Analysis of a High Rise Building Frame with Different Type of Slab Considering Seismic Forces with Lateral Load Resisting Members

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Abstract— Continuous developments in new forms of buildings and ever increasing demands to create aesthetically good looking structures without affecting the strength and overall cost has led designers and engineers all over the world to innovate and adopt different type of structural systems in building and other structures. Flat slab and grid beam systems are two major type of structural system of Reinforced concrete buildings which provide the advantage of cost effectiveness and aesthetics without seriously affecting the strength and serviceability aspects of buildings. An important type of structural system which affects the overall stability and strength of building is floor system which is also termed as roof system or slab system. "Flat slab" is the term given to the floor system in which roof slab is rested directly on column and whole load on slab is transferred directly to columns. Since beams are not used in this system hence cost is definitely reduced. Nevertheless the strength of building is affected as slab is now affected by other kinds of stresses, punching shear in particular. In case of heavy loads, the shear stresses in slabs around column may become significant therefore various methods are used to enhance it's stiffness like increasing the thickness, providing drops and/or capitals etc. The obvious advantage of flat slab is aesthetic appeal. The system gives plane ceiling without any discontinuity of beams. This also leads to indirect cost cutting in case of reducting in form work and ease of construction. In present study, two type of floor systems - flat slab and grid slab are compared for an RC building. The comparison is done under the criteria of strengths, stability and cost effectiveness. The analysis of building structures is performed considering seismic zone V and medium soil type in Staad.pro software which is a popular structural analysis and design software.

Key words: Analysis Tool, Slab Stiffness, Seismic Fore, High Rise, Structural Analysis, Diaphragm

I. Introduction

It has been seen in past seismic tremors that the structures on inclines serve more beastliness and overlay. Shivers make substantial damage structures, for case, frustration of people in the building and if the intensity of tremor is high it prompts breakdown of the structure. In past years people has been produced irrefutably and as a result of which urban zones and towns started spreading out. In light of this reason distinctive structures are being inalienable inclining zones. India has a wide shoreline forefront which is anchored with mountains and tendencies.

In addition to shear stresses, flat slabs are also affected more by lateral loads compared to conventional beam column system. Lateral loads due to earthquake or wind the overturning moments may be large in case of flat slabs which have less lateral stiffness owing to the absence of beams. This may lead to serious swaying actions especially in tall buildings. However, adoption of flat slabs require adequate analysis and is recommended to be performed by civil/structural engineer. The engineers are accompanied with various codes which have laid down the specifications for these type of system. Indian code IS 456:2000 has also given adequate provisions. Building codes of other countries like ACI etc. have also given methods of analysis of flat slab buildings. Another floor system prominently used in RC buildings is that of grid beam or waffle slab system. This system is in contrast to flat slab. Whereas in flat slab no beams were used, here the roof slab consists of various beams (called joists) of about 1 m length intersecting each other orthogonally.

K. Venkatarao (2016) studied the seismic behavior of conventional RC framed building, flat slab with drop and without drop building in all seismic zones of India. Different parameters like lateral drift, base shear, time period and axial force are compared. It was concluded that lateral displacement of conventional RC frame is less as compared to flat slab without drop building.

Durgesh Neve (July-2016) Analysis of Flat Slab Resting on Shear Walls by using ETABS-13, In this study, a building model is compared in different aspects such as storey drift, story displacement etc. for flat slab with columns and flat slab resting on shear walls.He observed that Flat slab with shear wall is advantageous concept to be used in a high rise building as shear walls are model according to plan which increases the carpet area, and also lateral story displacements and storey drift are reduced by used the shear wall.

Pradeep et. al (2016) [1] pondered the system to kill parallel forces following up on a building layout by familiarizing unbendable stomach with the structure also look at the three states of inflexible stomach, semi firm stomach and with no region, to comprehend which one is more valuable and inferred that utilization of relentless stomach is more powerful than other condition concerning segment and segment controls and dislodging

Rahul Chaurasia et. al. (2015) [2] Contemplated the impact of bracings at various position of the structure and contrasted it and unbending stomach structure under powerful stacking, utilizing examination apparatus staad.pro and inferred that inflexible stomach is relatively more successful in diminishing parallel powers likewise influencing the structure to financially savvy as far as support steel.

K.N.Mate (June 2015) analyzed the flat slab .Flat slab system is simple structure of RCC which provide long clear space, a good height, simple formwork and no delay time in construction. It is shown that why the flat slab is more feasible and flexible in comparison to other slab. This study includes complete analysis and design of flat slab as per Indian code of practices IS456:2000. Flat slab is more flexible and economical as compare to conventional slab.

This paper guide us how to select drop, panel width, thickness of slab and detailing of reinforcement.

A. *Objective*

1) To model flat slab and grid beam floor systems in RC buildings
2) To analyse and compare buildings provided with flat slab and grid beam for various structural criterion.
3) To compare both building for lateral force (response spectrum) dynamic analysis.
4) To determine the effect of bracing X at corners and shear wall at the centre of the structure.
5) To carry out cost estimation of all the cases as per SOR 2017.

II. METHODOLOGY

This study is attempted in following steps:

1) Step-1 selection of building geometry of G+10 storey of 3D frame. Fig. 1.

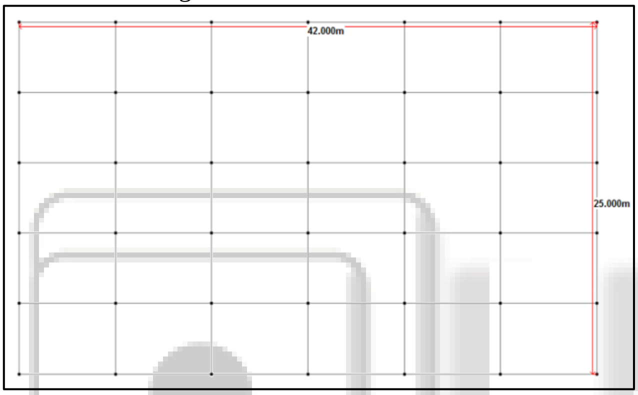

Fig. 1: Plan of building

2) Step-2 Assigning general property, section, material, supports and loading cases
3) Step-3 Selection of Seismic zones (Zone V) and medium type soil as per IS- 1893(part I) -2002.
4) Step-4 load combination as per 875-part-V

Load case no.	Load cases
1	D-L
2	L-L
3	EQ_X +ve
4	EQ_Z +ve
5	EQ_X-ve
6	EQ_Z-ve
7	1.5(D-L+L-L)
8	1.5(D-L+E.Q._X)
9	1.5(D-L-E.Q._X)
10	1.5(D-L+E.Q._Z)
11	1.5 (D.L-E.Q._Z)
12	1.2(D.L+L.L+E.Q._X)
13	1.2 (D.L+L.L-E.Q._X)
14	1.2 (D.L+L.L+E.Q._Z)
15	1.2 (D.L+L.L-E.Q._Z)
16	0.9 D.L. + 1.5 E.Q.
17	0.9 D.L. – 1.5 E.Q

Table 1: Number of load cases details

5) Step-5 3-Dimensional modeling of building frames using STAAD.Pro v8i.

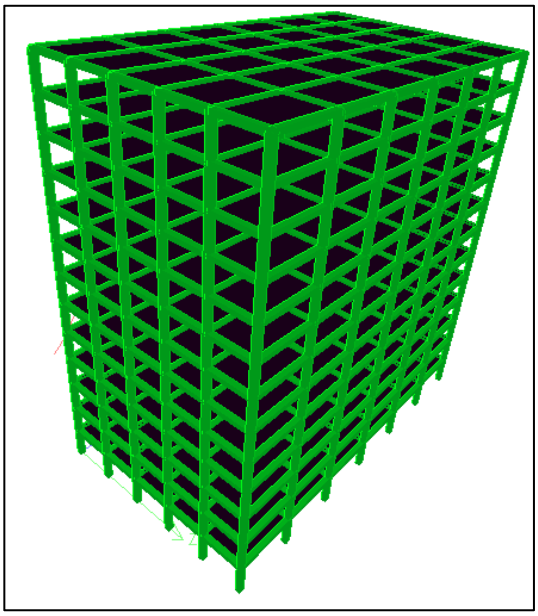

Fig. 2: 3-D rendering view

6) Step-6 Analysis of building frames considering seismic forces in X & Z direction and gravity load as shown in figure below.
7) Step-7 Designing structures as per I.S.456:2000 to determine the amount of reinforcement required in both the cases.

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TOTAL VOLUME OF CONCRETE =        92.6 CU.METER

          BAR DIA            WEIGHT
          (in mm)           (in New)
         --------           --------

             8                 19776
            12                 25131
            16                 31659
            20                 11402
            25                  5241
                        ------------
        *** TOTAL=             93209
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Design data of building	Dimension
Plan dimension	42x25
No. of bay in X direction	6 (Bay size 7m each)
No. of bay in Y direction	5 (Bay size 5m each)
No. of storey	G+10
Typical storey height	3.5m
Bottom storey height	3.5m
Column size	500 x 500
Beam size	450 x 300
Thickness of slab	150 mm for grid beam building
	230 mm for flat slab building
Grade of concrete	M30
Grade of steel	Fe-415
Wall thickness	230 mm for external wall
	115 mm for internal wall
Shear wall thickness	230mm
Concrete Bracing	300mmx450mm

Table 2: geometrical properties

A. Types of Cases Used For Analysis of Structures

The different cases are considered to study the seismic behaviour of both the slab with and without masonry infills. As previously mentioned two zones are considered with soil type II (medium) with different masonry such as shear wall and bracing. From the earlier papers concluded that building with shear wall along periphery shows good response against horizontal loading similarly in case of concrete bracing also the X-type bracing applied on vertical faces of building shows better improvement in resisting lateral forces. So in this present work also will take shear wall along periphery and X-type bracing on all four side of building with zone-V in medium soil. Thus in this way total 6 number of models will analyzed to study the different forces acting on structures. The following model with description as written below with same soil condition .

1) Case1) grid slabstructure (G+10).
2) Case 2) grid slab structure (G+10) with shear wall.
3) Case 3) grid slab structure (G+10) with X-type bracing at corners.
4) Case 4) Flat slab structure (G+10).
5) Case 5) Flat slab structure (G+10) with shear wall.
6) Case 6) Flat slab structure (G+10) with X-type bracing.

III. RESULT ANALYSIS

A. Max. Bending Moment in kN-m

Max. Bending Moment kN-m					
grid slab	grid slab with bracing	grid slab with shear wall	flat slab	flat slab with bracings	flat slab with shear wall
387.03	363.45	345.55	401.23	379.76	368.98

Table 3: Max. Bending moment (kN-m)

1) Inferences:

In the above figure it is clearly shown that max. bending moment is in Flat slab case whereas least is in grid slab with shear wall case, which prove that this case will require less reinforcement in comparison to others.

B. Max. Shear Force (kN)

Max. Shear Force kN					
grid slab	grid slab with bracing	grid slab with shear wall	flat slab	flat slab with bracings	flat slab with shear wall
563.32	570.12	572.45	580.09	582.43	580.02

Table 4: Shear Force in kN

1) Inferences:

It is clearly observed in above table, unbalance forces are maximum in case of flat slab as due to no column condition at the centre region of the structure, these forces are generating.

C. Axial Force

Max. Axial Force kN					
grid slab	grid slab with bracing	grid slab with shear wall	flat slab	flat slab with bracings	flat slab with shear wall
1132.76	1131.07	1135.98	1232.3	1198.06	1186.9

Table 5: Axial force in kN

1) Inferences:

As shown in figure above table, it can be said that it is varying in cases due to geometrical changes and can be said that flat slab shows worst result whereas grid slab with shear wall shows most suitable in resisting.

D. Support Reaction

Support reaction in Y direction					
grid slab	grid slab with bracing	grid slab with shear wall	flat slab	flat slab with bracings	flat slab with shear wall
10.09	12.76	12.45	9.45	11.87	11.12

Table 6: support reaction

1) Inferences:

Here results shows that Support reaction is more in grid slab case with bracing, whereas in flat slab case it is minimum.

E. Max. Storey Displacement (mm)

Deflection in mm						
S. No.	grid slab	grid slab with bracing	grid slab with shear wall	flat slab	flat slab with bracings	flat slab with shear wall
10 STOREY	69.852	43.594	31.045	71.23	46.568	45.32
9 STOREY	63.471	38.927	28.21	65.43	42.314	43.23
8 STOREY	56.941	34.294	25.307	58.3	37.961	38.87
7 STOREY	50.305	29.725	22.358	52.05	33.537	35.43
6 STOREY	43.603	25.276	19.379	45.59	29.068	31.23
5 STOREY	36.87	20.967	16.387	39.12	24.58	26.54
4 STOREY	30.141	16.848	13.396	32.66	20.094	22.34
3 STOREY	23.445	12.98	10.42	26.19	15.63	16.98
2 STOREY	16.811	9.44	7.472	19.73	11.207	12.78
1 STOREY	10.285	6.393	4.571	11.43	6.857	8.09
GF	4.071	3.966	1.809	5.43	2.714	3.88
BASE	0	0	0	0	0	0

Table 7: Storey displacement in mm

1) Inferences:

Here results shows that grid slab case with shear wall is most suitable and stable in resisting lateral forces.

F. Cost of Structure

S.No.	Frame type	Concrete cu.m	Rate of concrete (m^3) as per S.O.R.	Cost of concrete in INR (Rupees)
1	Grid slab	92.6	2000	1,85,200
2	grid slab with bracings	94.5	2000	1,89,000
3	grid slab with shear wall	97.54	2000	1,95,080
4	flat slab	94.34	2000	1,88,680
5	flat slab with bracings	97.89	2000	1,95,780
6	flat slab with shear wall	98.32	2000	1,96,640

Table 8: Concrete cost analysis

S.No.	Frame type	Reinforcement in kg	Rate of Rebar kg as per S.O.R.	Cost of Rebar in INR (Rupees)
1	Grid slab	9454.23	160	15,12,677
2	grid slab with bracings	9552.87	160	15,28,459
3	grid slab with shear wall	9423.87	160	15,07,819
4	flat slab	9489.09	160	15,18,254
5	flat slab with bracings	9587.98	160	15,34,077
6	flat slab with shear wall	9590.98	160	15,34,557

Table 9: reinforcement cost analysis

IV. CONCLUSION

From the present study it is seen that grid slab is comparatively more suitable that flat slab, in terms of following points find out in above chapter:

- Max. bending moment (kN-m): in the above chapter we determined that grid slab structure with shar wall is comparatively showing less moment which can said to be economical one.
- Shear force: In terms of shear force flat slab structure shows more value comparatively due to less number of columns unbalance forces are generating.
- Axial force: these vertical forces are maximum in flat slab condition where number of columns are less resulting in more distribution forces on columns.
- Support reaction: Here as per the results it can be concluded that vertical reactions at the base of support is comparatively low in flat slab condition
- Displacement: Storey displacement is occurring due to seismic lateral forces and in above chapter it is clearly observed that grid slab structure with shear wall is comparatively for resisting and stable in terms of storey wise displacement. As it is capable of resisting lateral forces more accurately.
- Cost comparison: The material quantities for buildings in all cases shows that grid slab with shear wall structure is comparatively proving more economical than other conditions. Approximately 15% lesser steel is required in this case comparing to others.

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