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Comparison on Soft Storey Effect at Different Level in Multi-Storey Buildings

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Abstract: Nowadays, according to social and functional needs, various types of multi-storey or high rise buildings are the mostly useable buildings in many towns and cities. Among them, some buildings are constructed as soft storey because of the space occupancy considerations. The soft storey has one level that is considerably greater flexible than the storey above and below it. This type of building has no masonry wall in this level or it can also have a greater height than the rest of the floors. Generally, the soft storey usually exists at the ground floor level but it can form any level of a high-rise building to fulfill necessity. In this study, analysis and design of superstructure for twelve-storey reinforced concrete building are presented. Analysis and design of superstructure of the selected building are carried out by using Extended Three Dimensional Analysis of Building Systems software. Firstly, the model is analysed by using software. For the superstructure, storey drift limitation, P-Δ effect, overturning, storey shear and torsional irregularities are carried out from design results. Secondly, the structural designs are made by change of storey height and without change of structural element size, seismic zone, exposure type and soil type. Finally, storey drift of all storey levels and the analysis results of structural performance are compared.

Keywords: multi-storey; soft storey; storey drift; P-Δ effect; overturning; torsional irregularities.

1. INTRODUCTION

All over the world, the multi-storey buildings are widely used due to the rapid growth of the urban population, the high cost of land, and potential of popularity in which the provision of soft storey is a common practice. Generally, the soft storey usually exists at the ground floor level and is known as a soft storey building or an open ground storey building. As per Indian standard code of practice, a soft storey has stiffness less than 70 percent of the storey immediately above, or less than 80 percent of the average stiffness of the three storeys above. If the stiffness of the storey meets at least one of above two criteria, the structure is considered to have a soft storey. Nowadays, some space need to be wider open space and higher floor level are considered for the purpose of a large meeting room, a showroom or a banking hall etc. Therefore, soft storey can form any level of a high-rise building. Some buildings are regarded with typical height and designed for same typical floors in structural design. But in practice, height is suddenly increased in one floor and structural elements for this changed height are not designed again. These structures can get soft storey effect and the effect of the seismic loading becomes more severe for heights above this floor level. When the lateral force acts on soft storey building, the building might become failure due to its less stiffness because the seismic force distribution is dependent on the distribution of stiffness and mass along the height. In this study, the structural designs are made by change of storey height and without change of structural element sizes, seismic zone, exposure type and soil type. The structural elements are designed to resist not only gravity forces but also lateral forces including earthquake and wind loads. The mostly failure of soft storey effect on the world are mainly due to the earthquake because the structural members are not strong enough to hold up the building during an earthquake. This indicate that those buildings possess storeys that are significantly weaker or more flexible than adjacent storeys and where deformations and damage tend to be concentrated. The Figure.1 is the soft storey failure in M7.4 earthquake, Tukery, August 17, 1999.

Figure.1 Soft storey failure in Tukery

2. METHODOLOGY

In this paper, The 12 multi-storey building will be analysed and designed by using Extended Three Dimensional Analysis of Building Systems (E-tabs) Software. All reinforced concrete members are designed with ultimate strength design using building code of American Concrete Institute (ACI) 318-99. Wind and earthquake loads are considered according to Uniform Building Code (UBC-1997). Exposure type (B) and soil type (D) are considered with design wind velocity

120 mph. Structural system is considered by concrete intermediate moment-resisting frame with over-strength factor 5.5. Firstly, the proposed model is statically analyzed and the structural elements of all storey levels will be compared to know whether or not soft storey effect for proposed buildings. And then, the results are carried out for the superstructure of the proposed model and finally these are compared.

3. TYPE OF STRUCTURE

3.1 Data Preparation

The following Tables describe the design data for five models having different geometrical configurations. Table 1 shows material specifications, Table 2 shows structural configurations, Table 3 shows different cases of five models, Table 4 shows storey heights of different configuration and Table 5 shows structural element sizes.

Table 1 . Material specifications

Concrete compressive strength (f_c')	4 ksi
Reinforcing yield strength (f_y)	50 ksi
Modulus of Elasticity	3605 ksi
Poisson’s ratio	0.2

Table 2. Structural configurations

Number of stories	12
Width of structure	68′-0″
Length of structure	95′-0″
Total height of structure	148′-0″
Number of bay’s along X	8
Number of bay’s along Y	6

Table 3. Different cases of five models

Model-1	Conventional
Model-2	Soft storey at ground floor
Model-3	Soft storey at first floor
Model-4	Soft storey at second floor
Model-5	Soft storey at third floor

Table 4. Storey heights of different configuration

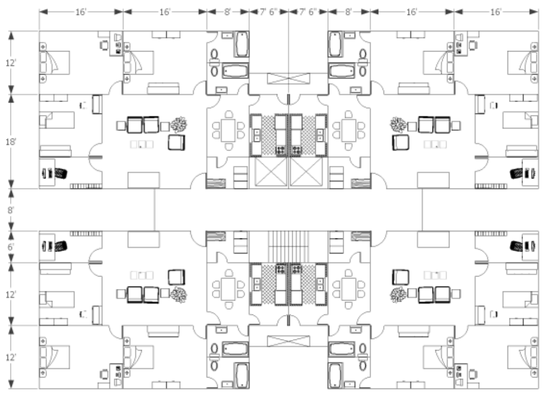
Storey	Height				
	Model M1	Model M2	Model M3	Model M4	Model M5
RT-1	10	10	10	10	10
RT	10	10	10	10	10
11F	10	10	10	10	10
10F	10	10	10	10	10
9F	10	10	10	10	10
8F	11	10	10	10	10
7F	11	10	10	10	10
6F	11	10	10	10	10
5F	11	10	10	10	10
4F	11	10	10	10	18
3F	11	10	10	18	10
2F	11	10	18	10	10
1F	11	18	10	10	10
GF to Base	10	10	10	10	10
Total height	148	148	148	148	148

Table 5. Structural element sizes

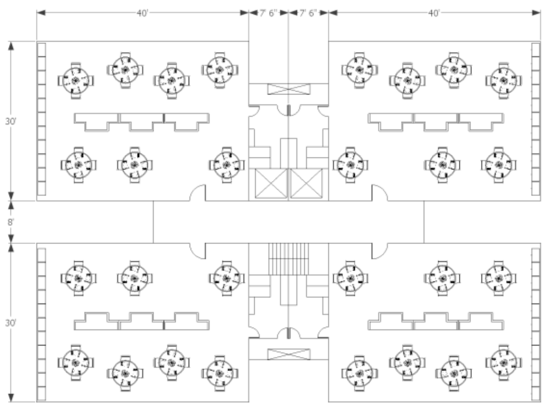
Column sizes	22″x22″, 20″x20″, 18″x18″, 16″x16″
Beam sizes for proposed buildings	18″x20″, 16″x18″ , 14″x18″, 12″x18″, 12″x14″, 10″x12″

3.2 Model Description

The Figure.2 shows the architectural floor plans of proposed buildings. The Figure.3 and Figure.4 show the layout plan of columns and beams of all models respectively.



(i)Typical floor plan



(ii)Soft storey floor plan

Figure.2 Architectural floor plan of proposed buildings

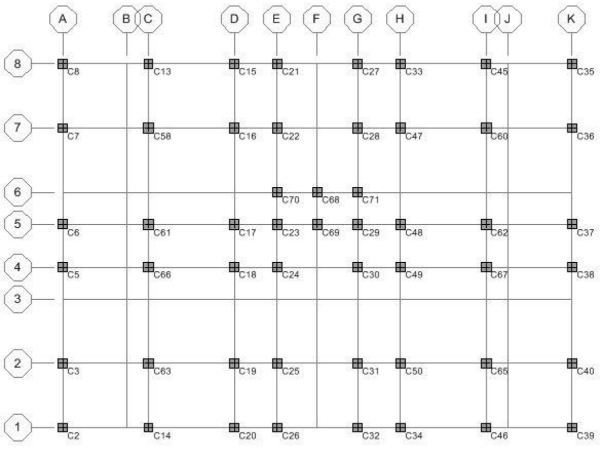


Figure.3 Typical layout plan of columns

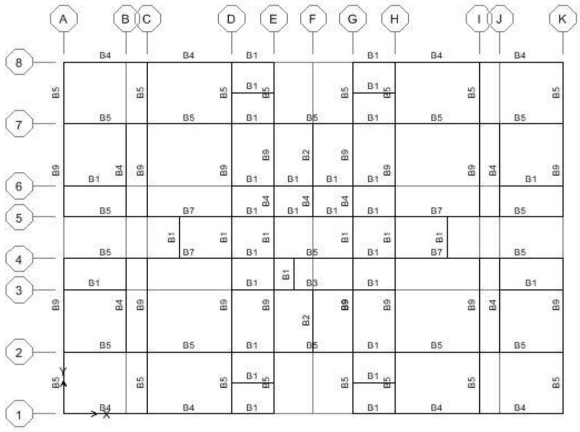


Figure.4 Typical layout plan of beams

4. LOAD COMBINATION

According to ACI (318-99), static design load combinations are as follows in Table 6.

Table 6. Load combination according to ACI (318-99)

1	1.4DL + 1.4SDL
2	1.4DL + 1.4SDL + 1.7LL
3,4	1.05DL + 1.05SDL + 1.275 LL ± 1.275WX
5,6	1.05DL + 1.05SDL + 1.275 LL ± 1.275WY
7,8	0.9DL + 0.9SDL ± 1.3WX
9,10	0.9DL + 0.9SDL ± 1.3WY
11,12	1.05DL + 1.05SDL + 1.28LL ± EQX
13,14	1.05DL + 1.05SDL + 1.28LL ± EQY
15,16	0.9DL + 0.9SDL ± EQX
17,18	0.9DL + 0.9SDL ± EQY
19,20	1.27DL + 1.27SDL + 1.28LL ± EQX
21,22	1.27DL + 1.27SDL + 1.28LL ± EQY
23,24	0.68DL + 0.68SDL ± 1.02EQX
25,26	0.68DL + 0.68SDL ± EQY

5. RESULTS AND DISCUSSIONS

In this section, the results obtained from the analysis of one conventional and four soft storey RC models using ETABS software have been tabulated and compared. The performance of structures on different criteria have been analyzed and discussed as follow.

5.1 Storey Drift

Storey drift is the lateral displacement of one level relative to the level above or below. The figure.5 and figure.6 show comparison of storey drift of five proposed models in x direction and y direction respectively. The storey drifts for models 2, 3, 4 and 5 suddenly increase at soft storey levels. From the following results, it can be seen that the storey drift of model 2 at soft storey level is maximum in both directions, the storey drift of model 3, model 4 and model 5 at that level are nearly equal in both directions and model 1 is minimum. The storey drifts in both direction at each soft storey level are more than drift limit so that the storey drift is significant in soft storey buildings.

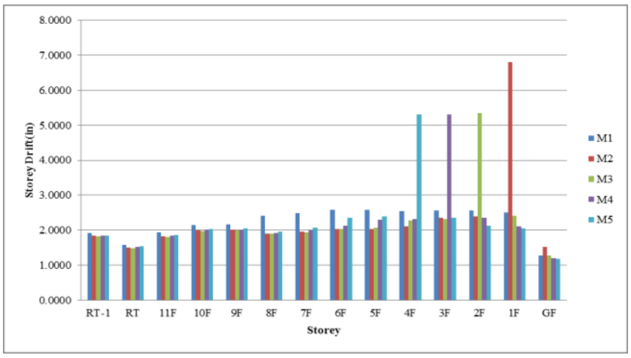


Figure.5 Comparison of storey drift in x direction

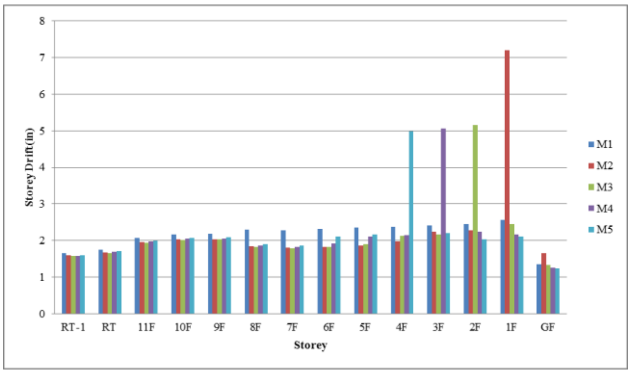


Figure.6 Comparison of storey drift in y direction

5.2 P-Δ Effect

The P-Δ effect results in additional forces and moments of frame members and increases storey displacement and overturning moment .The Figure.7 and Figure.8 show the comparison of P-Δ effect in x-direction and y-direction respectively. In comparison of both directions, the P-Δ effects of models 2, 3, 4 and 5 suddenly increase at soft storey level in which the P-Δ effect at soft storey level of model 2 and 3 in both directions and that of model 4 in X direction are more than limitation. The stability coefficient for x and y direction of model 1 and 5 is smaller than the allowable limit (0.1). Therefore, P-Δ effect is also significant in soft storey at lower level.

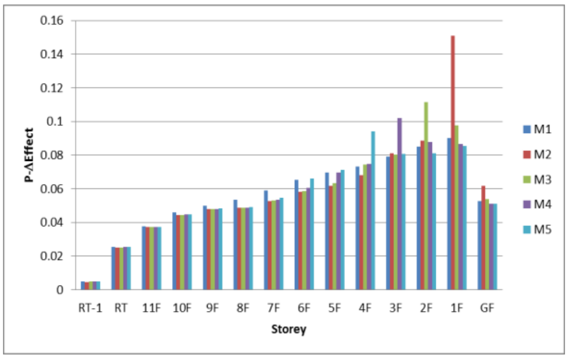


Figure.7 Comparison of P-Δ effect in x direction

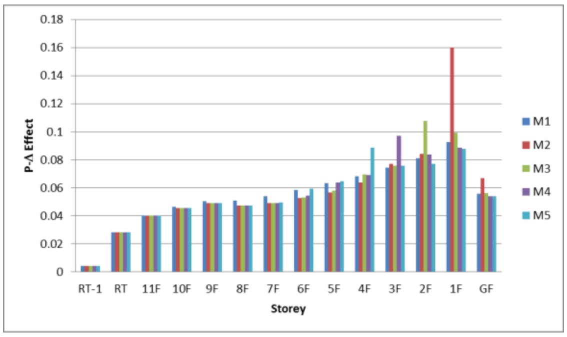


Figure.8 Comparison of P-Δ effect in y direction

5.3 Overturning Moment

The Figure.9 and Figure.10 show the comparison of overturning moment in x direction and y direction. In this comparison, for all models in both directions are nearly similar and it is increasing from top to bottom.

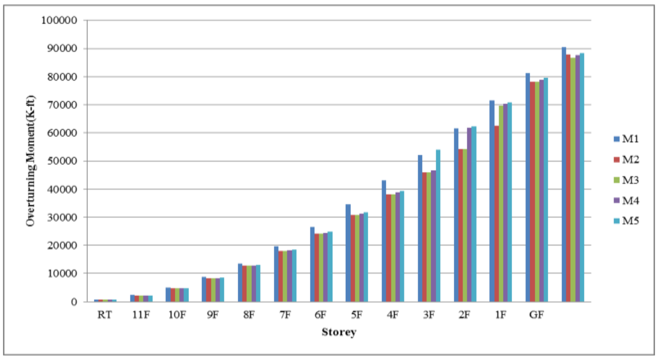


Figure.9 Comparison of overturning moment in x direction

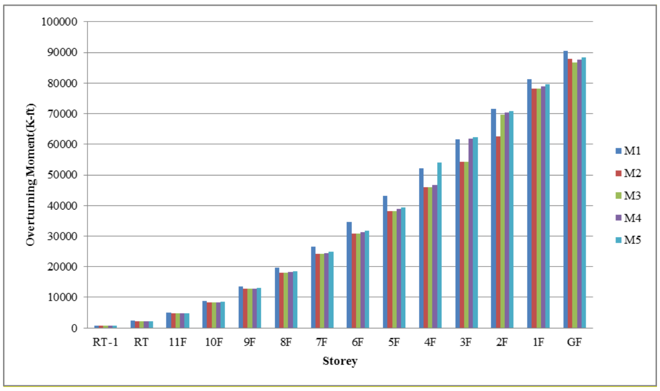


Figure.10 Comparison of overturning moment in y direction

5.4 Storey Shear

Storey shear is the summation of design lateral forces above the storey under consideration. The Figure.11 and Figure.12 show the comparison of storey shear in x direction and y direction. In this comparison, the results of storey shear for all models in x and y directions are nearly similar and it is increasing from top to bottom. Storey shear is the largest in footing and then it declines gradually from footing to top.

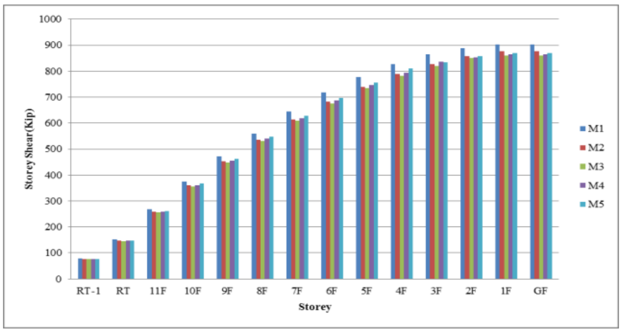


Figure.11 Comparison of storey shear in x direction

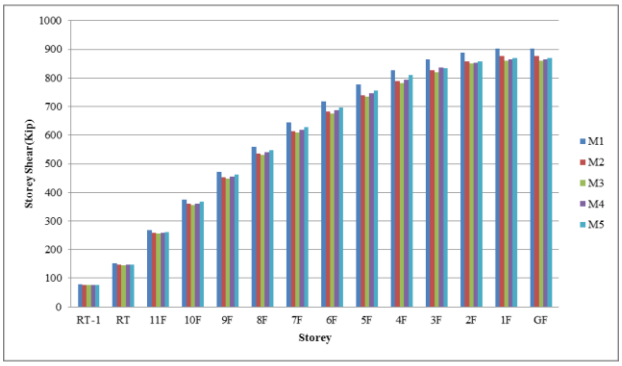


Figure.12 Comparison of storey shear in y direction

5.5 Torsional Iirregularity

The checking of torsional irregularity in both directions for this study is shown in Figure.13 and Figure.14. The torsional irregularity cannot exist as the values of Δmax/Δavg are smaller than the allowable limit (1.2) for all models.

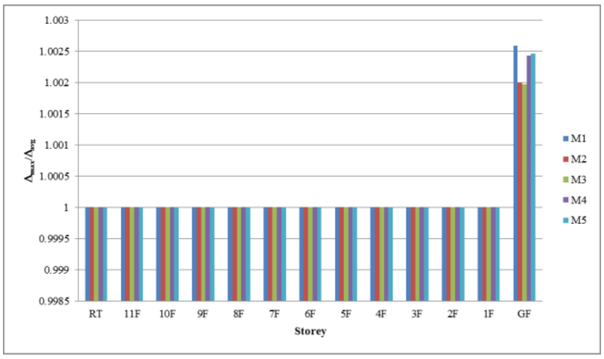


Figure.13 Comparison of $\Delta_{max}/\Delta_{avg}$ for torsional irregularity in x direction

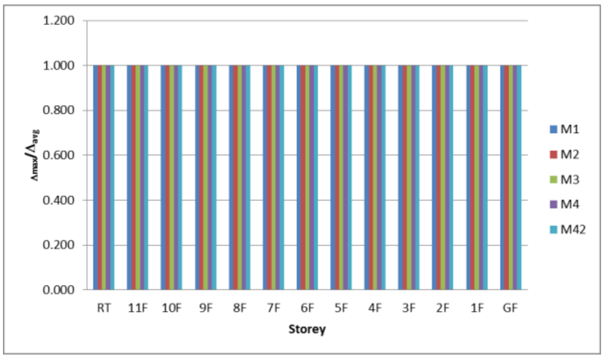


Figure.14 Comparison of $\Delta_{max}/\Delta_{avg}$ for torsional irregularity in y direction

6. CONCLUSION

1. Storey drifts of soft storey models in x-direction and y-direction are more than conventional building. It can be seen that the storey drift of model 2 at soft storey level is maximum in both directions. Storey drift of each soft storey level is more than drift limit and the higher the building, the more displacement will be there. Therefore, storey drift is significant in soft storey buildings.
2. P-Δ effect of model 1 and 4 are more than limitation in both directions. The stability coefficient for x and y direction of model 1 and 5 is smaller than the allowable limit in both directions. Therefore the P-Δ effect is more significant in soft storey models at low level.
3. Overturning moment of proposed models in x-direction and y-direction are nearly similar and it is increasing from top to bottom and these safety factors are less than 1.5.
4. The results of storey shear for all models in x and y directions are nearly similar. It is maximum at ground floor level and is gradually decreasing towards to the top storey of the structure.
5. The torsional irregularity cannot exist as the values of $\Delta max/\Delta avg$ are smaller than the allowable limit for all models.
6. According to study, overturning moment and torsional irregularity have less influence for soft storey level. However, the storey drift of model 2 at soft storey level is maximum in both directions and that of each soft storey level is more than limitation and the P-Δ effect is also significant in soft storey models at low level. Therefore, the structure is found more economical and safe when soft storey is avoided from ground, first and second storey.

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