A STUDY ON SEISMIC PERFORMANCE OF PLAN IRREGULAR BUILDING WITH DIFFERENT STRUCTURAL SYSTEMS

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Abstract – *Nowadays, we often see tall structures in metropolitan cities like Mumbai, Delhi, Bangalore, etc which are growing at high speed with our country as a developing nation. The point here is need of tall structures with increasing scarcity of lands in big city and appropriate structural systems for this kind of tall structures which can help our structure to withstand against strong wind and earthquake forces. Also with the increasing height of structures architects are also raising the bar of aesthetics of buildings. As the architects are going with more and more unconventional or irregular type of building from the aesthetic point view it increases the vulnerability of structures against seismic forces. To counteract this kind of situation we need special structural system which gives better stability to the structure and also can be suitably used for designing irregular type of structures ass per today's requirements. Hence, in this research we are going to study the seismic behavior of horizontally plan irregular building. We will be evaluating special structural systems like Shear walls, Framed tube, Tube in tube structural systems against earthquake forces with the help of Etabs software. We will be using Response Spectrum method for seismic analysis of G+40 storey building having different structural systems.*

Key Words: **Tall structures, Irregular building, structural systems, earthquake forces, MRF structure, shear wall, Framed tube structure, Tube in tube structure.**

1.INTRODUCTION

Tall buildings play a crucial role in today's urban landscape for several reasons:

- Space Optimization: As cities grow, land becomes scarce. Tall buildings allow us to maximize space vertically, accommodating more people and activities within limited areas. Population Density With increasing urbanization, tall structures provide housing, offices, and amenities for a densely populated world.

- Sustainability: Vertical growth reduces urban sprawl, minimizing the need for extensive transportation networks and preserving natural habitats. Tall buildings define city skylines, symbolizing progress, innovation, and architectural prowess. Modern skyscrapers integrate residential, commercial, and recreational spaces, fostering vibrant communities.

- Tall buildings are essential for efficient, sustainable, and vibrant urban living.

So far, many researchers had studied the effect of irregularities on the seismic performance of structure. Abraham, N.M. and SD, A.K. (2019) investigated seismic behavior of 9 storey building with different irregularities also including combination of irregularities by using Time history analysis. They had concluded that buildings having combination of stiffness and vertical geometric irregularities are more susceptible to earthquake forces whereas the combination of re-entrant corner and vertical geometric irregularities has shown lesser effect of earthquake forces.

Krishnan, P.A. and Thasleen, N.(2020) studied the seismic analysis of RCC buildings with plan irregularities mainly focusing on re-entrant corners type of irregularity. They observed High stress concentrations at all the re-entrant corners in the various models whereas columns and other members closer to the re-entrant corners were found to fail first. Firdose, H.A., Kumar, A.S., Narayana, G. and Narendra, B.K.(2022) studied the dynamic behavior of irregular reinforced concrete structures with different locations of shear walls in G+17 story building model. They found that shear wall is one of the best methods for the R.C frame irregular plans. Shear walls at corners is found as the best optimum location and positioning of shear walls. To, T.I., (2022) studied the seismic performance of framed, frame tube and tube-in-tube structures of G+39 and G+29 stories using Response Spectrum method. According to the authors tube-in-tube structural system is most effective in resisting lateral loads as tube-in-tube structures performed best with the least displacements followed by the framed tube.

Hussain, M., Hussain, L., Maher, A. and Zaidi, S.A.,(2020) carried out a comparison of four different types of tubular structural frames with varying column spacing of 7.5 ft, 10 ft, 15 ft, and 30 ft in the periphery of the 60 storey building. They concluded that tubular frame with 10 ft column spacing is the most optimal and economical solution compared to other tubular and moment-resisting frame structures. Revankar, N. and Fernandes, R.J., (2021) studied the performance of five different structural layouts for a 21-story high-rise building under earthquake forces using the equivalent static method. According to their findings tube and tube-in-tube structures perform well, but due to less favorable architectural and material consumption perspective. They concluded that moment frame with core shear wall is the optimized structural layout for high-rise buildings.

In this study various irregular plan buildings are studied with different structural systems to understand the seismic effect on structure. Total 30 models had prepared with plan irregularities like L,T,C,I, Step and 2 Step type of building. Structural systems like shear walls, Framed tube and Tube in tube system is used to counteract earthquake forces. Then Response spectrum analysis is carried out with the help of etabs software. The main purpose of this study is to identify the best structural system for tall structures.

1.1 Objective

Below are the objectives of this study:-

1. To study the seismic behavior of high rise buildings.
2. To identify the effects of plan irregularities on seismic response of the structure.
3. To study effectiveness of different structural systems against earthquake.
4. To study different structural parameters for different structural systems like Base shear, story shear, story displacement, displacement, etc.
5. To suggest optimum structural system for plan irregular buildings.

2. Methodology

First we are going to model the G+40 story building in ETABS software. For that we are going to define some material properties and material section in etabs then we will go for modeling. After the modeling is we will make some lode cases and the apply the load our structure. Then we can perform out response spectrum analysis to get various values like base shear, story drift, etc. Below is the input data and some procedure is given which we have used to make 30 models for this study.

2.1 Input data

Table 1 details of the building used for study

Type of Building	Commercial
Number of stories	G+40
Floor to Floor Height	3m,4m(for GF only)
Height of Building	124m
Grade of Concrete	M30
Grade of Steel	Fe500
Shear walls :- Base to 20th Storey 21th to 10th Storey	 350mm 230mm
Beam Size :- Base to 30th Storey 31th to 40th Storey	 400mm*700mm 400mm*550mm
Column Size :- Base to 11th Storey 12th to 31th Storey 32th to 40th Storey	 950mm*950mm 750mm*750mm 500mm*500mm
Slab Thickness	150mm
Live load	3 KN/m2
Floor Finish	1.25 KN/m2
For top slab :- Live load Floor Finish	1.5 KN/m2 2.5 KN/m2

Table 2 E-tabs model details

Type of Irregularities	Re-entrant Corner
Plan Irregular Plan R.C.C frames	L,I,C,T,STEP,2 STEP
Number of Bays in X-Direction	10
Number of Bays in Y-Direction	10
Spacing of bays	6m
Shear wall type	R.C Shear walls
Spacing of columns in tube structures	3m
Position of shear wall	At corner and core

Table 3 Earthquake load detail

Importance Factor	1.5
Response Reduction Factor	5
Seismic Zone factor	Zone 5: 0.36
Type of Soil	Hard
Time Period	Program Calculated
P delta combination	1.2 DL + 0.5 IL ±1.5 EL

Table 5 Cracked Section Properties of RC members

(*Clauses* 5.5.2,7.3.6, 8.1.3.2.1 *and* 7.2)

Sl No.	Structural Element	Serviceability Design		Strength Design	
		Cross-Sectional Area	Moment of Inertia	Cross-Sectional Area	Moment of Inertia
(1)	(2)	(3)	(4)	(5)	(6)
i)	Slabs	$1.0A_g$	$0.35I_g$	$1.00A_g$	$0.25\ I_g$
ii)	Beams	$1.0\ A_g$	$0.7\ I_g$	$1.00\ A_g$	$0.35\ I_g$
iii)	Columns	$1.0\ A_g$	$0.9\ I_g$	$1.00\ A_g$	$0.70\ I_g$
iv)	Walls	$1.0\ A_g$	$0.9\ I_g$	$1.00\ A_g$	$0.70\ I_g$

Fig. 1 Stiffness modifiers used in E-tabs models as per 16700 : 2023

2.2 Models used for study

We have prepared total 30 models with 6 type of plan irregularity listed below:-

1. L-plan building
2. T- plan building
3. C- plan building
4. I- plan building
5. Step-plan building
6. 2-Step plan building

With 5 different structural systems given below:-

1. MRF structure
2. MRF with shear wall structures
3. Framed tube structures
4. Framed tube with core shear wall system
5. Tube in tube structural system

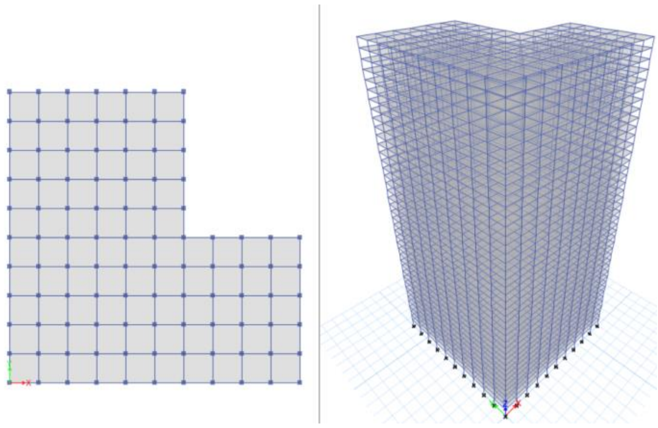

Fig. 2 L-plan MRF structure

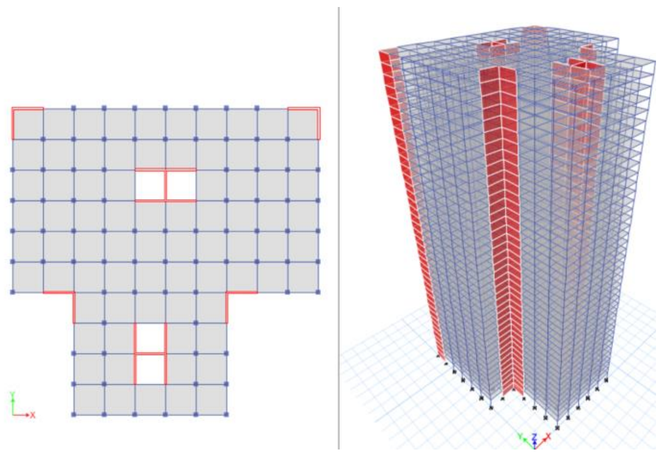

Fig. 3 T-plan MRF with Shear wall structure

For tube structures in outer or inner tube the column spacing will be 3m as in figure shown below.

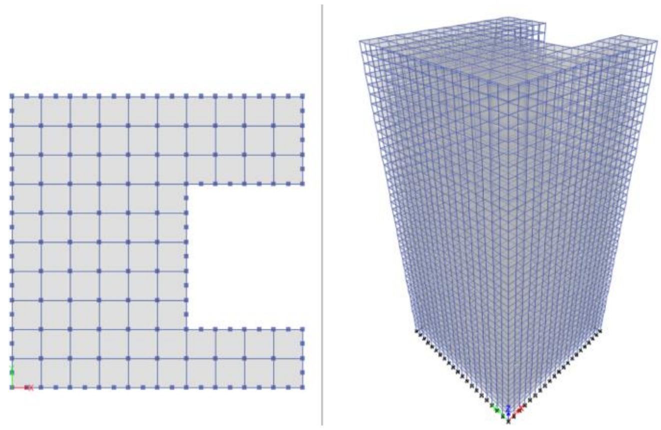

Fig. 4 C-plan Framed tube structure

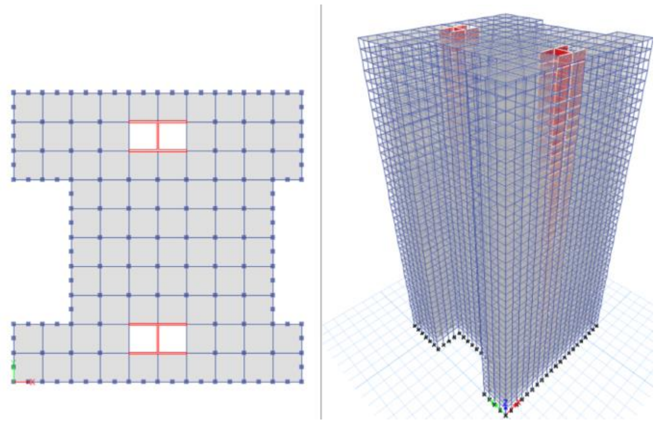

Fig. 5 I-plan Framed tube with core shear wall structure

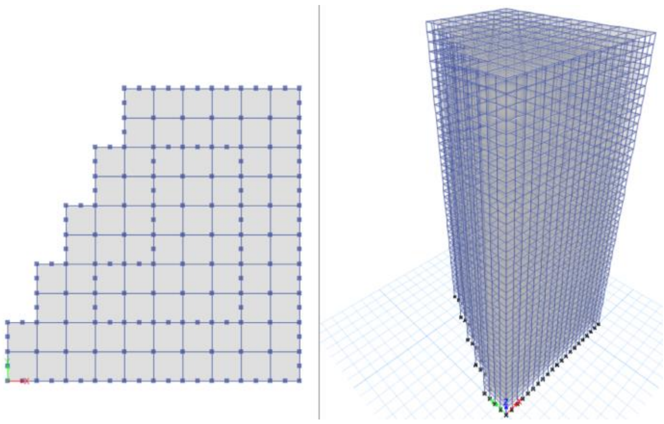

Fig. 6 Step-plan Tube in tube structure

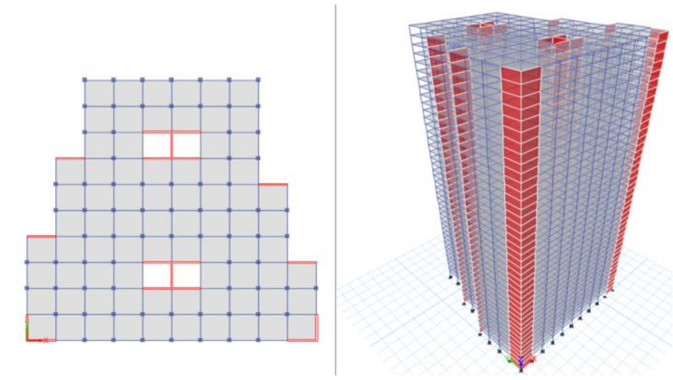

Fig. 7 2-Step plan MRF with shear wall structure

3. Observations

In this section we are going to see the results of various models for story displacement, story drift, base shear and time period values.

3.1 Storey Displacement

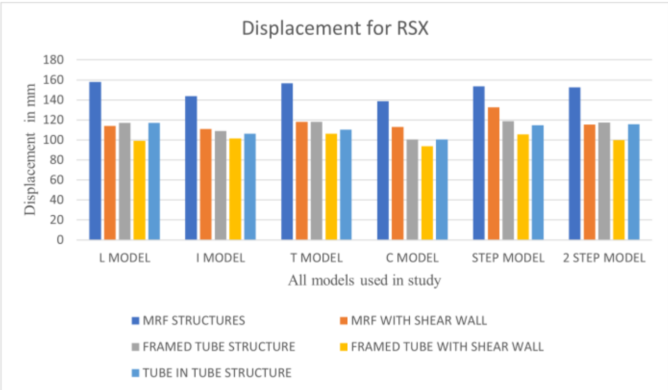

Chart. 1 Storey Displacement in X-direction

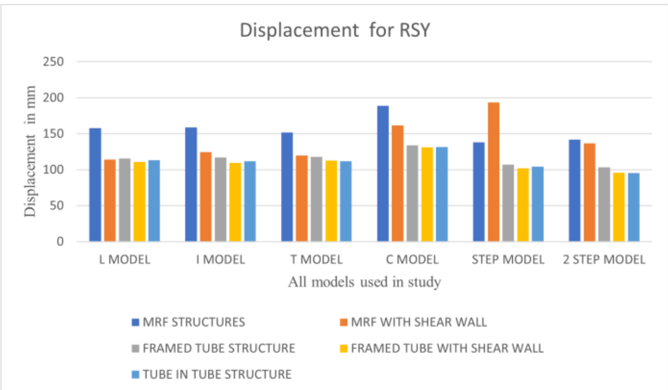

Chart. 2 Storey Displacement in Y-direction

All the 30 models displacement values with respect to X and Y direction are given above in the graph. As per the result we can see that we are having maximum displacement values for the Y direction 193.51mm in STEP MRF with shear wall structure and for the minimum value of displacement we are having in X direction 93.86mm in C type Framed tube with shear wall at core model.

3.2 Storey Drift

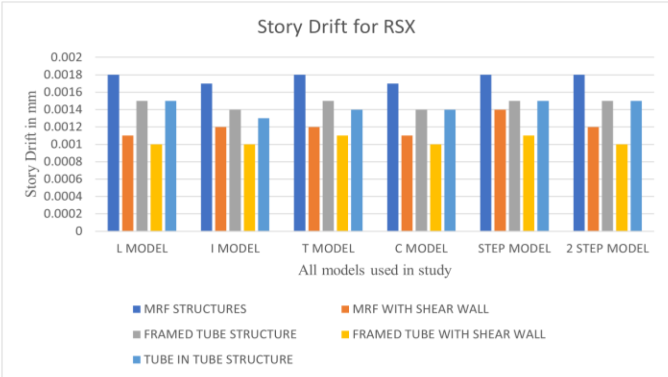

Chart. 3 Storey Drift in X-direction

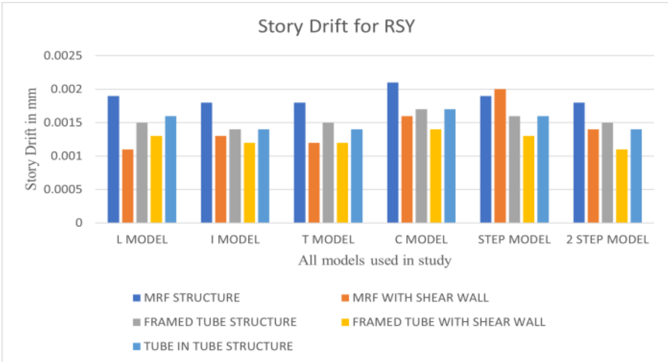

Chart. 4 Storey Drift in Y-direction

Now, for the story drift all the values are given above in the graph form which are in control as per the maximum limit of 0.004 given in IS 1893 : 2016. From the table we can see that the maximum story drift we are getting is 0.0021 for C type MRF model and minimum is 0.0010 for various type of model having framed tube with shear wall at core.

3.3 Base Shear

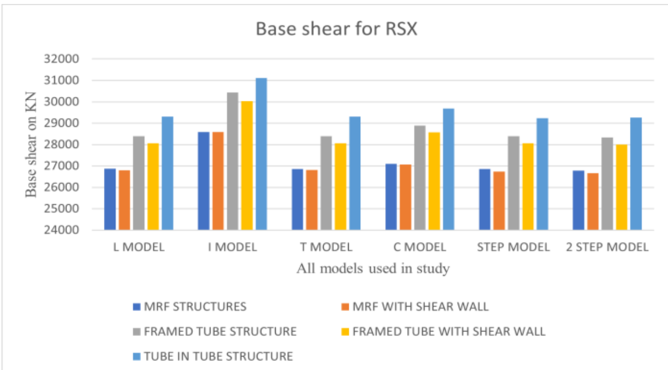

Chart. 5 Base shear in X-direction

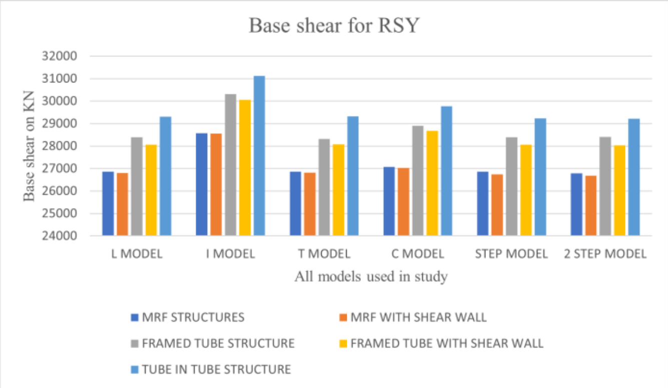

Chart. 6 Base shear in Y-direction

We are having all the base shear values in the table format below from which we can see that the I type Tube in tube structure is having maximum base shear value of 31125.81 KN of all the models and getting minimum base shear value of 28555.35 KN for I type MRF with shear wall structure.

3.4 Time period

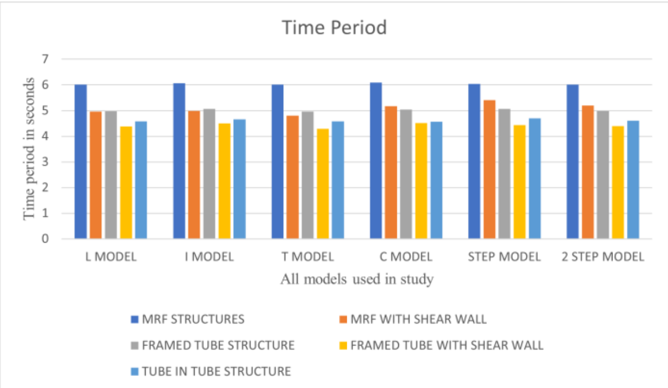

Chart. 7 Time period graph

From the graph we can easily understand the influence of various structural system on the total time period of the building. Here we can see that our graph is having maximum time period values for MRF type of structures and minimum time period values for Framed tube with shear wall core structures. Also all the time period values obtained are below 8 second as per IS 16700 : 2023

4. CONCLUSIONS

Below are some conclusion we can get from seismic response of irregular structures having different structural systems :-

- For the MRF type of structures with irregular shape it is having maximum values for story drift, time period, displacement and minimum value of base shear in all models. Hence we can say that for Tall and irregular building combination MRF type of structures can not resist earthquake forces effectively.
- Here, we are getting very interesting output about the shear wall from this study.

1. The structures having shear wall shown considerable decrease in the value of story drift compare to the structures not having shear walls.
2. As we can see from the graphs that we are having lesser values of base shear for structure having shear wall compare to the structures having only columns.
3. From the results we can see that in MRF structure by just adding shear wall at critical locations it can greatly affect the earthquake resisting capacity of structure.

- Now, for base shear we are getting maximum base shear values for tube in tube type of structural system compare to all other type of structural systems.
- As for the time period values we are having minimum time period values for Framed tube with core shear wall structural system compare to any other structural system.
- And for story displacement and story drift values we can see from the graphs that the structures having Framed tube with core shear wall structural system shows lesser values compare to other type of structural system.
- As per the results of this study if we have to opt for any single special structural system then here study suggests Framed tube with core shear wall structural system will be the best from the strength perspective and also from the architectural point of view as it gives satisfactory results for all the parameters. And if we have to go for second best then will suggest Tube in tube system but the only drawback of this system is inner tube which makes inner area of the building congested if columns are placed very closely.

5. Future scope

Below are some recommendations for the future studies in this area of research:-

1. We can try different building irregularity which haven't studied yet.
2. We can also change the type of building like steel structure or composite columns
3. We can try other structural systems like outriggers, braced frame, braced tube, bundle tube, etc.

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