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Research paper



Effect of load balancing on punching shear stress and deflection of post tensioning flat slab with different grade of concrete

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Abstract

Flat slabs are a widely adopted solution now a day for buildings, because of their economic and functional advantages. The main objective of this paper is to analysis of post tensioning flat slab by changing the different parameter such as span of slab, grade of concrete and load balancing and comparing the result such as deflection and punching shear. Grade of concrete and load balance directly influence to the deflection and punching shear of flat slab. So in this paper concrete grade varies M-35 to M-50 is considered and load balance varies from minimum 25% to maximum 100% is considered. The use of ADAPT-PT builder 2015 is recommended because of its friendly use and quick calculation capabilities. Use of the ACI Code equivalent frame method of analysis was performed using said software.

Keywords: *Post Tensioning Two-Way Flat Slab; Two-Way Concrete Design; Grade of Concrete; Load Balancing; Deflection; Punching Shear; Design-Tool ADAPT-PT/RC 2014.*

1. Introduction

Man is continuing search for new construction materials and methods. It is defined as the application of compressive stresses to concrete members. Those zones of the member ultimately required to carry tensile stresses under working load conditions are given an initial compressive stress before the application of working loads so that the tensile stresses developed by these working loads are balanced by induced compressive strength [1]. Post-tensioning is a method of reinforcing (strengthening) concrete or other materials with high-strength steel strands or bars, typically referred to as tendons. Post-tensioning applications include office and apartment buildings, parking structures, slabs-on ground, bridges, sports stadiums, rock and soil anchors, and water-tanks. In many cases, post-tensioning allows construction, which would otherwise be impossible due to either site constraints or architectural requirements. Designers commonly take advantage of this method to produce building and structure with large clear span allowing more architecture freedom. Reducing thickness of each structure member in building can reduce the total dead lead of the structure and decrease floor-to-floor height of each level. The following are just a few of the many advantages of post-tensioned floor construction. Long spans reduce the number of columns and foundations, providing increased flexibility for internal planning, and maximizing the available letting space of a floor.

- Minimum floor thickness

Minimum floor thickness maximizes the ceiling zone available for horizontal services, minimizes the self-weight and foundation loads, and keeps down the overall height of the building.

- Maximum floor height

Due to replacing beams, more floor height is achieved in post-tensioned construction.

- Deflection of the slab can be controlled

Deflection of the slab can be controlled enabling longer spans to be constructed with a minimum depth of construction.

- Crack-free construction

Crack free construction is provided by designing the whole slab to be in compression under normal working loads. Appropriate details may also be incorporated to reduce the effects of restraint, which may otherwise lead to cracking. This crack-free construction is often exploited in car parks with concrete surfaces exposed to an aggressive environment.

- Rapid construction

Rapid construction is readily achieved in multi-storey buildings as prestressing leads to less congested slab construction. Prefabrication of tendons reduces fixing time and early stressing enables forms to be stripped quickly and moved to the next floor.

- Flexibility of layout

Flexibility of layout can be achieved as the design methods can cope with irregular grids, and tendons can easily be deflected horizontally to suit the building's geometry or to allow for openings in slabs.

- Large area pours

Large area pours should be adopted on all concrete floors in order to reduce the number of pours and increase construction speed and efficiency.

Scope of the Study

By using post tensioning method one can design most economic and the safe design [2] but while using this method most precautions has to be consider for the punching shear and the deflection criteria for the slab. The design of the post tension flat slab can be done by using load balancing and equivalent frame method. Hence the present study aims to compare slab deflection, punching shear

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stress ratio with respect to exterior and interior span by using different grade of concrete such as M35, M40, M45 and M50 and different load balancing system varies 25%, 40%, 60% and 80%.For these purpose a tributary section with different span of 6.0 x 6.0 mt. to 10.0 x 10.0 mt. as flat plate are considered. For flat plate system 20 models is analysed using ADAPT-PT/RC2014. Finally graphs are plotted for above mention systems with respect to span of the member, different grade of concrete and different load balancing system.

2. Methodology

The above mention system of post tensioning is analysed using ADAPT-PTRC/2014 according to ACI 318:2003 and IS 1343-1980. Models details, post tension parameters considered in the present study given below.

Table 1: Details of Flat Plate Slat

Panel size in meter	Thickness in mm*	Grade of concrete	No. of models
6.0 x 6.0	170	M35,M40,M45,M50	4
7.0 x 7.0	200	M35,M40,M45,M50	4
8.0 x 8.0	225	M35,M40,M45,M50	4
9.0 x 9.0	250	M35,M40,M45,M50	4
10.0 x 10.0	275	M35,M40,M45,M50	4

* Span/depth is 36 (max value as per ACI 318 is 42).
Floor finish load2 kN/m2.

Table 3: General Input Data

Floor finish load	2 kN/m2
Live load	4kN/m2
Material	
Grade of concrete used	M35,M40,M45,M50
Ultimate creep co-efficient	2
For post-tensioning tendon, 12.7 mm diameter	7wires strand is used.
Ultimate strength of tendon	1860 N/mm2
Effective stress of tendon	1200 N/mm2
Minimum strand cover from top fiber	40 mm
Minimum strand cover from bottom fiber	40 mm
Minimum cover of non prestressed reinforcement For top & bottom	20 mm
Minimum average pre compression:	0.85 N/mm2
Maximum average pre compression	2.10 N/mm2
Minimum percentage of dead load to balance	25%
Maximum percentage of dead load to balance	100%
Age of concrete at stressing	5 days.
Concrete modulus of elasticity	5700 N/mm2
Load combinations	
Strength combination is	1.5 D.L+1.5 LL+ 1.5 P
Service combination is	1.0 D.L+1.0 L.L+1.0 P

3. Results and discussion

The analysis and design of post tensioning flat slab system is done and finally desirable outputs are found out. Figures show the comparison between grades of concrete, effect of punching shear ratio, deflection with respect to different span.

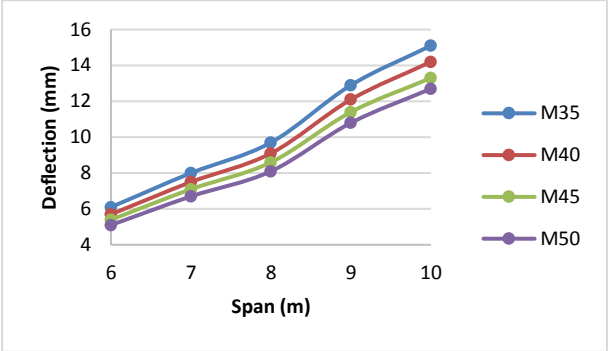


Fig. 1: Span vs Total Deflection of Exterior Span [25 to 100% Load Balance].

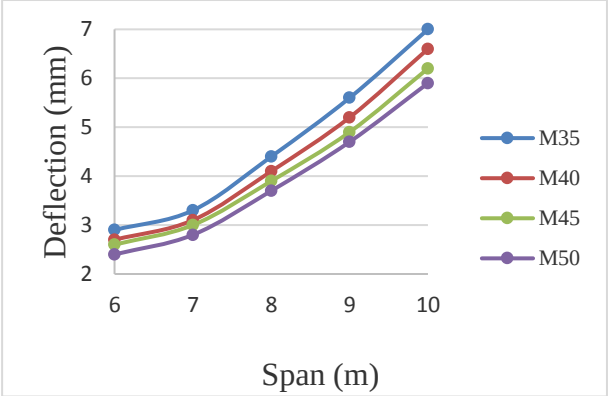


Fig. 2: Span vs Total Deflection of Interior Span [25 to 100% Load Balance].

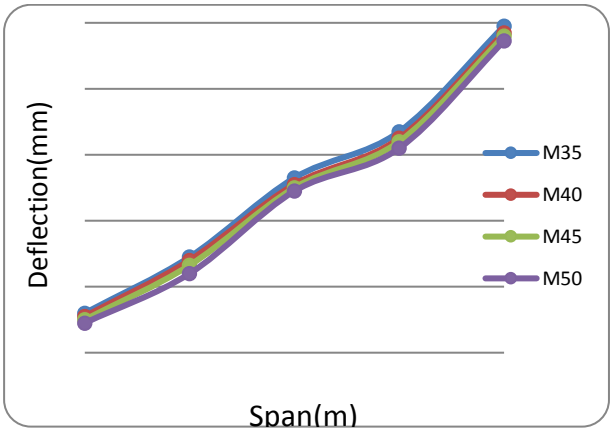


Fig. 3: Span vs Total Deflection of Exterior Span [40 to 100% Load Balance].

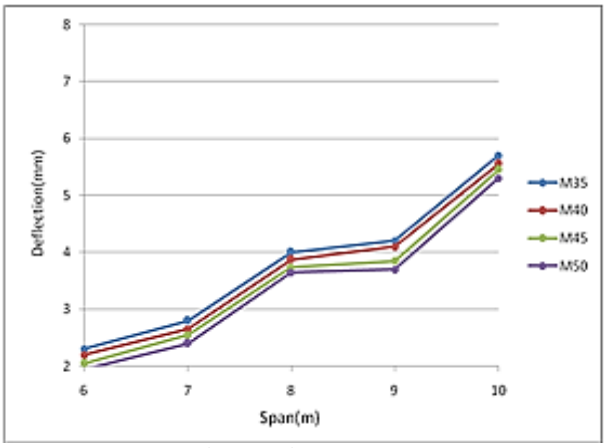


Fig. 4: Span vs Total Deflection of Interior Span [40 to 100% Load Balance].

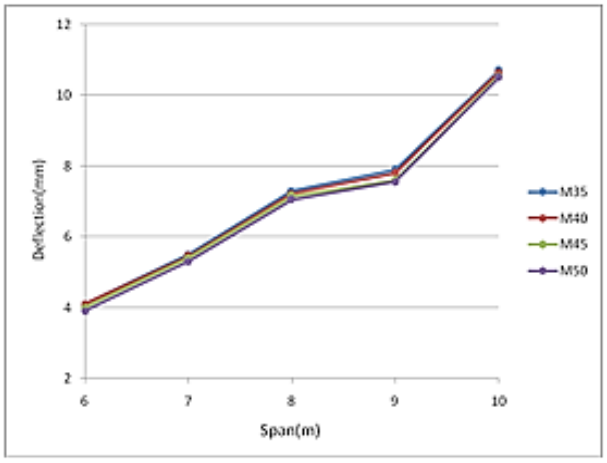


Fig. 5: Span vs Total Deflection of Exterior Span [60 to 100% Load Balance].

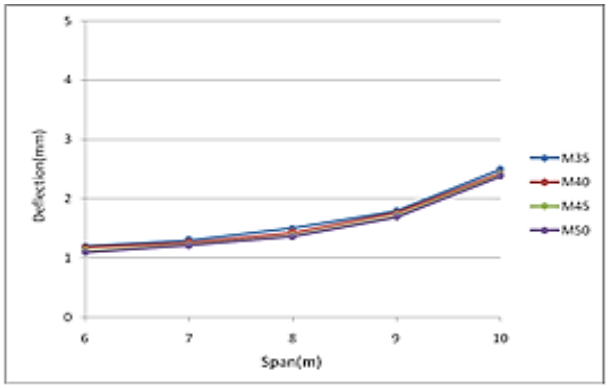


Fig. 6: Span vs Total Deflection of Interior Span [60 to 100% Load Balance].

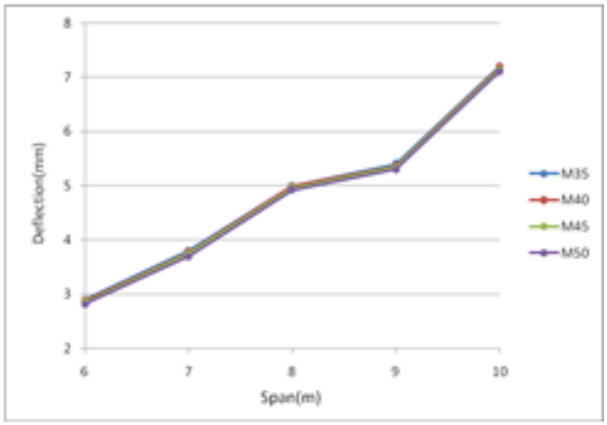


Fig. 7: Span vs Total Deflection of Exterior Span [80 To 100% Load Balance].

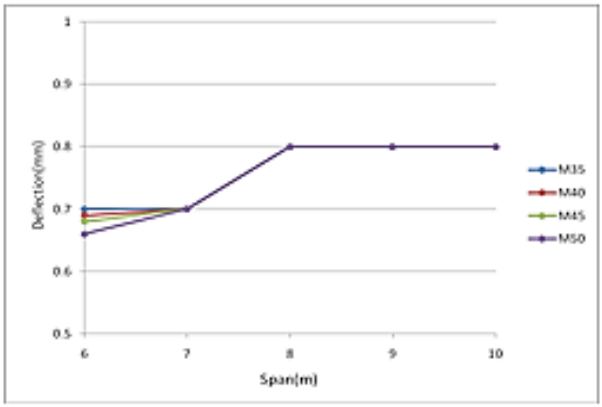


Fig. 8: Span vs Total Deflection of Interior Span [80 to 100% Load Balance].

Table 1: Comparison between Span vs Punching Shear Stress Ratio of Exterior Support [25 to 100% Load Balance]

Span in meter	Punching shear stress ratio of exterior support			
	M35	M40	M45	M50
6	1.03	0.96	0.91	0.86
7	1.16	1.09	1.03	0.97
8	1.18	1.1	1.04	0.98
9	1.34	1.25	1.18	1.12
10	1.35	1.26	1.19	1.13

Table 2: Comparison between Span vs. Punching Shear Stress Ratio of Interior Support [25to 100% Load Balance]

Span in meter	Punching shear stress ratio of middle support			
	M35	M40	M45	M50
6	0.88	0.83	0.78	0.74
7	0.99	0.93	0.87	0.83
8	1.01	0.95	0.89	0.85
9	1.12	1.05	0.99	0.94
10	1.14	1.06	1.0	0.95

Table 3: Comparison between Span vs. Punching Shear Stress Ratio of Exterior Support [40 To 100% Load Balance]

Span in meter	Punching shear stress ratio of exterior support			
	M35	M40	M45	M50
6	1.035	1.010	0.975	0.950
7	1.169	1.093	1.031	0.978
8	1.150	1.075	1.014	0.962
9	1.327	1.241	1.170	1.110
10	1.309	1.225	1.155	1.095

Table 4: Comparison between Span vs. Punching Shear Stress Ratio of Interior Support [40 To 100% Load Balance]

Span in meter	Punching shear stress ratio of exterior support			
	M35	M40	M45	M50
6	1.035	1.010	0.975	0.950
7	1.169	1.093	1.031	0.978
8	1.150	1.075	1.014	0.962
9	1.327	1.241	1.170	1.110
10	1.309	1.225	1.155	1.095

Table 5: Comparison between Span vs. Punching Shear Stress Ratio of Exterior Support [60 To 100% Load Balance

Span in meter	Punching shear stress ratio of interior support			
	M35	M40	M45	M50
6	1.017	0.951	1.045	0.991
7	1.185	1.108	1.045	0.991
8	1.148	1.074	1.012	0.960
9	1.331	1.245	1.174	1.114
10	1.301	1.217	1.148	1.089

Table 6: Comparison between Span vs. Punching Shear Stress Ratio of Interior Support [60 To 100% Load Balance]

Span in meter	Punching shear stress ratio of exterior support			
	M35	M40	M45	M50
6	0.972	0.909	0.857	0.813
7	1.114	1.042	0.982	0.932
8	1.093	1.022	0.964	0.914
9	1.260	1.178	1.111	1.054
10	1.240	1.160	1.094	1.038

Table 7: Comparison between Span vs. Punching Shear Stress Ratio of Exterior Support [80 to 100% Load Balance]

Span in meter	Punching shear stress ratio of interior support			
	M35	M40	M45	M50
6	1.021	0.955	0.901	0.855
7	1.188	1.112	1.048	0.994
8	1.153	1.078	1.017	0.964
9	1.336	1.249	1.178	1.117
10	1.307	1.223	1.153	1.094

Table 8: Comparison between Span vs. Punching Shear Stress Ratio of Interior Support [80 to 100% Load Balance]

Span in meter	Punching shear stress ratio of exterior support			
	M35	M40	M45	M50
6	0.920	0.861	0.812	0.770
7	1.051	0.983	0.927	0.879

8	1.030	0.963	0.908	0.862
9	1.183	1.106	1.043	0.990
10	1.164	1.089	1.027	0.974

4. Conclusion

The following conclusion has been derived based on parametric study done for the post tensioning flat plate system

- Deflection is reducing by increasing load balancing.
- With reduction of deflection the load carrying capacity is increasing for serviceability criteria.
- Approximately 22% reduction in deflection is found with increasing grade of concrete from M35 to M50 for all span.
- Deflection is lesser in continuous system hence deflection is less in interior span.
- Deflection of interior span with higher load balance is very less. After [8] mt span with increasing grade of concrete no significant change is there.
- The punching shear ratio criteria as given by code should be less than or equal to [1]. In several cases, it observed that the value is greater than [1].
- To satisfy these criteria for following changes can be done.

i) Minor variation increase in grade of concrete.
ii) Use rebar or stirrups
iii) Increasing the depth of slab around the column, say providing the drop cap.

- There is no significant change in punching shear ratio for exterior and interior support with change load balance. It is critical for interior support than exterior for any load balance and grade of concrete.

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