A Technical Approach to Flat Slab Multistorey Building under Wind Speed of 39 m/s

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Abstract - *In this scenario, for multistorey building and skyscraper building, beam slab structure is not used in India, it is replaced by flat slab construction. The flat slab is a reinforced concrete slab which is directly supported on column so for aesthetic purpose, it is decent as well as it is efficient. Flat slab is more flexible as compared to R.C. slab so it's advantages are more to design the flat slab. The flat slab has many advantages but the main problem is that the flat slab is weak against lateral loading such as wind and earthquake loading and with the help of equivalent frame method; the flat slab design is performed. In this work, taking the G+ 20 model building plan, which is rectangular in shape 36m x 44m in plan and this plan, is made with help of AutoCAD software. After fixing the plan, it has divided into different panels and each panels is designed by manual approach using equivalent frame method. This manual data inserted in Staad pro and analyze with providing shear wall at two different locations i.e. lift area and maximum stress in plate area of the building to minimize the same.*

***Key Words*: Column Stresses, Displacement, Equivalent frame method, Flat slab, Shear wall, Wind load.**

1.INTRODUCTION

A concrete slabs are a common structural element which is used generally in modern structural buildings. These slabs are horizontal and it is generally made up of concrete or steel typically between 100 and 500mm thick as per requirement, are most often used floors and ceiling. The two types of slab are basically used in present time in structural building-

- Common type slab
- Flat slab
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The common type of slab is supported by beams and beam is attached with the columns, this types of construction called as simple beam slab construction. The slab which is directly supported by columns known as flat slab. Flat slab is a reinforced concrete slab supported by column, it may be added or not added drops or the column may be added column heads or without column heads. Drop is a local thickening of the slab in the region of the column. In the current scenario flat slab is used instead of beam column construction because of its advantages over beam column connections. In architectural point of view, flat slab are better, also it permits flexibility in building construction. It takes clear space, low height, easy framework and takes less time therefore flat slab buildings are used now-a-days in India. Flat slab structures are weak against lateral loading such as seismic loading and wind loading so that the design and analysis of flat slab is very important. Therefore analysing the different types of flat slab, provided shear wall at various points in different types of flat slab under wind load condition using software Staad pro. In present time flat slab buildings are used in high rise buildings because of its advantages as it reduces time, cost effective, easy installation and required the least storey height. To increase the performance of buildings wind load behaviour of building should be properly checked.

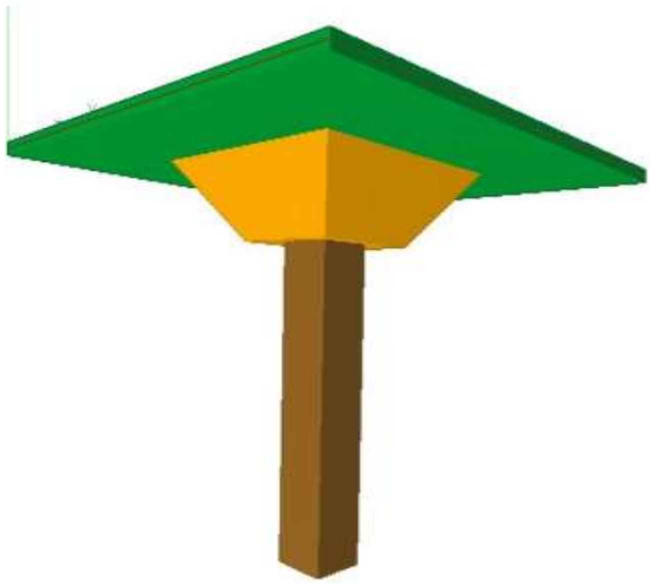

Fig -1: Flat Slab with Column Head

Mainly there are four types of flat slabs-

1. Simple flat slab
2. Flat slab added drop
3. Flat slab added column head
4. Flat slab added drop and column head

1. Simple flat slab - This type of flat slab having no drop and no column head so that this type of flat slab is known as simple flat slab. This type of flat slab is used in residential building that reduces the available net clear ceiling height. Hence in warehouses, offices and public halls sometimes beams are avoided and slabs are directly supported by column are called flat slab.

2. Flat slab added drop - Drops are provided to increase the shear strength of slab. In flat slab bending moments are generated more near to the column, so that provided thickness to the slab near to the column by providing the drops. Sometimes the drops are known as the capital of the column.

3. Flat slab added column capital - The column capital is provided sometimes widened because to reduce the punching shear in the slab. The column head is provided in any angle for architectural purpose but for design purpose it is provided on 45 degree from vertical. Therefore in multistorey buildings, to reduce the punching shear column head is provided in the slab.

4. Flat slab added drop and column capital - Both are the combinations are the best for the design of flat slab because of the advantages of drops and column heads. This type of flat slab has high strength in shear. It is provided stiffening to the slab so that it reduces deflection.

2. OBJECTIVES

The main purpose is to find the economical model case to counteract wind forces and analysis is done using software Staad pro. So for this, different loads applied and parametric values obtained are considered and point of comparison on different models is as follows:

1. To find maximum Nodal Displacement in X Direction and Z Direction.
2. To show the maximum Axial Force in Column at Ground Level.
3. To compare maximum Shear Force in Column Sy and Sz for all model cases.
4. To relate maximum Compressive Stress in Column.
5. To find and observe maximum Tensile Stress in Column.
6. To show and relate maximum Torsional Moment in Column for all model cases.
7. To obtain economical model among all model cases by observing and comparing their parametric values.

3. STRUCTURE CONFIGURATION AND METHODOLOGY

In this paper, taking G+20 model building with overall height of 80.01m with plan area (36mx44m) for four model cases. For this, the foundation depth is 3m and total height of each storey is 3.81m. Four different model cases are selected and modelled in Staad pro under basic wind speed of 39m/s with reference to Indian Standard code IS 875 Part 3. The main aim is to design the flat slab so for this, firstly the whole plan is differentiated into different panels and each panels are design by manually using Equivalent Frame Method and data obtained is provided to Staad pro for the detailed analysis of the structure. All panels are designed on the basis of:

- Roof
- Exterior wall
- Interior wall

The data selected such as Grade of concrete M35, Grade of steel Fe 415 is selected. The bar diameter selected as 12 mm with a Clear cover of 25 mm throughout the structure. Unit wt. of brick taken as 20 KN/m^3, height of floor selected as 3.81m for all the subsequent levels. Thickness of external wall and internal wall are 0.228m and 0.15m respectively with plaster thickness of 0.24m with 20KN/m^3 unit weight. Also, parapet height of 0.75 m is used. 10 mm mortar unit weight 0.42 KN/m^3 for ceiling and 10 mm thick terrazzo flooring with weight of 0.24 KN/m^2 is selected. Column size selected as 500 mm x 400 mm by hit and trial method. For load consideration, live load for floor and roof are 3.5KN/m^2 and 1.6KN/m^2.

DESIGN OF FLAT SLAB FOR PANEL SIZE 6X8

Step1- Thickness of Flat Slab-

Equivalent Frame M/D = Modification Factor (M.F) = 33.8
Overall depth (D) = Span/Ratio = 8000/33.8 = 237 mm
D Approx. = 294 mm
Let Effective Depth (d) = D - (Dia. of Bar / 2) - Clear Cover = 294 - (12/2) - 25
In Longer Direction (dl) = 263mm or .263m
In Shorter direction (ds) = Dl – Dia. of Bar = 263 - 12
ds = 251mm or .251m

Step 2 - Load Calculation
1 - Dead Load
A - Self load of slab = D x unit weight of concrete =.294 x 25 = 7.4 KN/m^2
B - Plate area load
1) Parapet wall load
PWL = (thickness x height x unit weight of brick) / plate area
PWL = [(.228 x 20 + .024 x 20) x .75] / (6 x 8) = .078 KN/m^2
C- for 10 mm mortar both side of roof and floor = .42 KN/m^2
D- Terrazzo floor tiles load 10 mm thick = 0.24 KN/m^2
Total dead load
For roof level dead load = 7.4 + .078 + .42 + 0.24 = 8.1 KN/m^2

2 - Live load-
For roof = 1.6 KN/m^2
Total load-

For roof level = 8.1 + 1.6 = 9.7 KN/m²

Total Factored Load -

For roof level = 1.5 x 9.7 = 14.6 KN/m²

Step 3 - Calculation of stiffness and alpha c (αc)

Along longer direction

For slab

Ks = (4 x E x I)/LL = (4 x E x 12665474635) /8000 = 6332737 x E

∑ks = 2 x 6332737 = 12665475

For column

Kc = (4 x E x I)/CH = (4 x E x 4166666667) / 3810 = 437474453 x E

∑kc = 2 x 437474453 = 8748906

Then, αC = ∑kc / ∑ks = (8748906 / 12665475 x E) = .7

Along shorter direction

A. For slab

Ks = (4 x E x I) / LL = (4 x E x 16887299514) / 6000 = 11258200 E

∑ks = 2 x 11258200 E = 22516399

B. For column

Kc = (4 x E x I) / CH = (4 x E x 2666666667) / 3810 = 2799650 E

∑kc = 2 x 2799650 = 5599300

Then, αC = ∑kc / ∑ks = 5599300 / 22516399 = .25

Step-4 Check for correction due to pattern loading

If ratio of Live Load and Dead Load is greater than 0.5, then pattern loading required

Live Load / Dead Load < = .5

At roof level = live load / dead load = 1.6 / 8.1 = .2 (not Required)

Step-4 Check for correction due to pattern loading

If ratio of Live Load and Dead Load is greater than 0.5, then pattern loading required

Live Load / Dead Load < = .5

At roof level = live load / dead load = 1.6 / 8.1 = .2 (not required)

Step- 5 Total moment calculation

In longer direction

Ln = 7.5 M L2 = 6 M Ln² = 56.25 m

Mo = (W x Ln x L2) / 8 or (w x L2 x Ln²) / 8 = (14.6 x 6 x 56.25) / 8 = 613

In shorter direction

Ln = 5.6 m L1 = 8 m Ln² = 31.36 m

Mo = (W x Ln x L1) / 8 or (w x L1 x Ln²) / 8 = (14.6 x 6 x 31.36) / 8 = 456

Step-6 Column strip and middle strips

In longer direction

Column strips

A- 2(.25 x L2) = 2(.25 x 6000) = 3000 mm

B- 2(.25 x L1) = 2(.25 x 8000) = 4000 mm

Lesser value will be taken (a or b) column strip = 3000 mm

Middle strips = L2 - column strips = 6000 - 3000 = 3000 mm

In shorter direction

Column strips

A- 2 (.25 x L1) = 2(.25 x 8000) = 4000 mm

B- 2 (.25 x L2) = 2(.25 x 6000) = 3000 mm

Lesser value will be taken (a or b) column strip = 3000 mm

Middle strips = L1 - column strip = 8000 - 3000 = 5000 mm

Step- 7 Reinforcement along longer direction

Moment in longer direction

$$Pt\ \% = [50 * (fck/fy)] * 1 - \sqrt{1 - (\frac{4.6Mu}{fckbd^2})}$$

Table 1: Moment in Longer Direction

Mu	Mu_{cn} = .65 x .75 x M_o = .65 x .75 x 613 = 300	Mu_{cp} = .35 x .6 x M_o = .35 x .6 x 613 = 130	Mu_{mn} = .65 x M_o - Mu_{cn} = .65 x 613 – 300 = 100	Mu_{mp} = .35 x M_o - Mu_{cp} = .35 x 613 -130 = 86
P_t	.42 %	.17 %	.13 %	.12 %
Total A_{st}	(P_t x b x d) /100 = (.42 x 263 x 3000) / 100 = 3310	(P_t x b x d) /100 = (.17 x 263 x 3000) / 100 = 1340	(P_t x b x d) /100 = (.13 x 3000 x 263) / 100 = 1025	(P_t x b x d) /100 = (.12 x 3000 x 263) / 100 = 946
A_{st}/m	1105	447	342	316

Step-8 Reinforcement along shorter direction

Table 2 : Moment in Longer Direction: For roof

Mu	Mu_{cn} = .65 x .75 x M_o = .65 x .75 x 456 = 223	Mu_{cp} = .35 x .6 x Mo = .35 x .6 x 456 = 96	Mu_{mn} = .65 x M_o -Mu_{cn} = .65 x 456 – 22 = 75	Mu_{mp} = .35 x M_o - Mu_{cp} = .35 x 456 – 96 = 64
P_t	.34 %	.15 %	.12 %	.06 % but take .12 %
Total A_{st}	(P_t x b x d) /100 = (.34 x 251 x 3000) / 100 = 2560	(P_t x b x d) /100 = (.15 x 251 x 3000) / 100 = 1130	(P_t x b x d) /100 = (.12 x 5000 x 251) / 100 = 1505	(P_t x b x d) /100 = (.12 x 5000 x 251) / 100 = 1505
A_{st}/m	855	380	300	300

Step- 9 Check for two way shear or punching shear

Shear force calculation

Vu = (L1 x L2 - critical section area) x factored load

= (6 x 8 - .750 x .650) 14.6 = 690 KN

Bo= 2 x critical section area = (650 + 750) x 2 = 2803

Bo x d = 2803 x 251 = 702610

Tau c = Vu / Bo x d = (690 / 702610) x 1000 = .98 N/mm²

From IS code 456 -2000 page no 58 (cl. 31.6.3.1)
Ks =1.3
Tau c = .35 x (fck).5 = 1.47
Tau c' = 1.47
For roof Tau c = .98 N/mm^2

4. LOADING DETAILS

With the help of IS 456-2000 and IS 875 Part-3, the load selected along with their combinations with appropriate partial factor of safety. Load taken in this work are as follows:

1. Wind in + X direction
2. Wind in - X direction
3. Wind in + Z direction
4. Wind in - Z direction
5. D.L.
6. L.L.
7. 1.5 (D.L + L.L)
8. 1.2 (D.L. + L.L ± Wind $_X$)
9. 1.2 (D.L. + L.L ± Wind $_Z$)
10. 1.5 (D.L. ± Wind $_X$)
11. 1.5 (D.L ± Wind $_Z$)
12. 0.9 (D.L. ± 1.5 Wind $_X$)
13. 0.9 (D.L. ± 1.5 Wind $_Z$)

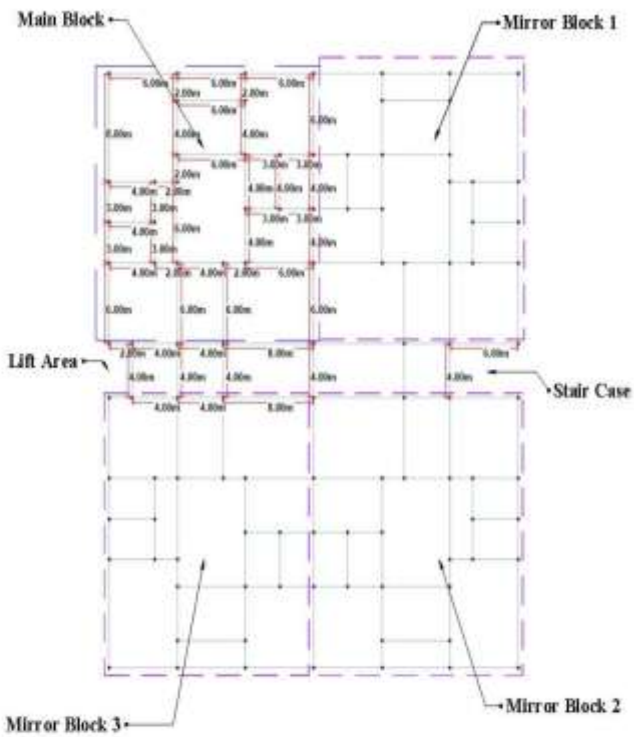

Fig -2: Plan of Building Model Case

5. STRUCTURE MODELING

In this work, the G+20 Model building plan selected and designed simple flat slab and added drop flat slab which is further extended into two other cases on the basis of stress location in flat slab. Different types of model are shown in Table 3.

Table 3 : Different Building Model Cases

Model No.	Name of models
Model M1	G+20 storey building with simple flat slab providing shear wall around the lift
Model M2	G+20 storey building with simple flat slab providing shear wall around the lift and the core
Model M3	G+20 storey building with added drop flat slab providing shear wall around the lift
Model M4	G+20 storey building with added drop flat slab providing shear wall around the lift and the core

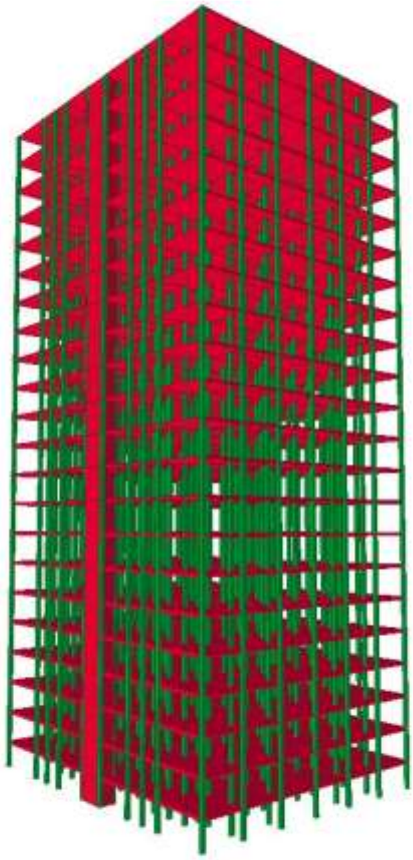

Fig -3: 3D view of Building Model Case

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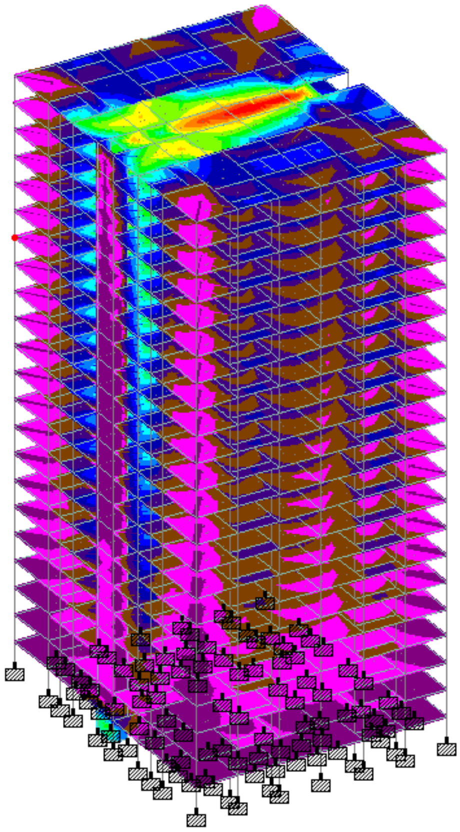

Fig -4: Maximum Stress Occurring in Model Case M1

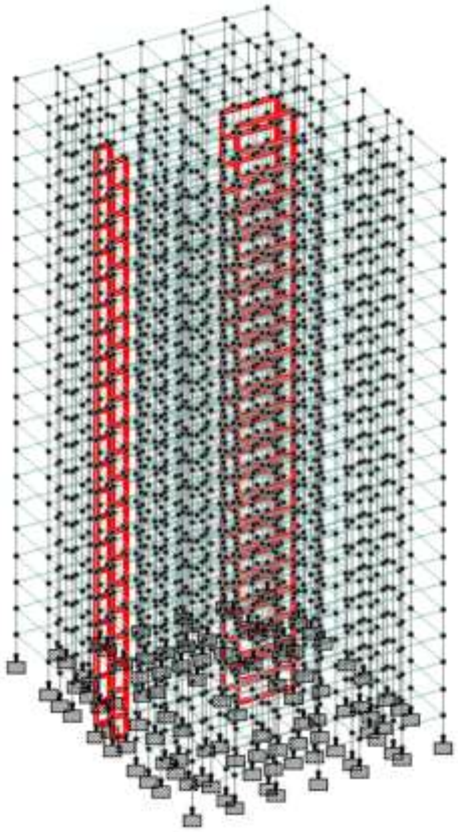

Fig -5: Shear Wall Location in G + 20 Storey Building

6. RESULTS AND DISCUSSION

When building analyzed under the influence of Wind load, the four different model case's result parameters are compared to find the most economical model therefore as per the objective of this work, the results obtained are shown in graphical form as well as in tabular form for different parameters which are as follows:

Table 4: Nodal Displacement in X and Z Direction

Maximum Displacement X-Direction (in mm)	Cases			
	Model case M1	Model case M2	Model case M3	Model case M4
	92.600	59.889	100.661	67.331
Maximum Displacement Z-Direction (in mm)	Model case M1	Model case M2	Model case M3	Model case M4
	113.159	104.184	118.624	109.113

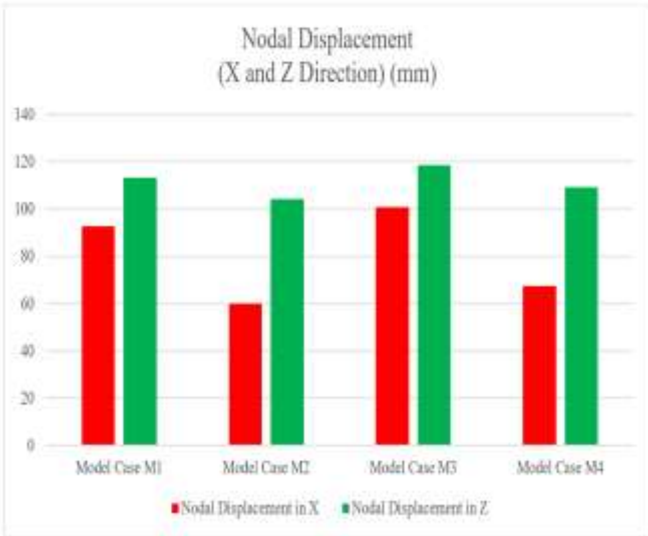

Chart -1: Nodal Displacement in X and Z Direction

In model case M2, the nodal displacement in X and Z Direction is least among all of four Model Cases M1, M3 and M4 in both directions.

Table 5: Axial Force in Column at Ground Level

Cases	Axial Force In Column At Ground Level (KN)			
	Model case M1	Model case M2	Model case M3	Model case M4
	12210.335	7874.994	12682.515	8213.113

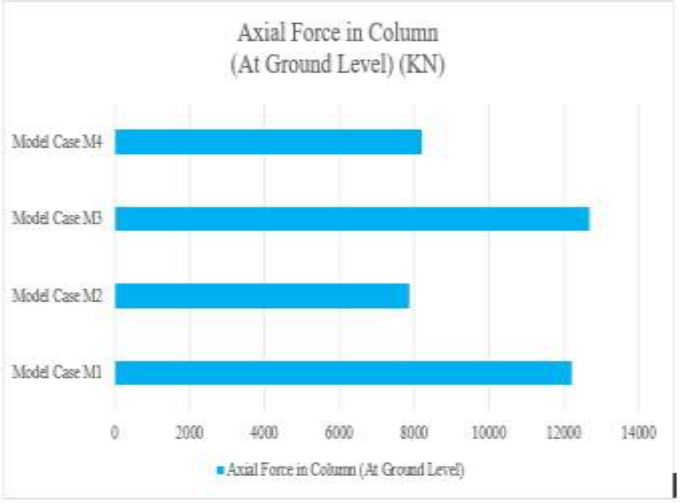

Chart -2: Axial Force in Column at Ground Level

The value of the Axial Force in column at ground level in Model Case M2 is 7874.994 KN, this value is lesser among all the model cases such as Model Case M1, M3 and M4.

Table 6: Shear Force in Column Sy and Sz

Shear Force In Column Sy (KN)	Cases			
	Model case M1	Model case M2	Model case M3	Model case M4
	346.813	242.059	360.085	251.007
Shear Force In Column Sz (KN)	Model case M1	Model case M2	Model case M3	Model case M4
	191.817	109.343	199.098	115.351

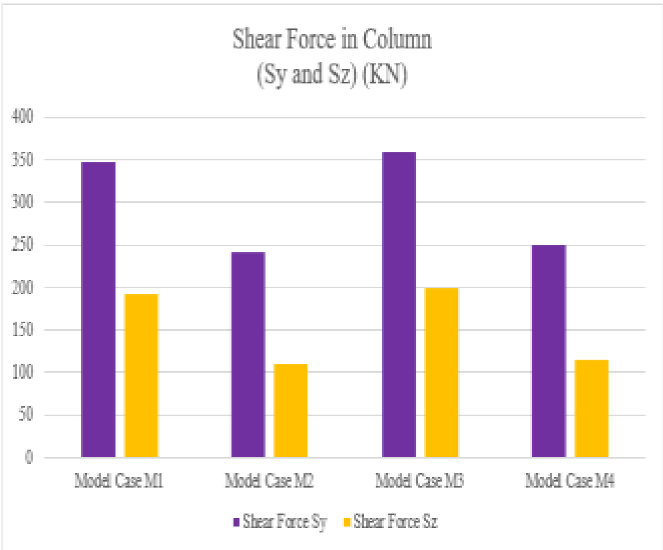

Chart -3: Shear Force in Column Sy and Sz

Comparing all Model Cases, Model Case M2 shows least values among all for Shear Forces Sy and Sz. Hence the optimum case will be Model Case M2.

Table 7: Maximum Compressive Stress in column

Cases	Maximum Compressive Stress In Column (N/mm^2)			
	Model case M1	Model case M2	Model case M3	Model case M4
	61.598	40.82	63.985	42.221

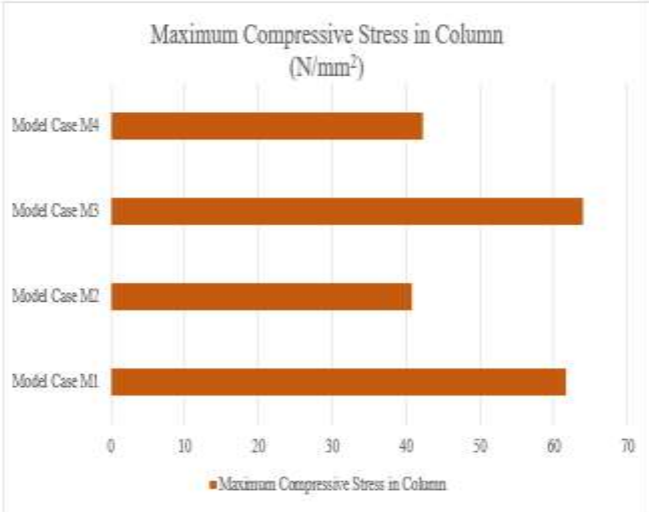

Chart -4: Maximum Compressive Stress in Column

The Maximum Compressive Stress in column seems to be minimum in Model Case M2 with a value of 40.82 N/mm^2 as compared to other models cases such as Model Case M1, M3 and M4.

Table 8: Maximum Tensile Stress In Column

Cases	Maximum Tensile Stress In Column (N/mm^2)			
	Model case M1	Model case M2	Model case M3	Model case M4
	49.24	36.974	51.098	38.317

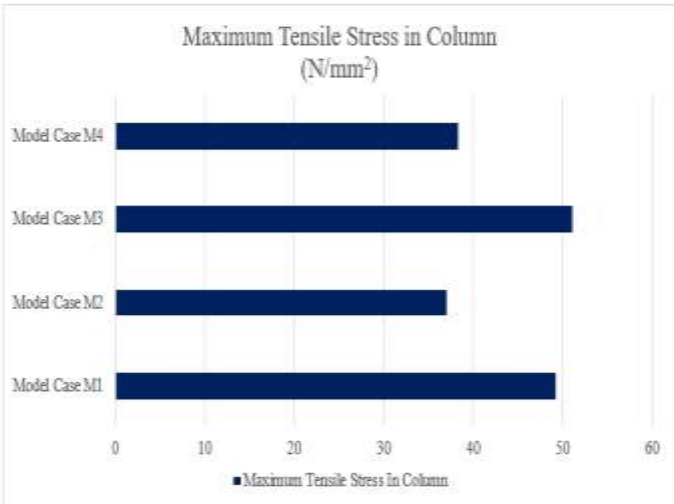

Chart -5: Maximum Tensile Stress in Column

The Maximum Tensile Stress in column observed maximum in Model Case M3 which is 51.098 N/mm² and lesser in Model Case M2, the value is 36.974 N/mm² which is minimum among all the Model Cases.

Table 9: Torsional Moment In Column

Cases	Torsional Moment in Column (KNm)			
	Model case M1	Model case M2	Model case M3	Model case M4
	2.500	2.143	2.808	2.582

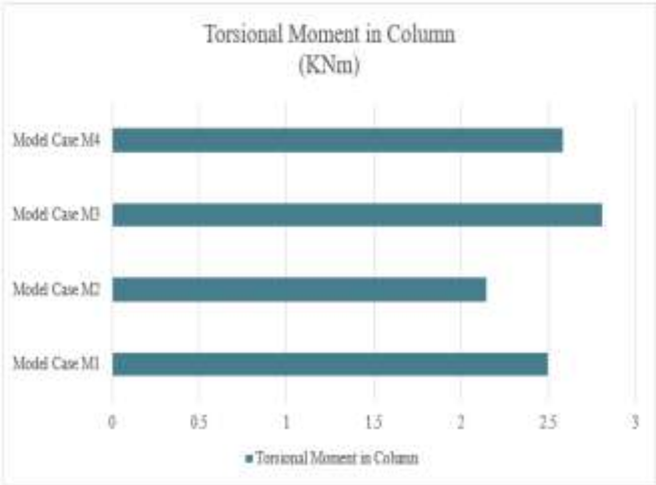

Chart -6: Maximum Torsional Moment in Column

The Torsional Moment in column is maximum in Model Case M3 which is 2.808 KNm but lesser in model case M2 and this value is smaller in all the Model Cases.

7. CONCLUSIONS

The some conclusions are written below according to some results parameters for four different cases:

1. In Model Case M2, the value of Nodal Displacement in X direction is least among all the Model Cases and the maximum value of Nodal Displacement in Model Case M3.
2. The Nodal Displacement in Z direction is minimum in Model Case M2 and Model Case M4 but maximum in model case M3.
3. The Axial Force in column at ground level is maximum in Model Case M3 but minimum in model case M2 and M4.
4. The Shear Force in column in Y direction is minimum in Model Case M2 which is lesser among all the model cases. Shear Force value in Z direction is maximum in Model Case M3 but lesser in Model Case M2 and M4.
5. The Maximum Compressive Stress in column is least in Model Case M2 but maximum in model case M3. Maximum Tensile in Column is least in model case M2 and model case M4.
6. The torsional moment in column is maximum in model case M3 but least in model case M2 and M1.
7. Observing all the result parameters Model Case M2 seems to be efficient among all four cases. Hence in G+20 storey building with simple flat slab providing shear wall around the lift and the core should be preferred.

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