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Seismic Performance Evaluation Of A G+10 RCC Building With Soft Storeys At Various Levels Using STAAD.Pro Across Different Seismic Zones

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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 four seismic zones (IV and V) 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.

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

Akshay Paidalwaar (2017) [1] This research, focusing on mid-rise Reinforced Concrete (RC) buildings in India, examines the soft storey effect caused by the absence of infill walls at the ground level (Open Ground Storey or OGS). We used both linear static and nonlinear static (pushover) analyses to assess this behaviour. Key evaluation factors were the building's displacement, drift demand, and overall structural response due to varying infill configurations. The study highlights that structural stiffness is crucial in OGS-type buildings. While infill walls increase stiffness, this increase is often insufficient to protect the structure against significant seismic forces. Furthermore, the soft storey problem is poorly identified by elastic analysis, as the initial stiffness of OGS buildings often appears similar to that of bare-frame structures.

Piyush Tiwari (2015) [2] The primary goal of this study is to evaluate the applicability of a 2.5 multiplication factor and the impact of infill wall strength and stiffness on the seismic analysis of Open Ground Storey (OGS) reinforced concrete (RC) framed buildings. Using the ETABS software, three models of an existing OGS building located in Seismic Zone V were analysed. The stiffness of the infill walls, including those with openings, was modelled using the Diagonal Strut approach. Both linear and nonlinear analyses were performed and the results compared. The study concluded that analysing a structure as a bare frame significantly underestimates the base shear. This underestimation can lead to the structural collapse of OGS buildings during an earthquake. Therefore, it is critical to accurately incorporate the infill walls into the seismic analysis for safety.

Kevin Shah (2017) [3] This study investigates the seismic response of a G+14 building located in the highly active Zone 5 region of India, focusing on the impact of various irregularities. We calculated the storey shear, storey drift, and storey displacement for the structure using the ETABS software. The irregularities considered were: Mass Irregularity (Soft Storey): The first floor lacks infill masonry walls, while all floors above it includes them and Vertical Geometric Irregularity: The building has an uneven shape and geometry in its vertical profile. In Zone 5, structures often fail due to extreme lateral loads. We analysed these lateral loads in both directions (EQx) and (EQy). The results indicated that the top storey displacement was highest for the vertically irregular structure and lowest for the symmetrical infill wall structure.

N. Anvesh (2015) [4] This study analyses a G+10 Reinforced Cement Concrete (RCC) building, comparing models with and without mass irregularity at the third and sixth floors. The core focus is to highlight the structural effects of floors having different loads (mass irregularity) in a multi-storey structure. Our results show that beams located in the refuse areas (the irregular floors) experience significantly higher shear force and bending moment. Crucially, the deflection in these refuse area beams is greater in the mass-irregular building compared to the regularly structured building. Furthermore, the analysis reveals a substantial increase of 67% in the moments of the mass-irregular buildings compared to the buildings without mass irregularity.

Mr. Pathan Irfan Khan (2016) [5] This paper investigates the influence of mass irregularity, specifically incorporating swimming pools on the 3rd, 6th, and 9th floors, on a G+10 reinforced concrete (RCC) building. Using Response Spectrum Analysis (RSA) within STAAD-Pro V8i, the seismic performance was assessed. Key parameters calculated include the maximum base shear in both X and Z directions, as well as the lateral displacements and storey drifts. Furthermore, the axial forces, torsion, and bending moments were evaluated for six critical columns. The RSA results consistently indicated that the storey shear force was highest at the first storey, progressively reducing to its minimum value at the topmost floor across all modelled scenarios.

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	IV/V
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-IV	S1
Soft Story at fifth floor in Zone-IV	S2
Soft Story at eleventh floor in Zone-IV	S3
Soft Story at ground floor in Zone-V	S4
Soft Story at fifth floor in Zone-V	S5
Soft Story at eleventh floor in Zone-V	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

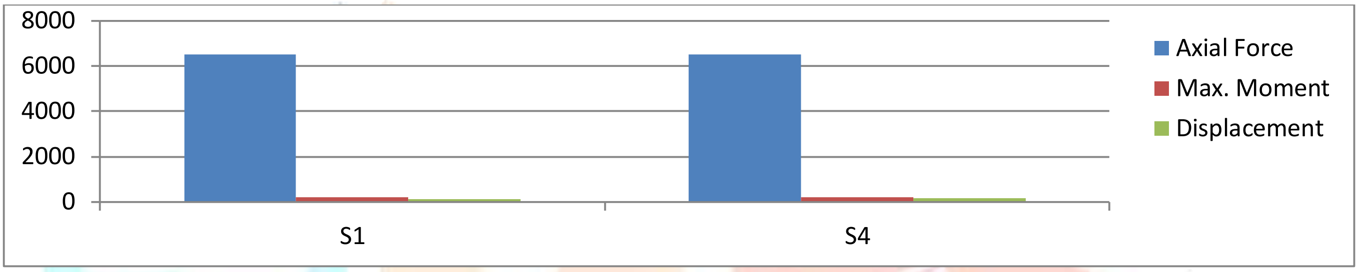
Results for various parameters of building such as Maximum Axial Forces, Maximum Storey Drift, Maximum Displacement, Base Shear Distribution, and Reinforcement quantity were plotted zone wise to understand the detail behaviour of each building.

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	249.68	171.46
2	S4	6506.51	315.07	223.59

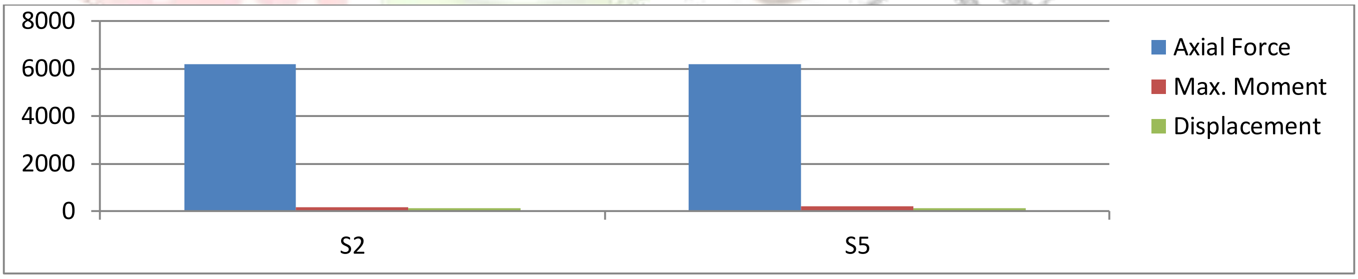


Graph 5.1 Comparison of Axial forces, Max. Moment, Max. Displacement for model S1, S4

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	238.91	158.26
2	S5	6213.90	289.58	189.26

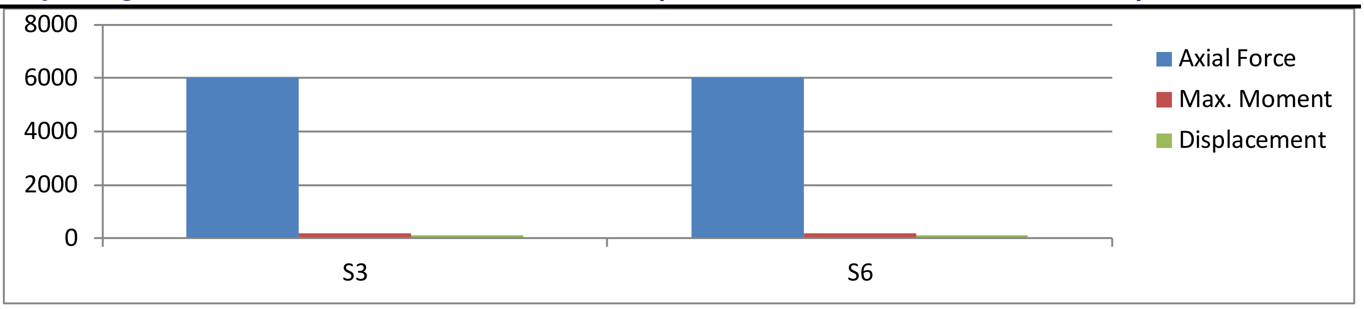


Graph 5.2 Comparison of Axial forces, Max. Moment, Max. Displacement for model S2, S5

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	236.64	151.19
2	S6	6067.52	294..71	183.31

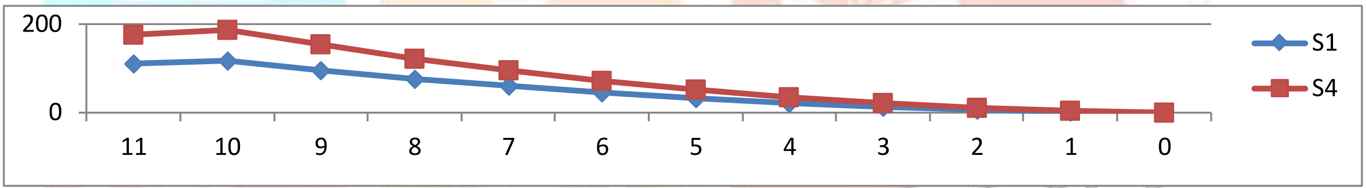


Graph 5.3 Comparison of Axial forces, Max. Moment, Max. Displacement for model S3, S6

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	265.81	395.91
2	34.00	10	286.62	429.65
3	30.60	9	235.65	359.10
4	27.20	8	186.32	265.51
5	23.80	7	143.23	220.27
6	20.40	6	110.29	159.56
7	17.00	5	86.56	125.71
8	13.60	4	54.86	86.16
9	10.20	3	39.34	49.87
10	6.80	2	17.50	20.69
11	3.40	1	7.73	6.73
12	0.00	0	0.17	0.39

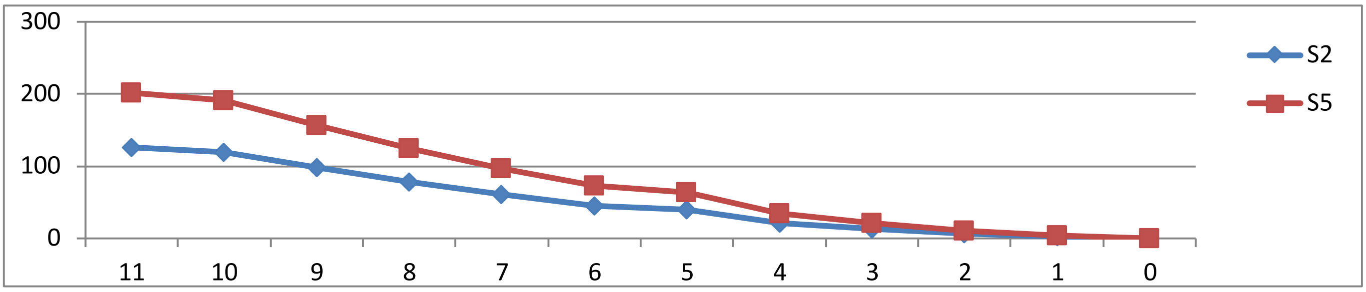


Graph 5.4 Comparison of Storey shear distribution for model S1, S4

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	303.43	455.43
2	34.00	10	287.16	431.48
3	30.60	9	235.87	352.38
4	27.20	8	187.69	281.14
5	23.80	7	146.43	219.43
6	20.40	6	109.15	164.76
7	17.00	5	94.79	142.47
8	13.60	4	52.36	78.05
9	10.20	3	31.15	46.84
10	6.80	2	15.73	23.53
11	3.40	1	5.32	8.27
12	0.00	0	0.46	0.21

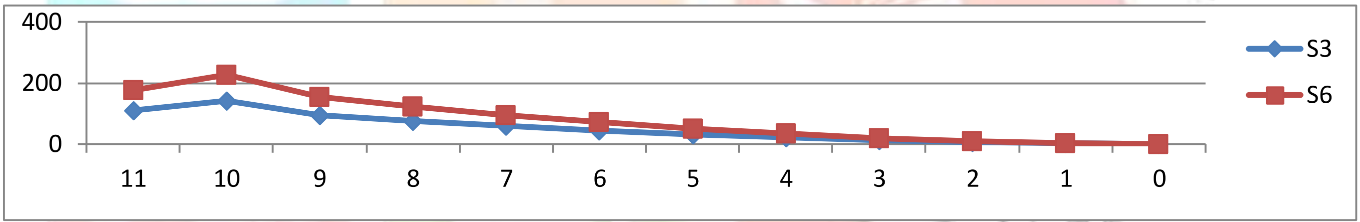


Graph 5.5 Comparison of Storey shear distribution for model S2, S5

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	267.24	400.24
2	34.00	10	343.16	515.78
3	30.60	9	231.43	346.35
4	27.20	8	184.79	277.29
5	23.80	7	143.63	215.60
6	20.40	6	107.10	161.70
7	17.00	5	76.43	115.17
8	13.60	4	51.79	76.72
9	10.20	3	30.11	46.04
10	6.80	2	15.96	23.16
11	3.40	1	5.63	8.05
12	0.00	0	0.22	0.27

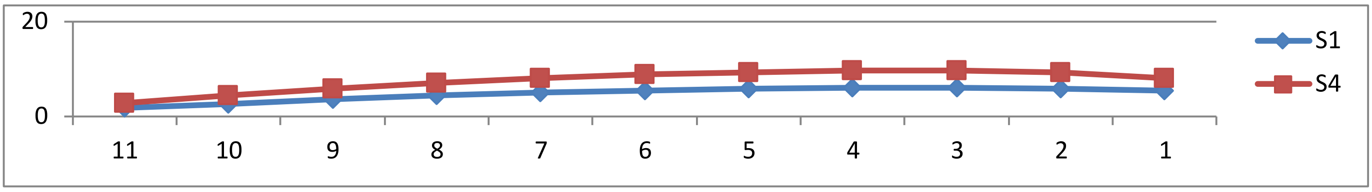


Graph 5.6 Comparison of Storey shear distribution for model S3, S6

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	5.36	6.63
2	34.00	392	6.10	9.85
3	30.60	357	8.67	13.24
4	27.20	322	10.43	15.19
5	23.80	287	11.99	18.56
6	20.40	252	13.39	19.10
7	17.00	217	14.13	20.24
8	13.60	182	14.65	21.91
9	10.20	147	14.97	21.64
10	06.80	112	13.14	20.20
11	03.40	77	12.65	17.53

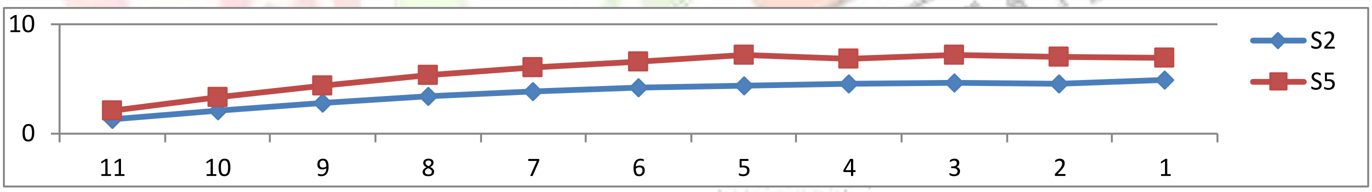


Graph 5.7 Storey displacement Comparison for model S1, S4

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	3.30	4.14
2	34.00	392	4.69	8.68
3	30.60	357	6.12	9.42
4	27.20	322	7.96	11.32
5	23.80	287	8.68	13.15
6	20.40	252	9.16	14.38
7	17.00	217	10.60	15.19
8	13.60	182	10.81	15.93
9	10.20	147	10.68	16.46
10	06.80	112	10.43	15.62
11	03.40	77	9.86	13.18

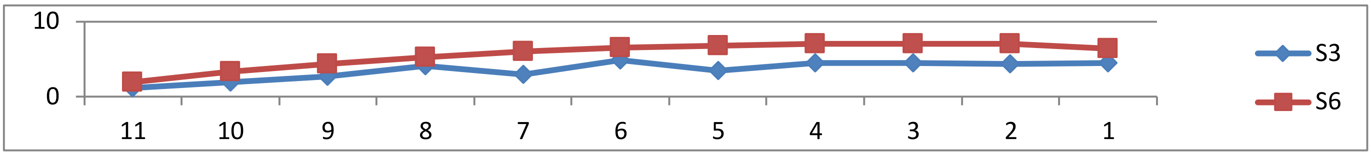


Graph 5.8 Storey displacement Comparison for model S2, S5

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	3.20	4.53
2	34.00	392	5.06	7.14
3	30.60	357	7.11	10.69
4	27.20	322	8.68	12.74
5	23.80	287	8.12	13.15
6	20.40	252	9.94	14.40
7	17.00	217	10.14	15.69
8	13.60	182	10.60	15.10
9	10.20	147	10.77	15.79
10	06.80	112	10.39	15.62
11	03.40	77	9.19	12.96

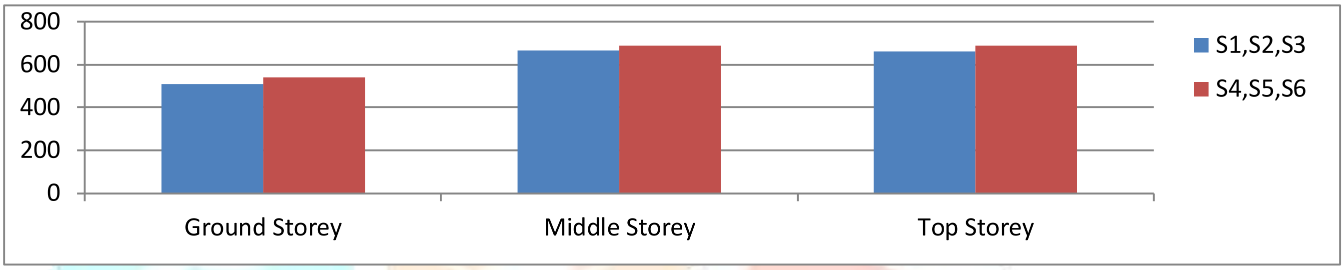


Graph 5.9 Storey displacement Comparison for model S3, S6

10) Reinforcement Comparison

Table 5.10 Reinforcement Comparison for all model

Sr. No.	Storey level	Model	Quantity (KN)
01	Ground Storey	S1	593.13
02		S4	692.97
03	Middle Storey	S2	593.41
04		S5	696.49
05	Top Storey	S3	596.16
06		S6	692.69



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.

VI. REFERENCES

1. Akshay S. Paidalwar1 et al. (2017) Seismic Analysis of Open Ground Soft Storey Building. International Journal of Civil Engineering Research
2. Piyush Tiwari et al. (2015). Earthquake Resistant Design of Open Ground Storey. International Research Journal of Engineering and Technology (IRJET)
3. Kevin Shah1 et al. (2027). Effects Of Vertical Geometric and Mass Irregularities in Structure. IKalpa Publications in Civil Engineering
4. N. Anvesh et al. (2015). Effect of Mass Irregularity on Reinforced Concrete Structure. International Journal of Innovative Research in Science, Engineering and Technology
5. Mr. Pathan Irfan Khan et al. (2016). Seismic analysis of Multistoried RCC building due to mass irregularity. International journal of Engineering development and research