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Seismic Analysis of Office Building with Prestressed Flat Slab

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***Abstract**: High rise building structures are both a necessity and a matter of sophistication and pride for structural engineers. Buildings crossing 25 to 30 storeys are a common phenomenon these days. But what happens to a structure as it crosses these height limits? Forces of nature in the form of earthquakes and cyclones starts playing brutal games with the structures. Higher the structure goes, higher it attracts the forces and wrath of nature in the form of seismic force.*

Seismic force, predominantly being an inertia force depends on the mass of the structure. As the mass of the structure increases the seismic forces also increase causing the requirement of even heavier sections to counter that heavy forces. And these heavy sections further increase the mass of the structure leading to even heavier seismic forces. Structural designers are met with huge challenge to balance these contradictory physical phenomena to make the structure safe. The structure no more can afford to be rigid.

This introduces the concept of ductility. The structures are made ductile, allowing it yield in order to dissipate the seismic forces. A framed structure can be easily made ductile by properly detailing of the reinforcement. But again, as the building height goes beyond a certain limit, these framed structure sections (columns) gets larger and larger to the extent that they are no more practically feasible in a structure.

A flat slab is a one-way or two-way system with thickenings in the slab at the columns and load bearing walls called 'drop panels'. Drop panels act as T-beams over the supports. They increase the shear capacity and the stiffness of the floor system under vertical loads, thus increasing the economical span range. A flat slab is a one-way or two-way system with thickenings in the slab at the columns and load bearing walls called 'drop panels' Figure 9. Drop panels act as T-beams over the supports. They increase the shear capacity and the stiffness of the floor system under vertical loads, thus increasing the economical span range.

Here an attempt has been made to study the behaviour of different structures of reinforced concrete with different prestressed systems. Studies have been carried out on sample model structures and analysis has been carried out by ETABS software. It has been ensured to consider sample models that represent the current practices in structural design to include different structural configurations.
Keywords: Flat Slab, Pre-Stressed Flat Slab System, Building Performance, Story drift, Design Basis, Earthquake (DBE), Storey Drift, Lateral Displacement, Time Period and Base Shear.

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1. INTRODUCTION

As the floor, the system plays an important role in the overall cost of a building, a post-tensioned floor system is invented which reduces the time for the construction and finally the cost of the structure. In some countries, including the U.S., Australia, South Africa, Thailand and India, a great number of large buildings have been successfully constructed using post-tensioned floors. The reason for this lies in its decisive technical and economic advantages. The common practice of design and construction is to support the slabs by beams and support the beams by columns. This may be called as beam-slab construction. The beams reduce the available net clear ceiling height. Hence, in warehouses, offices and public halls sometimes beams are avoided and columns directly support slabs. These types of construction are aesthetically appealing also. These slabs, which are directly supported by columns, are called Flat Slabs.

When a building is subjected to seismic excitation, horizontal inertia forces are generated in the building. The resultant of these forces are assumed to act through the center of mass (C.M) of the structure. The vertical members in the structure resist these forces and the total result of these systems of forces act through a point called as the center of stiffness (C.S). When the center of mass and center of stiffness does not coincide, eccentricities are developed in the buildings, which further generate torsion. When the buildings are subjected to lateral loads, then the phenomenon of torsional coupling occurs due to the interaction between lateral loads and resistant forces. In this study, the effects of slab types on the behaviour of load carrying systems are analysed on multi-storey reinforced concrete buildings under seismic loads according to the rules and regulations of the current Indian Earthquake Code. Slab openings in floor systems may cause irregularities in the horizontal plane according to the earthquake code. Analysis of the case in which the slab openings are formed very close to the vertical load carrying elements is also included in this study. The slab systems are explained and the roles of slabs among the whole load carrying systems are examined. The buildings having floor irregularities are explained and the earthquake regulations related to the construction of these buildings are mentioned. The rigid diaphragm and flexible slab modelling are explained and compared. A 28-storey building is chosen as an example and on that building, the structural system elements are designed with three different slab systems. Moreover, the modal analysis results are examined. In order to understand the differences between the rigid diaphragm and flexible slab modelling, a number of same buildings are analysed and the results are interpreted.

2. LITERATURE REVIEW

1. **Abhijit Salunkhea and Dr.D.N.Shindeb (2016)** Flat slabs is a system of construction is one in which the beams used in the conventional methods of constructions are done away with, Flat slab structure has advantages over conventional structure such as the economy in construction, its architectural appearance, flexibility and speed of the construction.

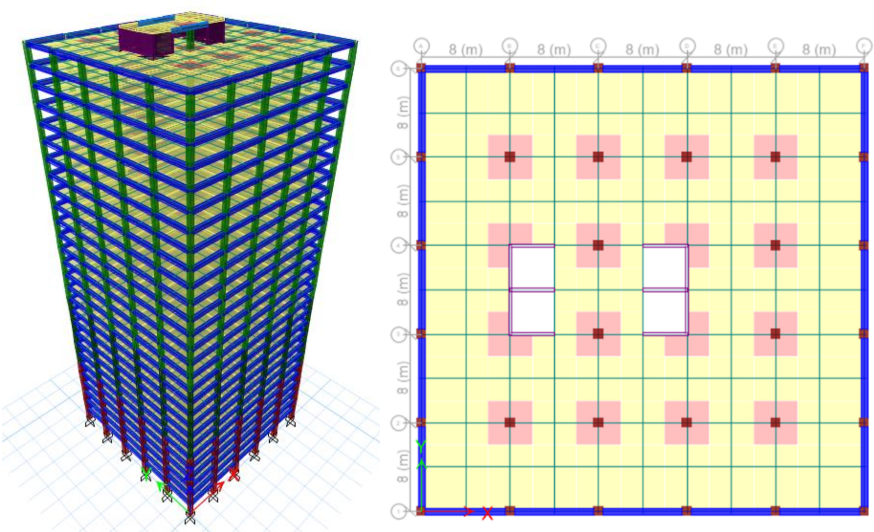
2. **Rajiv m s, Guru Prasad t n, Dharmesh, Madhusudhana y.b (2015)** In the present era, conventional Reinforced Concrete (RC) frame buildings are commonly used for the construction. The use of flat slab building provides many advantages over conventional RC Frame building in terms of architectural flexibility, use of space, easier formwork and shorter construction time. The performance of flat slab under different load conditions and vulnerability of frame were studied.
3. **K. G. Patwari, L. G. Kalurkar (2013)** Tall buildings are being increasingly designed with a structural system comprising of flat slab and shear wall core with or without perimeter beams. The behavior of this system under lateral loads is dependent on numerous parameters such as the height of the building, floor plate size, location of the shear wall core, flat slab spans and others.
4. **Dr. Uttamasha Gupta, Shruti Ratnaparkhe, Padma Gome (2012)** As flat slab building structures are significantly more flexible than traditional concrete frame/wall or frame structures, thus becoming more vulnerable to seismic loading.

5. **Prof. K S Sable, Er. V A Ghodechor, Prof. S B Kandekar (2012**) Tall commercial buildings are primarily a response to the demand by business activities to be as close to each other, and to the city center as possible, thereby putting intense pressure on the available land space.

6. **T. Ozturk and Z. Ozturk (2009)** It becomes so important to know the behaviour of reinforcing concrete, determine all possible earthquake loading effects on reinforced concrete buildings correctly and design the structural system so as to resist seismic effects.

3. DETAILED DESCRIPTION OF THE PROJECT

This is one of the landmark projects of Lotus Greens to be constructed at Plot No.-11-12, Sector-127, Noida (U.P.). The project has been conceptualized by Architect ACPL Design Limited and is being designed at CE CON Engg. This is going to be a 28-storey structure including 2 basements, 26 stories and 2 levels for staircase and water tank. The building will have commercial and office unit on each floor. The structure will be primarily RCC structure with columns, beams, slabs and shear walls. The structural framing system consists of columns, beams, shear walls & slabs to resist both vertical and lateral loads.



4. MODEL PARAMETERS

Seismic Parameters				
Seismic Zone (Z)		IV	Soil Type (S)	Medium
Response Reduction Factor (R)		4	Importance Factor (I)	1.2
Seismic Weight (W)		591216.85	Zone Factor	0.24
Total Height (m)		102.5	Length along X (m)	40
Basement Height (m)		8	Width along Y (m)	40
Height of Mumty (m)		3.5	Effective Height (m)	99
Acceleration, g (mm/s^2)		9806.65	Default Scale Factor	1470.9975
EQX	-12259.78	4.40E-06	Scale X	**1.73**
EQY	-2.9E-06	-1.23E+04		2541.01
SPECX	7097.2307	9.83E+00	Scale Y	**1.63**
SPECY	9.8338	7.53E+03		2395.57

Sl.	Description	Value	Reference
01	Terrain category.	4	IS-875
02	Class of structure.	C	IS-875
03	Probability factor, k1.	1.0	IS-875
04	Terrain, height and structure size factor, k2.	As/Height	IS-875
05	Topography factor, k3.	1.0	IS-875
06	Importance factor, k4 for the cyclonic region	1.0	IS-875

S. no.	**Particulars**	**Dimension/Size/Value**
1	Model	Commercial Building
2	Seismic Zones	IV
3	Floor height	3.5 m
4	Basement height	8 m
5	Building height	102.5 m
6	Plan size	Variable sizes at Different Floors
7	Size of columns	Variable sizes
8	Size of beams	Variable sizes
9	Shear Walls	Variable sizes
10	Thickness of slab	Variable sizes
11	Earthquake load	As per IS-1893-2002
12	Type of soil	Type -II, Medium soil as per IS-1893
13	E_c	$5000\sqrt{f_{ck}}$ N/ mm^2 (E_c is short term static modulus of elasticity in N/ mm^2)
14	Live load	4 kN/ m^2
15	Floor finish	1.5 kN/ m^2
16	Services	1.00kN/ m^2
17	Specific wt. of RCC	25.00 kN/ m^2

S No.	**Load combination**
1	DL+0.5LL
2	DL+0.25LL
3	DL± EQX, DL ± EQY
4	DL± SPECX , DL ±SPECY
5	DL±WLX, DL±WLY
6	0.9 (DL±1.5EQX), 0.9 (DL±1.5EQY)
7	0.9 (DL±1.5WLX), 0.9 (DL±1.5WLY)
8	0.9 (DL±1.5SPECX), 0.9 (DL±1.5SPECY)
9	1.2 (DL+LL±EQX), 1.2 (DL+LL±EQX)
10	1.2 (DL+LL±SPECX), 1.2 (DL+LL±SPECY)
11	1.2 (DL+LL±WLX), 1.2 (DL+LL±WLY)
12	1.5 (DL±WLX), 1.5 (DL±WLY)
13	1.5 (DL+SPECX), 1.5 (DL+SPECY)
14	1.5 (DL+LL)
15	1.5 (DL+EQX), 1.5 (DL+EQY)

MODELLING

The Buildings are designed to resist Dead load, Live load, and seismic load. As per IS- 456-2000, various load combination was taken and the worst case was considered in the designing of the building. The dead load consists of Self-weight, brick infill and floor load. Self-weight, which indicates the load of beams and columns that are being calculated by ETABS 2015 itself based on the dimensions, applied. Considering slab thickness, 230mm floor load was calculated based on the unit weight of concrete to be 5.75 kN/m2 and brick infill load was taken as a uniform force of 20 KN/m.

Zone Factor (Delhi) Z= 0.24 (Zone IV)

Importance Factor I= 1.0

Response reduction factor (RF) = 5 (Special Moment Resisting Frame)

Soil type= Medium Soil

Damping ratio = 0.05

VB= Z/2 * I/R * Sa/g *W

RESULT

Time Period and Base Shear						
Detail	Time Period (s)		S_a/g	A_h	V_B	% A_h
Bare Frame	T_a	**0.985**	1.380	0.0331	19585	3.31%
Above Basement	T_a	**0.985**	1.380	0.0331	19585	3.31%
With Infil	T_x	**0.387**	2.500	0.0600	35473	6.00%
	T_y	**0.774**	1.758	0.0422	24938	4.22%
Avarage	T_{avgx}	**0.686**	1.982	0.0476	28125	4.76%
	T_{avgy}	**0.880**	1.546	0.0371	21940	3.71%
Above Basement	T_x	**0.387**	2.500	0.0600	35473	6.00%
	T_y	**0.774**	1.758	0.0422	24938	4.22%
Without Mumty	T_x	**0.387**	2.500	0.0600	35473	6.00%
	T_y	**0.774**	1.758	0.0422	24938	4.22%

Building Lateral Displacement Check						
Permissible	WLX	62	Actual	WLX	3.1	SAFE
	WLY	62		WLY	13.5	SAFE
	EQX	124		SPECX	11.9	SAFE
	EQY	124		SPECY	15.7	SAFE
Permissible	WLX	62	Actual	DL+WLX	1.6	SAFE
	WLY	62		DL+WLY	15	SAFE
	EQX	124		DL+SPECX	13.5	SAFE
	EQY	124		DL+SPECY	17.3	SAFE
Permissible	WLX	62	Actual	DL-WLX	1.6	SAFE
	WLY	62		DL-WLY	15	SAFE
	EQX	124		DL-SPECX	13.5	SAFE
	EQY	124		DL-SPECY	17.3	SAFE

STATIC FORCE FOR WIND						
HEIGHT (m)	K_2	$V_{b,d}$	p_z	p_d	F_x	F_y
4.5	0.910	42.770	1.098	0.840	118.599	118.599
10.15	0.968	45.505	1.242	0.950	234.053	234.053
14.35	0.918	43.137	1.116	0.854	169.751	169.751
18.1	0.985	46.304	1.286	0.984	184.526	184.526
21.85	1.051	49.385	1.463	1.119	209.898	209.898
25.6	1.032	48.504	1.412	1.080	202.474	202.474
29.35	1.013	47.623	1.361	1.041	195.183	195.183
33.1	1.111	52.203	1.635	1.251	234.533	234.533
36.85	1.099	51.674	1.602	1.226	229.806	229.806
40.6	1.088	51.145	1.570	1.201	225.127	225.127
44.35	1.077	50.617	1.537	1.176	220.496	220.496
48.1	1.066	50.088	1.505	1.152	215.913	215.913
51.85	1.197	56.261	1.899	1.453	272.412	272.412
55.6	1.191	55.979	1.880	1.438	269.688	269.688
59.35	1.185	55.697	1.861	1.424	266.978	266.978
63.1	1.179	55.415	1.842	1.410	264.281	264.281
66.85	1.173	55.133	1.824	1.395	277.294	277.294
71.05	1.166	54.817	1.803	1.379	289.643	289.643
75.25	1.160	54.501	1.782	1.363	245.413	245.413
78.25	1.155	54.276	1.768	1.352	101.411	101.411

DESIGN OF FLAT SLAB BY DIRECT DESIGN METHOD				
Length in X	24	m	Column B	750
Length in Y	24	m	Column D	750
No of Spans in X	3			
No of Spans in Y	3			
Span Length in X, l_1	8	m		
Span Length in Y, l_2	8	m		
Grade of Concrete, f_{ck}	35	N/mm²		
Grade of Steel, f_y	500	N/mm²		
Clear cover, c	20	mm		
Recommended Slab Thickness	310	mm	Clause 31.2.1, IS456:2000	
Slab Thickness	250	mm		
Effective Slab Depth, d_s	224.0	mm		
Drop Provided?	Yes		Clause 31.2.2, IS456:2000	
Interior Panels Drop Length in X	4	m	2.666667	m
Exterior Panels Drop Width in X	2	m	1.333333	m
Interior Panels Drop Length in Y	4	m	2.666667	m
Exterior Panels Drop Width in Y	2	m	1.333333	m
Drop Thickness	500	mm	Minimum of	
Effective Drop Depth, d_{dr}	474	mm	489.5833	474
Floor Finish Thickness	50	mm		
Superimposed Dead Load	0.5	kN/m²		
Live Load (LL)	4	kN/m²		

Total Dead Load (DL)	**8**	**kN/m²**		
Pattern Loading Required?	No			
Total Design Load 1.5x(DL+LL)	**18.000**	**kN/m²**		
Design in X Direction				
Clear Span in X, L_{nx}	7.25	m		
Total Moment in X, $M_{0,x}$	946.125	kNm		
Negative Design Moment in X	614.981	kNm		
Positive Design Moment in X	331.144	kNm		
Column Strip Moments				
Interior Support	115.309	kNm/m		
Exterior Support	153.745	kNm/m		
Span Moment	49.6716	kNm/m		
Column Strip Reinforcement Required			Bar (mm)	Spacing (mm)
Interior Support (Top)	5.69	cm²	12	195
Exterior Support (Top)	7.63	cm²	12	145
Span Center (Bottom)	5.28	cm²	12	210
Column Strip Reinforcement Provided			Bar (mm)	Spacing (mm)
Interior Support (Top)	6.79	cm²	12	175
Exterior Support (Top)	9.05	cm²	12	125
Span Center (Bottom)	5.65	cm²	12	200
Middle Strip Moments				
Interior Support	38.436	kNm/m		
Exterior Support	5	kNm/m		
Span Moment	33.114	kNm/m		
Middle Strip Reinforcement Required			Bar (mm)	Spacing (mm)
Interior Support (Top)	4.05	cm²	10	190
Exterior Support (Top)	1.59	cm²	10	200
Span Center (Bottom)	3.48	cm²	10	225
Middle Strip Reinforcement Provided			Bar (mm)	Spacing (mm)
Interior Support (Top)	4.71	cm²	10	175
Exterior Support (Top)	3.93	cm²	10	200
Span Center (Bottom)	3.93	cm²	10	200
Design in Y Direction				
Clear Span in Y, L_{ny}	7.25	m		
Total Moment in Y, $M_{0,y}$	946.125	kNm		
Negative Design Moment in Y	614.981	kNm		
Positive Design Moment in Y	331.144	kNm		
Column Strip Moments				
Interior Support	115.309	kNm/m		
Exterior Support	153.745	kNm/m		
Span Moment	49.6716	kNm/m		
Column Strip Reinforcement Required			Bar (mm)	Spacing (mm)
Interior Support (Top)	5.69	cm²	12	195
Exterior Support (Top)	7.63	cm²	12	145
Span Center (Bottom)	5.28	cm²	12	210

CONCLUSION

Flat slab system is very simple to construct and is efficient in that it requires the minimum building height for a given number of stories. Unfortunately, earthquake experience has proved that this form of construction is vulnerable to failure, when not designed and detailed properly, in which the thin concrete slab fractures around the supporting columns and drops downward, leading potentially to a complete progressive collapse of a building as one-floor cascades down onto the floors below. This paper gives information about major issues associated with the flat slab and different method for analysis of flat slab use to confirm the behavior of flat slab. Structure with a shear wall along periphery is suitable for the effect of wind and earthquake load on the performance of the building. Stretching of cables can be done 1st in x-direction than in the y-direction, alternate stretching can be done to avoid the torsion of the slab.

REFERENCE

1 **Abhijit Salunkhea and Dr.D.N.Shindeb (2016)** "*A Comparative Study of Seismic Response of Flat Slab Structure and Conventional RC Framed Structure*"

2 **P. Manjunath and Yogeendra R. Holebsgilu (2016)** "*Seismic Analysis of Multi Storey Building with Flat Slab Resting on Plain and Sloping Ground*" Bonfring International Journal of Man Machine Interface, Vol. 4, Special Issue, July 2016.

3 **Rajiv m s, Guru Prasad t n, Dharmesh, Madhusudan y.b (2015)"** Seismic Behaviour of Multi-Storeyed RC Building Having Flat Slab With and Without Shear Walls" ISSN 2319-8885 Vol.04, Issue.29, August-2015, Pages:5696-5702.

4 **Pradip S. Lande, Aniket B. Raut (2015)** "Seismic Behaviour of Flat Slab Systems

5 **Ravi Kumar Makode, Saleem Akhtar, Geeta Batham (2014)** "*Dynamic Analysis of Multistory RCC Building Frame with Flat Slab and Grid Slab*"

6 **K. G. Patwari, L. G. Kalurkar (2013)** "Comparative study of RC Flat Slab & Shear wall with Conventional Framed Structure in High Rise Building".

7 **Dr. Uttamasha Gupta, Shruti Ratnaparkhe, Padma Gome (2012)** "*Seismic Behaviour of Buildings Having Flat Slabs with Drops*" International Journal of Emerging Technology and Advanced Engineering

