FLAT SLAB

Points to be covered are –

1. Definition of flat Slab.
2. Application of flat Slab.
3. Types of Construction of flat Slab.
4. Methods for analysis of flat Slab.
5. Design Steps as per IS 456:2000
6. Design Examples.


FLAT SLAB
VS
SLAB BEAM SYSTEM

Introduction →

In IS456 : 2000 → Page no → 53 to 61
clause no → (31)

→ Flat Slab → A flat slab is a reinforced concrete slab which is supported directly on columns without beams.

→ It may be supported with or without drop or with or without column head.

→ Drop is the thickened portion of slab over the column.

→ Column head is the flared portion of the column at the top where the slab is supported.

Application →

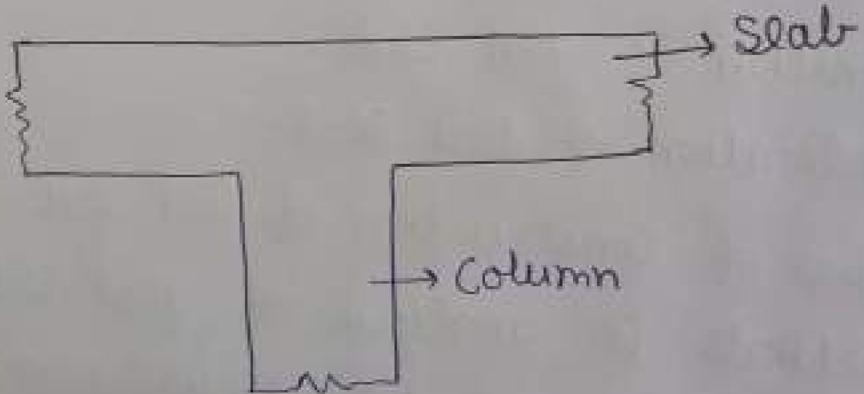
→ This type of construction is very pleasing in appearance due to plane ceiling and provide more headroom as compared to beam slab construction.

→ The flat Slab is also cheaper to construct as it requires less form work.

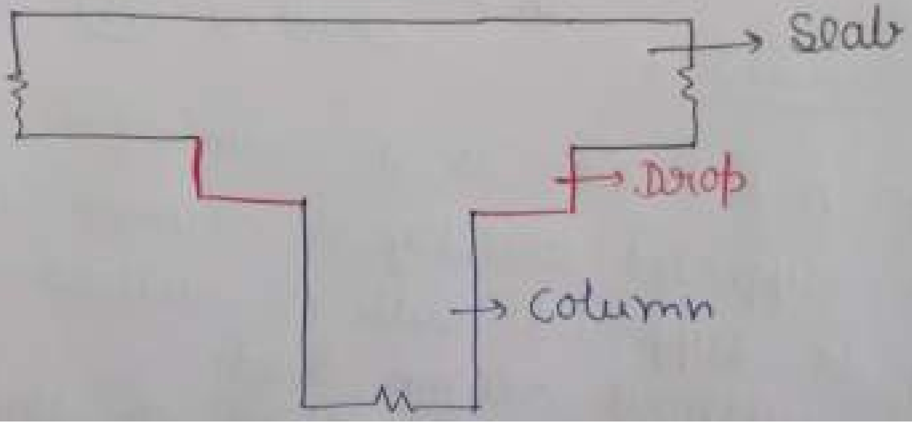
→ Places where flat slabs are provided are Parking Desk, Commercial Buildings, Hotels etc.

Types of Construction of flat slab→

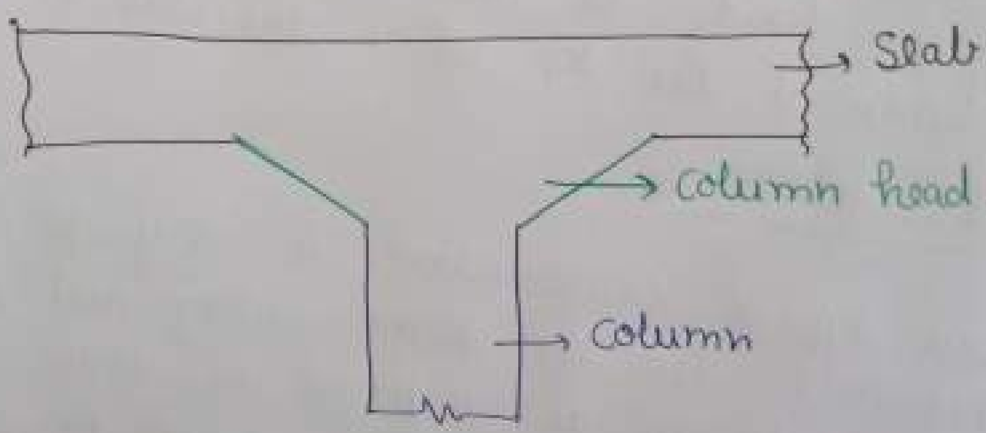
① Flat Slab without Column head and without Drop -



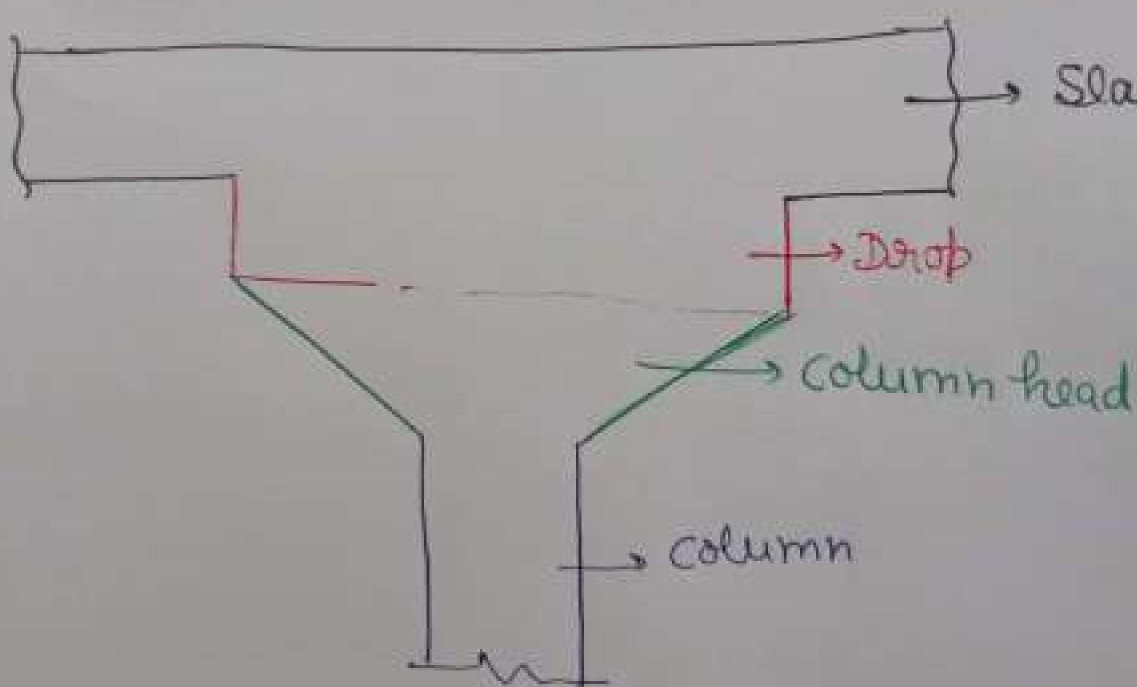
② Flat Slab without column head and with drop.



③ Flat Slab with column head and without drop.



④ Flat Slab with drop and with column head.



Methods for analysis of flat Slab →

① Direct design method or impirical coefficient method.
IS456:2000 Page no 54, 55, 56, clause no - 31.4

② Equivalent frame method
→ Slab system is assumed as a rigid continuous frame.

IS456:2000, Page no → 56, 57, clause no - 31.5

31.4 Direct Design Method

31.4.1 *Limitations*

Slab system designed by the direct design method shall fulfil the following conditions:

a) There shall be minimum of three continuous spans in each direction,

b) The panels shall be rectangular, and the ratio of the longer span to the shorter span within a panel shall not be greater than 2.0,

c) It shall be permissible to offset columns to a maximum of 10 percent of the span in the direction of the offset notwithstanding the provision in (b),

d) The successive span lengths in each direction shall not differ by more than one-third of the longer span. The end spans may be shorter but not longer than the interior spans, and

c) The design live load shall not exceed three times the design dead load.

31.4.2 *Total Design Moment for a Span*

31.4.2.1 In the direct design method, the total design moment for a span shall be determined for a strip bounded laterally by the centre-line of the panel on each side of the centre-line of the supports.

31.4.2.2 The absolute sum of the positive and average negative bending moments in each direction shall be taken as:

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

where

M_o = total moment;

W = design load on an area $l_2 l_n$;

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_o; and

l_2 = length of span transverse to l_1.

31.4.2.3 Circular supports shall be treated as square supports having the same area.

31.4.2.4 When the transverse span of the panels on either side of the centre-line of supports varies, l_2 shall be taken as the average of the transverse spans.

31.4.2.5 When the span adjacent and parallel to an edge is being considered, the distance from the edge to the centre-line of the panel shall be substituted for l_2 in **31.4.2.2**.

31.4.3 *Negative and Positive Design Moments*

31.4.3.1 The negative design moment shall be located at the face of rectangular supports, circular supports being treated as square supports having the same area.

31.4.3.2 In an interior span, the total design moment M_o shall be distributed in the following proportions:

Negative design moment	0.65
Positive design moment	0.35

31.4.3.3 In an end span, the total design moment M_o shall be distributed in the following proportions:

Interior negative design moment:

$$0.75 - \frac{0.10}{1 + \frac{1}{\alpha_c}}$$

Positive design moment:

$$0.63 - \frac{0.28}{1 + \frac{1}{\alpha_c}}$$

Exterior negative design moment:

$$\frac{0.65}{1+\frac{1}{\alpha_c}}$$

α_c is the ratio of flexural stiffness of 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

$$\alpha_c = \frac{\Sigma K_c}{K_s}$$

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.

31.4.3.4 It shall be permissible to modify these design moments by up to 10 percent, so long as the total design moment, M_o for the panel in the direction considered is not less than that required by **31.4.2.2.**

31.4.3.5 The negative moment section shall be designed to resist the larger of the two interior negative design moments determined for the spans framing into a common support unless an analysis is made to distribute the unbalanced moment in accordance with the stiffness of the adjoining parts.

31.4.4 *Distribution of Bending Moments Across the Panel Width*

Bending moments at critical cross-section shall be distributed to the column strips and middle strips as specified in **31.5.5** as applicable.

31.4.5 *Moments in Columns*

31.4.5.1 Columns built integrally with the slab system shall be designed to resist moments arising from loads on the slab system.

31.4.5.2 At an interior support, the supporting members above and below the slab shall be designed to resist the moment M given by the following equation, in direct proportion to their stiffnesses unless a general analysis is made:

$$M = 0.08\,\frac{(w_d + 0.5\,w_l)\,l_2\,l_n^2 - w'_d\,l'_2\,l'^2_n}{1+\frac{1}{\alpha_c}}$$

where

w_d, w_l = design dead and live loads respectively, per unit area;

l_2 = length of span transverse to the direction of M;

l_n = length of the clear span in the direction of M, measured face to face of supports;

α_c = $\frac{\Sigma K_c}{\Sigma K_s}$ where K_c and K_s are as defined in 31.4.3.3; and

w'_d, l'_2 and l'_n, refer to the shorter span.

31.4.6 *Effects of Pattern Loading*

In the direct design method, when the ratio of live load to dead load exceeds 0.5 :

a) the sum of the flexural stiffnesses of the columns above and below the slab, ΣK_c, shall be such that α_c is not less than the appropriate minimum value $\alpha_{c\,min}$ specified in Table 17, or

b) if the sum of the flexural stiffnesses of the columns, ΣK_c, does not satisfy (a), the positive design moments for the panel shall be multiplied by the coefficient β_s given by the following equation:

$$\beta_s = 1 + \left(\frac{2 - \frac{w_d}{w_1}}{4 + \frac{w_d}{w_1}} \right) \left(1 - \frac{\alpha_c}{\alpha_{c\,min}} \right)$$

α_c is the ratio of flexural stiffness of the columns above and below the slab to the flexural stiffness of the slabs 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 and K_s are flexural stiffnesses of column and slab respectively.

31.5 Equivalent Frame Method

31.5.1 *Assumptions*

The bending moments and shear forces may be determined by an analysis of the structure as a continuous frame and the following assumptions may be made:

a) The structure shall be considered to be made up of equivalent frames on column lines taken longitudinally and transversely through the building. Each frame consists of a row of equivalent columns or supports, bounded laterally by the centre-line of the panel on each side of the centre-line of the columns or supports. Frames adjacent and parallel to an edge shall be bounded by the edge and the centre-line of the adjacent panel.

b) Each such frame may be analyzed in its entirety, or, for vertical loading, each floor thereof and the roof may be analyzed separately with its columns being assumed fixed at their remote ends. Where slabs are thus analyzed separately, it may be assumed in determining the bending moment at a given support that the slab is fixed at any support two panels distant therefrom provided the slab continues beyond the point.

c) For the purpose of determining relative stiffness of members, the moment of inertia of any slab or column may be assumed to be that of the gross cross-section of the concrete alone.

d) Variations 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 column heads may be ignored.

31.5.2 *Loading Pattern*

31.5.2.1 When the loading pattern is known, the structure shall be analyzed for the load concerned.

Table 17 Minimum Permissible Values of α_c
(*Clause* 31.4.6)

Imposed Load/Dead Load	Ratio $\frac{l_2}{l_1}$	Value of $\alpha_{c,\ min}$
(1)	(2)	(3)
0.5	0.5 to 2.0	0
1.0	0.5	0.6
1.0	0.8	0.7
1.0	1.0	0.7
1.0	1.25	0.8
1.0	2.0	1.2
2.0	0.5	1.3
2.0	0.8	1.5
2.0	1.0	1.6
2.0	1.25	1.9
2.0	2.0	4.9
3.0	0.5	1.8
3.0	0.8	2.0
3.0	1.0	2.3
3.0	1.25	2.8
3.0	2.0	13.0

31.5.2.2 When the live load is variable but does not exceed three-quarters of the dead load, or the nature of the live load is such that all panels will be loaded simultaneously, the maximum moments may be assumed to occur at all sections when full design live load is on the entire slab system.

31.5.2.3 For other conditions of live load/dead load ratio and when all panels are not loaded simultaneously:

a) maximum positive moment near midspan of a panel may be assumed to occur when three-quarters of the full design live load is on the panel and on alternate panels; and

b) maximum negative moment in the slab at a support may be assumed to occur when three-quarters of the full design live load is on the adjacent panels only.

31.5.2.4 In no case shall design moments be taken to be less than those occurring with full design live load on all panels.

31.5.3 *Negative Design Moment*

31.5.3.1 At interior supports, the critical section for negative moment, in both the column strip and middle strip, shall be taken at the face of rectilinear supports, but in no case at a distance greater than 0.175 l_1 from the centre of the column where l_1 is the length of the span in the direction moments are being determined, measured centre-to-centre of supports.

31.5.3.2 At exterior supports provided with brackets or capitals, the critical section for negative moment in the direction perpendicular to the edge shall be taken at a distance from the face of the supporting element not greater than one-half the projection of the bracket or capital beyond the face of the supporting element.

31.5.3.3 Circular or regular polygon shaped supports shall be treated as square supports having the same area.

31.5.4 *Modification of Maximum Moment*

Moments determined by means of the equivalent frame method, for slabs which fulfil the limitations of **31.4** may be reduced in such proportion that the numerical sum of the positive and average negative moments is not less than the value of total design moment M_o specified in **31.4.2.2**.

31.5.5 *Distribution of Bending Moment Across the Panel Width*

31.5.5.1 *Column strip : Negative moment at an interior support*

At an interior support, the column strip shall be designed to resist 75 percent of the total negative moment in the panel at that support.

31.5.5.2 *Column strip : Negative moment at an exterior support*

a) At an exterior support, the column strip shall be designed to resist the total negative moment in the panel at that support.

b) Where the exterior support consists of a column or a wall extending for a distance equal to or greater than three-quarters of the value of l_2, the length of span transverse to the direction moments are being determined, the exterior negative moment shall be considered to be uniformly distributed across the length l_2.

31.5.5.3 *Column strip : Positive moment for each span*

For each span, the column strip shall be designed to resist 60 percent of the total positive moment in the panel.

31.5.5.4 *Moments in the middle strip*

The middle strip shall be designed on the following bases:

a) That portion of the design moment not resisted by the column strip shall be assigned to the adjacent middle strips.

b) Each middle strip shall be proportioned to resist the sum of the moments assigned to its two half middle strips.

c) The middle strip adjacent and parallel to an edge supported by a wall shall be proportioned to resist twice the moment assigned to half the middle strip corresponding to the first row of interior columns.

Design Steps →

1. Calculation of depth of slab.
2. Loading calculation.
3. Two way shear check.
4. Calculation of stiffness and α_c
5. correction due to pattern loading.
6. Total design moment
   Reinforcement along shorter and longer direction
7. Design of shear reinforcement.
8. Detailing.