IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

SEISMIC BEHAVIOUR OF MULTISTOREY BUILDING WITH FLAT SLAB AND PT SLAB

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Abstract: A floor system plays an important role in overall cost and service of the building. Flat plate/slabs are economical since they have no beams and hence can reduce the floor height by 10-15%. In this analysis of RC flat slab with drop and post-tensioned slab is carried out. This analysis is done for ground floor slab level and G+20 slab level. A finite element-based software ETABS (vr.2018) is used for analyzing parameters like strip wise bending moments, shear force and displacements. A comparative analysis is carried out for maximum values of bending moments, shear force and displacements found in RCC and PT flat slab. The present work provides reasonable information regarding the suitability of post-tensioned slab and RC flat slab. The work undertaken is an attempt to understand the fundamentals of PT and Flat slab building, its design & behavior under seismic loading. Specific guidelines are available for design of building in Indian codes.

Keywords: Finite Element Analysi, Post-Tensioned Slab, Strip Moments, Displacement, Shear Force, drop. ETABS

I. INTRODUCTION

In general, normal frame construction utilizes columns, slabs & Beams. However, it may be possible to undertake construction without providing beams, in such a case the frame system would consist of slab and column without beams. These types of Slabs are called flat slab, since their behavior resembles the bending of flat plates. A reinforced concrete slab supported directly by concrete columns without the use of beams.

Post tension slab is a combination of conventional slab reinforcement and additional protruding high-strength steel tendons, which are consequently subjected to tension after the concrete has set. This hybridisation helps achieve the formation of a much thinner slab with a longer span devoid of any column-free spaces.

Flat slabs are appropriate for most floor situations and also for irregular column layouts, curved floor shapes, ramps etc. The benefits of choosing flat slabs include a minimum depth solution, speed of construction, flexibility in the plan layout (both in terms of the shape and column layout), a flat soffit (clean finishes and freedom of layout of services) and scope and space for the use of flying forms. The flexibility of flat slab construction can lead to high economy and yet allow the architect great freedom of form.

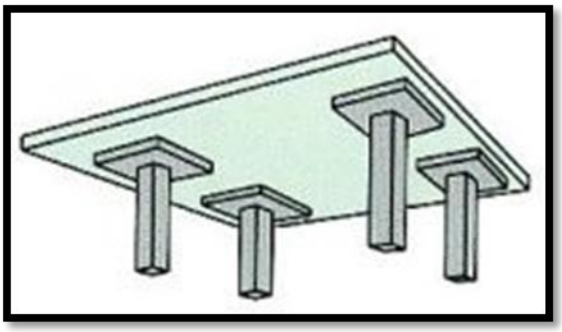

Figure 1. Solid Flat slab with Drop Panels

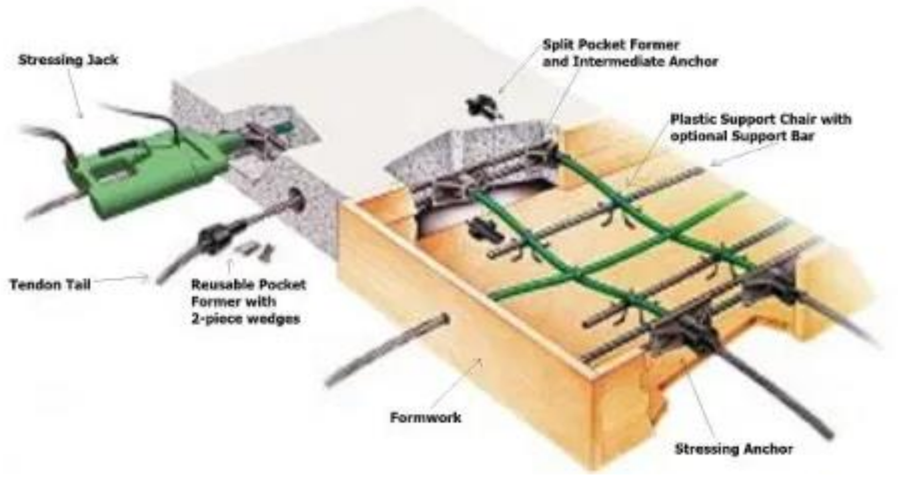

Figure 2. Typical Details of Post Tension Slab

Examples are; solid flat slab, solid flat slab with drop panel, solid flat slab with column head, coffered flat slab, coffered flat slab with solid panels, banded coffered flat slab.

concrete has a high compressive strength and steel has a high tensile strength, and when their combination is used to bear loads, the efficiency increases manifold. When a heavy live load is brought upon a structure, its concrete slab undergoes tension, which leads to the formation of cracks and ultimately deformation occurs. To mitigate this problem, post tensioned steel tendons are inserted at the time of concreting and tensioned after concreting with conventional rebars.

When these post tensioned steel tendons are stressed, the concrete is squeezed, in other terms, the concrete is compacted which increases the compressive strength of the concrete and at the same time the steel tendons that are pulled increase the tensile strength. As a result, the overall strength of the concrete increases Accordingly, by the review of the researchers on PT slab and Flat slab building the concerning factors for the structural design of the such buildings are as,

Pennung Warnitchai, Sommai Pongpornsup, Unnop Prawatwong, presented the "Seismic Performance of Post tensioned Interior Flat Slab Column Connections". This paper presents the results of reversed cyclic loading test of a 3/5 scale slab-column connection model, which was carefully design and constructed to represent a typical connection between interior column and post tensioned flat slab with bonded tendons in Thailand. A conventional displacement-controlled cyclic loading test with monotonically increasing drift levels until failure was adopted to investigate the seismic performance of the connection. The lateral force-deformation relation indicated that the connection model essentially behaved like a linear elastic system with low energy dissipation.

. Thayapraba M, presented "Cost Effectiveness of Post - Tensioned and Reinforced Concrete Flat Slab Systems", The inherent hurdle is undoubtedly the higher initialinvestment that is required from the clients. This has to be overlooked considering the significant benefits of post-Tensioning and the high benefit-aspect ratio that can be advantageously procured. In the present study an attempt is made to compare the cost effectiveness of post-Tensioned flat slab systems with respect to reinforced concrete flat slab system. Both the systems were analysed using SAP and MS Excel program was developed based on the design methodology.

Siddiqui Furkhan Ahmed, presented "Evaluation of Post Tensioned Slab and Its Contrast with Traditional Rcc Slab: Review", this paper research on the R.C.C and PT slab has been reviewed, with an integrative impact with the lateral load. The primary aim of this, is to review the reaction and behavioural characteristics of the post-tension flat plate during an earthquake and to contrast it with the traditional slab. For this purpose, the past papers related to the PT slab were studied and a successful conclusion has been made.

Advantages of Flat slab

i. The ease of the construction of formwork.
ii. The ease of placement of flexural reinforcement.
iii. The ease of casting concrete
iv. The free space for water, air pipes, etc between slab and a possible furred ceiling.
v. The free placing of walls in ground plan.
vi. The use of cost-effective pressurizing methods for long spans in order to reduce slab thickness and deflections as also the time needed to remove the formwork.

1.2 Disadvantages of Flat slab

There are two main failure modes of flat slabs:

a. Flexural Failure
b. Punching Shear Failure

Slabs are designed to fail by flexural failure, the failure mode is ductile therefore giving relatively large deflections under excessive loading and also cracks will appear on the bottom surface before failure occurs.

These signs allow the problem to be addressed before failure occurs.

Punching shear failure by comparison is a brittle failure mode when shear reinforcement is not added, meaning failure will occur before significant deflections take place, in addition to this any cracks that will develop before failure will propagate from the top surface.

Since this surface is typically covered, it is unlikely that there will be sufficient

Warning available before failure occur. Thornsteinsson noted that it can be difficult to classify a failure mode to be an ideal representation of either flexural or punching shear failure and instead these modes often interact.

1.3 Advantages of Post-Tensioned Floors

i. Longer Spans Longer spans can be used reducing the number of columns. This results in larger, column free floor areas which greatly increase the flexibility of use for the structure and can result in higher rental returns.

ii. Overall Structural Cost The total cost of materials, labour and formwork required to construct a floor is reduced for spans greater than 7 meters, thereby providing superior economy.

iii. Reduced Floor to Floor Height For the same imposed load, thinner slabs can be used. The reduced section depths allow minimum building height with resultant savings in facade costs. Alternatively, for taller buildings it can allow more floors to be constructed within the original building envelope.

iv. Deflection Free Slabs Undesirable deflections under service loads can be virtually eliminated.

v. Waterproof Slabs Post-tensioned slabs can be designed to be crack free and therefore waterproof slabs are possible. Achievement of this objective depends upon careful design, detailing and construction. The choice of concrete mix and curing methods along with quality workmanship also plays a key role.

II. OBJECTIVES

1. Identifying the general structural behavior and load transfer mechanisms of a flat slab and PT slab structure by analyzing a 3D computer model, under gravity loads as well as earthquake and wind loads.
2. Identifying the contribution of connections at junction in the performance of the lateral load resisting system
3. Providing the theoretical background to the necessary idealizations in preparing global structural models to analyze both buildings using commercially available software.
4. Evaluating the behavior of connection subjected to a lateral load through a detailed finite element analysis.

III. METHODOLOGY

The Although modular technology has been around for decades and established low rise examples have existed for over 20 years, the technology is relatively new in high rise construction and very limited examples exist that have been completed or are under construction. As such, large data set analysis is not currently possible and analysis must be limited to the few dozen projects available for review around the world. In light of this data set, the methodology of research primarily relies upon literature review, interviews, case studies and financial analysis based upon scenarios of available construction data.

Flat slab and PT slab buildings are analyzed with G+20 storey structure in which seismic and wind analysis performed with high grade concrete in building, Also, nonlinear dynamic time history analysis is also performed get severe situation condition in the structure.

IV. MODELING AND ANALYSIS

4.1 Material Properties and Section Properties:

Concrete grade: M30, Steel grade: HYSD500

Beam - 450X600 MM

300X600 MM

Column - 600X900 MM

Slab thickness -150MM and 250 MM

Drop – 200MM

4.2. Load calculations:

Dead load and live load calculation on slab (As Per IS 875- 2015 Part-1 & Part-2 clause 3.1 Table 1) :

Dead load calculation (from IS 875 part 1):

Dead Load = 1.5 KN/m2

Live Load = 2 KN/m2

4.3 Earthquake load (IS-1893-Part: 1-2016):

The building location where seismic Zone is IV with factor 0.24. Since it is a residential building, which is having importance factor 1.2. A Lateral force resisting system in which RC SMRF with response reduction factor (R) 5 is taken. Project building is located on soft soil site. For time history analysis, Fast Nonlinear Analysis Method is used to get accurate results. Ground motion data of Loma Prieta earthquake is taken which is having earthquake magnitude of 6.9 Mw, a maximum Modified Mercalli intensity of IX (Violent).

4.4 Wind load calculations:

Wind loads is calculated in accordance with IS 875: Part 3. Project is considered to be located in location where basic wind speed is 47 m/sec with fairly level topography with mean return period of 50 years is considered for which the k1 factor will be 1. Since the project building is considered to having some surrounding buildings of sizes up to 10 m in

4.5. Modeling in ETABS 2018- version 18.1.1

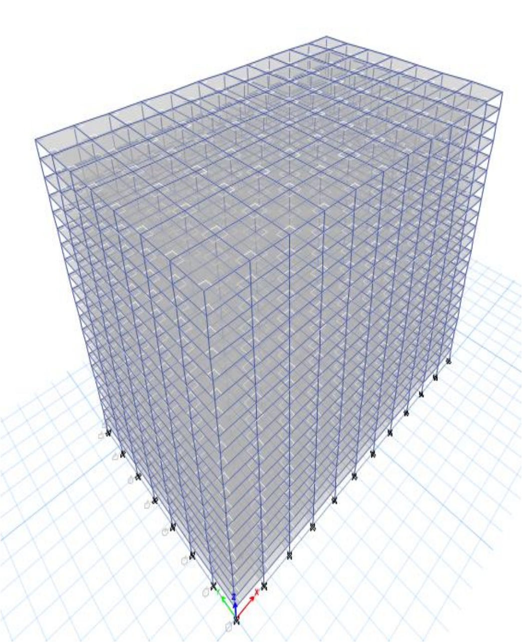

Figure 2. Building with flat slab

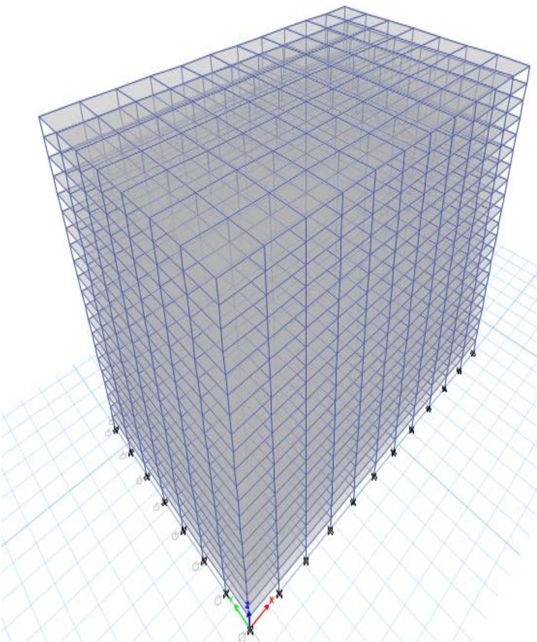

Figure 3. Building with PT slab

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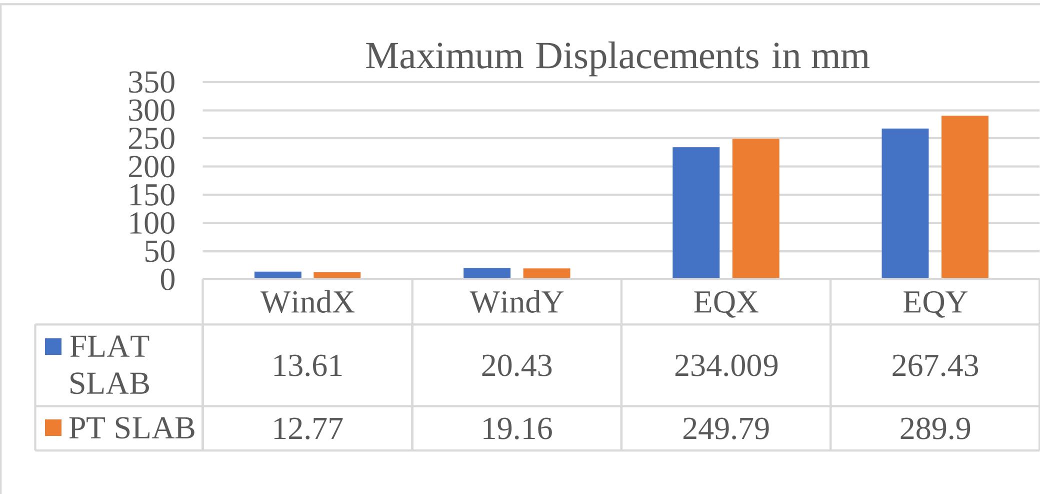
V. RESULTS AND DISCUSSION

5.1 Displacement :

The maximum allowable displacement for G+20 building, in earthquake it will be 264.8mm and in wind 132mm. Figure shows the maximum displacement for dynamic analysis i.e. response spectrum analysis, building with PT slab shows maximum displacement which is 249mm and 289mm in EQ-X and EQ-Y respectively. Maximum values in PT Slab building shows ductility and flexibility in building. Also, in case of wind forces, flat slab building shows maximum displacement which is around 5% more than the building with PT. It is clear that wind displacement shows almost same values in both the structural system.

Above result shows that the behavior of becomes more flexible when PT system installed. Which absorbs more amount of energy as compare to normal system.

Figure 4. Maximum horizontal displacement due to lateral force



5.2 Drift:

According to the storey drift limitation given in IS 1893 (Part I): 2016 each storey drifts must be limited to 0.004 times the storey height. In case of building with base isolation system shows maximum drift at the base of the structure but as the height of building increases it shows reduction in drift values.The standard deviations for each variable indicated that data were widely spread around their respective means.

Table 1. Drift in structure due to lateral force

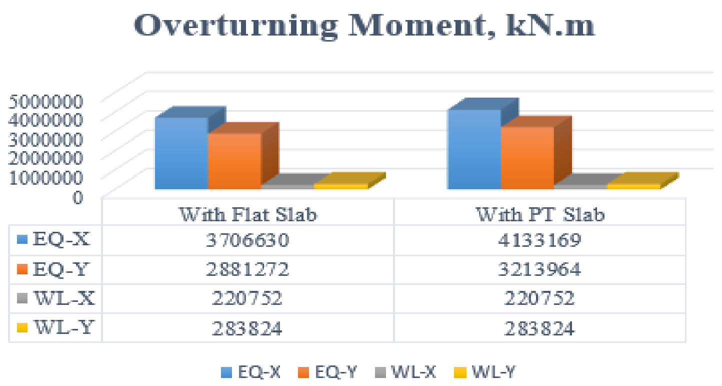
Storey	Building with Flat Slab		Building with PT Slab	
	EQ-X	EQ-Y	EQ-X	EQ-X
Terrace	0.00103	0.001308	Terrace	0.00103
Story20	0.001554	0.002072	Story20	0.001554
Story19	0.002082	0.002695	Story19	0.002082
Story18	0.002519	0.00316	Story18	0.002519
Story17	0.002864	0.003516	Story17	0.002864
Story16	0.003151	0.003804	Story16	0.003151
Story15	0.003408	0.004054	Story15	0.003408
Story14	0.003651	0.004281	Story14	0.003651
Story13	0.003879	0.004488	Story13	0.003879
Story12	0.004093	0.004675	Story12	0.004093
Story11	0.004296	0.004845	Story11	0.004296
Story10	0.004488	0.005	Story10	0.004488
Story9	0.004669	0.005138	Story9	0.004669
Story8	0.004834	0.005256	Story8	0.004834
Story7	0.004985	0.005349	Story7	0.004985
Story6	0.005132	0.005424	Story6	0.005132
Story5	0.005284	0.005495	Story5	0.005284
Story4	0.00542	0.005585	Story4	0.00542
Story3	0.005441	0.005724	Story3	0.005441
Story2	0.004992	0.005784	Story2	0.004992
Story1	0.002803	0.004015	Story1	0.002803

5.3 Overturning Moment :

The location of center of mass and center of stiffness in the structure is very important in overturning moment. As the center of mass and center of stiffness far from each other, maximum will be the overturning moment so as torsional moment in the structure. To avoid higher torsional moment in the structure IS 1893:2016 (Part-I) has given certain calculation in clause 7.8. As per this clause, eccentricity between center of mass and center of stiffness shall be maintained. Also, some types of vertical irregularities also cause overturning moment in the structure.

From belor fig., it can be observed that the value of overturning moment is less in flat slab building due to more lateral stiffness in building. The value of overturning moment is reduced about 10 to 20% in case of earthquake force, which shows reduction in torsion drastically.

Figure 5. Overturning moment comparison



5.4 Base Shear :

Table 2. Base in structure due to earthquake

	With Flat Slab	With PT Slab
Base shear EQX (kN)	91078.30	101677
Base shear EQY (kN)	72654.88	8111485
Dead Load (kN)	1144120.00	1276404
Live Load (kN)	229141.17	258720
% of earthquake (EQX)	7.5	7.5
% of earthquake (EQY)	6.0	6.75

Table 3. Base in structure due to wind

	With Flat Slab	With PT Slab
Base shear WLX (kN)	5949.37	5949.37
Base shear WLY (kN)	7649.18	7649.18

VI. .DISCUSSION

Displacement in building with flat slab and PT slab has drastic difference. Building with PT slab shows maximum displacement at the top which shows the ductile and flexible behavior of building. If observe displacement table it is clear that the 10 to 15% displacement increased in building with flat slab as compared to building with PT slab.
Flexible and ductile behavior of building can also be observed by values of time period in both the structures. There is increase in time period in flat slab building, which makes building flexible and ductile, also might reduce the reinforcement requirement in structure. Since, the flat slab absorbed most of lateral forces, building shows appropriate modes with good mass participation.
From observation of drift table, it can said that at the base of structure with flat slab and PT slab drift values are same but as the storey increased in structure drift shows incrementation, which shows that slabs absorbs lateral forces at the base and behaves accordingly, but transfer less forces at top. From drift table, around 25-35% drift reduced at top storey of structure.
Base shear and overturning moment in both the structure shows drastic difference. In case of earthquake force, base shear is reduced about 10-15% but in case of wind force base shear reduction is negligible which is due to application of wind load is from ground of structure. From table of base shear, it is observed that the values of earthquake percentage getting reduced when flat slab is applied to the structure.
Overturning moment is the factor which plays important role in inducing torsion in the building. When flat slab is applied to the structure, torsion in the structure is reduced which can be observed in table of modal mass participation values. Since, the building is regular and almost symmetric, values of torsion reduction doesn't shows much variation. Still around 15-20% reduction in overturning moment is shown due to flat slab application.

VII. CONCLUSION

i. Around 10 to 15% displacement increased in building with PT slab as compared to building with flat slab. Flexible and ductile behavior of building can also be observed by values of time period in both the structures. Building with PT slab show more ductile and flexible behavior than the building with flat slab. The ductility of the corner columns is also a critical criterion to maintain in order to achieve a better performance under high seismic loads. Although yielding may occur, high ductile columns may still prevent collapse and assist the horizontal members to redistribute the loads.

ii. At base of structure with both system drift values are maximum but as the storey increased in structure drift shows declination, which shows that slab systems absorb lateral forces at the base and behaves accordingly, but transfer less forces at top.

iii. Building with PT slab shows better lateral resistance and ductility than the building with flat slab.

iv. Slabs act as the key connections in which the columns are vertically connected. Therefore, these connections need to be designed to take the full shear force of the lateral loads.

v. Base shear and overturning moment in both the structure shows less difference. In case of earthquake force, base shear is reduced about 10-15% but in case of wind force base shear reduction is negligible which is due to application of wind load is from ground of structure.

vi. Finally, it is concluded that the PT slab building and flat slab building has their own advantages but the PT slab building found to be more stable in case of earthquake resistance

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