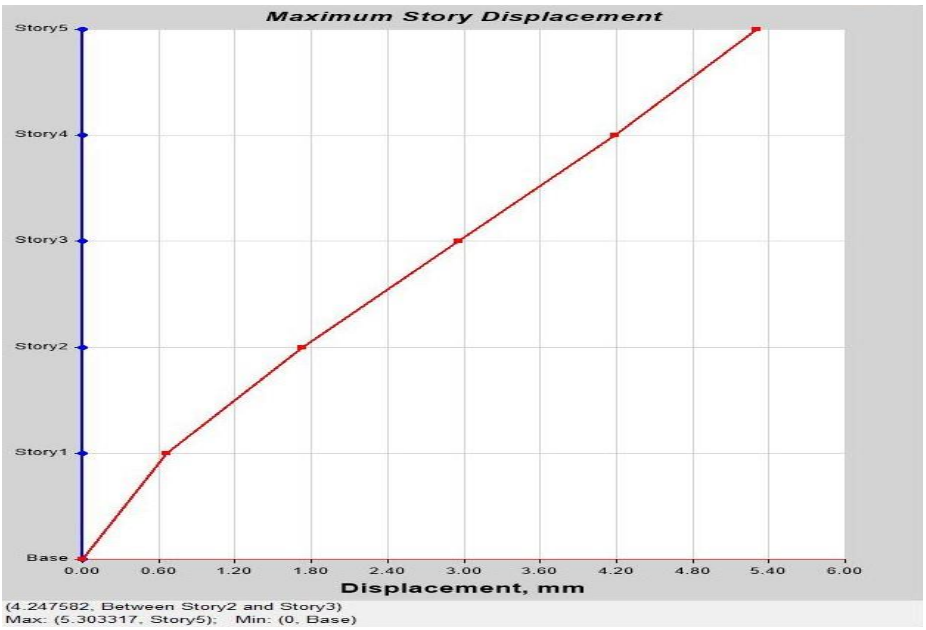


Fig.8.A

b. Maximum story drift

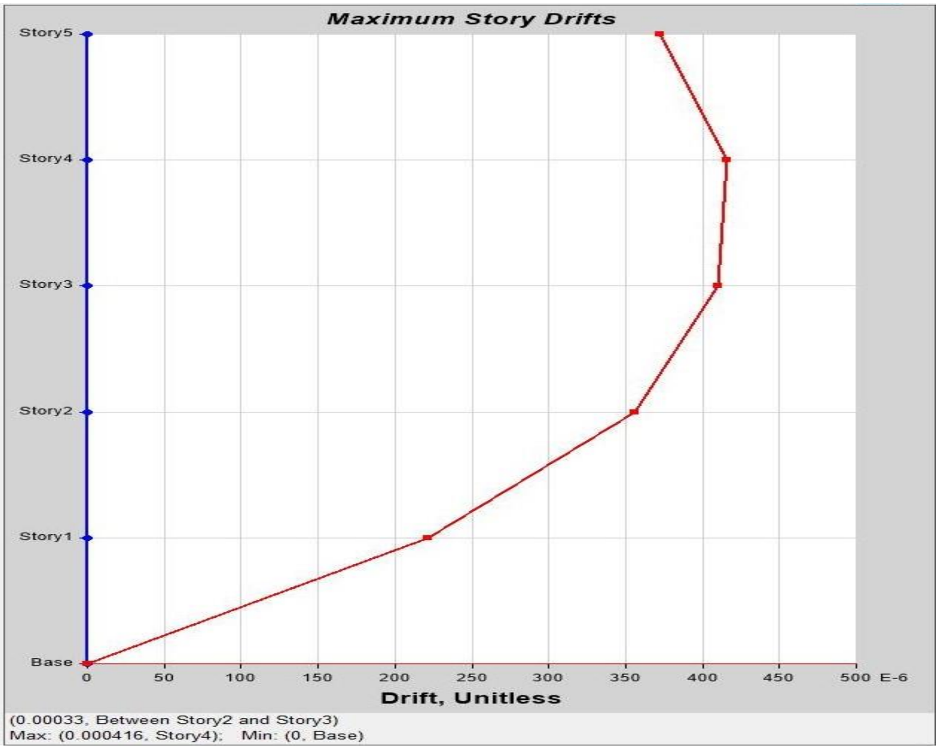


Fig.8.B

c. Story shear

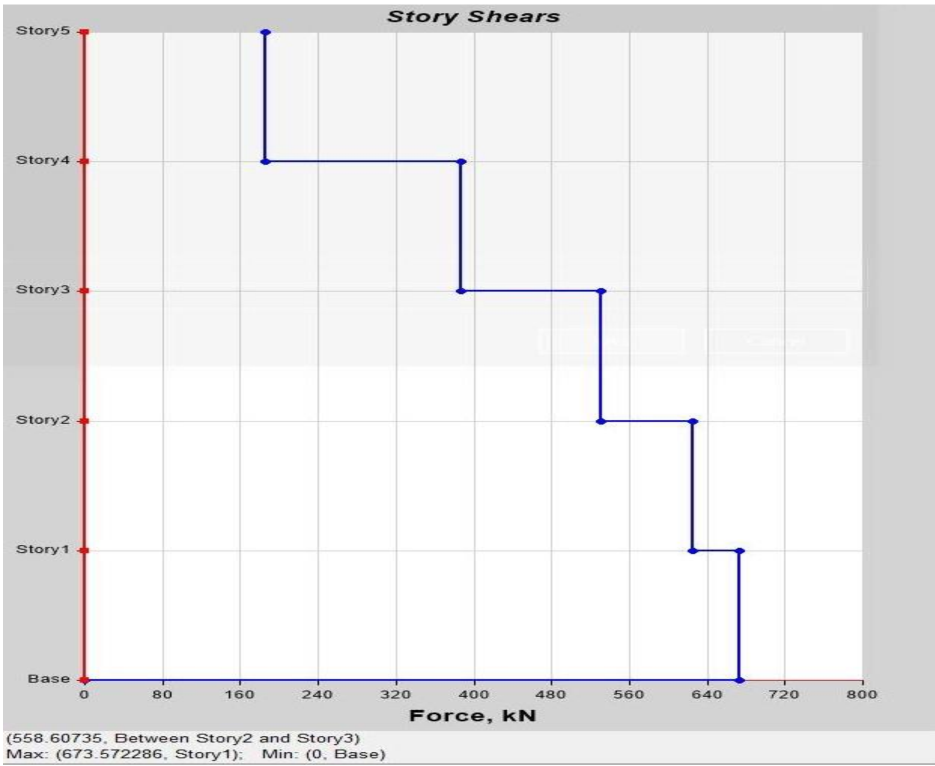


Fig.8.C

d. Story stiffness

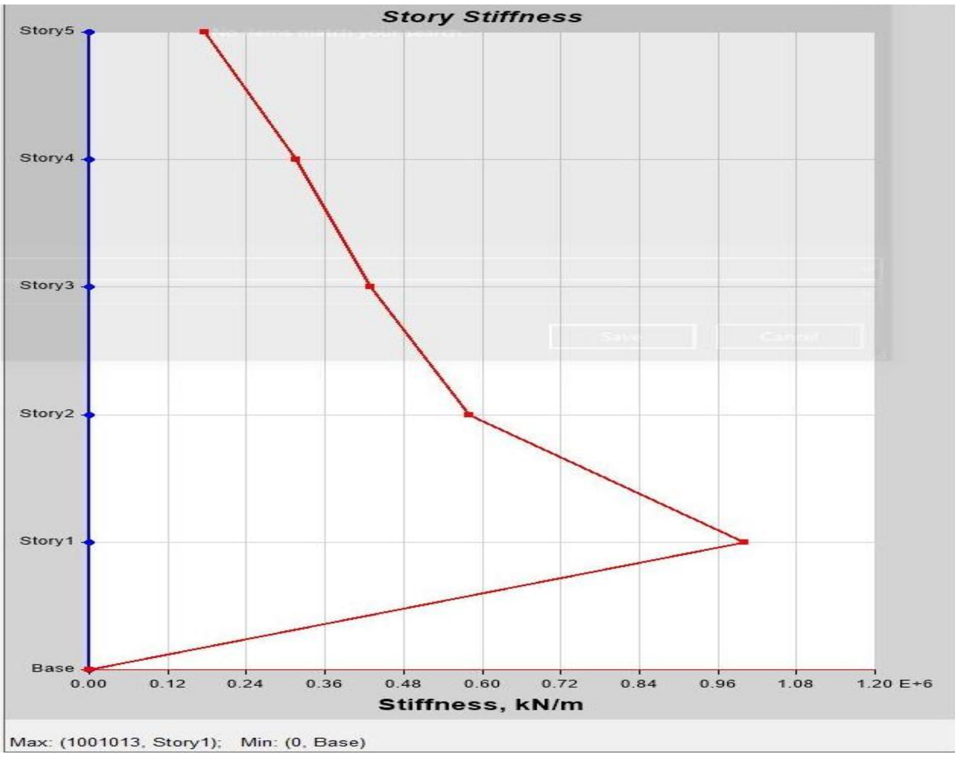


Fig.8.D

3. Viscous Fluid dampers

The mechanism of dampers is similar to a hydraulic shock absorber, which absorbs the seismic excitation and dampens the displacement. The function of the damper is to dissolute energy which is processed due to the lateral deviation of the building during

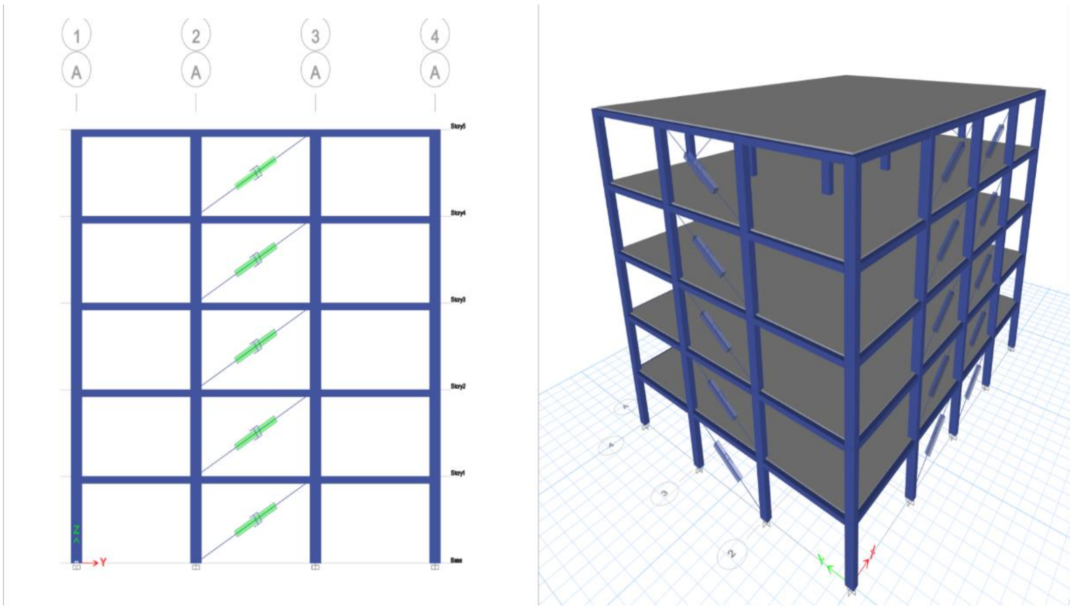


Fig.9.Model with dampers.

earthquake. During the process, the damper slips and the viscous fluid middled inside the damper acts as an energy dissipating medium. Installing dampers is one of the cheapest retrofitting techniques to mitigate soft story effects.

Results obtained after analysing the model structure retrofitted with dampers are given below:

a. Maximum story displacement

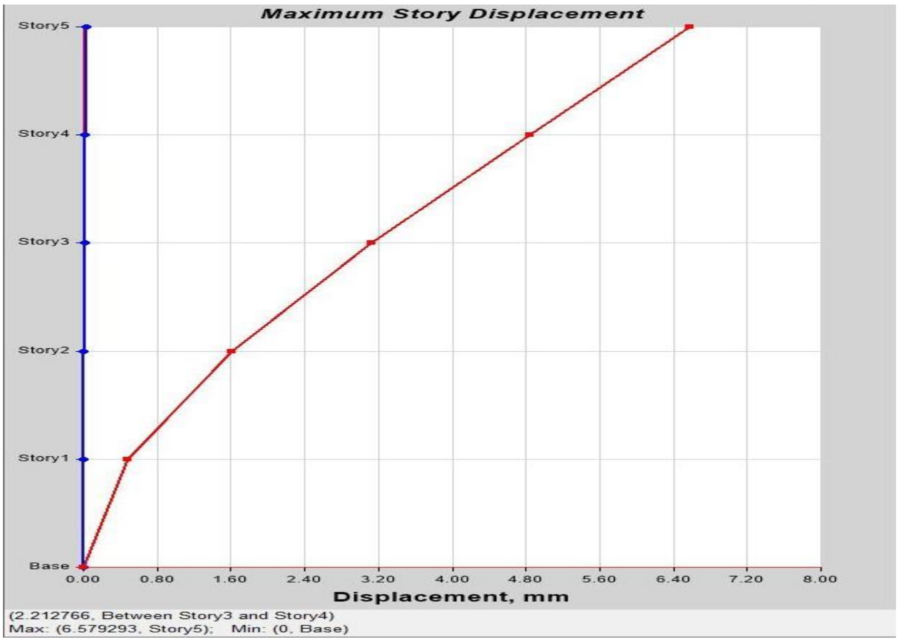


Fig.9.A

b. Maximum story drift

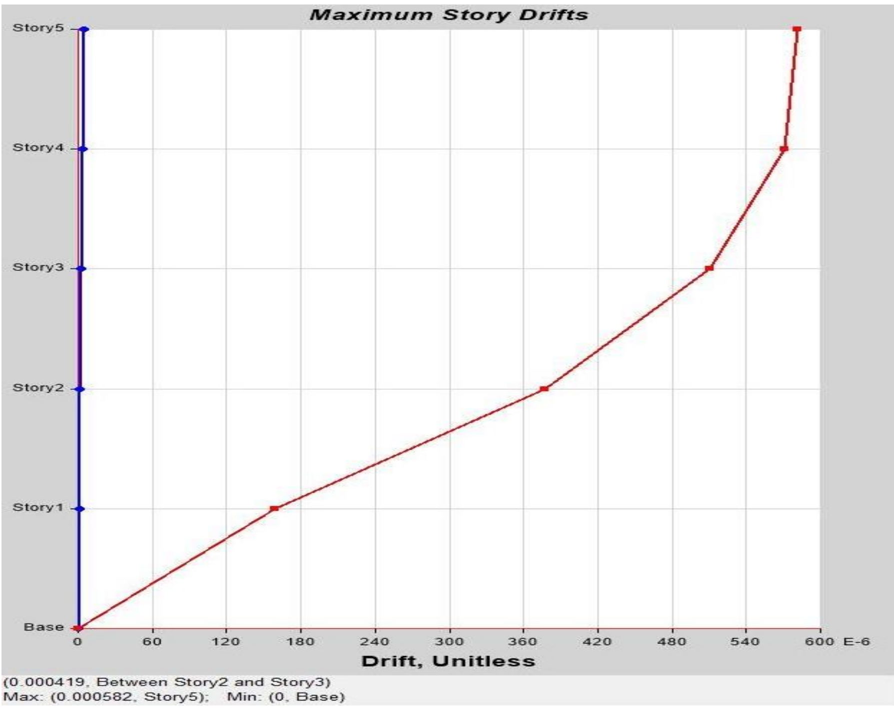


Fig.9.B

c. Story shear

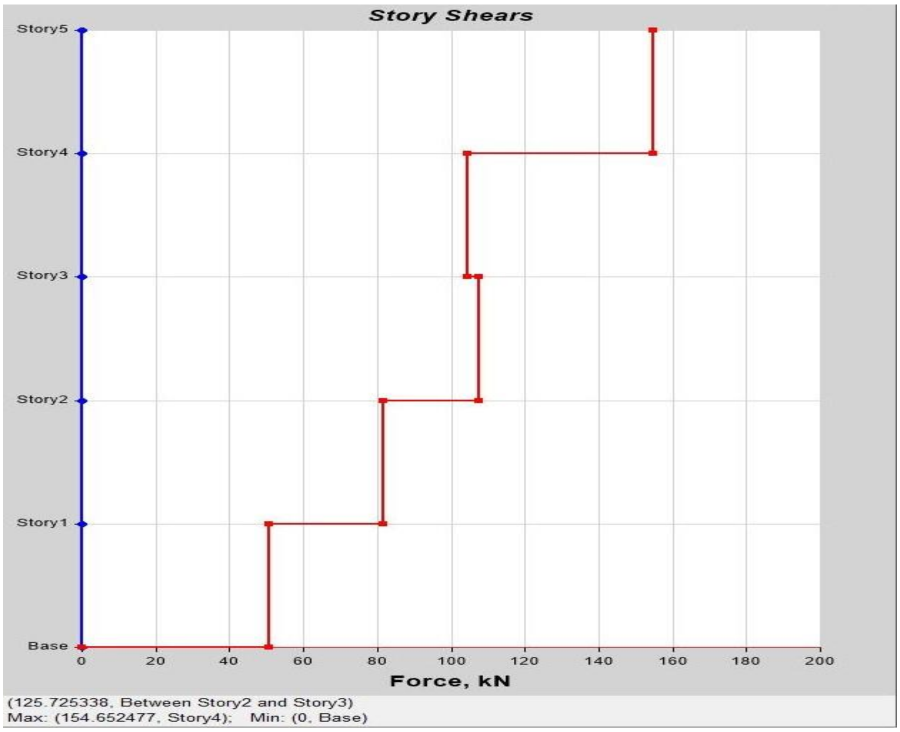


Fig.9.C

d. Story stiffness

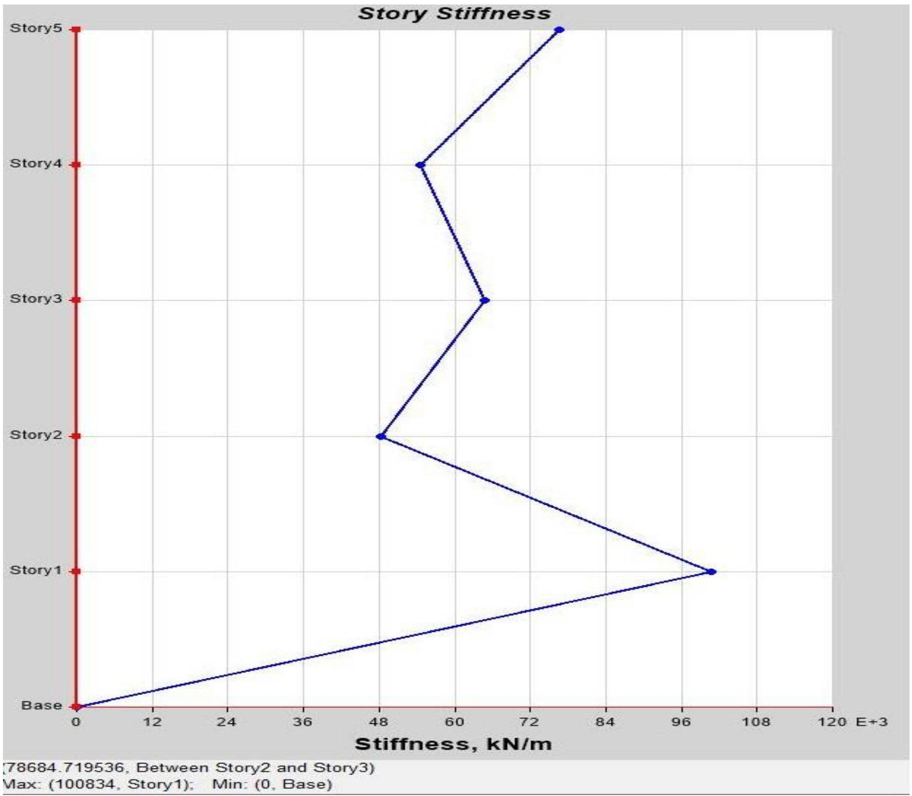


Fig.9.D

GRAPHICAL COMPARISON

Maximum story displacement, Maximum story drift, Story shear and Story stiffness for the ‘G+4’ floor model with and without retrofitting are compared graphically. The results are given below.

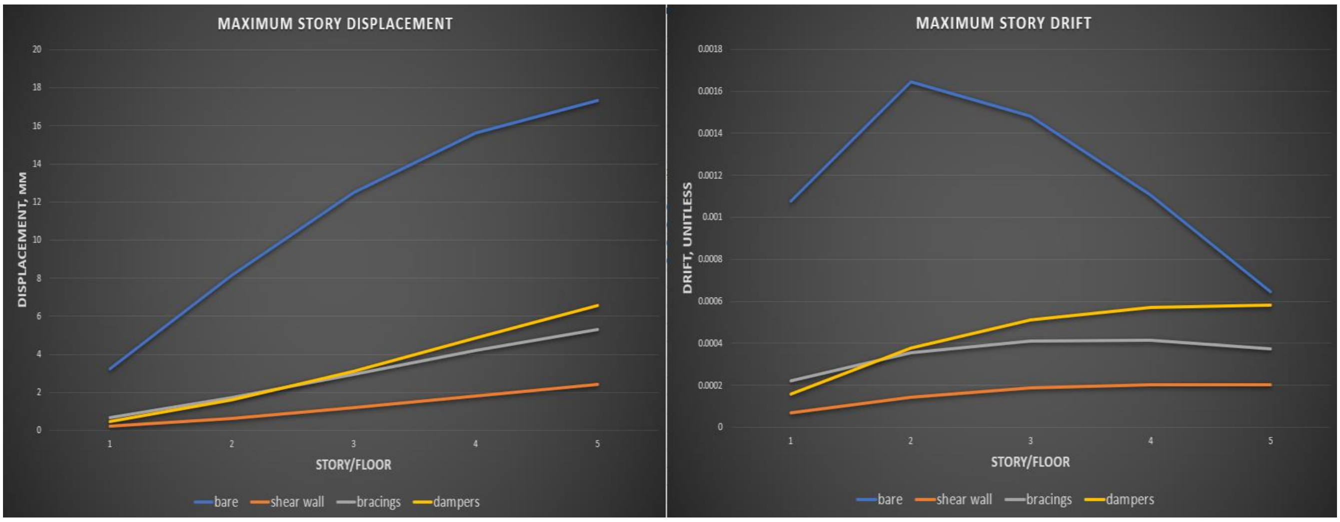
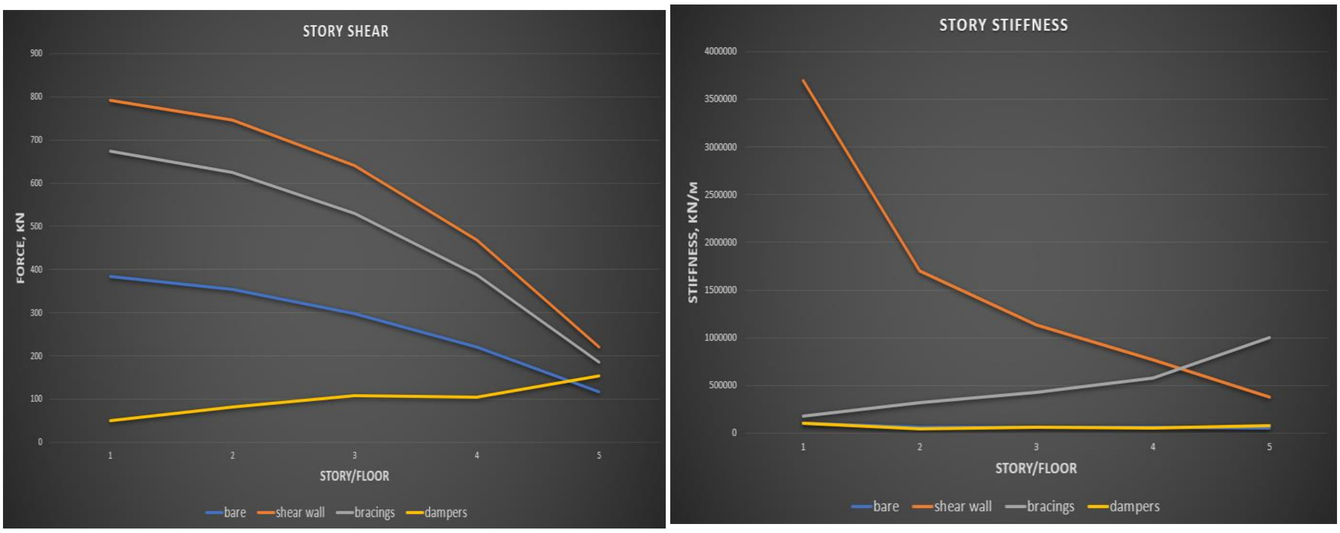


Fig.10. Graphical comparison.



OBSERVATION

From the above results, we can gather that the structural response of the model building is greatly influenced by the implementation of the retrofitting devices. We can observe the difference in the maximum story displacement, story drift etc. after executing different soft story mitigation techniques. By installing shear walls, there is a maximum decrease in the displacement and drift of the building during seismic excitation. There is also an increase in the building stiffness and better transmission of lateral loads to the base. Similarly, there is the steel bracing system and fluid dampers which also helps in minimizing the effects of the subject.

CONCLUSION

Design Response spectrum analysis was carried out on 'G+4' story building model as per IS 1893: 2016. 4 different models were selected and analysis was done using ETABs 2017. Maximum Story displacement, inter storey drift, Storey stiffness and Story shear of each model are obtained as results and a comparative study was carried out for finding model with better performance. When building with shear wall is compared with building without any retrofitting, there was a 95% increase in stiffness and 85% decrease in drift and displacement. When the shear wall model is compared with model with steel bracing system, it is found that that the shear wall model has about 115% increase in stiffness and about 52% decrease in displacement and drift. From the comparative study it is clear that building with shear walls has best performance and consequently; the steel bracing system and dampers, when seismic forces are considered.

REFERNCES

1. Gairola P, Dhyani MS. Seismic analysis of open soft storey building for different models.
2. https://en.wikipedia.org/wiki/Soft_story_building.
3. Bhusnar DL, Pise DC, Mohite DD, Pawar YP, Kadam SS, Deshmukh CM. Seismic behaviour of Multi-storey building with soft storey considering different infill materials: A Review. International Journal of Engineering Research and Applications.; 6(10):23-6.
4. https://www.ijser.org/researchpaper/Seismic-analysis-of-soft-storey-buildings.pdf
5. https://nptel.ac.in/content/storage2/courses/105101004/downloads/04%20Chapter.pdf
6. https://sjce.ac.in/wp-content/uploads/2018/01/EQ6-Methods-of-Analysis.pdf
7. Rad, M. A., Stefano Pampanin, and G. Rodgers. "Displacement-based retrofit of existing reinforced concrete frames using alternative steel brace systems." (2019).
8. Thomas, Eben C. "Seismic Response of Soft Storey Buildings with Viscoelastic Dampers."
9. Guleria, Abhay. "Structural analysis of a multi-storeyed building using ETABS for different plan configurations." *International Journal for Engineering Research and Technology* 3, no. 5 (2014).
10. All pictorial presentations are acquired through Google.