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Assessment of Post-Tensioned Slab along with Seismic Effect

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***Abstract* —** Construction industry is being revolutionized with growing technology and innovation. Man started to reach sky not in any aero plane but with the height of building. Tall structures have considerably reduced the problem of shelter but are considered highly susceptible to seismic loads and uneconomical. Both the problems are aroused due to high weight of the building. Of all the structural members in a building slabs are considered to be occupying high area and the load of the building is mostly contributed due to slab. In general for commercial areas normal slabs are not been considered, as the spans between the supports are more which leads to increasing in deflection and ultimately provision of huge depth and percentage of steel is increased beyond the codal provision ,once such solution to reduce the slab depth and provide economical design is flat slabs technology.

***Keywords* – Tall Structures, Slabs, deflection, flat slab, shelter.**

INTRODUCTION

A building is said to be always a building because there is always an opportunity to develop it again and again (Maaz Allah Khan, et al, 2013). In every building structure the main components are the floor systems which give the basic Skelton to the structure. In floor system a significant importance is of the post tensioned flooring it reduces the time involved in construction and also a prominent reduction can be seen in the cost (G.R. Chavan, et al, 2012). The post tensioning slabs and technology is widely adopted in various countries such as China, Thailand, United State of America and India. There is huge benefit and utilization of pre-stressed concrete technology in the seismic and earthquake prone areas and it gives good resistance to these lateral forces. For any section of reinforced concrete the stresses are needed to counterbalanced and in the case of prestreesed concrete the stresses generated internally that are induced due to external loads can also be counter balanced to a required degree. The high tensile steel tendons are used to generate the prestress in reinforced concrete sections (Maaz Allah Khan, et al, 2013). From the ancient times the prestress concept is experienced in the case of wooden and timber barrels in which certain forces are employed to make them shrink and tight, this can also be experienced in metal tyres. As it is known that concrete is a versatile material which is being used worldwide from various decades and being a versatile material it has a drawback of being weaken in the zone of tension. Ultimately concrete is not able to sustain the tensile stress. This drawback gives a reason to develop a new kind of concrete which can sustain the initial cracks which were introduced by non-familiarity with steel bars in tension, this newly developed concrete is known as “Pre-stressed concrete”. By using Pre-stressed concrete the stresses are integrally introduced in tension part of the section and these stresses are counteracted by the compressive stresses so that the reinforced concrete section can be utilized fully at its extreme conditions (Sreenivas P. Joshi, et al, 2014). The cost of the structure can be reduced significantly by using Pre-stressing concrete as the concrete section is fully utilized. Pre-stressed concrete requires less thickness of the structure so that the dead load is reduced and it also reduces the foundation and footings, it provides more clear height which gives an opportunity to increase more floors.

Post-tensioned flat slabs design and construction are having the same approach which are being used in traditional plate structure where high tensile steel reinforcement are used in place of normal reinforcement. The main benefit of using a post tensioning component with compare to normal rcc slab is that it is a crack free at the imposed and live loads.

This gives the smaller amount of deflection in compared with reinforced concrete slab constructed in an ordinary way. Hence in post tension slab the reduction in the thickness can be achieved in compared with normal RCC construction if the span of the slab is more than ten meters (Maaz Allah Khan, et al, 2013).

When the post tensioned slabs are analyzed then some secondary moments are obtained and their effect is considered. When the design of slab is carried out then the lateral loading is combined with secondary moments and gives the critical issue. This reason cause statistical behavior and response of the flat and post tensioned slab during high seismic altitude. Another arising issue in the present scenario is the scarcity of space which is compelling us to raise the height of buildings to accommodate the growing population. This increase in the height of building enforces consideration of the factors such as lateral loads like Stretching one cable produces secondary moment and hence strip moments in both direction changes drastically (Shriraj S. Malvade, 2015).

There are two methods which are available to design of post-tensioned slab, load balancing method and the equivalent frame method. T.Y. Lin introduced the load balancing method and it is not suitable for determinate structures only indeterminate structures can be analyzed by this method. The bending stresses are not induced in known load conditions in the flexure member if the dead load is balanced by 65 to 85 %. However the equivalent frame method is positively used in the designing of post tensioned slabs. The post tensioned slab with reinforced concrete beams is having higher cost than the post tensioned slabs. The post tensioned flat slab system requires less amount of concrete for the construction in compared with post tensioned slabs provided with reinforced beam (Boskey Bahoria et-al, 2010).

METHODOLOGIES/SOLUTION APPROACHES

Following methodology are considered during the analytical approach in the assessment of post-tensioned slabs-

- To meet the paper title, the design of post tensioned slabs with different end conditions are analyzed by analytical approach.
- For the investigation purpose a post tensioned slab with different sizes and end conditions are assumed to be situated in high seismic zone.
- The slab is analyzed for different end conditions such as two way support, continuous support and in the form of grid paneling floor.
- To analyze the efficiency of the different post tensioned slabs the design data are compared among the distinct cases and significant changes are found in terms of seismic stability and along with economy.

Following points are worth to discuss-

1 Different design approaches of Post-Tensioned Slab

2 Seismic behavior of Post-Tensioned Slabs

3 Experimentation of Standard and Post-Tensioned Slab

The basic outline of the design is as followed-

1. First step in the assessment of post tension slabs includes the determination of the major inputs desired for analysis purpose these are the geometrical aspects of slab including the span, width and the starting thickness along with the recognized compressive strength of concrete, columns sizes and different loading combination on post tension slabs.

a. In the current problem various regular and irregular shapes in terms of square & rectangular slabs have been considered having spans of 5, 6, 7, 8, 9, 11, 13, 14 and 16 meters.

b. Various changing thicknesses of Post tension slabs have been taken as 130, 150, 170, 190, 210 and 230 mm.

c. Only imposed load has been considered on the Post tensioned slab these are ranging in series 2, 3, 4, 5 and 6 kN/m^2.

d. Columns are having square cross section of 400mm x 400mm, 650mm x 650mm and 800mm x 800mm with 3m height are taken.

e. Grade taken for high strength concrete is M30, M 35, M 40, M45 and M50.

f. Characteristic strength of high tensile steel used in post tensioning is taken as 1800 MPa.

2. In the second stage the drop size is considered from the length ratio in terms of L/5 and B/5 in the individual directions and the depth of drop is taken as T/3. Here L, B

and T are the length, width and depth of the Post Tension slab to be designed respectively.

3. Thirty percent of live load is considered on the roof in addition to the dead load of the slab so the total load to be resisted is dead load plus thirty percent increment which are sustained by high tensile steel.

4. Cable profile is setup by taking a suitable cover.

5. In Pre-stressed concrete the losses due to friction, elastic shortening, creep and shrinkage are to be considered.

6. The effective pre-stressed is calculated including the losses which occurred during the construction stage.

7. The total prestressing force can be determined in relevance to the calculated effective stress.

8. The required area of high tensile steel is determined by dividing the total jacking force by the characteristics strength.

9. The permissible stresses are checked by determining the positive as well negative moments in the design of post tension slab.

10. Calculate the moment of inertia of the column strip as well as the middle strip.

11. Determine the overall deflection (max deflection at the center of panel).

RESULT AND ANALISIS

General input data used in Designing of PT slab-

The analysis and design of different post tensioned slabs are done and finally required results are determined. Various graphical representations shows the comparison between grade of concrete, effect of seismic ratio, deflection, factored moment at mid span Post Tension steel quantity and Non Post Tension steel for different span and for various floor systems.

Table 1 Specification of design

Floor Finish load	2.4-2.7 kN/m^2
Live Load	2-4 kN/m^2
Material	
Grade of Concrete	M35, M40, M45, M50
Ultimate creep coefficient	2
Steel reinforcement grade	Fe415-Fe500
For post tensioning tendons, 12.6 mm diameter	Three, Four, Seven, Nine, Eleven, Twelve wires strands are used
Ultimate strength of tendon	1720 N/mm^2
Effective stress of tendon	1100 N/mm^2
Min strand cover from top fibre	40 mm
Min strand cover from bottom fibre	40 mm
Min cover of non-pre-stressed reinforcement For top & bottom	20 mm
Minimum average pre compression	.80 N/mm^2
Maximum average pre compression	2.05 N/mm^2
Minimum percentage of dead load to balance	22%
Maximum percentage of dead load to balance	100%
Age of concrete at stressing	5 days
Concrete modulus of elasticity	5700 N/mm^2
Load Combinations	
Strength load combination	1.5 DL + 1.5 LL + 1.5 P
Service load combinations	1.0 DL + 1.0 LL + 1.0 P

Seismic Parameters	
Zone	IV
Response Reduction Factor	5
Importance Factor	1
Type of Structure	2
Damping Ratio	0.4
Time Period	$T_a = 0.075h^{.75}$

Results and comparison between various designing parameters-

The various results among the distinct parameters of post tension slab are co related below through graphical presentation.

Relationship between Span of Two Way PT Slab and total deflection of outer span

For Pre-stressed concrete two way slab relationship can be modeled between span of the slab to the total deflection of exterior span. The graphical representation is as shown below-

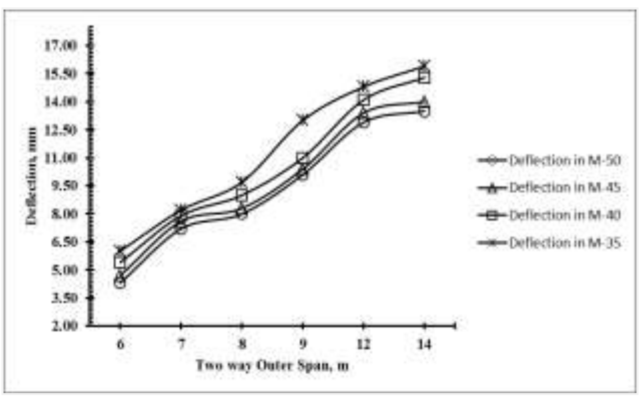
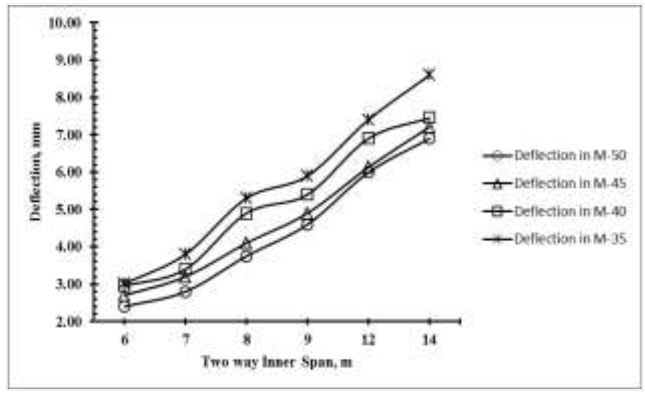


Fig. 1 Span of Two Way Post Tensioned Slab vs Total Deflection of outer span

It can be easily understood that for lower grade of concrete the deflection is increased with the increment of span but for the higher grade of concrete the deflection is in the controlled region. So in post tensioned slab high grade of concrete is desirable.

Relationship between Span of Two Way PT Slab and total deflection of inner-

For Pre-stressed concrete two way slab relationship can be modeled between span of the slab to the total deflection of interior span. The graphical representation is as shown below-



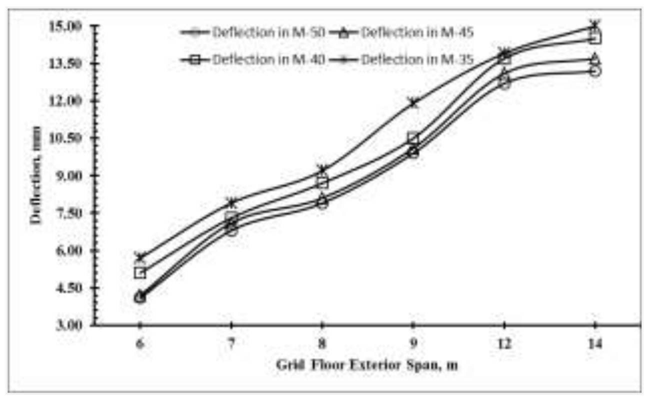


Fig. 2 Span of Two Way Post Tensioned Slab vs Total Deflection of inner span

The graph representation shows slightly different result from outer span, It can be easily concluded that for lower grade of concrete the deflection is increased with the increment of span but for the higher grade of concrete the deflection is in the controlled region. for smaller span with moderate grade of concrete the deflection is very small, So in post tensioned slab at middle span high grade of concrete is desirable even at smaller span.

Relationship between Span of continuous PT Slab and seismic effect of exterior span-

For Pre-stressed concrete continuous flat slab relationship can be modeled between span of the slab to the seismic effect of exterior span. The graphical representation is as shown below-

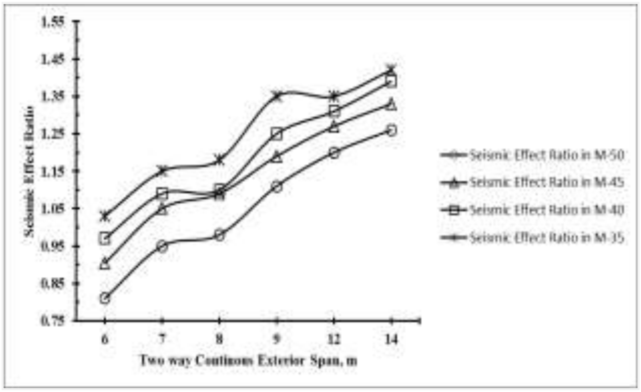


Fig. 3 Span vs seismic effect exterior span

Relationship between Span of grid floor and total deflection of exterior span-

For Pre-stressed concrete grid floor relationship can be modeled between span of the slab to the total deflection of exterior span. The graphical representation is as shown below-

Fig. 4 Grid floor Span vs deflection of Exterior span

Relationship between Span of grid floor slab and total deflection of interior span

For Pre-stressed concrete grid floor slab relationship can be modeled between span of the slab to the total deflection of interior span. The graphical representation is as shown below-

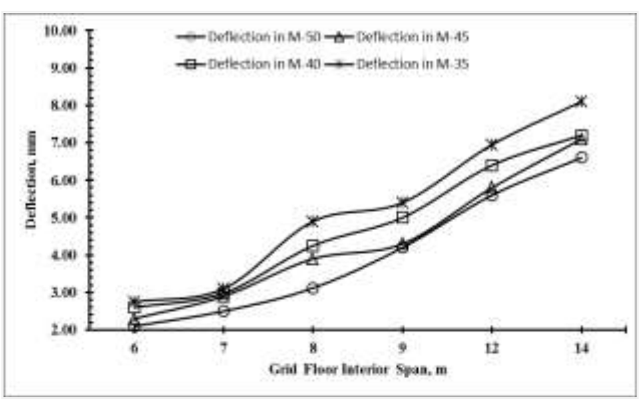


Fig. 5 Grid floor Span vs computed deflection of interior span

Relationship between Span of grid floor Slab and seismic effect of span

For Pre-stressed concrete grid floor slab relationship can be modeled between span of the slab to the seismic effect of exterior span. The graphical representation is as shown below-

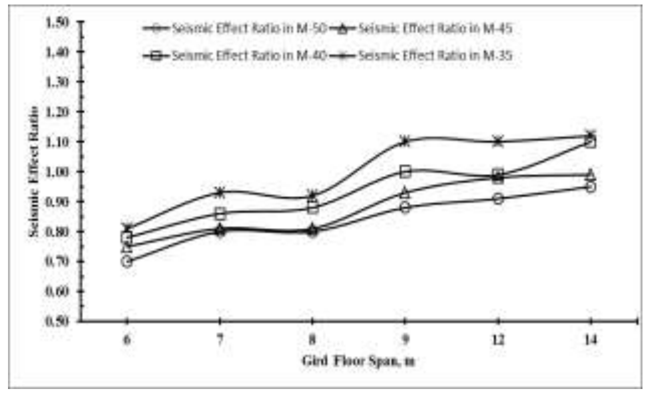


Fig. 6 Grid floor Span vs seismic effect

The graphical representation shows slightly different result from other span, It can be easily concluded that for lower grade of concrete the seismic effect is increased with the increment of span but for the higher grade of concrete the seismic effect is in the controlled region in compare with PT continuous slab. For smaller span with moderate grade of concrete the seismic effect is very small, So in post tensioned slab at middle span high grade of concrete is desirable even at smaller span for the control of deflection as the seismic effect distribution.

COST ANALYSIS

From the results a graphical comparative conclusion can be derived from all the types of Post tensioned slab with normal reinforce concrete cement slab. In among the entire slab divided into panels (grids) with post tension characteristics holds the top position with great resistivity to seismic effect and having good control at cost and economy.

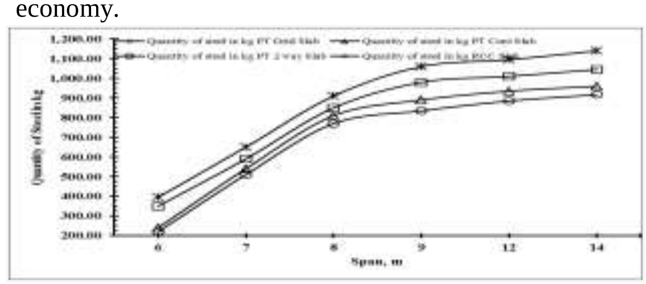


Fig. 7 Comparison of Various PT slab and Normal RCC Slab

Similarly the cost analysis between the PT slab and normal reinforced concrete slab is seen below-

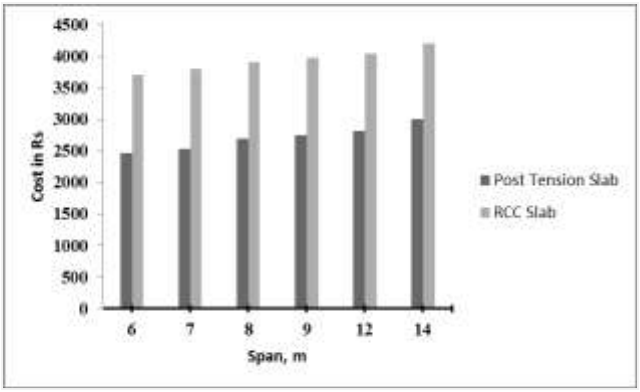


Fig. 8 Variation of cost of Post Tensioned slab along with span

It is clearly seen from the above chart that for span having less than 6 meter normal reinforced concrete is economical but whenever the span crosses 10 meter then post tensioned slabs are more economical. So for the longer span slabs high tensile steel slabs can be widely used.

SCOPE OF WORK

The post tensioning is new and innovative technique to resolve the various long span structural problems, in today's developing era there is no boundation on any structure where the buildings are touching the sky. If the long span slabs are carried out then heavy beams and columns are required to be established and leading to higher uneconomic to the structure so to reduce such problems and to enhance the construction stage post tensioning is introduced. Today this method is recognized by worldwide. Many researches and techniques have been evolved since its first time construction.

The main benefit to use post tensioning in today civil engineering structure is to achieve higher strength and to reduce the construction cost of the structure. In this study the assessment of the design of post tension slab in high seismic zones are considered as the post tensioning slab is mainly based on design of flat slabs and analysis. And the biggest drawback of flat slab that it is lower faithful in the zone of seismic areas.

CONCLUSION

The review and research of papers have been studied in the field of Post Tensioned slab to examine and determine present challenges and future scope of work. The review could fetch three issues such as different design approaches of PT slab, seismic behavior of PT slab, experimentation of standard and PT slab. After the review, one major issue was found in the literature which was based on experimental approach and analytical approach. Analysis of literature was carried out in depth with extraction of common findings of research works, strengths and weaknesses and gaps to build problem statement and objectives. Based on gaps observed the problem statement was framed to propose new methodology for designing seismic load resisting structure using equivalent frame, load balanced and pushover method.

Following conclusions were drawn after assessment of post tensioned slab with different end conditions.

- The post tension slab is quite good in comparison with normal reinforced concrete slab.
- In post tension slab a big saving in concrete and steel as it does not carry the beams and so many numbers of columns.
- Approximately 20 % reduction is found in defelction with increasing grade of concrete from M 35 to M 50 for all spans.
- For the post tension slab in two way end condition the lateral stability is less in compared with post tension slab in continuous span.
- It is observed that Post tensioned two way slab has a probability of failing in seismic behavior but post tensioned continuous slab is good strong to resist it.
- When slabs are divided into panels the seismic resistivity is increased drastically.
- It is observed that the design moment for middle of inner and outer panel for flat plate two way slabs is approximately 50-55% more than grid floor slab. So it is cleared that grid floor slab in the form of panel is better in flexural strength.

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