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# Flat Slab Construction in India

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Abstract— "Flat Slab" is better understood as the slab without beams resting directly on supports (like columns & or walls).By virtue of that large Bending Moment & Shear Forces are developed close to the columns. These stresses brings about the cracks in concrete & may provoke the failure of slab, thus there is a need to provide a larger area at the top of column recognized as column head/capital. The objective of this paper is to present the use of flat plate/slab construction in India. The applications in buildings followed by a comparative description of flat plate/slab structure designs based on Indian Standard 456:2000[1] and American Concrete Institute ACI-318[2] codes. The discussion of ***Reinforced Concrete (RCC) Flat Slabs preferred over those*** of Post-Tensioned (PT) flat slab. Also, we have ***studied*** that many of the usual advantages of using PT systems over conventional RCC including a nearly crack free slab at service load leading to smaller deflection and watertight structures. In practical we have observed that the PT structure doesn't reduce thickness of slab and also doesn't reduce in the cost of structure.

***Index Terms***—**Flat slab, IS code, ACI-318, Post-Tensioned(PT), RCC**

## I. INTRODUCTION

A flat slab consists of a reinforced concrete slab that is directly supported by concrete columns without the use of intermediate beams. C.A.P. Turner constructed flat slabs in U.S.A. in 1906 mainly using intuitive and conceptual ideas, which was start of this type of construction. Many slabs were load-tested between 1910- 20 in U.S.A. It was only in 1914 that Nicholas proposed a method of analysis of flat slabs based on simple statics. This method is used even today for the design of flat slabs and flat plates and is known as the direct design method. Structural engineers commonly use the equivalent frame method with equivalent beams such as the one proposed by Jacob S. Grossman in practical engineering for the analysis of flat plate structures. Floor systems consisting of flat slabs are very popular in countries where cast-in place construction is predominant form of construction because of many advantages in terms of architectural flexibility, use of space, easier formwork, and shorter construction time. Flat slabs are being used mainly in office buildings due to reduced formwork cost, fast excavation, and easy installation.

**Fig 1: Typical flat slab construction**

Architectural demands for **better illumination**, lesser fire resistance of sharp corners present in the form of beams & increase in the formwork cost, **optimum use of space** leads to the new concept in the field of structural engineering as Reinforced concrete flat slabs.


**Fig 2: Attractive and Optimum use of flat Slab for better illumination**

## II. DESIGN OF THE FLAT SLAB STRUCTURES

Despite the rapid growth of flat plate/slab construction, literature and tools available for designers to design and engineer flat plate/slabs in India, has been limited in terms of both Indian standards and Indian research papers. Indian engineers often have to resort to other standards to design flat plate/slab. The following is a discussion of the process of designing flat plate/slabs to meet Indian codes. Limitations in the Indian codes IS 456:2000 are overcome by utilizing ACI-318. Maintaining the Integrity of the Specifications

The design of flat slab structures involves three steps*:*

1) Framing system
2) Engineering analysis
3) Reinforcement design and detailing

***Framing System:***

Initial framing system formulation provides a detailed geometric description of the column spacing and overhang. Even though the architect provides this part of the design, the engineer should emphasize on the following:

1)Three continuous spans in each direction or have an overhang at least one-forth times adjacent span length in case

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of only two continuous spans.

2) Typical panel must be rectangular

3) The spans must be similar in length i.e. adjacent span in each direction must not differ in length by one-third

Engineering Analysis:

Flat plate/slab may be analyzed and designed by any method as long as they satisfy the strength, stiffness and stability requirements of the IS 456:2000[1] or ACI-318[2] codes. A typical flat plate/slab can be analyzed by direct design method or equivalent frame method as prescribed by the code. However, if the flat plate/slab is atypical with unusual geometry, with irregular column spacing, or with big opening then the designer may have to use finite element method model analysis using computers. The design of flat plate/slabs irrespective of the methodology used must first assume a minimum slab and drop thickness and a minimum column dimension to ensure adequate stiffness of the system to control deflection. The IS 456:2000 code is not clear on these minimums. However ACI specifies empirical formulas to arrive at these minimums. Refer to Table 1 for minimum slab thickness. Once the slab thickness and column dimensions with boundary conditions are selected, the structure is loaded for different load cases and combinations prescribed by the code. The computed forces and moments in the members should be used for reinforcement design. Critical reactions for the load combinations are used for the design of the supporting columns and foundations. Reinforcement Design and Detailing Reinforcement design is one of the critical parts of flat plate/slab design; maximum forces from the analysis shall be used in the design of the reinforcement. Reinforcement required for flexure by using minimum slab thickness per table 1 typically will not require compression reinforcement. The tension steel area required and detailing for appropriate strips can be per IS 456:2000 or ACI-318, both being similar. However design for punching shear force (including additional shear due to unbalanced moment) per IS 456:2000 is 32% conservative compared to ACI-318, because Indian code underestimates the concrete two-way shear strength by 32% compared to ACI.

**Table 1**

| | Without drop panels | | | With drop panels** | | |
|---|---|---|---|---|---|---|
| | Exterior panel | | Interior panel | Exterior panel | | Interior panel |
| Yield stress in steel | Without edge beams | With edge beams | | Without edge beams | With edge beams | |
| Fe 240 | Ln/33 | Ln/36 | Ln/36 | Ln/33 | Ln/36 | Ln/36 |
| Fe 415 | Ln/30 | Ln/33 | Ln/33 | Ln/30 | Ln/33 | Ln/33 |
| Fe 500 | Ln/28 | Ln/31 | Ln/31 | Ln/28 | Ln/31 | Ln/31 |

Where Ln is clear span in long direction

*Slabs with columns between, along exterior edge. The ratio of flexural stiffness of effective beam to Flexural stiffness of width of slab bounded laterally by the centerline of adjacent panel on either side of beam shall not be less than 0.8

** Minimum drop panel shall be at least one-sixth of the span in each direction and project below the slab at least one-quarter of the slab thickness. In order for the full effective death of the drop to be used for negative moment reinforcement, the maximum death of the drop shall not be assumed more than one-fourth of the distance between the edge of the drop and face of the column. Additionally, drop size can be made as large as possible to reduce deflection. The absolute sum of the positive and negative moment in each direction is given by

$$M_o = \frac{W L_n}{8}$$

Every code suggests any of the two methods as Direct Design Method and Equivalent Frame Method for analysis of flat slab. Design of Flat slab by Direct Design Method has some restrictions that

(a) It should have minimum three spans in each direction.

(b) It should not have staggered column orientation. Hence Equivalent Frame Method is adopted.

Using those calculated moments calculate negative moments at both left & right support i.e. ($M^-_u$) & the maximum positive moments in the middle of span i.e. ($M^+_u$).

All the Negative & Positive moments are distributed in the column strips & Middle strips respectively using equivalent codes.

IS 456-2000 Distribution of moments across panels for Exterior Slab

| Sr. No. | Distributed moment | Column strip moment % | Middle strip moment % |
|---|---|---|---|
| A | Negative BM at exterior support | 100 | 0 |
| B | Negative BM at interior support | 75 | 25 |
| C | Positive BM moment | 60 | 40 |

IS 456-2000 Distribution of moments across panels for Interior Slab

| Sr. No. | Distributed moment | Column strip moment % | Middle strip moment % |
|---|---|---|---|
| A | Negative BM at exterior support | 75 | 25 |
| B | Negative BM at interior support | 75 | 25 |
| C | Positive BM moment | 60 | 40 |

ACI 318 Distribution of moments across panels for Slab

| | Exterior edge Unrestrained | Slab with Beams Between all Supports | Slab without beams Between interior Supports | | Exterior edge Fully Restrained |
|---|---|---|---|---|---|
| | | | Without edge Beam | With edge beam | |

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| | | | | | |
|---|---|---|---|---|---|
| Interior Negative Moment | 0.75 | 0.7 | 0.7 | 0.7 | 0.65 |
| Positive Moment | 0.63 | 0.57 | 0.52 | 0.5 | 0.35 |
| Exterior Negative Moment | 0 | 0.16 | 0.26 | 0.3 | 0.65 |

Still moments in the slab remains unbalanced. These unbalanced slab moments at supports are transmitted to respective columns. These moments are transferred by punching shear & flexure in the column. The punching shear produces cracks at the critical section close to the column faces as shown below,

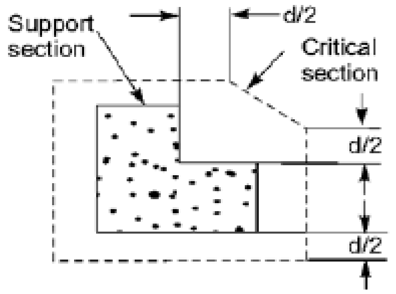


**Fig 3: Critical section for shear**

In such slabs large bending moments and shears develop near the junctions with columns. Therefore there is a need to spread the column at its top end or thicken the slab over column.

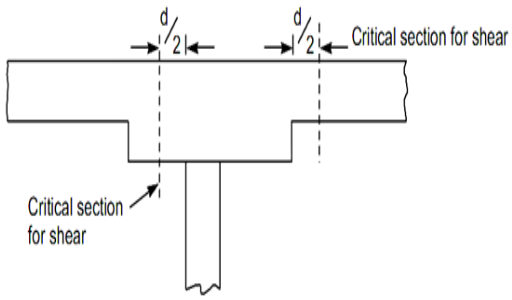


**Fig 4 : Flat slab with drop and column without column head**

The shear stess is calculated as given in IS code & ACI. If it is more than permissible the shear reinforcement is provided.

## III. POST-TENSIONED FLAT PLATE/SLAB

Post-tensioned flat plat/slabs are a common variation of the conventional plate structure where most of the reinforcement is replaced by post-tensioned strands of very high strength steel. The structural advantage of post tensioning over conventional RCC is that the slab is nearly crack- free at full service load. This leads to a smaller deflection compared to conventional RCC because of the higher rigidity of the un-cracked section. Hence reduction in thickness of the slab compared to conventional RCC is the rationale for using post-tensioning system for spans over 10m and above. Further the lack of cracking leads to a watertight structure. Flat plat/slab design and build contractors in India claim a 20% cost reduction compared to conventional RCC. However, our observation of post-tensioned flat plat/slab constructions used in two construction projects in India built by post tensioned concrete contractors utilizing PT system has been that there is no reduction in thickness of the slab compared to conventional RCC and the slabs are not crack free at service loads. Hence, the actual deflection in these structures is similar to that of theoretically computed RCC deflection. In addition, water tightness was not achieved in one of the projects. And with respect to costs involved, there is an escalation in cost by 15-20% rather than reduction as claimed by PT design & build contractor. And another disadvantage in using post tensioned system in commercial buildings in India is its lack of flexibility to create openings or drill into slabs to anchor services system when the slab is completed with post tensioning. Invariable the owner in India is not sure of the occupant when he starts the building and may have to change or create opening in slabs after construction to satisfied occupants requirement, which is not possible with a PT system.

## IV. CONCLUSION

Flat plate/slab construction is a developing technology in India. Flat plate/slab can be designed and built either by conventional rcc or post-tensioning. However, due to issues mentioned above with pt construction in india and its higher cost, conventional rcc should be the preferred choice for spans up to 10 meters. Design of conventional rcc flat plate/slab in India, utilizing Indian codes, has many shortcomings, which have to be addressed and revised soon. Until then Indian engineers will continue to use Indian codes in combination with other standards like the aci, bs or euro code to design and analyze flat slabs/plates.

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