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Optimum Location of Soft Storey in Multi-Storeyed Building

Md Imaduddin Affan, A Vimala

Abstract: The present study is focus on 11-storey reinforced concrete buildings to optimize the location of soft storey under seismic zone-v. The plan of building 40m x 40m is considered. In X- direction and y-direction number of bays is 8 and each bay width is 5m. To observe the non linear behaviour of multi-storeyed building will be studied for various position of soft storey by increasing the storey height. Soft storey is provided at 1st storey, 5th storey and 10th storey. In this first three models is analyzed by increasing height of storey as 4.5m and other three models is analyzed by increasing height of storey as 5.1m and remaining storey height is kept as 3m are compare with regular building by using ETABS software.

Comparison is made for the storey displacement, storey stiffness, base shear and formation of hinge patterns. The result remarks the conclusion that base shear carrying capacity of the structure increases as the soft storey is placed at higher levels and is least when the soft storey is at the ground. The seismic performance of structures is very sensitive to stiffness ratio. The lower the stiffness ratio of soft storey displacement of that structure is high.

Key Words: Soft storey, pushover analysis, stiffness ratio, Base shear, Storey stiffness.

I. INTRODUCTION

Construction of stiffness irregularity in buildings is a commonly used from recent few years. Soft storeys at different levels of buildings are constructed for offices or for any other purpose such as communication hall, banks, auditorium, cinema hall etc. In multi storeyed buildings, damages are due to location of stiffness irregularities so it is necessary to optimize the location of soft storey. In soft storey buildings, stiffness of the lateral load resisting system at that storey is quite less compared to that of other storey. Hence we need to design the structure to withstand these earthquakes.

- The stiffness ratio which 0.3 times of stiffness irregularity is considered by taking height of column as 4.5m and second is 0.2 times of stiffness irregularity is considered by taking height of column as 5.1m.
- To study the non linear behavior of building by providing stiffness irregularity at ground storey, fifth storey and tenth storey.

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***** Correspondence Author

Md Imaduddin Affan*, Master of Technology in structural engineering, Department of civil engineering, Anurag group of institutions, Venkatapur, Ghatkesar, Medchal Dist-TS, India. Email: mdimaduddinaffan@gmail.com

Dr. A. Vimala, Professor, Department of civil engineering, Anurag group of institutions, Venkatapur, Ghatkesar, Medchal Dist-TS, India. Email: vimlareddy@gmail.com

- To study the parameters such as displacement, base Shear, stiffness & formation of hinges for both Regular and Irregular building.

II. STRUCTURAL MODELLING

Pushover analysis was performed on bare frame of G+10 regular and vertical irregular buildings located in zone v by using ETABS at different levels of storeys.

Table -1: Modeling and Material Properties

Description	Regular and Irregular Building
Plan dimension	40m X 40m
Storey height	3m
No of bays in x-direction	8
No of bays in y-direction	8
Bay width	5m
No. Of Storey's	G+10
Grade of steel	Fe500
Grade of concrete	M25
Size of beams	230 X 380 mm
Size of columns	450 X 450 mm
Thickness of slab	130

III. OBJECTIVE

A 11- storey building is considered and analyzed by using Etabs. To identified the below objectives,

- The main aim of the project is to optimize the location of soft storey and compare the Regular and Stiffness Irregular building in Zone V as per IS 1893 (part-1): 2002 by using Pushover analysis in ETABS software.

The plan dimensions are 40m x 40m, 8 bays are considered in x-direction and y-direction and each bay width is 5m. Parameters which is used for analysis like material properties, loads, soil type, seismic zone etc as shown in table-3.1

Table-2: Loads

Type of load	Intensity
Live load	3 KN/m^2
Roof live	1.5 KN/m^2
Importance factor, I	1
Response reduction factor R	5
Soil type	II- Medium
Seismic zone	V

Table-2 shows types of loads which is consider for analysis dead load and live load is considered as per IS-875 part-1 and part-2, for load combinations IS-1893-2002 (part-1).

Table-3: Building Frames taken for the study

Model	Type
1	RC Regular frame
2	Soft storey with 30% at G.F
3	Soft storey with 30% at Fifth storey
4	Soft storey with 30% at Tenth storey
5	Soft storey with 20% at G.F
6	Soft storey with 20% at Fifth storey
7	Soft storey with 20% at Tenth storey

As shown in table-3, seven different models are analyzed in this case, first model which is took as regular building (M1) and other six models as stiffness irregular buildings namely ground storey, fifth storey and tenth storey as soft storey is consider. The irregularity in the building is generated by increasing the height of the storey. Thus the M2, M3 and M4 buildings are analyzed by using storey height of 4.5 and the M5, M6 and M7 buildings are analyzed by using storey height of 5.1m.

A. Modeling of building:

The below figure-1 shows the typical floor of building, in this the plan dimensions is consider as 40m x 40m, 8-bays is consider in both x-direction and y-direction and each bay width is consider as 5m and structural parameters which is consider as shown in table-1, the column dimensions and beam dimensions is took same for all storey's but in stiffness irregularity height of column changes.

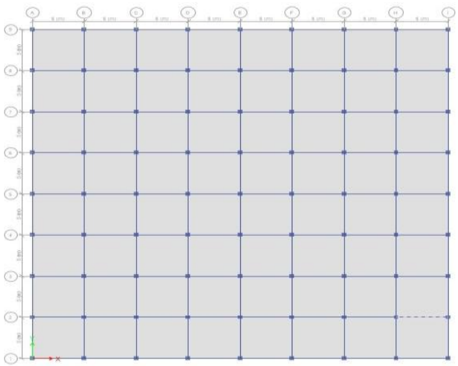

Figure 1: Plan of Building

1) Without stiffness irregularity:

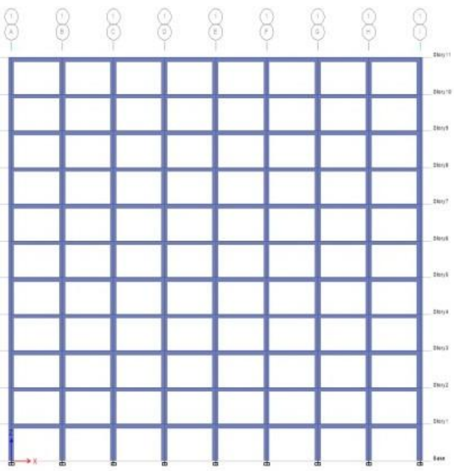

Figure 2: Elevation of Regular Building

In this model which is shown in above figure-2 is without stiffness irregularity and all heights of storeys is consider as 3m.

2) Stiffness irregularity (SR=0.3):

Stiffness of each column= $12EI/L^3$

Therefore, stiffness of ground storey/stiffness of other storey

$= (3/4.5)^3 = 0.3 < 0.7$

Hence as per IS 1893 (part-1): 2002 the building has stiffness irregularity.

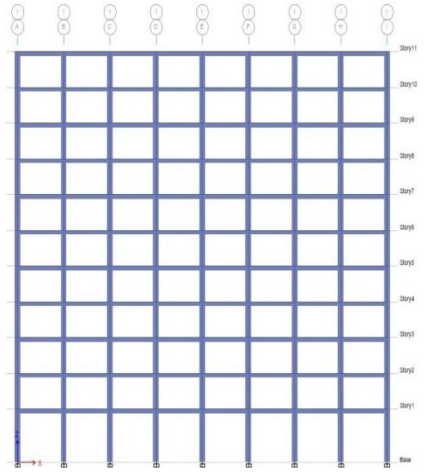

Figure 3: Elevation of of Ground storey as soft storey

In this model which is shown in above figure-3 G.F is consider as soft storey whose storey height is taken as 4.5m and remaining all storey's is kept as of 3m height.

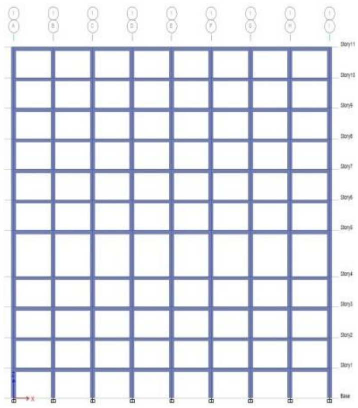

Figure 4: Elevation of Fifth storey as soft store

In this model which is shown in above figure-4 fifth storey is consider as soft storey whose storey height is taken as 4.5m and remaining all storey's is kept as of 3m height.

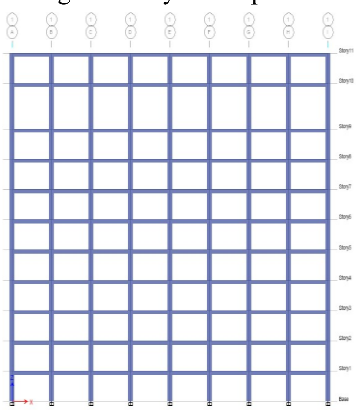

Figure 5: Elevation of Tenth storey as soft storey

In this model which is shown in above figure-5 tenth storey is consider as soft storey whose storey height is taken as 4.5m and remaining all storeys is kept as of 3m height.

3) Stiffness irregularity (SR=0.2):

Stiffness of each column= $12EI/L^3$

Therefore, stiffness of ground storey/stiffness of other storey

$= (3/5.1)^3 = 0.2 < 0.7$

Hence as per IS 1893 (part-1): 2002 the building has stiffness irregularity.

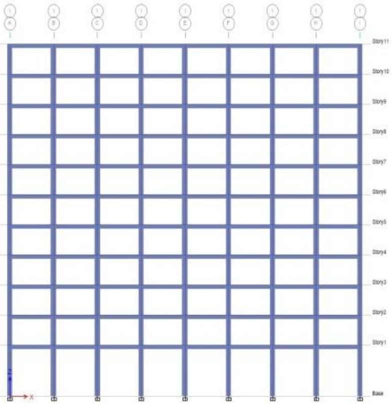

Figure 6: Elevation of of Ground storey as soft storey

In this model which is shown in below figure-6 ground storey is consider as soft storey whose storey height is taken as 5.1m and remaining all storeys is kept as of 3m height.

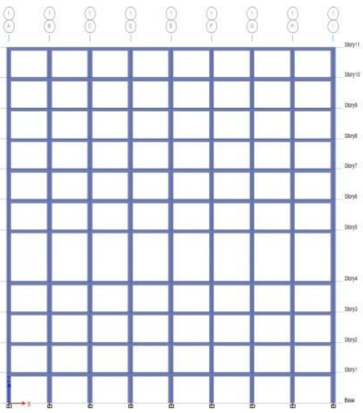

Figure 7: Elevation of Fifth storey as soft storey

In this model which is shown in above figure-7 fifth storey is consider as soft storey whose storey height is taken as 5.1m and remaining all storeys is kept as of 3m height.

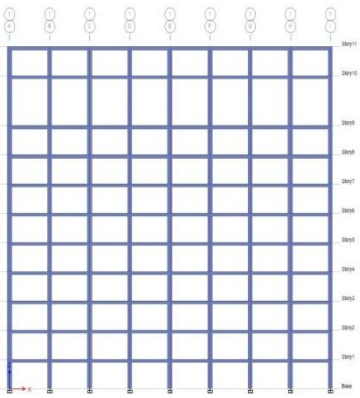

Figure 8: Elevation of Tenth storey as soft storey

In this model which is shown in above figure-8 tenth storey is consider as soft storey whose storey height is taken as 5.1m and remaining all storeys is kept as of 3m height.

IV. RESULTS

In this project, comparison of the regular building with vertical irregular building such as stiffness irregularity were carried out in seismic zone-v. A Non linear pushover analysis was done on bare frame. The structure is pushed in lateral direction until the formation of collapse mechanism. In this first 0.3 times of stiffness irregularity is compare with regular building and second 0.2 times of stiffness irregularity is compare with regular building, in both cases the stiffness irregularity were provided on ground storey, fifth storey and tenth storey.

A. Comparison of capacity curve (SR=0.3):

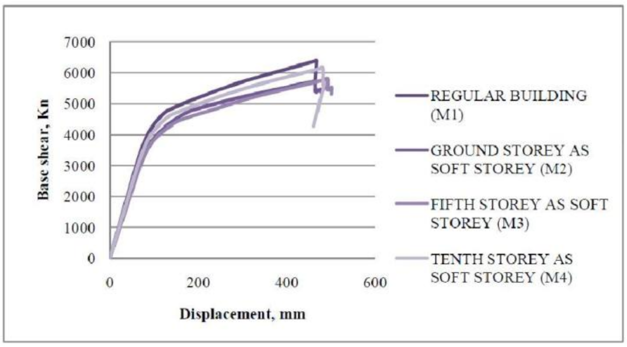

Figure 9: Comparison of Regular model with 0.3 stiffness irregularity models at different storey level

The figure-9 shows the displacement of all models with 4.5m height at different storey level. Model-3 which is taken as soft storey at 5th storey which has less base shear compare to M1 and M4 but has maximum displacement compare to all models. Model-4 which is taken as soft storey at 10th storey, the capacity curve of model-4 moves same as that of regular model (M1) and it has less base shear with small variation compare to regular model but it has maximum displacement compare to regular building.

B. Comparison of Capacity Curve (SR=0.2):

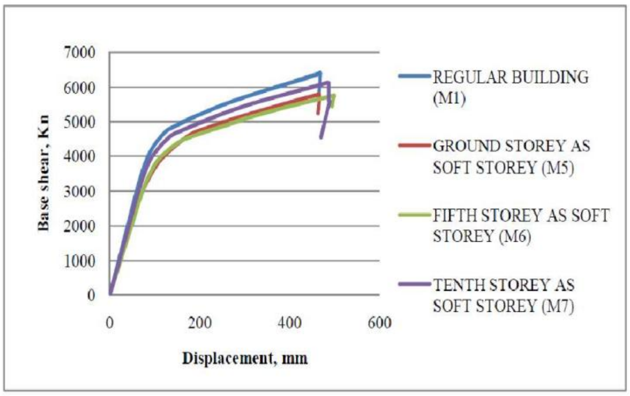

Figure 10: Comparison of Regular model with 0.2 stiffness irregularity models at different storey level

The figure-10 shows the displacement of all models with 5.1m height at different storey level.

Model-3 which is taken as soft storey at 5th storey which has less base shear compare to M1, M2 and M4 but has maximum displacement compare to all models. Model-4 which is taken as soft storey at 10th storey, the capacity curve of model-4 moves same as that of regular model (M1) and it has less base shear with small variation compare to regular model but it has maximum displacement compare to regular building.

C. Displacement Comparison:

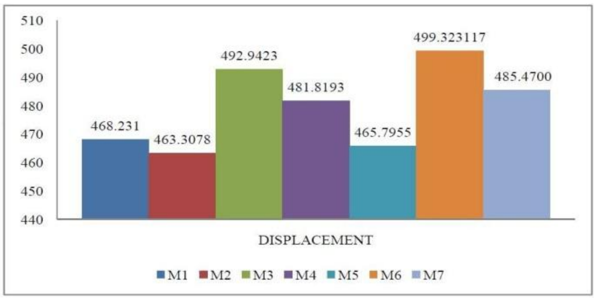

Figure 11: Displacement comparison of all models

From this figure-11 it is observe that the maximum displacement is obtained when soft storey is provided at 5th storey (M3) with 0.3 stiffness irregularity. Similarly the maximum displacement is obtained when soft storey is provided at 5th storey (M6) with 0.2 stiffness irregularity.

D. Stiffness Comparison:

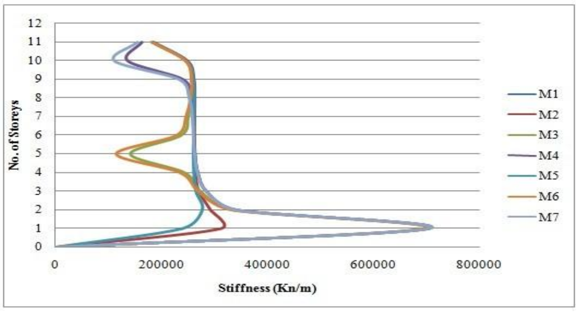

Figure 12: Storey stiffness of all models

The figure-12 shows the storey stiffness of all models with 0.3 and 0.2 stiffness irregularity at G.F, 5th and 10th storey. In case of stiffness irregular buildings, a sudden decrease in stiffness of the building has been found at the irregular storeys.

E. Hinge Formation:

Figure 13: Hinge Formation of Regular building (Model-1).

The above figure-13 shows the formation of hinges in case of without stiffness irregularity from this it is observed that the collapse hinges formed at storey 2 and storey 3.

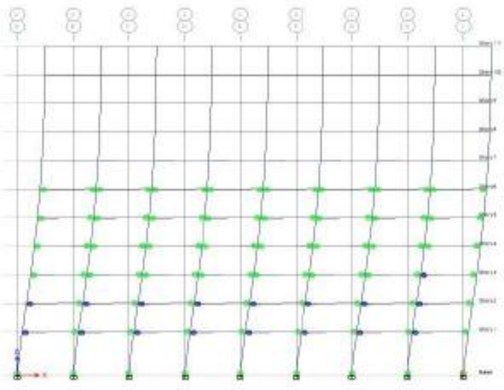

Figure 14: Hinge Formation of Soft storey at GF with 0.3 stiffness irregularity (Model-2).

The above figure-14 shows the formation of hinges in case of soft storey is provided at ground by increasing storey height as 4.5m from this it is observed that the collapse hinges formed at storey 1 and storey 2.

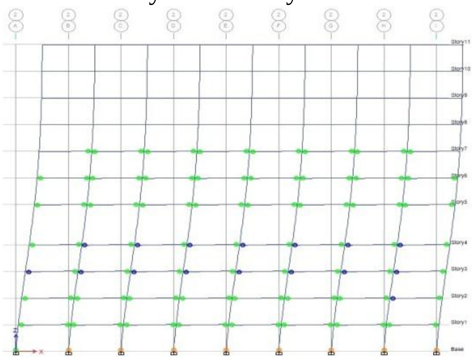

Figure 15: Hinge Formation of Soft storey at 5th with 0.3 stiffness irregularity (Model-3).

The above figure-15 shows the formation of hinges in case of soft storey is provided at 5th storey by increasing storey height as 4.5m from this it is observed that the collapse hinges formed at storey 3 and storey 4.

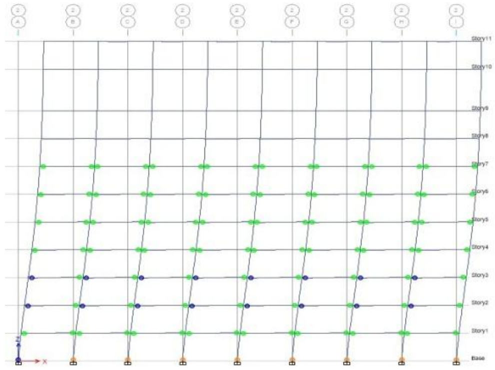

Figure 16: Hinge Formation of Soft storey at 10th with 0.3 stiffness irregularity (Model-4).

The above figure-16 shows the formation of hinges in case of soft storey is provided at 10th storey by increasing storey height as 4.5m from this it is observed that the collapse hinges formed at storey 2 and storey 3, same as of regular building.

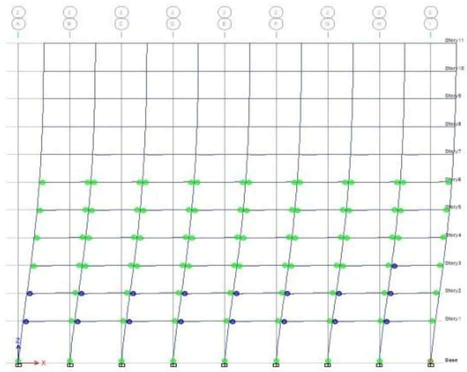

Figure 17: Hinge Formation of Soft storey at GFwith 0.2 stiffness irregularity (Model-5).

The above figure-17 shows the formation of hinges in case of soft storey is provided at ground by increasing storey height as 5.1m from this it is observed that the collapse hinges formed at storey 1 and storey 2.

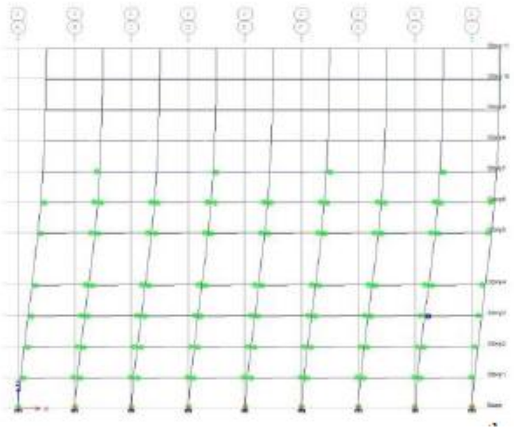

Figure 18: Hinge Formation of Soft storey at 5th with 0.2 stiffness irregularity (Model-6).

The above figure-18 shows the formation of hinges in case of soft storey is provided at 5th storey by increasing storey height as 5.1m from this it is observed that the collapse hinges formed at storey 3.

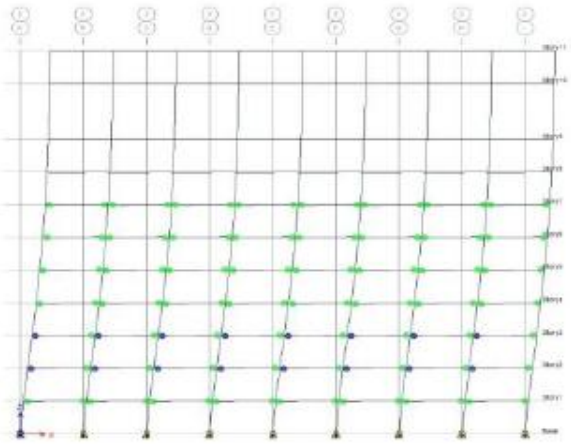

Figure 19: Hinge Formation of Soft storey at 10th with 0.2 stiffness irregularity (Model-7).

The above figure-19 shows the formation of hinges in case of soft storey is provided at 10th storey by increasing storey height as 5.1m from this it is observed that the collapse hinges formed at storey 2 and storey 3, same as of regular building.

V. CONCLUSION

- The base shear carrying capacity of the structure increases 4% as the soft storey is placed at higher levels and is decreased by 10% when the soft storey is at the ground level.
- The base shear carrying capacity of the structure reduces with the decrease in stiffness ratio.
- In case of 30% and 20% stiffness irregularity, the displacement is more than that of regular building with small variation and as considering displacement of 10th storey as soft storey it is less critical because its displacement is 2.8% and 3.5% more than that of regular building.
- In case of stiffness irregular buildings, a sudden decrease in stiffness of the building has been observed at the irregular storeys.
- In case of soft storey is placed at higher level collapse hinges performance is same as that of without stiffness irregularity.

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AUTHORS PROFILE

Md Imaduddin Affan, Master of Technology in structural engineering, Department of civil engineering, Anurag group of institutions, Venkatapur, Ghatkesar, Medchal Dist-TS, India.

Dr. A. Vimala, Professor, Department of civil engineering, Anurag group of institutions, Venkatapur, Ghatkesar, Medchal Dist-TS, India.