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Evaluation Of Seismic Performance Of G+10 Rcc Building With Soft Storey At Various Levels In Seismic Zone & Using Staad.Pro

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Abstract: This study investigates the seismic safety of high-rise reinforced cement concrete (RCC) buildings, specifically focusing on the soft storey irregularity often caused by open ground floors for vehicle parking. A G+10 building is analysed using STAAD.Pro software across India's two seismic zones (II and III) to evaluate performance under earthquake loads. By introducing soft storeys at various levels, the research compares key parameters like storey drift, lateral displacement, and base shear. The findings identify the most critical soft storey positions and highest vulnerability zones while benchmarking deviations. Ultimately, this comparative analysis aims to recommend improved design practices to enhance earthquake resistance and structural stability in multi-storey buildings facing potential seismic risks.

***Index Terms* -** Seismic Analysis, Soft Storey, Storey Drift, STAAD.Pro, G+10 RCC Building.

I. INTRODUCTION

In the rapidly densifying urban landscapes of India, the construction of multi-storey reinforced concrete structures is essential to accommodate the growing population. However, architectural and functional requirements often introduce vertical irregularities, specifically variations in stiffness. The most prevalent issue is the 'soft storey' effect, frequently created when the ground floor is kept open for vehicle parking, reception lobbies, or commercial shops. While this design is convenient, it significantly reduces stiffness due to the absence of masonry infill walls, making the building structurally vulnerable.

During seismic activity, the upper floors act as a rigid block, forcing the flexible soft storey to absorb the majority of the lateral deformation, which often results in catastrophic failure. Therefore, prioritising earthquake-resistant design is critical for civil engineers. This study uses advanced structural analysis tools like STAAD. Pro to model realistic building behaviour and accurately evaluate the impact of stiffness irregularities. By comparing the seismic response of buildings with and without soft storeys, the research aims to assess safety levels and propose effective retrofitting or design measures to enhance structural stability against earthquakes.

Types of Structural Irregularities

Structural irregularities are conditions where a building does not have uniform strength, mass, or stiffness, causing it to behave unpredictably during an earthquake. They are mainly classified into two groups: plan irregularities and vertical irregularities. Plan irregularities occur when the shape or layout of the building is uneven, leading to twisting or uneven distribution of forces. Vertical irregularities arise when the stiffness, mass, or geometry changes suddenly from one floor to another, such as in soft story, mass irregularity, or setback buildings. These irregularities make the structure more vulnerable to seismic forces and require special design considerations.

II. LITERATURE REVIEW

Pravesh Gairola (2019) [1] In this paper an investigation has been made to study the seismic behaviour of soft storey building with different models (Bare frame, Infill frame, Bracing Frame, Shear wall frame) in soft storey building when subjected to earthquake loading. It is observed that, providing different models improves resistant behaviour of the structure when compared to soft storey provided.

Akhilesh Yadav (2017) [2] Practising structural engineers often observe that the multiplication factor of 2.5 is unrealistic for low-rise buildings with an open ground storey (OGS). Hence, this thesis critically assesses this factor, considering the effects of masonry infill walls and support conditions. The analysis confirms that the value of 2.5 is excessive for such structures. It is noted that standard elastic analysis fails to accurately identify OGS vulnerabilities due to stiffness similarities with bare frames. However, nonlinear analysis reveals that these buildings succumb to a brittle soft-storey failure mechanism at lower base shear and displacement. Crucially, the study concludes that support conditions significantly influence the multiplication factor, necessitating a review of current design practices.

Jamdar Ameerhusain S (2020) [3] The present study focuses on investigating the impact of soft storey irregularities in high-rise multi-storied buildings. Using identical building plans, various models were created where the soft storey level is altered across different floors. The structural analysis was carried out using STAAD.Pro software, employing both equivalent static analysis and linear dynamic analysis, specifically the Response Spectrum method. The objective is to understand how shifting the location of the soft storey influences seismic behaviour. Key seismic parameters such as time period, storey shear, and storey displacement were meticulously examined. The findings conclude that the fundamental natural period of a bare frame depends not only on building height but also on span length and stiffness, factors often not fully quantified in Codal expressions.

Kiran Tidke (2016) [4] In this paper effect of masonry infill wall on building is studied. Dynamic analysis of building with different arrangement is carried out. For analysis G+7 R.C. frame building is modelled. The width of strut is calculated by equivalent diagonal strut method. Analysis is carried by SAP2000 software. Base shear, max. storey drift, Displacement is calculated and compared for all models. Some of main conclusion as follows, RC frame with masonry infill with and without soft storey is having highest value of base shear than bare frame. The presence of infill wall can affect the seismic behaviour of frame structure to large extent, and the infill wall increases the strength of stiffness of structure.

Ashitosh C. Rajurkar (2016) [5] This paper report comprises of seismic analysis of a six storied R.C. building with symmetrical plan. Analysis is performed for Bare frame, Frame with infill wall. Building is analysed using Equivalent static method. The building is modelled as a 3D space frame with six degrees of freedom at each node using the software STAAD.Pro V8i.Results are obtained by comparing base shear and maximum displacement in X & Z directions. So, it is concluded that. The consideration of stiffness of masonry infill greatly increases the stiffness of the structure and therefore reduces the natural period and consequently increase the response acceleration and therefore the seismic forces (i.e. base shear and correspondingly the lateral forces at each storey.

III. METHODOLOGY AND CASE CONSIDERATIONS

3.1 Methodology

The building was first modelled in STAAD.Pro using the planned dimensions, material properties, and structural details. Different versions of the model were then created by introducing a soft story at selected levels. Seismic loads were applied according to IS codes, and both static and dynamic analyses were performed. Key results such as displacement, drift and base shear were collected and compared between regular and soft-story models. The behaviour of the structure was then interpreted to understand how the soft story affects its seismic performance.

3.1.1 Literature review

Previous studies consistently show that soft-story irregularity greatly influences the seismic performance of multi-story buildings. Researchers have found that when one story has significantly lower stiffness, earthquake forces concentrate at that level, causing larger displacement and drift. Many authors highlight that open-ground-story buildings are especially vulnerable due to the absence of infill walls. Analytical studies using software like STAAD.Pro also indicate that soft story's increase column demand, reduce stability, and may lead to collapse during strong shaking. Overall, literature agrees that identifying and strengthening the soft story is crucial for improving seismic safety.

3.1.2 Modelling of Building

For easy work flow during progress of work, whole work is divided into various parts which are in detail as discussed below

3.1.3 Building Plan and Dimension Details

The following are the specification of G+ 10 storied irregular RC building. Here the rectangular shaped building is selected. For modelling in STAAD Pro.V8i software the first step is to specify nodal co-ordinate. Then beams, columns and plate elements to be modelled and assign the properties for beams, columns and the plates. After assigning the sectional property to the member it is important to assign it with member properties. Material properties include modulus of elasticity, poison's ratio, weight density, thermal coefficient, damping ratio and shear modulus.

3.1.4 Load Formulation

As it is well known that while analysing it is advised to go for various load combinations as they are more severe while studying the behaviours of building under earthquake. In the present work Static gravity loads were taken from IS 875 part 1 and part 2 and their combinations were as per IS 456:2000 while earthquake loads and their combinations were taken as per IS 1893 (part 1) 2002.

3.1.5 Analysis

The six dimensional reinforced concrete structures with G+10 storied building with soft storeys at different level are analysed using STAAD Pro software. The main code for the analysis is IS 1893 (Part I) 2002 and provide the outline for calculating seismic design force. The method of analysis used is Equivalent static analysis to calculate displacement, base shear and storey drift. Among the different types of analysis, seismic analysis comes forward because of its optimal accuracy, efficiency and ease of use. Seismic analysis is done to evaluate the maximum shear force, bending moment and the dynamic results in the form of storey drift and lateral displacements. Equivalent Static Analysis defines a series of forces acting on a building to represent the effect of earthquake ground motion.

3.2 Case Considerations

The various building parameters and material constants along with the detailed description about case considered as per tables given below.

3.2.1 Material Constants

Material constants were defined according to standard code specifications to ensure accurate modelling of the building. Concrete properties such as compressive strength, modulus of elasticity, Poisson's ratio and unit weight were assigned based on the selected concrete grade. Similarly, steel reinforcement was characterized using its yield strength, modulus of elasticity and density. These material constants provide the fundamental input needed by the software to simulate real structural behaviour and ensure reliable analysis results.

3.2.2 Building Parameters

Parameter	Value
Live load	3 KN/m2
Live load at upper soft story's	5 KN/m2
Density of concrete	25 KN/m3
Thickness of slab	125 mm
Depth of beam	380 mm
Width of beam	230 mm
Dimension of column	300 x 450 mm
Thickness of outside wall	230 mm
Thickness of Parapet wall (1m)	100 mm
Height of floor	3.40 m
Earthquake zone	II/III
Damping ratio	5%
Type of soil	II
Type of structure	Special moment resisting frame
Response reduction factor	5
Importance factor	1.5
Roof treatment	1 KN/m2
Floor finishing	1 KN/m2
Number of Story's	11 (G+10)
Depth of Foundation	1.50 m

Table 3.2 Building Parameters

3.2.3 Model Nomenclature

Model Description	Label
Soft Story at ground floor in Zone-II	S1
Soft Story at fifth floor in Zone-II	S2
Soft Story at eleventh floor in Zone-II	S3
Soft Story at ground floor in Zone-III	S4
Soft Story at fifth floor in Zone-III	S5
Soft Story at eleventh floor in Zone-III	S6

Table 3.2.3 Model Nomenclature

IV. ANALYSIS

4.1 Load consideration

As discussed earlier Static analysis for earthquake is performed on all 06 models.

4.1.1 Types of Loads and Their intensities

All the intensities of Gravity loads and Earthquake loads which are taken in this present work are as shown below, which are directly extracted from STAAD.Pro.

Load No.	Load Type	Title	Description / Intensities Extracted from STAAD.Pro
1	Seismic	Eq(-X)	1893 Load X = -1
2	Seismic	Eq(+X)	1893 Load X = +1
3	Seismic	Eq(-Z)	1893 Load Z = -1
4	Seismic	Eq(+Z)	1893 Load Z = +1
5	Dead Load (DL)	DL	- Self weight: Y = -1 - Floor Load: Y-range 3.4 to 40, Fload = -1 Gy - External Wall Load: 13.49 kN/m - Internal Wall Load: 6.04 kN/m
6	Live Load (LL)	LL	- Floor Load: Y-range 3.4 to 34, Fload = -3 Gy

4.2 Load consideration

All models were analysed with various loading combinations as per IS 1893 (part1) 2002. Following are the various combinations as in STAAD.Pro.

Combination No.	STAAD Title (Generated Indian Code)	Load Combination Expression
7	General_Structures 1	1.5 DL + 1.5 LL
8	General_Structures 2	1.2 DL + 1.2 LL
9	General_Structures 3	1.2 DL + 1.2 LL + 1.2 Eq(-X)
10	General_Structures 4	1.2 DL + 1.2 LL + 1.2 Eq(+X)
11	General_Structures 5	1.2 DL + 1.2 LL + 1.2 Eq(-Z)
12	General_Structures 6	1.2 DL + 1.2 LL + 1.2 Eq(+Z)
13	General_Structures 7	1.2 DL + 1.2 LL - 1.2 Eq(-X)
14	General_Structures 8	1.2 DL + 1.2 LL - 1.2 Eq(+X)
15	General_Structures 9	1.2 DL + 1.2 LL - 1.2 Eq(-Z)
16	General_Structures 10	1.2 DL + 1.2 LL - 1.2 Eq(+Z)
17	General_Structures 11	1.5 DL
18	General_Structures 12	1.5 DL + 1.5 Eq(-X)
19	General_Structures 13	1.5 DL + 1.5 Eq(+X)
20	General_Structures 14	1.5 DL + 1.5 Eq(-Z)
21	General_Structures 15	1.5 DL + 1.5 Eq(+Z)
22	General_Structures 16	1.5 DL - 1.5 Eq(-X)
23	General_Structures 17	1.5 DL - 1.5 Eq(+X)
24	General_Structures 18	1.5 DL - 1.5 Eq(-Z)
25	General_Structures 19	1.5 DL - 1.5 Eq(+Z)
26	General_Structures 20	0.9 DL + 1.5 Eq(-X)
27	General_Structures 21	0.9 DL + 1.5 Eq(+X)
28	General_Structures 22	0.9 DL + 1.5 Eq(-Z)
29	General_Structures 23	0.9 DL + 1.5 Eq(+Z)
30	General_Structures 24	0.9 DL - 1.5 Eq(-X)
31	General_Structures 25	0.9 DL - 1.5 Eq(+X)

32	General_Structures 26	0.9 DL - 1.5 Eq(-Z)
33	General_Structures 27	0.9 DL - 1.5 Eq(+Z)

V. RESULTS

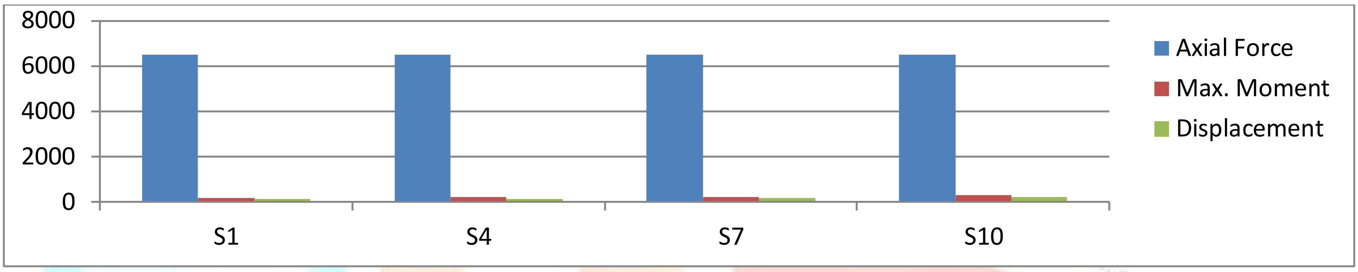
Results for various parameters of building such as Maximum Axial Forces, Maximum Storey Drift, Maximum Displacement, Base Shear Distribution, and Reinforcement quantity were plotted zone wise to understand the detail behaviour of each building.

5.1 Result Comparison for Similar level Soft Storey in all seismic zones

1) Comparison for Max. Axial Force, Moment and Displacement

Table 5.1 Axial Force, Moment and Displacement Comparison for S1, S4

Sr. No.	Model No.	Max. Axial Force (KN)	Max. Moment (KN.m)	Max. Displacement (mm)
1	S1	6506.51	197.68	131.46
2	S4	6506.51	217.05	143.59



Graph 5.1 Comparison of Axial forces, Max. Moment, Max. Displacement for model S1, S4

2) Comparison for Max. Axial Force, Moment and Displacement

Table 5.2 Axial Force, Moment and Displacement Comparison for S2, S5

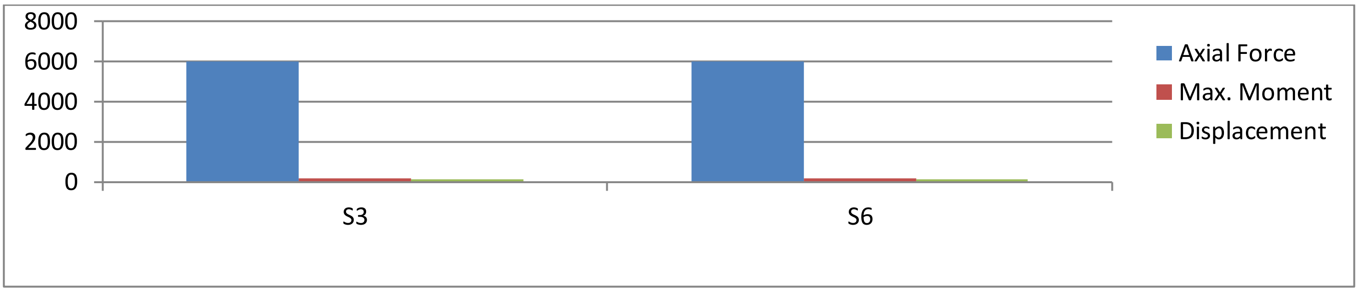
Sr. No.	Model No.	Max. Axial Force (KN)	Max. Moment (KN.m)	Max. Displacement (mm)
1	S2	6213.90	185.91	138.26
2	S5	6213.90	201.58	141.26

Graph 5.2 Comparison of Axial forces, Max. Moment, Max. Displacement for model S2, S5

3) Comparison for Max. Axial Force, Moment and Displacement

Table 5.3 Axial Force, Moment and Displacement Comparison for S3, S6

Sr. No.	Model No.	Max. Axial Force (KN)	Max. Moment (KN.m)	Max. Displacement (mm)
1	S3	6067.52	184.64	132.19
2	S6	6067.52	203..71	173.31

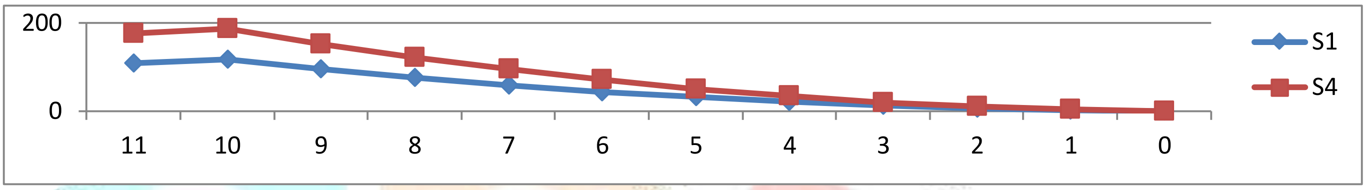


Graph 5.3 Comparison of Axial forces, Max. Moment, Max. Displacement for model S3, S6

4) Comparison for Base Shear Distribution

Table 5.4 Storey Shear Distribution Comparison for S1, S4

Sr. No.	Height	Storey Level	Model	
			S1	S4
1	37.40	11	110.81	171.91
2	34.00	10	120.62	182.65
3	30.60	9	092.65	156.10
4	27.20	8	079.32	128.51
5	23.80	7	061.23	96.27
6	20.40	6	049.29	73.56
7	17.00	5	035.56	52.71
8	13.60	4	029.86	39.16
9	10.20	3	016.34	23.87
10	6.80	2	009.50	14.69
11	3.40	1	003.73	5.73
12	0.00	0	000.13	0.19

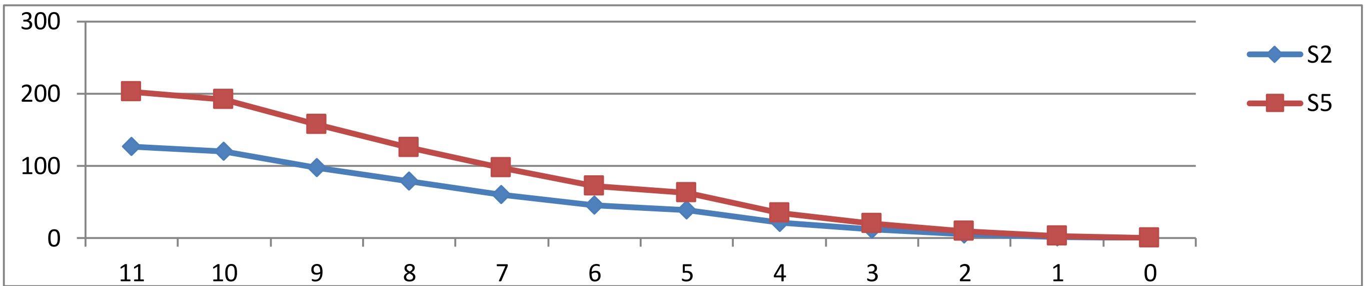


Graph 5.4 Comparison of Storey shear distribution for model S1, S4

5) Comparison for Base Shear Distribution

Table 5.5 Storey Shear Distribution Comparison for S2, S5

Sr. No.	Height	Storey Level	Model	
			S2	S5
1	37.40	11	132.61	210.39
2	34.00	10	121.16	193.51
3	30.60	9	102.64	169.13
4	27.20	8	83.73	134.10
5	23.80	7	59.83	97.14
6	20.40	6	47.62	76.91
7	17.00	5	36.48	67.20
8	13.60	4	25.82	39.12
9	10.20	3	17.07	22.65
10	6.80	2	8.51	12.73
11	3.40	1	5.16	5.49
12	0.00	0	0.085	0.17

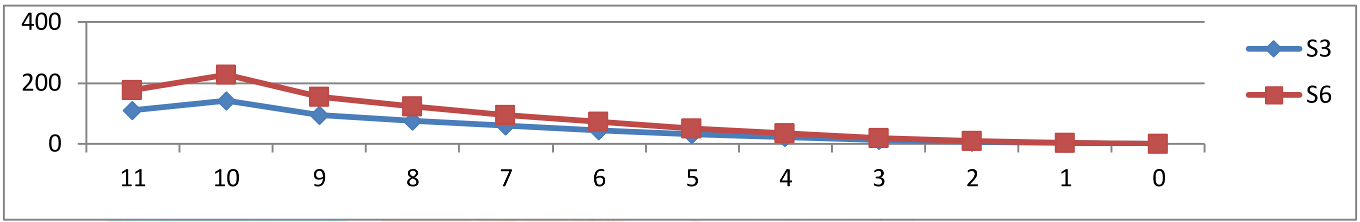


Graph 5.5 Comparison of Storey shear distribution for model S2, S5

6) Comparison for Base Shear Distribution

Table 5.6 Storey Shear Distribution Comparison for S3, S6

Sr. No.	Height	Storey Level	Model	
			S3	S6
1	37.40	11	114.13	183.61
2	34.00	10	135.13	223.16
3	30.60	9	85.32	165.12
4	27.20	8	76.00	129.20
5	23.80	7	59.31	98.71
6	20.40	6	42.04	77.71
7	17.00	5	35.61	49.45
8	13.60	4	26.31	36.15
9	10.20	3	17.30	26.42
10	6.80	2	8.43	19.32
11	3.40	1	5.41	4.29
12	0.00	0	0.49	0.16

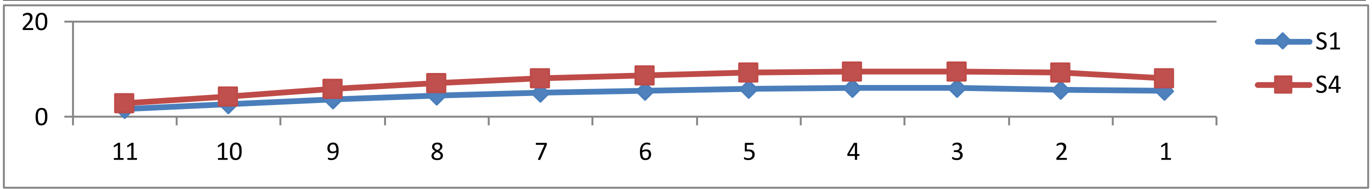


Graph 5.6 Comparison of Storey shear distribution for model S3, S6

7) Comparison for Storey Drift

Table 5.7 Storey displacement Comparison for model S1, S4

Sr. No.	Height	Node No.	Model	
			S1	S4
1	37.40	427	1.15	2.19
2	34.00	392	2.30	4.16
3	30.60	357	3.96	5.46
4	27.20	322	4.15	7.65
5	23.80	287	5.43	8.58
6	20.40	252	5.16	8.14
7	17.00	217	5.78	9.85
8	13.60	182	6.15	9.54
9	10.20	147	6.19	9.87
10	06.80	112	5.16	9.45
11	03.40	77	5.43	8.74

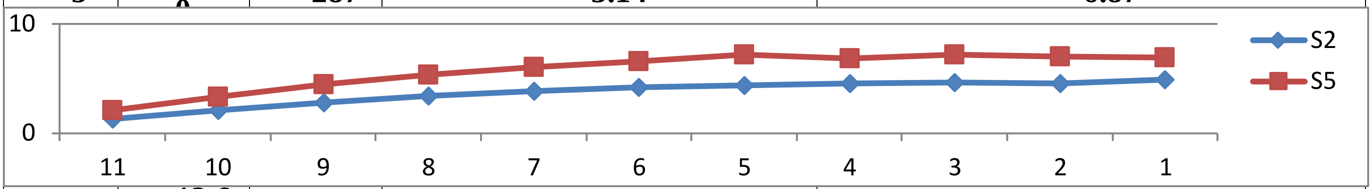


Graph 5.7 Storey displacement Comparison for model S1, S4

8) Comparison for Storey Drift

Table 5.8 Storey displacement Comparison for model S2, S5

Sr. No.	Height	Node No.	Model	
			S2	S5
1	37.40	427	1.87	2.84
2	34.00	392	2.41	3.15
3	30.60	357	2.80	4.49
4	27.20	322	3.89	5.58
5	23.80	287	3.14	6.87
8	13.60	182	4.21	6.56
9	10.20	147	4.85	7.48
10	06.80	112	4.47	6.36
11	03.40	77	4.95	6.41

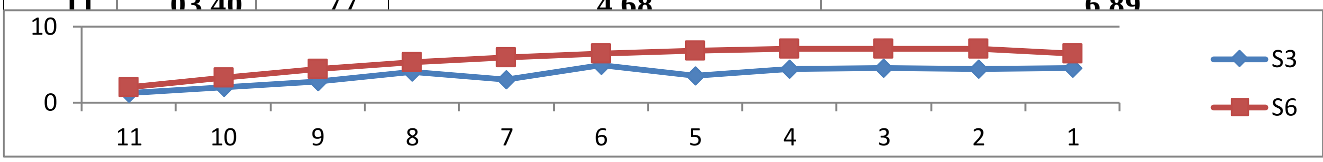


Graph 5.8 Storey displacement Comparison for model S2, S5

9) Comparison for Storey Drift

Table 5.9 Storey displacement Comparison for model S3, S6

Sr. No.	Height	Node No.	Model	
			S3	S6
1	37.40	427	1.41	2.10
2	34.00	392	2.50	3.65
3	30.60	357	2.65	4.41
4	27.20	322	4.74	5.56
5	23.80	287	3.84	6.78
6	20.40	252	4.41	6.12
7	17.00	217	3.88	6.75
8	13.60	182	4.11	7.12
9	10.20	147	4.58	7.87
10	06.80	112	4.41	7.15
11	03.40	77	4.68	6.89

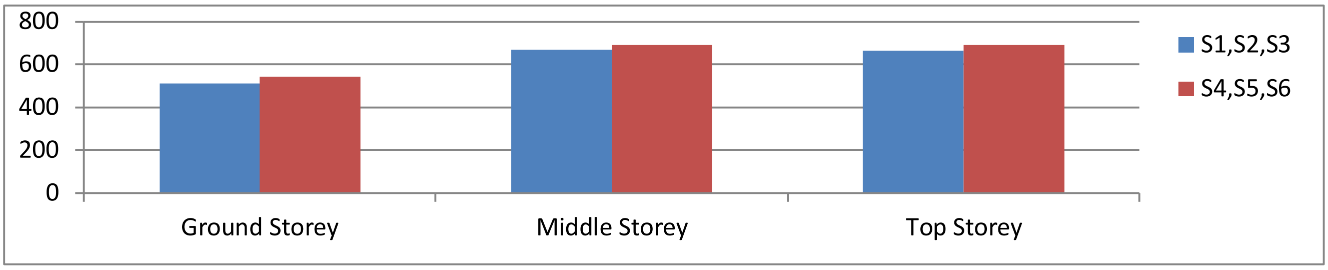


Graph 5.9 Storey displacement Comparison for model S3, S6

10) Reinforcement Comparison

Table 5.10 Reinforcement Comparison for all model

Sr. No.	Storey level	Model	Quantity (KN)
01	Ground Storey	S1	509.46
02		S4	541.15
03	Middle Storey	S2	665.63
04		S5	689.799
05	Top Storey	S3	663.16
06		S6	688.626



Graph 5.10 Reinforcement Comparison for all models

VI. CONCLUSIONS

Based on various model analysis and their result comparison following conclusions were drawn

1. Storey shear increases as the level of soft storey changes from lower to higher.
2. Bending moment in the structure decreases as the soft storey moves from lower location to higher location.
3. The displacement in the structure decreases with the variation in the zone in increasing order of the structure with the decrease in the bending moments.
4. Storey drift decreases as the location of soft storey in the structure changes from bottom upwards.
5. Storey drift increases with the change in location of structure with respect to the change in zone from lower to higher.
6. The stability of structure is more at the top than the soft storey at the middle of the structure.
7. The reinforcement requirement for soft storey at middle of the structure is maximum as compared to the soft storey at ground floor and top floor.

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