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ANALYTICAL IDENTIFICATION OF THE MOST APPROPRIATE LOCATION OF A SOFT STOREY IN RC BUILDING

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ABSTRACT

The term soft-storey describes one level of a structure that is considerably greater flexible than the stories above and below it. Soft-storey buildings are particularly susceptible to earthquake damage. Generally, the soft or weak storey usually exists at the ground floor level, but there has been a need to design soft storey at the floor other then ground level. In present study, the most appropriate location of a soft storey in RC building frame is studied. A 5 storey RC building, subjected to seismic force is considered for analysis. The various analyses are performed for different location and height of soft storey. STAAD Pro. Software has been used for analysis. The structural forces, displacement and material quantity obtained from various analyses are compared to identify the most appropriate location of soft storey in RC building frame. The results indicate that soft storey located at first/second storey causes higher forces in the structure. Also, the structure is found more economical when soft storey is avoided from first/second storey. The structural forces and displacement increases with the increase in soft storey height.

Keywords- *Soft story structure, STAAD PRO software, Seismic Loading, Drift etc.*

1. INTRODUCTION

Structures are classified as having a soft story if, that level is less than 70% as stiff as the floor immediately above it, or less than 80 % as stiff as average stiffness of the three floor above it. Often, open-ground-storey structures are also called soft storey building, even though their ground storey may be soft or weak. Generally, the soft or weak storey usually exists at the ground floor level, but it could be at any other floor level as well. Soft story buildings are characterize by having a story which is situated over ground level with huge opening, such as parking, garage or series of retails business with large windows etc. The behavior of soft storey building in seismic force is very significant because soft storey structure is more flexible than normal floor. In seismic condition vibration happens more in soft storey building as compared to normal building and therefore it becomes important to study its behavior during such a mishap. In order to make it earthquake resistant we provide shear wall and bracing in soft storey building. The story having less stiffness due to reduced brickwork infill walls is called as soft storey. This soft story is the cause of a major weakness due to large retail spaces without brickwork infill walls. The soft story is often in the ground level of a building but in past there has been a need to design soft story at the floor other then ground level.

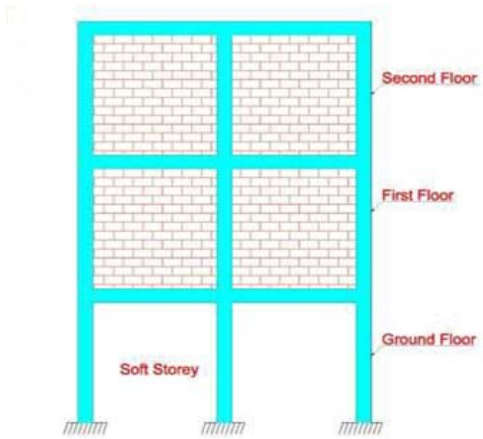

Figure 1: Soft storey structure

Chen and Constantinou (1990) studied that the practical system on purpose introduce flexibility at the first floor of a buildings was describe. In the structure use Teflon sliders to carry a part of the superstructure. Energy dissipation is provided by the first story ductile columns and by the Teflon sliders.

Sashi K. Kunnath (1991) emphasized the in-plane flexibility of floor-slab systems has been observed to influence the earthquake response of many types of reinforced concrete structures. The assumption of rigid floor diaphragms is often used to simplify engineering analyses without significant loss in the accuracy of earthquake response prediction for most structures. The study shows that the in-plane deflections of floor slabs impose a larger demand on strength and ductility of flexible frames than predicted values using the

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assumption of rigid or elastic slabs. These demands may in turn lead to a failure of the gravity-load supporting system.

Mo and Chang (1995) studied a practical system combining a flexible first story with sliding frictional interfaces. The system utilizes Teflon sliders at the top of the first story reinforced concrete framed shear walls to carry a portion of the superstructure.

Manabu Yoshimura, (1997) studied the strength deterioration was considering member nonlinearity, They virtual how the building behave and finally collapsed during the earthquake effect. The analysis was found to same structure and observed damages well, such as left displacement, mechanism and damages to members.

Kim Sang-Cheol and White Donald W (2004) studied recent seismic codes and standard generally use the same single degree-of-freedom (SDOF) model for low-rise building with inflexible diaphragms. On the other hand, flexible diaphragm structures behave in general as many degree-of-freedom (MDOF) systems. A simplified linear static methodology, applicable to structures with flexible storey, was proposed in this paper. The procedure was based on the assumption that the diaphragm stiff-nesses are small relative to the stiffness of the walls, and that the flexible diaphragms within the structure tend to respond independently of one another.

A. Plumier, et. al (2005) the objective of the study was to promote safety not including too much changing the constructional practice of reinforced concrete structures. A test plan was realize on cruciform beam-to-column nodes with a column inserted between infill. The complex solution increases the ductility significantly. The most common failure manner of reinforced concrete moment–frame building is the so called "soft storey" mechanism. It consists in the positions of structures' because the earthquake deformations and rupture in the bottom stories of the structures.

Ari Wibowo, et. al (2010) observed that precast soft storey structure had adequate displacement capacity for lower earthquake regions, but the performance was considered insufficient for higher earthquake regions.

Varadharajan et. al. (2013) conducted an extensive parametric study on plane RC moment resisting frames with setbacks. Firstly, a parameter called as irregularity index was proposed based on the dynamic characteristics of the frame to quantify the setback irregularity. Secondly, this paper aims to determine the affect of setback presence on inelastic deformation demands. To achieve this purpose, building frames with different arrangements of setbacks are modeled and designed in accordance with the European standard code of practice.

From the literature survey it is observed that researchers have worked in following areas of soft storey building-

- Analysis of soft storey building using Teflon sliders.
- Seismic analysis of soft storey three dimensional asymmetric multistory building.
- Seismic performance of soft storey building considering as moment- resisting steel frame.
- Seismic analysis of earthquake response of multistory mono-symmetric building
- Seismic analysis of earthquake response of multistory mono-symmetric building

2. PROBLEM FORMULATION

In the present work the effect of soft storey on structural performance having different geometrical configurations under earthquake force is studied. This problem associated with the soft story structure considering different geometrical and earthquake parameters. Here analysis of different structure of 12m x 16m in plan area and 5 storey (G+4) height is chosen for study. The results of member forces, drift, displacement and steel quantity for different geometrical configuration are compared to study the effect of soft storey position on structural behavior.

Table No.1 Details of soft storey structures

TYPE	Soft story floor height (m)	Foundation depth(m)
TYPE-A	4.0	1.5
TYPE-B	4.5	1.5
TYPE-C	5.0	1.5

Five soft story cases are generates for each type of structures as given in Table 2

Table No.2: Different cases of soft storey location

Case-I	Soft story at ground floor	
Case-II	Soft story at first floor	
Case-III	Soft story at second floor	
Case- IV	Soft story at third floor	
Case -V	Soft story at fourth floor	

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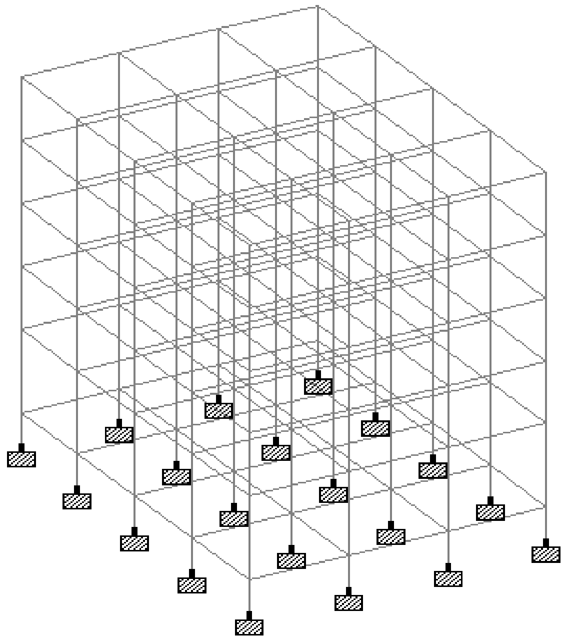

Figure 2: Isometric view of soft storey building (Type-A, B and C)

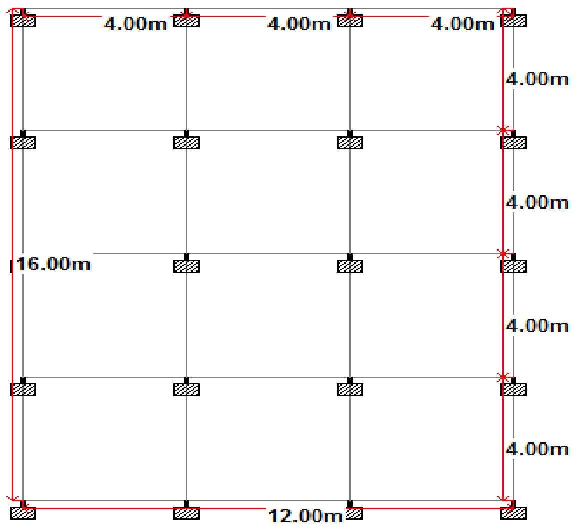

Figure 3: Plan of soft storey building (Type-A, B and C)

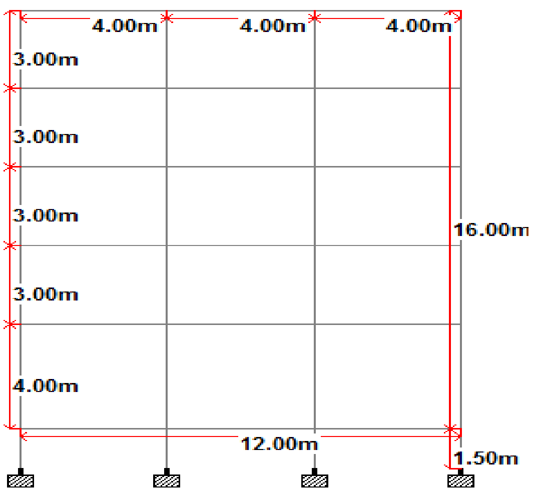

Figure 4: Elevation of Type-A structure

Live load:

Live load on top floor is taken as = 2 KN/m^2

Live load on intermediate floor is taken as = 4 KN/m^2

Table 3: Dead loads

Structural component	**Dead load** (kN)
(I) Outside wall (ii) Inside wall	12.88 kN/m 7.28 kN/m
(iii) Exterior member load at soft story(4m) floor height	17.48 kN/m
(iv) Exterior member load at soft story of (4.5m) floor height	19.78 kN/m
(v) Exterior member load at soft story of (5m) floor height	22 kN/m

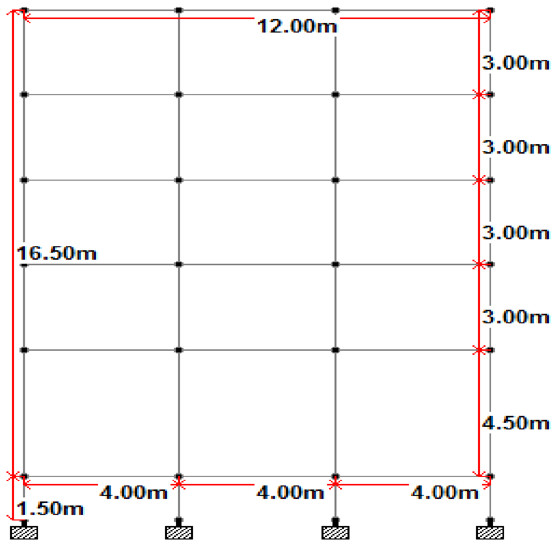

Figure 5: Elevation of Type-B structure

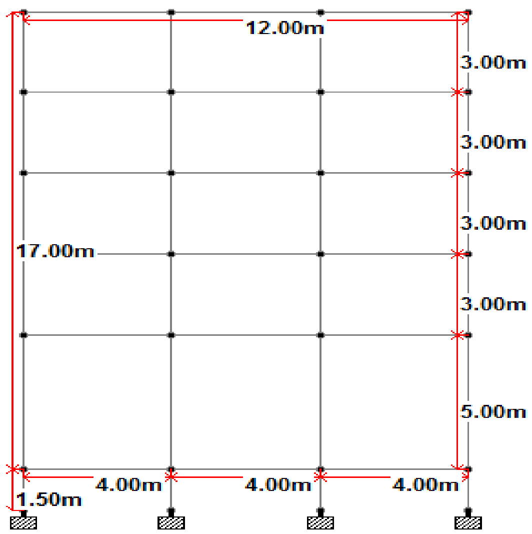

Figure 6: Elevation of Type-C structure

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3. DISSCUSSION

Discuss the structural force (bending moment in column and beam, shear force in beam, axial force in column), displacement in storey, storey drift, quantity of steel when soft storey at different location for Type A, B and C structure. The detail studies are shown in below-

3.1 Bending moment in column

Table 5: Depict the maximum bending moment in column for different soft storey location in Type-A structure and also obtained maximum bending moment at first and ground storey.

Table 4: Data/Parameters for analysis

S. No.	Description	Parameter
1	Depth of foundation	1.5 m
2	Floor to Floor height	3.00 m
3	Grade of concrete	M-25
4	Type of steel	Fe-415
5	Column size	0.4 m x0.4 m
6	Beam size	0.4 m x 0.4 m
7	Unit wt. of masonry wall	20 KN/m^3
8	Slab thickness	150 mm
9	Number of bays in lateral direction	3
10	Number of bays in transverse direction	4
11	Bay width in lateral direction	4 m
12	Bay width in transverse direction	4 m
13	Elastic modulus of concrete	2.5×10^7 KN/m^2
14	Poisson's ratio of concrete	0.17
15	Seismic zone	III
16	Importance factor	1
17	Building frame system	Ordinary RC moment-resisting frame
18	Response reduction factor	5

Table 5: Max. Bending moment (KN-m) in columns of Type-A structure

Cases	Column location					
	Below plinth	Ground Storey	1st Storey	2nd Storey	3rd Storey	4th Storey
Case 1	134.00	155.12	130.29	116.93	93.85	55.07
Case 2	122.95	146.19	167.58	125.43	96.19	55.83
Case 3	120.93	138.58	131.41	147.66	104.65	58.08
Case 4	120.53	137.19	123.52	115.53	121.24	64.22
Case 5	120.08	136.72	121.53	114.79	93.02	70.39

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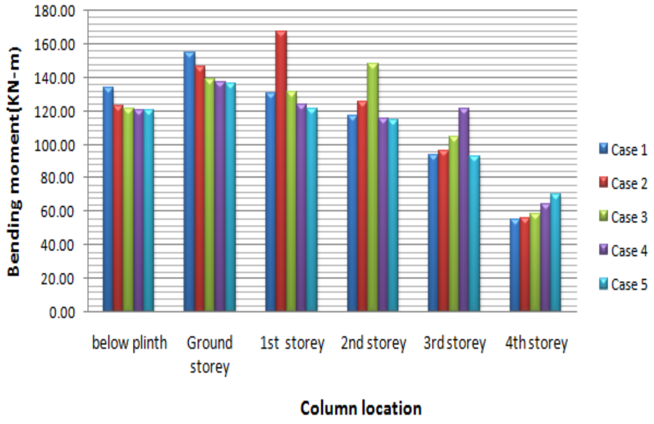

Figure 7: Maximum bending moment in column of Type A Structure

3.2 Comparisons of critical bending moment in column for Type A, B and C structures

Comparison of critical bending moment in column when soft storey at different location for Type A, B and C structures. It found critical bending moment at first storey among in all storey in each type of structures

Table 6: Comparison of critical bending moment (kN-m) at different stories of structures

Storey location	TYPE-A		TYPE-B		TYPE-C	
	Moment	Cases	Moment	Cases	Moment	Cases
Below plinth	134.00	I	138.639	I	143.51	I
Ground storey	155.12	I	168.83	I	193.18	I
First storey	167.58	II	180.43	II	182.25	II
Second storey	147.66	III	160.12	III	172.39	III
Third storey	121.24	IV	131.22	IV	141.62	IV
Fourth storey	70.39	V	76.48	V	83.14	V

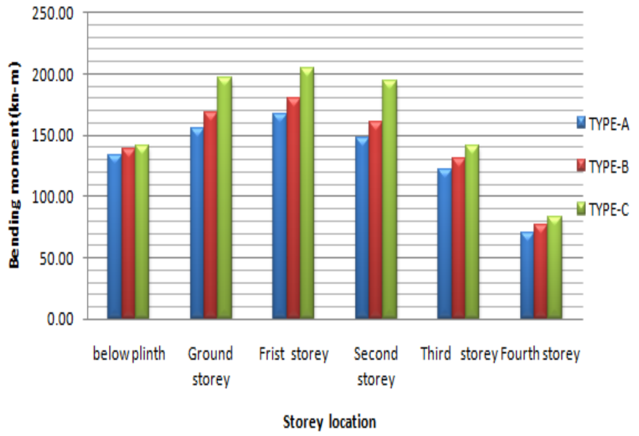

Figure 8: Comparison of critical bending moment (kN-m) at different stories of structures

3.3 Bending moment in beam:

Table 7: Depict the Maximum bending moment in beam when soft storey at different location for Type-A structure and found maximum bending moment at first and second floor among all floor.

Table 7: Max. Bending moment in beams of different storey for Type-A structure

Cases	Storey					
	Ground floor	First floor	Second floor	Third floor	Fourth floor	Fifth Floor
Case I	109.88	175.23	160.19	136.71	101.94	53.99
Case II	96.366	176.86	171.91	140.36	102.92	54.68
Case III	94.15	159.71	171.26	154.22	106.56	56.05
Case IV	93.75	157.31	159.36	150.67	116.35	59.38
Case V	92.89	156.42	156.41	136.96	112.64	61.73

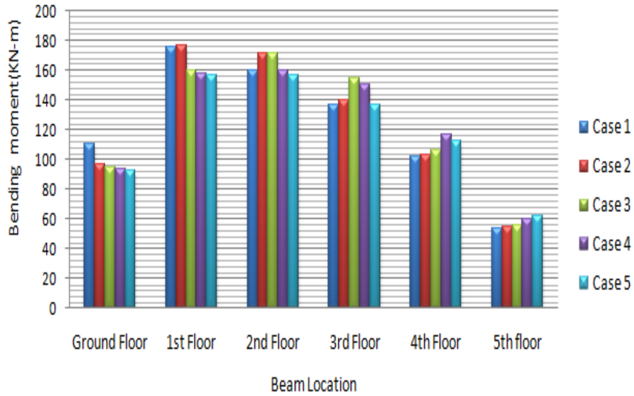

Figure 9: Max. Bending moment in beams of different storey for Type-A structure

3.4 Comparison of critical Bending moment beam for Type-A, B and C structures

Table 8: The comparison critical bending moment when soft storey at different location for Type-A, B and C structure and it found critical bending moment at first and second floor in each type of structures when soft storey located at first floor. This is represents graphically in fig.10

Table 8: Comparison of critical bending moment in beams for Type-A, B and C structures

Floor location	TYPE-A		TYPE-B		TYPE-C	
	Moment	Case	Moment	Case	Moment	Case
Ground floor	109.88	Case I	120.14	Case I	130.23	Case I
First floor	176.86	Case II	184.61	Case II	194.13	Case II
Second floor	171.91	Case II	182.31	Case II	193.12	Case II
Third floor	154.22	Case III	160.52	Case III	170.83	Case III
Fourth floor	116.35	Case IV	121.73	Case IV	128.68	Case IV
Fifth floor	61.73	Case V	65.27	Case V	69.42	Case V

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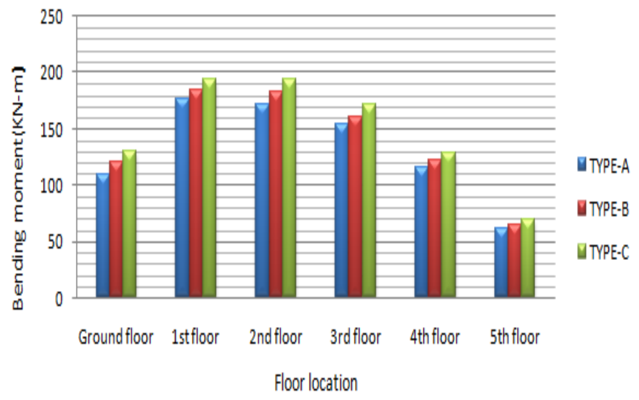

Figure 10: Comparison of critical bending moment in beams for Type-A, B and C structures

3.5 Shear force in beam for Type-A structure

Table 9: Depict the Maximum Shear force in beam when soft storey at different location for Type-A structure and found maximum shear force first/second floor among in all floor.

Table 9: Max. Shear force (kN) in beams of various storey for Type-A structure

Cases	Floors					
	Ground floor	First Floor	Second floor	Third floor	Fourth floor	Fifth Floor
Case I	91.38	123.328	113.11	101.62	57.64	47.49
Case II	78.25	134.4	121.46	103.45	88.51	47.51
Case III	77.41	115.74	132.86	111.09	89.24	47.86
Case IV	77.19	113.99	114.42	122.18	93.51	49.58
Case V	75.89	113.54	112.32	103.12	103.68	52.94

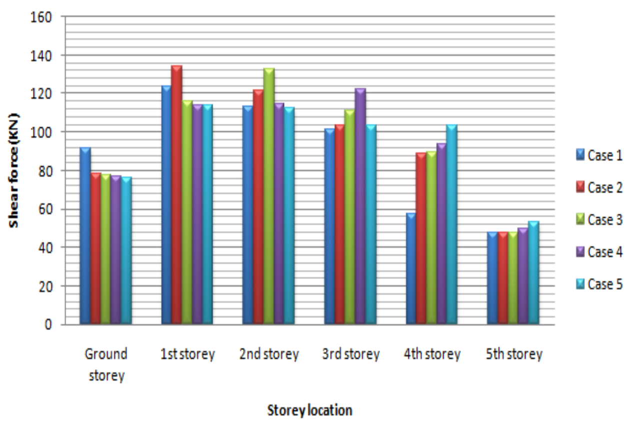

Figure 11: Max. Shear force (kN) in beams of various storey for Type-A structure

3.5 Comparison of critical Shear force in Beam for Type-A, B and C structures

Table 10: Comparison of max. Shear force when soft storey at different location for Type-A, B and C structure and it observed maximum shear force at first floor among in all floor. This is also represent graphically in fig.12

Table 10: Comparison of critical shear force (kN) in beam for Type-A, B and C structure

Beam location	TYPE-A		TYPE-B		TYPE-C	
	Moment	Cases	Moment	Cases	Moment	Cases
Ground floor	91.38	Case I	101.35	I	111.08	Case I
First floor	134.4	Case II	145.44	II	156.20	Case II
Second floor	132.77	Case III	132.877	III	154.51	Case III
Third floor	125.21	Case IV	125.21	IV	143.08	Case IV
Fourth floor	105.49	Case V	105.49	V	119.95	Case V
Fifth floor	55.09	Case V	55.09	V	57.55	Case V

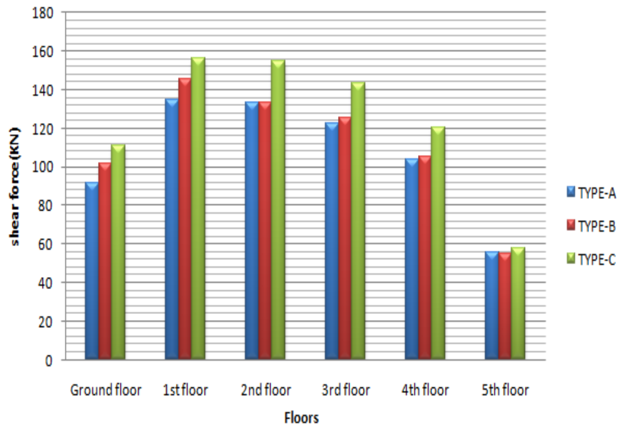

Figure 12: Comparison of critical shear force (kN) in beam for Type-A, B and C structure

3.6 Comparison of max. Displacement

Table 11: shows the comparison of maximum displacement between Type-A, B and C structure. The maximum displacement is found in fifth floor for case II

Table 11: Comparison of critical displacement (mm) in floors of Type-A, B and C structures

CASES	TYPE-A		TYPE-B		TYPE-C	
	DISPLACEMENT	FLOOR	DISPLACEMENT	FLOOR	DISPLACEMENT	FLOOR
Case I	43.27	Fifth	46.864	Fifth	51.05	Fifth
Case II	44.58	Fifth	48.743	Fifth	53.49	Fifth
Case III	43.49	Fifth	47.492	Fifth	53.04	Fifth
Case IV	43.03	Fifth	46.28	Fifth	50.00	Fifth
Case V	39.06	Fifth	41.32	Fifth	43.29	Fifth

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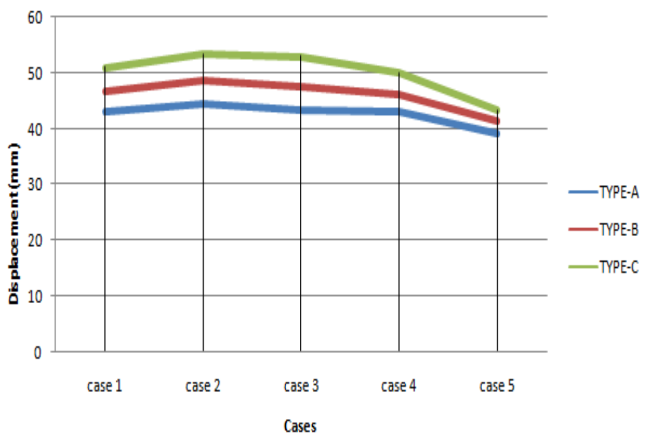

Figure 13: Representation of Critical case due to maximum displacement in floors of different structures

3.7. Comparison of steel quantity in Type-A, B and C structures

Table 12: Comparison of maximum quantity of steel when location of soft storey at different storey for Type-A, B and C structure, and found maximum quantity of steel are required in case II and minimum in case-V in each type of structures. This also represent graphically in fig. 14

Table 12: Comparison of quantity of steel (kN) required in different cases for Type A, B and C structure

Cases	TYPE-A	TYPE-B	TYPE-C
	Quantity of steel	Quantity of steel	Quantity of steel
Case-I	138.44 (2.4%)'	146.72 (8.32%)	157.06(13.98%)
Case-II	145.24 (7.40%)	152.12 (12.40%)	161.80(17.43%
Case-III	144.29 (6.70%)	151.92 (12.30%)	159.92(16.06%)
Case-IV	140.08 (3.6%)	144.82 (7.00%)	148.96 (7.91%)
Case-V	135.20 (--)	135.36 (--)	137.79 (--)

Note: Value in the bracket indicates percentage increase in steel with respect to case V

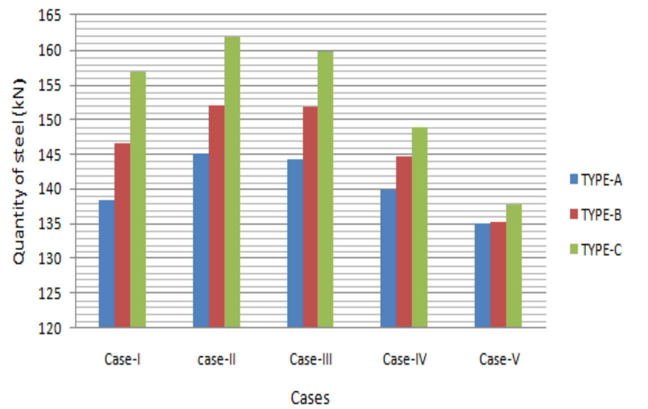

Figure 14: Comparison of quantity of steels in different cases for Type A, B and C structure.

4. CONCLUSIONS

The important conclusions drawn from the study are as follows-

1. For different locations of soft storey the bending moment in column is found to be higher at ground storey and first storey columns however lower bending moment is found in top storey columns. In a particular storey bending moment value is found to be critical when soft storey is located at that storey. The column forces increase with the increase in soft storey height.

2. For different locations of soft storey the bending moment in beam is found to be higher at first floor and second floor beam however lower bending moment is found at top floor beam. In a particular storey bending moment is found to be critical when soft storey is located at that storey.

3. For shear force in beam is found to be higher at first floor and second floor and minimum in top floor beam. In a particular storey shear force is found to be critical when soft storey is located at that storey. The beam forces increases with the increase in soft storey height

4. The results of present study indicate that the structural forces and displacements are found to be higher when soft storey is located at first/second storey. The reinforcement quantity required in structure is found to be approximately 10% higher if soft storey is provided at first/second storey in comparison to soft storey provided at top storey. Hence, soft storey should be avoided at first/second storey. However, if needed, it can be provided at top storey.

5. For different location of soft storey the displacement in floor is found to be higher at top floor. The lesser floor displacement is found for the floors located above the soft storey. The floor displacement increases with the increase in soft storey height.

6. Whereas drift in floors are found to be higher at second floor and found nature of drift is parabolic and maximum value of drift at second floor.

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