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Lateral Load Analysis of Post Tension Flat Slabs & Comparison of R.C.C. and Post Tensioned Structures

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Abstract

Due to the restriction from architect on depth of the slab and with few supports (i.e. larger span) in building, and early completion of project, it is difficult to adopt RCC slab system. It is a duty of structural engineer to provide a solution in the form of minimum depth of slab. Hence from last couple of decades post tension flat slab system are commonly adopted. Depending upon the nature of requirement one can adopt particular type of post tension flat slab.

The present study is concerned with the analytical findings of post tension flat slab depth requirement. In this report behavior of post tension flat slab have been studied in terms of bending moment, shear force, deflection, stresses and punching shear due to post tensioning. A (G+10) building is analyzed for lateral and gravity loading using ETABS V-9.14 and later on model is exported with all floor load to SAFE V-12 which has a capability of handling post stressing system using a finite element and equivalent frame method, with emphasis on post tension flat slab system.

This study gives bending moment, shear force, deflection, stresses punching shear and depth requirement for various span and various loading. Tables and Graphs were prepared for determining the required depth for different cases. Results are discussed in detail and conclusions are arrived based on tables and graphs. It is observed that the depth varies linearly almost parallel to each other as the span and load changes. It is also observed that effects of lateral load on slab are less as compared to the other gravity loads.

Introduction

With the increase in demand for space, construction of multistoried buildings has become a common feature in all the big cities. These multistoried buildings can be constructed using various structural systems. The choice of a particular structural system depends upon the total height of the building and type of the building i.e. commercial or residential etc. For commercial buildings rising up to 10 to 20 stories, flat slab construction is quite popular in the urban area.

Within the field of building structures, most pre-stressed concrete applications are in the form of simply supported precast floor and roof beams. The development of early cracks in reinforced concrete due to non-compatibility in the strains of steel and concrete was perhaps the starting point for the development of a new material like “Pre-stress concrete”.

Pre-stress concrete is the concrete in which there have been introduced internal stresses of such magnitude and distribution that the stresses resulting from given external loading are counteracted to a desired degree.

Pre-stressing is applied to concrete or steel and its ultimate purpose is

i] To induce desirable strain and stresses in the structure

ii] Counterbalance undesirable strain and stresses.

Literature Review

There are many other benefits of using PT slab. As the thickness of the slab is much lesser than the R.C.C flat slab, aesthetic look of the building may get enhanced leading to a clear height for a longer distance. Hence, using a PT Slab is more advisable for a commercial building than using a R.C.C Flat Slab. Construction of a structure using PT Slab also leads to a lighter structure as the Dead Load gets reduced. When a concrete slab is stressed by the posttensioning method, it means the steel is being tensioned and the concrete is being compressed. As a building material, concrete is very strong in compression but relatively weak in tension. Steel is very strong in tension. Putting a concrete slab into compression and the steel into tension. Before any substantial service loads are applied puts both building materials into their strongest states. The result is a ‘stiffer concrete slab’ that actively is compressed and has more capacity to resist tensile forces. Therefore, the stiffness and strength of the structure using PT Slab will be more than the structure constructed using R.C.C Flat Slab. Weight of Flat slab structure is quite low as compared to conventional slab structure. Flat slab structure leads to economic saving, aesthetic view and yet allow the architect from great freedom of form works as compared to conventional slab structure. Flat slab structures are the best solution for high rise structure as compared to conventional slab structure.

Gaps In Literature Review

1. Effect of different loading with different slab span can be done..
2. The work done in the above project can be further continued for span greater than 12m and effect on thickness of slabs can be observed.

Objectives

1. The work done in the above project can be further continued for span greater than 12m and effect of thickness can be observed.
2. Study of effect of various loading and span on Post tension flat slab.
3. Study of comparison of RCC and PT slab in terms of Depth of slab.

Scope Of Study

The scope of this project includes following aspects,

1. Structure- Flat slab structure of 10m span of 5 Bay is considered with loading of 2.5,5,7.5kn/m2.
2. Shear force ,Bending Moment ,Stresses, Punching Shear are calculated and compared.
3. Software Used – SAFE

Problem Statement

The aim of this study is to understand the requirement of depth for post tensioned slab in variation with different loading and various span. Post tension slab with 6, 8, 10, and 12 m span with 2.5, 5, and 7.5 kN/m^2 loading and lateral load is considered for analysis purpose. Initially lateral load analysis analysis of the building is carried using the software ETABS V-9.14. This will determine the forces on the slab like shear, bending moments, etc.

Later on, ETABS model is exported to Safe V-12 for analysis of Post tension flat slab keeping load varying at an interval of 2.5,5, and 7.5 kN/m^2 for span of 6,8,10, and 12 m. Based on the result from software, a parametric study is performed to understand the effect of variation in loading and span on thickness of post tension slab.

The parameters used in the study are:

1. Span
2. Loading

Methodology

The following inputs are given to the software ETABS V-9.14 for analysis.

Units: Force = kN Length = m

Axis location: Z vertical Direction; X & Y on horizontal plane

[A] Materials:

1. Grade of concrete slab fck = 45 mpa.

.2. Grade of untensioned steel fy = 500 mpa

[B] Modulus of elasticity:

For Slab/Column Ec = 5000√fck = 5000√ (45)

= 33541.05 N/mm^2

[C] Geometry:

1. Span i.e. 6m, 8m, 10m, and 12m.

2. Approximate thickness of slab

.

[D] Loading considered:

1. DL- Actual as per thickness @ Density 25kN/cu.m.

2. SIDL = 4 kN/m^2

3. LL- 2.5, 5, and 7.5 kN/m^2

.4. Lateral load:

a) Seismic load :

Z = 0.16 Zone factor

R = 3 Response reduction factor

I = 1 Importance factor

Soil type 1

b) Wind load :

K1 = 1 Risk coefficient

K2 = 1.055 Terrain, height and structure size factor

K3 = 1 Topography factor

Structure class = B

Terrain category = 3

Wind speed Vb = 44 m/s

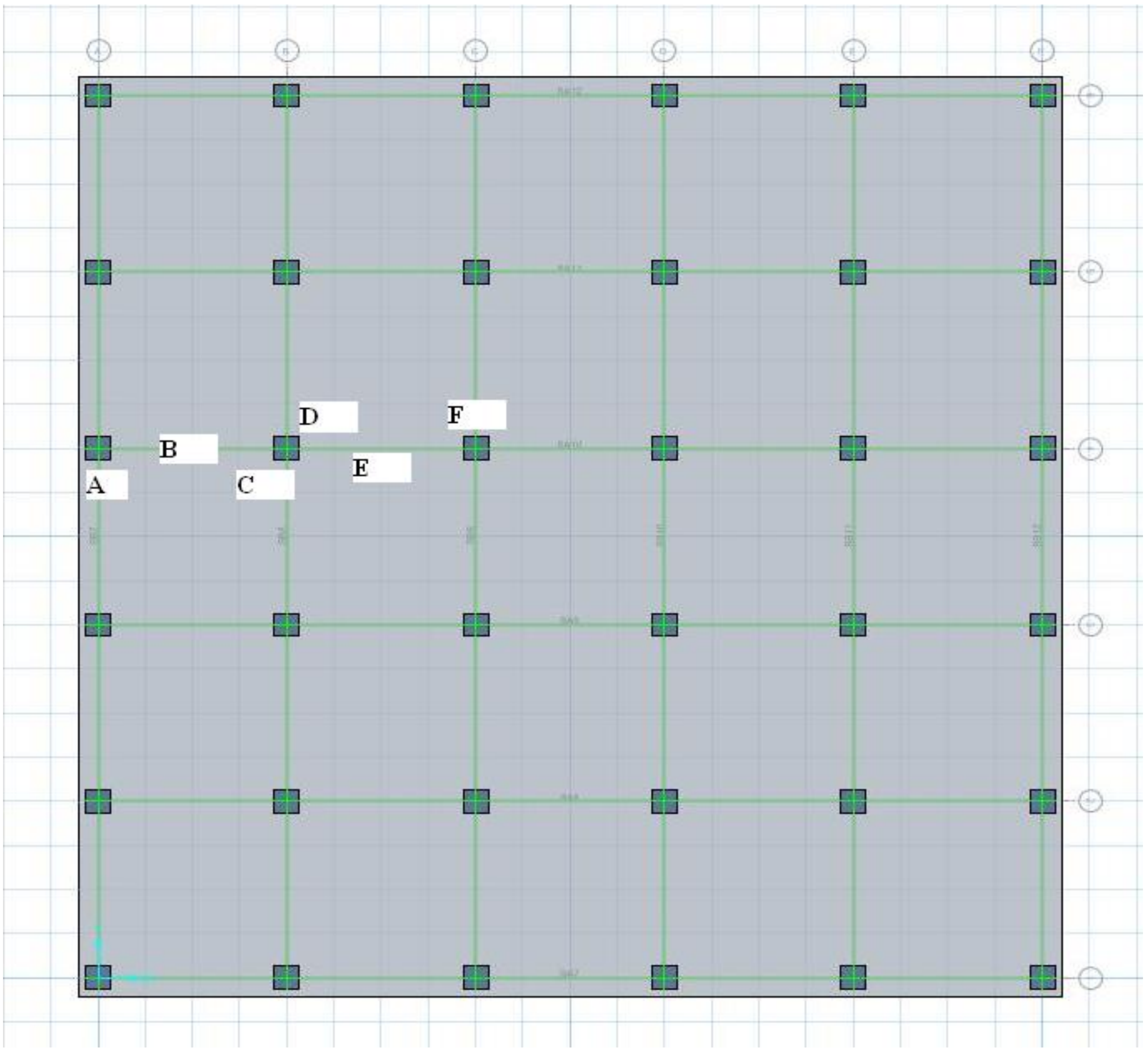
The following inputs are given to the software SAFE v-12 for analysis of post tension flat slab:

[E] Materials:

1. Grade of concrete slab fck = 45 mpa.
2. Strength of concrete at the time of stressing = 36 mpa

.3. Grade of untensioned steel fe = 500 mpa

4. High tension strand for pre stressing.
   a) Diameter of strand = 12.7 mm
   b) Ultimate tensile strength = 1860 mpa
   c) Jacking force = 0.8 UTS
   d) Initial loss of stress = 10 % UTS
   e) Long term loss = 5% UTS
5. Cable profile = Parabolic
   a) Jacking from both end
6. Type of structure = Type 2



Typical support location

All the slab being analyzed, the parametric study is carried out. The results of the analysis for span 6m, 8m, 10m, with loading of 2.5, 5, and 7.5 kN/m^2 are considered. The results of bending moment, shear force, stresses, deflection and punching shear are tabulated in tables at point A, B, C, D, E & F.

Results

1. **SUMMARY OF MAXIMUM B.M (kN-m) AT (A) DUE TO 2.5 kN/m^2**

Span (m)	DL	SIDL	LL	EQX	WINDX	PT-FINAL	PT-TRANSFER
0	0	0	0	0	0	0	0
6	-50.1249	-42.1578	-27.1237	3.416	0.3561	70.1094	74.9517
8	-140.842	-104.18	-65.125	3.5609	0.5156	126.1011	134.8704
10	-346.129	-205.962	-127.151	3.6653	0.4652	468.8162	506.1251
12	-730.918	-343.858	-216.098	3.8998	0.51265	875.1165	942.6332

2. **SUMMARY OF MAXIMUM B.M (kN-m) AT (A) DUE TO 5 kN/m^2**

Span (m)	DL	SIDL	LL	EQX	WINDX	PT-FINAL	PT-TRANSFER
0	0	0	0	0	0	0	0
6	-50.4214	-40.937	-50.4213	2.004	0.3526	51.8167	54.9565
8	-160.975	-103.67	-131.837	3.4248	0.4449	156.1297	166.7551
10	-365.66	-203.454	-245.067	4.2167	0.9967	299.8211	311.4996
12	-869.21	-350.613	-438.017	5.5159	1.6033	1018.828	1098.9683

3. **SUMMARY OF MAXIMUM B.M (kN-m) AT (A) DUE TO 7.5 kN/m^2**

Span (m)	DL	SIDL	LL	EQX	WINDX	PT-FINAL	PT-TRANSFER
0	0	0	0	0	0	0	0
6	-52.0725	-41.6578	-78.1085	1.8619	0.5152	81.6418	87.9219
8	-159.502	-102.117	-190.329	2.458	0.6019	212.1684	228.489
10	-398.21	-199.189	-373.479	3.9193	1.2529	229.321	246.9611
12	-972.421	-353.681	-663.152	7.7415	1.6133	1051.738	1132.6409

4. **SUMMARY OF MAXIMUM S.F (kN) AT (A) DUE TO 2.5 kN/m^2**

Span (m)	DL	SIDL	LL	EQX	WINDX	PT-FINAL	PT-TRANSFER
0	0	0	0	0	0	0	0
6	-57.004	-48.003	-30.002	0.82	0.15	75.143	80.923
8	-126.568	-92.062	-57.539	0.859	0.1956	118.383	127.49
10	-246.398	-146.008	-91.255	0.982	0.264	307.014	330.63
12	-451.437	-212.432	-132.77	1.664	0.335	338.655	364.705

5. **SUMMARY OF MAXIMUM S.F (kN) AT (A) DUE TO 5 kN/m^2**

Span (m)	DL	SIDL	LL	EQX	WINDX	PT-FINAL	PT-TRANSFER
0	0	0	0	0	0	0	0
6	-60.804	-48.643	-60.804	0.683	0.046	57.958	62.416
8	-138.745	-92.496	-115.62	1.144	0.184	146.353	157.611
10	-265.529	-146.5	-183.125	1.381	0.283	265.275	285.681
12	-527.718	-211.107	-263.884	1.523	0.429	380.924	410.226

6. SUMMARY OF MAXIMUM S.F (kN) AT (A) DUE TO 7.5 kN/m^2

Span (m)	DL	SIDL	LL	EQX	WINDX	PT-FINAL	PT-TRANSFER
0	0	0	0	0	0	0	0
6	-61.243	-48.994	-91.863	0.684	0.108	91.61	98.657
8	-143.125	-91.606	-171.54	1.09	0.148	197.575	212.774
10	-292.788	-146.39	-274.481	1.56	0.187	346.5	373.154
12	-606.775	-220.63	-413.681	2.207	0.231	455.929	491

7. SUMMARY OF MAXIMUM B.M (kN-m) AT (B) DUE TO 2.5 kN/m^2

Span (m)	DL	SIDL	LL	EQX	WIND X	PT-FINAL	PT-TRANSFER
0	0	0	0	0	0	0	0
6	42.0639	35.4222	22.1389	-2.5298	-0.1861	-35.218	-37.9271
8	96.0343	66.3776	40.736	-2.74033	-0.3812	-56.0952	-58.3332
10	251.2132	148.6751	93.2969	-2.8435	-0.7493	-210.879	-226.9466
12	545.5587	256.3677	160.9798	-2.9895	-0.8688	-479.438	-516.1638

8. SUMMARY OF MAXIMUM B.M (kN-m) AT (B) DUE TO 7.5 kN/m^2

Span (m)	DL	SIDL	LL	EQX	WINDX	PT-FINAL	PT-TRANSFER
0	0	0	0	0	0	0	0
6	40.5465	32.4373	60.8199	-1.4245	-0.2705	-32.694	-35.2089
8	107.4686	68.7741	129.1338	-1.8983	-0.5159	-106.356	-114.5376
10	280.1695	140.0712	262.6335	-4.0783	-0.9134	-340.382	-351.1802
12	702.794	255.5279	479.1149	-8.6312	-1.3319	-673.858	-725.693

9. SUMMARY OF MAXIMUM B.M (kN-m) AT (B) DUE TO 5 kN/m^2

Span (m)	DL	SIDL	LL	EQX	WINDX	PT-FINAL	PT-TRANSFER
0	0	0	0	0	0	0	0
6	42.3816	31.9053	41.3817	-1.9245	-0.2616	-25.2736	-26.2947
8	102.274	61.179	80.7238	-2.4934	-0.3729	-89.4985	-98.5369
10	258.1079	145.1943	166.2429	-3.5307	-0.7235	-153.667	-162.0261
12	649.3496	265.0095	325.5119	-5.7817	-1.1763	-488.871	-521.8606

10. SUMMARY OF MAXIMUM S.F (kN) AT (B) DUE TO 2.5 kN/m^2

Span (m)	DL	SIDL	LL	EQX	WINDX	PT-FINAL	PT-TRANSFER
0	0	0	0	0	0	0	0
6	16.67	14.038	8.774	0.812	0.158	-23.756	-25.583
8	68.477	49.781	31.113	0.839	0.1957	-53.547	-58.019
10	176.581	104.629	65.393	0.951	0.263	-216.585	-233.245
12	267.248	125.741	78.588	1.659	0.332	-303.088	-326.403

11. SUMMARY OF MAXIMUM S.F (kN) AT (B) DUE TO 5 kN/m^2

Span (m)	DL	SIDL	LL	EQX	WINDX	PT-FINAL	PT-TRANSFER
0	0	0	0	0	0	0	0
6	17.099	13.679	17.099	0.684	0.046	19.302	20.787
8	74.51	49.666	62.083	1.144	0.184	-79.315	-85.417
10	188.086	103.765	129.706	1.381	0.283	-249.949	-269.176
12	317.355	126.896	158.62	1.51	0.429	-325.069	-350.074

12. SUMMARY OF MAXIMUM S.F (kN) AT (B) DUE TO 7.5 kN/m^2

Span (m)	DL	SIDL	LL	EQX	WINDX	PT-FINAL	PT-TRANSFER
0	0	0	0	0	0	0	0
6	16.687	13.35	25.031	0.684	0.108	27.056	29.138
8	78.036	49.932	93.969	1.09	0.148	-97.934	-105.467
10	206.973	103.463	193.994	1.56	0.187	-302.667	-325.949
12	346.244	125.895	236.052	2.207	0.231	-405.044	-436.201

13. SUMMARY OF MAXIMUM DEFLECTION DUE TO 2.5 kN/m^2

Span (m)	DL	SIDL	LL	PT-FINAL	PT-TRANSFER
0	0	0	0	0	0
6	-1.56456	-1.28781	-0.80488	1.344729	1.602015
8	-2.69809	-1.94158	-1.21349	3.168077	3.488698
10	-5.03113	-2.92778	-1.83299	5.68163	6.280217
12	-6.61776	-4.41034	-2.71961	8.29745	9.074185

14. SUMMARY OF MAXIMUM STRESS (N/mm^2) DUE TO 2.5 kN/m^2 (AT TRANSFER)

Span (m)	Top (N/mm^2)		Bottom (N/mm^2)	
	Tension	Compression	Tension	Compression
0	0	0	0	0
6	1.2619	2.4119	0.8716	2.4766
8	1.71307	2.62116	1.12723	3.031665
10	1.54943	3.22983	0.73327	3.764723
12	2.01217	3.36533	0.97494	4.07325

15. SUMMARY OF PUNCHING SHEAR RATIO

SPAN (m)→	6	8	10	12
Loading ↓	Punching shear ratio			
LL 2.5kN/m^2	0.846	0.710	0.921	0.963
LL 5kN/m^2	0.848	0.727	0.856	0.969
LL 7.5kN/m^2	0.885	0.916	0.995	0.983

16. SUMMARY OF DEPTH REQUIREMENT FOR DIFFERENT LOADING

SPAN (m)→	6	8	10	12
Loading ↓	Over all depth mm			
LL 2.5kN/m^2	190	220	270	340
LL 5kN/m^2	200	240	290	400
LL 7.5kN/m^2	210	250	320	440

Conclusion

1. Lateral load is resisted by all columns.

2. The effect of lateral force is not significant but it is advisable to use slab top and bottom mesh reinforcement at the slab column junction as it is effective in resisting moment developed due to lateral loading.

3. Difficult to adopt a RCC flat slab for larger span, it would be better to adopt post tension flat slab especially in case of depth constraint.

4. Post tensioned flat plate systems are very efficient, because of improved deflection control.

5. Depth requirement in RCC flat Slab is more around 15% as compared to Post Tension slab.

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