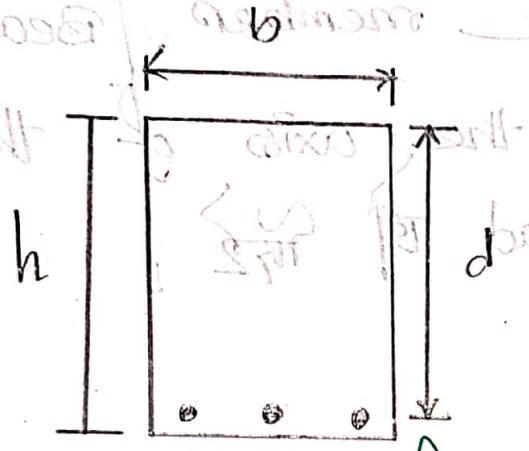
May Allah bless Sir

Lecture Video-01

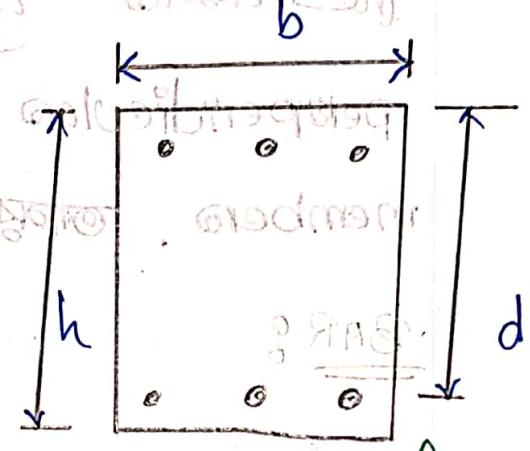
EWC-315

04-05-2021

Flexural Analysis And Design of Doubly Reinforced Beam



Singly Reinforced Section



Doubly Reinforced Section

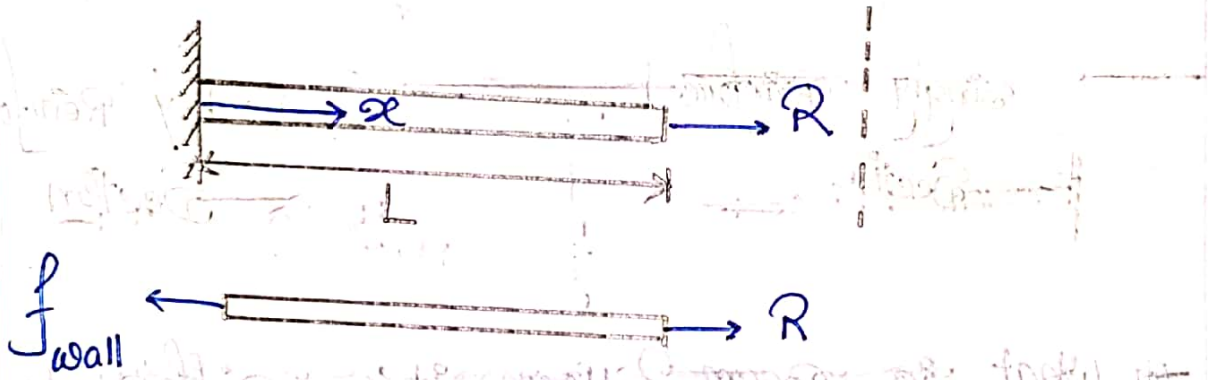
What is Beam? How it's different from a BAR?

Solution:

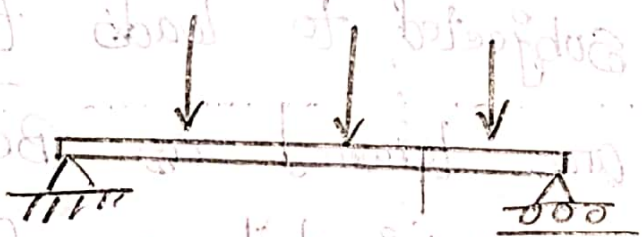
Members subjected to loads transverse to the axis are termed as Beam. The members are subjected to forces or moments having their vectors perpendicular to the axis of the member.

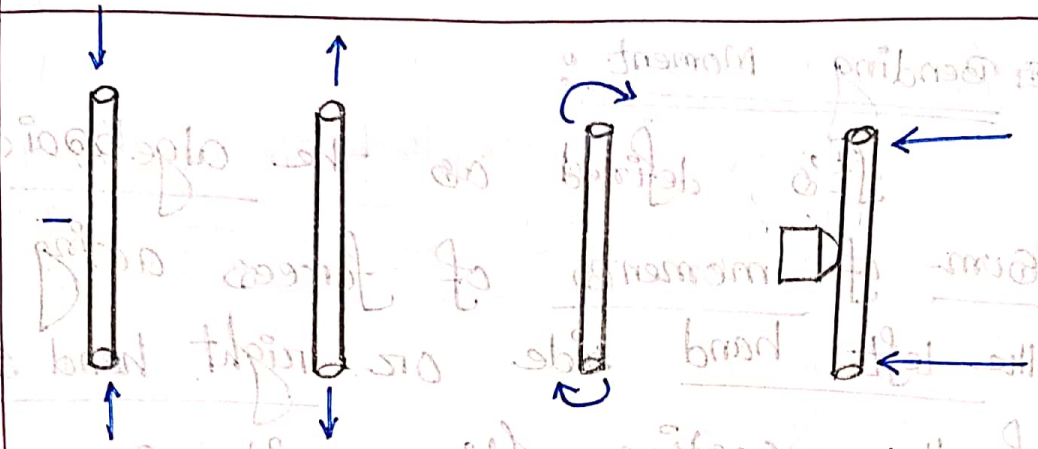
BARs are subjected to forces or moments having their vectors along the axis of the member. [Beam ও perpendicular to the axis of the members. আবার load টা দেয়।

BAR :



Beam :





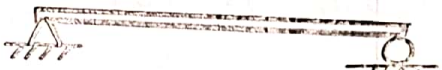
Types of Beam :-

(i)



Cantilever

(ii)



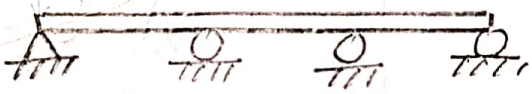
Simply Supported

(iii)



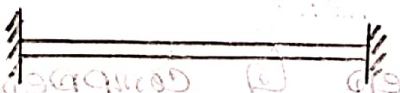
Overhanging

(iv)



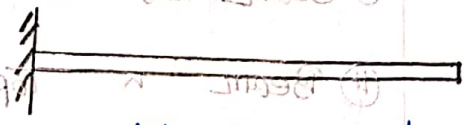
Continuous

(v)



Fixed Ended

(vi)

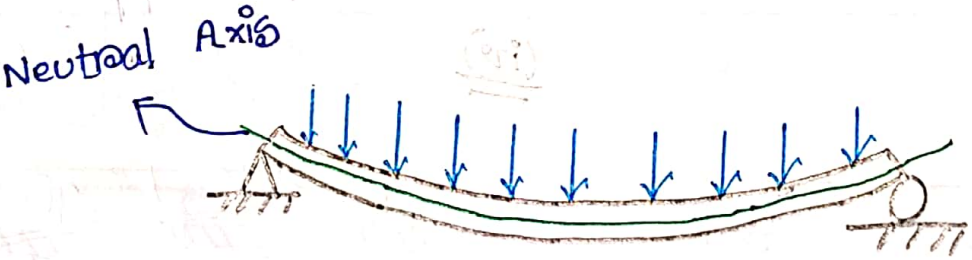


Cantilever, Simply Supported

Bending Moment :

It's defined as the algebraic sum of moments of forces acting on the left hand side or right hand side of the section. It's unit is "N-mm" or "KN-mm"





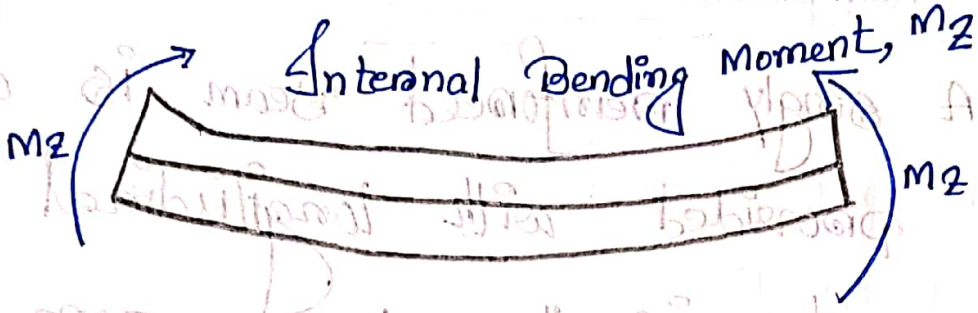
Note:

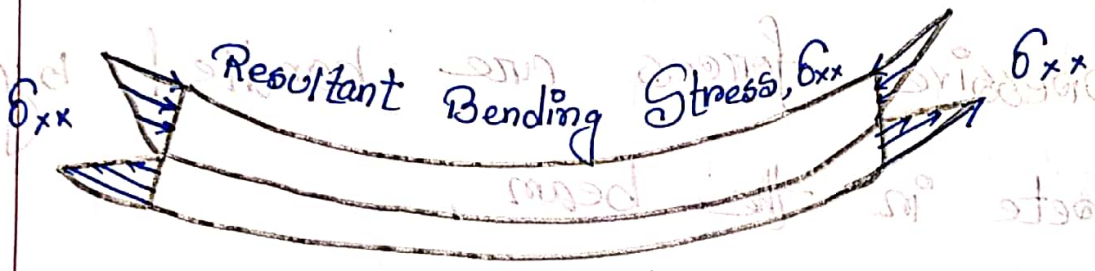
(i) Beam का Bottom fiber ला Tension असतो.

(ii) Beam चा Top fiber ला compression.

(iii) Cantilever Beam ला Top fiber ला Tension.

(iv) Cantilever Beam ला Bottom fiber ला compression





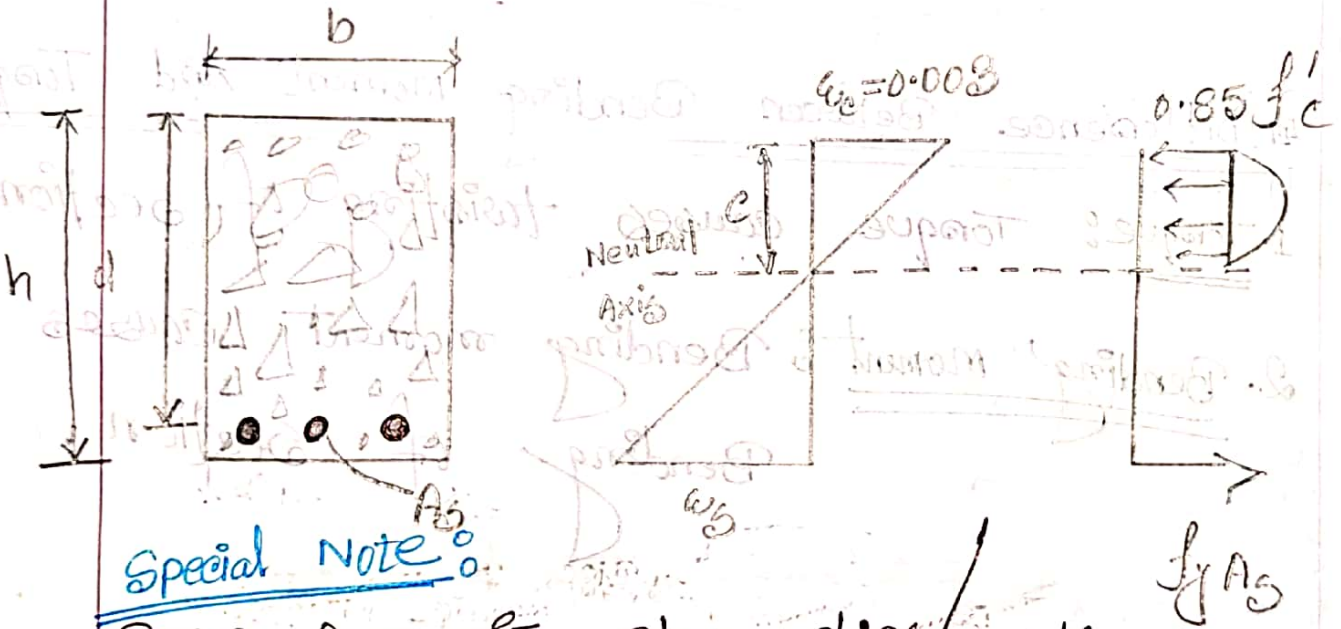
Difference Between Bending Moment and Torque

1. **Torque:** Torque causes twisting of section.

2. **Bending Moment:** Bending moment causes Bending of section.

Singly Reinforced Beam :

A singly reinforced Beam is a beam provided with longitudinal reinforcement in the tension zone only. Compressive forces are handled by the concrete in the beam,



Special Note :

Beam এর মধ্যে Stone chips/Brick chips use করি। ভাল মানের Stone chips এ 4000–4500 psi strength লাগবে, Cylinders Test এর মাধ্যমে compressive strain বের করতে পারবো।

"How to determine the Compressive strength of Concrete".

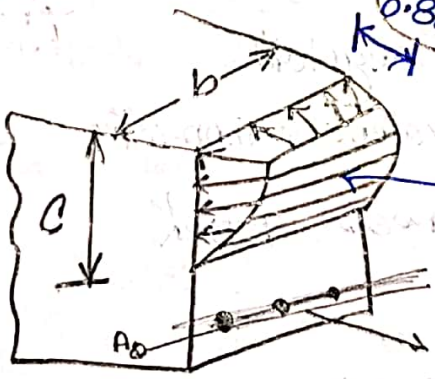
Whitney's Rectangular Stress Distribution:

For purposes of simplification and practical application, a fictitious but equivalent rectangular Concrete stress distribution was proposed. This rectangular stress distribution was proposed by Whitney (1942) and subsequently adopted by the ACI Code.

ACI → American Concrete Institute

ACI code এ আছে

$0.85f_c'$ → Block এ maximum compressive stress



Note:

Neutral Axis থেকে যত বেশী উপরে যাবে তত compressive stress develop হবে।

#very very important parts —

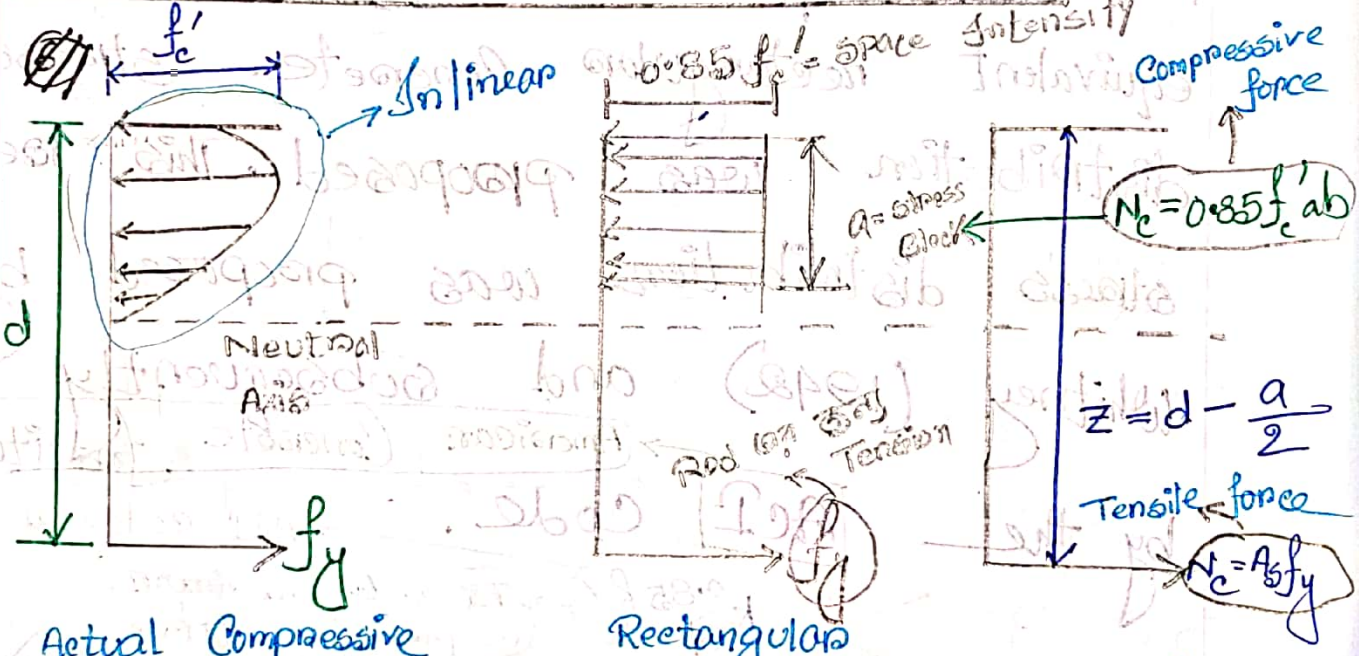
① what is stress.

② what is strain.

③ what is Bending

④ what is twisting

⑤ what is Poison Ratio.



Actual Compressive Stress Block

Rectangular Equivalent Compressive Stress Block

Internal Couple

Note :-

1. f_c' = concrete এর stress

2. f_y = steel এর yield Stress

Doubly Reinforced Beam :

Beams reinforced with steel in compression and tension zones are called doubly Reinforced Beams. This type of Beam will be found necessary when due to head room consideration or architectural consideration the depth of the beam is restricted. The beam with its limited depth, if reinforced on the tension side only, may n't have enough moment of resistance, to resist the bending moment. By increasing the quantity of steel in the tension zone, the moment of resistance can't be increased indefinitely. [Doubly Reinforced Beam ও Tensile এবং compression ২ জায়গায় reinforcement দিতে হবে, Doubly Reinforced Beam ব্যবহার করি কারণ —

(৪) কক্ষের উচ্চতা অধিক পাওয়ার ক্ষেত্রে, যেমনঃ আমাদের Classroom.

(৫) বীমের আকার সীমিত রাখা হয়।

(৬) অধিক বেন্ডিং মোমেন্ট প্রতিরোধ করতে হয়।

(৭) বীমের span অধিক হয়

(৮) বীমের অতিরিক্ত load আরোপিত হয়।

Singly Reinforced Beam এবং Doubly Reinforced Beam এর মধ্যে পার্থক্য:

(১) যেন শুধুমাত্র প্রতিরোধ করার জন্য কেবলমাত্র টেনসাইল জোনে Reinforcement প্রদান করাকে Singly reinforced Beam বলে, অপরদিকে যে সকল বীমে compressive stress এবং tension stress উভয়কে প্রতিরোধ করার জন্য উভয় জোনে পৃথক পৃথক ভাবে Reinforcement ব্যবহার করা হয়, তাকে Doubly reinforced Beam বলে।

② Singly Reinforced Beam এ বীমের আকার নির্দিষ্ট থাকে না কিন্তু Doubly Reinforced Beam এ বীমের আকার নির্দিষ্ট থাকে।

③ Single Reinforced Beam এ Reinforcement তুলনামূলকভাবে কম লাগে কিন্তু Doubly Reinforced Beam এ Reinforcement তুলনামূলকভাবে বেশি লাগে।

④ Single reinforced Beam এ বীমের কক্ষ উচ্চতা তুলনামূলকভাবে কম পাওয়া যায় কিন্তু Double reinforced Beam এ বীমের কক্ষ উচ্চতা তুলনামূলকভাবে বেশি পাওয়া যায়।

Md Abdur Kharim Sir

Lecture Video — 02

18-05-2021

Doubly Reinforced Beam is used in the following circumstances:

The external live loads may alternate i.e may occur on either face of the member.

For example:

(1) A pile may be lifted in such a manner that the tension and compression zones may alternate.
[Pile এ Doubly Reinforced Beam use করা হয়, কারণ যখন load আসে তখন tension zone এ develop হয় আবার compression zone এ develop হয়।]

(2) The loading may be eccentric (ধাপছাড়া) and the eccentricity of the load may change from one side of the axis to another side.

③ The member may be subjected to a shock or impact or accidental lateral thrust. → ধাক্কা দেওয়া [member এর প্রভাব বা accidently পার্শ্বীয় চাপ দেওয়া হতে পারে।]

④ We prefer Doubly Reinforced Beam in the following situations :

① Doubly reinforced sections are generally resorted to in situations where the cross sectional dimensions of the beam are restricted (By architectural or other considerations)

② Where singly reinforced section isn't adequate in terms of moment resisting capacity. [singly reinforced section Moment resisting capacity জন্য পর্যাপ্ত নয়]

③ Doubly reinforced sections also used in a situations where reversal of the moment is likely. [Doubly reinforced section যেমন situation এ used করা হয় যেখানে reversal moment এর সম্ভাবনা থাকে।]

The presence of compression reinforcement reduces long term deflections due to shrinkage and creep.

Singly Reinforced Beam ⇒ Chapter-4 (4.2)

Reinforced Concrete Beam Behaviour:

Stage-1: Uncracked concrete stage

[যখন load এ Beam এর নীচে অর্ধাংশ Neutral axis এর ... নীচের part এ concrete আছে তা ফাটে না। তাই নীচের part এ reinforced দিয়েছি]

Concrete এর lower portion এ cracked করছে না

Stage-2: Un cracked concrete stage But concrete in Tension has cracked

[Compression zone এ কোনো cracked করছে না, Tension zone এ cracked করা শুরু হয়ে গেছে।]

80 → Page

Stage-3 : Uncracked concrete stage but concrete in Tension has cracked

[আস্তে আস্তে বাড়তেছে]

Stage-4 : The ultimate strength stage

[Ultimate দিয়ে যেটা বুঝে Design করা strength Stage যেখানে গিয়ে যেটা design করা cracked করতেছে।]

Moment Curvature Diagram For a RC Beam

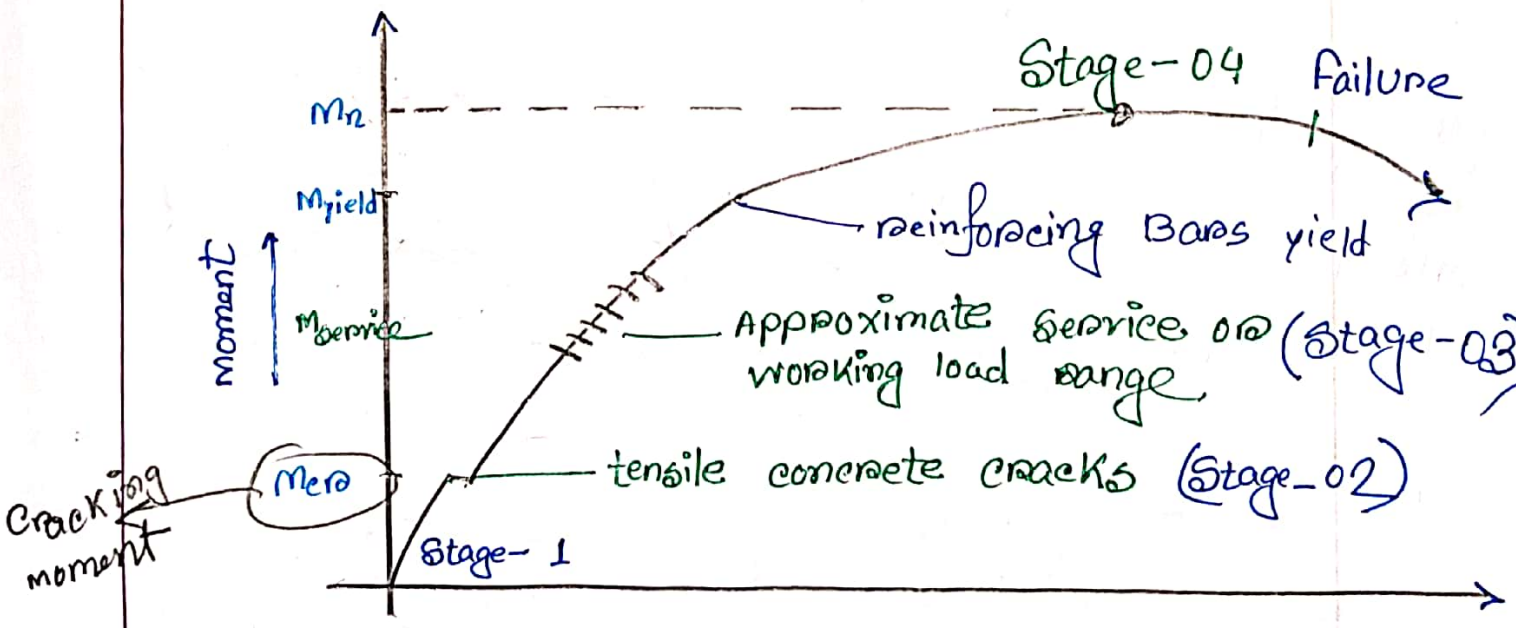
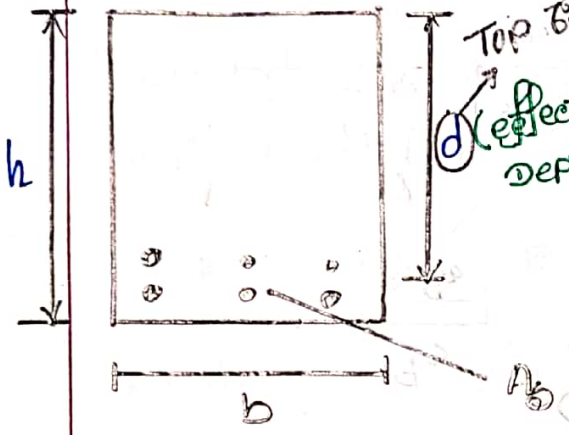
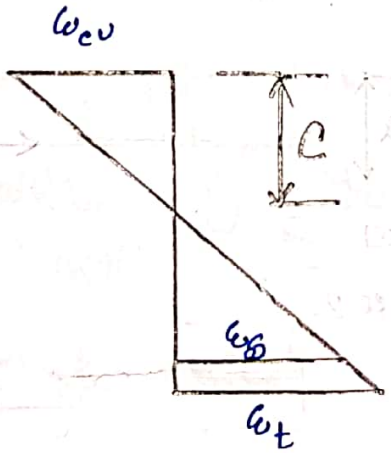


Fig: Moment-curvature Diagram for reinforced concrete Beam with

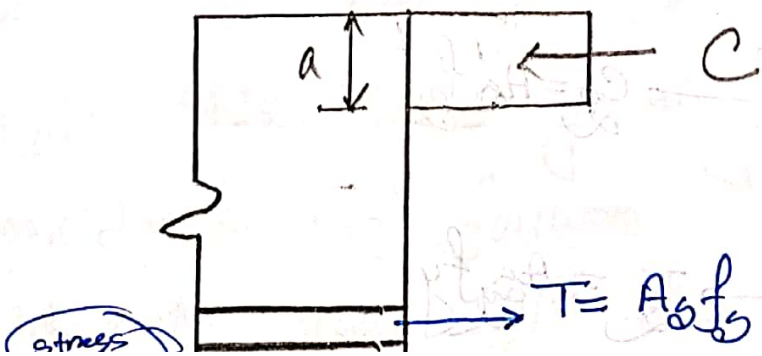
Schematic Representation of Stresses And Strains in a typical singly reinforced concrete Beam Section



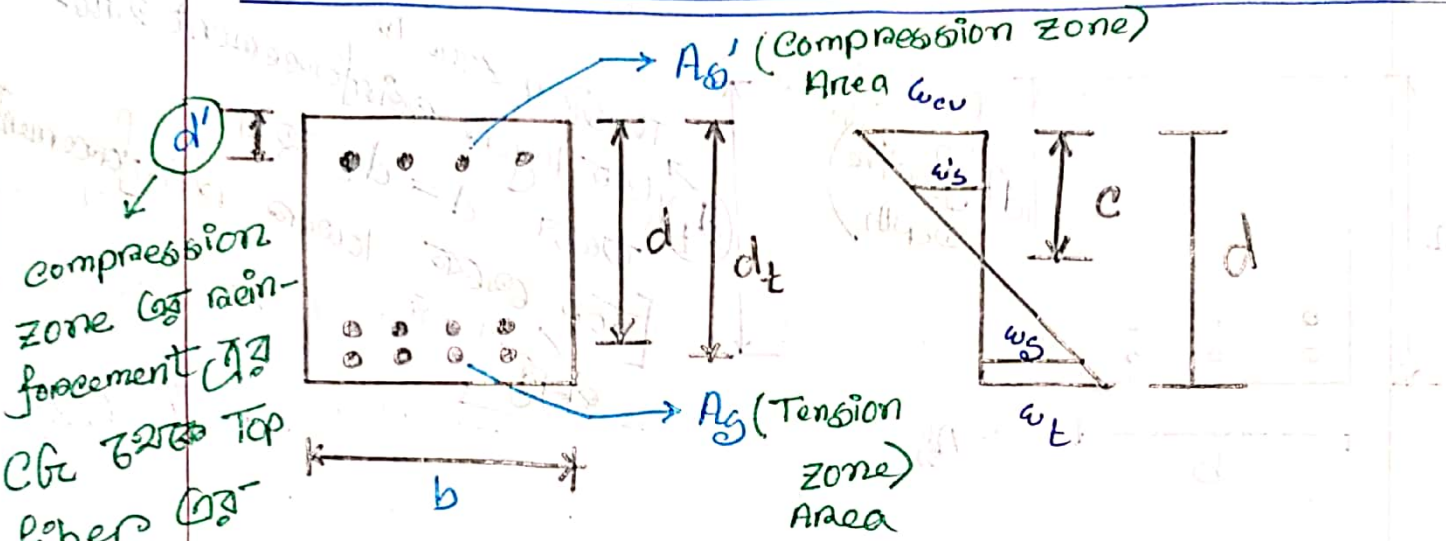


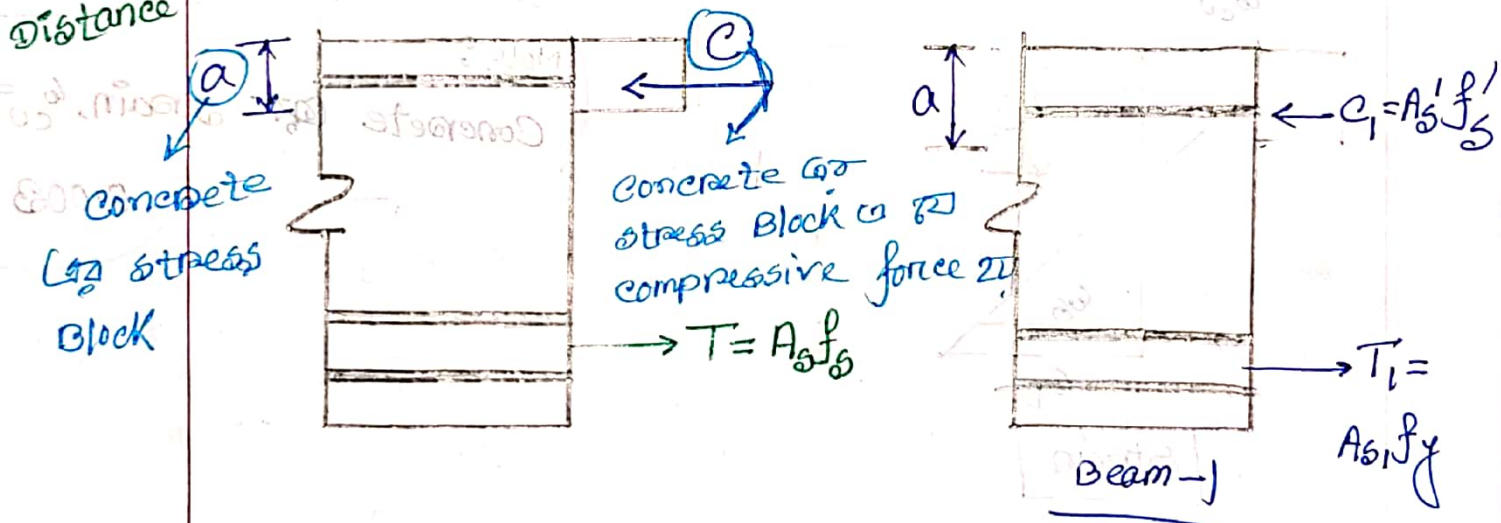
Strain

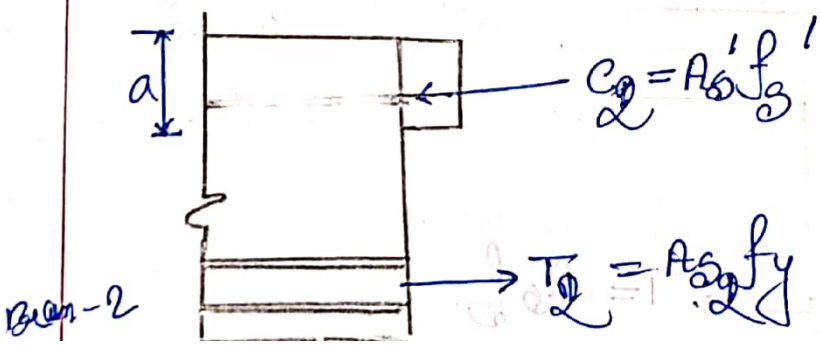
Note:
Concrete এর strain, ω_{cu} = 0.003,



Schematic Representation of stresses and strains in a typical Doubly reinforced concrete Beam Section







Balanced section:

The steel provided in the beam is such that both concrete and steel reach the limiting values of strain simultaneously [Balanced section হল concrete and steel এর limiting value এর Design করতেছি Base on strain যেন reach করবে simultaneously.]

Under Reinforced section:

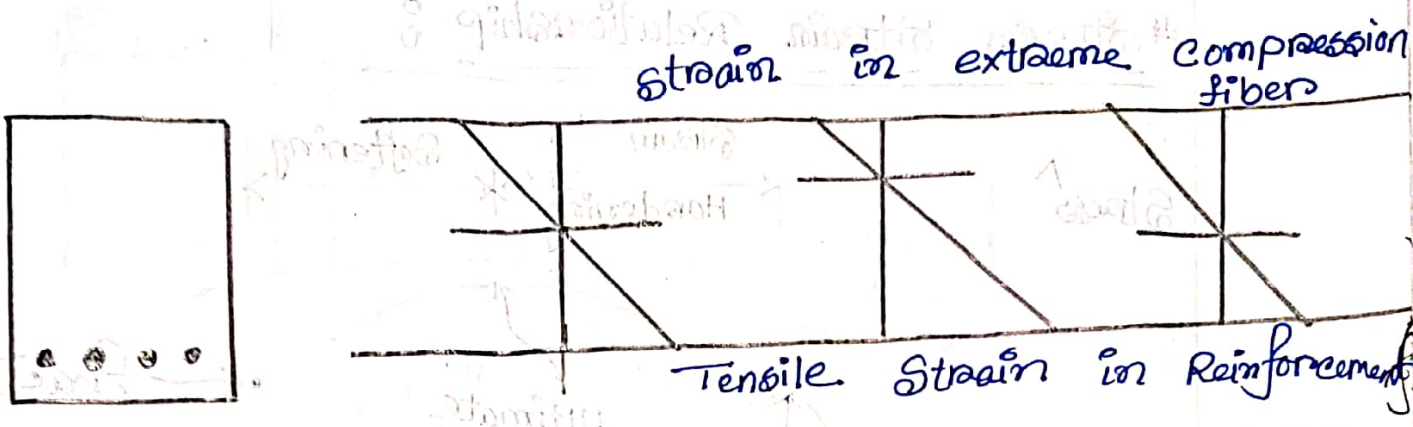
The steel provided in the beam is such that steel reach the limiting values of strain prior (পূর্বে) to concrete. [Ductile failure হবে], this results in yielding of the steel and steel could yield till it attains the ultimate strain at which point it breaks. It's important to notice that it's the yielding strain that is considered as failure strain for steel and not the ultimate fracture strain.

সহ্য করবে

the steel still has to undergo strain hardening, softening and then fracture.

Over Reinforced Section:

The steel provided in the beam is such that concrete reach the limiting values of strain prior to steel. This results in breaking of concrete and since there is no concrete present to take the compression; therefore, the beam fails suddenly.



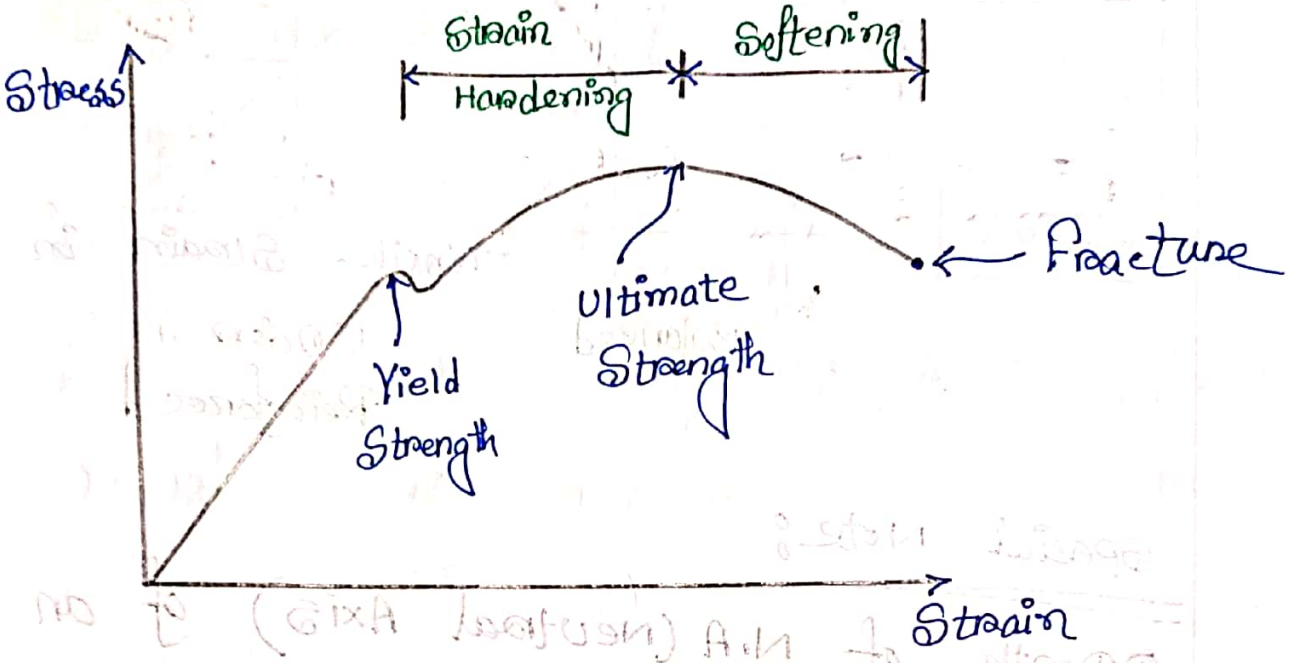
Special Note:

① Depth of N.A (Neutral Axis) of an Under reinforced section will be less than that of a Balanced section.

② Depth of N.A of an Over reinforced section will be greater than that of a Balanced section.

Concrete or modulus of elasticity ⇒

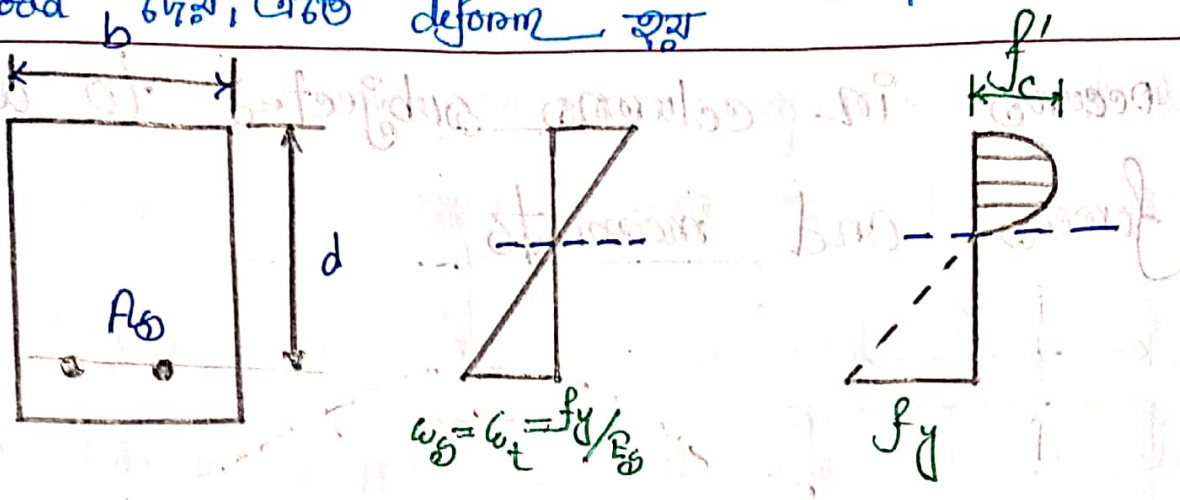
Stress Strain Relationship :



Balanced Strain Condition :

The Balanced strain condition develops in the section when the tension steel with first yield reaches a strain corresponding to its yield strength, f_y or $\varepsilon_s = \frac{f_y}{E_s}$, Just as the maximum strain in concrete at the extreme compression fibers reaches 0.003

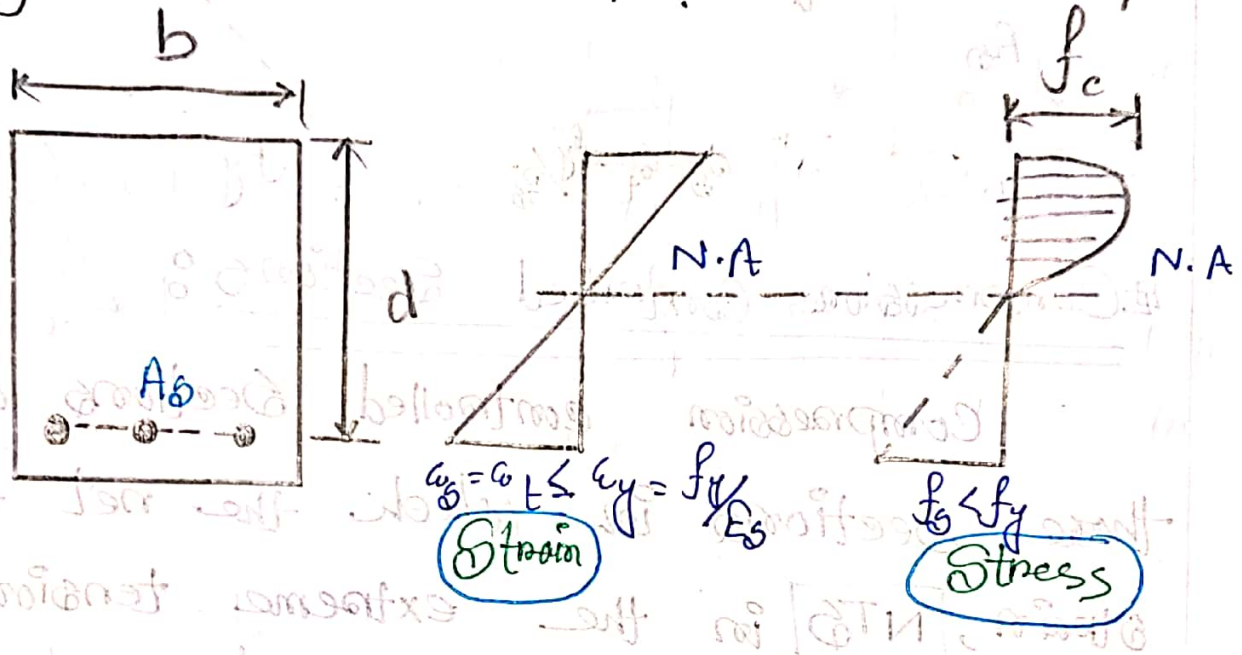
আমরা সাধারণত Tension control section Design করতে চাইবো কিন্তু কোন কোন Beam এর ক্ষেত্রে, Beam এ Transverse load দিলে, সেটা deform হয়



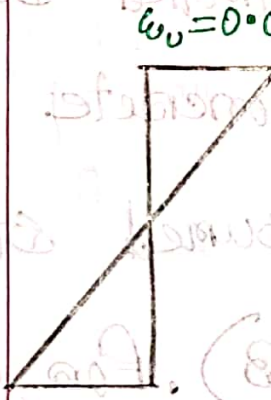
Compression Controlled Sections:

Compression controlled sections are those sections in which the net tensile strain, NTS in the extreme tension steel at nominal strength is equal to or less than the compression controlled strain limit at the time when concrete in compression reaches its assumed strain limit of 0.003 ($\epsilon_c = 0.003$). For grade 60 steel ($f_y = 60$ ksi), the compression controlled strain limit may be taken as a net strain of 0.002. This case

occurs in columns subjected to axial forces and moments.



"Net Tensile Strain and c/d_t Ratio"

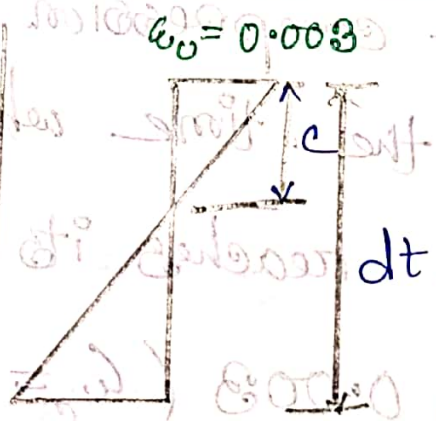


$\omega_t = 0.005$

$\frac{c}{d_t} = \frac{0.003}{0.003 + 0.005}$

$= 0.375$

(a) Tension controlled member

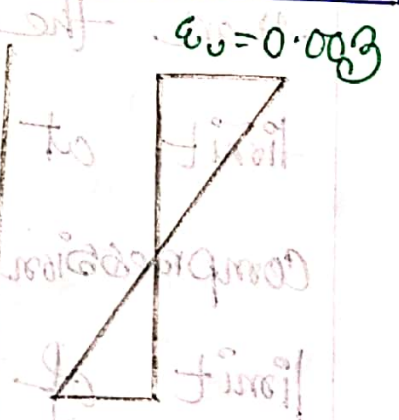


$\omega_t = 0.004$

$\frac{c}{dt} = \frac{0.003}{0.003 + 0.004}$

$= 0.429$

(b) minimum Net tensile Strain for flexural member



$\omega_t = 0.002$

$\frac{c}{d_t} = \frac{0.003}{0.003 + 0.002} = 0.600$

(c) Compression controlled member.

Strain Limits, Variation of Strength reduction Factor ভালো করে পড়বে, বই Page : 94, 95

Difference Between Analysis and Design :

Analysis : Design করে দিয়েছে, Design টা যেমন যে Tension zone এ কোথায়, compression zone এ কোথায়; height, width, Length সব দিয়েছে, সে টা Analysis করে দেখবে required moment ঠিক আছে কী না যেটা দরকার তা fulfill করতেছে কী না।

Design : Design হচ্ছে সব কিছু বের করতে হবে, load হিসাব করতে হবে, Moment Diagram দেখাতে হবে, Shear force, Bending moment দেখাতে হবে, সব কিছু Detailing করতে হবে,

Assignment

Steel এবং concrete এর modulus of elasticity কত? এটা কিভাবে Determine করা হয়।

Analysis of a Doubly Reinforced Beam:

A doubly reinforced rectangular section has the following properties:

$b = 11$ inch ; $d = 20$ inch ; $d' = 2$ inch,

(b = width; d' = Clear cover from the top fiber to the compression zone Reinforcement)

$A_s' = 1 \text{ in}^2$

(A_s' = Compression zone এ থাকা Reinforcement এর area)

$A_s = 4 \text{ in}^2$

$E_s = 29 \times 10^6$ psi

(E_s = modulus of elasticity of steel)

$f_y = 40{,}000$ psi

Calculate the design moment capacity of the beam if (a) $f_c' = 3000$ psi and (b) $f_c' = 5000$ psi

Note:

1. Strength Reduction factor (ϕ) বলতে কি বুঝায়? member এর size বেড়ে গেলে, member এর size বেড়ে যাওয়া মানে খরচ বাড়বে

2. n denote the nominal strengths in flexure, thrust and shear.

3. U = factored load moment, thrust and shear.

Design Strength ≥ Required Strength

$\phi M_n \geq M_U$ → Ultimate moment

ϕ → Strength Reduction factor

M_n → nominal moment

→ Basic

Formula:

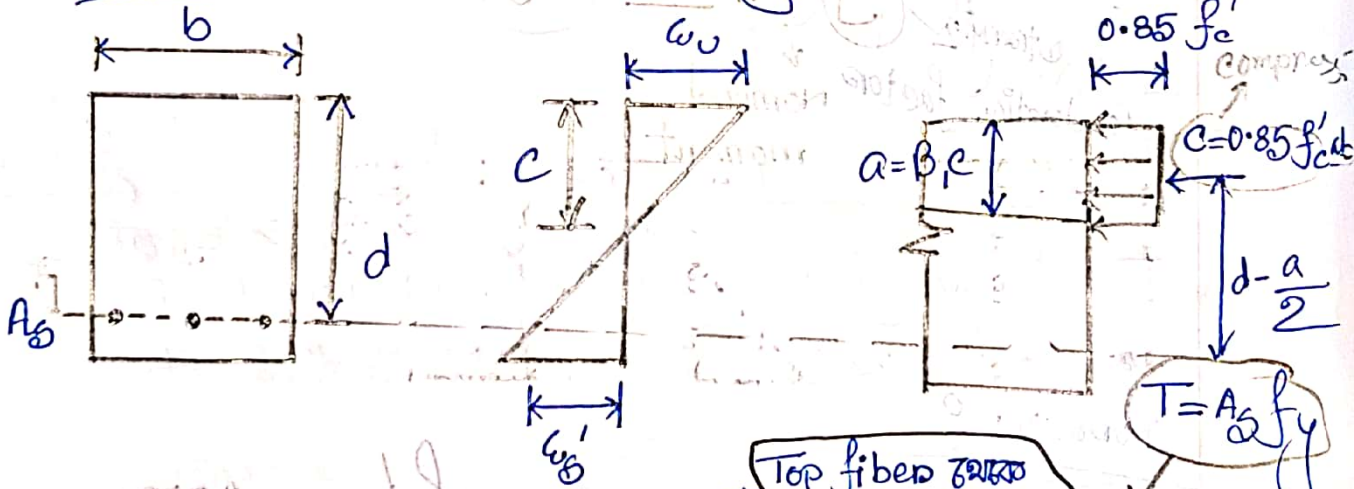
$$\beta_1 = 0.85 - 0.05 \frac{f'_c - 4000}{1000} \; ; 0.65 \leq \beta_1 \leq 0.85$$

∴ The maximum reinforcement ratio for a tension controlled Beam,

$$\rho_{0.005} = 0.85 \times \beta_1 \times \frac{f'_c}{f_y} \times \frac{\omega_u}{\omega_u + 0.005}$$

0.005 → Strain of Reinforcement → Tension কারণ

Singly Reinforced Rectangular Beam :



$$M_n = A_s f_y \left(d - \frac{a}{2}\right)$$

Top fiber থেকে $\frac{a}{2}$ অংকা দিলে আসবেছে

d → effective depth

$$a = \frac{A_s f_y}{0.85 \times f_c' \times b}$$

$$a = \frac{A_s f_y}{0.85 \times f_c' \times b}$$

Proof: $C = T$

or, $0.85 \times f_c' \times a \times b = A_s f_y$

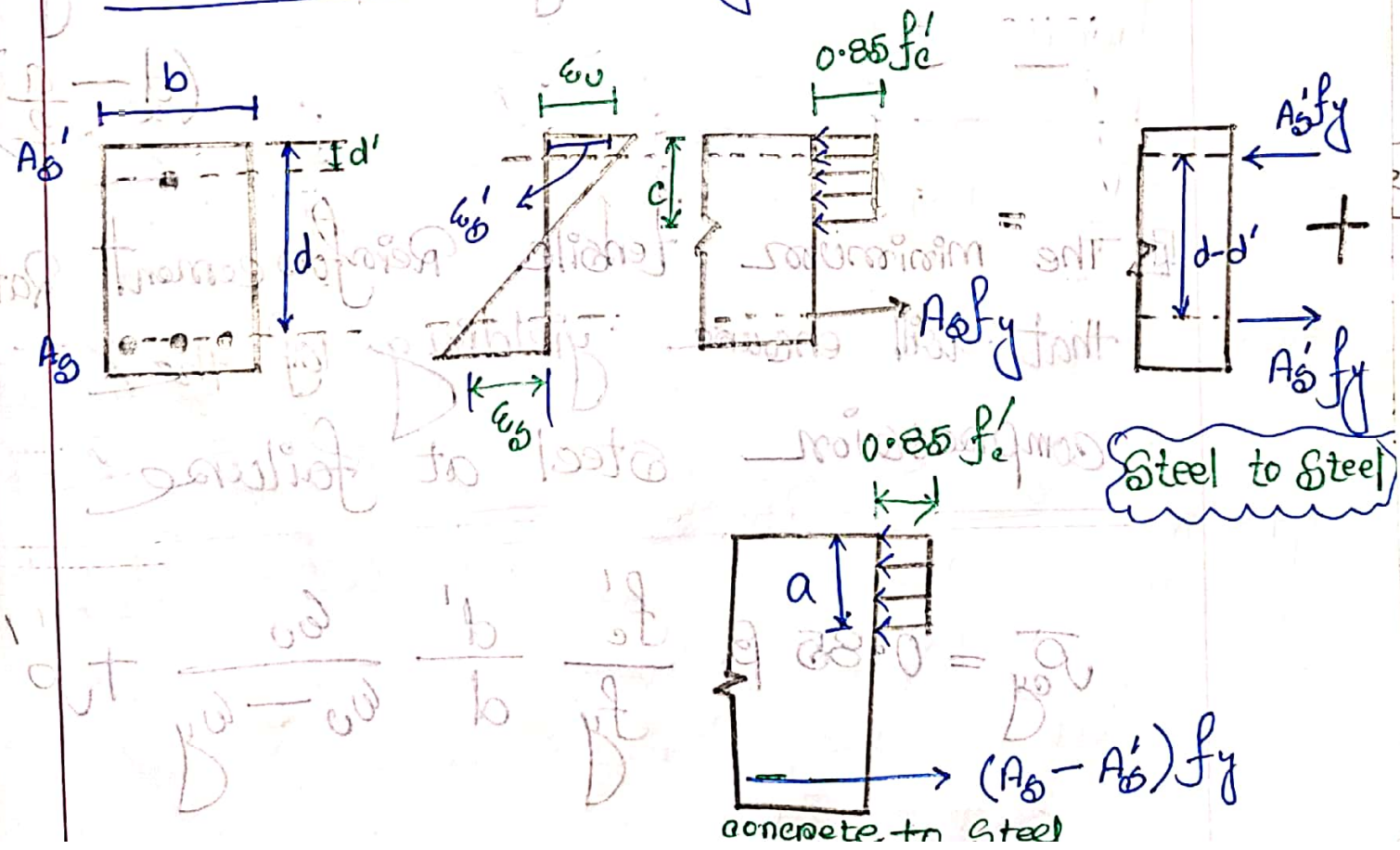
or, $a = \frac{A_s f_y}{0.85 \times f_c' \times b}$

Minimum Reinforcement Ratio

$$\rho_{min} = \frac{3\sqrt{f_c'}}{f_y} \geq \frac{200}{f_y}$$

Page-98

Doubly Reinforced Rectangular Beam



$$M_{n1} = A_s' f_y (d - d')$$ → Steel to Steel

$$M_{n2} = (A_s - A_s') f_y \left(d - \frac{a}{2}\right)$$ → Concrete to Steel

$$a = \frac{(A_s - A_s') f_y}{0.85 f_c' b}$$

$$\therefore M = M_{n1} + M_{n2} = A_s' f_y (d - d') + (A_s - A_s') f_y \times \left(d - \frac{a}{2}\right)$$

- The minimum tensile Reinforcement Ratio that will ensure yielding of the compression steel at failure

$$\rho_{cy} = 0.85 \beta_1 \frac{f_c'}{f_y} \frac{d'}{d} \frac{\omega_v}{\omega_v - \omega_y} + \rho'$$

Problem-1

Analysis of a Doubly Reinforced Beam :

A doubly reinforced Rectangular Section has the following properties : $b = 11$ inch ; $d = 20$ inch ; $d' = 2$ inch ; $A_s' = 1\ in^2$; $A_s = 4\ in^2$; $E_s = 29 \times 10^6$ psi ; $f_y = 40{,}000$ psi . Calculate the design moment capacity of the beam if

(a) $f_c' = 3000$ psi

(b) $f_c' = 5000$ psi

Solution :

(a) $\rho = \frac{A_s}{bd} = \frac{4}{11 \times 20} = 0.018$ [Tension zone]

$\rho' = \frac{A_s'}{bd} = \frac{1}{11 \times 20} = 0.00455$ [compression zone]

maximum Reinforcement Ratio for $f_c' = 3000$ psi

$$\therefore \rho_{0.005} = 0.85 \times \beta_1 \times \frac{f_c'}{f_y} \times \frac{\epsilon_u}{\epsilon_u + 0.005}$$

$$= 0.85 \times 0.85 \times \frac{3000}{40,000} \times \frac{0.003}{0.003+0.005}$$

$$= 0.0203$$

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From Table 4.1 [Concrete Stress Block Parameter]

$f_c' \leq 4000$ psi $\Rightarrow$ $\beta_1 = 0.85$

Again,

$f_c' \geq 4000$ psi $\Rightarrow$

$\beta_1 = 0.85 - 0.05 \frac{f_c' - 4000}{1000}$

$0.65 \leq \beta_1 \leq 0.85$

$\therefore \rho_{actual} < \rho_{0.005}$

So, the beam should be analyzed as Singly Reinforced Beam (Ans:)

(b) Maximum Reinforced ratio for $f_c' = 5000$ psi.

$$\rho_{0.005} = 0.85 \times \beta_1 \times \frac{f_c'}{f_y} \times \frac{\omega_u}{\omega_u + 0.005}$$

$$= 0.85 \times 0.80 \times \frac{5000}{40,000} \times \frac{0.003}{0.003+0.005}$$

$$= 0.0319$$

From Table 4.1

$f_c' = 5000$ psi

$\therefore \beta_1 = 0.80$

$\therefore \rho_{actual} < \rho_{0.005}$.

So, the beam should be analyzed as Singly Reinforced Beam (Ans:)

Possible Four condition of Yielding of Reinforcement

1. Both Tension steel and Compression steel yield.
2. Tension steel yields but Compression steel doesn't yield.
3. Tension steel doesn't yield but compression steel Yields.
4. Neither Tension steel nor Compression steel Yields.

1. If both Tension and Compression reinforcement yield.

At Yield stress,

$\varepsilon_s = \varepsilon_y$ for Tension steel

$\varepsilon_s' = \varepsilon_y$ for Compression steel

Suppose, steel 6000 psi

$$\text{strain} = \frac{6000}{29 \times 10^6} = 2.069 \times 10^{-4}$$

অন্যথায় না হলে ——→

$M_n = M_{n1} + M_{n2}$

$$= A_s' f_y (d - d') + (A_s - A_s') f_y \left(d - \frac{a}{2}\right)$$

For compression steel to yield, condition can be found out by,

$$\frac{c}{d'} = \frac{\omega_v}{\omega_v - \omega_y}$$

$$\therefore c = \frac{\omega_v}{\omega_v - \omega_y} \times d'$$

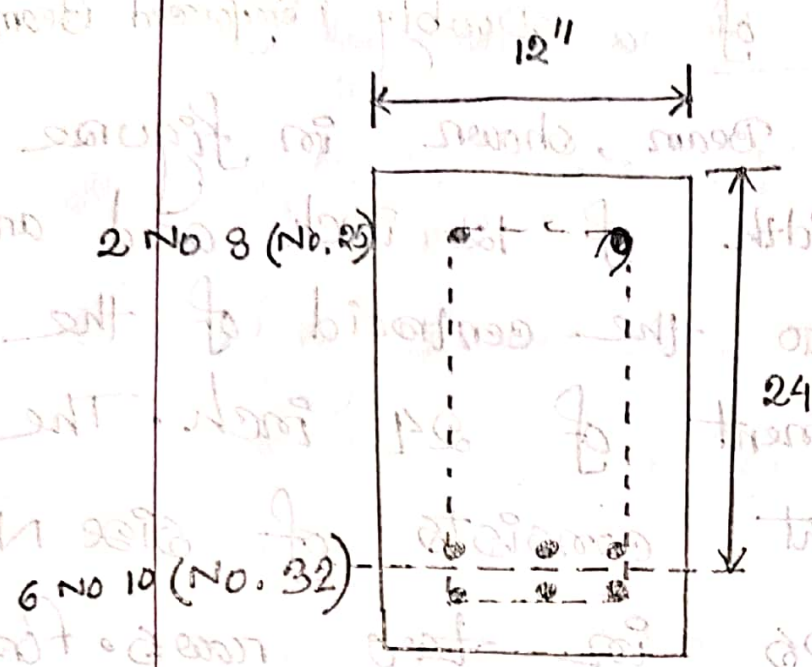
$$\therefore \overline{\rho}_{cy} = 0.85 \beta_1 \frac{f_c'}{f_y} \frac{d'}{d} \frac{\omega_v}{\omega_v - \omega_y} + \rho'$$

If the tensile reinforcement ratio is greater than $\overline{\rho}_{cy}$, the compression steel will yield when the beam fails

$$\rho_{actual} > \overline{\rho}_{cy}$$

Problem – 2 & Analysis of a Doubly Reinforced Beam

A rectangular Beam, shown in figure below, has a width of 12 inch and an effective depth to the centroid of the tension reinforcement of 24 inch. The tension reinforcement consists of size No 10 (No 32) bars in two rows. for simplicity in calculating c_t, d_t will be taken as d. Compression reinforcement consisting of two No 8 (No. 25) bars is placed 2.5 inch from the compression face of the beam. If f_y = 60,000 psi and f'_c = 5000 psi. what is the design moment capacity of the beam?



Solution:

Area of No. 8 Bars, $A_s' = (2 \times 0.79)\ in^2$ (No 8 Bars Area)

$\therefore A_s' = 1.58\ in^2$

Area of No 10 Bars, $A_s = (6 \times 1.27)\ in^2$

$= 7.62\ in^2$

$$\rho = \frac{A_s}{bd} = \frac{7.62}{12 \times 24} = 0.0264$$

$$\rho' = \frac{A_s'}{bd} = \frac{1.58}{12 \times 24} = 0.0055$$

Ductile failure

Maximum reinforcement ratio of singly reinforcement tension controlled beam

$$\rho_{0.005} = 0.85\,\beta_1 \frac{f_c'}{f_y} \times \frac{\omega_v}{\omega_v + 0.005}$$ [Equation 4.26(c) or Table A4

$$= 0.85 \times 0.80 \times \frac{5000}{60000} \times \frac{0.008}{0.008 + 0.005}$$

$$= 0.0213$$

Given,
$f_c' = 5000$ psi
$f_y = 60,000$ psi

$\therefore \rho_{actual} > \rho_{0.005}$.

So, the beam must be analyzed as Doubly Reinforced Beam.

For compression steel to yield condition:

$$\overline{\rho}_{cy} = 0.85 \times \beta_1 \frac{f_c'}{f_y} \times \frac{d'}{d} \times \frac{\omega_v}{\omega_v - \omega_y} + \rho'$$

$$= 0.85 \times 0.8 \times \frac{5000}{60,000} \times \frac{2.5}{24} \times \frac{0.003}{0.003 - 0.0027} + 0.0055$$

$$= 0.0245$$

$\therefore \rho_{actual} > \overline{\rho}_{cy}$.

Note: RCC তে Detailing of Reinforcement V.V. Im
BNDC - 1998, 2006, 2015
Best

So, the compression steel will yield.

For tension steel to yield,
The maximum reinforcement ratio is given by

$$\rho_{0.005} = \rho_{0.005} + \rho'$$

$$= 0.0213 + 0.0055$$

$$= 0.0268$$

$$\therefore \rho < \rho_{0.005}$$

So, the tension steel will able yield.

$\therefore$ Steel block of Concrete, $a = \frac{(A_s - A_s')f_y}{0.85 \times f_c' \times b}$

$$= \frac{(7.62 - 1.58) \times 60,000}{0.85 \times 5000 \times 12}$$

$$= 7.11 \text{ inch}$$

$\therefore$ Top fiber to Neutral Axis Location, $C = \frac{a}{\beta_1}$

$$= \frac{7.11}{0.8}$$

$= 8.89$ inch

Strength Reduction factor, $\omega_t = \omega_u \left(\frac{d_t - c}{c}\right)$

$= 0.003 \left[\frac{24 - 8.89}{8.89}\right]$

$= 0.005 \mid > 0.005$

So, it's tension controlled

Now, strength Reduction Factor, $\phi = 0.90$ (Lecture-6, Slide 31 onwards)

∴ Design moment, $M_n = M_{n1} + M_{n2}$ → Rest of the tensile steel area : concrete area for moment

Compression steel area

Tensile steel area

Moment

$= A_s' f_y (d - d') + (A_s - A_s') f_y \left(d - \frac{a}{2}\right)$

$= 1.58 \times 60 \times (24 - 2.5) + (7.62 - 1.58) \times 60 \times \left[24 - \frac{7.11}{2}\right]$

$= 9450$ inch-Kip

∴ Design strength, $\phi M_n = (0.90 \times 9450)$ in-Kip

$= 8500$ inch-Kip (Ans)

Problem-3 : Design of Doubly Reinforced Beam

A rectangular beam that must carry a service live load of 2.47 kips/ft and a calculated Dead load of 1.05 kips/ft on an 18 ft simple span is limited in cross section for architectural reasons to 10 inch width and 20 inch total depth. If $f_y = 60{,}000$ psi and $f_c' = 4000$ psi, what steel area(s) must be provided?

Solution :

Factored load, $w = 1.2\,DL + 1.6\,LL$

$= [1.2 \times 1.05 + 1.6 \times 2.47]$ kip/ft

$= 5.21$ kip/ft

Factored load moment, $M_u = \frac{wL^2}{8}$

$= \frac{5.21 \times (18)^2}{8}$ ft-kip

$= 211$ ft-kip

$= (211 \times 12) = 2533$ kip-inch

এত moment কাজে 260

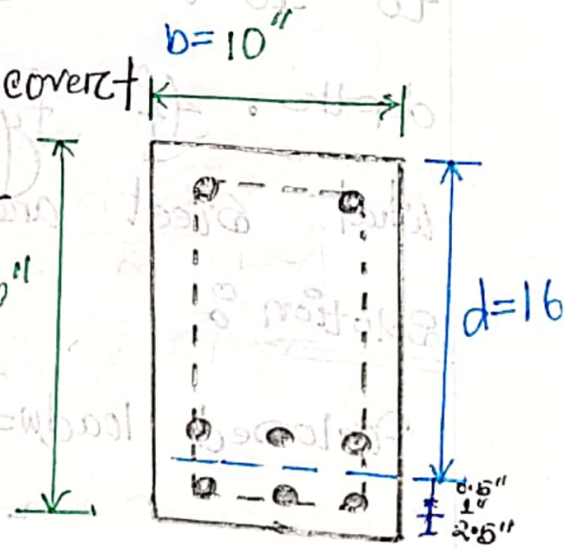
Top fiber বরাবর tension reinforcement এর জন্য

Effective depth, (d) [deduct minimum 2.5 inch to 3.5 inch from h]

Cover for Compressive Steel, (d') [minimum 2.5 inch]

Top fiber বরাবর compression reinforcement এর জন্য

∴ Effective depth, d = h − [clear cover + Reinforcement + Distance between reinforcement and CG]



$= 20 - [2.5 + 1 + 0.5]$

$= 16''$

By Assuming, it's tension control beam and singly reinforced Beam.

$$\rho_{0.005} = 0.85 \times \beta_1 \times \frac{f'_c}{f_y} \times \frac{\omega_u}{\omega_u + 0.005}$$

$$= 0.85 \times 0.85 \times \frac{4000}{60,000} \times \frac{0.003}{0.003 + 0.005}$$

$$= 0.0181$$

From, $f'_c = 4000$ psi the Table, $\beta_1 = 0.85$

Now,

$$\rho = \frac{A_s}{bd}$$

or, $A_s = \rho bd$

$$= 0.0181 \times 10 \times 16$$

$$= 2.90 \text{ in}^2$$

By assuming tensile reinforcement is yielded. ($f_s = f_y$)

$$a = \frac{A_s f_y}{0.85 \times f'_c \times b} = \frac{2.90 \times 60,000}{0.85 \times 4000 \times 10} = 5.12 \text{ inch}$$

$$\therefore f_s' = \omega_s' \times E_s$$

$$= 0.00175 \times 29 \times 10^6$$

$$= 50870 \text{ psi}$$

$$= 50.87 \text{ Ksi}$$

Now,

$$M_{n1} = A_s' f_y (d - d')$$

$$\therefore A_s' = \frac{M_{n1}}{f_y (d - d')}$$

$$= \frac{475}{50.87 (16 - 2.5)}$$

$$= 0.7 \text{ in}^2$$

It's the reinforcement needed in compression zone.

∴ Total reinforcement in tensile zone,

$$A_s = A_{s2} + A_s' \left(\frac{f_s'}{f_y} \right)$$

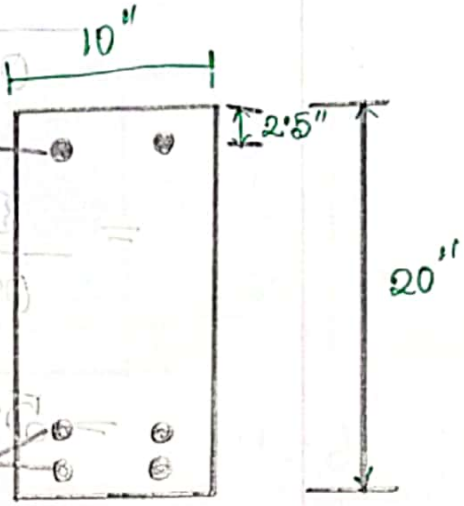
Singly Reinforced Beam Area

$$= 2.90 + 0.7 \times \left[\frac{50.87}{60} \right]$$

9 No bar area = 1

6 No bar area = 0.44

$= 3.50 \text{ in}^2$



Steel Area in Tension, 2 No 6

$A_s = 4 \times 1 = 4 \text{ in}^2$

Steel Area in Compression,

$A_s' = 2 \times 0.44$ 4 No 9

$= 0.88 \text{ in}^2$

Final Check:

Two No-6 Bars and 4 No 9 Bars will provide.

So, a final check is made to ensure that the selection of reinforcement doesn't creatic a lower compression than assumed 50.87 Ksi.

$$A_s - A_s' \left(\frac{f_s'}{f_y} \right) = 4 - 0.88 \left[\frac{50.87}{60} \right]$$

$= 3.25 \text{ in}^2$

which is greater than 2.90 in^2,

$$a = \frac{[A_s - A_s' (\frac{f_s'}{f_y})] \times f_y}{0.85 \times f_c' \times b}$$

$$= \frac{3.25 \times 60}{0.85 \times 4i. \times 10}$$

$$= 5.74 \text{ inch}$$

$$\therefore c = \frac{a}{\beta_1} = \frac{5.74}{0.85} = 6.75 \text{ inch}$$

$$\omega_s' = \omega_u \times \frac{(c - d')}{c}$$

$$= 0.03 \times \left[\frac{6.75 - 2.5}{6.75}\right]$$

$$= 0.0019$$

$$f_s' = \omega_s' \times E_s$$

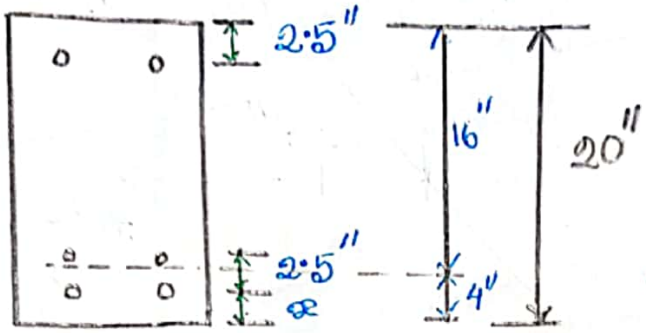
$$= 0.0019 \times 29 \times 10^6$$

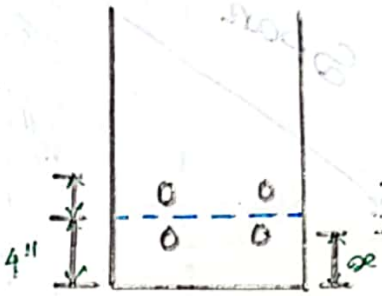
$$= 55100 \text{ psi}$$

$$= 55 \text{ ksi} > 50.87 \text{ ksi}$$ (Checked)

$\frac{x}{4} = \frac{2.5}{1.5}$

Determine d_t ?





Here,

$\frac{2.5}{2} = 1.25$

$\therefore x = 4 - 1.25$

$= 2.75"$

$\therefore d_t = 20 - 2.75$

$= 17.25"$

Now, $\epsilon_t = \epsilon_u \times \frac{d_t - c}{c}$

$= 0.003 \times \left[\frac{17.25 - 6.75}{6.75}\right]$ $(\because c = 6.75 \text{ inch})$

$= 0.0046$

0.005	0.9
0.00206	0.65
0.0046	?

Now interpolation,

$$\frac{0.005 - \frac{60}{29000}}{0.0046 - \frac{60}{29000}} = \frac{0.9 - 0.65}{0.9 - \phi}$$

$\therefore \phi = 0.87$

Design moment,

$$\phi M_n = \phi \left[A_s f_y \left(d - \frac{a}{2}\right) + A_s' f_y' (d - d')\right]$$

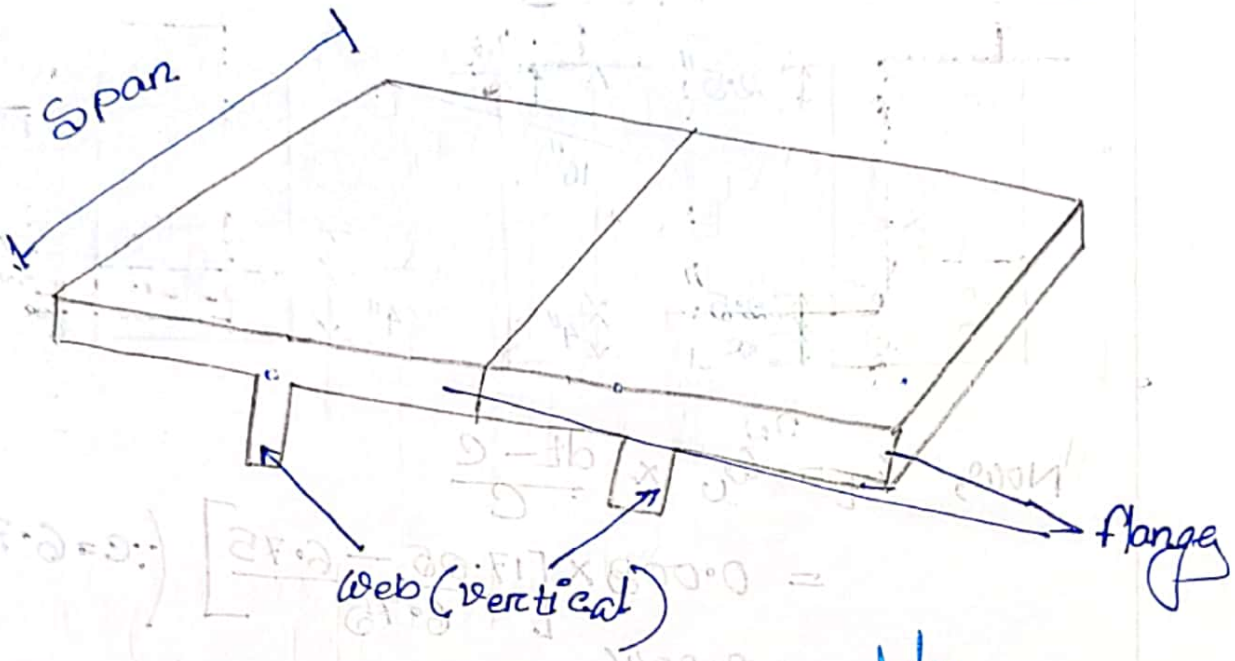
$$= 0.87 \left[3.25 \times 60 \left[16 - \frac{5.74}{2}\right] + 0.88 \times 55 \left[16 - 2.5\right]\right.$$

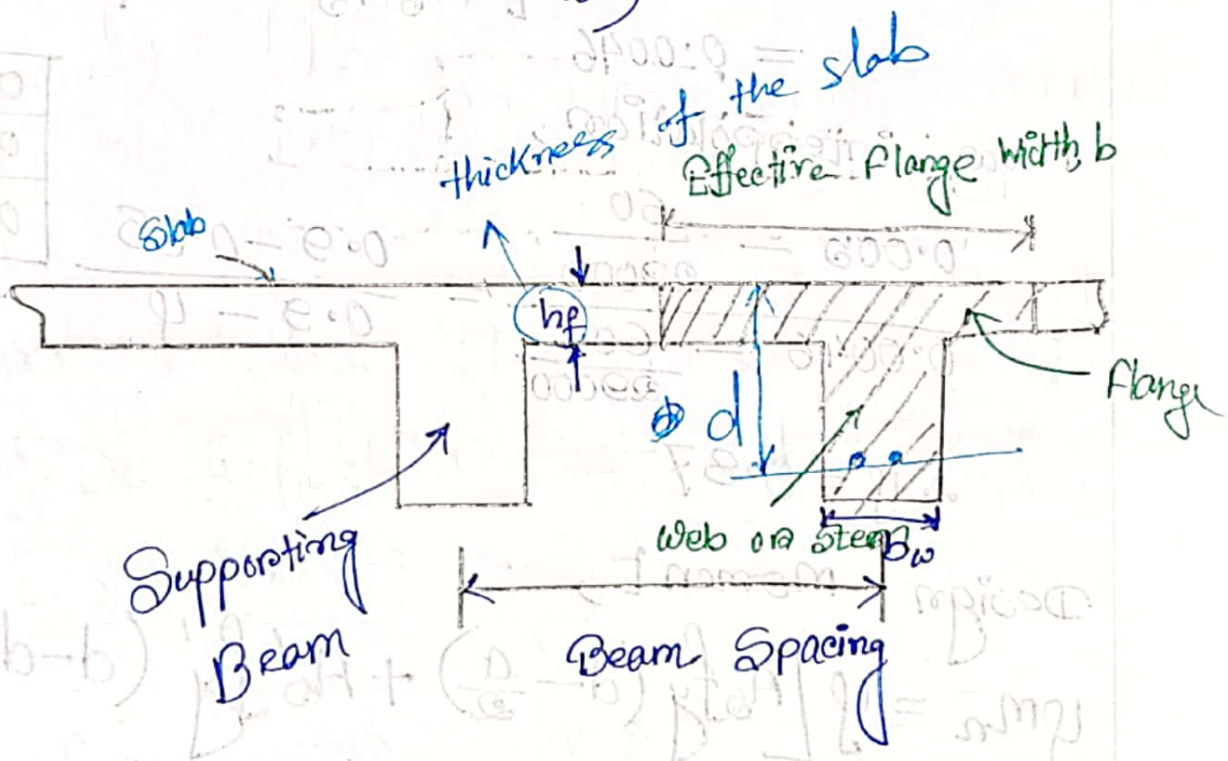
$= 2880$ Kip-inch

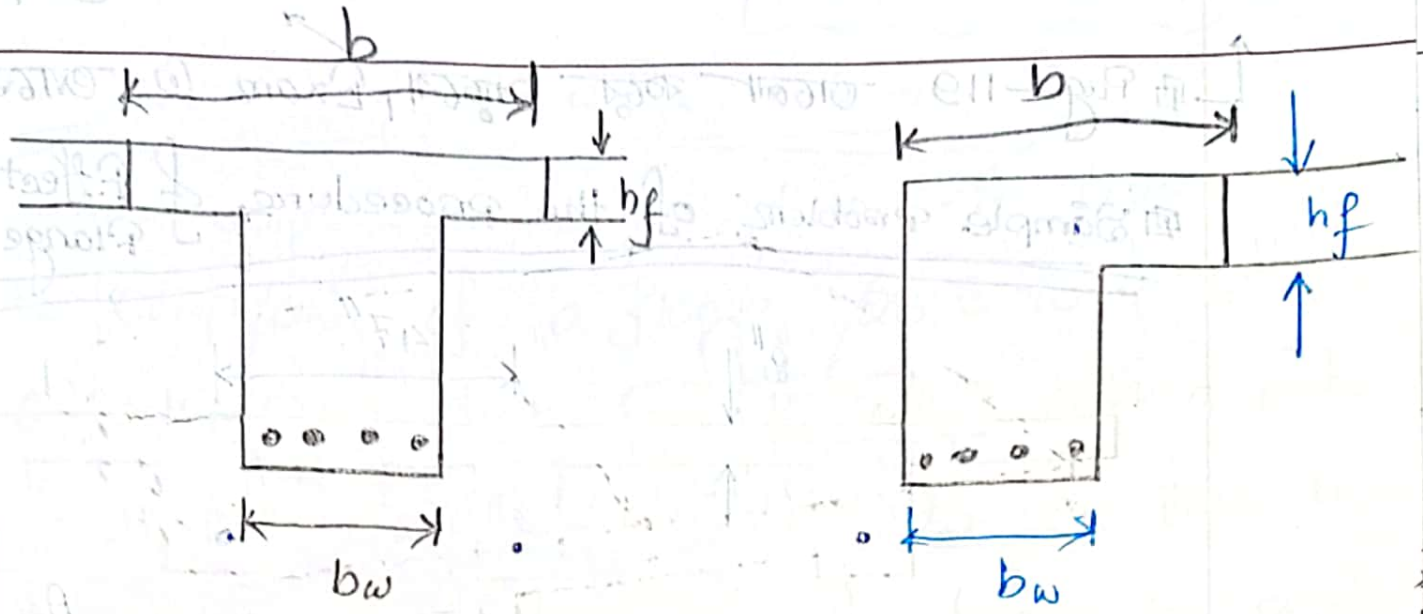
$\therefore \phi M_n > 2533$ kip-inch

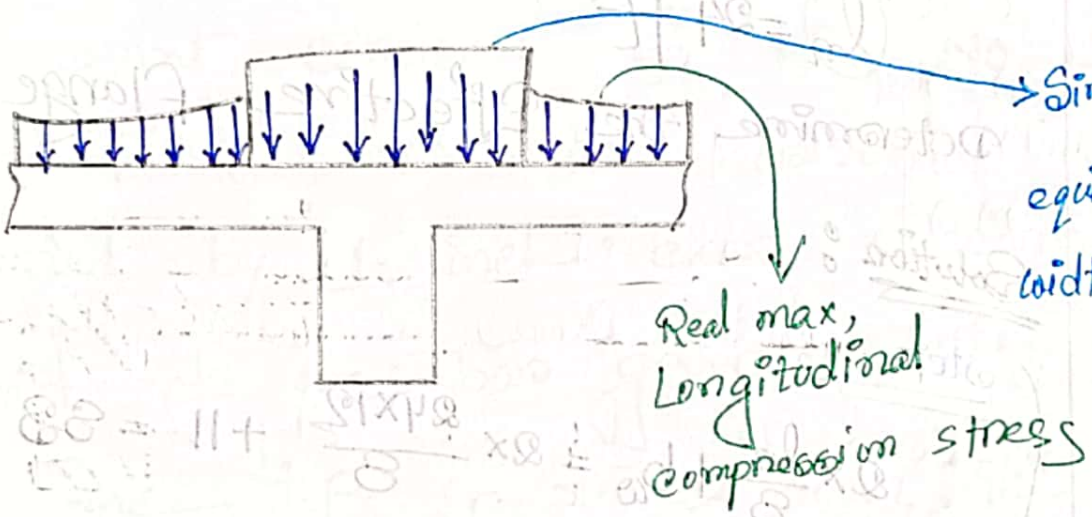
$\therefore$ So No further reinforcement is necessary.

09-06-2021


Span
flange
Web (vertical)


Thickness of the slab
Effective Flange width, b
Slab
hf
d
flange
Supporting Beam
Web or Stem b_w
Beam Spacing





Effective Flange Width :

It mainly depends on ——

① Span of Beam

② Breadth of Beam, b_w

③ width of slab on Adjacent sides.

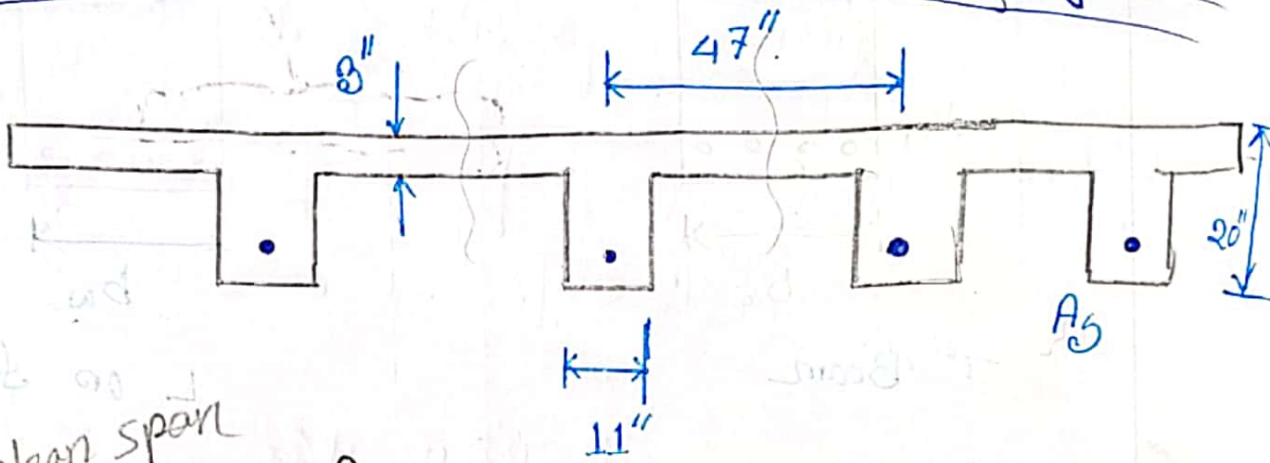
④ Thickness of slab

Exam এ আসবে

3 টা criteria দেয়া

Page-119 ভালো করে পড়বে, Exam এ আসবে,

Simple Problem of the procedure of Effective Flange width



clean span $\leftrightarrow (l_n) = 24$ ft

Determine the Effective flange width

Solution :

Step-1 :

$$2 \times \frac{l_n}{8} + b_w = 2 \times \frac{24 \times 12}{8} + 11 = 83 \text{ inch}$$

1st criteria

Step-2 :

$$2 \times 8h_f + b_w = 16 \times 3 + 11 = 59 \text{ inch}$$

Step-3

Centerline এ beam Spacing = 47 inch

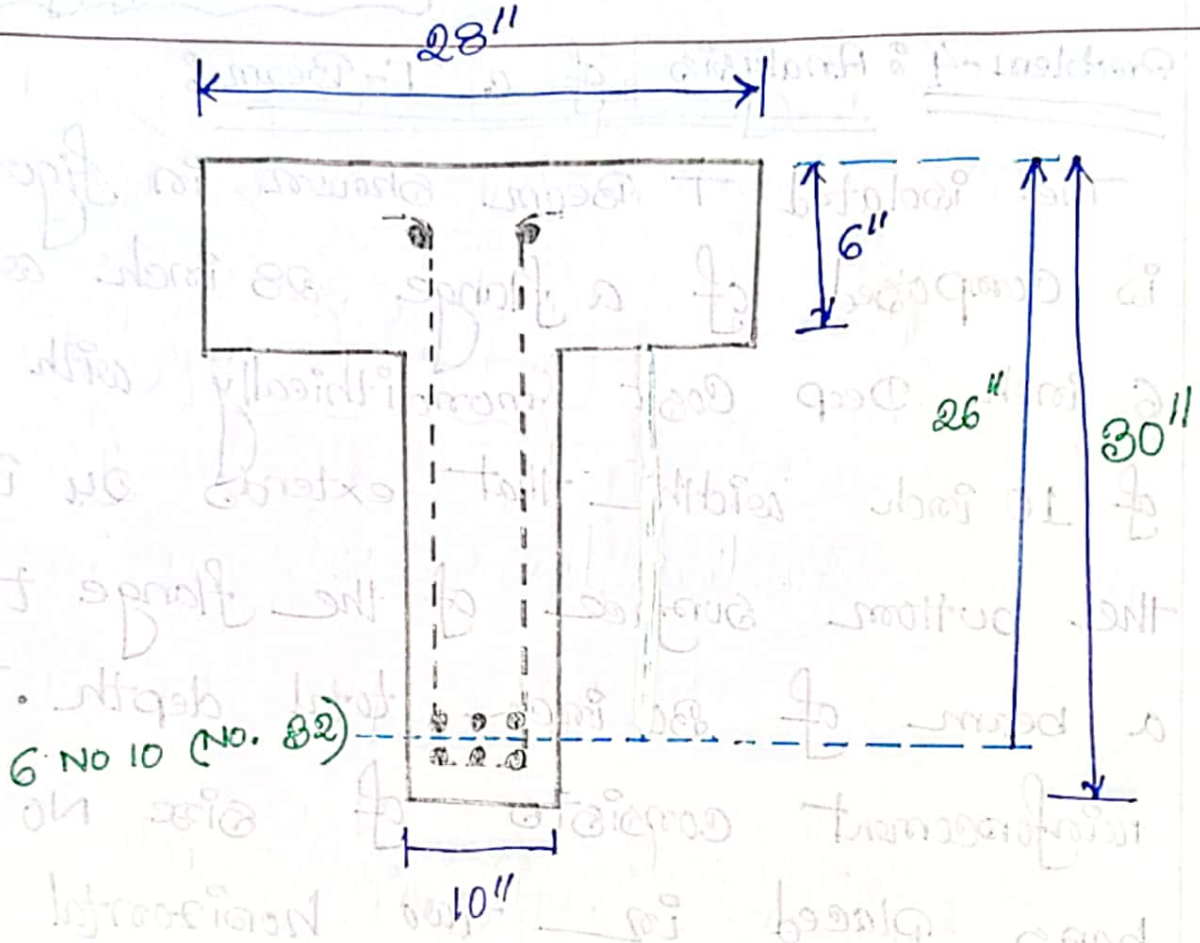
Here, the effective flange width = 47 inch

৩টা step এ ৩টা value পেলাম

monolithically মানে একসাথে ঢালাই, অর্থাৎ Beam এবং Slab একসাথে aggregate দেয়া হয়।

Problem-4 : Analysis of a T-Beam :

The isolated T Beam shown in figure 4.21 is composed of a flange 28 inch wide and 6 inch Deep Cast monolithically with a web of 10 inch width that extends 24 inch below the bottom surface of the flange to produce a beam of 30 inch total depth. Tensile reinforcement consists of size No 10 (No 3) bars placed in two horizontal rows separated by 1 inch clear spacing. The centroid of the bar group is 26 inch from the top of the beam. The concrete has a strength of 3000 psi and the yield strength of the steel is 60,000 psi. What is the design moment capacity of the beam?



Solution :

For isolated Beams in which the flange is used only for the purpose of providing additional compressive area, the flange thickness shall not be less than one half the width of the web (b_w) and the total flange width shall not be more than 4 time of the web width (b_w)

Here,

Flange $= 28''$

width $(b_w) = 10''$

$\therefore \frac{10}{2} = \frac{b_w}{2} = 5''$

$\therefore$ So, $5'' < 6''$ Satisfy

Again,

$\therefore 10 \times 4 = 40 > 28$ satisfy

So, $b_f = 28''$

~~Considering rectangular Beam~~

Now, Steel area,

$A_s = 6 \times 1.27$ → 10 No bar cut area

$= 7.62$

$\therefore b = b_f = 28''$

considering as a rectangular Beam,

$$a = \frac{A_s f_y}{0.85 \times f_c' \times b}$$

$$= \frac{7.62 \times 60}{0.85 \times 3 \times 28} = 6.40 \text{ inch}$$

$a > h_f$

This exceeds the flange thickness. So, T- Beam analysis is required.

$$A_{sf} = \frac{0.85 \times f_c' \times (b_f - b_w) \times h_f}{f_y}$$

$$= \frac{0.85 \times 3 \times [28 - 10] \times 6}{60}$$

$$= 4.59 \text{ in}^2$$

$$M_{n_1} = A_{sf} \times f_y \left(d - \frac{h_f}{2}\right)$$

$$= 4.59 \times 60 \times \left(26 - \frac{6}{2}\right)$$

$$= 6330 \text{ kip-inch}$$

$$a = \frac{(A_s - A_{sf}) f_y}{0.85 f_c' b_w}$$

$$= \frac{(7.62 - 4.59) \times 60}{0.85 \times 3 \times 10}$$

$$a = 7.13 \text{ inch}$$

$$M_{n2} = (A_s - A_{sf}) \times f_y \left(d - \frac{a}{2}\right)$$

$$= (7.62 - 4.59) \times 60 \times \left[26 - \frac{7.13}{2}\right]$$

$$= 4080 \text{ in-kips}$$

The depth of neutral Axis, $c = \frac{a}{\beta_1}$

$$= \frac{7.13}{0.85}$$

$$= 8.39 \text{ inch}$$

$\therefore dt = (30 - 2.5)$ inch $= 27.5$ inch [It's lowest Bar]

$$\frac{c}{dt} = \frac{8.39}{27.5} = 0.305 < 0.375$$ [Fig: 4.9; Page-95]

So, it's tension controlled Beam.

So, $\epsilon_t > 0.005$

$\therefore \phi = 0.90$

$\therefore \phi M_n = 0.9 (6330 + 4080)$

$= 9370$ kip-inch (Ans:)

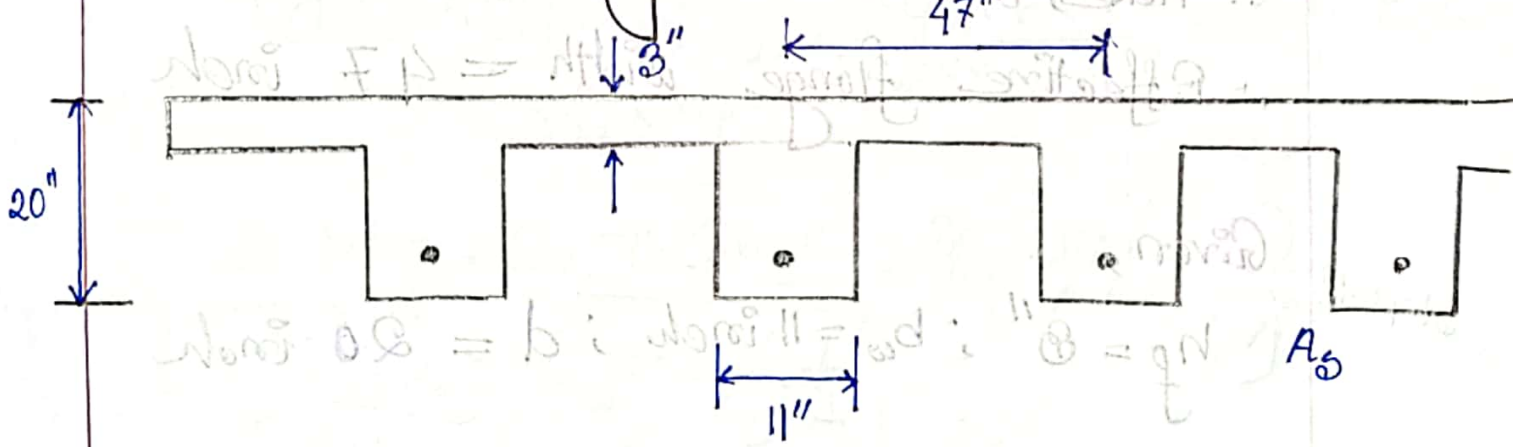
Lecture Video – 11 15-06-2021

Design of T-Beam :

In theory, the design of T-beams involves finding the flanges thickness, the width and depth of the web and the amount of reinforcement required. In practice, however, the flange thickness is determined when designing the slab. The size of the web is selected to resist not only the moments at the supports (no T-beam action) but to provide adequate shear capacity and to simplify formwork layout for ease of construction.

Question – 05: Design of T Beams

A floor system, shown figure below, consists of a 3 inch concrete slab supported by continuous T Beam with a clear span $l_n = 24$ ft, 47 inch on centers. Web dimensions, as determined by negative moment requirements at the supports are $b_w = 11$ inch and $d = 20$ inch. What tensile steel area is required at midspan to resist a factored moment of 6400 kip-inch if $f_y = 60{,}000$ psi and $f'_c = 3000$ psi



Solution :

Step:1 Ultimate moment, $M_u = 6400$ in-kips

Again, This is T Beam and T-Beam with flanges on Both sides of the web

Effective flange width $= 2\frac{l_n}{8} + b_w$

criteria:1

$= 2 \times \frac{24'}{8} + 11$

$= 2 \times \frac{24 \times 12}{8} + 11$

$= 83$ inch

Step-2

criteria:2

$8 \times 2 \times h_f + b_w = 16 \times 3 + 11 = 59$ inch

criteria:3

Centerline Beam Spacing = 47 inch

∴ Here, the smaller value is 47 inch.

∴ Effective flange width = 47 inch

Step-3 Given,

$h_f = 8''$; $b_w = 11$ inch ; $d = 20$ inch

By assuming Compression zone within Flange and Tensile Steel yields.

$f_s = f_y$

$$A_s = \frac{M_u}{\phi f_y (d - \frac{h_f}{2})}$$

$$= \frac{6400}{0.9 \times 60 \times (20 - \frac{3}{2})}$$

$$= 6.41 \text{ in}^2$$

Again,

$$a = \frac{A_s f_y}{0.85 \times f_c' \times b_f} = \frac{6.41 \times 60}{0.85 \times 3 \times 47} = 3.2 \text{ inch}$$

$\therefore a > h_f$. So, T-Beam is required.

[$a < h_f$; design as rectangular Beam with effective flange width]

$$A_{sf} = \frac{0.85 f_c' (b_f - b_w) h_f}{f_y}$$

$$= \frac{0.85 \times 8 \times (47 - 11) \times 3}{60}$$

$$= 4.59 \text{ in}^2$$

Find ϕM_{n1} and M_{n2}:

$$\phi M_{n1} = \phi \times A_{sf} f_y \left(d - \frac{h_f}{2}\right)$$

$$= 0.9 \times 4.59 \times 60 \times \left[20 - \frac{3}{2}\right]$$

$$= 4590 \text{ in-Kips}$$

$$\phi M_{n2} = M_u - \phi M_{n1}$$

$$= (6400 - 4590) \text{ inch-Kips}$$

$$= 1810 \text{ in-Kip}$$

$$A_s - A_{sf} = \frac{\phi M_{n2}}{\phi f_y (d - \frac{a}{2})} \quad [\text{Assume, } a = 4 \text{ inch}]$$

$$= \frac{1810}{0.90 \times 60 \times (20 - \frac{4}{2})}$$

$= 1.86 \text{ in}^2$

Now,

$$a = \frac{(A_s - A_{sf}) f_y}{0.85 \times f'_c \times b_w}$$

$$= \frac{1.86 \times 60}{0.85 \times 3 \times 11}$$

$$= 3.98 \text{ inch}$$

Here, $a = 3.98$ inch is less than assumed value $a = 4$ inch

Now,

$$A_s = A_{sf} + (A_s - A_{sf})$$

$$= 4.59 + 1.86$$

$$= 6.45 \text{ in}^2$$

Check wheather A_s is more than $A_{s(min)}$

$$A_{s(min)} = \frac{3\sqrt{f'_c}}{f_y} \times b_w \times d$$

$$= \frac{3\sqrt{3000}}{60,000} \times 11 \times 20$$

$$= 0.6024 \text{ in}^2$$

$\therefore A_s > A_{s(min)}$ [checked]

Check the strength reduction factor,

$$c = \frac{a}{\beta_1} = \frac{3.98}{0.85} = 4.68 \text{ inch}$$

$$dt = (20 - 2.5) = 17.5 \text{ inch}$$

$$\therefore \frac{c}{dt} = \frac{4.68}{17.5} = 0.26 < 0.375$$

So, this is tension controlled Beam.

We use, $\phi = 0.90$ is checked.

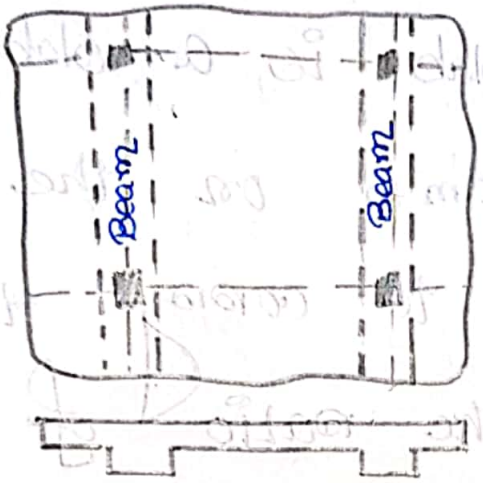
So, the approximate tensile steel area at midspan is required 6.45 in^2.

Lecture video - 12

16-06-2021

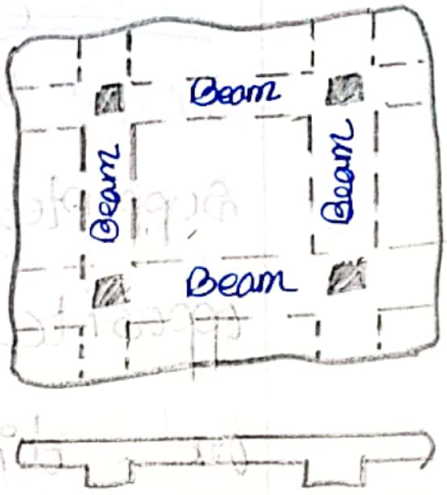
"One way Slab"

(i)

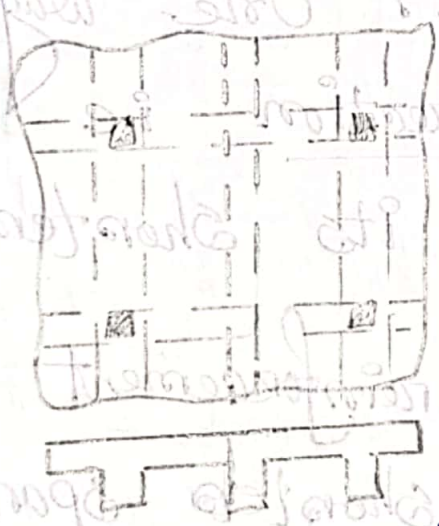


(i) One-way slab

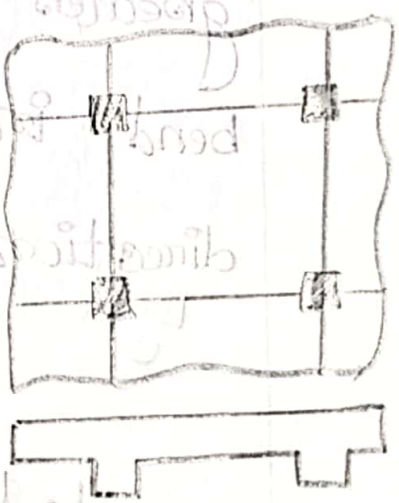
(ii)



(ii) Two way Slab



(iii) One way Slab



(iv) Flat ~~Slab~~ plate

One way Slab :

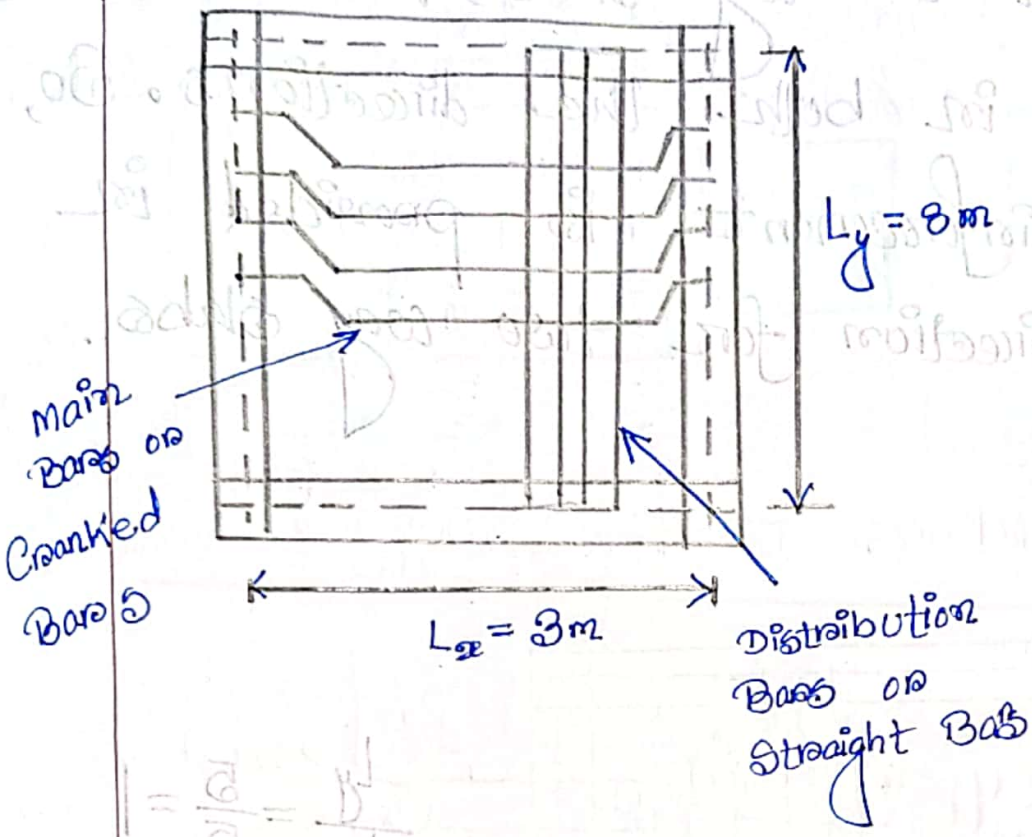
One way slab is a slab which is supported by beams on the two opposite sides to carry the load one direction. The ratio of longer span to shorter span is equal or greater than 2. One way slab will bend in one direction i.e in the direction along its shorter span.

Main reinforcement is provided in shorter span and shrinkage and Temperature reinforcement in longer span

Generally all the cantilever slabs are one way slab. (Chajjas) and verandahs are practical example of that.

Sun shade

One Way Slab :



$$\frac{L_y}{L_x} = \frac{8}{3} = 2.66$$

which is ≥ 2

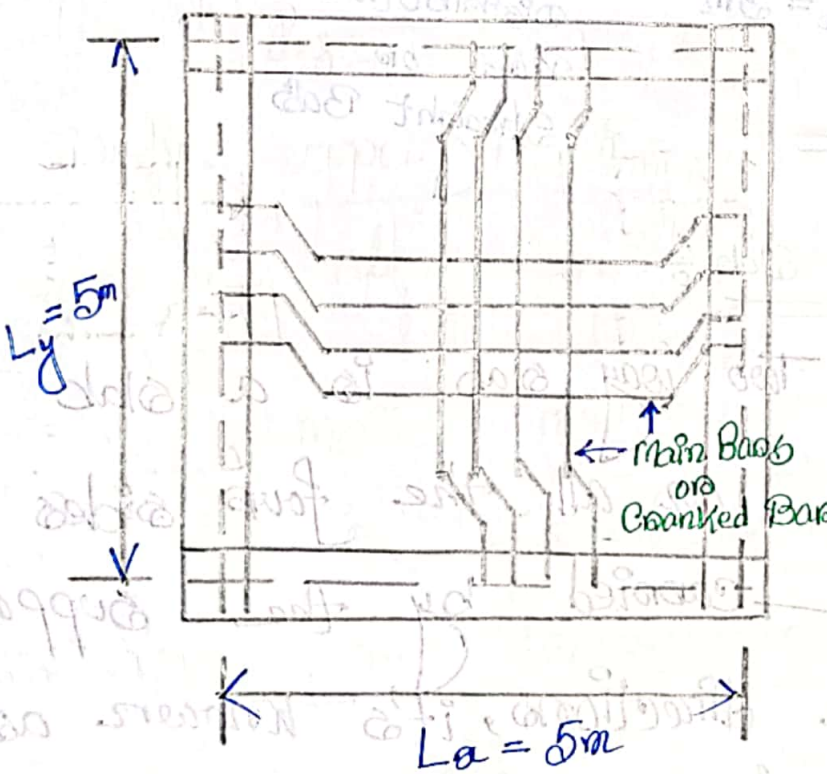
Hence, one way slab is adopted

Two Way Slab :

Two way slab is a slab supported by beams on all the four sides and the loads are carried by the supports along both directions, it's known as two way slab. In two way slab, the ratio of longer span to shorter span is less than

Q.

In two way slabs, load will be carried in both the directions. So, main reinforcement is provided in both direction for two way slabs.



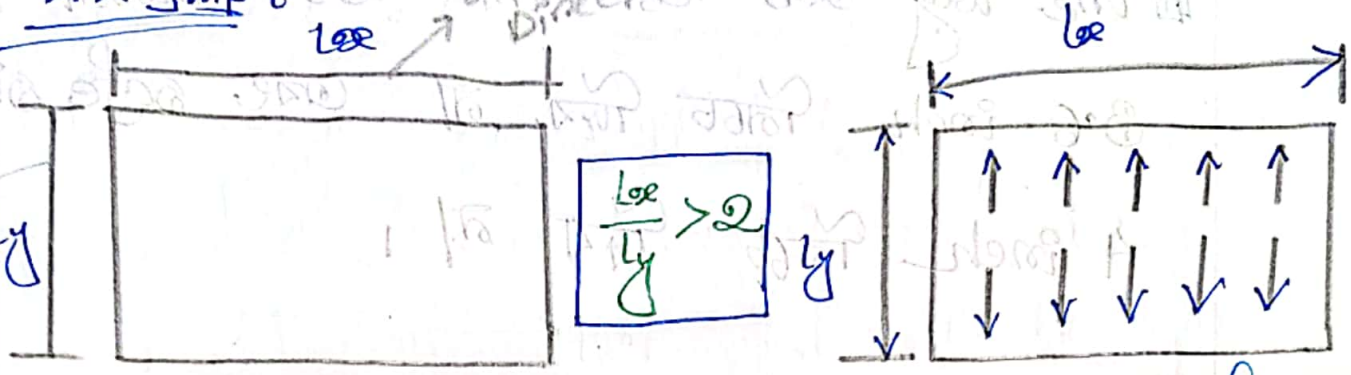
$$\frac{L_y}{L_x} = \frac{5}{5} = 1$$

which is < 2

∴ Two way slab is adopted

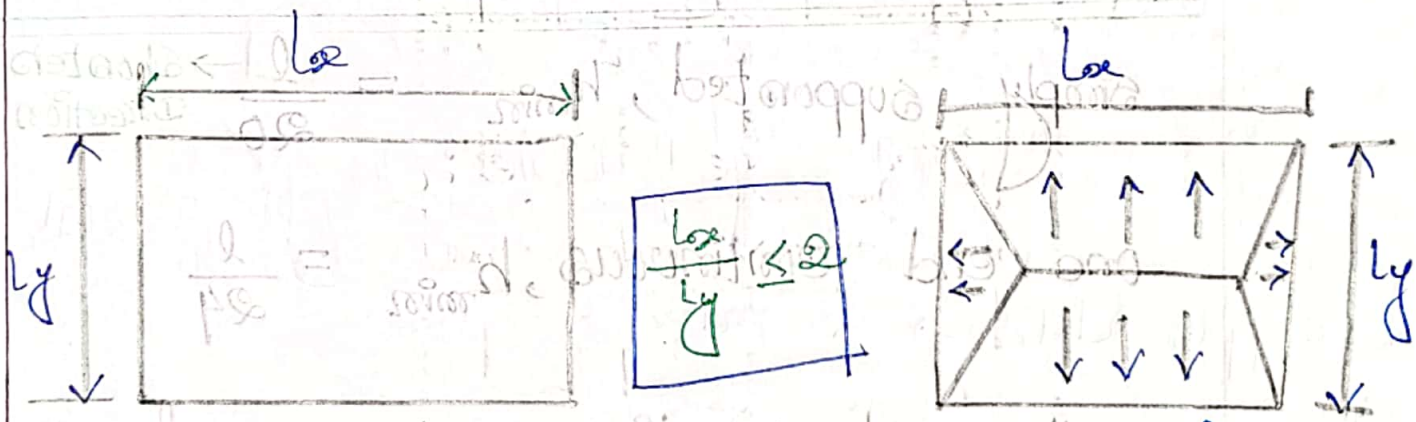


V.V. Imp°



One way slab

Load Transfer - One way slab



Two way slab

Load Transfer - Two way slab

⊞ One way slab এর thickness কমপক্ষে 3.6 inch নিতে পারি। তবে safe side 4 inch নিতে পারি।

Table : 12.1

Minimum thickness h of nonpreastressed one way slabs

Simply supported, $h_{min} = \frac{l}{20}$ → Shorter Direction length

One end continuous, $h_{min} = \frac{l}{24}$

Both ends discontinuous, $h_{min} = \frac{l}{28}$

Cantilever, $h_{min} = \frac{l}{10}$

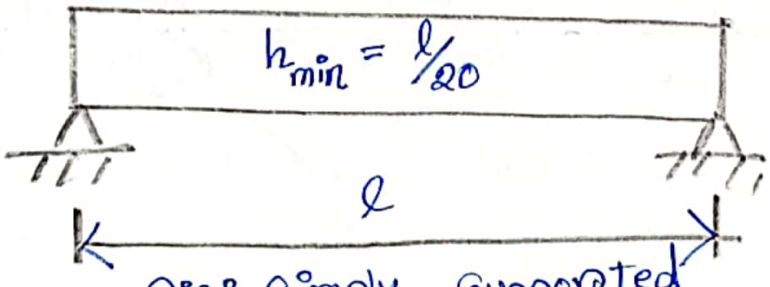
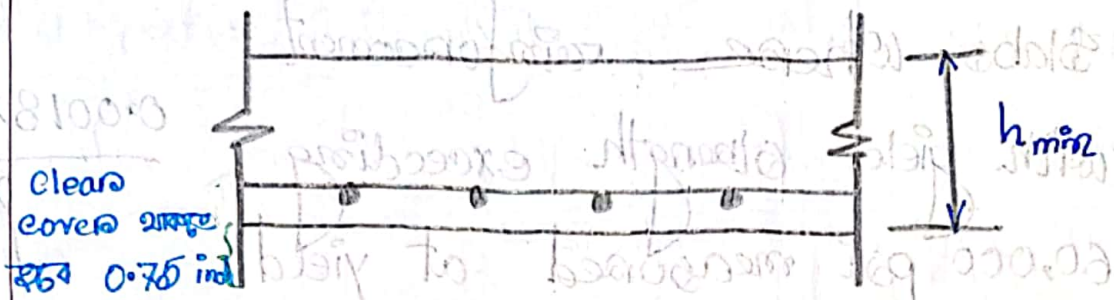


Fig: Simply supported



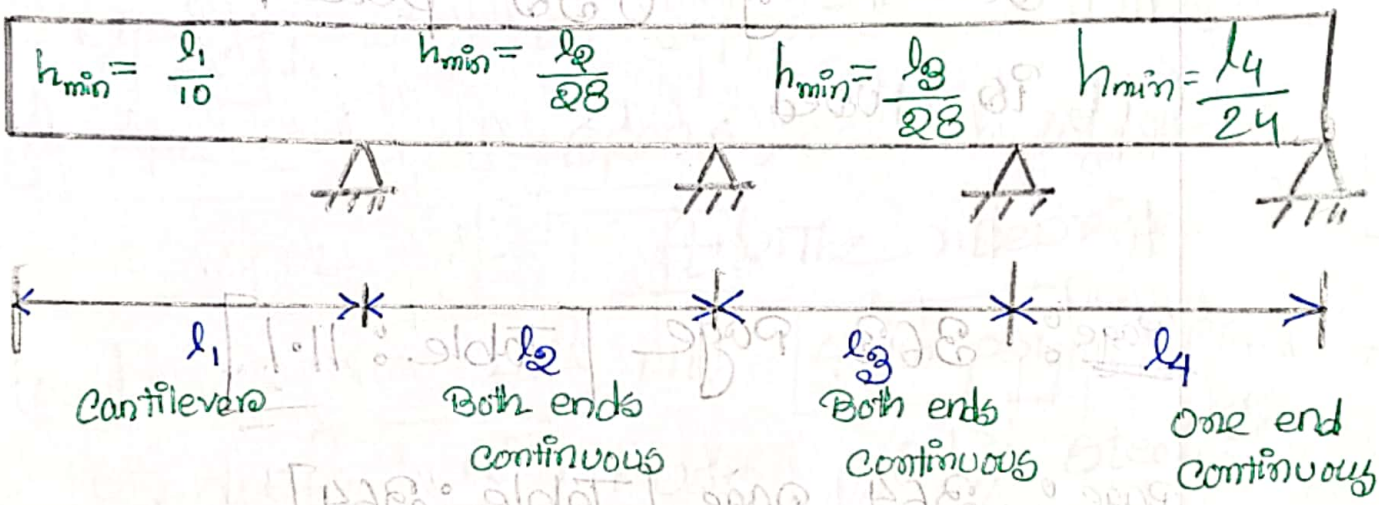


Table – 12.2

Minimum ratio of temperature and shrinkage Reinforcement in Slabs Based on gross Concrete area

1. Slabs where Grade 40 or 50 deformed Bars are used	0.0020
2. Slabs where Grade 60 deformed bars or welded wire fabric (Smooth or deformed) is used	0.0018

3. Slabs where reinforcement with yield strength exceeding 60,000 psi measured at yield strain of 0.35 percent is used

$$\frac{0.0018 \times 60{,}000}{f_y}$$

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Page: 364 page [Table: 364]

Problem: 6

"Design of One way slab"

A reinforced concrete slab is built integrally (অবিচ্ছিন্নভাবে, এক fixed support) with its supports and consists of three equal spans, each with a clear span of 15 ft. The service live load is 100 psf and 4000 psi concrete is specified for use with steel with a yield stress equal to 60,000 psi. Design the slab, following the provisions of the ACI Code.

Solution:

Assume minimum thickness (h) of the slab as per ACI Code.

$$\therefore h_{min} = \frac{l}{28} = \frac{(15) \times 12}{28} = 6.43 \text{ inch}$$

$$= 6.5 \text{ inch}$$

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one way slab ⇒ compulsory Ques

Because of the quantities of concrete involved in floor slabs, their depths are rounded off to closer values than are used for beam depths. Slab thickness are usually rounded off to the nearest 1/4 inch on the high side for slabs of 6 inch or less in thickness and to the nearest 1/2 inch on the high side for slabs thicker than 6 inch

slab thickness rounded করার সময় 6 inch বা কম হলে তখন 0.25 inch round off করবে এবং more than 6 inch হলে, তখন 0.50 inch rounded off করবে।

- clear cover provide করা হয় —
  1. RCC structure to protect the reinforcement from corrosion.
  2. It provide fire resistance and insulation to steel which is embedded in concrete.

13-03-21

উপরে তিনটি বের করতে হবে One way slab এর জন্য—

(i) slab এর height কত / slab এর thickness কত

(ii) main direction এর reinforcement কত

(iii) কোন কোন direction আছে যার জন্য load কে কত transfer হচ্ছে ~~কোথায়~~ কোথায় shrinkage এবং temperature reinforcement

2 Determine the factored Loads on the slab on a 1 ft wide strip

$$DL = \frac{6.5}{12} \times 150 = 81 \text{ psf}$$

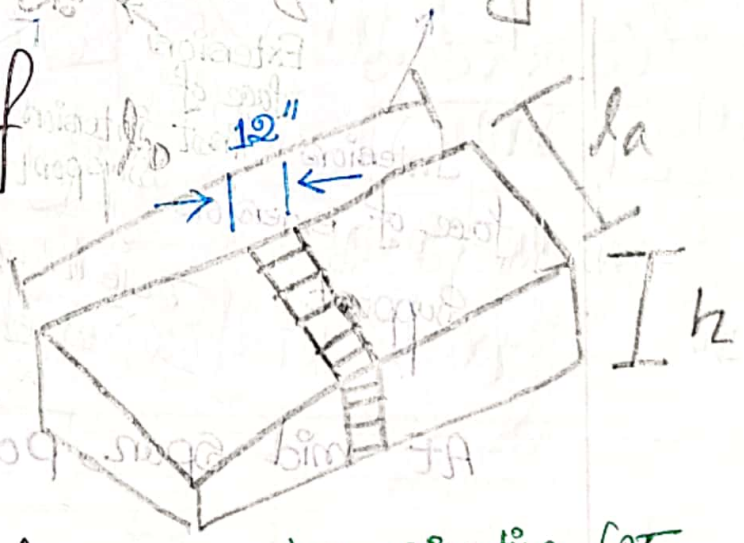
$$LL = 100 \text{ psf}$$

$$\therefore \text{Factored load} = 1.2 \times 81 + 1.6 \times 100$$

$$= 257 \text{ psf}$$

$$= 0.257 \text{ ksf}$$

[1 psf = 0.001 ksf]



Shorter Direction এর parallel 1 ft wide strip

Notice :
① মাঝখানে span এ positive moment হয়
② close to the support এ Negative Moment হয়

3. Determine factored moments at Critical Section using ACI Moment coefficient.

a) At Interior Support, Negative Moment.

b) At mid span, Positive Moment

c) At Exterior Support, Negative Moment.

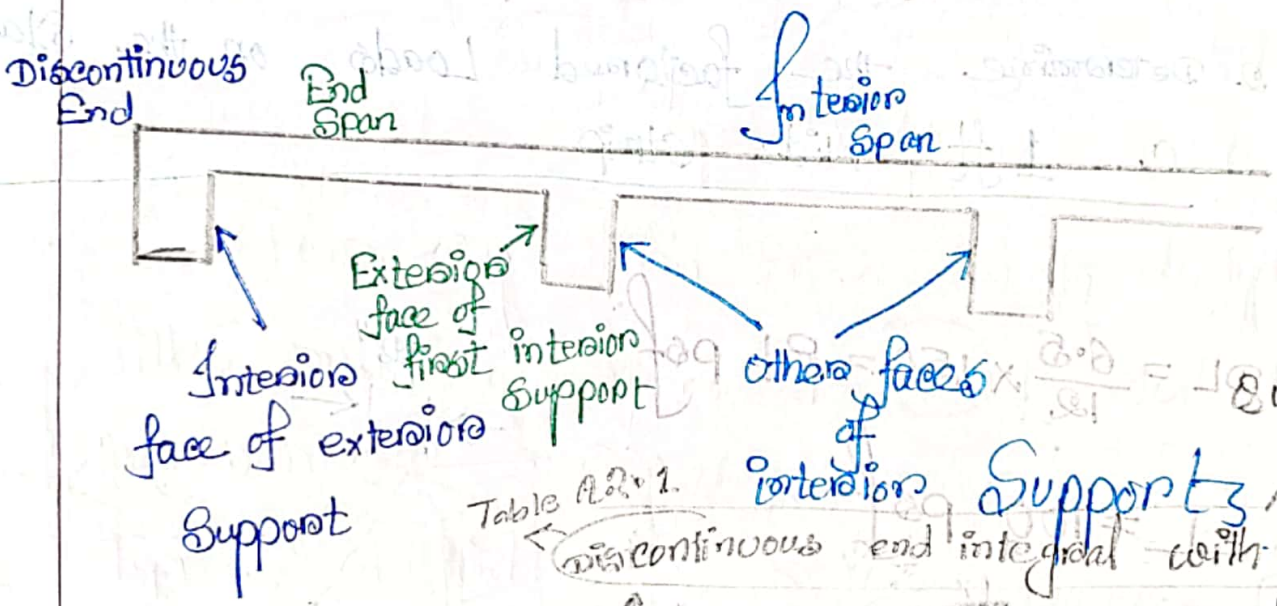


Table A2.1.

discontinuous end integral with support

At mid span, positive moment, $M = \frac{w_u l_n^2}{14}$

$= \frac{(0.257) \times (15)^2}{14}$

$= 4.13$ kft

unrestrained ⇒ simply support [restrained না]

more than 2 span [যেখানে 3 টা span]

At Interior Support,

Negative span, $M = \frac{w_u l_n^2}{10}$

$= \frac{(0.257) \times (15)^2}{10}$

$= 5.7825$ kgf

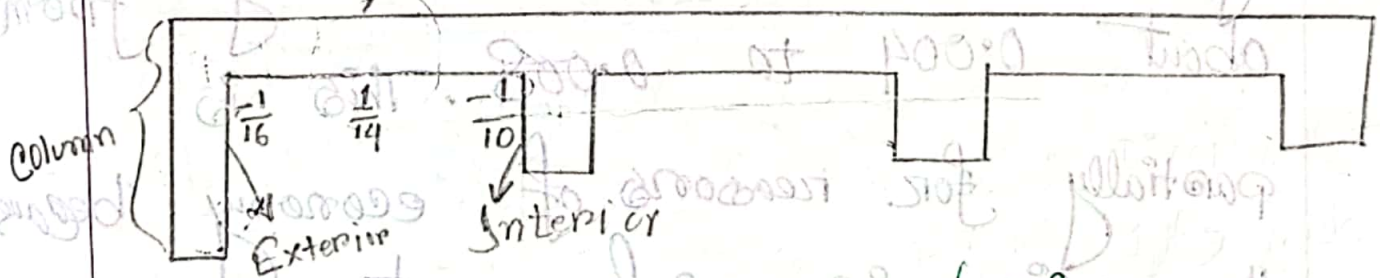
At Exterior Support, (where supported column)

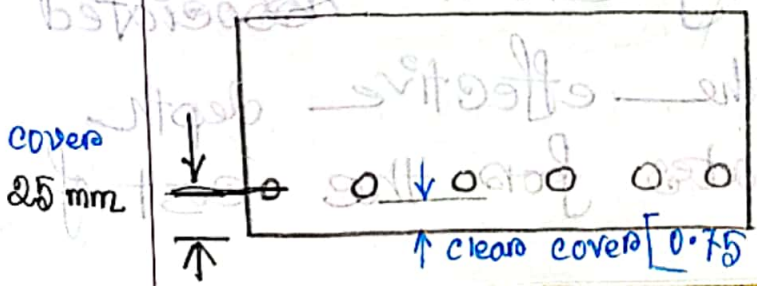
Negative Moment, $M = \frac{w_u l_n^2}{16}$

$= \frac{0.257 \times (15)^2}{16}$

$= 3.614$ kgf

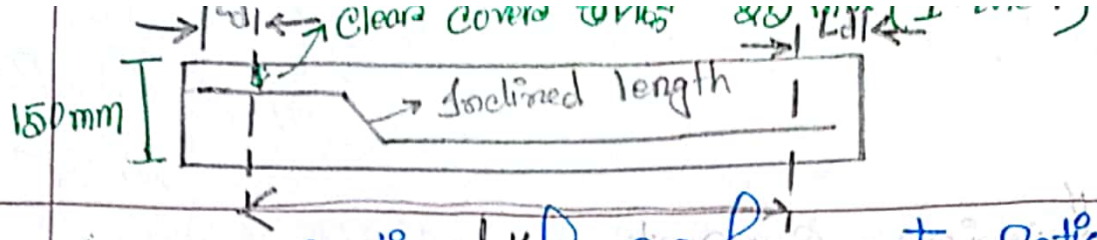
Slab এর জন্য:





Imp:

① Beam এর clear cover 1.5 inch এবং Slab এর clear cover 0.75 inch



4. Determination of Reinforcement Ratio (ρ)

The maximum practical reinforcement ratio is

Tension Controlled হলে $\rho = \rho_{0.005}$

$$\rho_{0.005} = 0.85\beta_1 \times \frac{f'_c}{f_y} \times \frac{\omega_v}{\omega_v + 0.005}$$

$$= 0.85 \times 0.85 \times \frac{4}{60} \times \frac{0.003}{0.003 + 0.005}$$

$$= 0.0181$$ [Page-745 থেকে direct 0.0181 value পাওয়া যাবে]

এর থেকে আরো কম ratio তে design করা হয়

one way slabs are normally designed with tensile reinforcement ratios well below the maximum practical value of $\rho_{0.005}$. Typical reinforcement ratios range from about 0.004 to 0.008. This is partially for reasons of economy because the saving in reinforcement associated with increasing the effective depth more than compensates for the cost of

the additional concrete and partially because very thin slabs with high reinforcement ratios would be likely to permit large deflections. [Typically reinforcement ratio 0.004 থেকে 0.008. উপর economy থাকতে হলে যদি reinforcement বেশি use করি তাহলে Depth কম আসতে আবার Depth বেশি বড়ায় reinforcement কম লাগতে, যেই সেই হিসাব করে Balance করতে হবে।]

Thus flexural design may start with selecting a relatively low reinforcement ratio, say about 0.3 $\rho_{0.005}$. [30% reinforcement ratio দিয়ে 1st এ কাজ করা যায়]

এটা দিয়ে প্রথমে safe কিনা Test and Trial করে নিতে হয়

Reinforcement for Negative Moment at Interior Support

If this value of ρ were actually used, the minimum required effective depth, controlled by negative moment at the interior support, would be found by —

$$d^2 = \frac{M_u}{\phi_b f_y b \left(1 - 0.59 \frac{\rho f_y}{f_c'}\right)}$$

$$= \frac{5.78 \times 12}{0.90 \times 0.0181 \times 60 \times 12 \left[1 - 0.59 \times \frac{.0181 \times 6}{4}\right.}$$

$$= 7.83 \text{ in}^2$$

$d = 2.65$ inch → h_{min} হচ্ছে or তার চেয়ে d হচ্ছে, $\therefore h_{min} > d$ হচ্ছে

clear cover + ½ bar dia + 1 in = 6.50 inch

This is less than the effective depth of (6.50 − 1) inch = 5.50 inch

→ 5.78 Ref

At the Interior support, considering the stress block depth $a = 1$ inch, the area of steel required per foot width in the top of the slab.

$$A_s = \frac{M_u}{\phi f_y (d - \frac{a}{2})}$$

$$= \frac{5.78 \times 12}{0.90 \times 60 \times [5.50 - \frac{1}{2}]}$$

$$= 0.26 \text{ in}^2/\text{ft}$$

By checking, the assumed depth, $a = \frac{A_s f_y}{0.85 \times f_c' \times b}$

$$= \frac{0.26 \times 60}{0.85 \times 4 \times 12}$$

$$= 0.38 \text{ inch}$$

এখানে $a = 1$ ধরেছিলাম,
check করার পর $a = 0.38$ inch
∴ The Design is OK

The second trial ——

$$A_s = \frac{M_u}{\varphi f_y \left[d - \frac{a}{2}\right]}$$

$$= \frac{5.78 \times 12}{0.90 \times 60 \times \left[5.50 - \frac{0.98}{2}\right]}$$

$$= 0.24 \text{ in}^2/\text{ft}$$

For which,

$$a = 0.98 \times \frac{0.26}{0.24}$$

$$= 0.41 \text{ inch}$$

Reinforcement for Positive Moment at Mid Span

Here, Positive moment = 4.13 K-ft

$$d^2 = \frac{4.13 \times 12}{0.90 \times 0.0181 \times 60 \times 12 \left[1 - 0.59 \times 0.0181 \times \frac{60}{4}\right]}$$

$$= 5.03 \text{ in}^2$$

$\therefore d = 2.24$ inch

Counter check: $5.5 > 2.24$ design safe.

$$d^2 = \frac{M_u}{\varphi \rho f_y b \left[1 - 0.59 \rho \frac{f_y}{f'_c}\right]}$$

This is less than the effective depth of $(6.50 - 1) = 5.50$ inch.

At the mid span, considering the stress block depth $a = 1$ inch, the area of steel required per foot width in the top of the slab.

$$A_s = \frac{M_u}{\phi f_y \left[d - \frac{a}{2}\right]}$$

$$= \frac{4.13 \times 12}{0.90 \times 60 \left[5.5 - \frac{1}{2}\right]}$$

$$= 0.18 \text{ in}^2/\text{ft}$$

By checking the assumed depth a, we get

$$a = \frac{A_s f_y}{0.85 \times f_c' \times b} = \frac{0.18 \times 60}{0.85 \times 4 \times 12} = 0.26 \text{ in}$$

The second trial ——

$$A_s = \frac{m_u}{\phi f_y (d - \frac{a}{2})}$$

$$= \frac{4.13 \times 12}{0.90 \times 60 \times \left[5.50 - \frac{0.26}{2}\right]}$$

$$= 0.17 \text{ in}^2/\text{ft}$$

For which,

$$a = 0.26 \times \frac{0.18}{0.17}$$

$$= 0.28 \text{ inch}$$

Reinforcement for Negative moment at Exterior Support

Here, Negative moment = 3.61 Kcf

$$d^2 = \frac{m_u}{\phi f_y b \left[1 - 0.59 \rho \frac{f_y}{f_c'}\right]}$$

$$= \frac{3.61 \times 12}{0.90 \times 0.0181 \times 60 \times 12 \left[1 - 0.59 \times 0.0181 \times \frac{60}{4}\right]}$$

$= 4.39 \text{ in}^2$

$\therefore d = 2.097$ inch

This is less than the effective depth of $(6.50 - 1) = 5.50$ inch

$\therefore$ Design is OK

At the exterior support, considering the stress block $a = 1$ inch,

$$A_s = \frac{M_u}{\phi f_y \left[d - \frac{a}{2}\right]}$$

$$= \frac{3.61 \times 12}{0.90 \times 60 \times \left[5.50 - \frac{1}{2}\right]}$$

$$= 0.160 \text{ in}^2/\text{ft}$$

By checking depth, $a = \frac{A_s f_y}{0.85 \times f'_c \times b}$

$$= \frac{0.16 \times 60}{0.85 \times 4 \times 12}$$

$$= 0.235 \text{ inch}$$

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The second trial ⇒

$$A_s = \frac{M_u}{\phi f_y \left[d - \frac{a}{2}\right]}$$

$$= \frac{3.61 \times 12}{0.90 \times 60 \times \left[5.50 - \frac{0.235}{2}\right]}$$

$$= 0.149 \text{ in}^2/\text{ft}$$

$$= 0.15 \text{ in}^2/\text{ft}$$

For which,

$$a = 0.235 \times \frac{0.16}{0.15}$$

$$= 0.25 \text{ inch}$$

Remember :

① One way slab thickness = 4"
② Two way slab thickness = 3.5"

} minimum slab thickness According to BNBC

Now, shrinkage and Temperature Reinforcement

Area, $A_s = 0.0018 \times 6.5 \times 12$

$= 0.14 \text{ in}^2/\text{ft}$

This is the minimum reinforcement required in shorter and longer direction.

Factored shear force at a distance d from the face of interior support and nominal shear strength.

∴ Factored Shear, $V_u = 1.15 \times \left(\frac{257 \times 15}{2}\right) - \frac{257 \times 5.5}{12}$ (Shear (Table 2270), d distance 260)

$= 2100 \text{ lb}$

∴ Nominal shear strength $= 2\lambda\sqrt{f'_c}\, bd$

$= 2 \times 1 \times \sqrt{4000} \times 12 \times 5.5$

$= 8350 \text{ lb}$

Design strength of the Concrete Slab,

$\phi V_c = 0.75 \times 8350 = 6260$ lb

It's well above the required strength

$V_u = 2100$ lb

∴ Design is OK

Detailing of Reinforcement:

Bar for positive moment:

Shorter direction ও positive moment এর জন্য

Required, $A_s = 0.17$ in²/ft (Table A1.2)

slab এর জন্য ← Using #4 Bar [Area = 0.20 in², Dia = 0.50 inch]

∴ Spacing of Bar, $S = \frac{\text{Area of bar used} \times \text{width of strip}}{\text{Required } A_s}$

$= \frac{0.20 \times 12}{0.17}$

$= 14.12$ inch

$= 14$ inch

main bar spacing 18 inch এর বেশি হলে ডবল হবে। 250। ∴ 18" > 14"

∴ Crank 50% Bars to Negative zone or 2 out of 3 will be bent part

Bars for Negative Moment :- max. ~~Pi.6~~ করতেই, Interior Span

Required $A_s = 0.24$ in²/ft → control করতেছে

$A_{minimum} = 0.14$ in²/ft #4 Bars Area

Cracked 50% Bars to Negative Zone

∴ Already Provided, $A_s = \frac{0.20 \times 12}{28}$ in²/ft

28 inch. প্রস্থ

$= 0.085$ in²/ft [14×2] = 28 inch

∴ Required $A_s = [0.24 - 0.085]$ in²/ft

$= 0.155$ in²/ft

আমরা সবই straight করং এক করে Alternate দিচ্ছি

∴ Bar Spacing, $S = \frac{\text{Area of the bars used} \times \text{width of strip}}{\text{Required } A_s}$

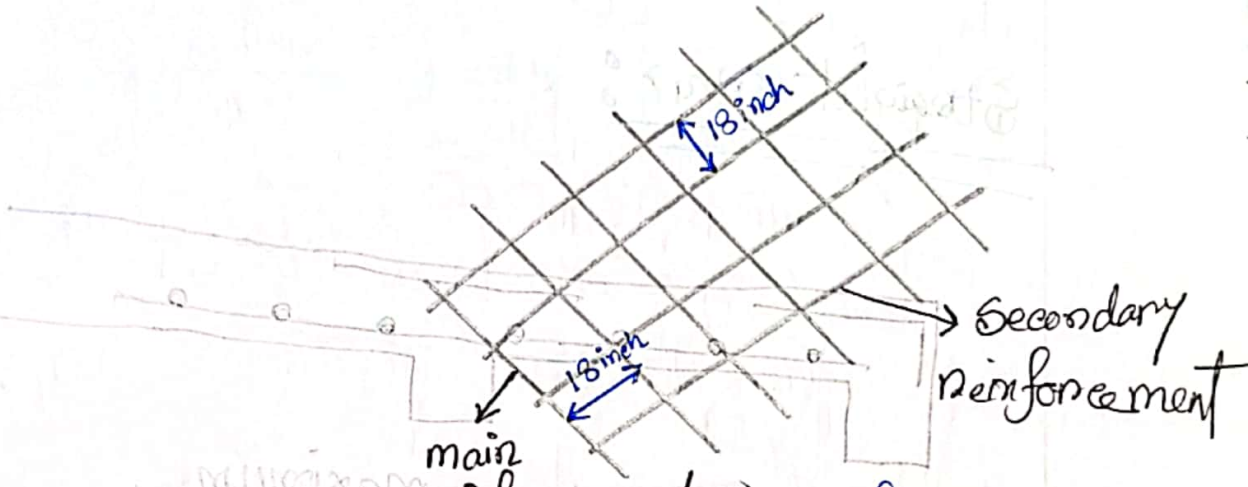
$= \frac{0.20 \times 12}{0.155}$ inch

$= 15.48$ inch

≈ 15 inch (Ans:) //

Main Reinforcement Spacing :

3 h or 18 inch [minimum of these two]

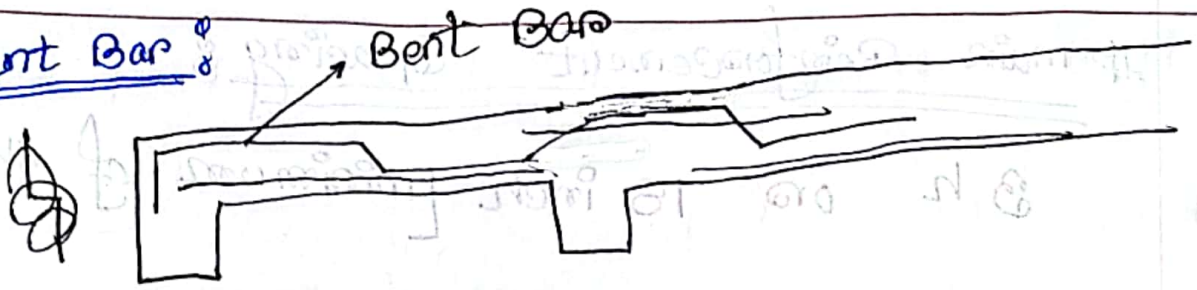


Shrinkage and Temperature Reinforcement Spacing

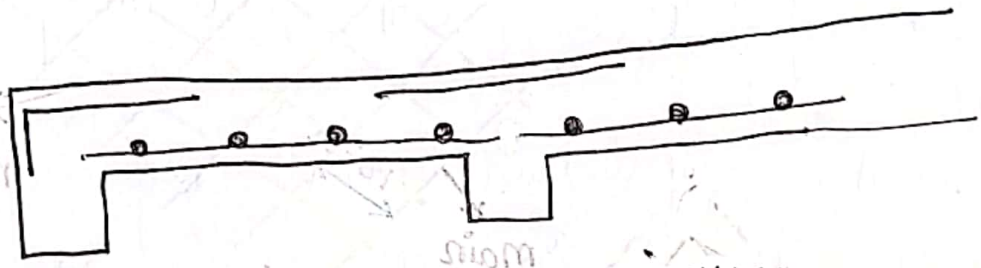
It shouldn't be largers than 5h or 18 inch (minimum of these two)

Main reinforcement Bar নিচে হবে এবং longers Direction Bar উপরে হবে, main reinforcement Bar নিচে হবে কারণ effective depth বেশি পাব, তবে Moment নিয়ে অনেক বড়ায় দিবে।

Bent Bar :



Straight Bar :



তাদাচেত maximum Bent Bar use করে

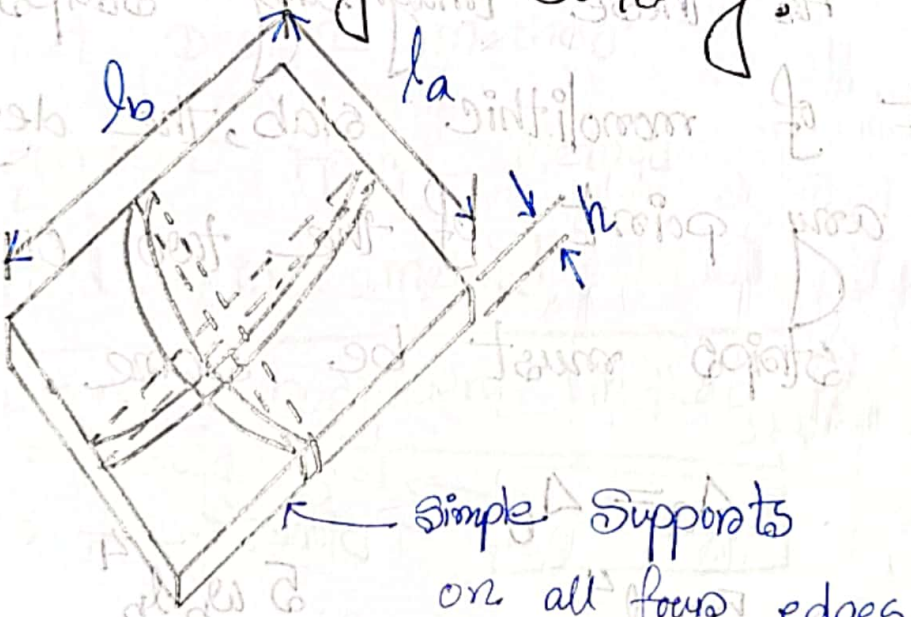
Lec-16

28-06-2021

"Two Way Slab"

Two Way Slab :

Two way slab is a slab supported by beams on all the four sides and the loads are carried by the supports along with both directions, Example: Two way slab are used in constructing floors of a multi-storeyed Building.



⊞ Behaviour of Two Way Slab :

More load and moment in short direction due to size of the slab.

$$\Delta_{\text{central strip}} = \frac{5wl^4}{384EI}$$

As these imaginary strips are part of monolithic slab, the deflection at any point of the two orthogonal slab strips must be same.

$$\Delta_a = \Delta_b$$ → long direction এর shorter direction same

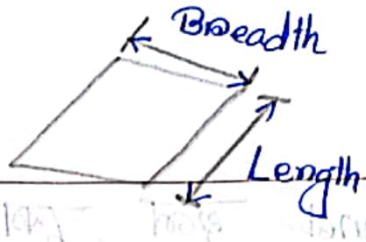
$$\text{or, } \frac{5w_a l_a^4}{384EI} = \frac{5w_b l_b^4}{384EI}$$

$$\text{or, } \frac{w_a}{w_b} = \frac{l_b^4}{l_a^4}$$

$$\therefore w_a = w_b \frac{l_b^4}{l_a^4}$$

[Shorter Direction এ Load বেশী যায়]

[The larger share of load is taken by the Shorter Direction]



Short Note:

1. Oneway Slab = $\frac{\text{Length}}{\text{Breadth}} \geq 2$

2. Two way Slab = $\frac{\text{Length}}{\text{Breadth}} < 2$

Two way Slab Design Method:

i) Direct Design method

ii) Equivalent Frame Method

iii) Yield Line method

iv) Moment coefficient method → এটি বিস্তারিত

Important:

→ ACI Code for the first time in 1963.

→ Permissible under ACI 318-08 code provision (13.5.1)

Panel হল কোনো বড় Slab এর অংশ।





Panel এর সব side এ continuous



Panel এর ২ side এ Discontinuous বাকি ২ side এ continuous

Problem 07 [Design of Two Way Slab]

Design a slab panel 20 ft by 25 ft to support a uniform live load of 125 psf. The panel is a corner panel of a group. A 3000 psi concrete and steel with f_y 60,000 psi are used in connection with USD Method. Design the slab, following the provisions of the ACI code

Solution:

1 MPa = 145.038 psi

420 × 145.038 = 60915.9 psi

Assume,

Minimum thickness (h) of the slab as per ACI Code.

For $f_y = 300$ MPa,

$$h_{min} = \frac{2 \times [L_x + L_y]}{180}$$

For $f_y = 420$ MPa,

$$h_{min} = \frac{2 \times [L_x + L_y]}{165}$$

Note:

L_x = Clear span in short Direction

L_y = Clear span in Long Direction

যেটা বড় সেটা Applicable

To limit the deflection, codes provide a minimum thickness of the two way slab shall be 3.5 inch or the panel perimeter divided by 180.

$$h_{min} = \frac{2 \times [L_{xe} + L_y]}{165}$$

$$= \frac{2 \times (20+25) \times 12}{165}$$

$$= 6.48 \text{ inch}$$

$\therefore h_{min} = 6.50$ inch [Considered]

Here,

Dead Load (DL) $= \frac{6.5}{12} \times 150 = 81.25$ psf

$\therefore$ Factored Dead Load $= (1.2 \times 81.25)$ psf

$= 97.5$ psf

Again,

Live Load (LL) $= 125$ psf

∴ Factored Live Load = (1.6 × 125) psf

= 200 psf

∴ Total factored Load, W_u = [200 + 97.5] psf

= 297.5 psf

We knows,

$$m = \frac{A}{B} = \frac{20}{25} = 0.8$$

[A = Shorter length of the slab
B = longer Length of the slab

Note :

Table ⓐ Negative Moments at Continuous Edges : $\frac{l_a}{l_b}$

Table ⓑ Positive Moments Due to Dead load.

Table ⓒ Positive Moment due to Live Load

Table ⓓ provides the coefficients for determining Shear on the slab and loads on edge beams.

a. At Continuous Edges [Negative Moment] from Table 1

$M_A(\text{Negative}) = 0.071 \times 297.5 \times (20)^2$ → Table 1, Case 4

$= 8449$ ft-lb

$M_B(\text{Negative}) = 0.029 \times 297.5 \times (25)^2$ → Table 1, Case 4

$= 5392$ ft-lb

b. At Middle Strip [Positive Moment] From Table 2, 3

$M_A(\text{Positive}) = 0.039 \times 97.5 \times (20)^2 (DL) +$ → Shorter Direction [Case 4, Table 2]

$0.048 \times 200 \times (20)^2 (LL)$ → Shorter Direction [Case 4, Table 2]

$= 5361$ ft-lb

$M_B(\text{Positive}) = 0.016 \times 97.5 \times (25)^2 (DL) +$ → longer Direction [Case 4, Table 2]

$0.020 \times 200 \times (25)^2 (LL)$ → longer Direction [Case 4, Table 3]

$= 3475$ ft-lb

C. At Discontinuous Edges [Negative Moment]

Note:

The code provides that negative moments at discontinuous edges shall be assumed equal to $\frac{1}{3}$ of the positive moments for the same direction.

$$M_A \text{ (Negative)} = \frac{1}{3} \times 5361 = 1787 \text{ ft-lb}$$

$$M_B \text{ (Negative)} = \frac{1}{3} \times 3475 = 1158 \text{ ft-lb}$$

Here,

maximum practical Reinforcement Ratio,

$$\rho_{0.005} = 0.085 \times \beta_1 \times \frac{f'_c}{f_y} \times \frac{\omega_u}{\omega_u + 0.005}$$

$$= 0.85 \times 0.85 \times \frac{3000}{60,000} \times \frac{0.003}{0.003 + 0.005}$$

$$= 0.0135$$

Now,

Minimum required Effective Depth Control,

$$d^2 = \frac{M_u}{\phi \rho f_y b \left[1 - 0.59 \rho \frac{f_y}{f'_c}\right]}$$

$$= \frac{8449 \times 12}{0.90 \times 0.0135 \times 60{,}000 \times 12 \left[1 - 0.59 \times 0.0135 \times \frac{60{,}000}{3000}\right]}$$

$$= 13.786 \text{ in}^2$$

$\therefore d = 3.71$ inch

$\therefore d = (6.5 - 1) = 5.5$ inch

If it's OK only then proceed. Otherwise increase the thickness of slab

$$A_s = \frac{M_u}{\phi f_y \left[d - \frac{a}{2}\right]}$$

$$= \frac{8449 \times 12}{0.96 \times 60{,}000 \times (5.50 - \frac{1}{2})} \quad [\text{Assumed, } a = 1]$$

$$= 0.375 \text{ in}^2/\text{ft}$$

By checking the assumed effective depth, $a = \frac{A_s f_y}{0.85 \times f'_c \times b}$

$= \frac{0.375 \times 60,000}{0.85 \times 3000 \times 12}$

$= 0.7$ inch

A second trial $\Rightarrow$

$A_s = \frac{M_u}{\phi f_y \left[d - \frac{a}{2}\right]} = \frac{8449 \times 12}{0.90 \times 60,000 \times \left[5.50 - \frac{0.70}{2}\right]}$

$= 0.364 \text{ in}^2/\text{ft}$ [shorter direction for continuous edge negative edge]

For which,

$a = 0.7 \times \frac{0.375}{0.364}$

$= 0.72$ inch

Again,

For moment = 5392 ft-lb [At continuous edge]

Minimum required Effective Depth control,

$d^2 = \frac{M_u}{\phi \omega f_y b \left[1 - 0.59 \omega \frac{f_y}{f'_c}\right]}$

$$= \frac{5392 \times 12}{0.90 \times 0.0135 \times 60,000 \times 12 \times \left[1 - \frac{0.59 \times 0.0135 \times 60000}{3000}\right]}$$

$$= 8.798 \text{ in}^2$$

$\therefore d = 2.96$ inch

$d = (6.5 - 1) = 5.50$ inch

If it's okay only then proceed. Otherwise increase the thickness of slab,

$$A_s = \frac{M_u}{\phi f_y \left[d - \frac{a}{2}\right]}$$

$$= \frac{5392 \times 12}{0.90 \times 60000 \left[5.50 - \frac{1}{2}\right]} \quad \left[\text{Assume, } a = 1\right]$$

$$= 0.239 \text{ in}^2/\text{ft}$$

By checking the assumed depth, a

$$a = \frac{0.239 \times 60,000}{0.85 \times 3000 \times 12} \quad \left[a = \frac{A_s f_y}{0.85 \times f_c' \times b}\right]$$

$$= 0.47 \text{ inch}$$

$$\approx 0.5 \text{ inch}$$

A second trial $\Rightarrow$

$$A_s = \frac{M_u}{\phi f_y \left[d - \frac{a}{2}\right]}$$

$$= \frac{5392 \times 12}{0.90 \times 60,000 \times \left(5.50 - \frac{0.5}{2}\right)}$$

$$= 0.227 \text{ in}^2/\text{ft} \quad \left[\begin{array}{l}\text{Longer Direction} \\ \text{for} \\ \text{continuous Edge} \\ \text{for} \\ \text{Negative Edge}\end{array}\right]$$

For which,

$$a = 0.5 \times \frac{0.239}{0.227} \text{ inch}$$

$$= 0.53 \text{ inch}$$

→ Shorter Direction

For Positive Moment (5361 ft-lb) [At middle strip]

Minimum Required Effective Depth control,

$$d^2 = \frac{M_u}{\phi f_y \rho b \left[1 - 0.59 \rho \frac{f_y}{f_c'}\right]}$$

$$= \frac{5361 \times 12}{0.90 \times 0.0135 \times 60{,}000 \times 12 \times \left[1 - 0.59 \times 0.0135 \times \frac{60{,}000}{3000}\right]}$$

$$= 8.75 \text{ in}^2$$

$\therefore d = 2.96$ inch

$\therefore d = (6.5 - 1) = 5.5$ inch

∴ Design is OK. Otherwise increase the thickness of slab.

$$A_s = \frac{M_u}{\phi f_y \left[d - \frac{a}{2}\right]}$$

$$= \frac{5361 \times 12}{0.9 \times 60000 \times \left[5.5 - \frac{1}{2}\right]}$$

$$= 0.238 \text{ inch}^2/\text{ft}$$

By checking the assumed depth,

$$a = \frac{A_s f_y}{0.85 \times f_c' \times b}$$

$$= \frac{0.238 \times 60{,}000}{0.85 \times 3000 \times 12}$$

$$= 0.46 \text{ inch}$$

A second trial $\Rightarrow$

$$A_s = \frac{M_u}{\phi f_y \left[d - \frac{a}{2}\right]}$$

$$= \frac{5361 \times 12}{0.9 \times 60000 \times \left[5.5 - \frac{0.46}{2}\right]}$$

$$= 0.226 \text{ in}^2/\text{ft}$$

For which,

$$a = 0.46 \times \frac{0.238}{0.226}$$

$$= 0.48 \text{ inch}$$

∓ For Positive moment (3475 ft-lb) [At middle strip]

From Moment = 3475 ft-lb

$$d^2 = \frac{M_u}{\phi \rho f_y b \left[1 - 0.59 \rho \frac{f_y}{f_c'}\right]}$$

$$= \frac{3475 \times 12}{0.90 \times 0.0135 \times 60{,}000 \times 12 \left[1 - 0.59 \times 0.0135 \times \frac{60{,}000}{3000}\right]}$$

$$= 5.67 \text{ in}^2$$

$$d = 2.38 \text{ inch}$$

$\therefore d = (6.5 - 1) = 5.5$ inch.

∴ The design is OK. Otherwise increase the the thickness of slab

$$A_s = \frac{M_u}{\phi f_y \left[d - \frac{a}{2}\right]}$$

$$= \frac{3475 \times 12}{0.90 \times 60000 \times \left[5.50 - \frac{1}{2}\right]} \quad \left[a = 1\right]$$

$$= 0.154 \text{ in}^2/\text{ft}$$

By checking the assumed depth, a

$$a = \frac{A_s f_y}{0.85 \times f_c' \times b}$$

$$= \frac{0.154 \times 60{,}000}{0.85 \times 3000 \times 12}$$

$$= 0.301 \text{ inch}$$

A second trial,

$$A_s = \frac{M_u}{\phi f_y \left[d - \frac{a}{2}\right]}$$

$$= \frac{3475 \times 12}{0.90 \times 60000 \times \left[5.50 - \frac{0.301}{2}\right]} \quad \left[a = 0.301^{4}\right]$$

$= 0.144 \text{ in}^2/\text{ft}$

For which,

$$a = 0.301 \times \frac{0.154}{0.144}$$

$$= 0.322 \text{ inch}$$

For negative moment (1787 ft-lb) [At Discontinuous edges]

$$d^2 = \frac{M_u}{\phi \rho f_y b \left[1 - 0.59 \rho \frac{f_y}{f'_c}\right]}$$

$$= \frac{1787 \times 12}{0.90 \times 0.0135 \times 60000 \times 12 \left[1 - 0.59 \times 0.0135 \times \frac{60000}{3000}\right]}$$

$\therefore d^2 = 2.91 \text{ in}^2$

$\therefore d = 1.70 \text{ inch}$

$\therefore d = (6.5 - 1) = 5.5 \text{ inch}$

$\therefore$ The design is okay. Otherwise increased the thickness of slab.

$$A_s = \frac{M_u}{\phi f_y \left[d - \frac{a}{2}\right]}$$

$$= \frac{1787 \times 12}{0.90 \times 60000 \times \left[5.5 - \frac{1}{2}\right]} \quad \left[a = 1\right]$$

$$= 0.0794 \text{ in}^2/\text{ft}$$

By checking the assumed depth,

$$a = \frac{A_s f_y}{0.85 \times f'_c \times b}$$

$$= \frac{0.0794 \times 60000}{0.85 \times 3000 \times 12} \text{ inch}$$

$$= 0.155 \text{ inch}$$

A second trial $\Rightarrow$

$$A_s = \frac{M_u}{\phi f_y \left[d - \frac{a}{2}\right]}$$

$$= \frac{1787 \times 12}{0.90 \times 60000 \times \left[5.5 - \frac{0.155}{2}\right]}$$

$$= 0.073 \text{ in}^2/\text{ft}$$

For which,

$$a = 0.155 \times \frac{0.0794}{0.073}$$

$$= 0.168 \text{ inch}$$

For Negative Moment [1158 ft-lb] [At Discontinuous edge]

$$d^2 = \frac{m_u}{\varphi_s f_y b \left[1 - 0.59 \rho \frac{f_y}{f_c'}\right]}$$

$$= \frac{1158 \times 12}{0.9 \times 0.0135 \times 60000 \times 12 \left[1 - 0.59 \times 0.0135 \times \frac{60000}{3000}\right]}$$

$$= 1.89 \text{ in}^2$$

$$\therefore d = 1.37 \text{ inch}$$

$$\therefore d = (6.5 - 1) = 5.5 \text{ inch}$$

∴ The Design is OK. Otherwise increased the thickness of slab

$$A_s = \frac{M_u}{\phi f_y \left[d - \frac{a}{2}\right]}$$

$$= \frac{1158 \times 12}{0.90 \times 60000 \times \left[5.50 - \frac{1}{2}\right]} \quad \left[\text{Assume, } a = 1\right]$$

$$= 0.0514 \text{ in}^2/\text{ft}$$

By checking the assumed depth,

$$a = \frac{A_s f_y}{0.85 f_c' b}$$

$$= \frac{0.0514 \times 60000}{0.85 \times 3000 \times 12} \text{ inch}$$

$$= 0.1 \text{ inch}$$

A second trial,

$$A_s = \frac{M_u}{\phi f_y \left[d - \frac{a}{2}\right]}$$

$$= \frac{1158 \times 12}{0.90 \times 60,000 \times \left[5.50 - \frac{0.1}{2}\right]}$$

$$= 0.47 \text{ in}^2/\text{ft}$$

For which,

$$a = 0.1 \times \frac{0.0514}{0.047} \text{ inch}$$

$$= 0.109 \text{ inch}$$

Detailing of Reinforcement:

Shorter Direction:

Bar for positive moment:

Required $A_s = 0.226 \text{ in}^2/\text{ft}$

Using #3 Bars

Area of the #3 Bar used = 0.11 in^2 (Table A1.2)

$$\therefore \text{Spacing of Bar} = \frac{\text{Area of the bar used} \times \text{Width of the strip}}{\text{Required } A_s}$$

$$= \frac{0.11 \times 12}{0.226}$$

$$= 5.84 \text{ inch}$$

$$\approx 6 \text{ inch}$$

Choice বন্ধুটি

Crank 50% Bar to negative zone or 2 out 3 will bent

Bar for Negative moment:

Required $A_s = 0.364$ in^2/ft [Shorter Direction for continuous edge for Negative edge]

2 out 3 will bent → 3 Bar এর মধ্যে 2টি Bar bent up করতে হবে

we know,

$$\text{Spacing of Bar} = \frac{\text{Area of the Bar Used} \times \text{width of the strip}}{\text{Already Provided } A_s}$$

3 Bar এর মধ্যে Area

$$\therefore \text{Already Provided} = A_s = \frac{0.11 \times 12}{\frac{6 \times 3}{2}}$$

width

6 inch পর পর spacing

3 Bar আছে

2 Bar use করতে হবে

$$= 0.147 \text{ in}^2$$

$$\therefore \text{Required } A_s = [0.364 - 0.147] \text{ in}^2$$

$$= 0.217 \text{ in}^2$$

$$\therefore \text{Spacing of Bar} = \frac{\text{Area of the bar used} \times \text{width of strip}}{\text{Required } A_s}$$

$$= \frac{0.11 \times 12}{0.217}$$

$$= 6.1 \text{ inch}$$

$$\approx 6 \text{ inch} \quad \text{(Ans:)}$$

Longer Direction:

Bar for positive moment:

Required $A_s = 0.144 \text{ in}^2/\text{ft}$

Using #3 Bar

Area of the #3 Bar used $= 0.11 \text{ in}^2$

$$\therefore \text{Spacing of the Bar} = \frac{\text{Area of the Bar Used} \times \text{width of the strip}}{\text{Required } A_s}$$

$$= \frac{0.11 \times 12}{0.144} \text{ inch}$$

$$\approx 9 \text{ inch}$$

Bar for Negative Moment:

Required $A_s = 0.227 \text{ in}^2/\text{ft}$ [Longer Direction for continuous Edge for Negative edge]

2 out 3 will bent

Already Provided, $A_s = \dfrac{0.11 \times 12}{\frac{9 \times 3}{2}}$

$= 0.098$ inch

$\therefore$ Required $A_s = [0.227 - 0.098]$ inch

$= 0.129$ inch

$\therefore$ Spacing of Bar $= \dfrac{\text{Area of the bar used} \times \text{width of strip}}{\text{Required } A_s}$

$= \dfrac{0.11 \times 12}{0.129}$

$= 10$ inch (Ans:)