PARAMETRIC STUDY OF VERTICALLY IRREGULAR BUILDING HAVING MASS AND STIFFNESS IRREGULARITIES

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ABSTRACT

Nowadays, as in the urban areas the space available for the construction of buildings is limited. So in limited space we have to construct such type of buildings which have can be used for multiple purposes such as lobbies, car parking etc. To fulfil this demand, buildings with irregularities is the only option available. The structures having discontinuity are termed as Irregular structures. Irregular structures contribute a large portion of urban infrastructure. During an earthquake, failure of structure starts at points of weakness. This weakness arises due to discontinuity in mass, stiffness and geometry of structure. Vertical irregularities are one of the major reasons of failures of structures during earthquakes. To study the behaviour of the building having mass, stiffness and vertical irregularities at different floors models were analyzed in ETABS 2013. For this study of behaviour of building we are considering all models in seismic zone III. Parameters should be considered for this study- Base shear, Storey drift and Lateral displacement, Time period in various mode shapes, Force in Beam and Column.

Keyword: - *Mass irregularity. Stiffness irregularity, Time period, Response spectrum analysis, Mode shape, Etabs.*

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1. Introduction

Buildings come in a variety of sizes, shapes and functions, and have been adapted throughout history for a wide number of factors, from building materials available, to weather conditions, to land prices, ground conditions, specific uses and aesthetic reasons. A building as a shelter represents a physical division of the human habitat and the outside. Buildings may be damaged during the construction of the building or during maintenance. There are several other reasons behind building damage like accidents such as storms, explosions, poor foundations and building irregularities. Many buildings in the present scenario have irregular configurations both in plan and elevation. This in future may subject to devastating earthquakes. Earthquakes are the most unpredictable and devastating of all natural disasters, which are very difficult to save over engineering properties and life, against it. Hence in order to overcome these issues we need to identify the seismic performance of the built environment through the development of various analytical procedures, which ensure the structures to withstand during frequent minor earthquakes and produce enough caution whenever subjected to major earthquake events. So that can save as many lives as possible. To perform well in an earthquake, a building should possess four main attributes, namely simple and regular configuration, and adequate lateral strength, stiffness and ductility. Buildings having simple regular geometry and uniformly distributed mass and stiffness in plan as well as in elevation, suffer much less damage than buildings with irregular configurations. According to IS: 1893, the irregularity in the building structures may be due to irregular distributions in their mass, strength and stiffness along the height of building. When this type of building are constructed in high intensity zones, the design and analysis of structure becomes complicated.
Parameter consider for regular building with the building having irregularity, Base shear, Storey drift, Lateral displacement, Time Period and Mode shape analysis done with ETABS 2013.

1.1 Stiffness Irregularity

Soft Storey:
As per IS 1893-2002, A soft storey is one in which the lateral stiffness is less than 70% of that in the storey above or less than 80% of the average lateral stiffness of the three storeys above.

Extreme Soft Storey:
An extreme soft storey is one in which the lateral stiffness is less than 60% of that in the storey above or less than 70% of the average stiffness of the three storeys above.

1.2 Mass Irregularity

As per IS Code 1893-2002, Mass irregularities are considered to exist where the effective mass of any storey is more than 200% of effective mass of an adjacent storey. A roof that is lighter than the floor below need not be considered. The effective mass is the real mass consisting of the dead weight of the floor plus the actual weight of partition and equipment. Excess mass can lead to increase in lateral inertial forces, reduced ductility of vertical load resisting elements, and increased tendency towards collapse due to P-Δ effect. . The central force of gravity is shifted above the base in the case of heavy masses in upper floors resulting in large bending moments.

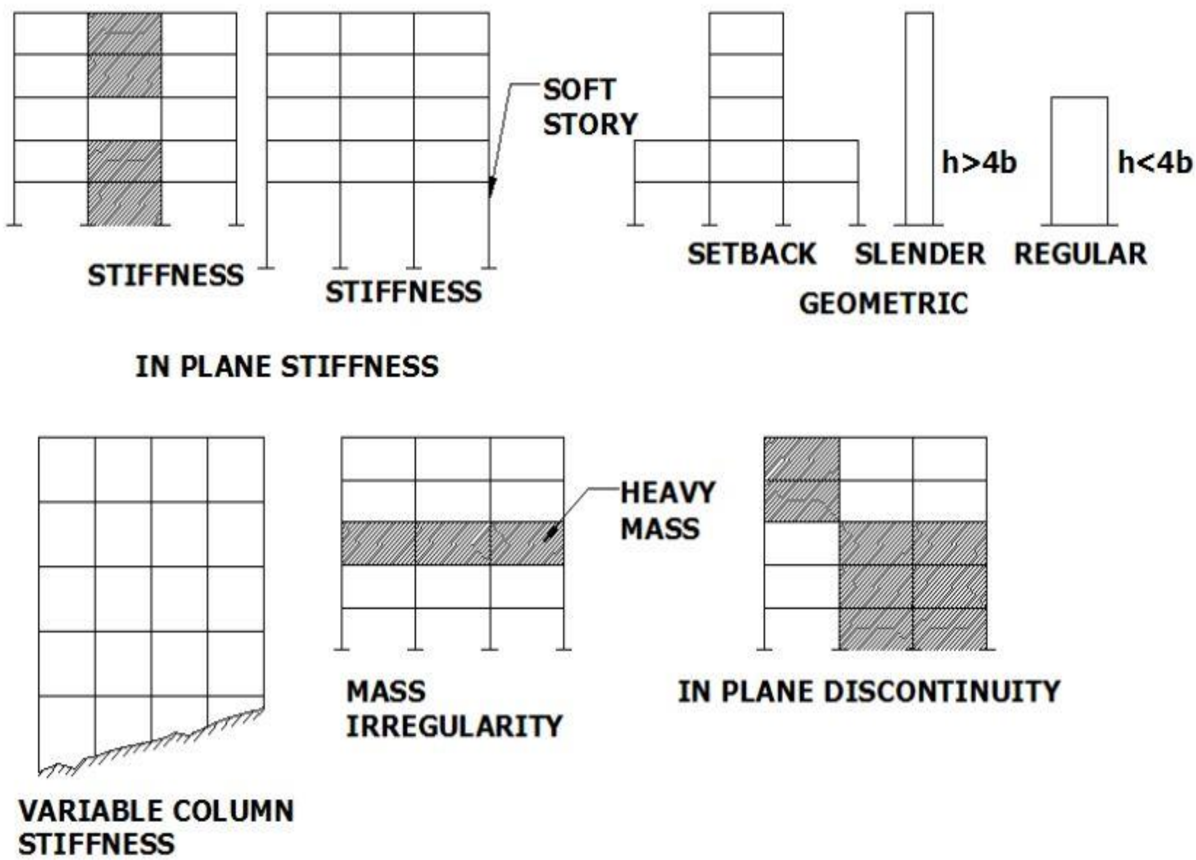


Fig-1 Mass and Stiffness Irregularity

2. ANALYTICAL WORK

Models are prepared in ETABS 2013 software. Software validation was carried out on the regular building to check whether the input provided gave the desired outcome or not. For this purpose, the regular building considered for the study.

Table 1 Model irregularity

Model	**Irregularity**
M1	Regular frame structure.
M2	Mass Irregularity at 2nd floor.
M3	Mass Irregularity at 7th floor.
M4	Mass Irregularity at 2nd and 7th floor.
M5	Stiffness Irregularity at 2nd floor.
M6	Stiffness Irregularity at 7th floor.
M7	Mass Irregularity and Stiffness Irregularity at 2nd floor.
M8	Mass Irregularity and Stiffness Irregularity at 7th floor.
M9	Mass Irregularity at 2nd floor and Stiffness Irregularity at 7th floor.
M10	Mass Irregularity at 7th floor and Stiffness Irregularity at 2nd floor.

Table 2 Typical Specification of Regular Frame Structure.

Type of Building.	Commercial Building
Seismic Zone.	III
No. of Storey.	G+10
No. of Bays in X and Y direction	11
Bay Width – X	5m
Bay Width – Y	5m
Plan Area.	50m x 50m
Grade of Concrete.	M30
Grade of Steel.	Fe 415
Beam size.	450mm x 600mm
Column size.	450mm x 450mm
Slab thickness	125mm
Density of Concrete.	25kN/m3

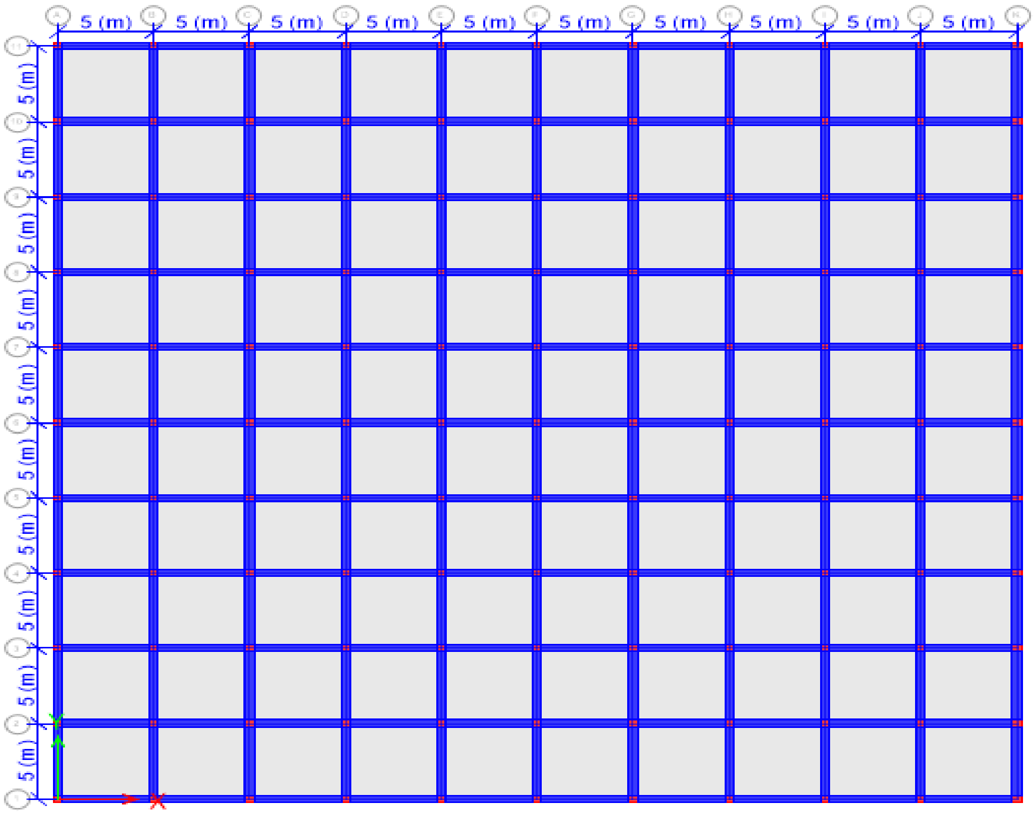


Fig 2 Model "M1" plan

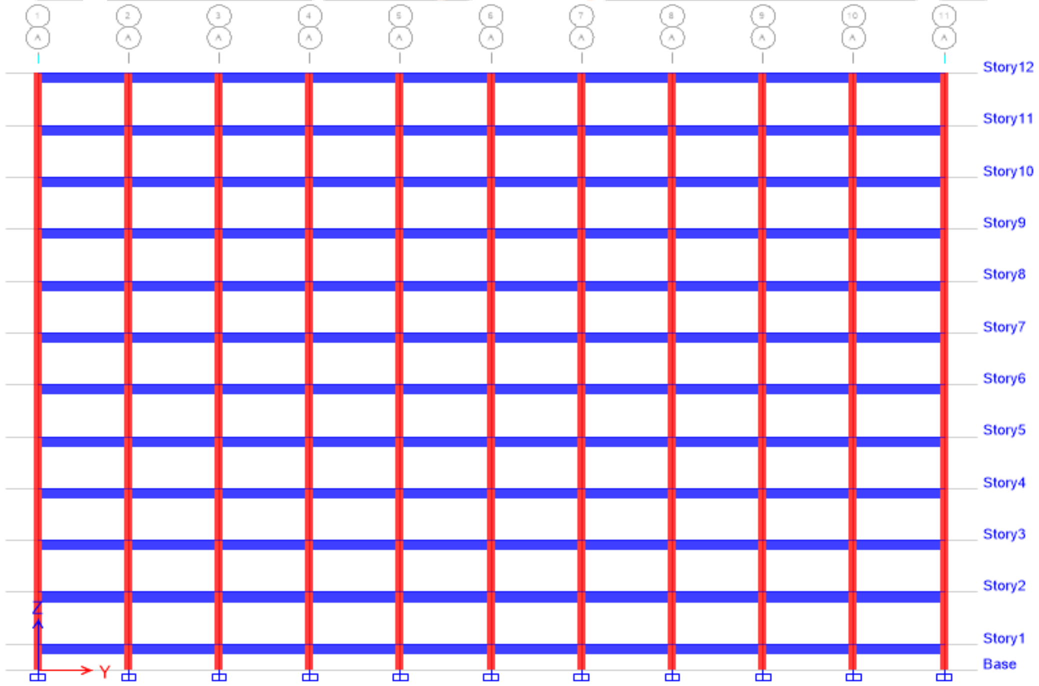


Fig 2 Model "M1" elevation

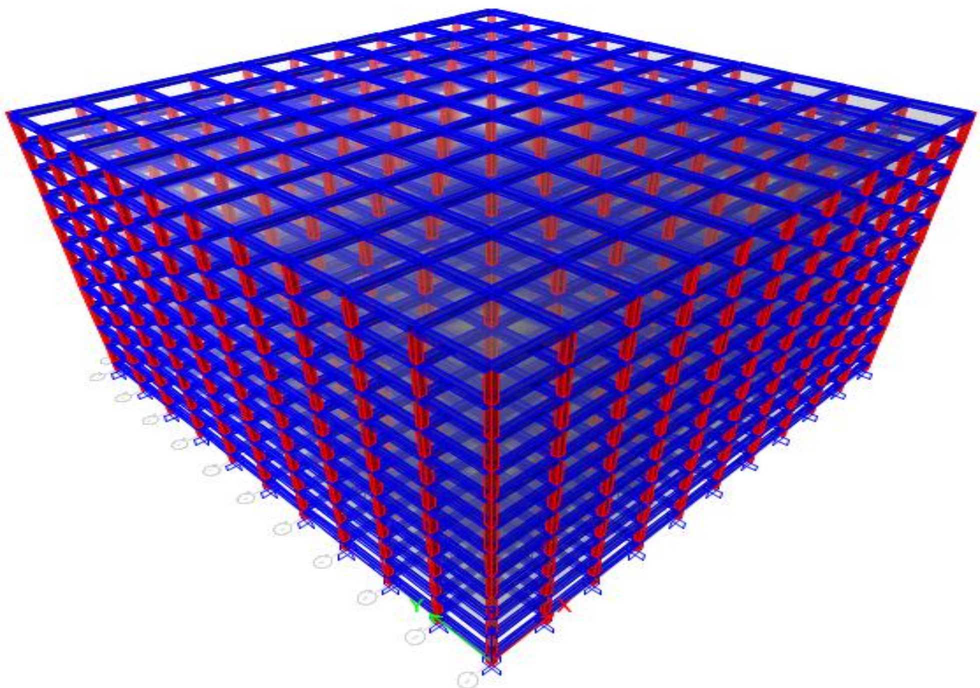


Fig 3 Model "M1" 3D view

2.1 Load calculation

1. **Dead load calculation.**

- Dead Load is applied in accordance to IS : 875 (Part I).
- Dead load includes – self weight of the members, external wall load, partition wall load, parapet wall load, composite slab self-weight and floor finish.

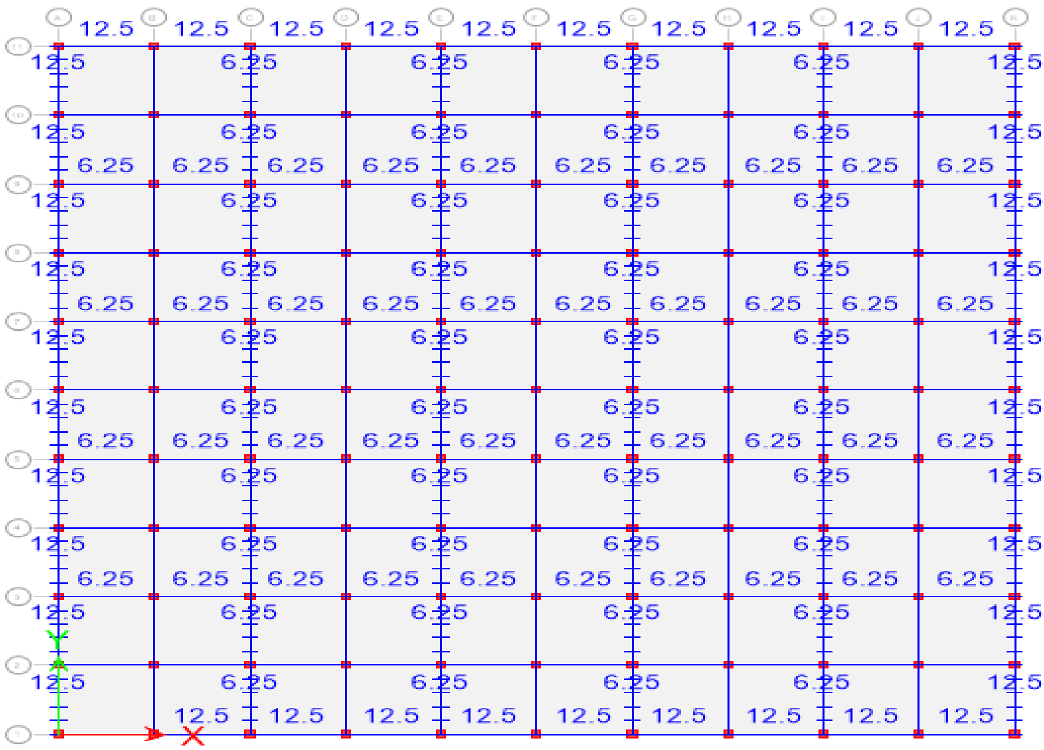


Fig 4 Dead load calculation for Model "M1".

Table 3 Dead load calculation of Model "M1"

External Wall Load	230 mm thick	0.23 x (3-0.6) x 22	12.50 kN/m^2
Partition Wall Load	115 mm thick	0.115 x (3-0.6) x 22	6.25 kN/m^2
Parapet Wall Load	115 mm thick	0.115 x 1.2 x 22	3.036 kN/m^2
Floor Finish	-	-	1.5 kN/m^2

2 Live load calculation.

- Live Load is applied in accordance to IS : 875 (Part II).
- According to the code, Live Load for a building to be used as Office is to be taken as = 4 KN/m^2.
- Above stated Live load is for a typical floor and excludes Ground floor and Terrace floor.
- For Terrace, Live Load is taken as = 1.5 KN/m^2.

3 Seismic load calculation.

- Seismic Load is applied in accordance to IS : 1893-2002.
- The seismic zone selected is = Zone III.
- Importance factor for the building is = 1.0.
- Response reduction factor (considering the type of frame selected as mentioned in IS : 800-2007) is = 5.
- Damping ratio considered is = 2 %.
- Soil condition considered is = Medium soil condition.

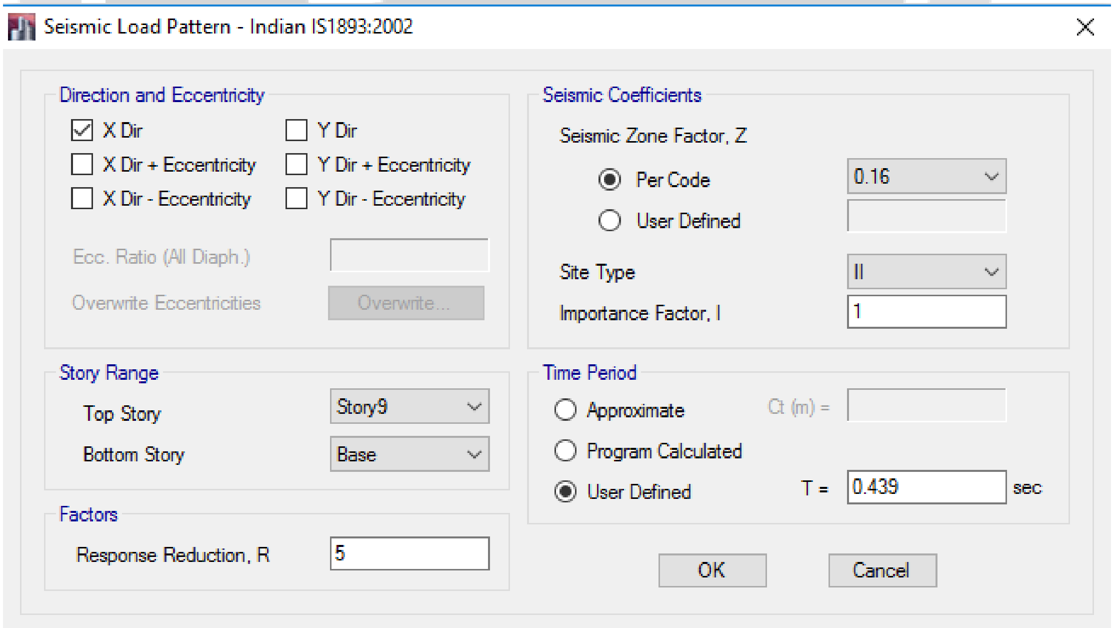


Fig 5 Seismic load pattern in x direction

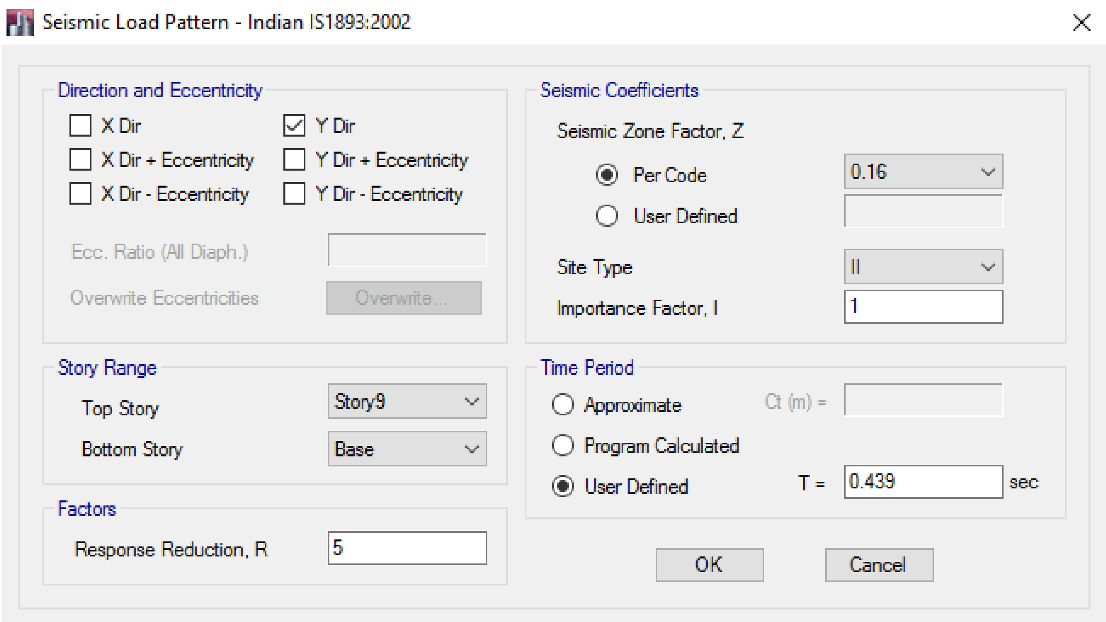


Fig 6 seismic load pattern in y direction

4 Load combination.

- Load combinations are provided as stated in IS : 1893-2002 and IS : 800-2007.
- Factored as well as unfactored, both kinds of Load combinations are provided.

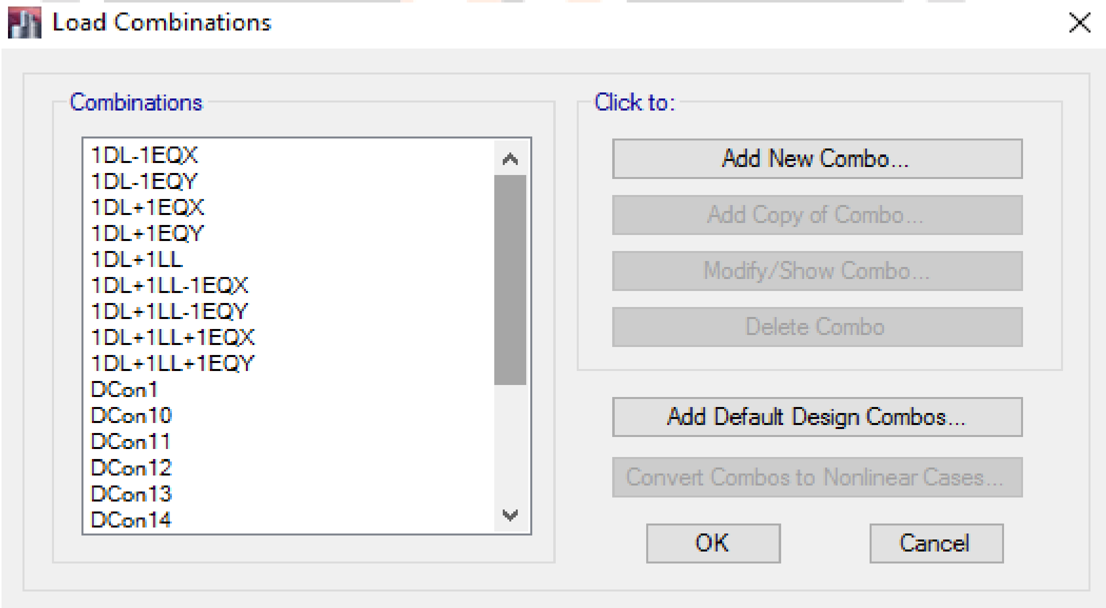


Fig 7 Load combination.

3. RESULTS

3.1 Equivalent linear static analysis method

Linear static analysis was performed on 9 models having mass irregularity and stiffness irregularity on different floors and a regular building having no irregularity. The results obtained from this analysis are as following,

- **Base Shear**
- Base shear is the total design lateral force at the base of a structure.

- Base shear is calculated by the formula,

  $\mathbf{V_b = A_h \times W.}$

  Where, V_b = Design Base Shear.

  A_h = Design horizontal acceleration spectrum value.

  W = Seismic weight of the building.

  $\mathbf{A_h = [(Z \times I) / (2 \times R)] \times (Sa / g)}$

  Where, Z = Zone factor.

  I = Importance factor.

  R = Response reduction factor.

  Sa/g = Average response acceleration coefficient.

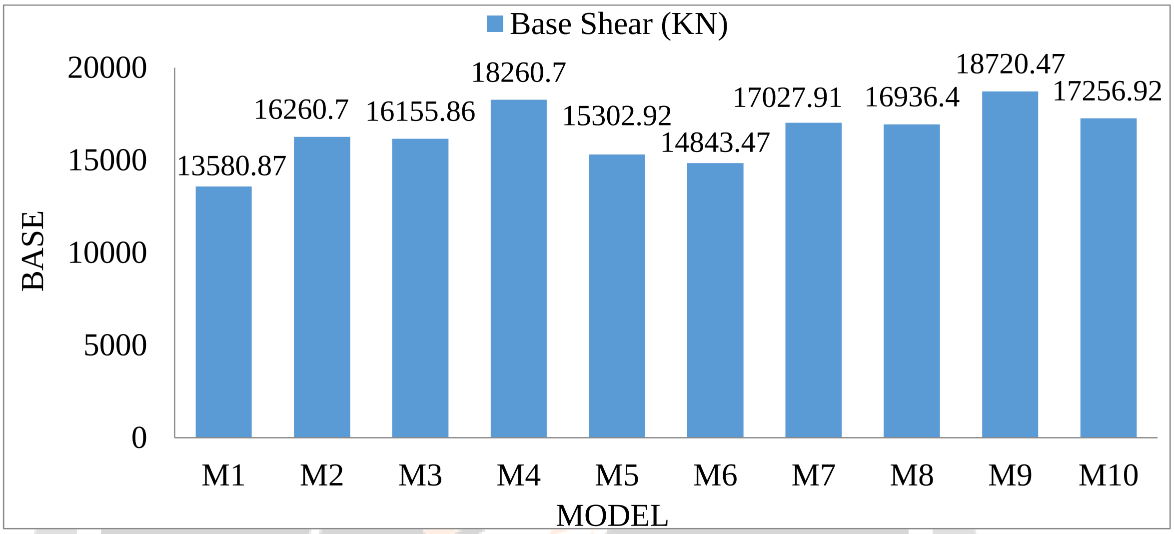


Fig 8 Base Shear comparison of models after Equivalent Linear Static Analysis.

- **Lateral displacements**

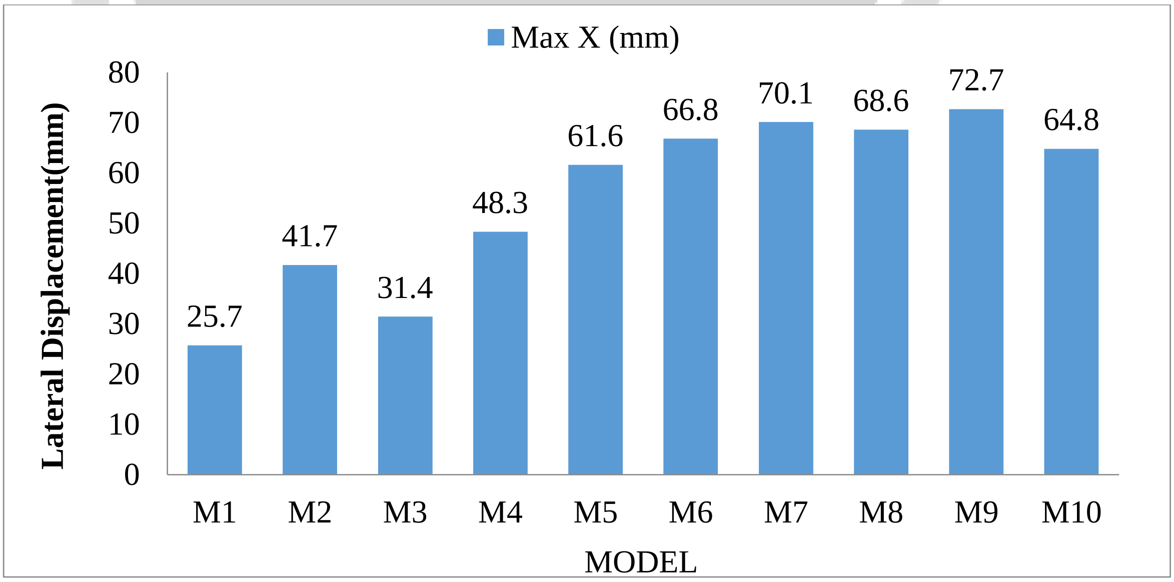
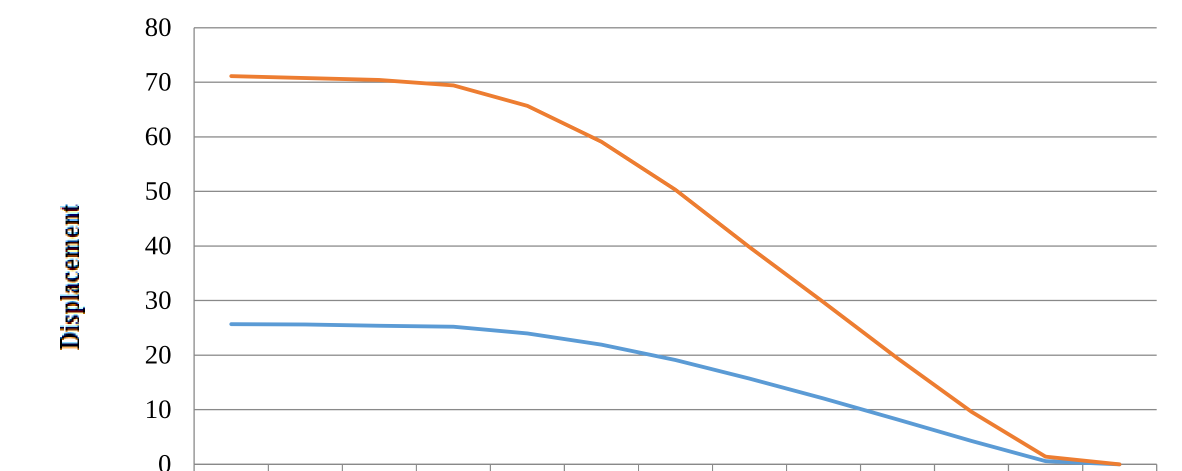


Fig 9 Lateral displacement in x direction after static analysis method

- **Storey drift**
- Under this point of discussion variation of displacement values of each storey is considered for both linear static and linear dynamic analysis.
- Graphs are plotted for the displacement values at each storey using both linear static and linear dynamic method for all cases considered, and comparing the difference in displacement values by both analysis methods.



	storey 12	storey 11	storey 10	storey 9	storey 8	storey 7	storey 6	storey 5	storey 4	storey 3	storey 2	storey 1	Base
M2=X	45.4	45.2	45	44.2	41.7	37.2	31.2	24.1	17.6	11.2	5.3	0.8	0
M1=X	25.7	25.6	25.4	25.2	24	21.9	19.1	15.7	12.1	8.2	4.3	0.6	0

Fig 10 column displacement value for model 1 and model 2 in x direction

3.2 Response spectrum analysis

Response Spectrum analysis was performed on 9 models having mass irregularity and stiffness irregularity on different floors and a regular building has no irregularity.

- **Lateral displacement**

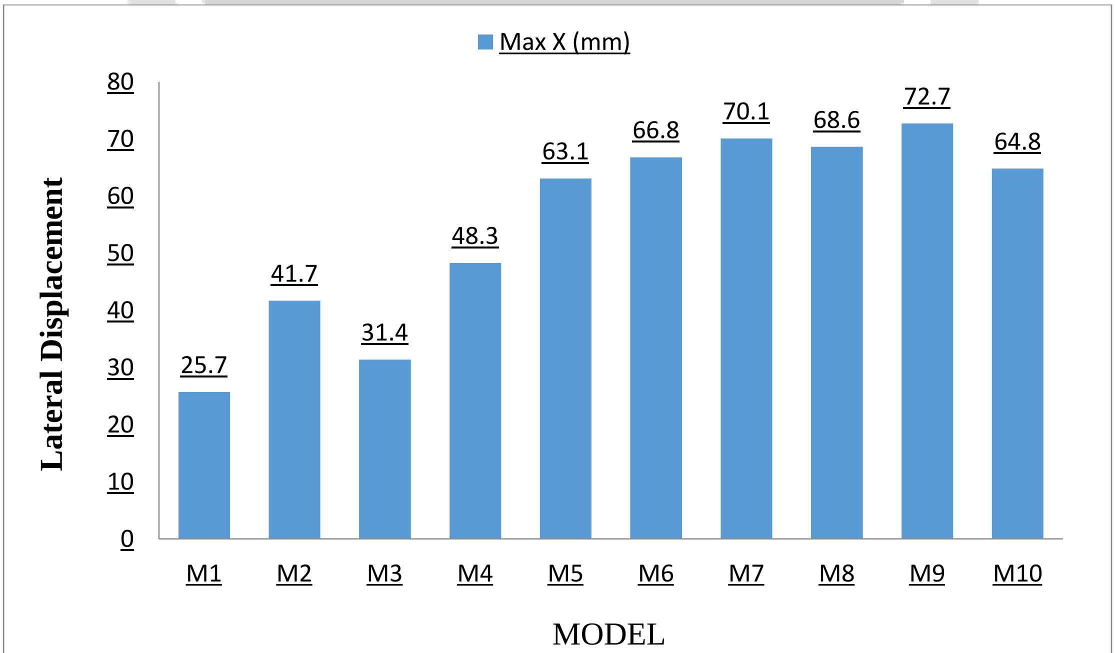
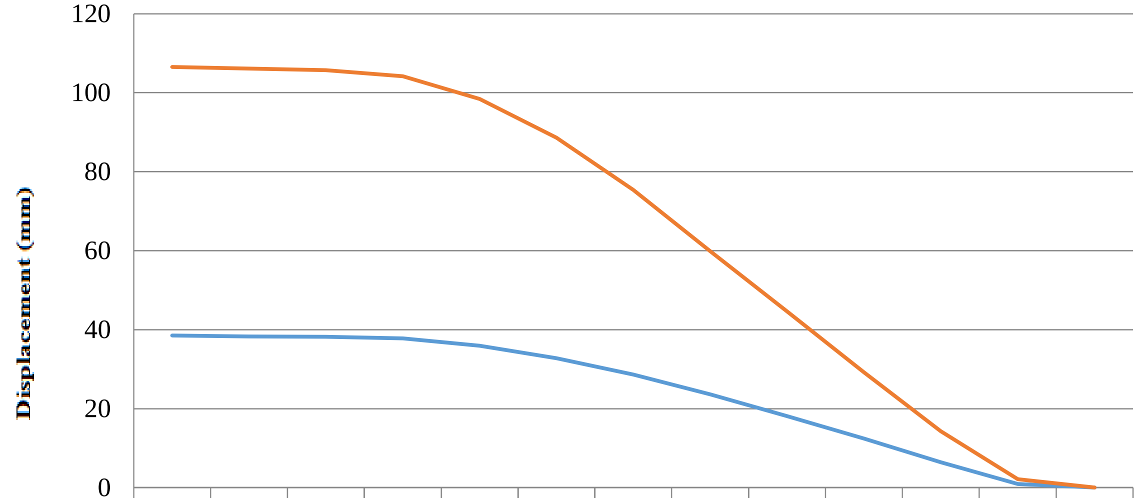


Fig 11 Lateral displacement in x direction after Response spectrum analysis

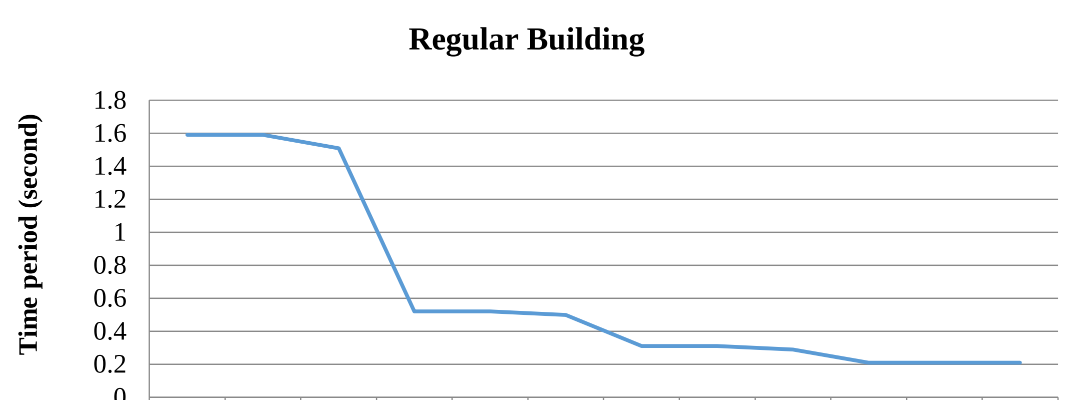
- **Storey drift**



	storey 12	storey 11	storey 10	storey 9	storey 8	storey 7	storey 6	storey 5	storey 4	storey 3	storey 2	storey 1	Base
M2=X	68	67.8	67.5	66.4	62.5	55.8	46.8	36.2	26.5	16.8	7.9	1.2	0
M1=X	38.5	38.3	38.2	37.8	35.9	32.8	28.6	23.6	18.1	12.4	6.4	0.9	0

Fig 12 column displacement value for model 1 and model 2 in x direction after Response spectrum analysis

- **Time period**



	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6	Mode 7	Mode 8	Mode 9	Mode 10	Mode 11	Mode 12
Time Period	1.59	1.59	1.51	0.52	0.52	0.5	0.31	0.31	0.29	0.21	0.21	0.21

Fig 13 Regular building time period for different 12 modes

- **Mode shape**

After carrying out linear static analysis on all the cases taken up for the studies following data have been collected, which includes time period.

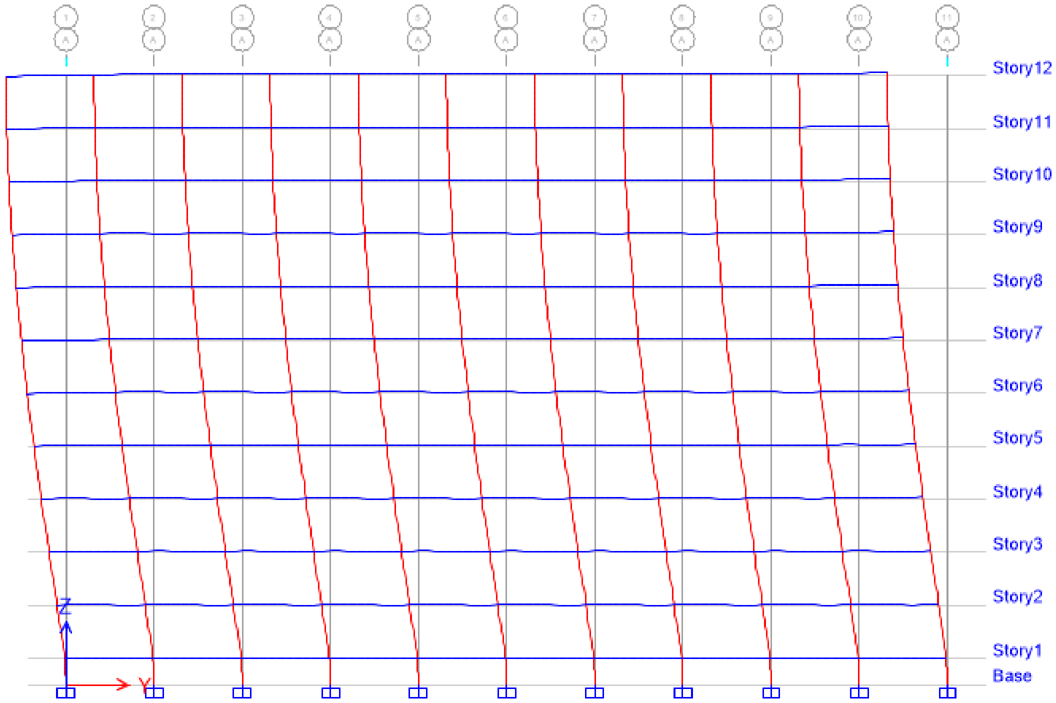


Fig 14 Mode shape and time period for mode 1 and model 1

Table 4 Time period for 12 modes and 12 models

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10
Mode 1	1.59	1.98	1.72	2.11	1.83	1.77	1.9	1.8	1.76	2
Mode 2	1.59	1.98	1.72	2.11	1.83	1.77	1.9	1.8	1.6	2
Mode 3	1.51	1.88	1.63	1.99	1.73	1.67	1.79	1.7	1.68	1.88
Mode 4	0.52	0.68	0.53	0.69	0.62	0.69	0.63	0.71	0.71	0.55
Mode 5	0.52	0.68	0.53	0.69	0.62	0.69	0.63	0.71	0.71	0.55
Mode 6	0.5	0.65	0.5	0.65	0.59	0.66	0.6	0.67	0.68	0.52
Mode 7	0.31	0.4	0.34	0.44	0.33	0.34	0.35	0.35	0.35	0.32
Mode 8	0.31	0.4	0.34	0.44	0.33	0.34	0.35	0.35	0.35	0.32
Mode 9	0.29	0.38	0.32	0.41	0.31	0.32	0.33	0.33	0.34	0.3
Mode 10	0.21	0.27	0.2	0.27	0.24	0.27	0.27	0.27	0.28	0.23
Mode 11	0.21	0.27	0.2	0.27	0.24	0.27	0.27	0.27	0.28	0.23
Mode 12	0.21	0.25	0.19	0.26	0.23	0.26	0.26	0.26	0.27	0.22

4. CONCLUSION

After undertaking static analysis and response spectrum analysis, the results obtained gave the following conclusion,

- As understood, due to decrease in the mass of the building the base shear is to be decreased and that can be clearly reflected from the results of base shear obtained by static analysis.
- Lateral displacement of the building in X and Y direction increased as the irregularity increased.
- For response spectrum analysis time period of the building from mode 1 to mode 12 of the building. Comparison of the all model and different modes can be seen in the results.

- First mode time period increase as irregularity increased and other thing was whenever we introduced mass irregularity and stiffness irregularity in one structure time period is increased higher compare to regular building and any particular irregularity.
- Lateral displacement of the building in X and Y direction increased with increased in irregularity for both maximum and minimum X and Y.
- Finally we can say that from the all results irregularity increased does affect lateral displacement increased with increased as irregularity. There for care should be taken as to be provide proper measure to reduce the lateral drift if it exceeds the code provisions.
- The main conclusion obtained from the present study is that for the models having the mass irregularity at different floor levels, storey drift is found to be at second floor for the models having mass irregularity at second floor i.e. for model M2. Also for the models having the mass irregularity at seventh floor is showing maximum moments for that floor and that place where mass and stiffness introduced that floor drift should drastically increased compare to other floor and regular building.

5. ACKNOWLEDGMENT

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