ANALYSIS OF MODE SHAPE BEHAVIOUR OF RCC STRUCTURE

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Abstract: The present work is concentrated to perform the modal analysis of building with plan irregularities by a method of response spectrum analysis with the help of STAAD pro vi8 software. The study includes modeling a G+10 RCC building of 33m height of each storey 3m height with four different shapes i.e., a Rectangular, a Square of two different sizes and L shaped building of sizes (95mX50m), (50mx50m), (95mx95m) and (145mx10m) respectively. The analysis is used to understand the seismic perform of the structure by the parameters of storey drift, displacement, mode shapes, base shear, and Eigen values in both lateral and perpendicular directions under seismic zone III at wind intensity of 50 m/s. The work is to focus on the comparative study of each model with the above mentioned parameters.

Index Terms: Response spectrum analysis, Plan irregularities, Mode shapes, Eigen values.

1. INTRODUCTION

Designing a safe, useful, and long-lasting structure with economy and elegance is the art and science of structural design. The entire process of structural planning and design necessitates sound knowledge of the science of structural engineering in addition to knowledge of practical aspects, such as the applicable design codes and bye-laws, supported by sample experience, institution, and judgment. Imagination and conceptual thinking are important components of the art of designing, but they are only one part of what is required for the entire process.

The process of design commences with planning of a structure, primarily to meet the functional requirements of the user or the client. The requirements proposed by the client may not be well defined. They may be vague and may also be impracticable because is not aware of the various implications involved in the process of planning and design and about the limitations and the intricacies of structural science. The functional requirements and the aspect of aesthetics are look into normally by an architect while the aspect of safety, serviceability, durability and economy of the structure for its intended use over life span of the structure are attended by the Civil engineers or structural designers (many times, a Civil engineer or structural engineer is require to act in capacities of both the architect and the structural designer).

In this study the models are considered in four distinct shapes, an intended L-shape with a variable length-to-width ratio was utilized to analyze how irregularities were organized. A few standards, including IS 456: 2000, IS 1893: 2016 (Part 1), and IS 875 components, have planning requirements that the construction conforms to (I, II, III). The structures have undergone response spectrum analysis, which includes mode shape performance, wind analysis, and seismic demand prediction. The STAAD PRO program is used to finish the analysis and analyze the results of parameters like eigen-values and mode vs. frequency variation.

1.1 OBJECTIVES:

- ✓ To develop the STAAD model
- ✓ To find the Eigen values for a RC building as per IS Code
- ✓ To obtain the moment variation respect to the plan irregularities
- ✓ To determine the variations of mode shape with respect to the plan irregularities
- ✓ To gather and contrast data based on characteristics, such as displacement, drift, base shear, and other stresses of column and beam

2. DESIGN PROCEDURE:

Before it was modeled in STAAD Pro, the architectural plan and structural frame plans for a G+10 floor residential building with four different plan irregularities were developed as shown in the image below. The IS code clause was taken into consideration throughout the entire building analysis, which was completed in one step. The entire structure has been broken down into its structural elements, including the slab, beams, columns, and footings. These parts are created for Fe415 grade steel and M25 grade concrete.

The slabs were initially divided into two types based on the edge circumstances, spans, dimensions, Lx and Ly ratios, and recommendations from usual analysis. Both the dead load and the live load of these slabs are transferred to the beam in both the X and Y directions. Based on the loads passing through the slab, their own dead weight (section assumed), and the entire wall loads coming as such, a preliminary design of a standard beam had been completed. To support the loads, the column section has been proportioned. For the beam and column, the maximum positive moment and shear have been assessed.

2.1 About the Project

This document relates to the structural designs created for a section of the aforementioned residential township project due to various design flaws. The construction is located in seismic Zone III. At the site of the development, the average wind speed is 50 m/s. According to soil research, the SBC of soil is 200 KN/m2. The design criteria taken into account follow the Indian Standard Code of Practice.

Four types of plans were considered in this project to find the variations of mode shape.

1. Rectangular– 2904m2
2. Square–1824m2
3. Square– 3984m2
4. L Square–7632m2

2.2 Statement of the Project

- The design data shall be as follows:
- Live load : 3.0 kN/m^2
- Floor finish : 1.0kN/m^2
- Location : (Zone -III)
- Depth of foundation below ground : 2.5 m
- Safe bearing capacity (SBC) of the soil :200 kN/m^2
- Typical Storey height : 3 m
- Floors : G + 10 floors.
- Exterior Walls : 300 mm thick brick masonry walls only at periphery.
- Inner Walls :230 mm thick brick masonry walls
- Parapet Wall :1.0 m

2.3 Material Properties :

Concrete& Steel

All components unless specified in design: M25 grade all and HYSD Reinforcement Fe415.

2.4 Load Combinations:

- Dead load + Live load
- Dead load + live load + seismic load
- Dead load + live load + wind load
- Dead load + wind load
- Dead load + seismic load
- Live load + wind load
- Partial safety factor for loads : 1.5
- Partial safety factor for steel : 1.15
- Partial safety Factor for Concrete : 1.5

2.6 Building Elevationstaad Rendering View

Structural Framed rendering image of residential building G+10 from STAAD pro.

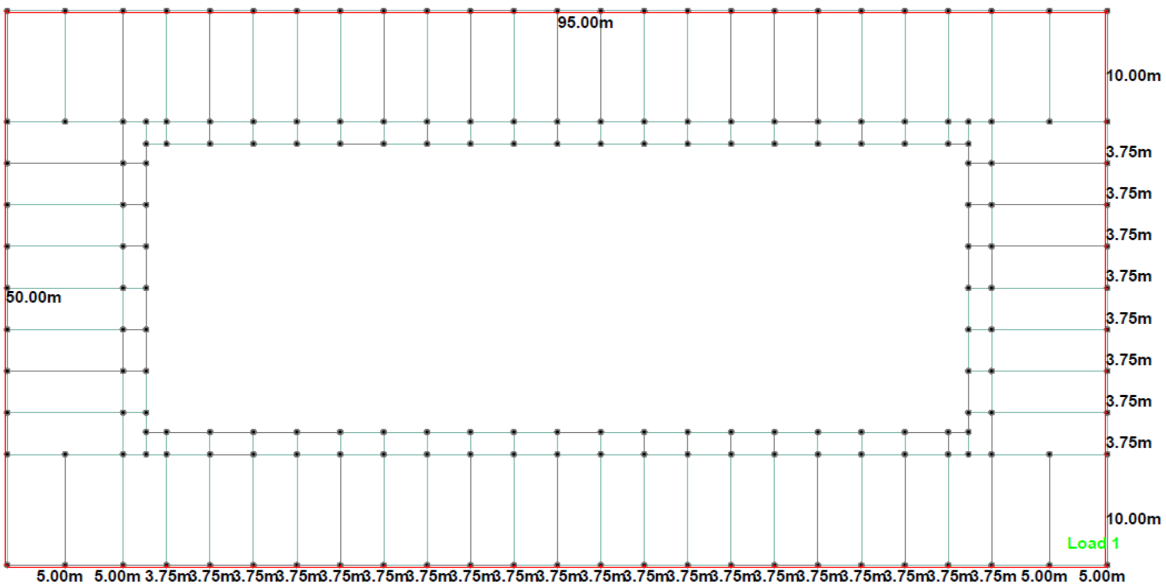

Fig 1: Plan view of the rectangular building of size (95mx50m)

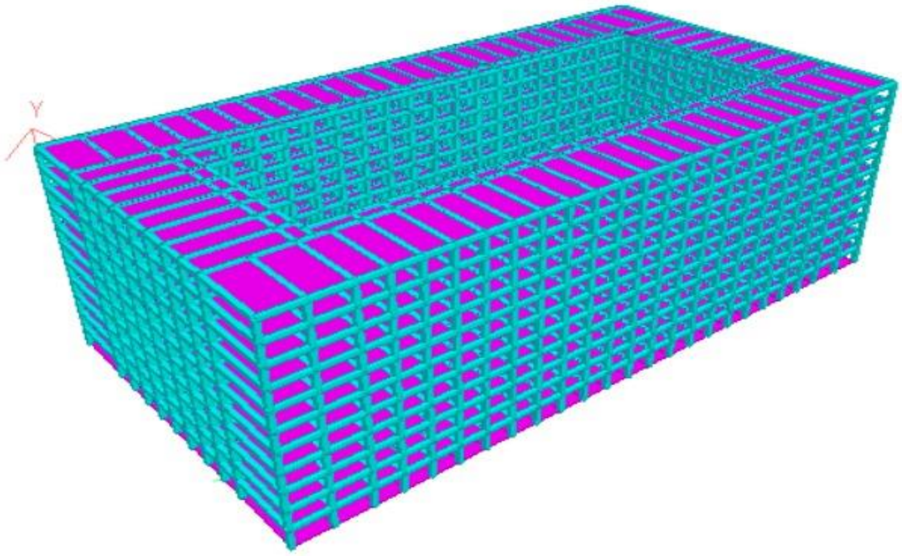

Fig 2: RECTANGLE Shaped Building Elevation in STAAD Rendering View

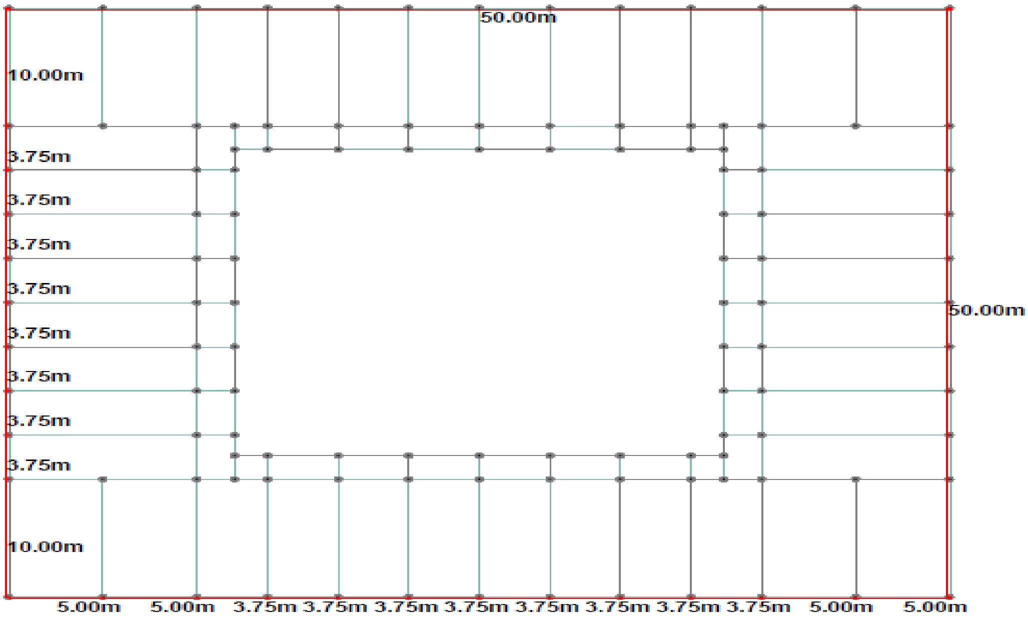

Fig 3: Plan view of the rectangular building of size (50mx50m)

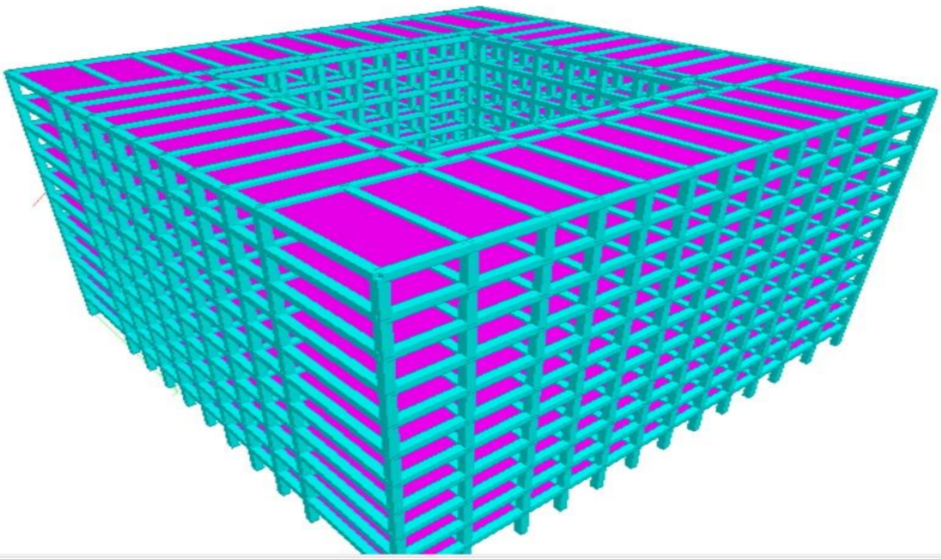

Fig 4: Plan view of the rectangular building of size (50mx50m)

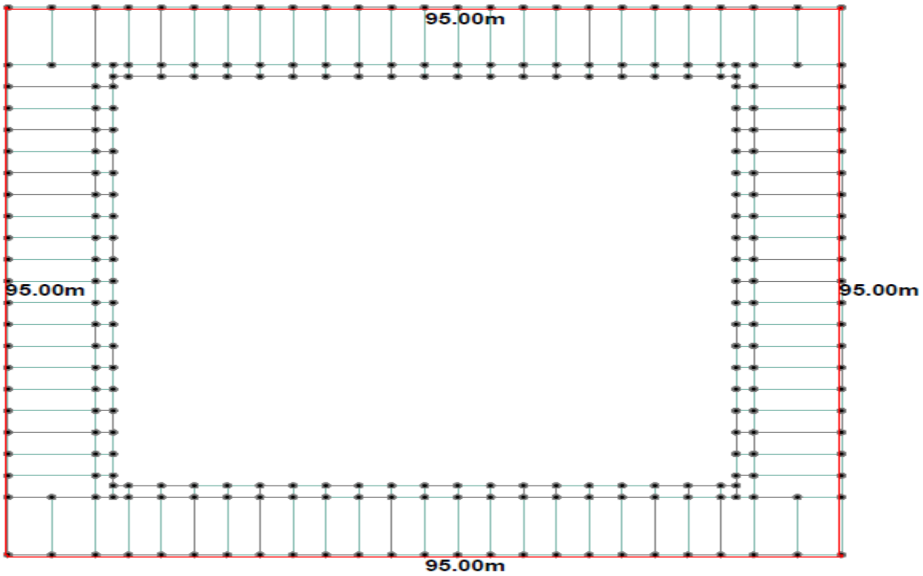

Fig 5: Plan view of the Square building of size (95mx95m)

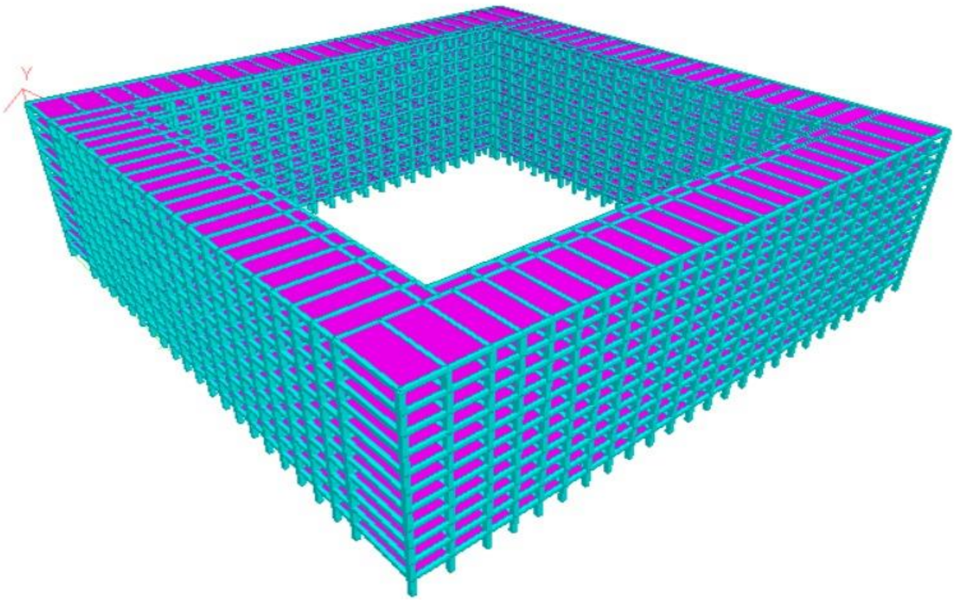

Fig 6: SQUARE Shaped Building Elevation in STAAD Rendering View

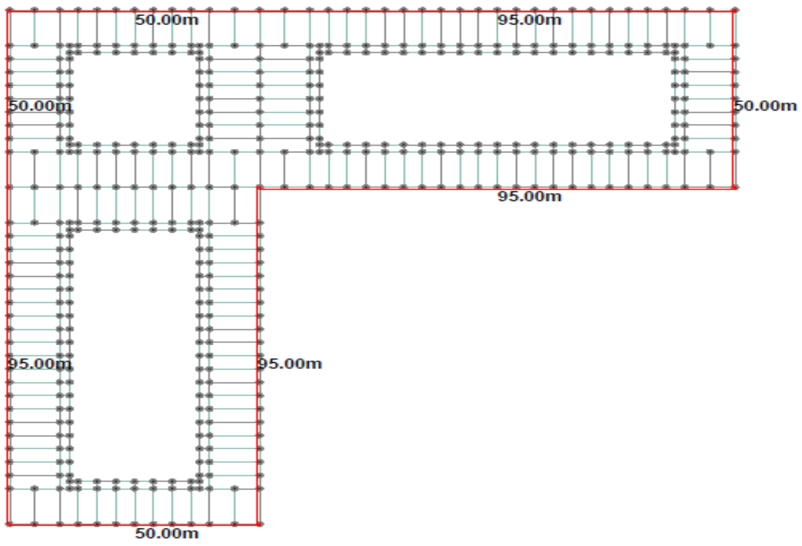

Fig 7: Plan view of the L shaped building

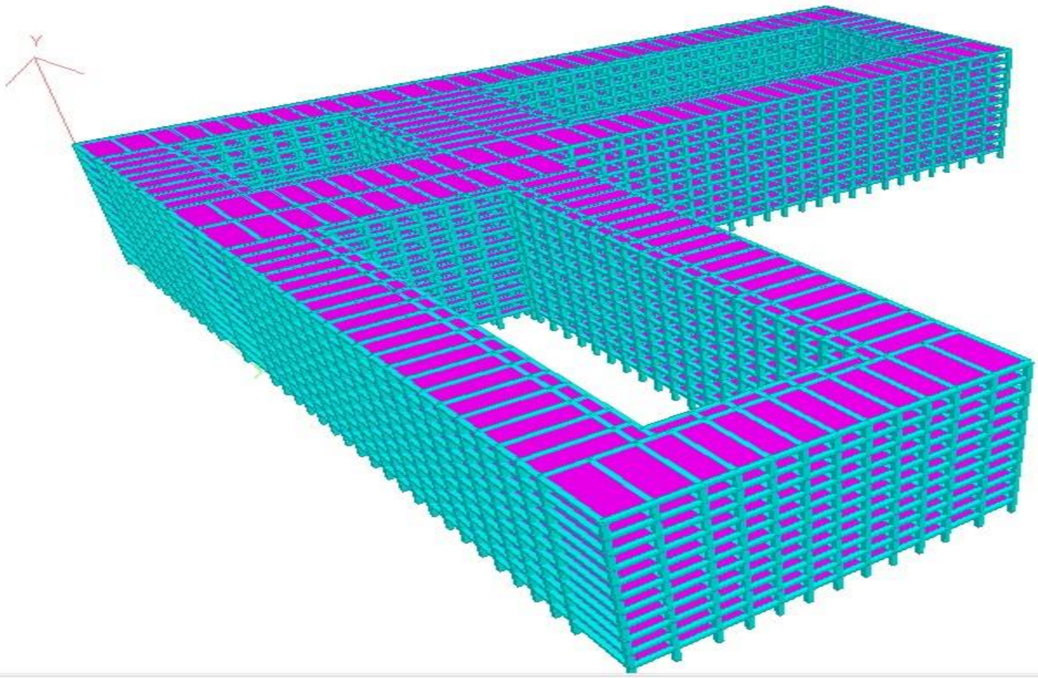

Fig 8: L Shaped Building Elevation in STAAD Rendering View

3. Method of Analysis

There are various analysis techniques with varying degrees of accuracy. Three criteria can be used to classify the analysis process: the kind of external loads, the behaviour of the structure or its constituent parts, and the kind of structural model chosen. The analysis can be further divided into linear static analysis, linear dynamic analysis, nonlinear static analysis, and nonlinear dynamic analysis depending on the type of external action and the behaviour of the structure.

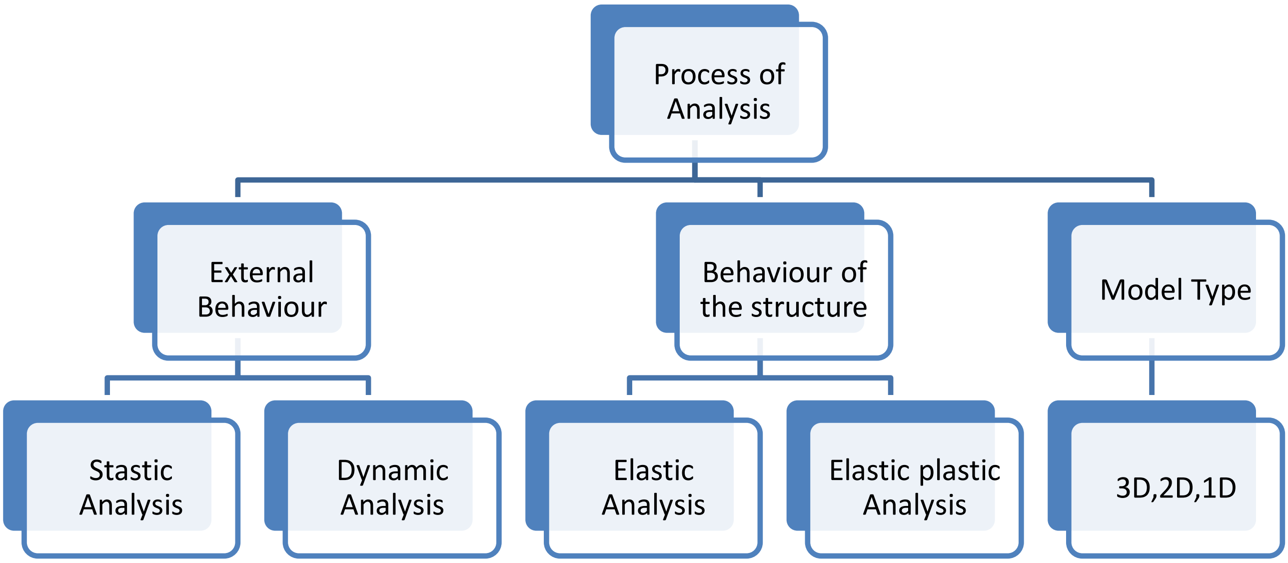

Fig 9: Analysis Process

Linear static analysis or equivalent static analysis can only be used for regular structure with limited height. Linear dynamic analysis can be performed in two ways either by mode superposition method or response spectrum method and elastic time history method. This analysis will produce the effect of the higher modes of vibration and the actual distribution of forces in the elastic range in a better way. They represent an improvement over linear static analysis. The significant difference between linear static and dynamic analysis is the level of force and their distribution along the height of the structure.

Non-linear static analysis is an improvement over the linear static or dynamic analysis in the sense that it allows the in elastic behavior of the structure. The method still assumes a set of static incremental lateral load over the height of the structure. The method is relatively simple to be implemented, and provides information on the strength, deformation and ductility of the structure and the distribution of demands. This permit to identify critical members likely to reach limit states during the earthquake, for which attention should be given during the design and detailing process. But this method contains many limited assumptions, which neglect the variation of loading patterns, the influence of higher modes, and the effect of resonance. This method, under the name of Push over Analysis has acquired a great deal of popularity now-a-days and in spite of these deficiencies this method provides reasonable estimation of the global deformation capacity, especially for structures which primarily respond according to the first mode. A non-linear dynamic analysis or inelastic time history analysis is the only method to describe the actual behavior of the structure during an earthquake. The method is based on the direct numerical integration of the motion differential equations by considering the elasto-plastic deformation of the structural element. This method captures the effect of amplification due to resonance, the variation of displacements at diverse levels of a frame, an increase of motion duration and a tendency of regularization of movement's results as far as the level increases from bottom to top. The present study is concern with analysis of buildings with different shapes using Equivalent static method and Response spectrum method described in detail below.

3.1 Equivalent Static Analysis

The equivalent static method is the simplest method of analysis. Here, force depend upon the fundamental period of structures defined by IS Code 1893:2002 with some changes. First design base shear of complete building is calculated, and then distributed along the height of the building, based on formulae provided in code. Also, it is suitable to apply only on buildings with regular distribution of mass and stiffness.

3.2 Bending Moment:

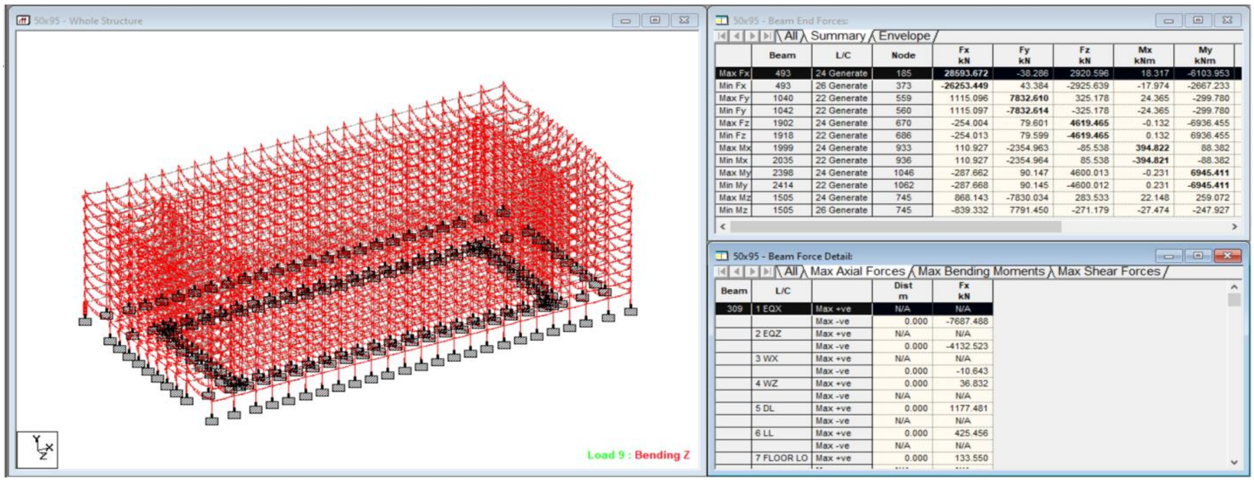

Fig 10: Bending moment

3.3 Shear Diagram

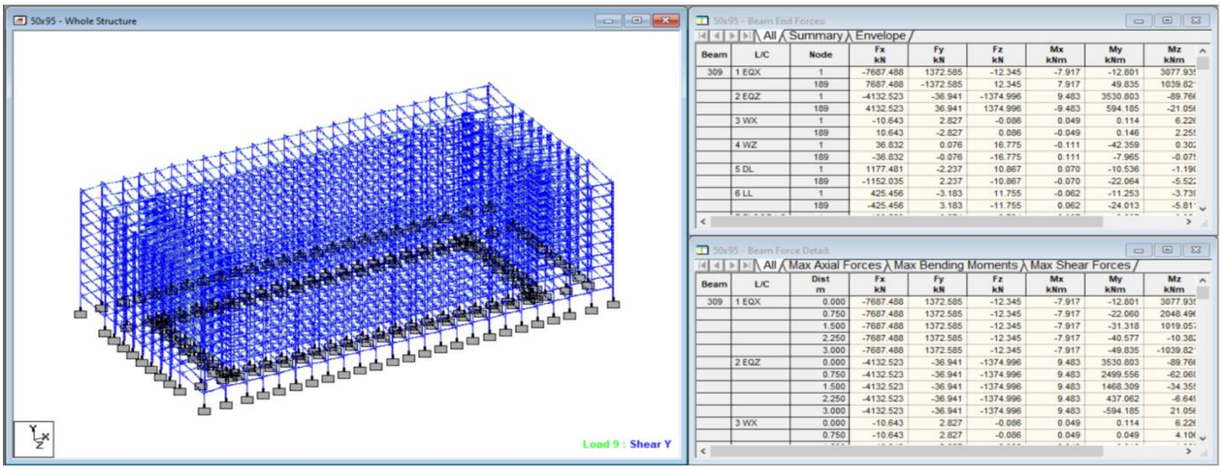

Fig11: Shear Diagram

3.4 Beam and column Results

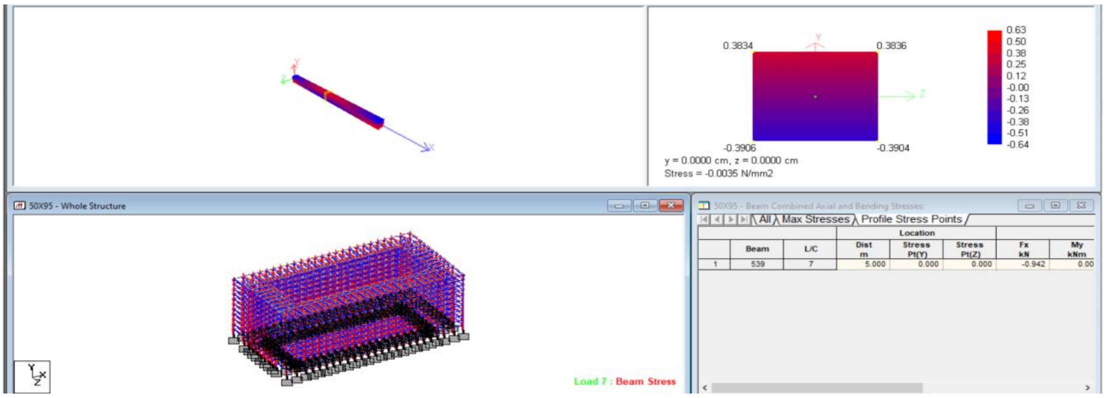

Fig 12: stress diagram of Beam

3.5 Column Stress Diagrams

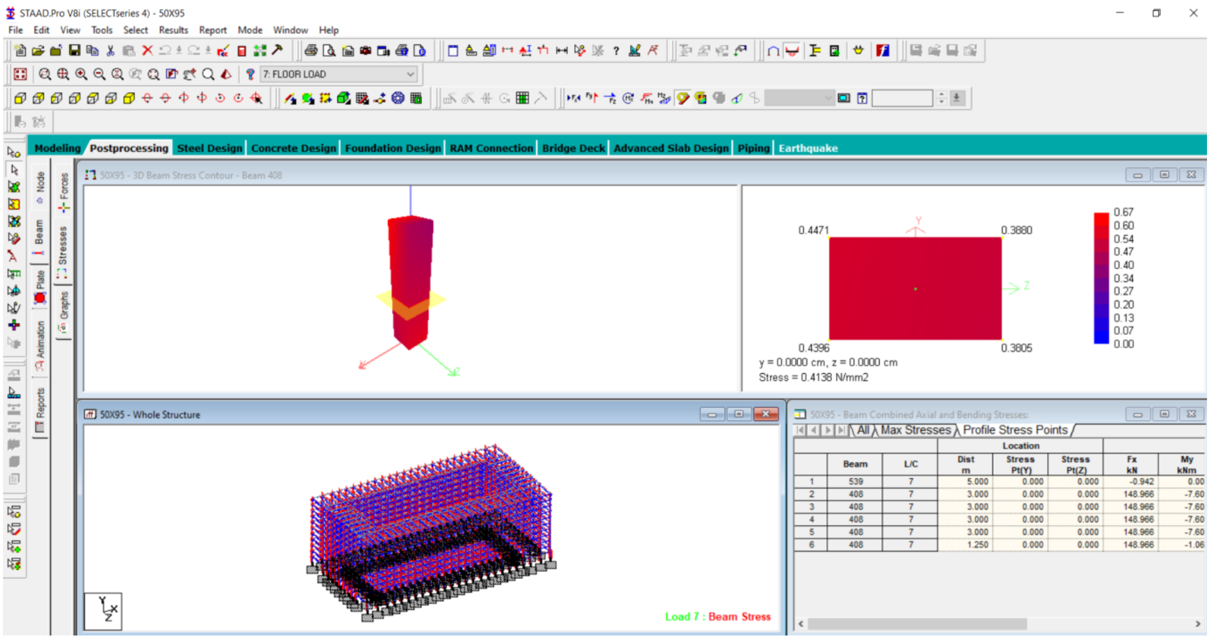

Fig 13: Stress diagram of columns

4. COMPARISION AND RESULTS

Table 1:Maximum moment and forces on the beams (case 1)

Beam no	FxkN	FykN	FzkN	Mx kNm	My kNm	MzkNm
360	4053.87	0.527	46.88	-0.021	-44.591	0.917
5263	-5.828	191.300	0.892	5.165	-0.774	192.577
5757	-85.354	72.538	2.285	15.421	-1976	90.426
4985	-13.593	133.632	0.002	0.770	-0.011	247.575
5270	329.181	-19.706	117.245	0.109	214.00	-26.074

Table 2: Maximum moment and forces on the beams (case 2)

Beam no	FxkN	FykN	FzkN	Mx kNm	My kNm	MzkNm
216	4053.744	0.512	46.942	-0.006	-44.701	0.871
3224	-6.686	191.262	1.424	5.127	-1.378	192.542
3240	329.183	21.280	117.338	-0.020	214.122	-35.373
3526	-89.587	72.987	5.021	15.500	-4.397	90.745
3153	-13.553	133.652	0.001	-0.728	0.004	247.679

Table 3: Maximum moment and forces on the beams (case 3)

Beam no	FxkN	FykN	FzkN	Mx kNm	My kNm	MzkNm
652	5878.313	-19.914	0	0	-0	-26.438
960	2.688	312.933	-0.044	0.156	0.112	193.029
7310	328.212	-15.826	114.853	0.067	210.482	-20.695
7989	70.986	69.127	-27.946	14.993	26.481	86.959
6906	-13.625	133.080	-0.008	-0.720	-0.008	244.814

Table 4: Maximum moment and forces on the beams (case 4)

Beam no	FxkN	FykN	FzkN	Mx kNm	My kNm	MzkNm
794	6467.609	0.929	0.966	-0.042	-1.099	0.996
12925	0.598	200.164	0.66	7.205	-0.038	204.142
13579	370.432	-7.523	132.098	0.179	235.324	-10.196
14173	-82.695	77.254	4.736	17.949	-4.033	95.221
12632	-10.431	-140.172	-0.016	-0.439	-0.074	282.637

Table 5: Maximum nodal displacement (case 1)

Node	X mm	Ymm	Zmm	Resultant
2089	8.219	-5.117	-0.487	9.694
1501	-0.003	0.285	5.555	5.562
2225	-0.00	-3.325	13.894	14.287

Table 6: Maximum nodal displacement (case 2)

Node	X mm	Ymm	Zmm	Resultant
1381	14.095	-3.422	0.000	14.505
926	-0.051	-9.093	0.020	9.093
1367	0.000	-3.382	15.372	15.740

Table 7:Maximum nodal displacement (case 3)

Node	X mm	Ymm	Zmm	Resultant
3103	16.459	-3.256	-0.000	16.778
2077	-0.014	0.339	6.963	6.972
3065	-0.00	-3.249	16.842	17.153

Table 8:Maximum nodal displacement (case 4)

Node	X mm	Ymm	Zmm	Resultant
5589	17.946	-3.207	0.027	18.230
3744	0.029	0.423	8.246	8.275
5408	-0.513	-3.180	-18.884	19.149

Table 9: Mode shape for the rectangular building (case 1)

Mode	Frequency(Hz)	Time period(sec)
1	1.019	0.981
2	1.678	0.596
3	3.138	0.319
4	3.847	0.260
5	5.498	0.182
6	6.086	0.164

Table 10: Mode shape for the square building (case 2)

Mode	Frequency(Hz)	Time period(sec)
1	1.097	0.912
2	1.545	0.647
3	3.386	0.295
4	4.318	0.232
5	5.959	0.168
6	6.927	0.144

Table 11:Mode shape for the Square building (case 3)

Mode	Frequency(Hz)	Time period(sec)
1	1.088	0.919
2	1.358	0.736

3	2.801	0.357
4	3.303	0.303
5	3.702	0.270
6	4.060	0.246

Table 11Mode shape for the L type building (case 4)

Mode	Frequency(Hz)	Time period(sec)
1	1.070	0.935
2	1.242	0.805
3	2.549	0.392
4	3.238	0.309
5	3.345	0.299
6	3.523	0.284

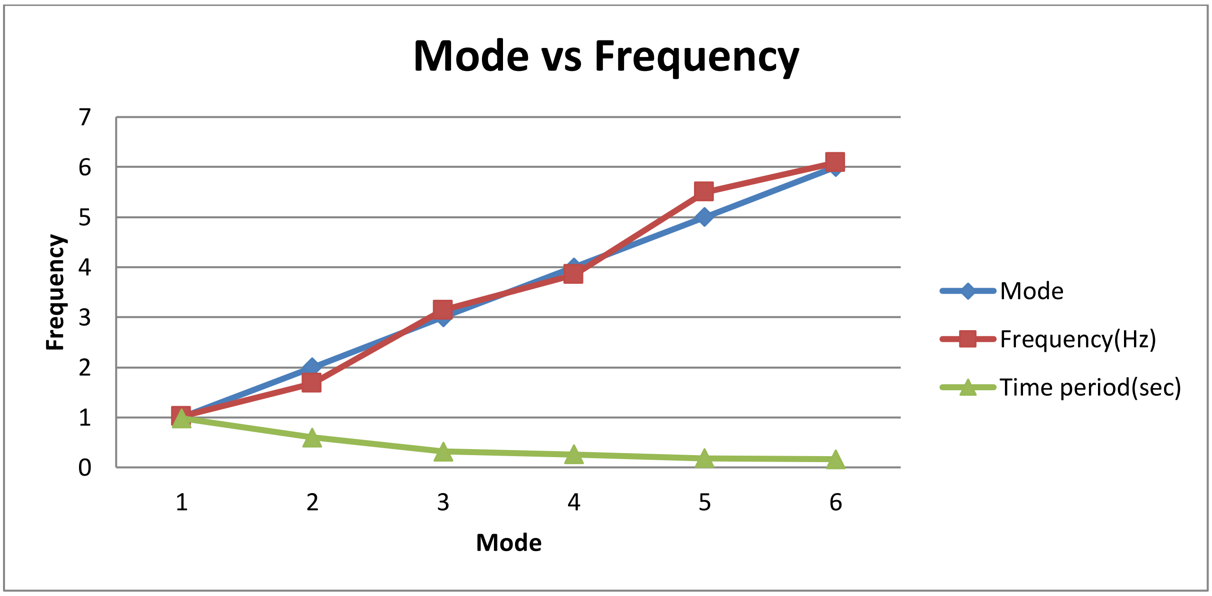

Fig 14 Mode vs Frequency -Case 1

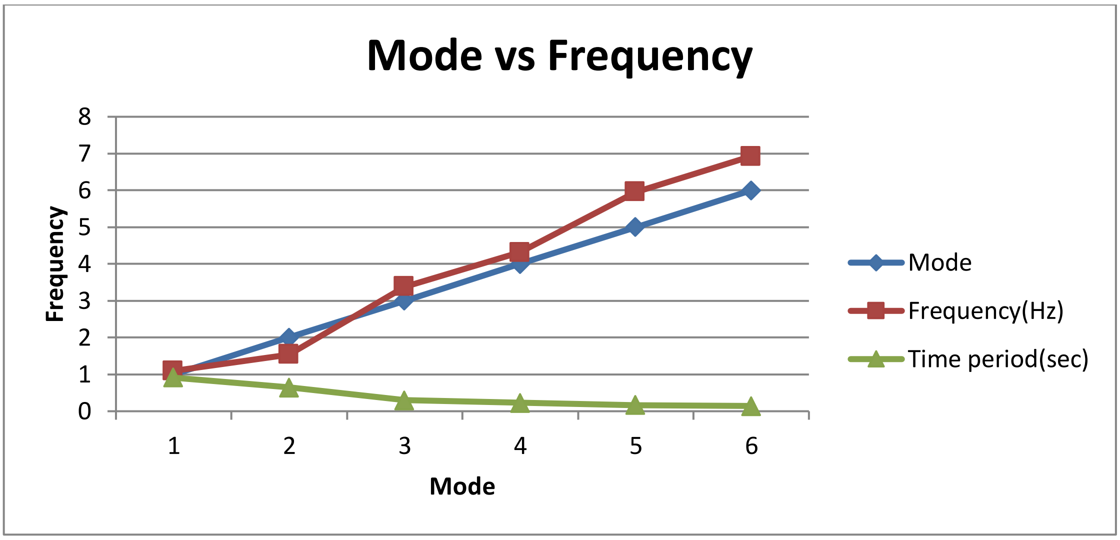

Fig 15 Mode vs. Frequency -Case 2

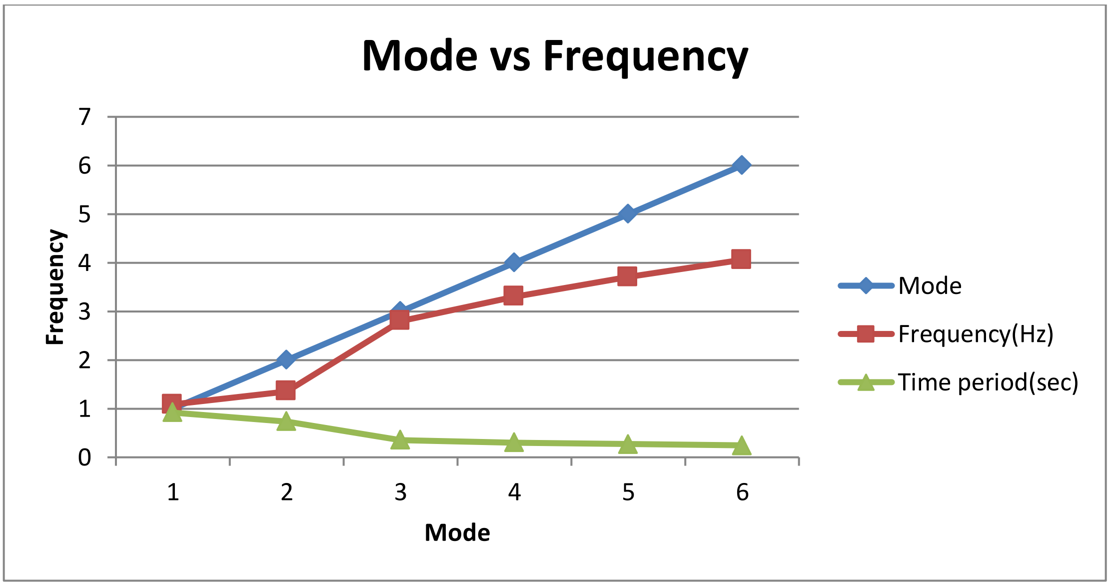

Fig 16 Mode vs Frequency -Case 3

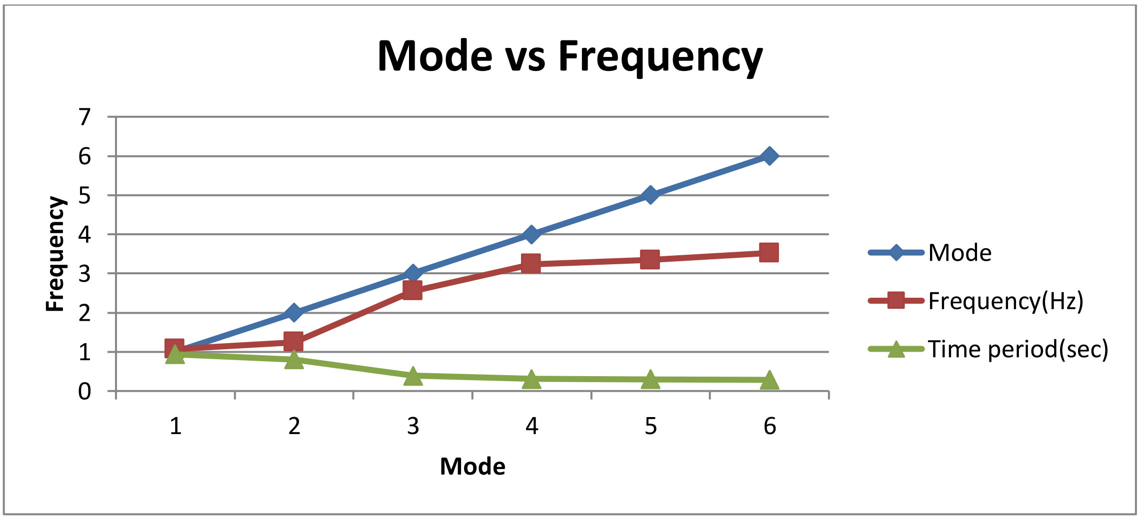

Fig 17 Mode vs Frequency -Case 4

CONCLUSIONS AND RECOMMENDATIONS

In the current paper, the response spectrum method is used to conduct an analytical investigation of an irregularly shaped building. It is carried out on the building model G+10 storey of various shapes to investigate and pinpoint the building's mode shape behavior. According to the results as a building's shape changes, its ability to carry lateral loads likewise changes, but the resulting displacement increases. In comparison to a rectangular building, as a building's irregularities increase, base shear drops but displacement does not.

Every building has a different base shear in the X and Z dimensions. Buildings with square and rectangular shapes have the same base shear, however. This is as a result of the building's orientation and irregularity percentage. It is also clear that as the amount of irregularity rises, the base shear increases across the entire structure.

As the plan irregularity percentage varies the mode shape behavior is observed to be higher to lower from square building, rectangular building and L shaped building.

On the basis of present study following conclusion can be drawn:-

- Out of all the structure maximum bases hear is the building which has maximum percentage of irregularity.
- Maximum displacement in X direction for square shaped building of (50m*50m)is observed as 14.044mm
- Maximum displacement in Z direction for rectangular shaped building of (50m*50m) as 16.445
- Base shear in irregular shaped building is more than in rectangular shaped buildings.
- It is observed that the Eigen values are considerable less in L shaped building when compared with rectangular and square
- It is understood that the there is no major changes with the movement .the moments remain same with the change of the plan area.
- It is seen that the mode shapes are comparatively similar to the rectangular and square building
- The mode shape of the L shaped building is found with low intensity ,the frequency got gradually decreased from mode 1 to mode 6
- It is concluded that the L and square shaped building of areas (3984m^2) and (7682m^2) respectively will be served good.

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