International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 7 July 2022, pp: 79-89 www.ijaem.net ISSN: 2395-5252

"Seismic Analysis on RCC Frames of Different Shapes by Using STAAD. Pro Software"Seismic Analysis on different RCC frames on plan irregularity and by varying both beams and columns sizes

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Submitted: 25-06-2022 Revised: 01-07-2022 Accepted: 06-07-2022

ABSTRACT— In this study, four different-shaped G+9 storey RCC frame buildings were analyzed by STAAD.Pro.V8i (Series 6) for seismic Zone -II, Raipur, Chhattisgarh. Furthermore, the purpose of this study was to perform a response spectrum analysis (RSA) of four different shapes of RCC frame buildings by considering the same physical properties such as building area, beam dimensions, column dimensions, load calculations, seismic parameters, and material specifications. and makes every frame economical. Comparison of seismic parameters would allow us to propose the best building layout on the existing conditions. The research study focuses on the seismic analysis of various forms of the RCC frame building by varying the column size (outside and inside) as well as the carrier sizes (in floors) and to solve the problem of the maximum moved building by means of some retrofitting measures. The main goals of this project are to improve the quality of life for residents of this area, and to reduce crime in the area. More specifically, the salient objectives of this project are:

- To compare the seismic parameters such as story displacement, compressive stress of all frames and,
- To improve the structure by providing different retrofitting's in ideal location.

Keywords: RSA, RCC, Response Spectrum Analysis, ZONE II, G+9, STAAD Pro. V8i.

I. INTRODUCTION

Seismicity - areas known to be earthquake-prone have been identified on the basis of scientific input relating to earthquakes that have occurred in the past and the tectonic setup of the region. The Bureau of Indian Standards (IS 1893, Part I: 2002) has classed the country into four seismic zones, based on the level of seismic activity. Figure shows the different methods for seismic analysis. There is no one-size-fits-all answer to this question. Each person's experience and needs will be different.

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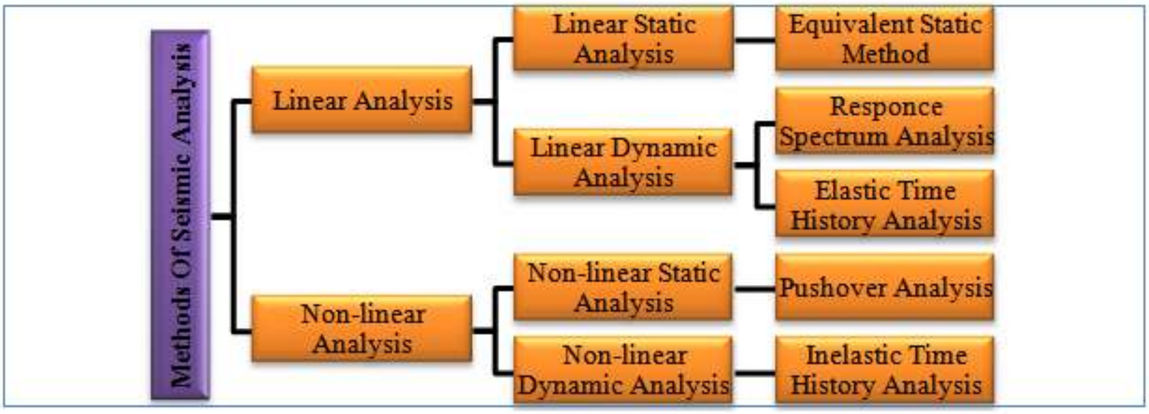

Fig. 1.1 Flow Chart of Methods of Seismic Analysis

Nearly all RC buildings with shear walls also have columns; these columns are primarily used to carry gravity loads. Shear walls provide a large amount of strength and stiffness in the direction of their orientation, which reduces the lateral sway of the building and thereby reduces damage to the structure and its contents. The Shear walls are shaped like an oblong. One dimension of their cross-section is much larger than the other. While the rectangular cross-section is most common, other shapes, such as the L- and U-shaped sections, are also used. RC shafts around the elevator core of buildings can help resist earthquake forces, so reinforcement bars should be installed in grids in regularly spaced vertical and horizontal directions. The vertical and horizontal reinforcement in the wall can be placed in one or two parallel layers called curtains. Horizontal reinforcement needs to be anchored at the ends of walls to be effective. The minimum area required to reinforce is dependent on the material and its intended use.

Table 1.1 Recent Earthquakes in India

Date	Location	Magnitude	Deaths	Damages
3-Jan-16	North East India	6.7	11	Regional event that affected India, Myanmar, and Bangladesh.
26-Oct-15	Northern India	7.7	>400	Moderate earthquake in northern areas
28-Jun-15	Dibrugarh, Assam	5.6	0	3 injured in Assam, West Bengal, Meghalaya and Bhutan
12-May-15	Nepal	7.3	218	Epicenter 17 km Nepal , Delhi, West Bengal, Bihar, U.P.

II. LITERATURE REVIEW

Mahesh N. Patil[1] & Yogesh N. Sonawane[2](2017) have investigated in their work that the effective design and construction of earthquake-resistant structures is of much greater importance worldwide. In this work, the seismic response of a symmetrical multi-storey building is studied by manual calculation and with the help of the software ETABS 9.7.1. The method includes the seismic coefficient method such as IS 1893:2002. The answers obtained by manual analysis as well as by soft computing are compared. This paper provides a complete guideline for both manual and software analysis of the seismic coefficient method.

Imranullahkhan[1], Shri Satya Eswar Sanyasi Rao[2] (2017) studied the behavior of a g+9 storey asymmetric plan building under seismic loading using linear dynamic analysis. (Response Spectrum Method) to assess storey shifts and drifts. The present study is limited to multi-storey reinforced concrete (RC) residential buildings.

Gourav Sachdeva [1], Ankit Sachdeva [2], Prof. P. Hiwase [3] (2017) work on the behavior of column shapes. In this work two shapes are considered i.e., circular & rectangular. Height & Cross sectional areas of both shapes of columns are kept constant and OMRF is used. Seismic forces are considered to figure out the realistic behavior of structures. The analytical approach is based over two models. The dimensions of columns & beams are taken as per the requirements of construction practice. The conclusion of this work is presented which is based on the variation of floor wise shear forces and the equations for the same are developed.

III. METHODOLOGY

The main purpose of the study is frame and seismic analysis of different regular and irregular shapes of RCC frame by varying beam & column sizes Using STAAD Pro. The method of seismic analysis is Response Spectrum. The built-up area considered for four different shaped frames (i.e. Square, Hollow-core, T-Shape, and U-Shape) is 441 m^2 each. These RCC frames buildings are of (G+9) Storey having total height of 30 meter each. The frame which to be analyzed are - **Case 1 (Square), Case 2 (Hollow-Core), Case 3 (T-Shape) & Case 4 (U-Shape) shown in fig. 3.1 & 3.2 .**

The size of column in each frame is 0.6 X 0.6 m (Exterior columns) & 0.54 X 0.54 m (Interior Columns).The size of beams vary with respect to floor having 0.55 X 0.30 m (1st, 2^{nd}& 3^{rd} Story), 0.50 X 0.30 m (4^{th} , 5^{th}& 6^{th} Story) , 0.45 X 0.30 (7^{th} , 8^{th} , 9^{th}& 10^{th} Story). The Slab thickness of each frame cases is 150 mm.

In this study, the each frame cases also includes main and partition walls having thickness of 200 mm, 105 mm without plaster respectively. The inner and outer plaster is of 12 mm & 15 mm thick in each frame cases. The material used in RCC frame cases is concrete of M30 Grade & steel of Fe415 Grade.

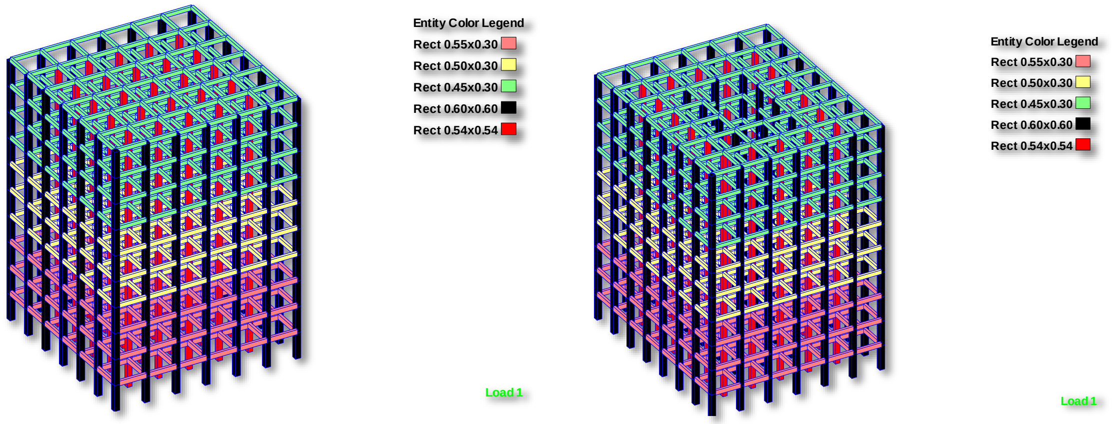

Fig. 3.1 Case 1 Frame & Case 2 Frame

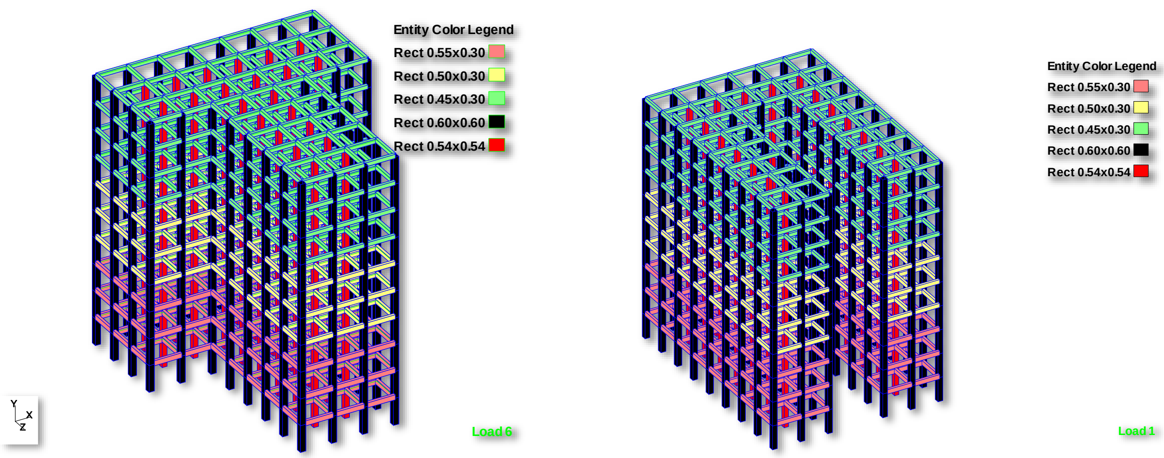

Fig. 3.2 Case 3 Frame & Case 4 Frame

The load considered in the software is primary loads & their load combinations according to IS 1893: 2002 (Earthquake Resistant design). The primary loads commonly used for all frame cases – **Dead Load (DL), Live Load (LL), Roof Live load (RLL) , Seismic Load (DX & DZ).**The Load Combinations Used in the software is according to IS 1893: 2002 –

The calculation of primary loads to be assigned in the software common for all frame cases –

➢ **Dead Load (DL) –** In this analysis, dead load includes dead load of the slab, dead load of beam & column, dead load of external walls and dead of internal walls to be inserted in software.DEAD LOAD is designated as D.Lin Staad Pro. Consideredas per IS 875 Part-1.

 # Self-Weight of Slab/Plate = 25 X 0.15
=3.75 KN/m^2

 # Self-Weight of Exterior Column = (25 X 0.60X 0.60)
= 9 KN/m (per meter height)

 # Self-Weight of Interior Column = (25 X 0.54X 0.54)
= 7.29 KN/m (per meter height)

 # Self-Weight of 1st floor, 2nd floor & 3rd floor Beam = 25 X 0.55 X 0.30
= 4.125 KN/m

 # Self-Weight of 4th floor, 5th floor & 6th floor Beam = 25 X 0.50 X 0.30
=3.75 KN/m

 # Self-Weight of 7th, 8th, 9th floor & 10th floor Beam = 25 X 0.45 X 0.30
=3.375 KN/m

 # Self-Weight of Main wall and Partition wall-

For Main wall and Partition wall load including plaster (for 1st, 2nd& 3rd floor having beam size 0.55 X 0.30)

Main Wall load =20 X (0.20 + 0.015 + 0.012) X (3 – 0.55)
= 11.123 KN/m
Partition Wall load = 20 X (0.105 + 0.012 + 0.012) X (3 - 0.55)
=6.321 KN/m

For Main wall and Partition wall load including plaster (for 4th, 5th& 6th floor having beam size 0.50 X 0.30)
MainWall load = 20 X (0.20 + 0.015 + 0.012) X (3 – 0.50)
= 11.35 KN/m
Partition Wall load = 20 X (0.105 + 0.012 + 0.012) X (3 - 0.50)
= 6.45 KN/m

For Main wall and Partition wall load including plaster (for 7th, 8th, 9th& 10th floor having beam size 0.45 X 0.30)
Main Wall load = 20 X (0.20 + 0.015 + 0.012) X (3 – 0.45)
= 11.577 KN/m
Partition Wall load = 20 X (0.105 + 0.012 + 0.012) X (3 - 0.45)
=6.579 KN/m

➢ **Live Load (L.L) –** All the consideration is as per IS 875 Part-2. Live load common for all the floors considered is 4 KN/m^2& Live load for roof is 1.5 KN/m^2.

➢ **Seismic Load (DX & DZ) –** The seismic load calculation involves the full dead load plus the percentage of live or imposed load as per IS 1893:2002.The seismic parameters used commonly for all case frames are - Seismic Zone is Zone –II with importance factor 1.0. The soil type is medium soil and damping ratio is 5 %. The response factor is Ordinary moment resisting frame.
The following general sequence of steps involved in a response spectrum analysis –

1) Feeding the dimensions to the software for creating the Case 1 to 4 frame and giving height to the structure by translational repeat command bar.
2) After creating frame model, section properties is defined i.e. beams, columns & slab.
3) Assigning of beam section to first to tenth story by cut section command bar.
4) Assigning of column section i.e. at exterior and interior columns in all frames.
5) Creating the plate/ slab by “filling grid with plates” to all the frame cases.
6) Assigning of Slab to the surface of all the frames.
7) Create fixed supports and assign to the case frames.
8) Now, primary load is defined i.e. DL, LL, RLL, DX & DZ by “load & Definition” command
9) Assign the primary loads & load combinations common for all case 1 to 4 frames.
10) Concrete is designed by IS 456 by adding parameters as cover, concrete & steel grade, reinforcement detail and giving command design of beam, column & slab.
11) Adding Seismic definition and Run analysis command to complete seismic analysis.

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IV. RESULTS & DISCUSSIONS

❖ **Story Height V/s Story Displacement –**

The framework analysis of the report on the history of movement of case 1, case 2, case 3 and case 4 is presented in the table below. In case 1 the lowest cost of movement is shown, and in case 4 the maximum cost of movement history is shown.The report says the value of movement history is due to the seismic load allocated along the directions X & Z. The reports show that at a height of 3 meters (I.E. Surface), there is a small increase in movement due to the seismic load applied on the ground, and as the height of the floor increases, the history of movement also gradually increases to the upper floor I.E. Therefore, move history at the maximum 10th floor at a height of 30 meters and at least on the ground at a height of 3 meters. There is no load. 11 shows the maximum cost of the history movement in each history of the frame (see: Reference to 4.5.3 Thus, the higher the height of the building increases, the greater the movement of history.

Most RC buildings with shear walls also have columns; these columns primarily carry gravity loads. Shear walls provide large strength and stiffness to buildings in the direction of their orientation, which significantly reduces lateral sway of the building and thereby reduces damage to structure and its contents. The Shear walls are oblong in cross-section, i.e., one dimension of the cross section is much larger than the other. While rectangular cross-section is common, L- and U-shaped sections are also used. Thin walled hollow RC shafts around the elevator core of buildings also act as shear walls, and should be taken advantage of to resist earthquake forces.

Reinforcement Bars in RC shear walls are to be provided in walls in regularly spaced vertical and horizontal grids. The vertical and horizontal reinforcement in the wall can be placed in one or two parallel layers called curtains. Horizontal reinforcement needs to be anchored at the ends of walls. The minimum area of reinforcing steel to be provided is 0.0025 times the cross-sectional area, along each of the horizontal and vertical directions. This vertical reinforcement should be distributed uniformly across the wall cross-section. Bracing is also a type of retro fitting's made of steel. A braced frame is a structural system commonly used in structures subject to lateral loads such as wind and seismic pressure. The members in a braced frame are generally made of structural steel, which can work effectively both in tension and compression.

Table 4.1 Case 1 Displacement Report

STORY	BEAM	Load Combination	Length (m)	STORY DISPLACEMENT (IN MM)
Base	NIL	NIL	NIL	0
Story 1	136	11:1.5(DL+DX)	3	2.18
Story 2	284	11:1.5(DL+DX)	3	5.628
Story 3	422	11:1.5(DL+DX)	3	9.189
Story 4	566	11:1.5(DL+DX)	3	12.747
Story 5	710	11:1.5(DL+DX)	3	16.201
Story 6	854	11:1.5(DL+DX)	3	19.337
Story 7	998	11:1.5(DL+DX)	3	22.165
Story 8	1142	11:1.5(DL+DX)	3	24.588
Story 9	1253	11:1.5(DL+DX)	3	26.389
Story 10	1410	11:1.5(DL+DX)	3	27.583

Table 4.2 Case 2 Displacement Report

STORY	BEAM	Load Combination	Length (meter)	STORY DISPLACEMENT (IN MM)
Base	NIL	NIL	NIL	0
Story 1	122	11:1.5(DL+DX)	3	2.129
Story 2	261	11:1.5(DL+DX)	3	5.393
Story 3	389	11:1.5(DL+DX)	3	8.73
Story 4	493	11:1.5(DL+DX)	3	12.043
Story 5	660	11:1.5(DL+DX)	3	15.241
Story 6	771	11:1.5(DL+DX)	3	18.124
Story 7	921	11:1.5(DL+DX)	3	20.703
Story 8	1059	11:1.5(DL+DX)	3	22.887
Story 9	1159	11:1.5(DL+DX)	3	24.484
Story10	1300	11:1.5(DL+DX)	3	25.484

Table 4.3 Case 3 Displacement Report

STORY	BEAM	Load Combination	Length (m)	STORY DISPLACEMENT (IN MM)
BASE	NIL	NIL	NIL	0
STORY 1	106	11:1.5(DL+DX)	3	2.462
STORY 2	246	11:1.5(DL+DX)	3	6.472
STORY 3	386	11:1.5(DL+DX)	3	10.647
STORY 4	522	11:1.5(DL+DX)	3	14.838
STORY 5	663	11:1.5(DL+DX)	3	18.918
STORY 6	803	11:1.5(DL+DX)	3	22.639
STORY 7	942	11:1.5(DL+DX)	3	26.002
STORY 8	1081	11:1.5(DL+DX)	3	28.891
STORY 9	1217	11:1.5(DL+DX)	3	31.071
STORY 10	1359	11:1.5(DL+DX)	3	32.539

Table 4.4 Case 4 Displacement Report

STORY	BEAM	Load Combination	Length (m)	STORY DISPLACEMENT (IN MM)
BASE	NIL	NIL	NIL	0
STORY 1	108	11:1.5(DL+DX)	3	2.279
STORY 2	258	11:1.5(DL+DX)	3	6.172
STORY 3	422	11:1.5(DL+DX)	3	10.351
STORY 4	572	11:1.5(DL+DX)	3	14.618
STORY 5	719	11:1.5(DL+DX)	3	18.824
STORY 6	870	11:1.5(DL+DX)	3	22.721
STORY 7	1019	11:1.5(DL+DX)	3	26.316
STORY 8	1168	11:1.5(DL+DX)	3	29.496
STORY 9	1315	11:1.5(DL+DX)	3	32.024
STORY 10	1466	11:1.5(DL+DX)	3	33.874

❖ **STORY V/S COMPRESSIVE STRESS –**

The frame analysis report of compressive stress of case 1, case 2, case 3 & case 4 is represented in below table. The Case 1 shows the minimum stress and the Case 4 shows the maximum compressive stress. So, the square frame is more efficient or regular shape building is better in terms of compressive stress in the study.According to the report all the values of maximum compressive stress is given by vertical members only. It is very clear that at 30 meter height (i.e. top floor), there is least value of compressive stress and at 3 meter height (i.e. ground floor), and there is maximum value of compressive stress. Hence, the compressive stress is maximum at the ground, more the height of building increases the stress in ground floor also increases.

Table 4.5 Case 1 Stress Report

STORY	Beam	Load Combinations	Length (meter)	Max Compressive Stress (N/mm^2)
Story 10	1306	11:1.5(DL+DX)	3	3.251
Story 9	1173	11:1.5(DL+DX)	3	4.40
Story 8	1040	11:1.5(DL+DX)	3	5.715
Story 7	931	11:1.5(DL+DX)	3	6.887
Story 6	774	11:1.5(DL+DX)	3	8.069
Story 5	641	11:1.5(DL+DX)	3	8.993
Story 4	532	11:1.5(DL+DX)	3	10.071
Story 3	399	11:1.5(DL+DX)	3	10.758
Story 2	256	11:1.5(DL+DX)	3	11.697
Story 1	121	11:1.5(DL+DX)	3	12.788

Table 4.6 Case 2 Stress Report

Story	Beam	Load Combinations	Length (meter)	Maximum Compressive Stress (N/mm^2)
Story 10	1413	11:1.5(DL+DX)	3	3.377
Story 9	1269	11:1.5(DL+DX)	3	4.618
Story 8	1125	11:1.5(DL+DX)	3	5.954
Story 7	1006	11:1.5(DL+DX)	3	7.156
Story 6	837	11:1.5(DL+DX)	3	8.342
Story 5	693	11:1.5(DL+DX)	3	9.272
Story 4	574	11:1.5(DL+DX)	3	10.38
Story 3	429	11:1.5(DL+DX)	3	11.07
Story 2	284	11:1.5(DL+DX)	3	12.085
Story 1	126	11:1.5(DL+DX)	3	13.298

Table 4.7 Case 3Stress Report

Story	Beam	Load Combinations	Length(m)	Maximum Compressive Stress (N/mm²)
Story 10	1379	11:1.5(DL+DX)	3	3.527
Story 9	1240	11:1.5(DL+DX)	3	4.723
Story 8	1101	11:1.5(DL+DX)	3	6.189
Story 7	969	11:1.5(DL+DX)	3	7.612
Story 6	830	11:1.5(DL+DX)	3	8.741
Story 5	691	11:1.5(DL+DX)	3	9.808
Story 4	552	11:1.5(DL+DX)	3	11.125
Story 3	413	11:1.5(DL+DX)	3	11.852
Story 2	274	11:1.5(DL+DX)	3	12.706
Story 1	134	11:1.5(DL+DX)	3	13.253

Table 4.8 Case 4Stress Report

Story	Beam	Load Combinations	Length (m)	Maximum Compressive Stress (N/mm²)
Story 10	1474	11:1.5(DL+DX)	3	3.495
Story 9	1325	11:1.5(DL+DX)	3	4.72
Story 8	1176	11:1.5(DL+DX)	3	6.095
Story 7	1027	11:1.5(DL+DX)	3	7.143
Story 6	878	11:1.5(DL+DX)	3	8.455
Story 5	729	11:1.5(DL+DX)	3	9.355
Story 4	595	11:1.5(DL+DX)	3	10.692
Story 3	446	11:1.5(DL+DX)	3	11.521
Story 2	297	11:1.5(DL+DX)	3	12.472
Story 1	105	11:1.5(DL+DX)	3	12.841

❖ **Comparison of Story Displacement –** According to the report analysis the maximum value of story displacement is at top floor i.e. **25.484 mm (Square) <27.583 mm (Hollow-core) <32.539 mm (T-Shape) <33.874 (U-shape)**shown in table 4.9 & graph 4.1.

Table 4.9 Comparison Report for Story Displacement

Story	Square Displacement (In mm)	Hollow-Core Displacement (In mm)	T-Shape Displacement (In mm)	U-Shape Displacement (In mm)
BASE	0	0	0	0
Story 1	2.129	2.18	2.462	2.279
Story 2	5.393	5.628	6.472	6.172
Story 3	8.73	9.189	10.647	10.351
Story 4	12.043	12.747	14.838	14.618
Story 5	15.241	16.201	18.918	18.824
Story 6	18.124	19.337	22.639	22.721
Story 7	20.703	22.165	26.002	26.316
Story 8	22.887	24.588	28.891	29.496
Story 9	24.484	26.389	31.071	32.024
Story 10	25.484	27.583	32.539	33.874

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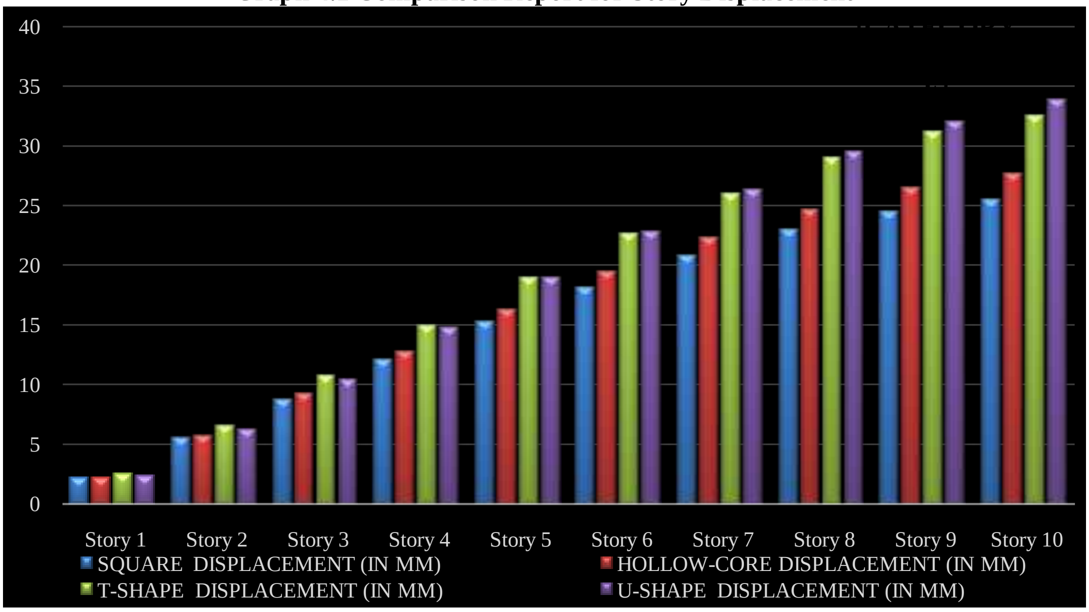
Graph 4.1 Comparison Report for Story Displacement



It is concluded from the comparison report that the maximum story displacement is shown by U-shape building and the minimum story displacement is shown by square building Hence, the square building is better in terms of displacement (it should be minimum at the topmost floors.)

❖ **Comparison of Compressive Stress –**

According to the report analysis maximum value of compressive stress is given by story 1 or base story i.e. **12.788 N/mm^2 (Square) < 12.841 N/mm^2 (U-Shape) < 13.253 N/mm^2 (T-Shape) < 13.298 N/mm^2 (Hollow-core)** respectively shown in table 4.10& graph 4.2.

Table 4.10 Comparison Report for Compressive Stress

STORY	Square Max Comp Stress (N/mm2)	U-Shape Max Comp Stress (N/mm2)	T-shape Max Comp Stress (N/mm2)	Hollow-Core Max Comp Stress (N/mm2)
Story 1	12.788	12.841	13.253	13.298
Story 2	11.697	12.472	12.706	12.085
Story 3	10.758	11.521	11.852	11.07
Story 4	10.071	10.692	11.125	10.38
Story 5	8.993	9.355	9.808	9.272
Story 6	8.069	8.455	8.741	8.342
Story 7	6.887	7.143	7.612	7.156
Story 8	5.715	6.095	6.189	5.954
Story 9	4.4	4.72	4.723	4.618
Story 10	3.251	3.495	3.527	3.377

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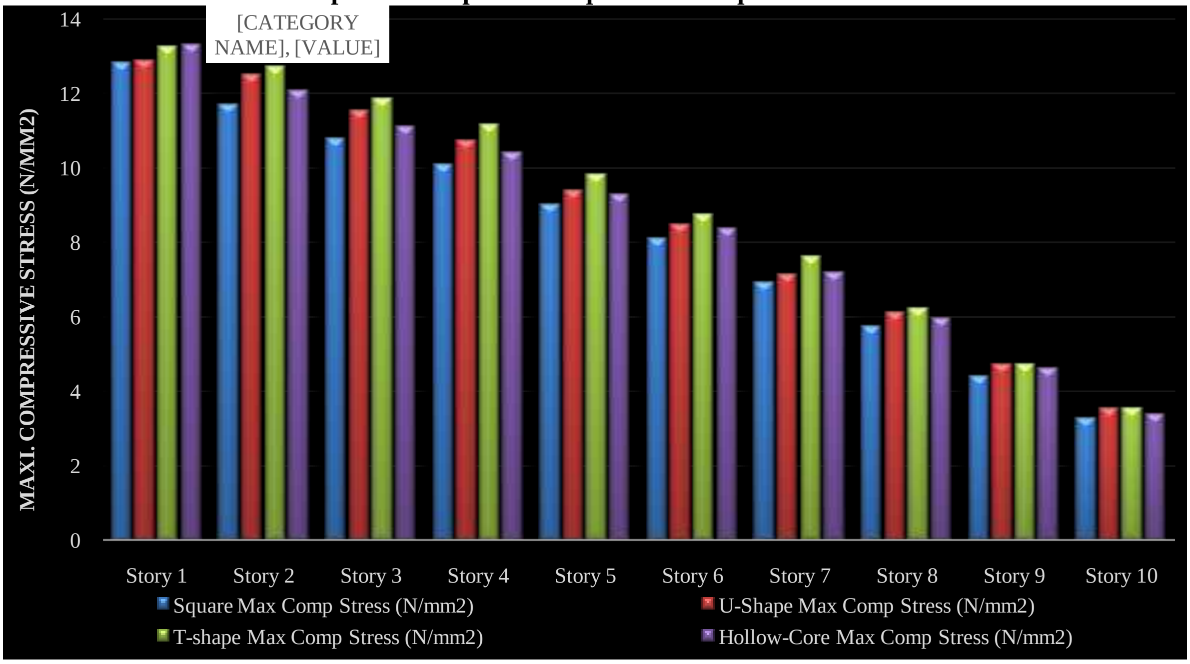
Graph 4.2 Comparison Report for Compressive Stress

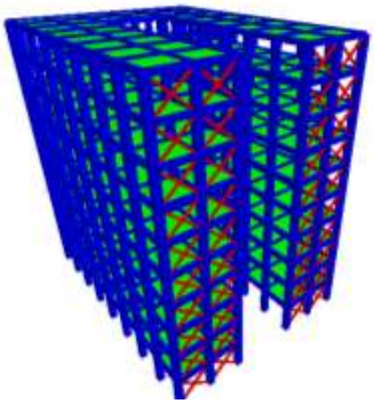


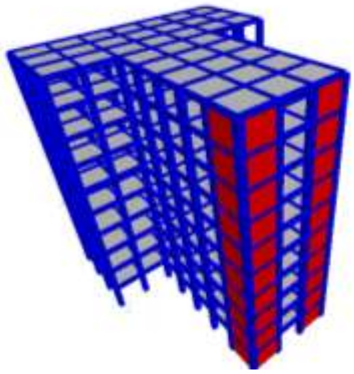
It is very clear that at 3 meter height (i.e. ground floor) there is maximum value of compressive stress. The compressive stress is maximum for the Hollow –Core shape frame building and minimum for square shape building. Hence, the square building is better in terms of compressive stress because minimum stress is better for RCC structure at the top floors

V. CONCLUSIONS

The following conclusions were made after the dynamic analysis –

1) It is been concluded that the displacement of regular shape frame is very much less to the irregular U-Shape framed structure. As regular frames has more rigid members which result in minimum displacement as concluded from analysis.
2) Observations from the analysis results show that the compressive is maximum at the 10th story of all case frame. The square frame has very much less compressive stress as compare to maximum stress in hollow-core frame in top story.
3) From observation of analysis, overall efficient building (i.e. respect to quantity of steel & concrete) is Case 1 frame when compared to Case -4 frame which is least efficient building.
4) The Case1 frame is applied for jacketing of column which shows increase in shear capacity of columns. It also improve the column’s flexural strength.
5) By considering the shear wall, inside the core of Hollow- core building these walls area can be used as a lift or elevator as it prevents seepage of water into lift pit. As steel lift frames are drilled to the shear wall, these concrete shear wall will provide better anchorage.
6) The Case 3 Frame deflection can be minimized by applying the L-shaped Shear wall. The remaining open portion shown in figure between the shear walls can be used as a duct (passages) for proper ventilation of cool air.
7) Case 4 frame displacement is reduced by applying X-bracing. The arrangements or ideal location of bracing have great influence on seismic performance of the building. In this study, ideal location of bracing depends on the story displacement of the U-Shape building.





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