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Study of Flat Slab

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Abstract: ***The flat-slab system is a special structural form of reinforced concrete construction that possesses major advantages over the conventional moment-resisting frames. The former system provides architectural flexibility, unobstructed space, lower building height, easier formwork and shorter construction time. This paper gives the guidelines for analysis of flat slab.***

Keywords: Flat slab, Drops, Head**.**

1. Introduction

The scarcity of space in urban areas has led to the development of vertical growth consisting of low-rise, medium-rise and tall buildings. Generally framed structures are used for these condition buildings. They are subjected to both vertical and lateral loads. Lateral loads due to wind and earthquake governs the design rather than the vertical loads. The buildings designed for vertical load may not have the capacity to resist the lateral loads. The lateral loads are the premier ones because in contrast to vertical load that may be assumed to increase linearly with height; lateral loads are increase with increase height of building is very rapidly. Under this situation uniform wind and earthquake loads the overturning moment at the base is very large and varies in proportion to the square of the height of the building. The lateral loads are considerably higher in the top storey rather than the bottom storey due to which building tends to act as cantilever. These lateral forces tend to sway the frame. In many of the seismic prone areas there are several instances of failure of buildings which have not been designed for earthquake loads. but this condition flat slab reduces effect of earthquake because less story height as compare to frame structure.

2. Flat Slab

Normally the slab is supported by beam and beam is supported by column is called as slab beam frame construction.. The beams reduce the available net clear floor to floor height of structure. Hence in warehouses, commercial building shopping mall, offices and public halls sometimes beams are avoided and slabs are directly supported by columns. These types of construction are aesthetically appealing and avoid the obstruction due to the beam. These type of slabs which are directly supported by columns . these type structure are also called flat slab.

3. General

Common practice of design and construction is to support the slabs by beams and support the beams by columns. This may be called as beam-slab construction. The beams reduce the available net clear ceiling height. Hence in warehouses, offices and public halls sometimes beams are avoided and slabs are directly supported by columns. These types of construction are aesthetically appealing also. These slabs which are directly supported by columns are called Flat Slabs.

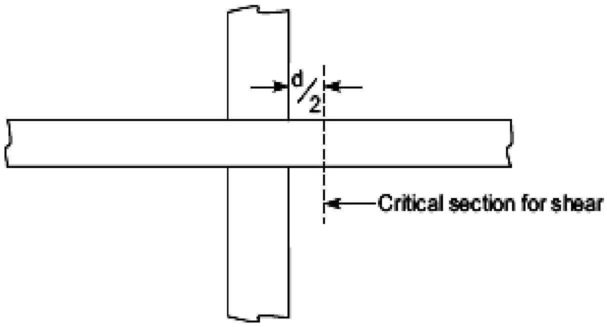

Figure 3.1: Typical flat slab (without drop and column head)

The column head is sometimes widened so as to reduce the punching shear in the slab. The widened portions are called column heads. The column heads may be provided with any angle from the consideration of architecture but for the design, concrete in the portion at 45º on either side of vertical only is considered as effective for the design

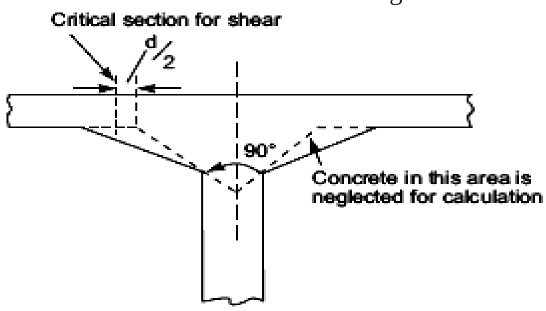

Figure 3.2: Slab without Drop and Column with Column Head

Moments in the slabs are more near the column. Hence the slab is thickened near the columns by providing the drops as shown in figure 3.3. Sometimes the drops are called as capital of the column. Thus we have the following types of flat slabs:

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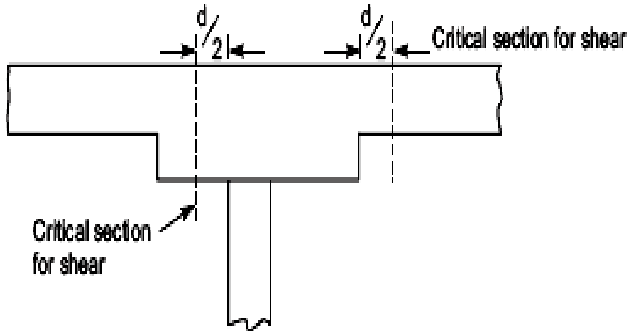

Figure 3.3: Slab with Drop and Column without Column Head

(i) Slabs without drop and column head (Figure 3.1).
(ii) Slabs without drop and column with column head (Figure 3.2).
(iii) Slabs with drop and column without column head (Figure 3.3).
(iv) Slabs with drop and column head as shown in (Figure3.4)

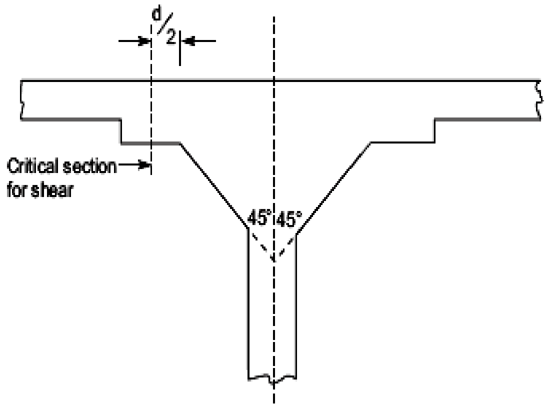

Figure3.4: Slab with Drop and Column with Column Head

The portion of flat slab that is bound on each of its four sides by centre lines of adjacent columns is called a panel. The panel shown in figure3.5 has size L_1 X L_2. A panel may be divided into column strips and middle strips. Column Strip means a design strip having a width of $0.25L_1$ or $0.25L_2$, whichever is less. The remaining middle portion which is bound by the column strips is called middle strip. Figure 3.5 shows the division of flat slab panel into column and middle strips in the direction y.

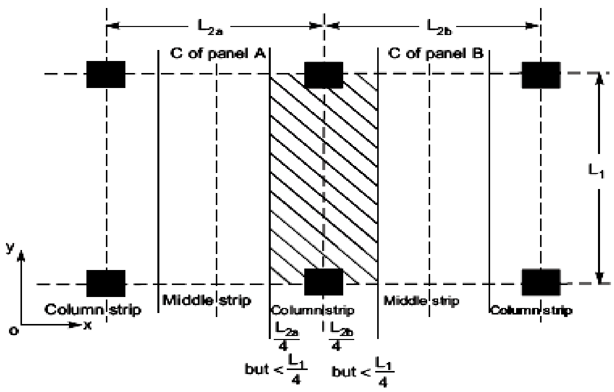

Figure 3.5: Panel Column Strips and Middle Strip is Y-Direction

Proportioning of Flat Slabs
IS 456-2000 [Clause 31.2] gives the following guidelines for proportioning.

3.2.1Drops
The drops when provided shall be rectangular in plan, and have a length in each direction not less than one third of the panel in that direction. For exterior panels, the width of drops at right angles to the non continuous edge and measured from the centre-line of the columns shall be equal to one half of the width of drop for interior panels.

3.2.2 Column heads
Where column heads are provided, that portion of the column head which lies within the largest right circular cone or pyramid entirely within the outlines of the column and the column head, shall be considered for design purpose as shown in figure 3.2 and 3.4

3.2.3Thickness of flat Slab
The thickness of the flat slab up to spans of 10 m shall be generally controlled by considerations of span(L) to effective depth (d) ratios given as below:

Table 1: Span to depth ratio

Cantilever	7
Simply supported	20
Continuous	26

For slabs with drops, span to effective depth ratios given above shall be applied directly; otherwise the span to effective depth ratios in accordance with above shall be multiplied by 0.9. For this purpose, the longer span of the panel shall be considered. The minimum thickness of slab shall be 125 mm.

3.3 Analysis and Design of Flat Slab for Vertical Load

For this IS 456-2000 permits use of any one of the following two methods:
The Direct Design Method
The Equivalent Frame Method

3.1 The direct design method

This method has the limitation that it can be used only if the following conditions are fulfilled. There shall be minimum of three continuous spans in each direction. The panels shall be rectangular and the ratio of the longer span to the shorter span within a panel shall not be greater than 2.The successive span length in each direction shall not differ by more than one-third of longer span. The design live load shall not exceed three times the design dead load. The end span must be shorter but not greater than the interior span. It shall be permissible to offset columns a maximum of 10 percent of the span in the direction of the offset not with standing the provision in (b).

Total Design Moment
The absolute sum of the positive and negative moment in each direction is given by

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$M_0 = \frac{WL_n}{8}$

Where,

M_0 = Total moment

W = Design load on the area L_2 x L_n

L_n = Clear span extending from face to face of columns, capitals, brackets

or walls but not less than 0.65 L_1

L_1 = Length of span in the direction of M_0; and

L_2 = Length of span transverse to L_1

In taking the values of L_n, L_1 and L_2, the following clauses are to be carefully noted

When the transverse span of the panel on either side of the centre line of support varies,

L_2 shall be taken as the average of the transverse spans. In Fig. 1.5 it is given by $\frac{(L_{2a}\ X\ L_{2b})}{2}$.

When the span adjacent and parallel to an edge is being considered, the distance from to the centre-line of the panel shall be substituted for L_2.Distribution of Bending Moment in to –ve and +ve Moments

The total design moment M_0 in a panel is to be distributed into –ve moment and +ve moment as specified below.

In an interior span

Negative Design Moment 0.65 M0

Positive Design Moment 0.35 M0

In an end span

Interior negative design moment

$$= \left[0.75 - \frac{0.10}{1+\frac{1}{\alpha_c}}\right] M_0$$

Positive design moment

$$= \left[0.63 - \frac{0.28}{1+\frac{1}{\alpha_c}}\right] M_0$$

Exterior negative design moment

$$= \left[\frac{065}{1+\frac{1}{\alpha_c}}\right] M_0$$

where α_c is the ratio of flexural stiffness at the exterior columns to the flexural stiffness of the slab at a joint taken in the direction moments are being determined and is given by

$$\alpha_c \frac{\Sigma k_c}{\Sigma k_s}$$

Where, K_c= Sum of the flexural stiffness of the columns meeting at the joint; and

K_s= Flexural stiffness of the slab, expressed as moment per unit rotation.

Distribution of Bending Moment across the Panel Width

The +ve and –ve moments found are to be distributed across the column strip in a panel as shown in table 3.1. The moment in the middle strip shall be the difference between panel and the column strip moments.

Table 3.1: Distribution of Moment across the Panel Width in a Column Strip

Table 2: Percentage of Moment

Sr. No.	Distributed Moment	Percent of Total Moment
A	Negative BM at the exterior support	100
B	Negative BM at the interior support	75
C	Positive bending moment	60

Moment in Column

In this type of constructions column moments are to be modified as suggested in IS 456–2000 [Clause No. 31.4.5].

shear Force

The critical section for shear shall be at a distance $\frac{d}{2}$ from the periphery of the column/capital drop panel. Hence if drops are provided there are two critical sections near columns. These critical sections are shown in figure . The shape of the critical section in plan is similar to the support immediately below the slab as shown in figure

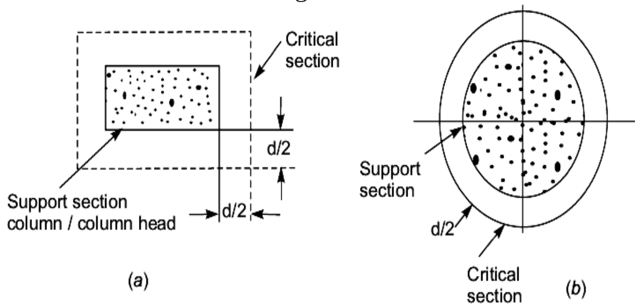

Figure 3.6: Critical Section for Shear

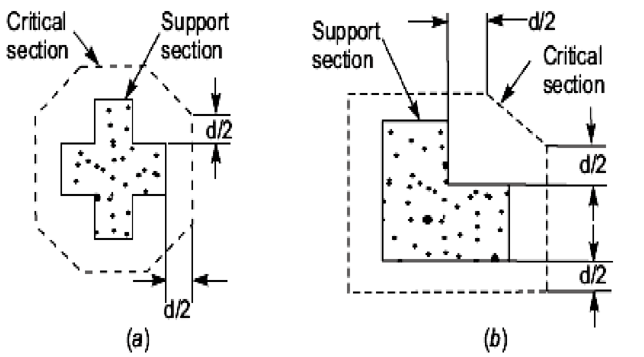

Figure 3.7: Critical Section for Columns Sections with Re-Entrant Angles

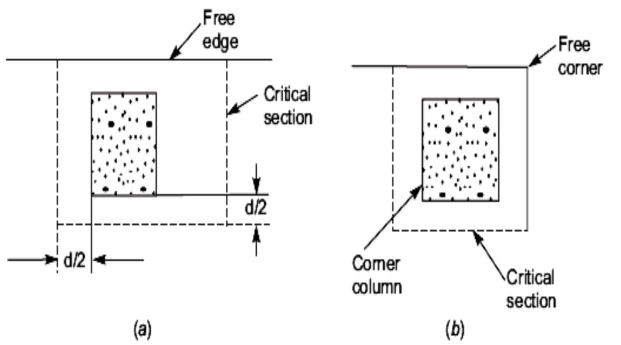

Figure 3.8: Critical Section for Columns near the Free Edge of a Slab

The nominal shear stress may be calculated as

$$\tau_v = \frac{V}{b_o d}$$

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Where, V – is shear force due to design
b_0 – is the periphery of the critical section
d – is the effective depth
The permissible shear stress in concrete may be calculated as $k_s\tau_c$,
where k_s= 0.5 + β_c but not greater than 1, where βc is the ratio of short side to long side of the column/capital; and

$\tau_c = 0.25\sqrt{f_{ck}}$

If shear stress $\tau_v<\tau_c$ - no shear reinforcement are required. If $\tau_c<\tau_v<1.5\ \tau_c$, shear reinforcement shall be provided. If shear stress exceeds 1.5 τ_c flat slab shall be redesigned.

3.3.2 Equivalent frame method

IS 456–2000 recommends the analysis of flat slab and column structure as a rigid frame to get design moment and shear forces with the following assumptions:

Beam portion of frame is taken as equivalent to the moment of inertia of flat slab bounded laterally by centre line of the panel on each side of the centre line of the column. In frames adjacent and parallel to an edge beam portion shall be equal to flat slab bounded by the edge and the centre line of the adjacent panel.

Moment of inertia of the members of the frame may be taken as that of the gross section of the concrete alone.

Variation of moment of inertia along the axis of the slab on account of provision of drops shall be taken into account. In the case of recessed or coffered slab which is made solid in the region of the columns, the stiffening effect may be ignored provided the solid part of the slab does not extend more than 0.15 l_{ef} into the span measured from the centre line of the columns. The stiffening effect of flared columns heads may be ignored.

Analysis of frame may be carried out with substitute frame method or any other accepted method like moment distribution or matrix method.

Loading Pattern
When the live load does not exceed ¾th of dead load, the maximum moments may be assumed to occur at all sections when full design live load is on the entire slab.
If live load exceeds ¾th dead load analysis is to be carried out for the following pattern of loading also:
(i) To get maximum moment near mid span
– ¾th of live load on the panel and full live load on alternate panel
(ii) To get maximum moment in the slab near the support
– ¾th of live load is on the adjacent panel only

It is to be carefully noted that in no case design moment shall be taken to be less than those occurring with full design live load on all panels. The moments determined in the beam of frame (flat slab) may be reduced in such proportion that the numerical sum of positive and average negative moments is not less than the value of total design moment $M_0 = \frac{WL_n}{8}$.
The distribution of slab moments into column strips and middle strips is to be made in the same manner as specified in direct design method.

3.3.3 Slab reinforcement

Spacing
The spacing of bars in a flat slab shall not exceed 2 times the slab thickness.

Area of Reinforcement
When the drop panels are used, the thickness of drop panel for determining area of reinforcement shall be the lesser of the following:
a) Thickness of drop, and
b) Thickness of slab plus one quarter the distance between edge of drop and edge of capital.
The minimum percentage of the reinforcement is same as that in solid slab i.e., 0.12 percent if HYSD bars used and 0.15 percent, if mild steel is used.

Minimum Length of Reinforcement
At least 50 percent of bottom bars should be from support to support. The rest may be bent up. The minimum length of different reinforcement in flat slabs should be as shown in figure 1.9 (Figure 16 in IS 456–2000). If adjacent spans are not equal, the extension of the –ve reinforcement beyond each face shall be based on the longer span. All slab reinforcement should be anchored property at discontinuous edges.

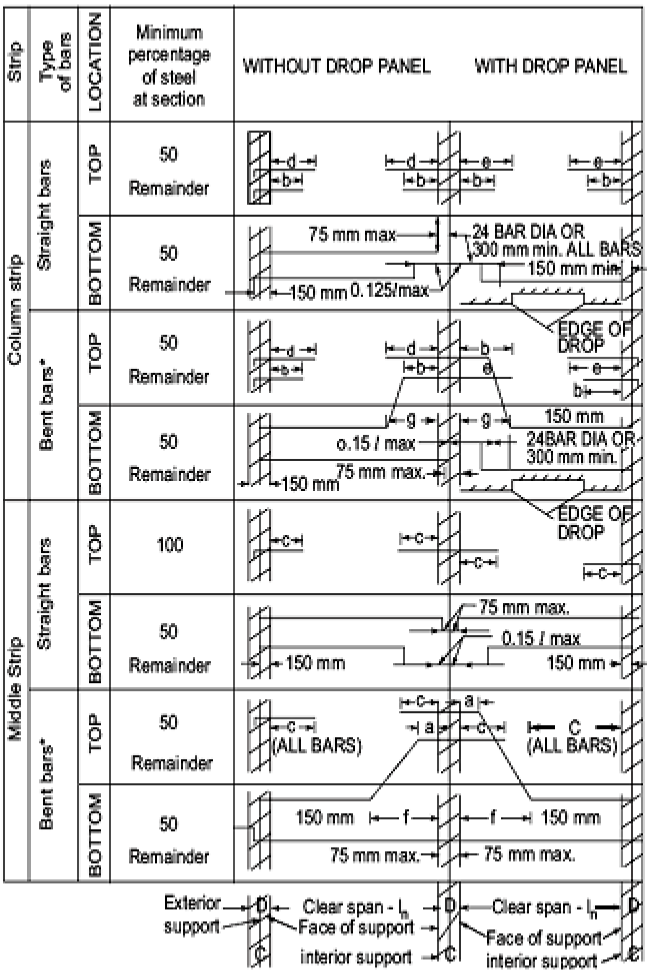

Figure 3.9: Minimum Bend Joint and Extension for Reinforcement in Flat Slab (IS 456-2000)

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4. Conclusion

This study present a complete detail procedure of analysis and design of flat slab structure with is 456:2000. in this paper follow the guideline given by the is code and limitation of it. flat slab gives the advantage over beam slab structure. this slab increase efficiency of structure and require less construction cost as compare to beam slab construction. this paper gives the guideline for selection of drop , panel width, slab thickness and gives the reinforcement details.

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