Chapter 1

1.1 Introduction

A reinforced concrete slab is a structural member, usually horizontal whose depth h, is small compared to their length, L and width, S. It may be supported by reinforced concrete beams, by masonry or reinforced concrete wall, by structural steel members, directly by columns.

The structural systems designed in third year (junior year) involved one-way slabs that carried load to beams, which, in turn, transmitted to column, and two way solid slabs by **method -3**, this method is no longer available in ACI code.

1.2 Loads

Loads that act on structures can be divided into three broad categories: **dead load**, **live load**, and **environmental loads**.

1.2.1 Dead loads

- Are those that are constant in magnitude and fixed in location throughout the lifetime of the structure.
- Usually the major part of the dead load is the weight of the structure itself. This can be calculated with good accuracy from the design configuration, dimensions of the structure, and density of the material.
- For buildings, floor fill, finish floor, and plastered ceilings are usually included as dead loads.

1.2.2 Live loads

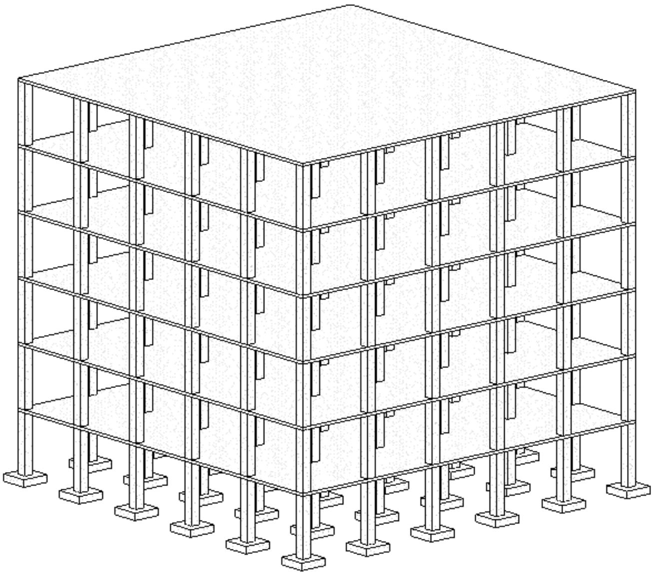
Consist chiefly of occupancy loads in buildings and traffic loads on bridges. They may be either fully or partially in place or not present at all, and may also change in location. Their magnitude and distribution at any given time are uncertain, and even their maximum intensities throughout the lifetime of the structures are not known with precision for values for live load to be used in building are found in **ASCE 7-10**.

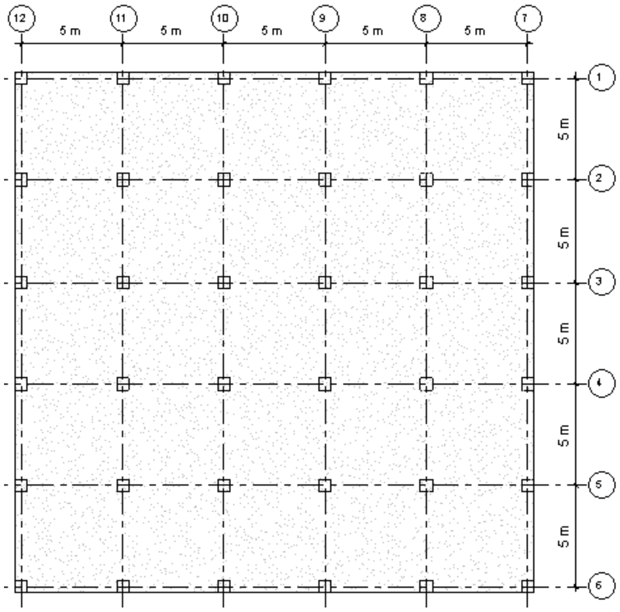
1.2.3 Environmental loads

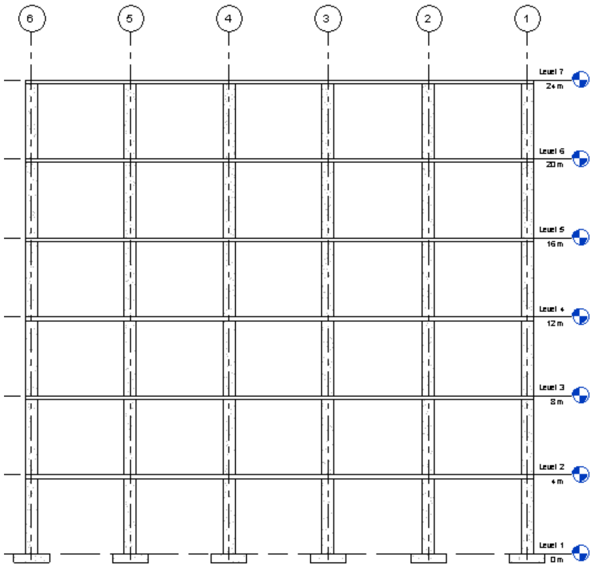
Consist mainly of snow loads, wind pressure, earthquake loads, soil pressures on subsurface portions of structures, loads from possible ponding of rainwater on flat surface, and force caused by temperature differentials. Like live load s, environmental loads at any given time are uncertain in both magnitude and distribution.

Example: For the flat plate system shown below in figure below is proposed for a hospital building. Almost all floors to be patient rooms.

- According to requirements of ASCE 7-10, select an appropriate value for floor live load.



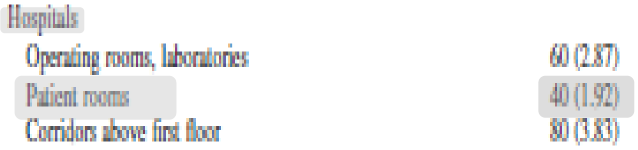




Solution:

According to **Table 4-1** from **ASCE 7-10**

Minimum live (W_L) load for hospitals for patient rooms is equal to 1.92 kN/m^2 ■



Hospitals	
Operating rooms, laboratories	60 (2.87)
Patient rooms	40 (1.92)
Corridors above first floor	80 (3.83)

1.3 Types of slabs

1.3.1 One Way Slabs

Slab may be supported on two opposite sides only as shown in **Fig. 1.1**, in which case the structural action of the slab is essentially one-way, the loads being carried by the slab in the direction perpendicular to the supporting beams the design of one-way slab was discussed in junior year.

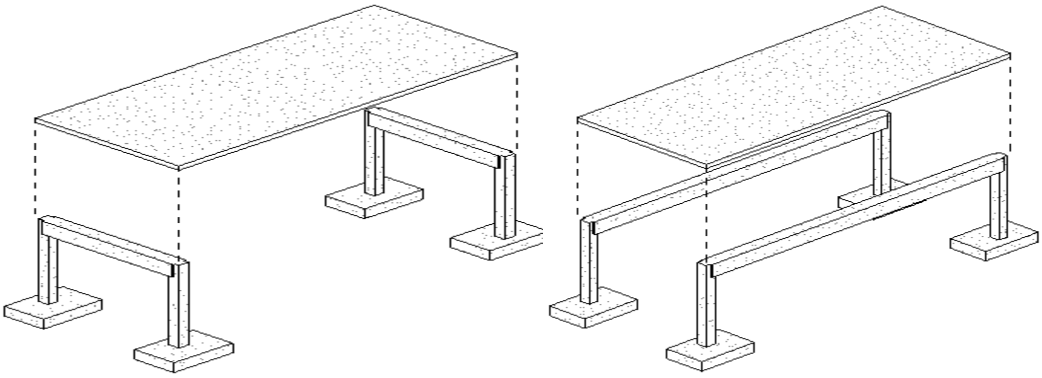


Fig.1.1 One way slab supported on two opposite sides only.

There may be beams on all four sides, as shown in **Fig. 1.2** and of the ratio of length to width of one slab panel is larger than about 2, most of the load is carried in short direction to the supporting beams and **one-way action** is obtained in effect, **even though supports are provided on all sides**.

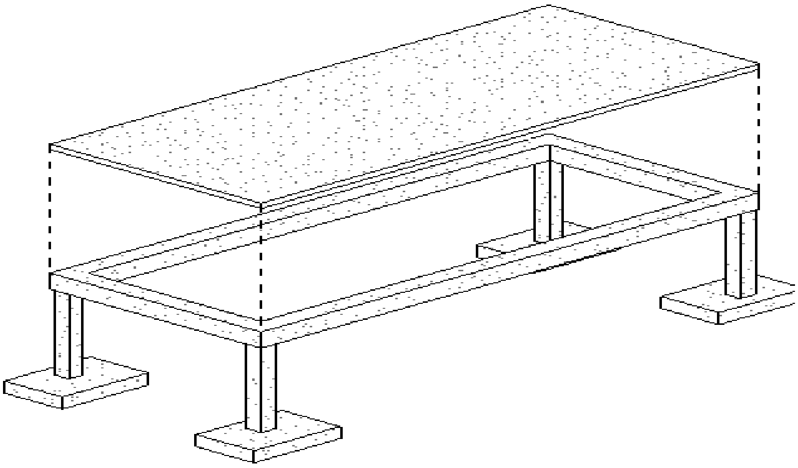
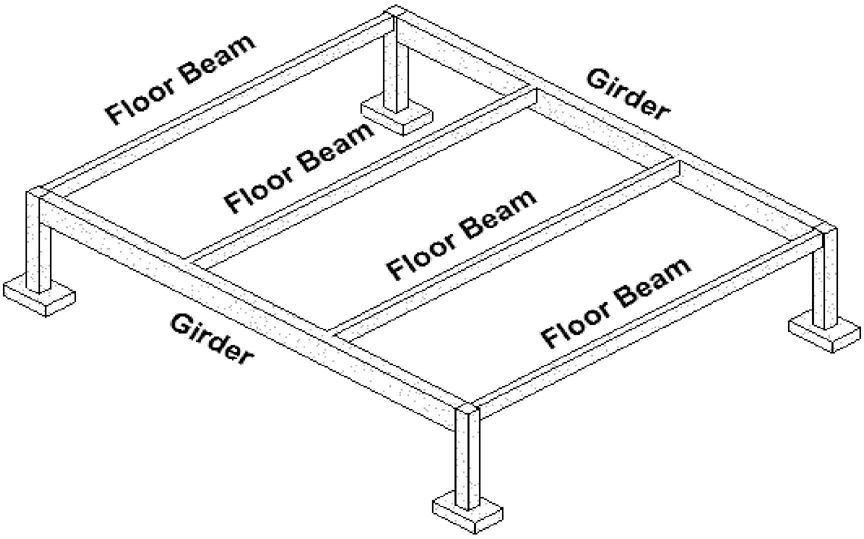


Fig.1.2 One way slab supported on four sides with length to width larger than 2.

- For large column spacing, load may be transferred from the slab to the floor beams, then to larger beams (usually called the girders) and in turn to the supporting columns.



1.3.2 Two Way Slab

1.3.2.1 Two Way Slab with beams

When slab supported on four sides with ratio of length to width equal or less than 2, so that two way slab action is obtained as shown in **Fig. 1.3.**

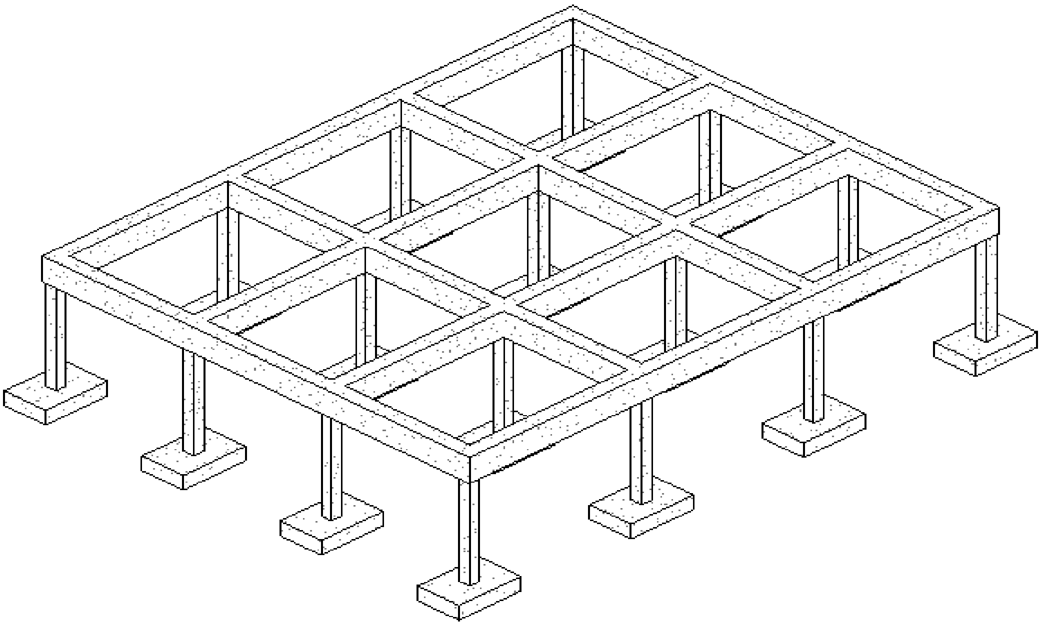


Fig.1.3 two way slabs supported on four sides with length to width equal or less than 2.

1.3.2.1 Flat plate

Concrete slabs in some cases may be carried directly by columns, as shown in **Fig. 1.4**. Without the use of beams or girders, such slabs are described as **flat plates,** this type of slab maybe used when the spans are not large and loads particularly not heavy.

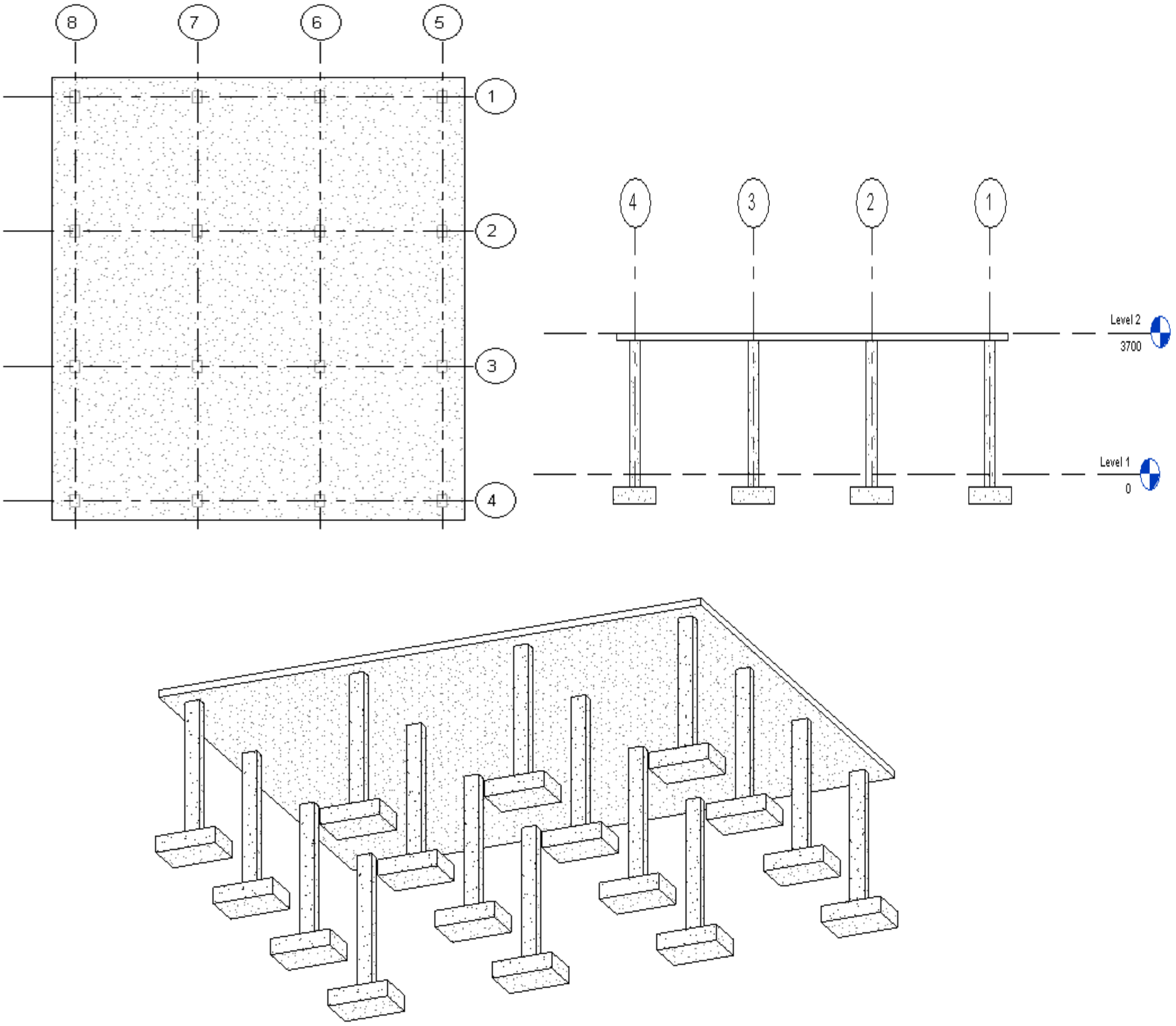


Fig.1.4 two way flat plates.

1.3.2.2 Flat Slab

Flat slab is also beamless but incorporates a thickened slab region in the vicinity of the column and often employs flared column tops. Both are devices to reduce the **stresses due to negative bending and shear** around the columns, they are referred as **drop panels** and **column capitals** respectively. **Fig. 1.5a and b** is showing the flat slab.

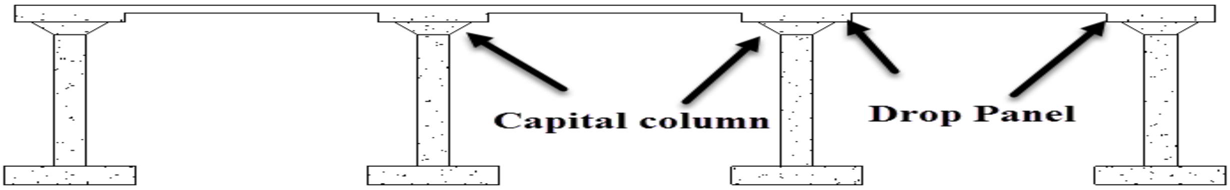


Fig.1.5a two way flat slabs with both drop panels and column capitals.

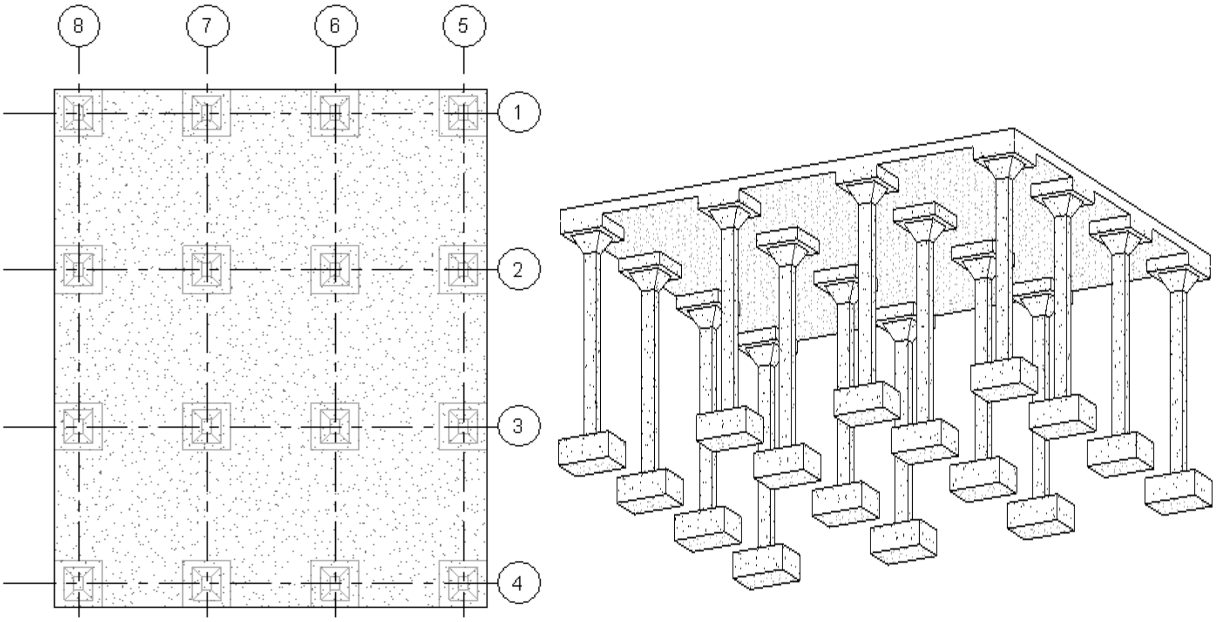


Fig.1.5b two way flat slabs with both drop panels and column capitals.

- Slabs may have only drop panels, this type of slab commonly used in parking garage as shown if **Fig. 1.6.**

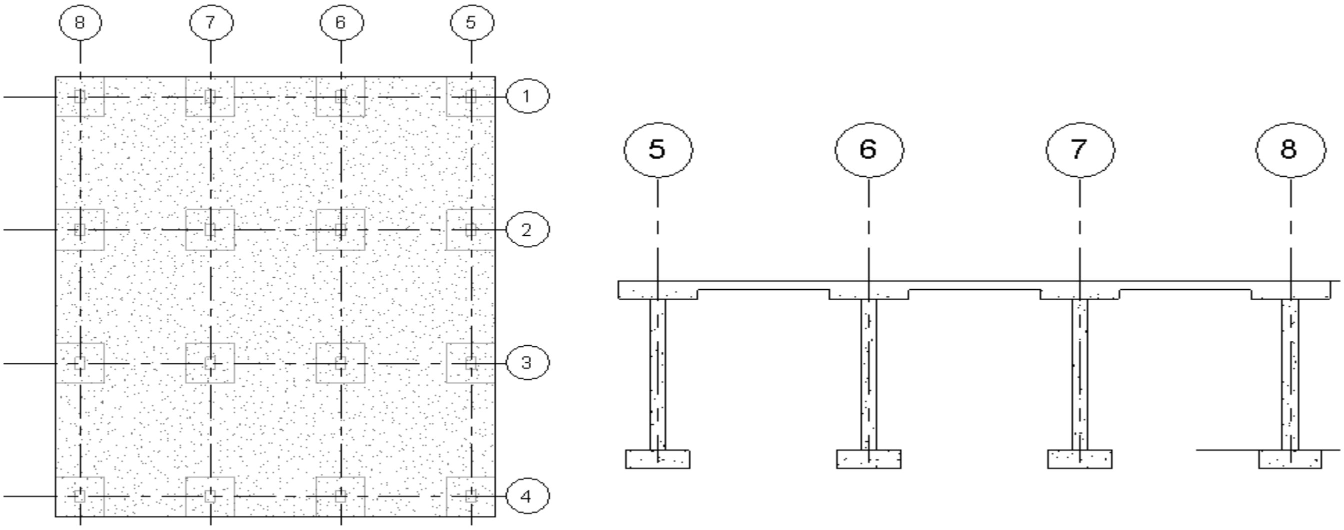


Fig.1.6 two way flat slabs drop panels only.

- Slab may be constructed with capital column without drop panel as shown in **Fig1.7**; this type of slab is rarely.

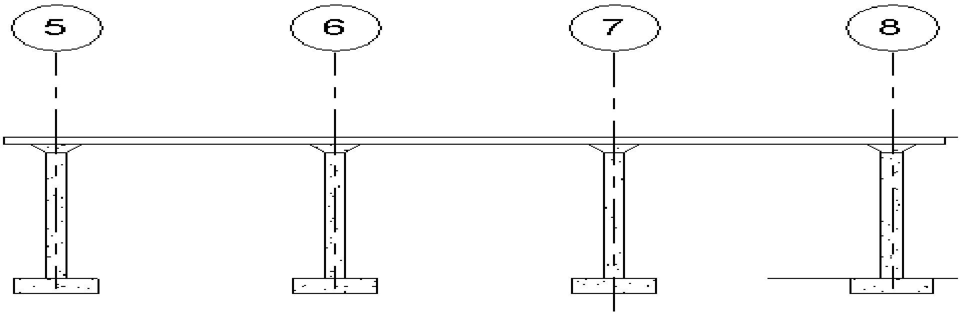


Fig.1.7 two way flat slabs column capital only.

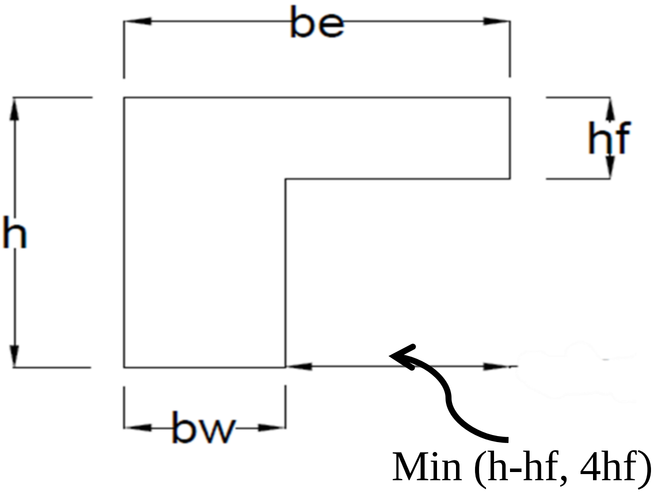
- Very often slabs built **without interior beams** between the columns but the **edge beams** running around **the perimeter** of the building as shown in **Fig. 1.8**. These beams are very helpful in **stiffening** the slabs and **reducing the deflections** in the exterior slab panels.
- The stiffness of slabs with edge beams is expressed as a function of α_f. This expression is used to represent the ration of **flexural stiffness of a beam (Ecb*Ib) to flexural stiffness of the slab (Ecs*Is)**. If no beams are used as in the case for **the flat plate α_f will equal to 0**.

$$\alpha_f = \frac{Ecb*Ib}{Ecs*Is} = \frac{\cancel{Ecb}*Ib}{\cancel{Ecs}*Is} = \frac{Ib}{Is}$$

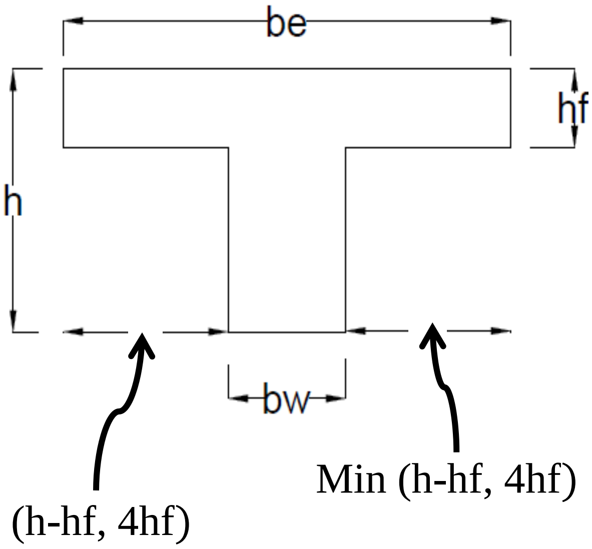
- In which **Ecb** and **Ecs** are the moduli of elasticity of the beam and slab concrete **(usually the same)** and **Ib** and **Is** are the moments of inertia of the effective beam and the slab.
- The moment of inertia of a flange beam about it is own centroid axis can be computed based on simple definition of centroid or by approximate method.

$$Ib = k* \frac{b_w.h^3}{12}$$

$$k \approx 1+0.2(\frac{b_e}{b_w}) \quad \text{for} \quad 2< \frac{b_e}{b_w} <4 \quad \text{and} \quad 0.2< \frac{h_f}{h} <0.5$$



L-beam **<u>(Exterior Beam</u>)**

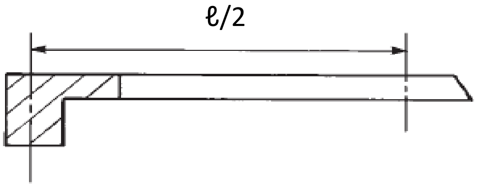


T-beam **<u>(interior Beam</u>)**

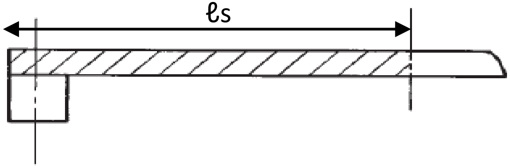
- $Is = \frac{\ell s * h_{slab}^3}{12}$

ℓs= is the width of the frame in the direction **perpendicular** to the beam required to calculate α_f.

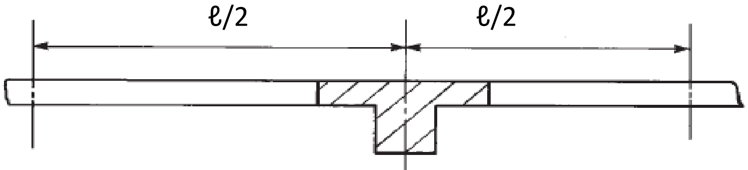
h_{slab}= thickness of slab



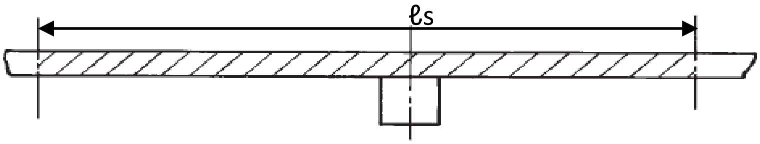
(a) Section for I_b—Edge beam.



(b) Section for I_s—Edge beam.



(c) Section for I_b—Interior beam.



(d) Section for I_s—Interior beam.

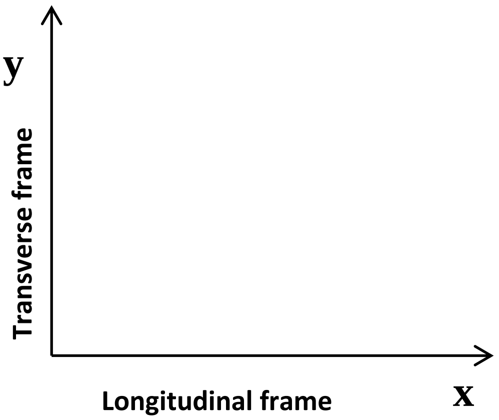
Types of frames in slab

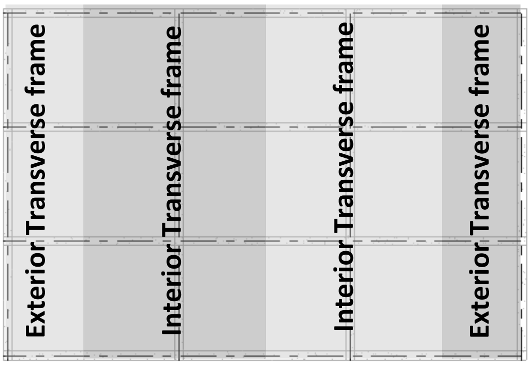
1. Longitudinal frames

- Exterior frame
- Interior frame

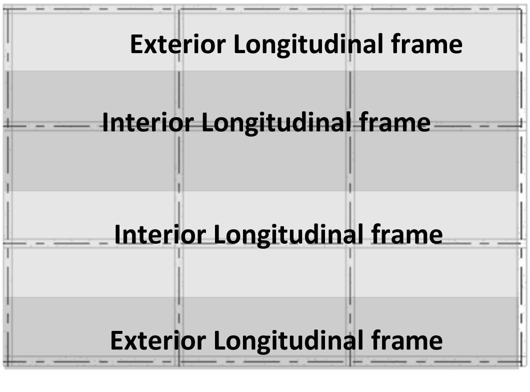
2. Transverse frames

- exterior frame
- Interior frame



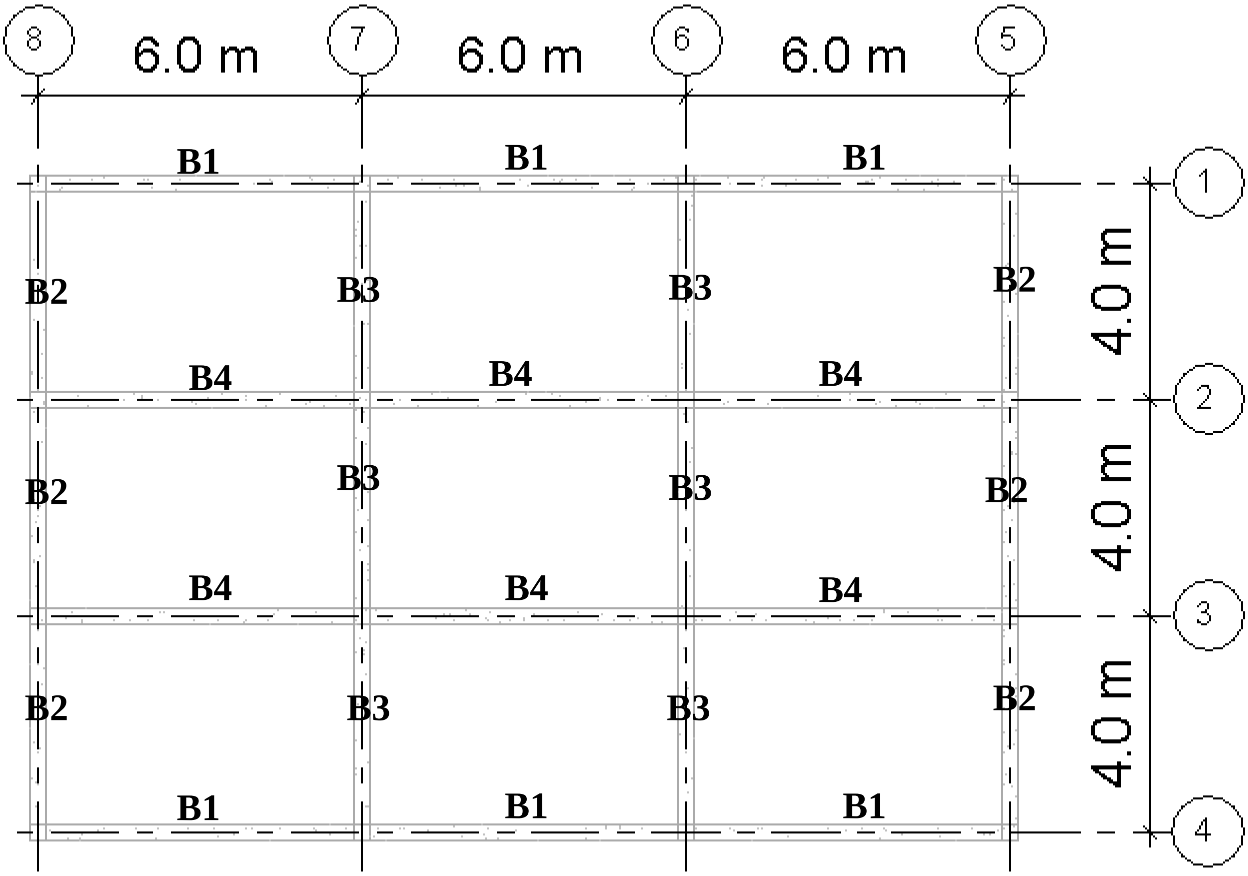


Transverse frames



Longitudinal frames

Example: for the slab showing below calculate α_f for B1, B2, B3 and B4 All beams dimensions are (300 x 600) and columns dimensions (300 x 300) mm and slab thickness is (180) mm.



Solution:

For B1

Min(h-hf,4hf)=min(600-180,4*180)

Min(**420**,720) use **420** mm

be=300+420=**720**

$\alpha_f = \frac{\text{Ib}}{\text{Is}}$

$\text{Ib} = \text{k}* \frac{\text{b}_\text{w}.\text{h}^3}{12}$

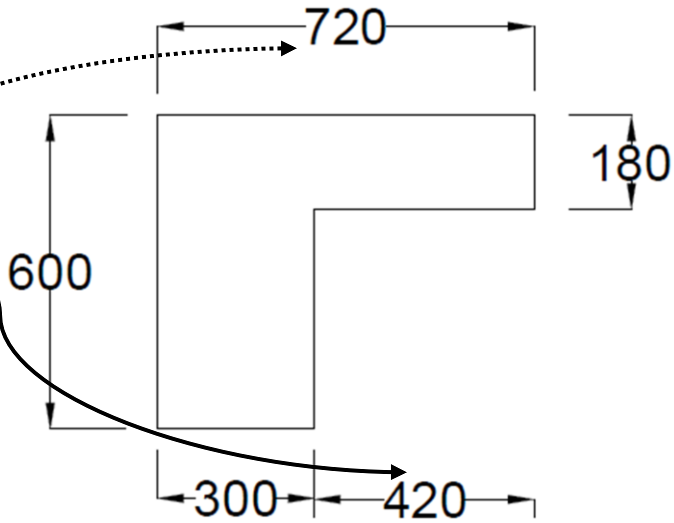
Check

$2< \frac{b_e}{b_w} = \frac{720}{300} = 2.4 <4$

$0.2< \frac{h_f}{h} = \frac{180}{600} = 0.3 <0.5$

O.k

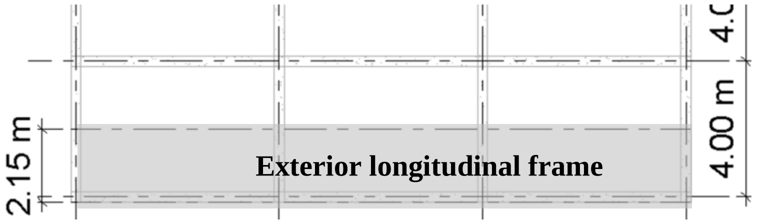
$\text{k}=1+0.2(\frac{b_e}{b_w}) =1+0.2*2.4=1.48$

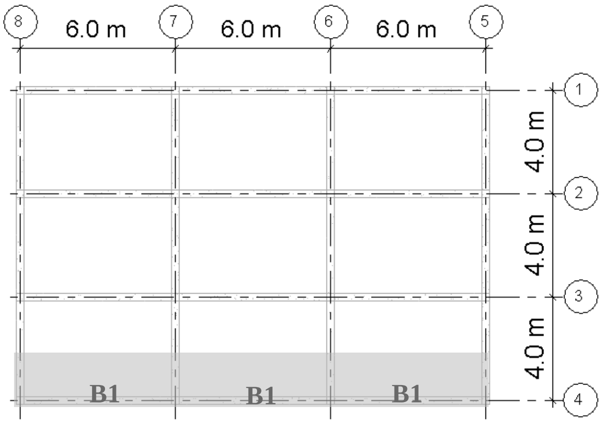


Section for B1 (exterior beam)

$$Ib = k* \frac{b_w.h^3}{12} = 1.48* \frac{300*600^3}{12} = 7.992*10^9 \text{ mm}^4$$

$$\ell s = \frac{\ell 2}{2} + \frac{Column\ width}{2} = \frac{4000}{2} + \frac{300}{2} = 2150 \text{ mm}$$





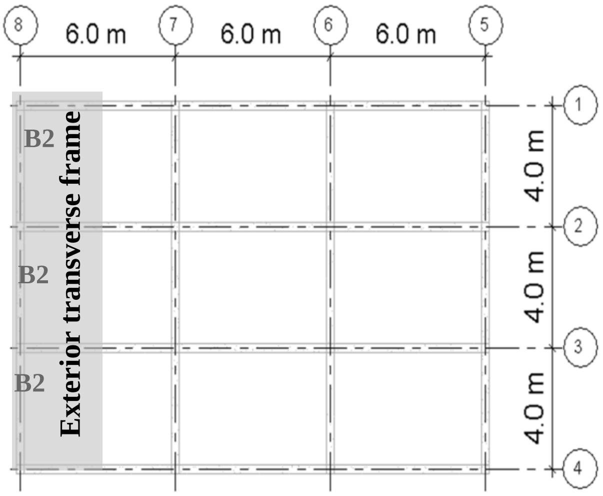
Exterior longitudinal frame

$$Is = \frac{\ell s * h_{slab}^3}{12} = \frac{2150*180^3}{12} = 1.045*10^9 \text{ mm}^4$$

$$\alpha_{f1} = \frac{Ib}{Is} = \frac{7.992*10^9}{1.045*10^9} = 7.64$$

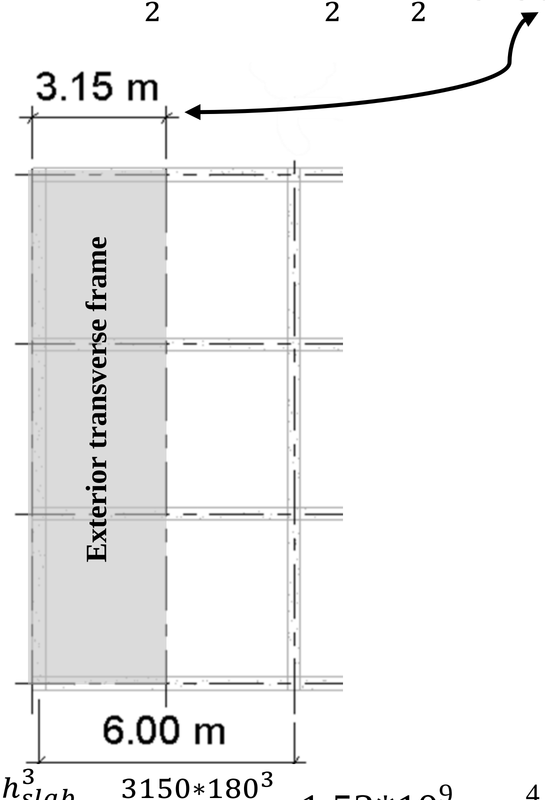
For B2

Beam (B2) has the same moment of inertia of (B1) **because the beam has the same dimensions**.



$$Ib = k* \frac{b_w.h^3}{12} = 1.48* \frac{300*600^3}{12} = 7.992*10^9 \text{ mm}^4$$

$$\ell s = \frac{\ell 2}{2} + \frac{Column\ width}{2} = \frac{6000}{2} + \frac{300}{2} = 3150 \text{ mm}$$



$$Is = \frac{\ell s * h_{slab}^3}{12} = \frac{3150*180^3}{12} = 1.53*10^9 \text{ mm}^4$$

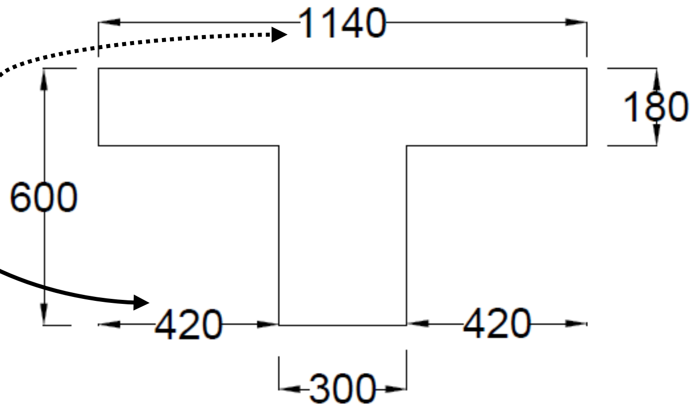
$$\alpha_{f2} = \frac{Ib}{Is} = \frac{7.992*10^9}{1.53*10^9} = 5.223$$

For B3

Min(h-hf,4hf)=min(600-180,4*180)

Min(**420**,720) use **420** mm

be=420+300+420=**1140** mm



Section for B3 (interior beam)

$\alpha_f = \frac{Ib}{Is}$

$Ib = k * \frac{b_w.h^3}{12}$

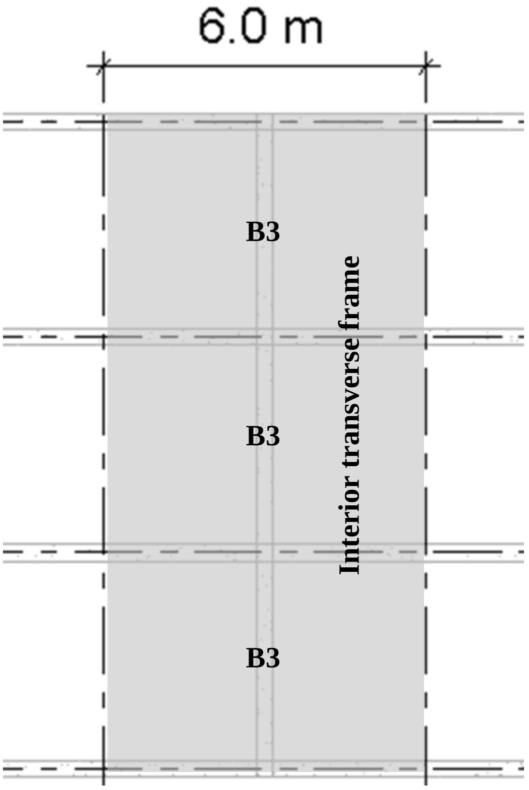
Check

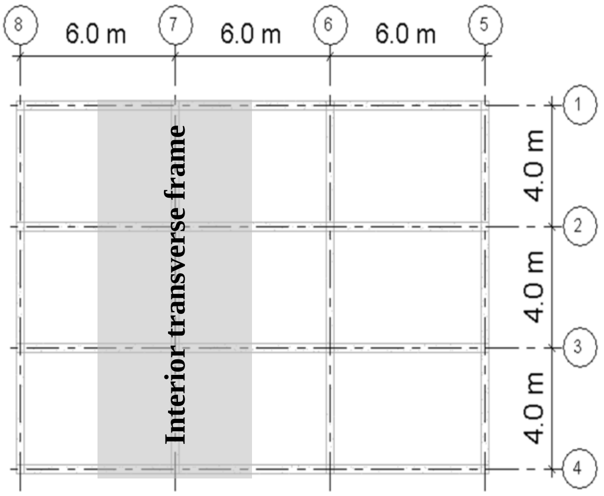
$$\left.\begin{array}{l} 2< \frac{b_e}{b_w} = \frac{1140}{300} = 3.8 <4 \\ 0.2< \frac{h_f}{h} = \frac{180}{600} = 0.3 <0.5 \end{array}\right\} \text{O.k}$$

$k=1+0.2(\frac{b_e}{b_w}) =1+0.2*3.8=1.76$

$Ib = k* \frac{b_w.h^3}{12} = 1.76* \frac{300*600^3}{12} = 9.504*10^9 \text{ mm}^4$

$\ell s = \frac{\ell 1}{2} + \frac{\ell 1}{2} = \frac{6000}{2} + \frac{6000}{2} = 6000 \text{ mm}$





$Is = \frac{\ell s * h_{slab}^3}{12} = \frac{6000*180^3}{12} = 2.916*10^9 \text{ mm}^4$

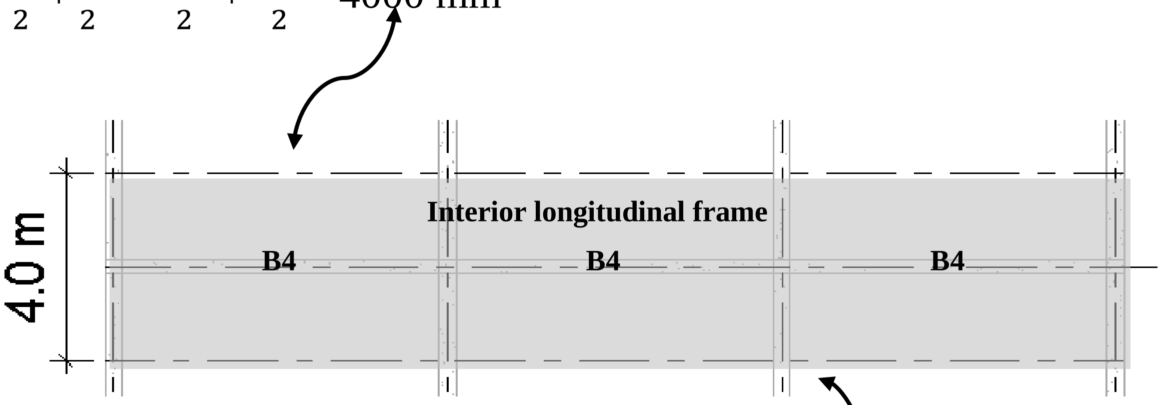
$\alpha_{f3} = \frac{Ib}{Is} = \frac{9.504*10^9}{2.916*10^9} = 3.259$

For B4

Beam (B4) has the same moment of inertia of (B3) **because the beam has the same dimensions.**

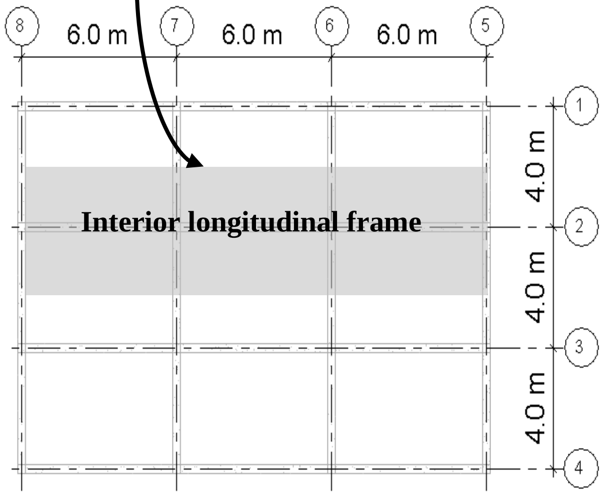
$$\text{Ib} = k*\frac{b_w.h^3}{12} = 1.76*\frac{300*600^3}{12} = 9.504*10^9\ \text{mm}^4$$

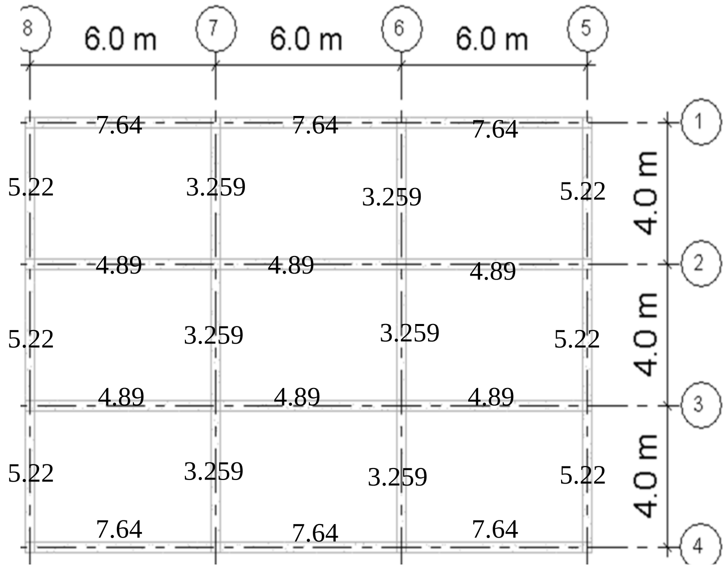
$$\ell s = \frac{\ell 2}{2} + \frac{\ell 2}{2} = \frac{4000}{2} + \frac{4000}{2} = 4000\ \text{mm}$$



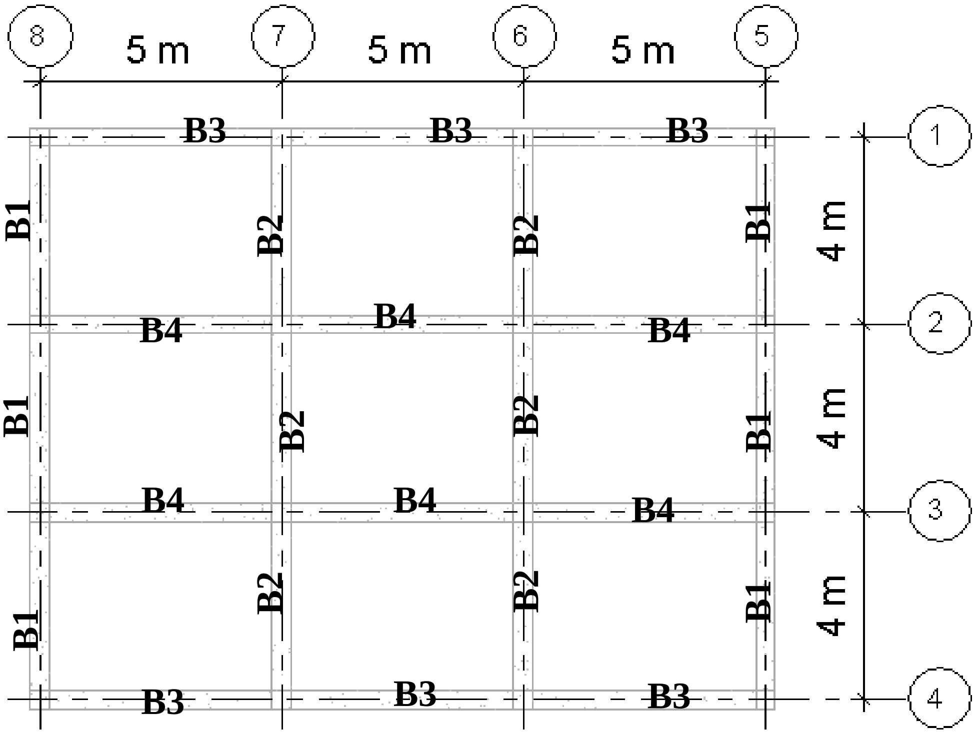
$$\text{Is} = \frac{\ell s * h_{slab}^3}{12} = \frac{4000*180^3}{12} = 1.944*10^9\ \text{mm}^4$$

$$\alpha_{f4} = \frac{\text{Ib}}{\text{Is}} = \frac{9.504*10^9}{1.944*10^9} = 4.89 \quad \blacksquare$$



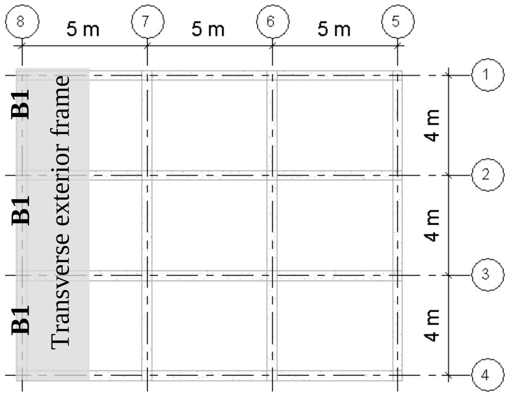


Example: For the slab with beams shown below calculate α_f for **B1, B2, B3 and B4**. All beams and columns dimensions are (600 x 400) mm (400 x 400) mm respectively, and slab thickness is (150) mm



Solution:

Calculating α_f for B1



$$\alpha_f = \frac{\text{Ib}}{\text{Is}}$$

Check

$$2< \frac{b_e}{b_w} = \frac{850}{400} = 2.125 <4$$

$$0.2< \frac{h_f}{h} = \frac{150}{600} = 0.25 <0.5$$

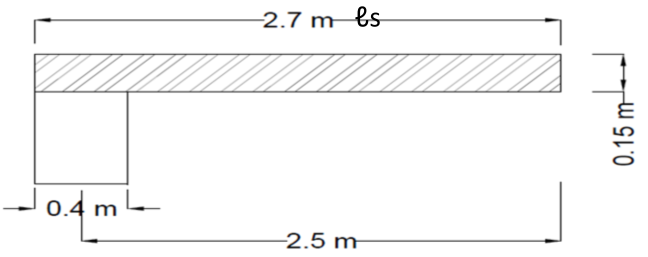
$$k=1+0.2(\frac{b_e}{b_w})=1+0.2*2.125=1.425$$

$$\text{Ib} =k* \frac{b_w.h^3}{12}=1.425*\frac{400.600^3}{12}=1.026*10^{10}$$

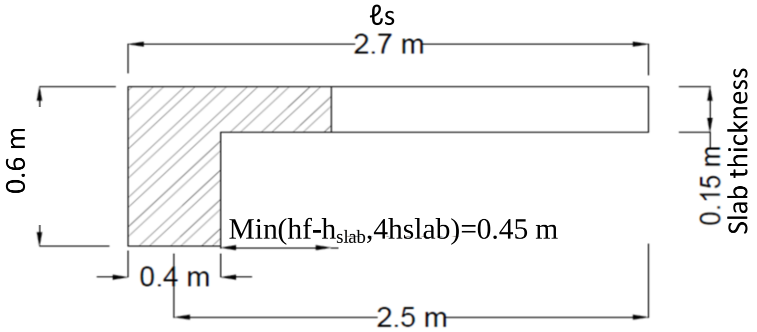
$$\ell s=2500+200=2700 \text{ mm}$$

$$\text{Is}=\frac{\ell s*hslab^3}{12}=\frac{2700*150^3}{12}=7.59*10^8 \text{ mm}^4$$

$$\alpha_{f1} = \frac{\text{Ib}}{\text{Is}} = \frac{1.026*10^{10}}{7.59*10^8} = 13.52$$



Slab section for B1 transverse exterior frame



Beam section for B1 in transverse exterior frame

Calculating α_f for B2

$$\alpha_f = \frac{Ib}{Is}$$

Check

$$2 < \frac{b_e}{b_w} = \frac{1300}{400} = 3.25 < 4$$

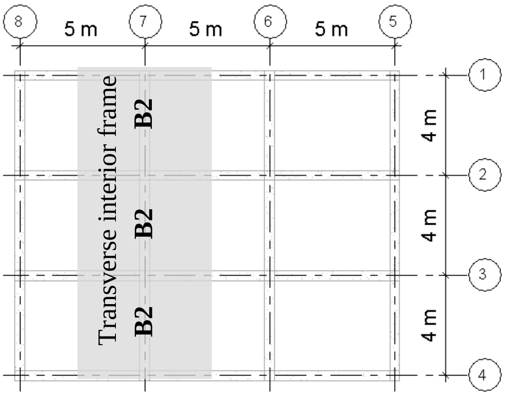
$$0.2 < \frac{h_f}{h} = \frac{150}{600} = 0.25 < 0.5$$

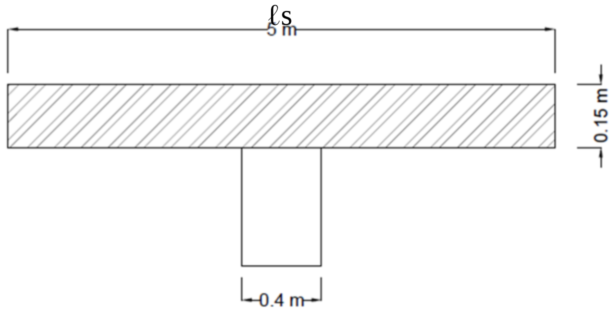
$$k = 1 + 0.2(\frac{b_e}{b_w}) = 1 + 0.2*3.25 = 1.65$$

$$Ib = k* \frac{b_w.h^3}{12} = 1.65*\frac{400.600^3}{12} = 1.188*10^{10}$$

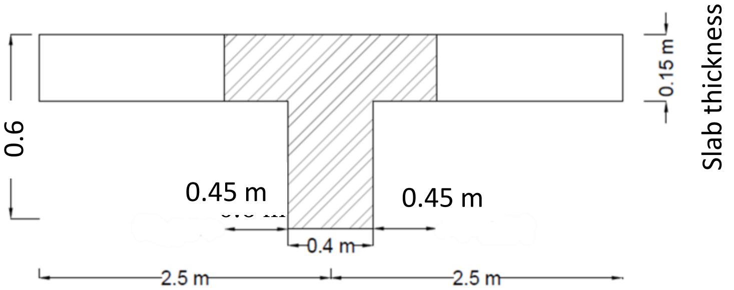
$$Is = \frac{\ell s*hslab^3}{12} = \frac{5000*150^3}{12} = 1.4*10^9 \text{ mm}^4$$

$$\alpha_{f2} = \frac{Ib}{Is} = \frac{1.188*10^{10}}{1.4*10^9} = 8.48$$





Slab section for B2 in transverse interior frame



ℓs=2.5+2.5=5m

Beam section for B2 in transverse interior frame

Calculating α_f for B3

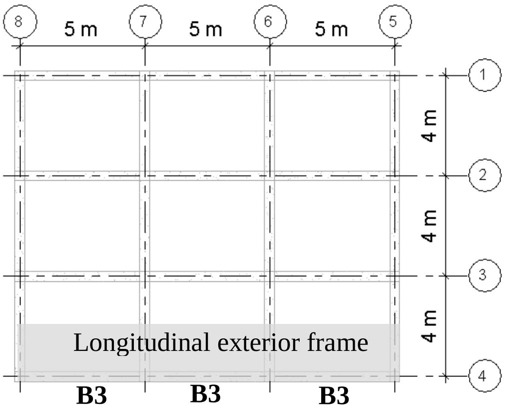
$$\alpha_f = \frac{Ib}{Is}$$

$Ib = 1.026*10^{10}$

$\ell s = 2000 + 200 = 2200$ mm

$$Is = \frac{\ell s*hslab^3}{12} = \frac{2200*150^3}{12} = 6.18*10^8 \text{ mm}^4$$

$$\alpha_{f3} = \frac{Ib}{Is} = \frac{1.026*10^{10}}{6.18*10^8} = 16.6$$



Calculating α_f for B4

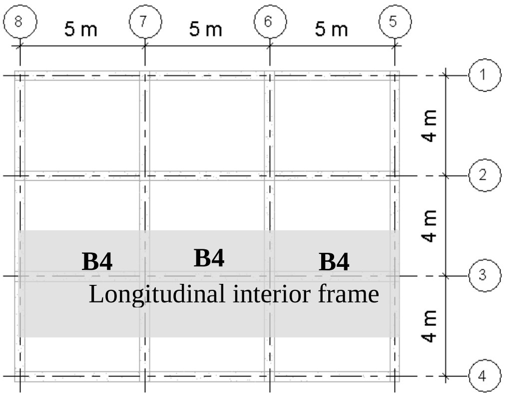
$$\alpha_f = \frac{Ib}{Is}$$

$Ib = 1.188*10^{10}$

$\ell s = 2000 + 2000 = 4000$ mm

$$Is = \frac{\ell s*hslab^3}{12} = \frac{4000*150^3}{12} = 1.125*10^9 \text{ mm}^4$$

$$\alpha_{f4} = \frac{Ib}{Is} = \frac{1.188*10^{10}}{1.125*10^9} = 10.56$$ ■



- For slabs with beams between columns along **exterior edges** α_f for the edge beams **may not be < 0.8**.

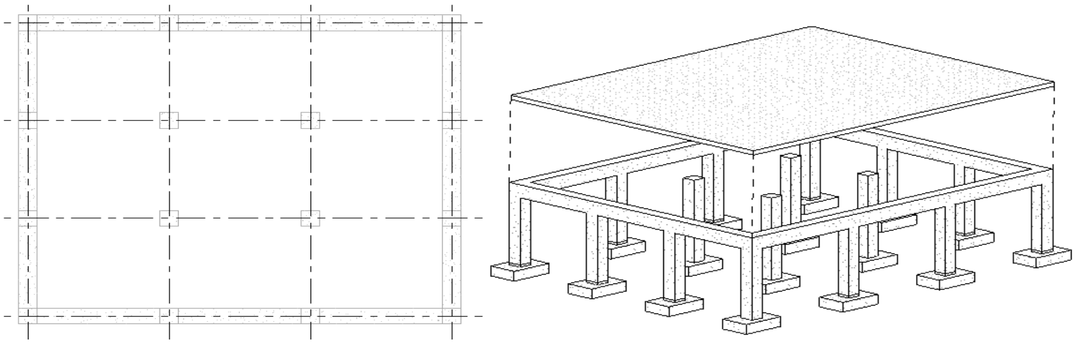
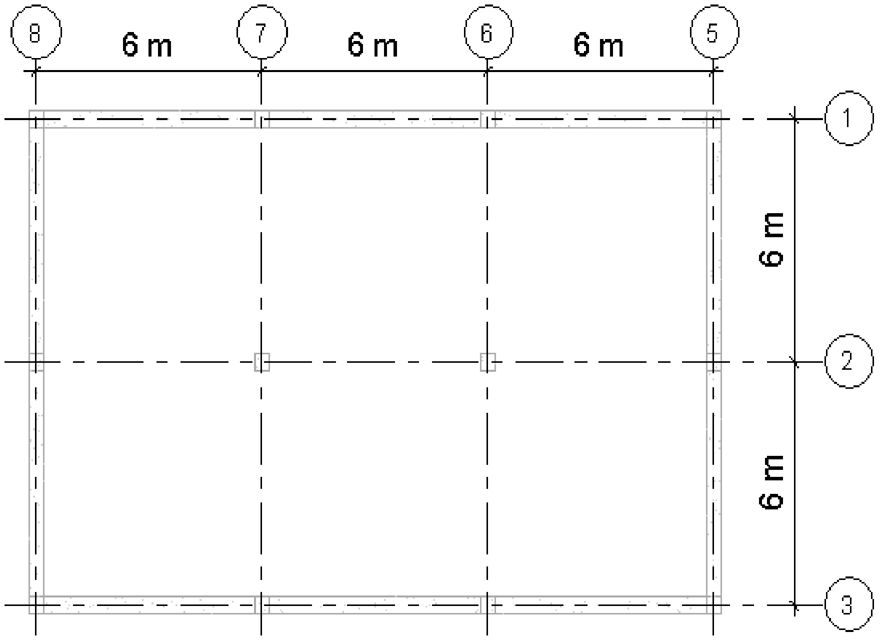


Fig.1.8 two way flat slabs with edge beams.

Example: Check whether if the slab below is considered as a slab with or without edge beam according to ACI requirements. Edge beams dimensions are (600x250) mm and slab thickness is (150) mm, Column dimensions (250 x 250) mm



Solution:

- According to footnote in **table 8.3.1.1 of ACI Code** for slabs with beams between columns along exterior edge α_f for the edge beams shall **not be less than 0.8**, otherwise the slab will be considered as slab without edge beams.

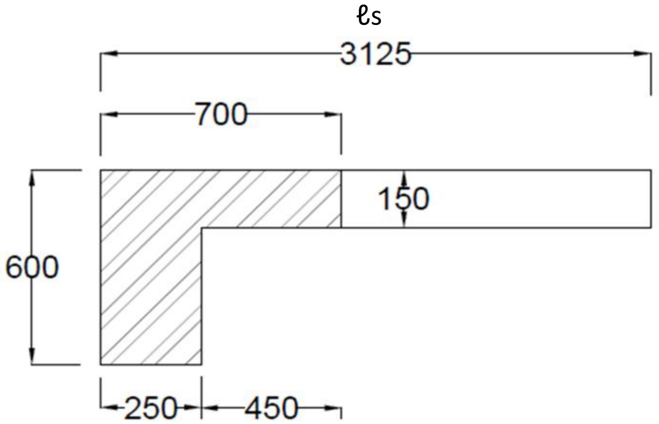
$$\alpha_f = \frac{\text{Ib}}{\text{Is}}$$

Check

$$2< \frac{b_e}{b_w} = \frac{700}{250} = 2.8 <4$$

$$0.2< \frac{h_f}{h} = \frac{150}{600} = 0.25 <0.5$$

$$\text{k}=1+0.2(\frac{b_e}{b_w}) =1+0.2*2.8=1.56$$



$Ib = k * \frac{b_w.h^3}{12} = 1.56 * \frac{250*600^3}{12} = 7.02*10^9 \text{ mm}^4$

$\ell s = 3000+125 = 3125$ mm

$Is = \frac{\ell s * hslab^3}{12} = \frac{3125*150^3}{12} = 8.78*10^8$

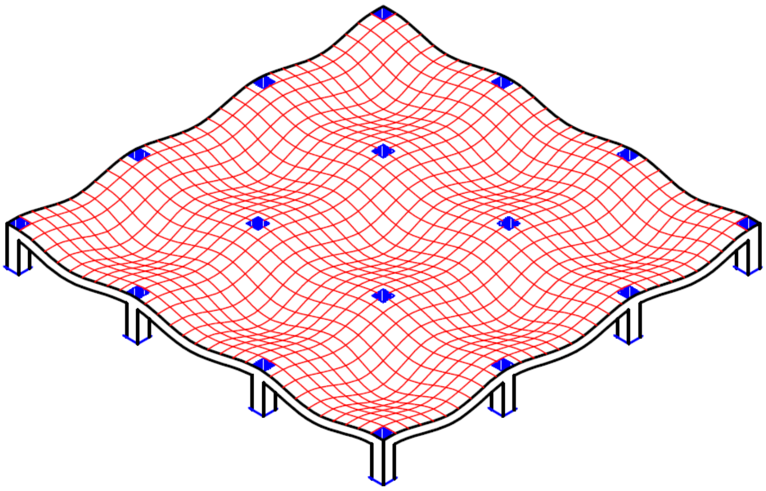
$\alpha_f = \frac{Ib}{Is} = \frac{7.02*10^9}{8.78*10^8} = 7.995 > 0.8$

Then the slab is considered with edge beams. ■

1.4 Behavior of two way slab

Two-way slabs bend under load into dish-shaped surface, so there is bending in both principal directions. As a result they must be reinforcement in both directions by layers of bars that are perpendicular to each other.

The ACI Code specifies two methods for designing two-way slabs. These are the **direct design method** and **the equivalent frame method**.



- The direct-design method is emphasized in this course because an understanding of the method is essential for understanding the concepts of two-way slab design. In addition, it is an excellent method of checking slab design calculations.

1.5 Minimum thickness for Drop panel

Flat plates present a possible problem in transferring the shear at the perimeter of the columns. In other words, there is a danger that the columns may punch through the slabs as shown in **Fig 1.9**. Then the slab can be strengthened by thickening of the slabs around the columns **(drop panels)** as shown in **Fig 1.6.**

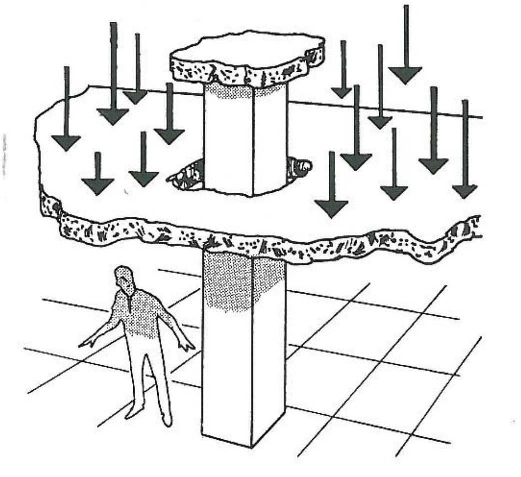


Fig 1.9 punching of two-way flat slab.

They are provided for <u>three</u> main reasons:

1. The minimum thickness of slab required to limit deflections may be reduced by 10% if the slab has drop panels, the drop panel stiffens the slab in the region of highest moments and hence reduces the deflection.
2. A drop panel can be used to reduce the amount of negative-moment reinforcement required over a column in flat slab.
3. A drop panel gives additional slab depth at the column, thereby increasing the area of the critical shear perimeter.

- According to **ACI Code 8.2.4** a drop panel shall be project below the slab at least **one-fourth** of the **slab thickness.**
- And shall extend in each direction from centerline of support a distance not less than **one-sixth** the span length measured from center to center of supports in that direction as shown in **Fig1.10**.

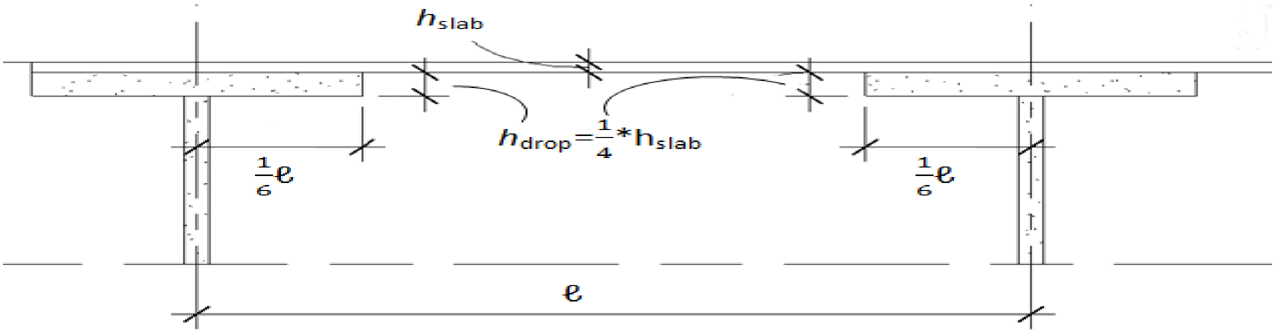
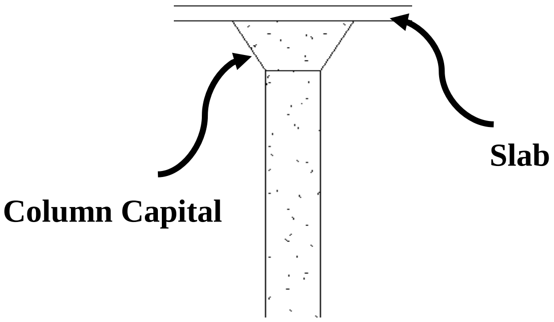


Fig 1.10 Dimensions of Drop panel.

- If drop panels do not satisfy the length requirements given in **ACI Code 8.2.4** still can be used for added shear strength and are sometimes referred as **shear capitals** or **shear caps** (**ACI Code 8.2.5).**

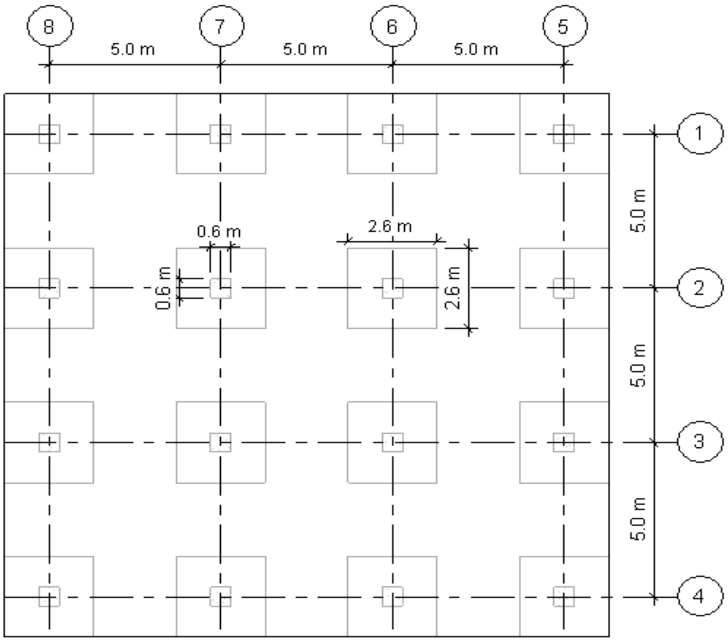
1.6 Column Capitals

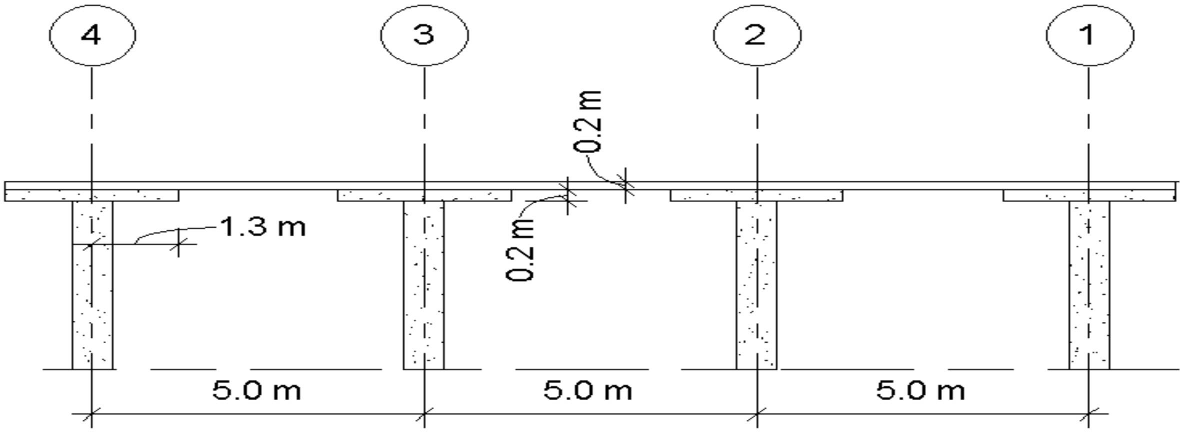
Occasionally, the top of a column will be flared outward as shown below, then this called a column capital and it located directly below the slab or a drop panel that is cast **monolithically** with the column.



This is done to provide a larger shear perimeter at the column and to **reduce the clear span ℓ_n**, used in computing the moments.

Example: check the dimensions of drop panel shown in figure below according to ACI code. Column dimension is (600 x 600) mm, slab thickness is (200) mm, drop panel thickness is (400) mm.





Solution:

- Check the projected thickness for drop panel

According to ACI Code 8.2.4 a drop panel shall be project below the slab at least one-fourth of the slab thickness.

h_{drop}=200 mm ? $\frac{hslab}{4}$

h_{drop}=200 mm ? $\frac{200}{4}$

h_{drop}=200 mm> 50 mm the projected thickness is ok.

- Check the length of drop panel

ACI Code state that each direction from centerline of support shall extend a distance not less than one-sixth the span length measured from center to center of supports in that direction

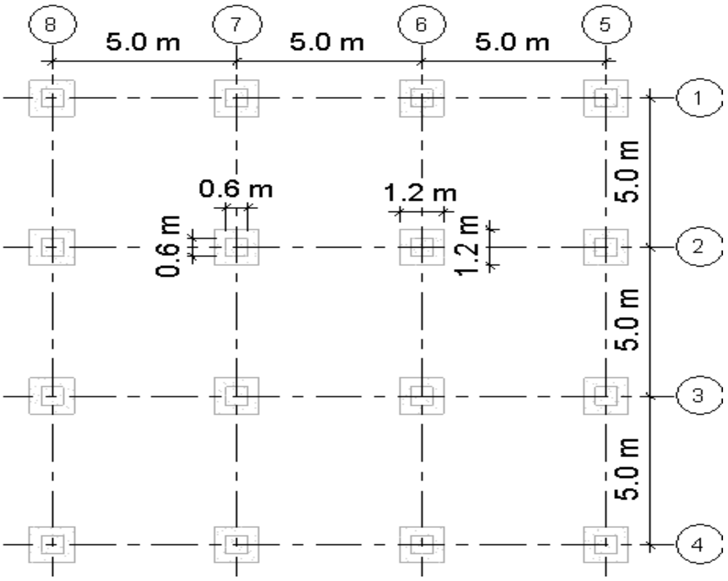
1.3 ? $\frac{\ell}{6}$

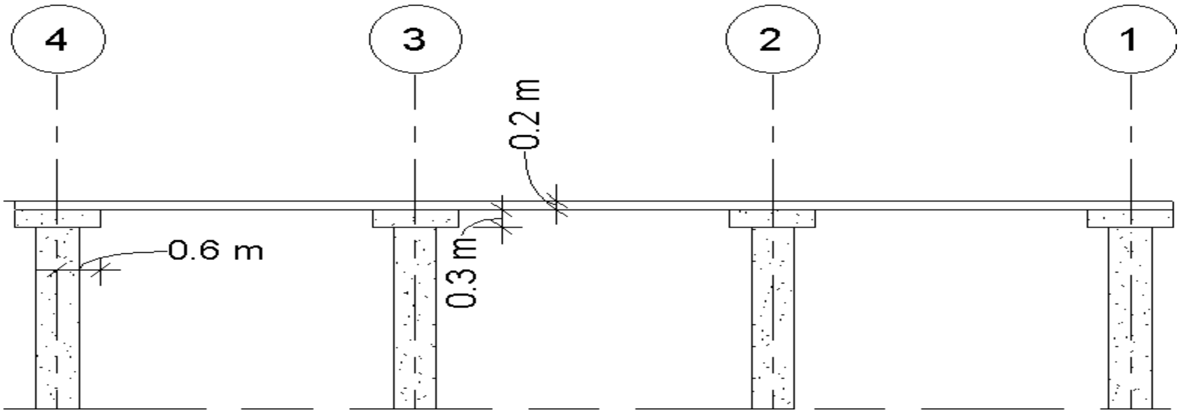
1.3 ? $\frac{5}{6}$

1.3 m > 0.83 m ok

All requirements are satisfying for a drop panel ■

Example: check the dimensions of drop panel shown in figure below according to ACI code. Column dimension is (600 x 600) mm, slab thickness is (200) mm, drop panel thickness is (500) mm.





Solution:

- Check the projected thickness for drop panel

h_{drop}=300 mm ? $\frac{hslab}{4}$

h_{drop}=300 mm ? $\frac{200}{4}$

h_{drop}=300 mm> 50 mm the projected thickness is ok.

- Check the length of drop panel

  0.6 ? $\frac{\ell}{6}$

  0.6 ? $\frac{5}{6}$

  0.6 m < 0.83 m not ok ■

1.7 Minimum Thickness for two way slab

1.7.1Minimum thickness for flat and plate slabs.

To ensure that slab deflections is service will not be troublesome, the best approach is to compute deflections with limiting value, methods have been developed that are both simple and acceptable accurate of predicting deflection of two-way slabs.

Alternatively deflection control can be achieved indirectly by adhering to more or less arbitrary limitation of minimum slab thickness, limitations developed from review of test data and study of the observed deflections of actual structures.

ACI Code Table 8.3.1.1 establishes minimum thickness for two-way slabs; simplified criteria are included pertaining slab thickness for flat and plate slabs **(without interior beams).**

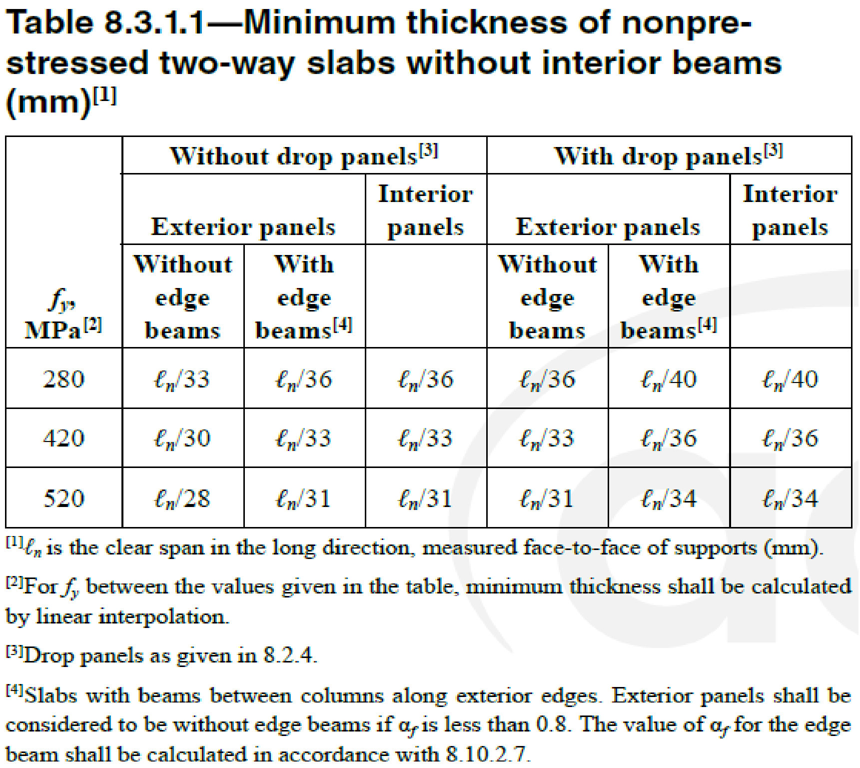


Table 8.3.1.1—Minimum thickness of nonprestressed two-way slabs without interior beams (mm)[1]

	Without drop panels[3]			With drop panels[3]		
	Exterior panels		Interior panels	Exterior panels		Interior panels
f_y, MPa[2]	Without edge beams	With edge beams[4]		Without edge beams	With edge beams[4]	
280	$\ell_n/33$	$\ell_n/36$	$\ell_n/36$	$\ell_n/36$	$\ell_n/40$	$\ell_n/40$
420	$\ell_n/30$	$\ell_n/33$	$\ell_n/33$	$\ell_n/33$	$\ell_n/36$	$\ell_n/36$
520	$\ell_n/28$	$\ell_n/31$	$\ell_n/31$	$\ell_n/31$	$\ell_n/34$	$\ell_n/34$

[1] ℓ_n is the clear span in the long direction, measured face-to-face of supports (mm).

[2] For f_y between the values given in the table, minimum thickness shall be calculated by linear interpolation.

[3] Drop panels as given in 8.2.4.

[4] Slabs with beams between columns along exterior edges. Exterior panels shall be considered to be without edge beams if α_f is less than 0.8. The value of α_f for the edge beam shall be calculated in accordance with 8.10.2.7.

In all cases, the minimum thickness of slabs without interior beams **must not less** than the following:

For slabs without drop panels: 125mm
For slabs with drop panels: 100 mm

ℓ_n = is the length of the clear span in **the long direction** of two way slab, measured **face to face** of the **supports** (**column and capital column**) is slabs without beams and face of **beams or other supports (like walls)** in other cases. See the **Fig.1.11.**

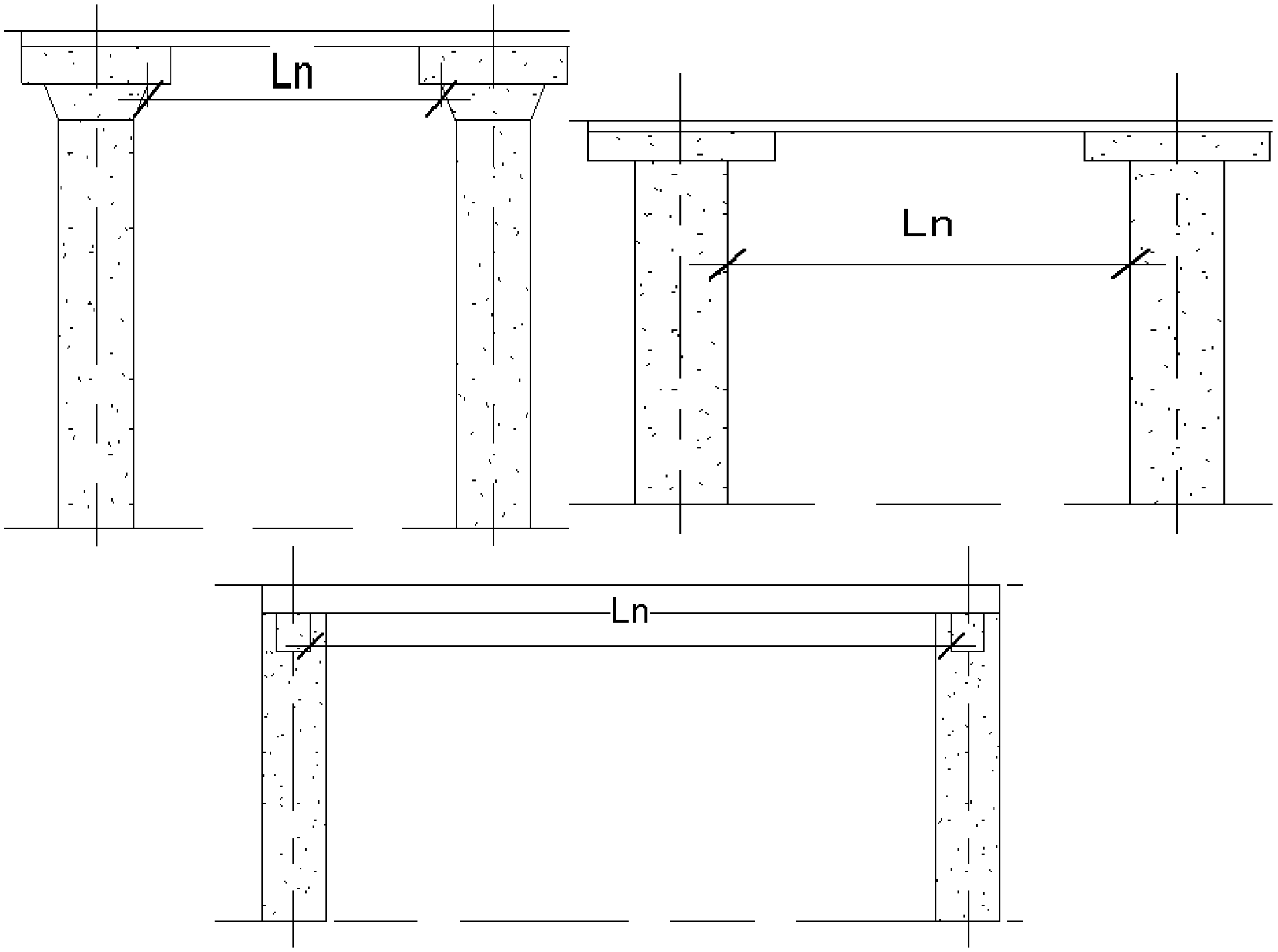
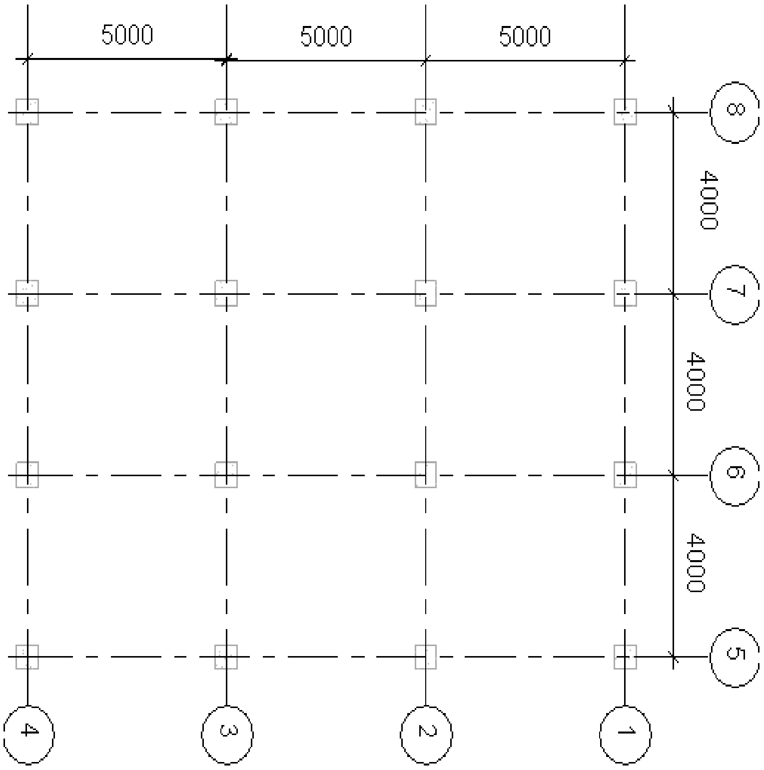


Fig 1.11: ℓ_n in two-way slab.

Example 1: Find the minimum required slab thickness according to ACI Code for building shown below in Fig. below, use f_y=420 Mpa, the slab is without edge beams, Columns dimensions are (300x300) mm.



Solution:

For exterior panel

ℓ_n =5000-150*2

ℓ_n=4700 mm

By using **ACI code Table 8.3.1.1**

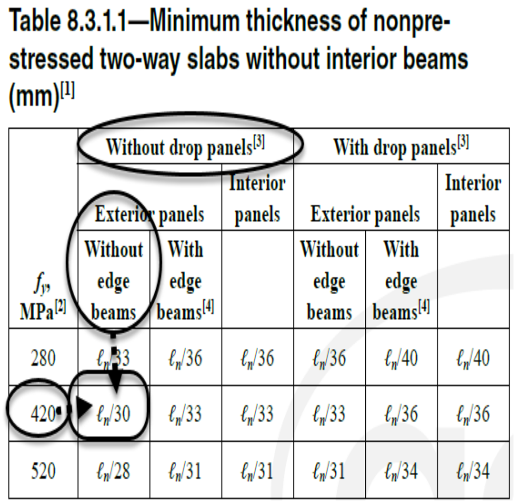
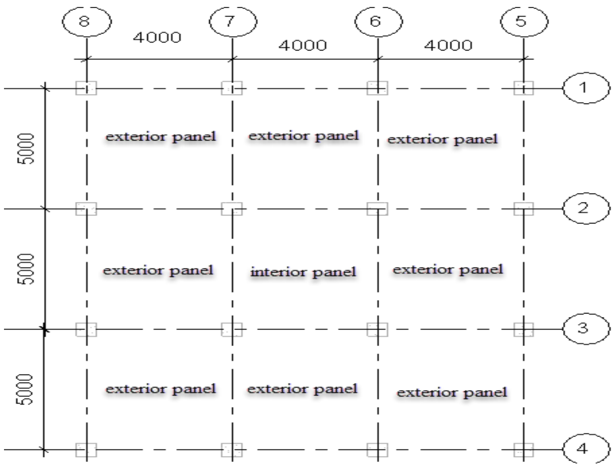


Table 8.3.1.1—Minimum thickness of nonprestressed two-way slabs without interior beams (mm)[1]

f_y, MPa[2]	Without drop panels[3]			With drop panels[3]		
	Exterior panels		Interior panels	Exterior panels		Interior panels
	Without edge beams	With edge beams[4]		Without edge beams	With edge beams[4]	
280	$\ell_n/33$	$\ell_n/36$	$\ell_n/36$	$\ell_n/36$	$\ell_n/40$	$\ell_n/40$
420	$\ell_n/30$	$\ell_n/33$	$\ell_n/33$	$\ell_n/33$	$\ell_n/36$	$\ell_n/36$
520	$\ell_n/28$	$\ell_n/31$	$\ell_n/31$	$\ell_n/31$	$\ell_n/34$	$\ell_n/34$



$$h_{min}=\frac{\ell n}{30}=\frac{4700}{30}=156 \text{ mm} \approx 160 \text{ mm.}$$

For interior panel

$$h_{min}=\frac{\ell n}{33}=\frac{4700}{33}=142\ \text{mm}\approx 150\ \text{mm}.$$

- In common practice we use same thickness for all slab panels
- Use the larger h=160 mm > 125 mm o.k ■

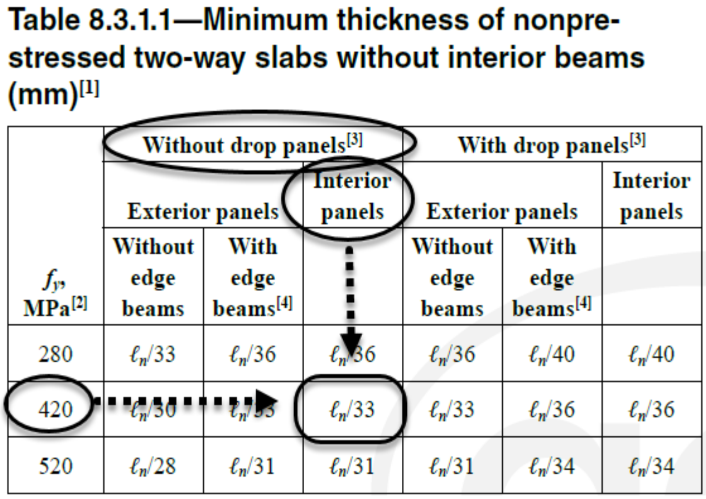


Table 8.3.1.1—Minimum thickness of nonprestressed two-way slabs without interior beams (mm)[1]

f_y, MPa[2]	Without drop panels[3]			With drop panels[3]		
	Exterior panels		Interior panels	Exterior panels		Interior panels
	Without edge beams	With edge beams[4]		Without edge beams	With edge beams[4]	
280	$\ell_n/33$	$\ell_n/36$	$\ell_n/36$	$\ell_n/36$	$\ell_n/40$	$\ell_n/40$
420	$\ell_n/30$	$\ell_n/33$	$\ell_n/33$	$\ell_n/33$	$\ell_n/36$	$\ell_n/36$
520	$\ell_n/28$	$\ell_n/31$	$\ell_n/31$	$\ell_n/31$	$\ell_n/34$	$\ell_n/34$

Example 2: resolve the previous example by assuming f_y=350 Mpa

Solution:

By using interpolation

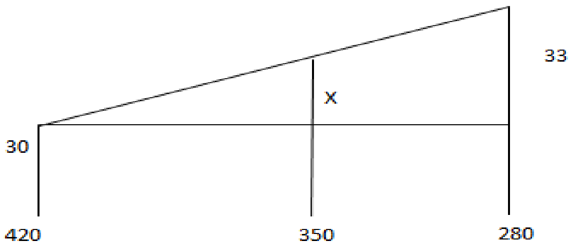
For exterior panel

$$\frac{33-30}{420-280}=\frac{X}{420-350}$$

X=1.5

Total factor=30+1.5=31.5

$$h_{min}=\frac{4700}{31.5}=149\ \text{mm}\approx 150\ \text{mm}$$



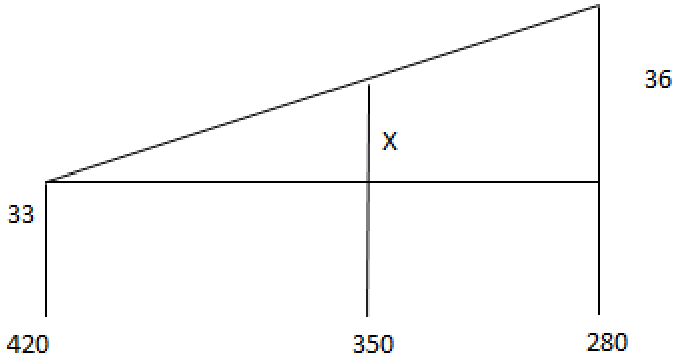
For interior panel

$$\frac{36-33}{420-280}=\frac{X}{420-350}$$

X=1.5

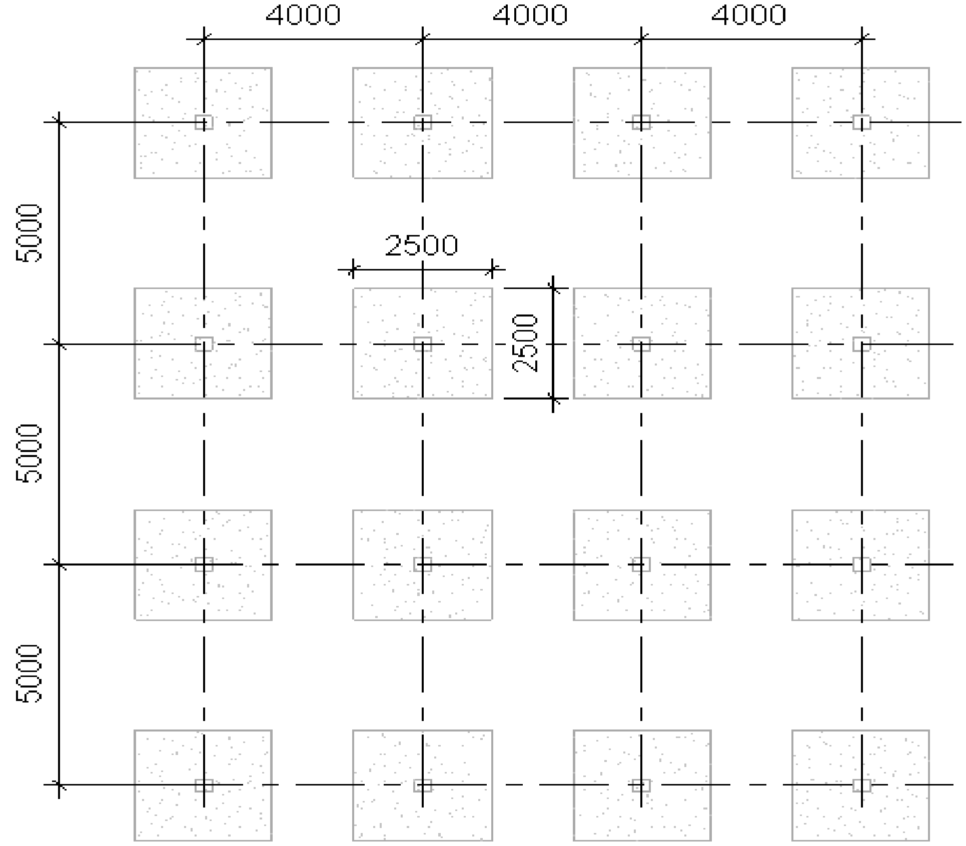
Total factor=33+1.5=34.5

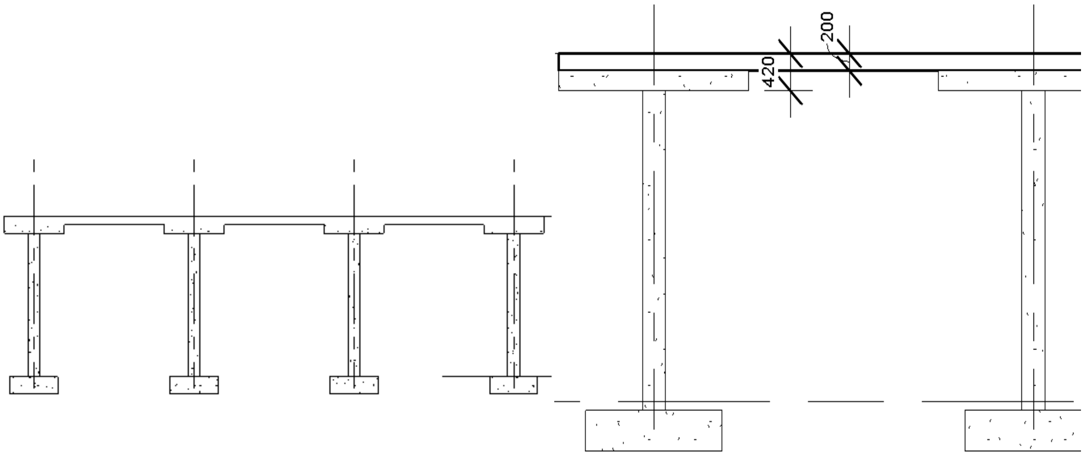
$$h_{min}=\frac{4700}{34.5}=136\ \text{mm}\approx 140\text{mm}$$



For all panels use the larger h=150 mm > 125mm O.K ■

Example 2: Check the slab thickness and drop panel dimension according to ACI Code for building indicated in Fig. below, use f_y=420 Mpa, slab thickness is 200 mm, drop panel thickness is 420 mm.





Solution:

Check drop panel thickeness and dimesntions

$\frac{2500}{2}$? $\frac{\ell 1}{6}$ =$\frac{4000}{6}$ =666.66 mm

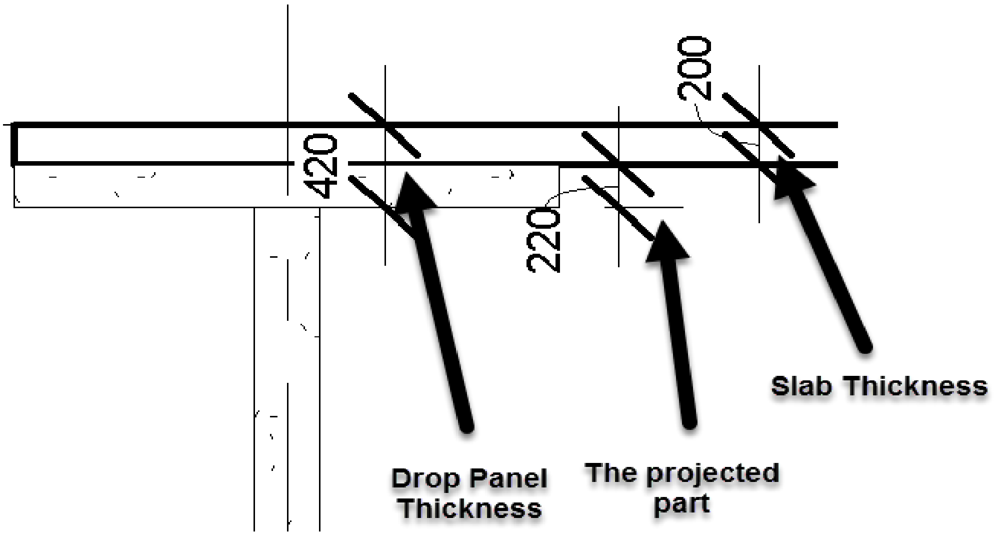
1250 mm > 666.66 mm

$\frac{2500}{2}$? $\frac{\ell 2}{6}$ =$\frac{5000}{6}$ =833.33 mm

1250 mm>833.33 mm

The thickness is o.k.

-According to **ACI Code 8.2.4** the project part of drop panel shall be below the slab at least **one-fourth** of the **slab thickness.**



$$220 \ ? \ \frac{hslab}{4} = \frac{200}{4} = 50$$

220 mm > 50mm O.K.

Check slab thickness

For exterior panel

ℓn = 5000-150*2=4700mm

$$h_{min} = \frac{\ell n}{33} = \frac{4700}{33} = 142mm \approx 145 \ mm$$

200>145 the thickness is O.K.

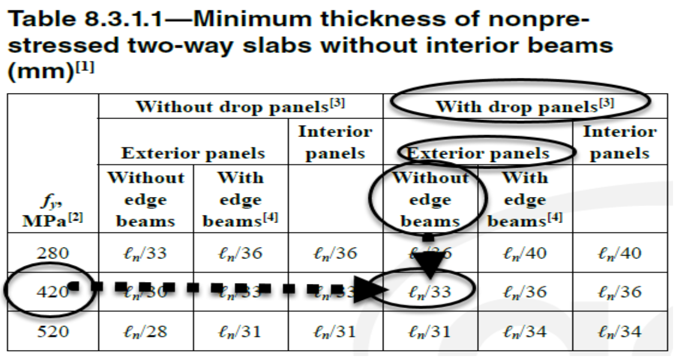


Table 8.3.1.1—Minimum thickness of nonprestressed two-way slabs without interior beams (mm)[1]

	Without drop panels[3]			With drop panels[3]		
	Exterior panels		Interior panels	Exterior panels		Interior panels
f_y, MPa[2]	Without edge beams	With edge beams[4]		Without edge beams	With edge beams[4]	
280	$\ell_n/33$	$\ell_n/36$	$\ell_n/36$	$\ell_n/36$	$\ell_n/40$	$\ell_n/40$
420	$\ell_n/30$	$\ell_n/33$	$\ell_n/33$	$\ell_n/33$	$\ell_n/36$	$\ell_n/36$
520	$\ell_n/28$	$\ell_n/31$	$\ell_n/31$	$\ell_n/31$	$\ell_n/34$	$\ell_n/34$

For interior panel

ℓn = 5000-150*2=4700mm

$$h_{min} = \frac{\ell n}{36} = \frac{4700}{36} = 130.5mm \approx 135 \ mm$$

200>135 the thickness is O.K. ■

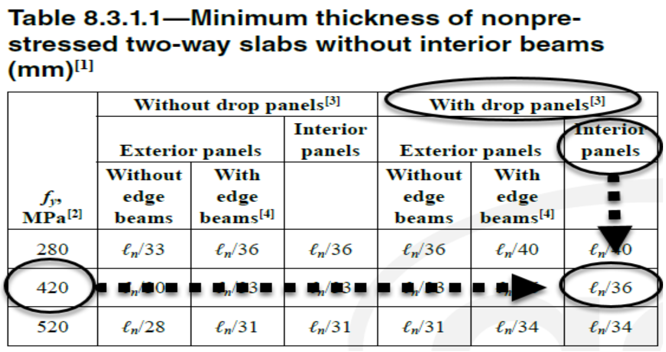
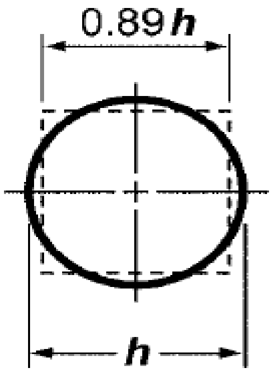
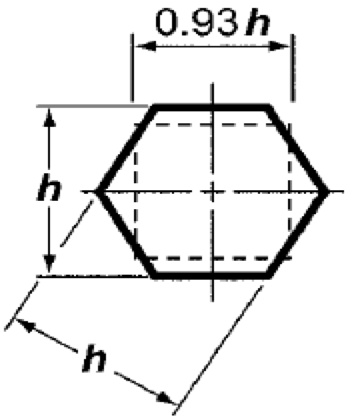


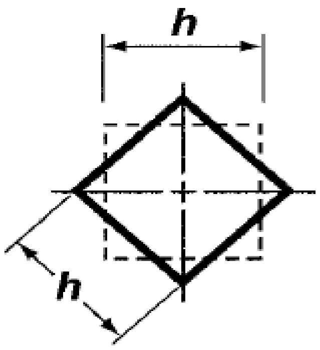
Table 8.3.1.1—Minimum thickness of nonprestressed two-way slabs without interior beams (mm)[1]

	Without drop panels[3]			With drop panels[3]		
	Exterior panels		Interior panels	Exterior panels		Interior panels
f_y, MPa[2]	Without edge beams	With edge beams[4]		Without edge beams	With edge beams[4]	
280	$\ell_n/33$	$\ell_n/36$	$\ell_n/36$	$\ell_n/36$	$\ell_n/40$	$\ell_n/40$
420	$\ell_n/30$	$\ell_n/33$	$\ell_n/33$	$\ell_n/33$	$\ell_n/36$	$\ell_n/36$
520	$\ell_n/28$	$\ell_n/31$	$\ell_n/31$	$\ell_n/31$	$\ell_n/34$	$\ell_n/34$

-According to **ACI Code 8.10.1.3** circular or polygon-shaped supports **(Columns and column capitals)** shall be treated as a **square supports** with same area.







Example 4: the architectural engineer assumes 200 mm slab thickness, check weather if this thickness is satisfying the deflection requirement of ACI Code, use f_y=420 Mpa.

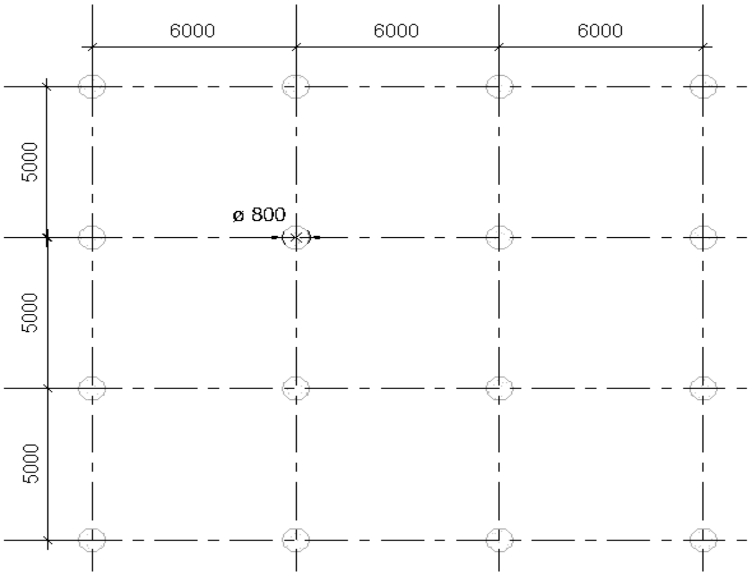
<u>Solution:</u>

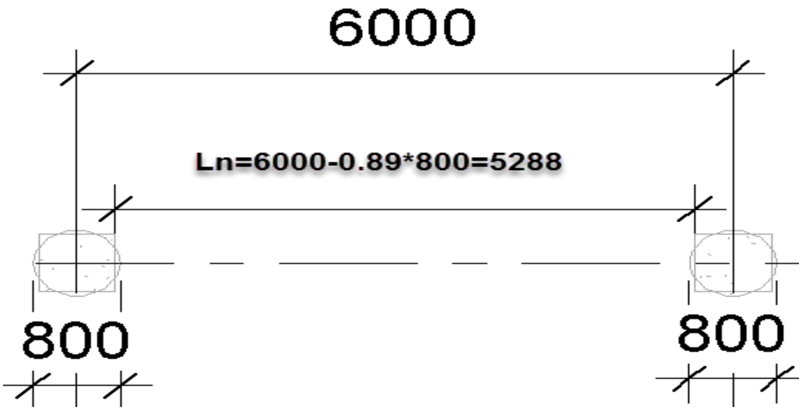
ℓn = 6000-0.89*800=5288 mm

$h_{min}=\frac{\ell n}{30}=\frac{5288}{30}$ =176.26mm≈180 mm

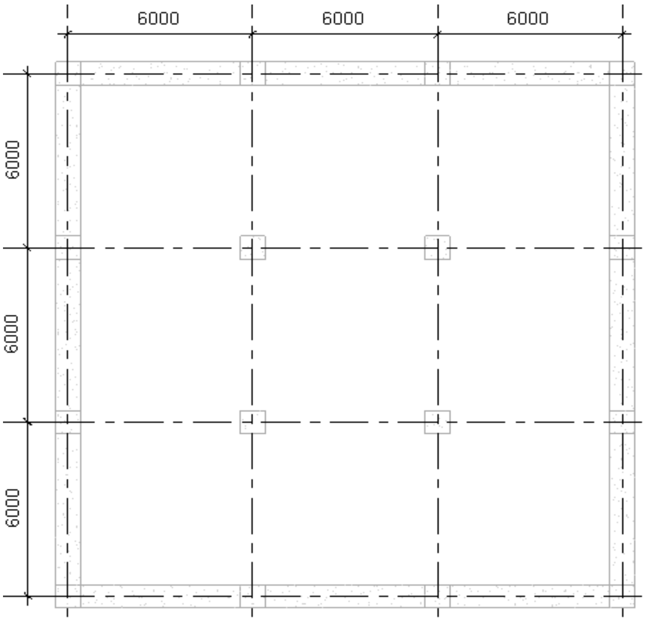
200 mm>180mm the thickness is O.K. ■

<u>Note:</u> we check the thickness for exterior panel only, because it gives the largest thickness for deflection control.





Example 5: Check the slab thickness according to deflection requirement if the slab thickness is (180) mm, and the slab is supported by edge beam (300*600) mm, columns (300 x 300) mm f_y=420 Mpa.`



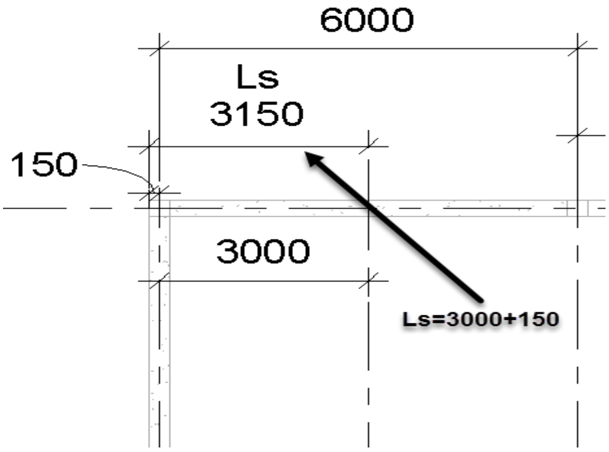
Solution:

- The slab is with edge beam.

ℓn =6000-2*150=5700 mm

$h_{min}=\frac{\ell n}{33}=\frac{5700}{33}$ =172.73mm≈175 mm

180 mm>175 mm the thickness is O.K ■



Example 6: Check the slab thickness according to deflection requirement for example 5 by assuming there are no edges beams if and slab thickness is (150) mm,. f_y=420 Mpa.

Solution:

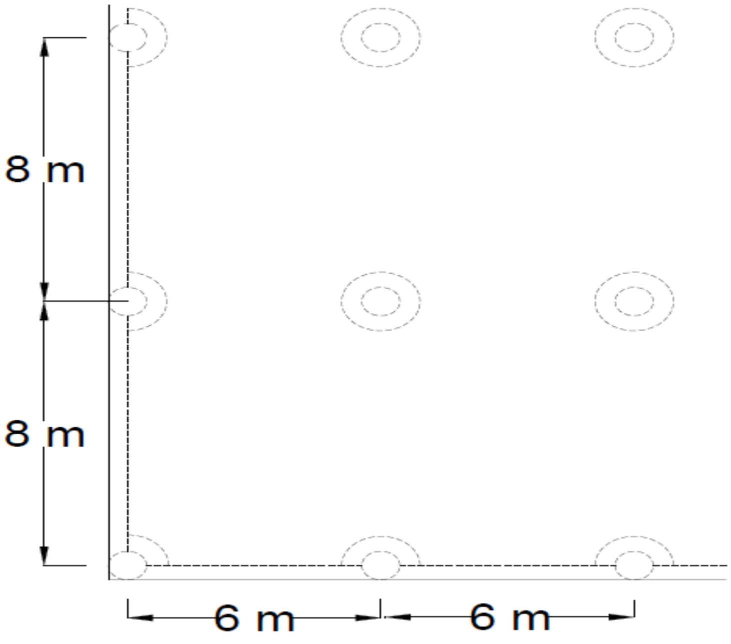
ℓn =6000-2*150=5700 mm

$h_{min}=\frac{\ell n}{30}=\frac{5700}{30}$ = 190 mm

150 mm < 190 mm the thickness is **not O.K**.

- Slab thickness is needed to be **increasing to 190** mm or larger. ■

Example 6: Find the thickness of the slab shown below, the slab is supported by edge beams and column capital diameter (1000) mm fy=420 Mpa



Solution:

For exterior panel

- According to **ACI Table 8.3.1.1**

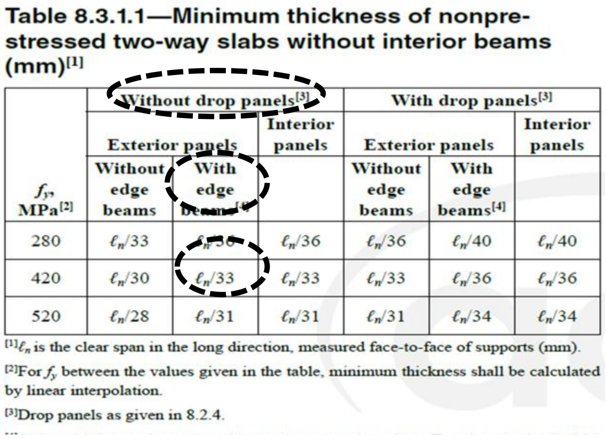


Table 8.3.1.1—Minimum thickness of nonprestressed two-way slabs without interior beams (mm)[1]

f_y, MPa[2]	Without drop panels[3]			With drop panels[3]		
	Exterior panels		Interior panels	Exterior panels		Interior panels
	Without edge beams	With edge beams[4]		Without edge beams	With edge beams[4]	
280	$\ell_n/33$	$\ell_n/36$	$\ell_n/36$	$\ell_n/36$	$\ell_n/40$	$\ell_n/40$
420	$\ell_n/30$	$\ell_n/33$	$\ell_n/33$	$\ell_n/33$	$\ell_n/36$	$\ell_n/36$
520	$\ell_n/28$	$\ell_n/31$	$\ell_n/31$	$\ell_n/31$	$\ell_n/34$	$\ell_n/34$

[1] ℓ_n is the clear span in the long direction, measured face-to-face of supports (mm).

[2] For f_y between the values given in the table, minimum thickness shall be calculated by linear interpolation.

[3] Drop panels as given in 8.2.4.

$$h = \frac{\ell n}{33}$$

ℓn=8000-0.89*1000=7110 mm

$h = \frac{\ell n}{33} = \frac{7110}{33}$=215.4 mm≈220 mm>125 mm O.K

For interior panel

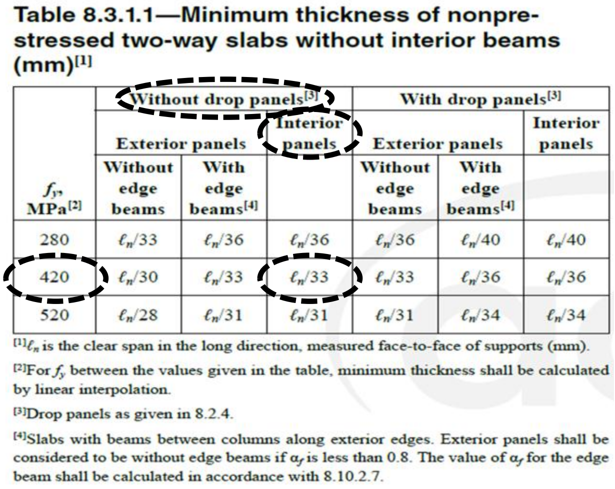


Table 8.3.1.1—Minimum thickness of nonprestressed two-way slabs without interior beams (mm)[1]

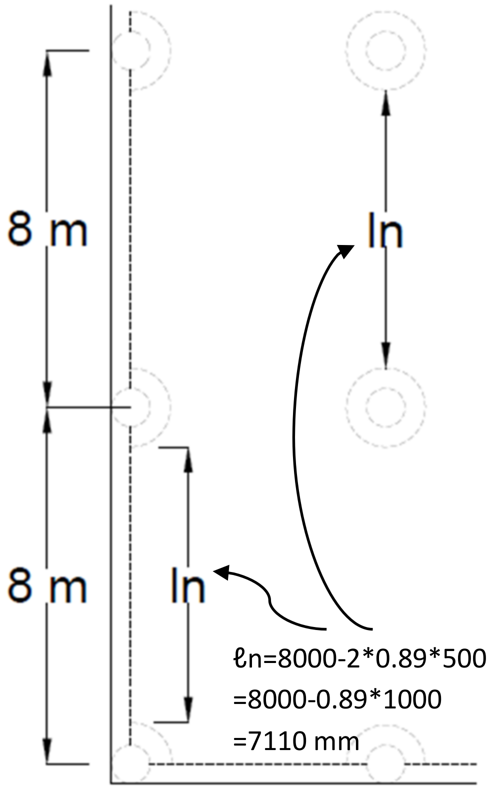
f_y, MPa[2]	Without drop panels[3]			With drop panels[3]		
	Exterior panels		Interior panels	Exterior panels		Interior panels
	Without edge beams	With edge beams[4]		Without edge beams	With edge beams[4]	
280	$\ell_n/33$	$\ell_n/36$	$\ell_n/36$	$\ell_n/36$	$\ell_n/40$	$\ell_n/40$
420	$\ell_n/30$	$\ell_n/33$	$\ell_n/33$	$\ell_n/33$	$\ell_n/36$	$\ell_n/36$
520	$\ell_n/28$	$\ell_n/31$	$\ell_n/31$	$\ell_n/31$	$\ell_n/34$	$\ell_n/34$

[1] ℓ_n is the clear span in the long direction, measured face-to-face of supports (mm).

[2] For f_y between the values given in the table, minimum thickness shall be calculated by linear interpolation.

[3] Drop panels as given in 8.2.4.

[4] Slabs with beams between columns along exterior edges. Exterior panels shall be considered to be without edge beams if α_f is less than 0.8. The value of α_f for the edge beam shall be calculated in accordance with 8.10.2.7.



ℓn=8000-2*0.89*500
=8000-0.89*1000
=7110 mm

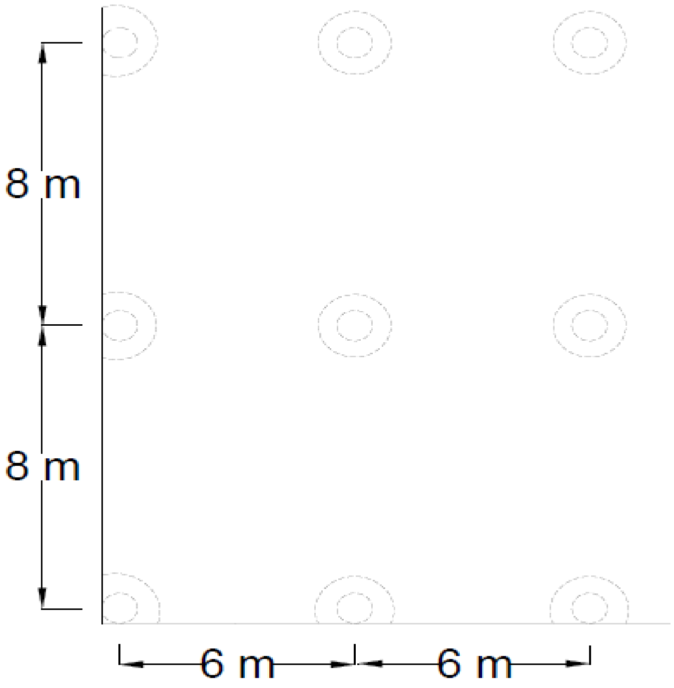
$$h = \frac{\ell n}{33}$$

ℓn=8000-0.89*1000=7110 mm

$h = \frac{\ell n}{33} = \frac{7110}{33}$=215.4 mm≈220 mm>125 mm O.K

Use h=220 mm ■

Example 6: Find the thickness of the slab shown below, the slab is without edge beams and column capital diameter (1000) mm f*y*=420 Mpa



Solution:

For exterior panel

- According to **ACI Table 8.3.1.1**

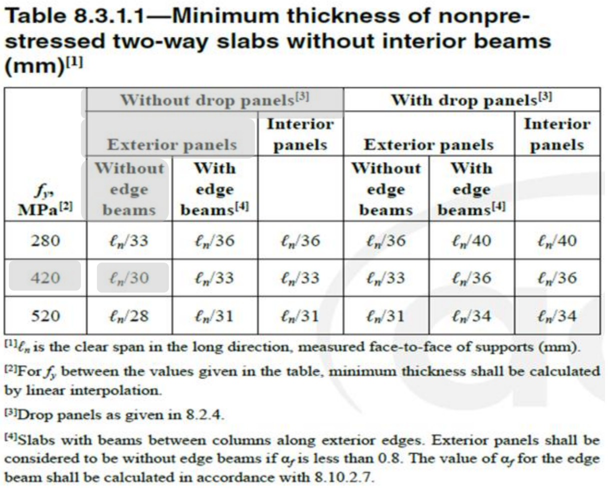


Table 8.3.1.1—Minimum thickness of nonprestressed two-way slabs without interior beams (mm)[1]

	Without drop panels[3]			With drop panels[3]		
	Exterior panels		Interior panels	Exterior panels		Interior panels
f_y, MPa[2]	Without edge beams	With edge beams[4]		Without edge beams	With edge beams[4]	
280	$\ell_n/33$	$\ell_n/36$	$\ell_n/36$	$\ell_n/36$	$\ell_n/40$	$\ell_n/40$
420	$\ell_n/30$	$\ell_n/33$	$\ell_n/33$	$\ell_n/33$	$\ell_n/36$	$\ell_n/36$
520	$\ell_n/28$	$\ell_n/31$	$\ell_n/31$	$\ell_n/31$	$\ell_n/34$	$\ell_n/34$

[1] ℓ_n is the clear span in the long direction, measured face-to-face of supports (mm).

[2] For f_y between the values given in the table, minimum thickness shall be calculated by linear interpolation.

[3] Drop panels as given in 8.2.4.

[4] Slabs with beams between columns along exterior edges. Exterior panels shall be considered to be without edge beams if α_f is less than 0.8. The value of α_f for the edge beam shall be calculated in accordance with 8.10.2.7.

$$h=\frac{\ell n}{30}$$

ℓn=8000-0.89*1000=7110 mm

$$h=\frac{\ell n}{30}=\frac{7110}{30}=237 > 125 \text{ mm}$$

For interior panel

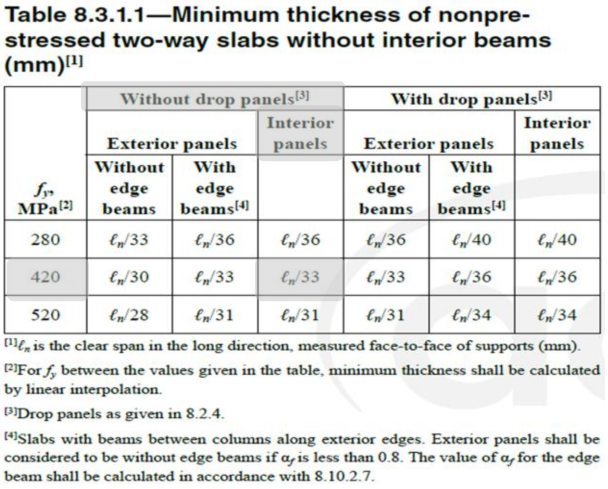


Table 8.3.1.1—Minimum thickness of nonprestressed two-way slabs without interior beams (mm)[1]

	Without drop panels[3]			With drop panels[3]		
	Exterior panels		Interior panels	Exterior panels		Interior panels
f_y, MPa[2]	Without edge beams	With edge beams[4]		Without edge beams	With edge beams[4]	
280	$\ell_n/33$	$\ell_n/36$	$\ell_n/36$	$\ell_n/36$	$\ell_n/40$	$\ell_n/40$
420	$\ell_n/30$	$\ell_n/33$	$\ell_n/33$	$\ell_n/33$	$\ell_n/36$	$\ell_n/36$
520	$\ell_n/28$	$\ell_n/31$	$\ell_n/31$	$\ell_n/31$	$\ell_n/34$	$\ell_n/34$

[1] ℓ_n is the clear span in the long direction, measured face-to-face of supports (mm).

[2] For f_y between the values given in the table, minimum thickness shall be calculated by linear interpolation.

[3] Drop panels as given in 8.2.4.

[4] Slabs with beams between columns along exterior edges. Exterior panels shall be considered to be without edge beams if α_f is less than 0.8. The value of α_f for the edge beam shall be calculated in accordance with 8.10.2.7.

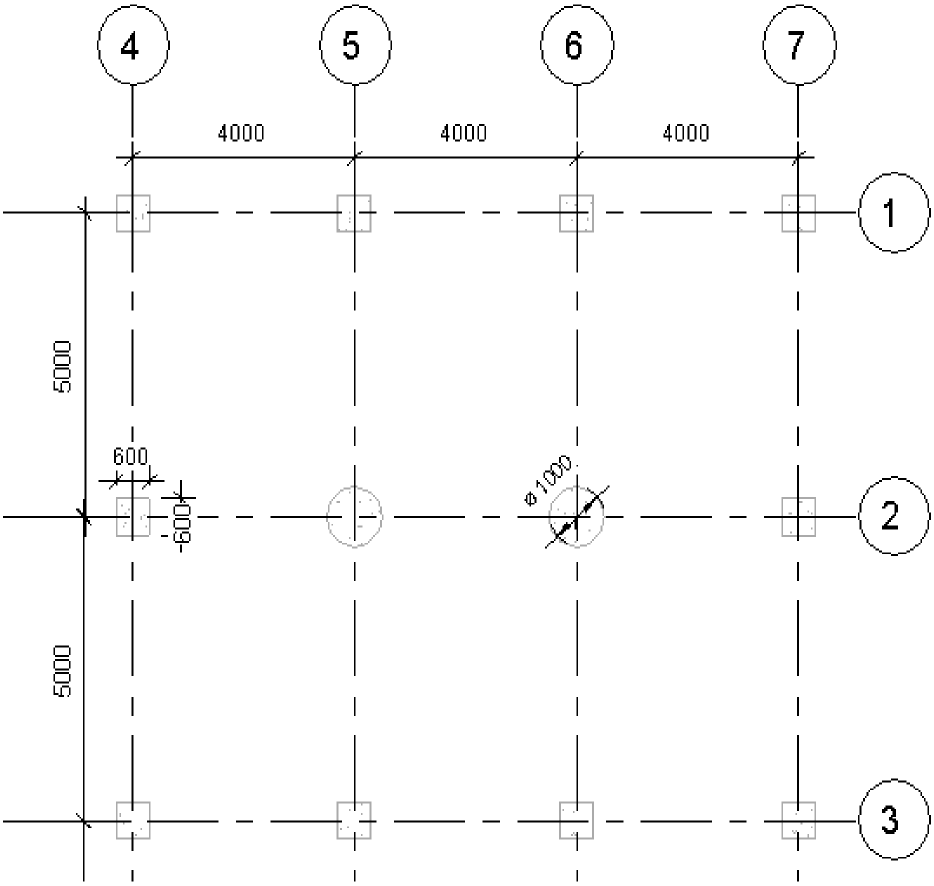
$$h=\frac{\ell n}{33}$$

ℓn=8000-0.89*1000=7110 mm

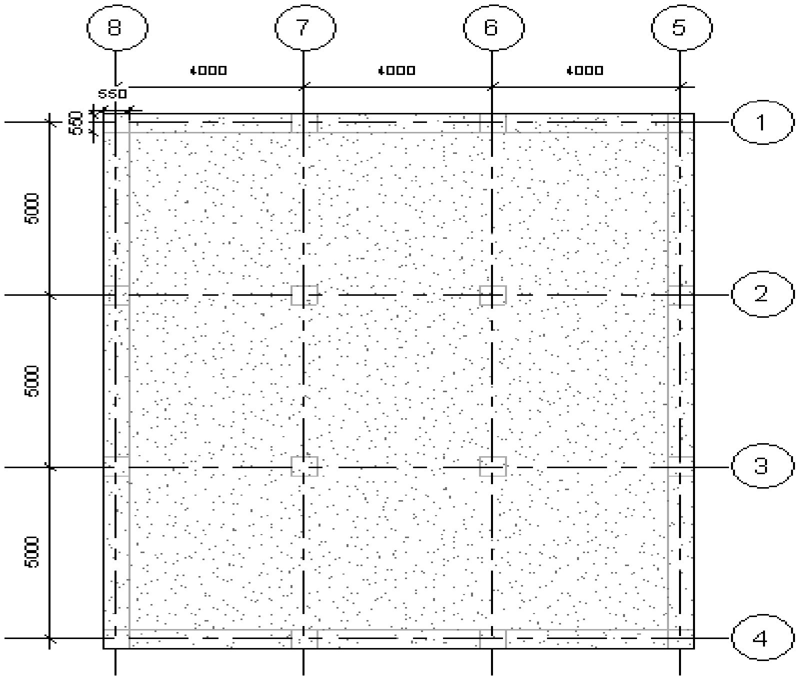
$$h=\frac{\ell n}{33}=\frac{7110}{33}=215.4\text{mm} > 125 \text{ mm}$$

Use h =240 mm ■

H.W 1: Find the minimum required slab thickness according to ACI Code for the slab shown below Fig. use f_y=420 Mpa.



H.W 2: Find the minimum required slab thickness according to ACI Code for the slab shown below Fig. use f_y=420 Mpa. Beam Dimensions are (300x600) mm.



1.5.2Minimum Thickness for Two-Way Slab with Interior Beams.

The parameter used to define the relative stiffness of the beam and slab spanning in either direction is α_f.it can be calculated by equation below:

$$\alpha f = \frac{Ecb * Ib}{Ecs * Is}$$

In which **Ecb** and **Ecs** are the moduli of elasticity of the beam and slab concrete **(usually the same)** and **Ib** and **Is** are the moments of inertia of the effective beam and the slab.
The moment of inertia of a flange beam about it is own centroid axis can be computed based on simple definition of centroid or by approximate method.

- **According to ACI code**, the two-way slab with interior beams can be found by **Table 8.3.1.2**

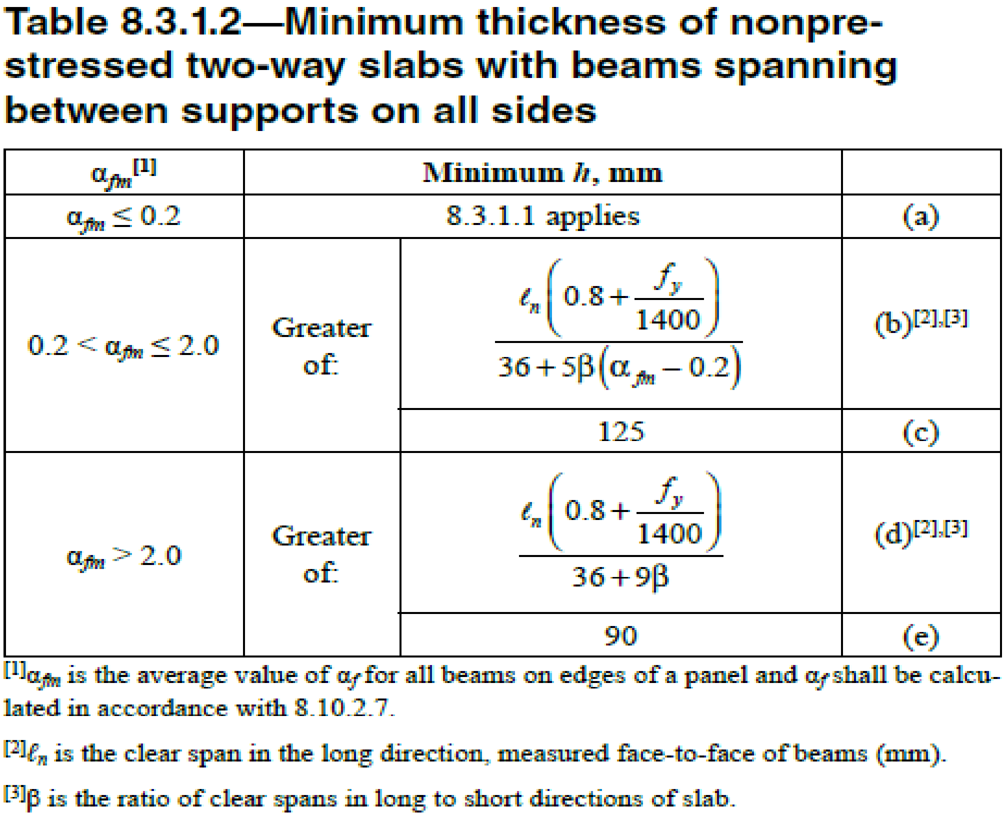


Table 8.3.1.2—Minimum thickness of nonprestressed two-way slabs with beams spanning between supports on all sides

α_{fm}[1]	Minimum h, mm		
$\alpha_{fm} \le 0.2$	8.3.1.1 applies		(a)
$0.2 < \alpha_{fm} \le 2.0$	Greater of:	$\dfrac{\ell_n\left(0.8+\dfrac{f_y}{1400}\right)}{36+5\beta\left(\alpha_{fm}-0.2\right)}$	(b)[2],[3]
		125	(c)
$\alpha_{fm} > 2.0$	Greater of:	$\dfrac{\ell_n\left(0.8+\dfrac{f_y}{1400}\right)}{36+9\beta}$	(d)[2],[3]
		90	(e)

[1] α_{fm} is the average value of α_f for all beams on edges of a panel and α_f shall be calculated in accordance with 8.10.2.7.

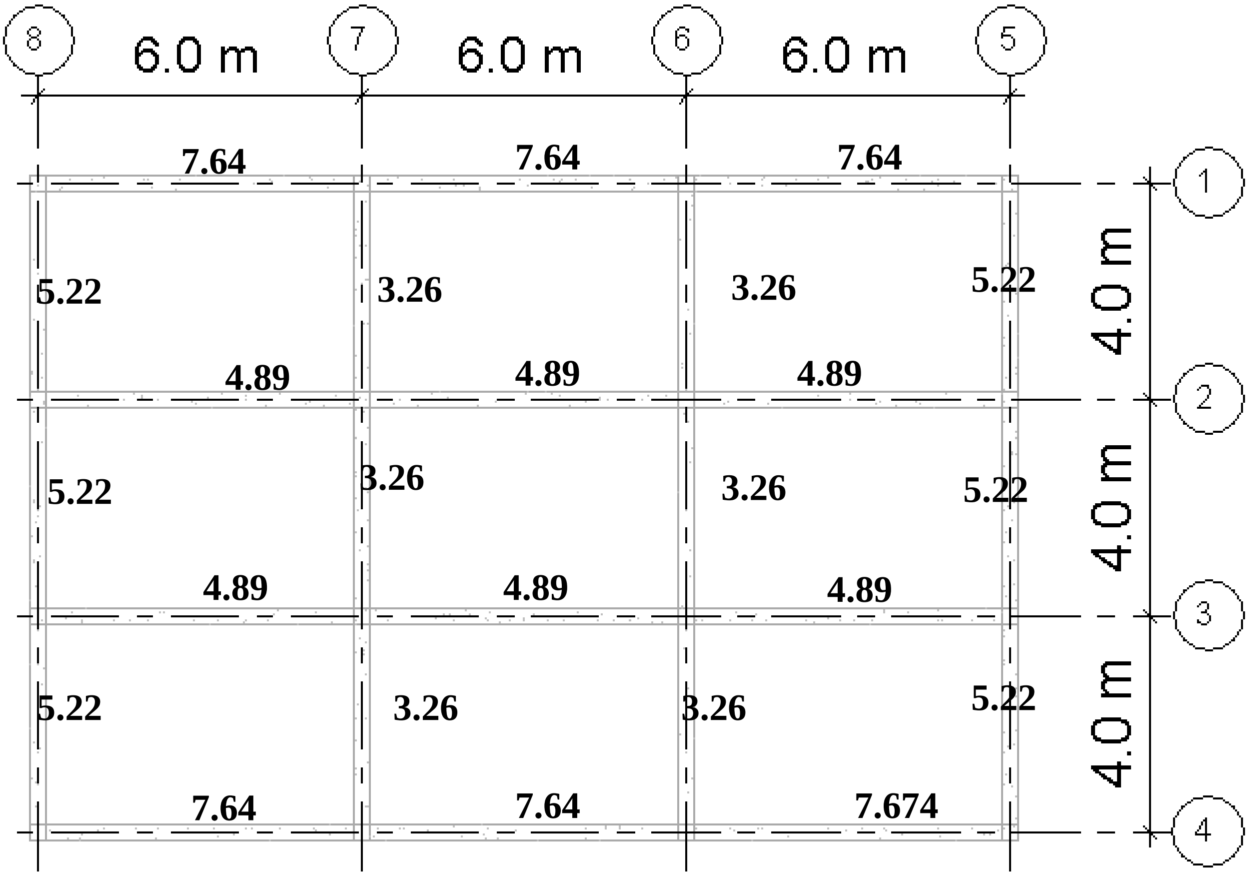
[2] ℓ_n is the clear span in the long direction, measured face-to-face of beams (mm).

[3] β is the ratio of clear spans in long to short directions of slab.

Notes:

- $\beta = \frac{clear\ span\ in\ the\ long\ direction}{clear\ span\ in\ the\ short\ direction} = \frac{\ell n}{sn}$
- Both of **ℓn** and **Sn** are measured from **face of beams.**
- α_{fm} is the **average value** of α_f for all beams on edges of a panel.

Example: For the slab with beams shown below in Figure is satisfactory, use f_y=420 Mpa, beam dimension (300x600) mm ,α_{f1} for each beams are indicated in figure below.



Solution:

Find α_{fm} for each panel:

Panel 1

$$\alpha_{fm}=\frac{4.89+4.89+3.26+3.26}{4}=4.075$$

$\alpha_{fm} > 2$

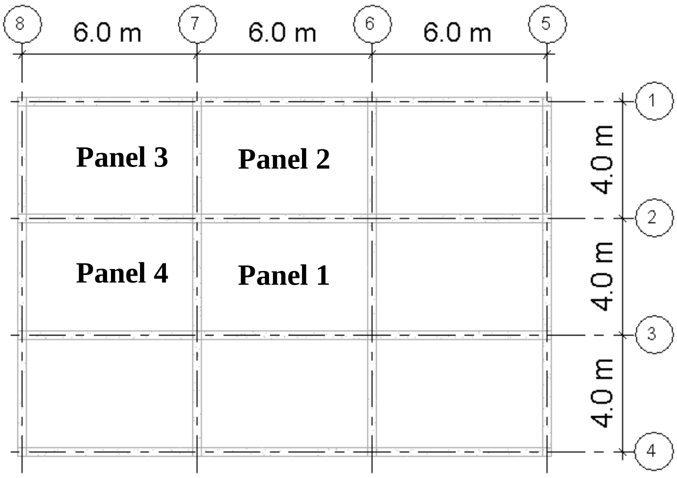
- By using the equation in **ACI Code Table 8.3.1.2**:

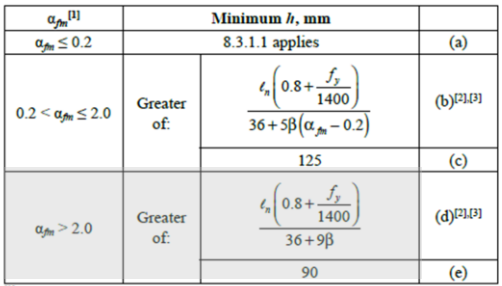
$$h=\frac{\ell n(0.8+\frac{fy}{1400})}{36+9\beta} \text{ or 90 } \textbf{(choose larger)}$$

$$\beta=\frac{\ell n}{sn}=\frac{6000-300}{4000-300}=\frac{5700}{3700}=1.54$$

$$h=\frac{\ell n(0.8+\frac{fy}{1400})}{36+9\beta}=\frac{5700(0.8+\frac{420}{1400})}{36+9*1.54}=125.75 \text{ mm} > 90 \text{ mm O.K}$$

Use h≈130 mm





α_{fm}[1]	Minimum h, mm		
$\alpha_{fm} \le 0.2$	8.3.1.1 applies		(a)
$0.2 < \alpha_{fm} \le 2.0$	Greater of:	$\frac{\ell_n\left(0.8+\frac{f_y}{1400}\right)}{36+5\beta\left(\alpha_{fm}-0.2\right)}$	(b)[2],[3]
		125	(c)
$\alpha_{fm} > 2.0$	Greater of:	$\frac{\ell_n\left(0.8+\frac{f_y}{1400}\right)}{36+9\beta}$	(d)[2],[3]
		90	(e)

Panel 2

$\alpha_{fm}=\frac{7.64+3.26+3.26+4.89}{4}=4.76$

$\alpha_{fm}>2$

$h=\frac{\ell n(0.8+\frac{fy}{1400})}{36+9\beta}$ or 90

$\beta=\frac{\ell n}{sn}=\frac{6000-300}{4000-300}=\frac{5700}{3700}=1.54$

$h=\frac{\ell n(0.8+\frac{fy}{1400})}{36+9\beta}=\frac{5700(0.8+\frac{420}{1400})}{36+9*1.54}$ =125.75 mm> 90 mm O.K

Use h≈130 mm

Panel 3

$\alpha_{fm}=\frac{7.64+3.26+5.22+4.89}{4}=5.25$

$\alpha_{fm}>2$

$h=\frac{\ell n(0.8+\frac{fy}{1400})}{36+9\beta}$ or 90

$\beta=\frac{\ell n}{sn}=\frac{6000-300}{4000-300}=\frac{5700}{3700}=1.54$

$h=\frac{\ell n(0.8+\frac{fy}{1400})}{36+9\beta}=\frac{5700(0.8+\frac{420}{1400})}{36+9*1.54}$ =125.75 mm> 90 mm O.K

Use h≈130 mm

Panel 4

$\alpha_{fm}=\frac{4.89+3.26+5.22+4.89}{4}=4.565$

$\alpha_{fm}>2$

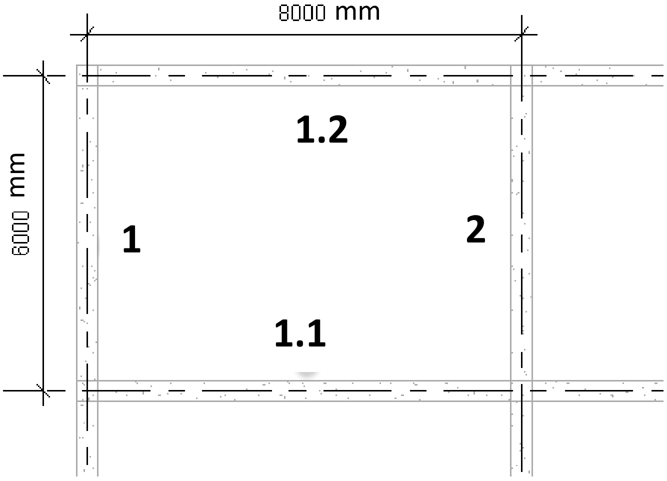
$h=\frac{\ell n(0.8+\frac{fy}{1400})}{36+9\beta}$ or 90

$\beta=\frac{\ell n}{sn}=\frac{6000-300}{4000-300}=\frac{5700}{3700}=1.54$

$h=\frac{\ell n(0.8+\frac{fy}{1400})}{36+9\beta}=\frac{5700(0.8+\frac{420}{1400})}{36+9*1.54}$ =125.75 mm> 90 mm O.K

Use h≈130 mm for all slab panels ■

Example: Find slab thickness for the following panel, α_f for each beams are indicated in Fig. below, Fy=420 Mpa. Beam dimensions are (400x600) mm.



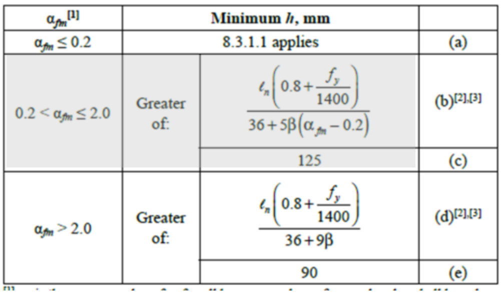
Solution:

Find α_{fm} for the panel:

Panel 1

$$\alpha_{fm}=\frac{1+1.1+2+1.2}{4}=1.325$$

$$0.2<\alpha_{fm}\le 2$$



α_{fm}[1]	Minimum h, mm		
$\alpha_{fm} \le 0.2$	8.3.1.1 applies		(a)
$0.2 < \alpha_{fm} \le 2.0$	Greater of:	$\frac{\ell_n\left(0.8+\frac{f_y}{1400}\right)}{36+5\beta\left(\alpha_{fm}-0.2\right)}$	(b)[2],[3]
		125	(c)
$\alpha_{fm} > 2.0$	Greater of:	$\frac{\ell_n\left(0.8+\frac{f_y}{1400}\right)}{36+9\beta}$	(d)[2],[3]
		90	(e)

- By using the equation in **ACI Code Table 8.3.1.2**:

$$h=\frac{\ell n(0.8+\frac{fy}{1400})}{36+5\beta(\alpha_{fm}-0.2)} \text{ or } 125$$

$$\beta=\frac{\ell n}{sn}=\frac{8000-400}{6000-400}=\frac{7600}{5600}=1.357$$

$$h=\frac{\ell n(0.8+\frac{fy}{1400})}{36+5\beta(\alpha_{fm}-0.2)}=\frac{7600(0.8+\frac{420}{1400})}{36+5*1.357(1.325-0.2}=191.6 \text{ mm} > 125 \text{ mm O.K}$$

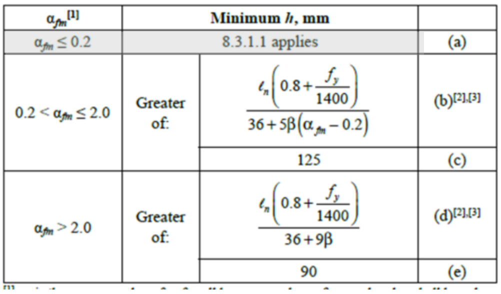
Use h≈200 mm ■

Example: Find slab thickness for the interior panel that showing if figure below, α_f for all beams are 0.1, *fy*=420 Mpa. Beams and columns dimensions are (300x300) mm.

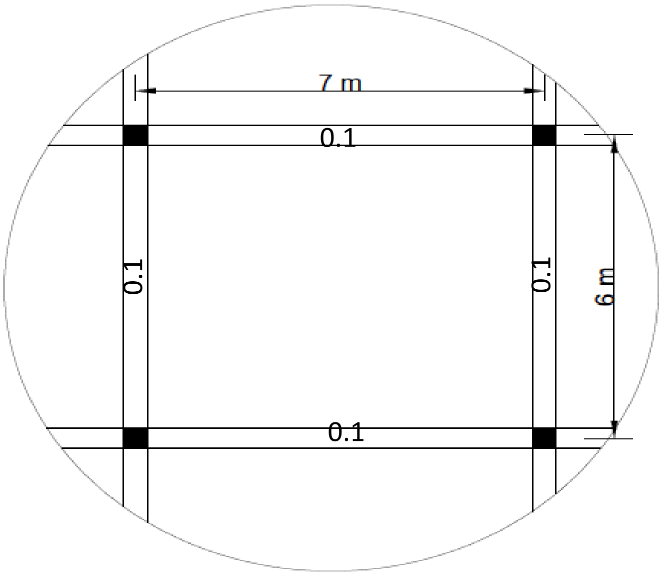
Solution:

Find α_{fm}

$$\alpha_{fm}=\frac{0.1+0.1+0.1+0.1}{4}=0.1<2$$



α_{fm}[1]	Minimum h, mm		
$\alpha_{fm} \le 0.2$	8.3.1.1 applies		(a)
$0.2 < \alpha_{fm} \le 2.0$	Greater of:	$\frac{\ell_n\left(0.8+\frac{f_y}{1400}\right)}{36+5\beta\left(\alpha_{fm}-0.2\right)}$	(b)[2],[3]
		125	(c)
$\alpha_{fm} > 2.0$	Greater of:	$\frac{\ell_n\left(0.8+\frac{f_y}{1400}\right)}{36+9\beta}$	(d)[2],[3]
		90	(e)



- Since α_{fm} for the panel is **<u>less than or equal to 0.2</u>** ,then the slab us considered without beams and **ACI Table 8.3.1.1** must apply

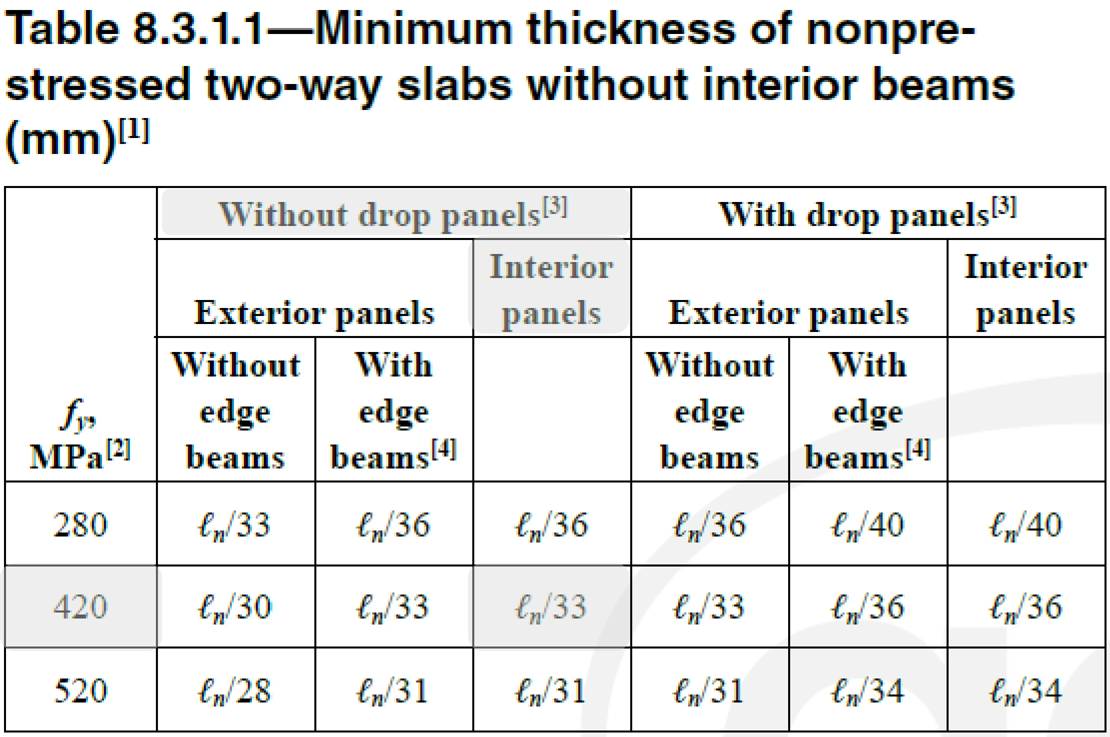


Table 8.3.1.1—Minimum thickness of nonprestressed two-way slabs without interior beams (mm)[1]

f_y, MPa[2]	Without drop panels[3]			With drop panels[3]		
	Exterior panels		Interior panels	Exterior panels		Interior panels
	Without edge beams	With edge beams[4]		Without edge beams	With edge beams[4]	
280	$\ell_n/33$	$\ell_n/36$	$\ell_n/36$	$\ell_n/36$	$\ell_n/40$	$\ell_n/40$
420	$\ell_n/30$	$\ell_n/33$	$\ell_n/33$	$\ell_n/33$	$\ell_n/36$	$\ell_n/36$
520	$\ell_n/28$	$\ell_n/31$	$\ell_n/31$	$\ell_n/31$	$\ell_n/34$	$\ell_n/34$

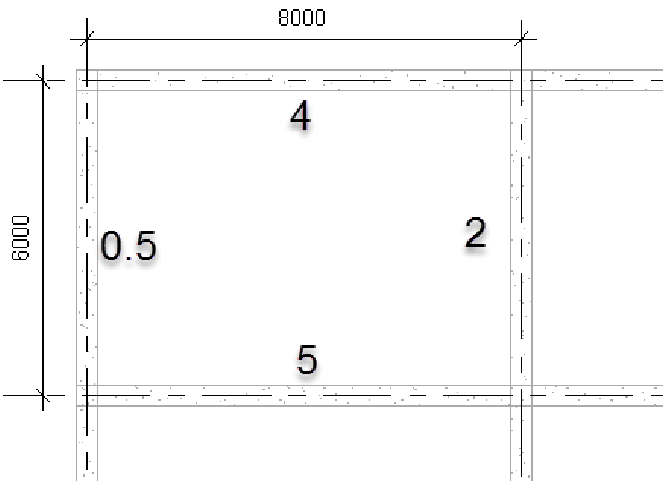
$$h=\frac{\ell n}{33}$$

ℓn=7000-300=6700 mm

$h=\frac{6700}{33}$=203 mm ≈210 mm > 125 mm ■

<u>Note:</u> According to **ACI Code 8.3.1.2.1** at discontinuous edges of slabs, if an edge beam with $\boldsymbol{\alpha_f} < \mathbf{0.8}$ then the minimum thickness required by **(b)** or **(d)** of **Table 8.3.1.2** shall be increased at least **10 percent** in the panel with discontinuous edge.

<u>Example:</u> Find slab thickness for the following panel, $\boldsymbol{\alpha_f}$ for each beams are indicated in Fig. below, Fy=420. Beam digestions are (400x600) mm.



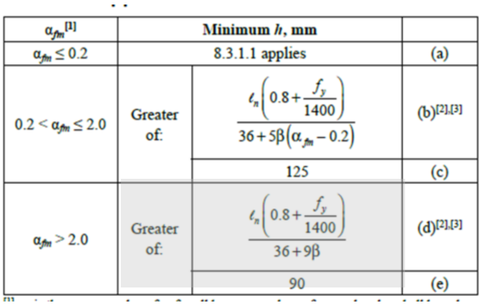
<u>Solution:</u>

$$\alpha_{fm}=\frac{4+2+5+0.5}{4}=2.875$$

α_{fm} =2.875 > 2

By using the equation in **ACI Code Table (8.3.1.2)**:

$$h = \frac{\ell n(0.8+\frac{fy}{1400})}{36+9\beta}$$ Or 90 **(greater)**



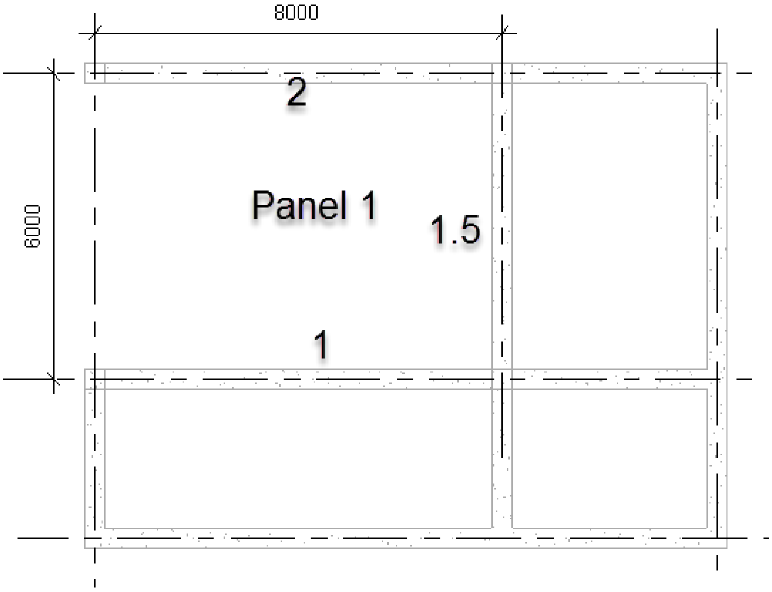
α_{fm}[1]	Minimum h, mm		
$\alpha_{fm} \le 0.2$	8.3.1.1 applies		(a)
$0.2 < \alpha_{fm} \le 2.0$	Greater of:	$\frac{\ell_n\left(0.8+\frac{f_y}{1400}\right)}{36+5\beta(\alpha_{fm}-0.2)}$	(b)[2],[3]
		125	(c)
$\alpha_{fm} > 2.0$	Greater of:	$\frac{\ell_n\left(0.8+\frac{f_y}{1400}\right)}{36+9\beta}$	(d)[2],[3]
		90	(e)

- Since α_f for edge beam **0.5 < 0.8**, then the equation shall be increased by **10 percent**.

$$h = 1.1 * \frac{\ell n(0.8+\frac{fy}{1400})}{36+9\beta}, \beta = \frac{\text{clear span in long direction}}{\text{clear span in short direction}} = \frac{8000-400}{6000-400} = \frac{7600}{5600} = 1.36$$

$$h = 1.1 * \frac{7600(0.8+\frac{420}{1400})}{36+9*1.36} = 190.63 > 90 \text{ use h} \approx 200 \text{ mm} \blacksquare$$

H.W: Find slab thickness for the panel 1, α_f for each beams are indicated in Fig. below, Fy=420. Beam digestions are (300x600) mm.



General Examples for calculating slab thickness

Example 1: Find the minimum thickness of a slab for an interior panels due to deflection control for the following: Use *fy*=350 Mpa

a. Slab with beams (8.1 x 8.2) m clear span with **α_{fm}=2.3**
b. Flat plate (4.4 x 4.6) m clear span.
c. Flat slab with drop panels (6.2 x 6.2) m clear span.

Solution:

Slab with beams (8.1 x 8.2) m clear span with α_{fm}=2.3

$\alpha_{fm}=2.3 > 2$

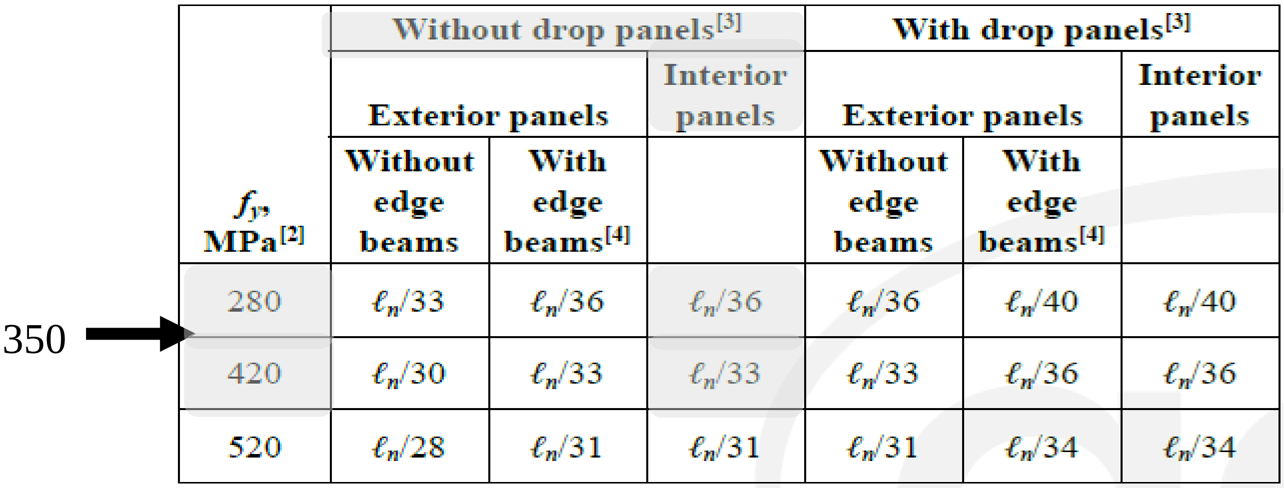
$$h = \frac{\ell\text{n}(0.8 + \frac{fy}{1400})}{36 + 9\beta}$$

$$\beta = \frac{\ell\text{n}}{\text{sn}} = \frac{8200}{8100} = 1.012$$

$$h = \frac{8200*(0.8+\frac{350}{1400})}{36+9*1.012} = 190.87 \text{ mm} > 90 \text{ mm O.K}$$

Flat plate (4.4 x 4.6) m clear span.

From **ACI Table 8.3.1.1**



	Without drop panels[3]			With drop panels[3]		
	Exterior panels		Interior panels	Exterior panels		Interior panels
f_y, MPa[2]	Without edge beams	With edge beams[4]		Without edge beams	With edge beams[4]	
280	$\ell_n/33$	$\ell_n/36$	$\ell_n/36$	$\ell_n/36$	$\ell_n/40$	$\ell_n/40$
420	$\ell_n/30$	$\ell_n/33$	$\ell_n/33$	$\ell_n/33$	$\ell_n/36$	$\ell_n/36$
520	$\ell_n/28$	$\ell_n/31$	$\ell_n/31$	$\ell_n/31$	$\ell_n/34$	$\ell_n/34$

350

For fy=280 Mpa $\frac{\ell n}{36}$

For fy=420 Mpa $\frac{\ell n}{33}$

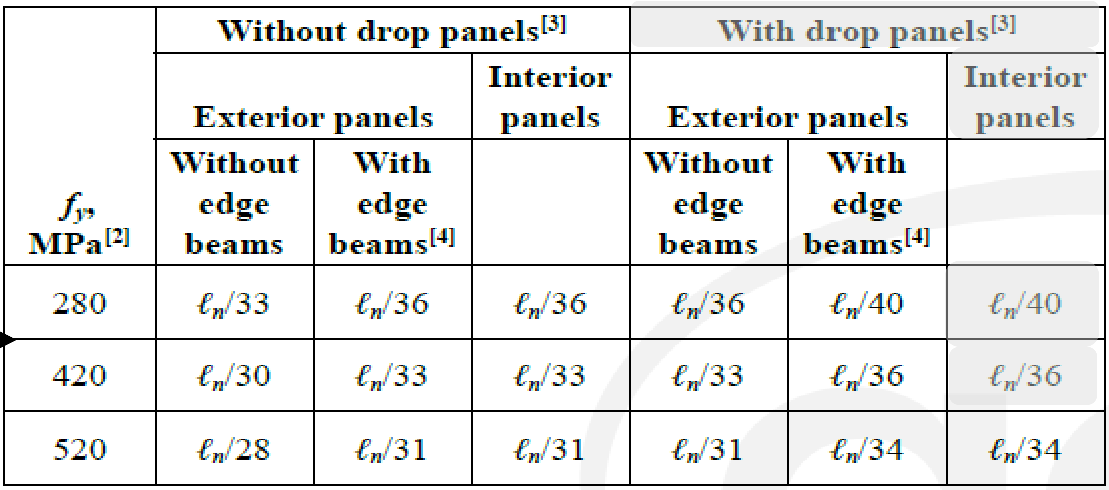
For fy=350 Mpa $\frac{\ell n}{34.5}$ (by linear interpolation)

$h=\frac{\ell n}{34.5}=\frac{4600}{34.5}$ =133.33 mm > 125 mm O.k

c. Flat slab with drop panels (6.2 x 6.2) m clear span.

From **ACI Table 8.3.1.1**

350 →



f_y, MPa[2]	Without drop panels[3]			With drop panels[3]		
	Exterior panels		Interior panels	Exterior panels		Interior panels
	Without edge beams	With edge beams[4]		Without edge beams	With edge beams[4]	
280	$\ell_n/33$	$\ell_n/36$	$\ell_n/36$	$\ell_n/36$	$\ell_n/40$	$\ell_n/40$
420	$\ell_n/30$	$\ell_n/33$	$\ell_n/33$	$\ell_n/33$	$\ell_n/36$	$\ell_n/36$
520	$\ell_n/28$	$\ell_n/31$	$\ell_n/31$	$\ell_n/31$	$\ell_n/34$	$\ell_n/34$

For fy=280 Mpa $\frac{\ell n}{40}$

For fy=420 Mpa $\frac{\ell n}{36}$

For fy=350 Mpa $\frac{\ell n}{38}$ (by linear interpolation)

h=$\frac{\ell n}{38}$=$\frac{6200}{38}$ =163.15 mm > 100 mm O.k ■

<u>Example 2:</u> Find the minimum thickness of a slab for an interior panels due to deflection control for the following: Use fy=420 Mpa

a. Slab with beams (8.2 x 7.7) m clear span with **α_{fm}=2.3**

b. Slab without drop panels (5.4 x 4.8) m clear span with **α_{fm}=0.18**

c. Flat plate (4.2 x 4.6) m clear span.

d. Flat slab with drop panels (6 x 6.2) m clear span.

e. Slab with beams (5.8 x 5.8) m clear span with **α_{fm}=1.5**

<u>Solution:</u>

a. Slab with beams (8.2 x 7.7) m clear span with α_{fm}=2.3

α_{fm}=2.3 > 2

$$h = \frac{\ell n(0.8 + \frac{fy}{1400})}{36 + 9\beta}$$

$$\beta = \frac{\ell n}{sn} = \frac{8200}{7700} = 1.065$$

$$h = \frac{8200*(0.8+\frac{420}{1400})}{36+9*1.065} = 197.87 \text{ mm} > 90 \text{ mm O.k}$$

Use h ≈ 200 mm

b. Slab without drop panels (5.4 x 4.8) m clear span with α_{fm}=0.18

$\alpha_{fm}=0.18 < 0.2$

Then the slab is considered without beams, use **ACI Table 8.3.1.1**

$h=\frac{\ell n}{33}=\frac{5400}{33}$ = 163.65 mm > 125 mm O.K

Use h ≈ 170 mm

c. Flat plate (4.2 x 4.6) m clear span.

From **ACI Table 8.3.1.1**

$h=\frac{\ell n}{33}=\frac{4600}{33}$ = 139.4 mm > 125 mm O.K

Use h ≈ 140 mm

d. Flat slab with drop panels (6 x 6.2) m clear span.

From **ACI Table 8.3.1.1**

$h=\frac{\ell n}{36}=\frac{6200}{36}$ = 172.2 mm > 100 mm O.K

Use h ≈ 175 mm

e. Slab with beams (5.8 x 5.8) m clear span with α_{fm}=1.5

$0.2 < \alpha_{fm}=1.5 < 2$

$$h=\frac{\ell n\left(0.8+\frac{fy}{1400}\right)}{36+5\beta\left(\alpha_{fm}-0.2\right)}$$

$$\beta=\frac{\ell \text{n}}{\text{sn}}=\frac{5800}{5800}=1$$

$$h=\frac{5800*\left(0.8+\frac{420}{1400}\right)}{36+5*1*(1.5-0.2)}=150.12 \text{ mm} > 125 \text{ mm O.K}$$

Use h ≈ 160 mm ■

Example 3: Find the minimum thickness of a slab for an interior panels due to deflection control for the following: Use fy=420 Mpa (60000 psi)

a. Flat slab with drop panels (6.4 x 6.4) m clear span

b. Slab with beams (6.0 x 6.0) m clear span with $\boldsymbol{\alpha_{fm}}$**=2.7**

c. Slab with beams (5.4 x 4.5) m clear span with $\boldsymbol{\alpha_{fm}}$**=0.7**.

d. Flat plate (4.6 x 4.6) m clear span.

Solution:

a. Flat slab with drop panels (6.4 x 6.4) m clear span

From ACI Table 8.3.1.1

$h=\frac{\ell n}{36}=\frac{6400}{36}$ = 177.78 mm > 100 mm O.K

Use h ≈180 mm

b. Slab with beams (6.0 x 6.0) m clear span with $\boldsymbol{\alpha_{fm}}$=2.7

$$h=\frac{\ell\text{n}(0.8+\frac{fy}{1400})}{36+9\beta}$$

$\beta=\frac{\ell\text{n}}{\text{sn}}=\frac{6000}{6000}$=1

$h=\frac{6000*(0.8+\frac{420}{1400})}{36+9*1}$ = 146.77 mm > 90 mm O.K

Use h≈150 mm

c. Slab with beams (5.4 x 4.5) m clear span with $\boldsymbol{\alpha_{fm}}$=0.7.

$0.2 < \alpha_{fm}=0.7 < 2$

$h=\frac{\ell n\left(0.8+\frac{fy}{1400}\right)}{36+5\beta(\alpha_{fm}-0.2)}$

$\beta=\frac{\ell\text{n}}{\text{sn}}=\frac{5400}{4500}$=1.2

$h=\frac{5400*\left(0.8+\frac{420}{1400}\right)}{36+5*1.2*(0.7-0.2)}$ = 152.3 mm > 125 mm O.K

Use h≈160 mm

d. Flat plate (4.6 x 4.6) m clear span.

From **ACI Table 8.3.1.1**

$h=\frac{\ell n}{33}=\frac{4600}{33}$ = 139.39 mm > 125mm O.K

Use h≈140 mm ■

Example 4: Find the minimum thickness of a slab for an interior panels due to deflection control for the following: Use fy=280 Mpa (40000 psi)

a. Slab (2.5 x 3.5) m clear span with **α_{fm}=3.2**

b. Flat plate (6.5 x 7.0) m clear span.

c. Slab without drop panels (6.5 x 5.5) m clear span with **α_{fm}=0.12**

d. Slab with drop panels (6.0 x 7.5) m clear span with **α_{fm}=0.15**

Solution:

a. Slab (2.5 x 3.5) m clear span with α_{fm}=3.2

$\alpha_{fm}=3.2 > 2$

$$h = \frac{\ell n(0.8 + \frac{fy}{1400})}{36 + 9\beta}$$

$\beta = \frac{\ell n}{sn} = \frac{3500}{2500} = 1.4$

$h = \frac{3500*(0.8+\frac{280}{1400})}{36+9*1.4}$ =72.01 mm < 90 mm Not O.K

Use h=90 mm

b. Flat plate (6.5 x 7.0) m clear span.

By using **ACI Table 8.3.1.1**

h=$\frac{\ell n}{36} = \frac{7000}{36}$ =194.44 mm > 125 O.K

Use h≈200 mm

c. Slab without drop panels (6.5 x 5.5) m clear span with α_{fm}=0.12

α_{fm}=0.12 < 0.2

Then the slab is considered without beams

By using **ACI Table 8.3.1.1**

h= $\frac{\ell n}{36} = \frac{6500}{36}$ = 180.55 mm > 125 mm O.K

Use h≈190 mm

d. Slab with drop panels (6.0 x 7.5) m clear span with α_{fm}=0.15

α_{fm}=0.15< 0.2

Then the slab is considered without beams

By using **ACI Table 8.3.1.1**

h= $\frac{\ell n}{40} = \frac{7500}{40}$ =187.5 mm > 100 mm O.K

Use h≈190 mm ■

Home Work

Find the minimum thickness of a slab for an interior panel due to deflection control for the following. Use fy=420 Mpa (60000 psi)

a. Flat slab with drop panels (6.4 x 6.0) m clear span
b. Flat plate (4.4 x 4.0) m clear span.
c. Slab with beams (5.8 x 5.6) m clear span with with $\boldsymbol{\alpha_{fm}=1.7}$
d. Slab with beams (8.0 x 6.5) m clear span with with $\boldsymbol{\alpha_{fm}=3.4}$
e. Slab without drop panels (5.5 x 4.8) m clear span with $\boldsymbol{\alpha_{fm}=0.19}$