CE 3115

Reinforced Concrete -1

Credit 3 14.2.22

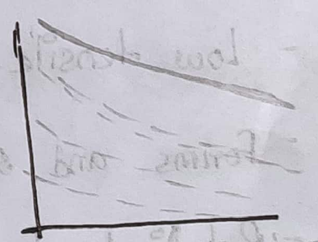
Book - Design of Concrete Structures [H. Nilson, David Dolon] 7th, 14th

Reinforced Concrete - Mechanics & Design [James. K. Wight]

Concrete :

- Concrete is a stonelike material obtained by mixing cement, sand, other aggregate and water.
- is being used for thousands of years, lime mortar 12000 B.C.
- Compressive strength high. Tensile strength small
- It is not economical to use concrete in members subject to tension

Why is strength the property most valued in concrete by Engineers?



→ Strength of concrete is commonly considered its most valuable property, although in many practical cases other properties like durability & impermeability may in fact be more important. Nevertheless strength usually gives the over all picture of quality of concrete. Strength of concrete are following types

- Compressive,
- Tensile
- Flexural
- Shear

From above discussion, it can be said that if a desirable strength if concrete structure can be acquired then the other properties will be fullfilled.

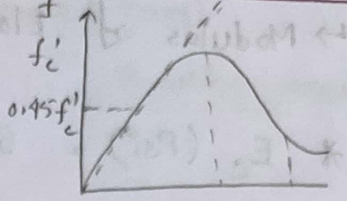
• Factors affecting choice of Reinforced Concrete for structure.

- economy. Economical compare to concrete.
- Easily give shape to our desire architechtural and structural function
- Fire resistance
- Rigidity
- Low maintainance
- Availability of materials

• Factors that may cause one to select a material other than reinforced concrete.

- Low tensile strength
- Forms and shoring
- Relatively low strength per unit of weight or volume.
- Form work
  - ↳ Removal of forms
  - ↳ Fresh concrete required support weight until strength is adequate.
  - ↳ Labour/Materials cost not required for ~~that~~ other types of materials.
- Time dependent volume changes
  - ↳ Concrete & steel undergo similar expansion and contraction
  - ↳ Concrete undergoes drying shrinkage, which may cause deflections & cracking
  - ↳ Creep of concrete under sustained loads causes an increase in deflection with time.

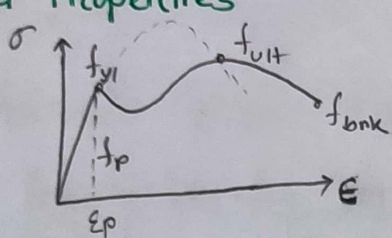
- Concrete Properties
- Concrete strain at max, compressive stress, ε_u
  - ε_u varies between 0.0015 – 0.003
  - For normal strength concrete, $\varepsilon_u \sim 0.002$

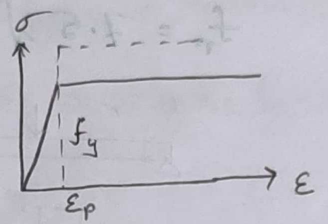


- Maximum useable strain, ε_u
  - ACI code : $\varepsilon_u = 0.003$
  - Used for flexural and axial compression

Concrete brittle material

Steel Properties





The elastic perfectly plastic (EPP) model for steel assumes the stress to vary linearly with strain up to yield point (f_y) and remain consta beyond that.

Concrete –

Age	7days	14days	28days	3month	6month	1yr	2yr	5y
Strength ratio	0.67	0.86	1.0	1.17	1.23	1.27	1.31	1.3

Normally use 28 day strength for design strength

- Poisson's Ratio, ν

↳ $\nu \sim 0.15$ to 0.20, usually use, $\nu = 0.17$

↳ Modulus of Elasticity for normal weight concrete ($w_c \cong 150$ pcf)

* $E_c\ (psi) = 57000 \sqrt{f'_c}\ (psi)$

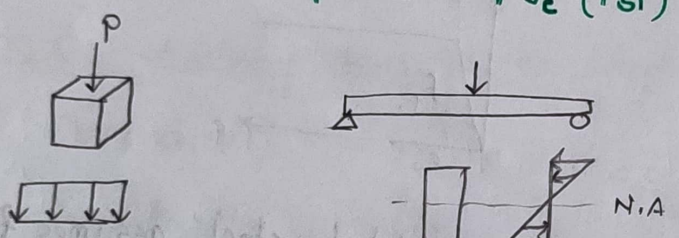
$E_c\ (psi) = 33\ w^{1.5} \sqrt{f'_c}\ (psi)$

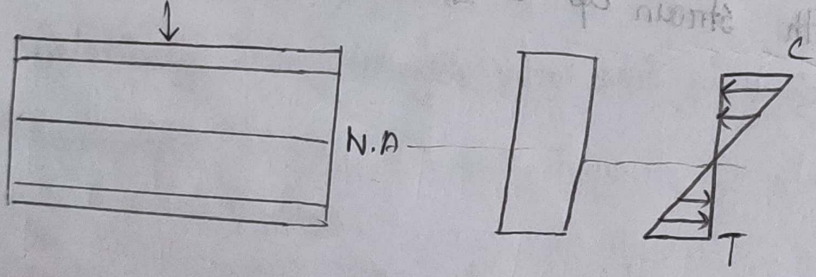
w = unit weight

f'_c = compressive strength at 28 days.

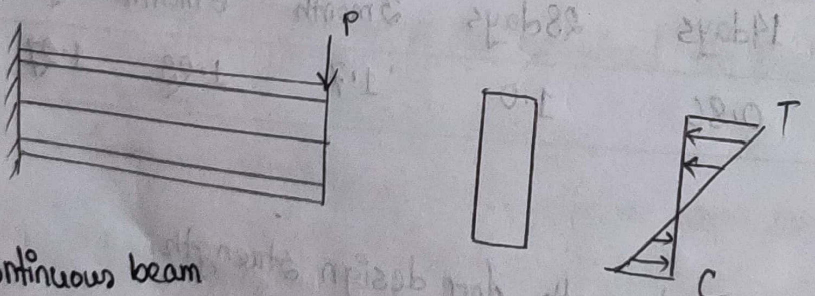
□ Modulus of Rupture, f_r

$$f_r = 7.5 \sqrt{f'_c}\ (psi)$$

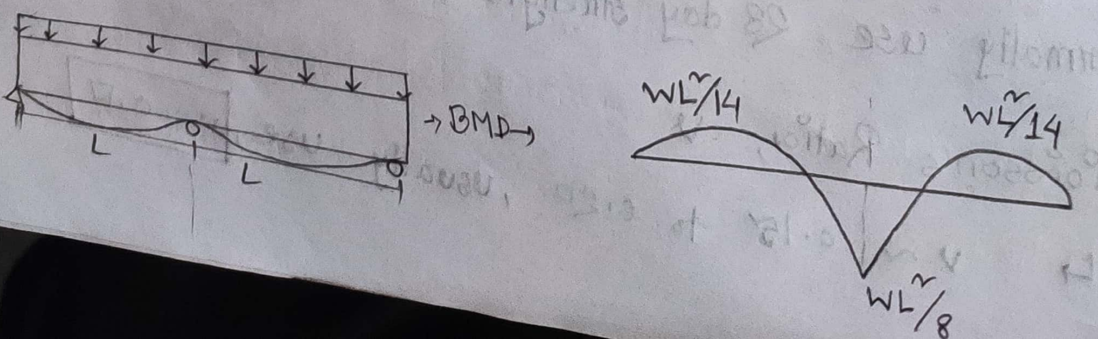




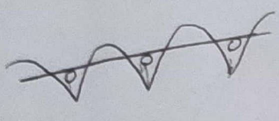
Cantilever beam

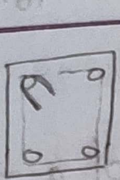


Continuous beam

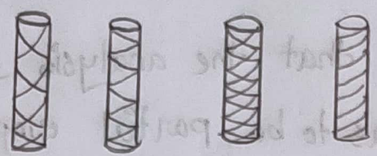


[Interior Support moment -ve হয়]





Reinforcing Bars (Deformed bars)



Bonding ensure করে।

- Why is Mild steel Reinforcing Bar?
  - The coefficient of concrete and steel (0.3×10 3.3×10^{-6}) are sufficiently close to resist undesirable differential thermal deformation.
  - Corrosion resistance of bare steel is poor where as together use minimizes excellent corrosion resistant >> maintainan cost.
  - Thermal conductivity of concrete is relatively low and provides insulation for steel rebars.

BMBC

ACI Building Codes

It is understandable that the analysis for strength of a reinforced concrete member has to be partial empirical although rational.

These semi-rational principles and methods are being constant as a result of theoretical and experimental research accumulate.

The American Concrete Institute (ACI), serves as clearing house for these changes, issues building code requirements.

Design Philosophy

WSD & USD. ⟶ Ultimate strength Design
↳ Working Stress Design

Strength Design Method

the service loads are increased sufficiently by factors to obtain the load at which failure is considered to be 'imminent / close to occur'. — factored load or factored service load.

Strength provided ≥ [Strength required to carry factored loads]

Advantage of USD over WSD

1. Consider mode of failure
2. Non linear behavior of concrete
3. More realastic F.S. (factor of safety)

④ Ultimate load prediction 5%

⑤ Saving

Safety Provisions

Structures and structural members must always be designed to carry some reserve load above what is expected under normal use.

There are 3 main reasons why some sort of safety factors are necessary in structural design -

- Variability in resistance
- Variability in loading
- Consequences of failure

Consequences of failure

A number of subjective factors must be considered in determining an acceptable level of safety.

- Potential loss of life
- Cost of clearing the debris and replacement of the structure and its contents.
- Cost to society
- Type of failure warning of failure, existence of alternative of load paths.

Loading

1. Specifications
   - BNBC (Bangladesh National Building Code)
   ACI, IS,

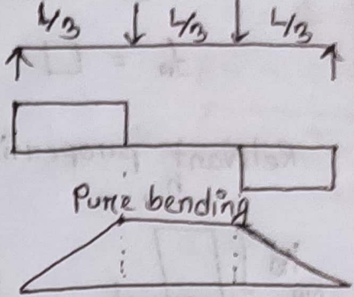
Environmental loads -

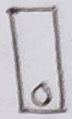
- Earthquake
- Tsunami
- Wind
- Soil pressure
- Ponding of Rainwater
- Temperature Differential
- Snow loads

05.04.22

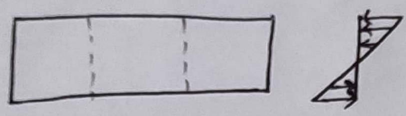
$f_s = nf_c$ $\qquad n = \frac{E_s}{E_c} = \frac{29\times10^6 \text{ (fixed)}}{57000\sqrt{f_c'} \text{ (psi)}}$

13th edition বই





Article - 3.3 : Reinforced concrete beam behavior



load এর পরিমান বাড়ালে crack বাড়বে moment যেখানে বেশি, সেখানে crack হওয়ার সম্ভাবনা বেশি। Hair crack

Concrete can not axially carry tensile load.

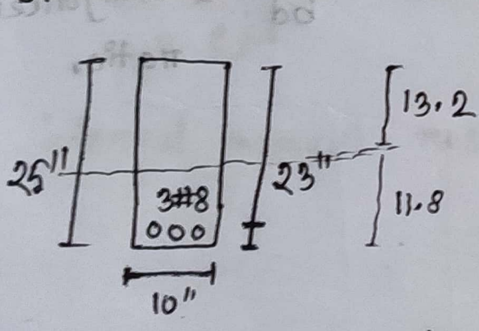
failure condition এ diagram non-linear -

Working Stress Design (WSD)

Ultimate strength Design (USD)

Problem 1. Stresses elastic section cracked

3#8 = 3 no. 8 bar



Overall depth 25"

effective depth 23"

Check weather the beam is cracked. if applied bending momen M = 90 kip-ft. Also calculation relevant properties.

$I_t = 14740 \text{ in}^4$

$f_{ct} = \frac{Mc}{I} = \frac{90\times12\times1000\times11.8}{14740} =$

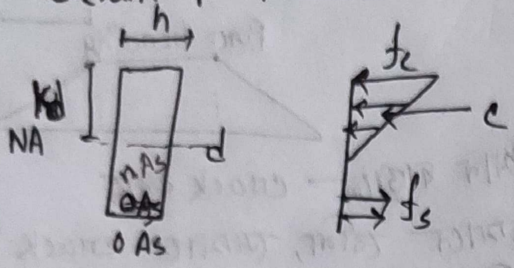
$= 864.5$ psi

Tensile strength

$f_{ct} > f_r$

$f_r = \square$

Relevant properties –



location of neutral axis can be found by equating the moment of tensile & compression radius.

$$b \cdot kd \cdot \frac{kd}{2} = nA_s\,(d - kd) \quad (\text{moment})$$

$$kd = \square$$

$$k = \sqrt{(pn)^2 + 2pn} - pn \qquad p = \rho = \frac{A_s}{bd} = \text{reinforcement ratio.}$$

location of neutral axis =

এত load থাকবে, neutral axis তত উপরে থাকবে।

$p = \frac{3 \times 0.79}{10 \times 23}$

$= 0.0103$

$n = 8$

$pn = 0.0824$

$k = \sqrt{.0824^2 + 2 \times .0824} - .0824$

$= 0.33$

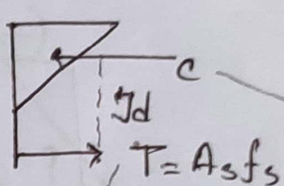
$kd = 0.33 \times 23 = 7.63$

Total compression $= \frac{f_c}{bkd}$

= comp. area x average comp. stress

$= b \cdot kd \cdot \left(\frac{f_c + 0}{2}\right) = \frac{1}{2} f_c \cdot bkd$

Total tensile force $= A_s f_s$



$jd = d - \frac{kd}{3}$

$J = 1 - k/3$

$M = A_s f_s jd = Tjd$ → Taking moment about T

$M = \frac{1}{2} f_c jkbd^2$ → Taking moment about C

$= cjd$

internal moment resisting capacity – minimum হবে

10.04.22

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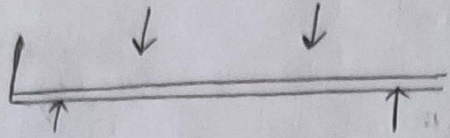
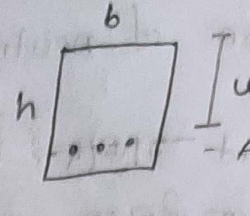
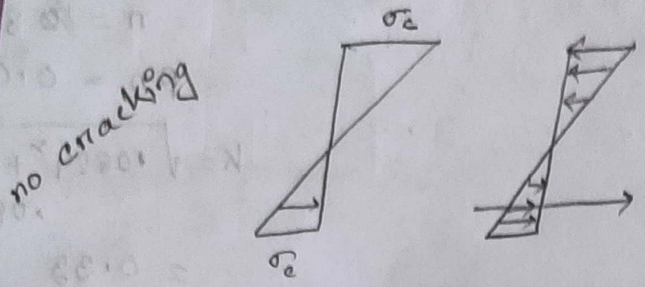
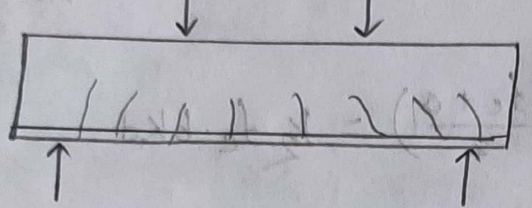
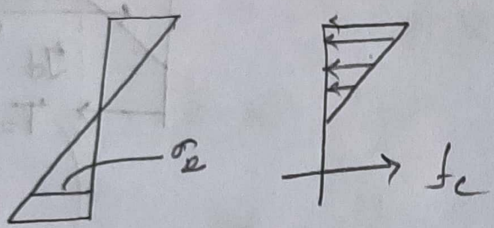
fig 3.2



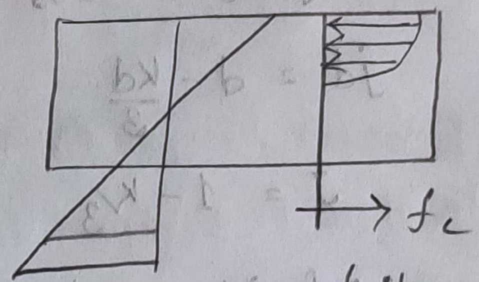




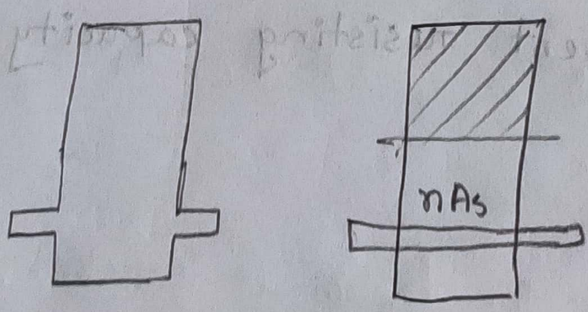




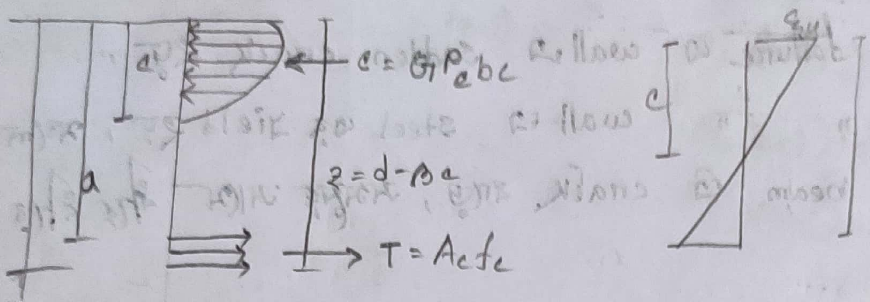
up to elastic limit



Just before failure
(USD method)



Flexural Strength - General Analysis

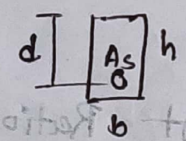


Three possibilities in inelastic Behavior -

- Compression Failure - (over reinforced beam)
- Tension Failure - (under reinforced beam)
- Balanced Failure - (Balanced reinforcement)

$f_y = 60000$ psi (Steel এর yield)

$\epsilon_y = \frac{f_y}{E_s}$



ϵ_s & ϵ_{cu} } Balanced

Balanced reinforcement ratio, $\rho = \frac{A_s}{bd}$

Tension Failure : Steel will yield first and concrete will fail by secondary condition. ρ will be less than ρ_b.

- Concrete fail করলো - secondary.

Compression Failure : Concrete will yield first and steel will not reach yield stress.

this section is known as over reinforce section.

Compression failure is ~~better~~ not better than tensile failure. ~~Safer~~.

Compression failure এ wall এ sudden crack হয়।

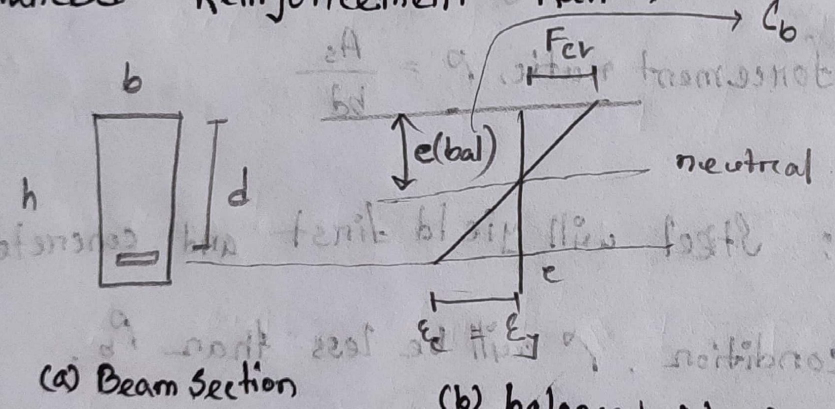
tensile " " wall এ steel এর yield হয়, অনেক

wall এর beam এ crack করে, সময়ের আগে ধীরে ধীরে বাড়ে,

$f_s < f_y$ over reinforce এ - neutral উপরে

$\rho > \rho_b$ under " " - " নিচে

Balanced Reinforcement Ratio.



(a) Beam Section

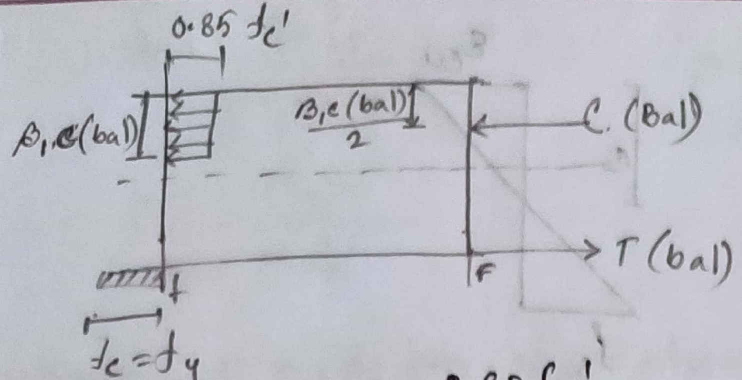
(b) balanced strain distribution.

$$\frac{c_b}{\varepsilon_{cu}} = \frac{d}{\varepsilon_{cu} + \varepsilon_y}$$

$$c_b = \left(\frac{\varepsilon_{cu}}{\varepsilon_{cu} + \varepsilon_y} \right) d$$

$\varepsilon_{cu} = 0.003 \sim 0.004$

ACI, $\varepsilon_{cu} = 0.003$

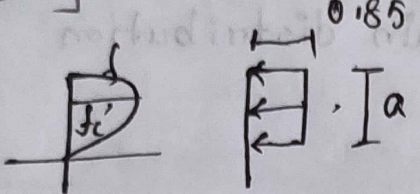


$T(bal) = C_c(bal)$

$A_s(bal) \times f_y = 0.85 f_c' a_b b$

$A_s(bal) \times f_y = 0.85 f_c' (\beta_1 c_b) b$

$A_s(bal) = \frac{1}{f_y} \cdot (0.85 \beta_1 f_c' c_b b)$



$T(bal) = A_s f_y$

C_c = Compression area x Compression stress
0.85 f_c'

with of beam x depth of ~~beam~~ comp. block → a → $\beta_1 c$

$$\rho_b = \frac{A_s(bal)}{bd} = \frac{0.85 \beta_1 f_c'}{f_y} \times \frac{b}{bd} \times \left(\frac{\varepsilon_{cu}}{\varepsilon_{cu} + \varepsilon_y}\right) d$$

$$\rho_b = \frac{0.85 \beta_1 f_c'}{f_y} \left(\frac{\varepsilon_{cu}}{\varepsilon_{cu} + \varepsilon_y}\right)$$

Substitute $\varepsilon_{cu} = 0.003$ and multiplying both numerator and denominator by $E_s = 29,000,000$

$$\rho_b = 0.85 \times \frac{\beta_1 f_c'}{f_y} \cdot \left(\frac{87,000}{87,000 + f_y}\right).$$

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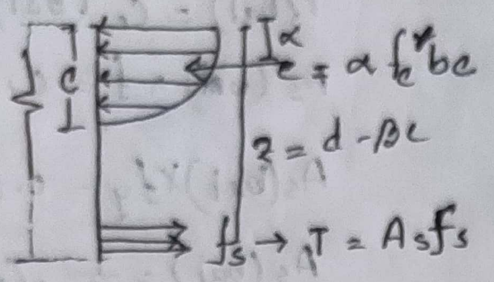
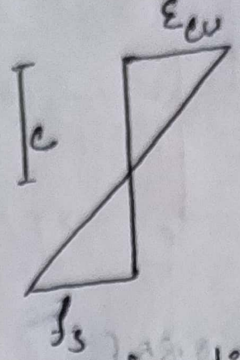


Stress distribution



strain distribution

Under reinforce section :

The value of f_s here is equal to f_y.

1. $f_s = f_y$.

2. $C = \alpha f_c' bc$. bc = area of compression block.

$\therefore \alpha = f_{av}/f_c'$

3. $\alpha = 0.72$ for f_c' less or equal to 4000 psi and decrease by 0.04 for every 1000 psi above 4000 psi

4. $\beta = 0.425$ for $f_c' \leq 4000$ psi and decrease by 0.025 for every 1000psi above 4000psi.

T = Area of steel x Stress in steel

$C = T$

$\Rightarrow \alpha f_c' bc = A_s f_y$

Table A.5
Book

$$c = \frac{A_s f_y}{\alpha f_c' b} \qquad \rho = \frac{A_s}{bd}$$

$$c = \frac{\rho f_y d}{\alpha f_c'}$$

where, c = depth of neutral axis from compression face

Nominal Moment Capacity (M_n):

$$M_n = Tz = A_s f_y (d - \beta c)$$

$$c = \frac{\rho f_s d}{\alpha f_c'}$$

$$M_n = A_s f_y \left(d - \frac{\beta \rho f_y d}{\alpha f_c'}\right) \qquad \beta = 0.425$$

$$\alpha = 0.72$$

$$= A_s f_y \left(1 - 0.59 \frac{f_y}{f_c'} \rho\right)$$

Taking moment load ; T

$$M_n = Cz = \alpha f_c' bc (d - \beta c)$$

$$= \alpha f_c' b \frac{\rho f_y d}{\alpha f_c'} \left(d - \beta \frac{\rho f_y d}{\alpha f_c'}\right)$$

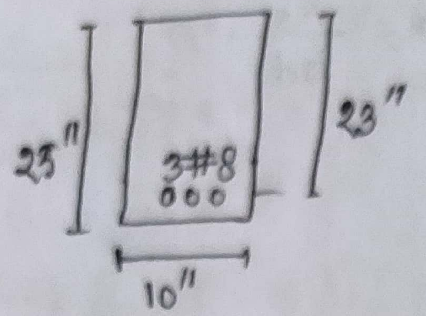
$$= \rho f_y bd \left(d - 0.59 \frac{f_y \rho}{f_c'} d\right)$$

$$= \rho f_y bd^2 \left(1 - 0.59 \frac{\rho f_y}{f_c'}\right) = R bd^2$$

Problem :

$f_y = 60000$ psi

$f_c' = 4000$ psi



determine 1. Working moment capacity

2. Nominal moment at which the beam will fail.

Soln : 1. Working moment capacity

$M = \frac{1}{2} f_c J K b d^2$

$M = A_s f_s J d$

(যেটাতে কম মান পাব সেটা দিয়ে হিসাব করব].

Relevant properties :

$n = 8$, $K = 0.33$, $J = 0.89$

f_c = allowable stress of concrete

$= 0.45 f_c' = 0.45 \times 4000 = 1800$ psi.

f_s = allowable stress of steel

$= 0.4 f_y = 0.4 \times 60000 = 24000$ psi.

$M = \frac{1}{2} \times 1800 \times 0.89 \times 10.33 \times 10 \times 23^2 = 1.39 \times 10^6$

$= 116.5$ k-ft

$M = 2.37 \times 24000 \times 0.89 \times 23 = 1.16 \times 10^6 = 97.03$ k-ft

2. Nominal moment capacity : (depends on mode of failure)

$\rho < \rho_b$ হলে under reinforce.

$$\rho_b = 0.85 \beta_1 \frac{f_c'}{f_y} \cdot \frac{\varepsilon_{cu}}{\varepsilon_{cu} + \varepsilon_y}$$

$\beta_1 = 0.85$ for $f_c' \leq 4000$ psi and decrease by 0.05 for every 1000 psi above 4000 psi.

Here, $\beta_1 = 0.85$

$$\varepsilon_y = \frac{f_y}{E_s} = \frac{60000}{29 \times 10^6} = 0.0021$$

$\varepsilon_{cu} = 0.003$

$$\rho_b = 0.85 \times 0.85 \times \frac{~~1800~~ 4000}{60000} \times \frac{0.003}{0.003 + 0.0021}$$

$= 0.028.$

$$\rho = \frac{A_s}{bd} = \frac{2.37}{10 \times 23} = 0.0103$$

$\rho < \rho_b$

Thus, the section is under reinforce section and tension failure will occur.

$$M_n = A_s f_y d \left(1 - 0.59 \frac{f_y}{f_c'} \rho\right)$$

$$= 2.97 \times 10^6 \text{ lb-in}$$

$$= 247.5 \text{ k-ft}$$

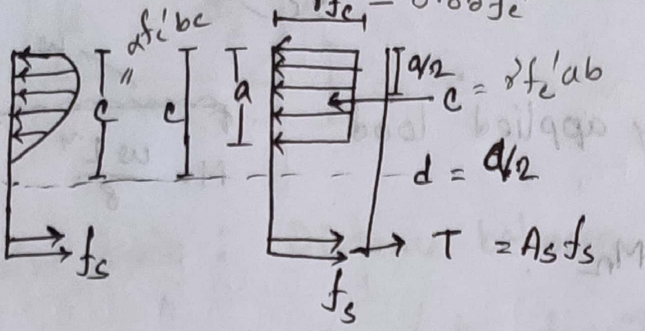
$$c = \frac{\rho f_y d}{\alpha f_c'} = \frac{0.0103 \times 60000 \times 23}{0.72 \times 4000} = 4.93''$$

$$c_b = ?$$

12.04.2022

Equivalent Rectangular Stress Distribution

Condition: $C = \alpha f_c' bc = \gamma f_c' ab$



$a = \beta_1 c$

$\beta_1 = 2\beta = 0.85$ for $f_c' \leq 4000$ psi and decrease by 0.05 for every 1000psi above 4000 psi.

$\gamma = \alpha/\beta_1 = 0.85$ for $f_c' \leq 6000$ pi

Under reinforced Section:

$f_s = f_y$

$C = T$

$\Rightarrow 0.85 f_c' ab = A_s f_y$

$a = \frac{A_s f_y}{0.85 f_c' b} = \frac{\rho f_y d}{0.85 f_c'}$ $\left[\because \rho = \frac{A_s}{bd}\right]$

~~Mome~~ Nominal moment Capacity, $M_n = Tz = A_s f_y (d - a/2)$

$M_n = Cz = 0.85 f_c' ab (d - a/2)$

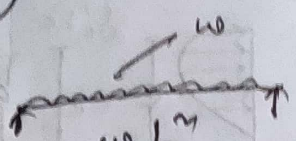
$= 0.85 f_c' \beta_1 c\, b \left(d - \frac{~~0.85~~ \beta_1 c}{2}\right)$ $[a = \beta_1 c]$

$= 0.85 f_c' \beta_1 \gamma f_c' ab \cdot b \left(d - \frac{\beta_1 \gamma f_c' ab}{2}\right)$

$= 0.85 f_c'^2 \beta_1 \gamma ab^2 \left(d - \frac{\beta_1 \gamma f_c' ab}{2}\right)$

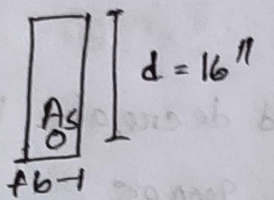
$$= \rho f_y bd^2 \left(1 - 0.59 \frac{\rho f_y}{f_c'}\right)$$

moment produced by applied load



$M = \frac{wL^2}{8}$

moment capacity M_n



Ultimate moment capacity / Design moment —

$M_u = \phi M_n$ ϕ = Capacity Reduction Factor

Value of ϕ depends on —

① Mode of failure

② Consequence of failure

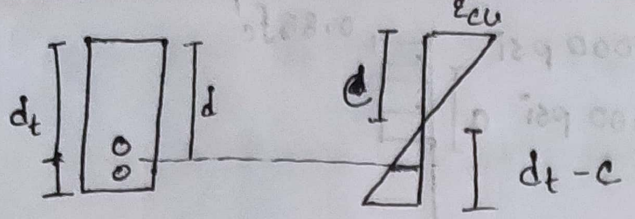
(beam column এর failure এর মান কমাতে ϕ use করি) Tensile / compression এ ϕ কম,

$\phi = 0.9$ if $\varepsilon_t \geq 0.005$ — Tensile

$\phi = 0.65$ if $\varepsilon_t \leq 0.002$ — compression

$\phi =$ ~~0.65~~ $0.65 + (\varepsilon_t - 0.002)\frac{250}{3}$

ε_t = Net tensile strength.



$$\varepsilon_t = \varepsilon_{cu} \frac{d_t - c}{c}$$

Effective depth : Distance between compression phase and centroid of the tensile reinforcement.

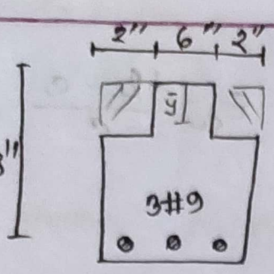
d_t = Distance between compression phase and furthest layer of reinforcement. (সবশেষের নিচে)

$d_t > d$ for multiple layer reinforcement

$d_t = d$ for single layer reinforcement.

আগের math এর ultimate moment = ?

16.05.22

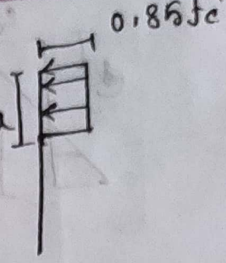


$f_c' = 5000$ psi

$f_y = 6000$ psi

$M_n = ?$

$M_u = ?$



$C = 0.85 f_c' ab$

Sol^n:

Balance steel ratio, $\rho_b = 0.85 \beta_1 \frac{f_c'}{f_y} \frac{\varepsilon_u}{\varepsilon_u + \varepsilon_y}$

$\beta_1 =$

$\beta_1 = 0.85 - 0.05 = 0.80$

$\varepsilon_y = \frac{f_y}{E_s} = \frac{60000 \text{ psi}}{29 \times 10^6 \text{ psi}} = 0.002$

$\rho_b = 0.85 \times 0.80 \times \frac{5}{60} \times \frac{0.003}{0.003 + 0.002}$

$= 0.034.$

$\rho = \frac{A_s}{bd} = \frac{3 \times 1}{10 \times 18 - (2 \times 3 \times 2)}$

$= 0.017.$

$\rho < \rho_b$, so, the section is under reinforced section.

Steel will yield, $f_s = f_y$

(যে অংশটা বাদ যাবে)

$C = 0.85 f_c' ab - 0.85 f_c' \times (2 \times 3) \times 2$

$T = A_s f_y = 3 \times 60$

$c = 0.85 f_c' \times ab - 0.85 f_c' \times (2 \times 3 \times 2)$

$\Rightarrow 3 \times 60 = 0.85 \times 5000 \times a \times 10 - 0.85 \times 5000 \times 2 \times 3 \times 2$

$\Rightarrow a = 5.44''$

$c = a/\beta_1 \Rightarrow c = \dfrac{5.44}{0.80} = 6.8''$

$M_n = A_s f_y \times (d - a/2) \times$

$\bar{y} = \dfrac{5.44 \times 10 \times \frac{5.44}{2} - 2 \times 3 \times 3/2 \times 2}{5.44 \times 10 - 2 \times 3 \times 3}$

$= A_s f_y (d - \bar{y})$

$= 3.065$

$= 3 \times 60000 (18 - 3.06)$

$= 2.68 \times 10^6$.

$\varepsilon_t = \varepsilon_u \dfrac{d_t - c}{c}$

$d_t = d = 18''$

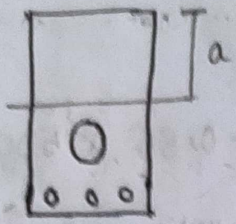
$= 0.003 \times \dfrac{18 - 6.8}{6.8} = 0.0049 < 0.005$

$\phi < 0.9$

$M_u = \phi M_n$

$= 0.9 \times 2.68 \times 10^6$

$=$



Over reinforced section :

under reinforced → $f_s = f_y$

$C = T = A_s f_y$

for over reinforced → $f_s < f_y$

$$f_s = \varepsilon_s E_s$$

$$= \varepsilon_u \frac{d-c}{c} E_s$$

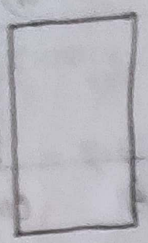
$$T = A_s f_s = A_s E_s \varepsilon_u \frac{d-c}{c}$$

$$C = 0.85 f_c' ab = 0.85 f_c' \beta_1 c b$$

$$C = T \Rightarrow 0.85 \beta_1 f_c' bc = A_s E_s \varepsilon_u \frac{d-c}{c}$$

$c = ?$

10 ≥ Beam



$f_c' = 5000$ psi

$f_y = 60{,}000$ psi

d =

Moment এর eq অনুযায়ী $M = \frac{1}{2} f_c jk bd^2$
এক্ষেত্রে b > d হওয়া সুবিধাজনক, কারণ
bending d এর জন্য বেশি বাড়ে।
So, h বাড়ালে moment বাড়ে।
↳ deflection $\propto \frac{1}{I E_s}$ $I = \frac{bh^3}{12}$ b×h
So, deflection কম হয়

Calculate the amount of reinforcement to ensure:

1. Tension failure
2. Balanced failure
3. Compression failure

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1. Tension failure

$\rho_b = \frac{A_s}{bd} = \qquad = 0.034$

$A_{sb} = \rho_b \times bd = 0.034 \times 12 \times 24 = 9.792$

$h = 24$

$d = h - (\_\_\_\_) = 21$

$A_{sb} = \rho_b \times bd = 0.034 \times 12 \times 21 = 8.57 \text{ in}^2$.

$d = h - (\qquad) A_s = 10 \text{ in}^2$ (over reinforced section)

$A_s = 6.00 \text{ in}^2$. (Under reinforced section)

Design of Simply reinforced Beam (USD method)

Minimum thickness of beam, t =

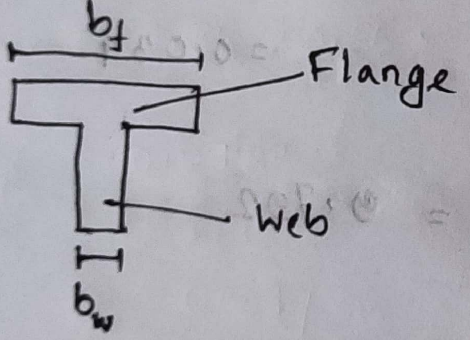
	Simply supported	one end cont	Both end cont.	Cantilever
t =	L/16	L/18.5	L/24	L/8

Minimum reinforcement

$$A_s = \frac{3\sqrt{f_c'}}{f_y} b_w d \geq \frac{200\, b_w d}{f_y}$$

Maximum reinforcement

$$\rho_{max} = 0.85\, \beta_1 \frac{f_c'}{f_y} \cdot \frac{\varepsilon_u}{\varepsilon_u + 0.005}$$



Problem - 1 : Design a simply supported beam over 20' stand to carry a super imposed dead load = 2 k/ft (additional load) and a live load = 2.5 k/ft. Follow USD method and use $f_c' = 4000$ psi and $f_y = 60000$ psi.

[Super imposed বললে dead load আলাদা হিসাব করে]

Solⁿ: $t_{min} = \frac{20 \times 12}{16} = 15$ in.

Let, 12 × 18 in section will be used

Load Calculation:

1. Dead load :

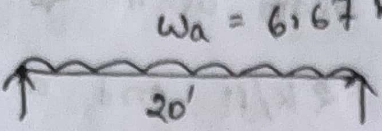
(i) Self weight of the beam : $\frac{12 \times 18}{12 \times 12} \times 150 = 225$ lb/ft

$= 0.225$ k/ft.

(ii) Super imposed dead load = Total dead load = $\frac{2 + 0.22}{~~2.225~~}$ = 2

2. Live load = 2.5 k/ft

3. Factored load W_a = ~~12~~ 1.2 DL + 1.6 LL = 1.2 ×



$$M_{Max} = \frac{w_a L^2}{8} = \frac{6.67 \times (20)^2}{8} = 333.5 \text{ K-ft}$$

Dead load, Live load বাড়ানো হল, safety বাড়ানোর জন্য .

Depth check :

$M_u = \phi M_n$

~~$M_n = \rho f_y bd^2 \left(\frac{1 - 0.59 \rho f_y}{f_c'}\right)$~~

$= \rho f_y bd^2 \left(1 - 0.59 \frac{\rho f_y}{f_c'}\right)$

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

$= 0.018$.

Let, $\rho = 0.017$ $\quad \phi = 0.9$

$\therefore M_u = \phi M_n$

$\Rightarrow 333.5 \times 12 = \phi \rho f_y bd^2 \left(1 - 0.59 \frac{\rho f_y}{f_c'}\right)$

$= 0.9 \times 0.017 \times 60 \times 12 \times d^2 \left(1 - 0.59 \frac{0.017 \times 60}{4}\right)$

$\Rightarrow d = 20.67''$. (depth required)

$t = 18''$

$\therefore d_{act} = 18 - 2.5 = 15.5$ (Actual depth) $<$ $d_{required}$

Section should be revised.

Trial #2: 12" × 24"

Self weight $= \frac{12 \times 24}{12 \times 12} \times 150 = 300 \text{ lb/ft} = 0.3 \text{ K/ft}$

Super imposed dead load = $2 + 0.3 = 2.3$

Factored load $w_a = 1.2 \times DL + 1.6 LL = 1.2 \times 2.3 + 1.6 \times 2.5$

$= 6.76 \text{ k/ft}$

$M_{max} = \frac{w_a L^2}{8}$

$= \frac{6.76 \times (2}{8}$

$M_u = \phi M_n$

$338 \times 12 = 0.9 \times 0.017 \times 60 \times 12 \times d^2 \left(1 - 0.59 \frac{0.017 \times 60}{4}\right)$ $= 338$

$d =$

[$t = 18$]

$d_{act} = 24 - 2.5 = 21.5 > d_{required}$.

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Reinforcement Calculation:

$A_s = \rho bd$

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

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

$\Rightarrow A_s = \frac{M_u}{\phi f_y (d - a/2)} = \frac{338}{0.9 \times 60 (21.5 - \frac{1.47 A_s}{2})}$

$a = \frac{A_s \times 60}{0.85 \times 4 \times 12} = 1.47 A_s$ in

$\therefore A_s = 4.06 \text{ in}^2$.

Method 2:

$A_s = \frac{M_u}{\phi f_y (d - a/2)}$ let, $a = 6''$ [$t/4$ or $d/4$] assume করে

$= \frac{338 \times 12}{0.9 \times 60 (21.5 - 6/2)} = 4.06 \text{ in}^2$.

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

$= \frac{4.06 \times 60}{0.85 \times 4 \times 12} = 5.97$ in.

a যদি মান কাছাকাছি না আসে তাহলে আবার check করতে হবে।

A_s এর eq^n solve করলে দুইটা মান আসবে. $A_s < \rho_{max} bd$ হতে হবে। তাহলে acceptable.

$$A_{s\,min} = \frac{3\sqrt{f_c'}}{f_y} b_w d = \frac{3\sqrt{4000}}{60000} \times 12 \times 21.5$$
$$= 0.82 \text{ in}^2$$

$$A_{s\,min} = \frac{200}{f_y} b_w d = \frac{200}{60000} \times 12 \times 21.5 = 0.86 \text{ in}^2.$$

minimum এর অন্তত মানে বড় যে পরিমাণ reinforcement দিতে হবে।

$$A_{s\,min} = \frac{3\sqrt{f_c'}}{f_y} \times b_w d \geq \frac{200}{f_y} b_w d. \quad \text{should be.}$$

Bar size #5

$6\#8 \rightarrow A_s = 4.06 \text{ in}^2$

$7\#7 \rightarrow A_s = 4.20 \text{ in}^2$

8#

A =

$A_1 = 0.6$ in

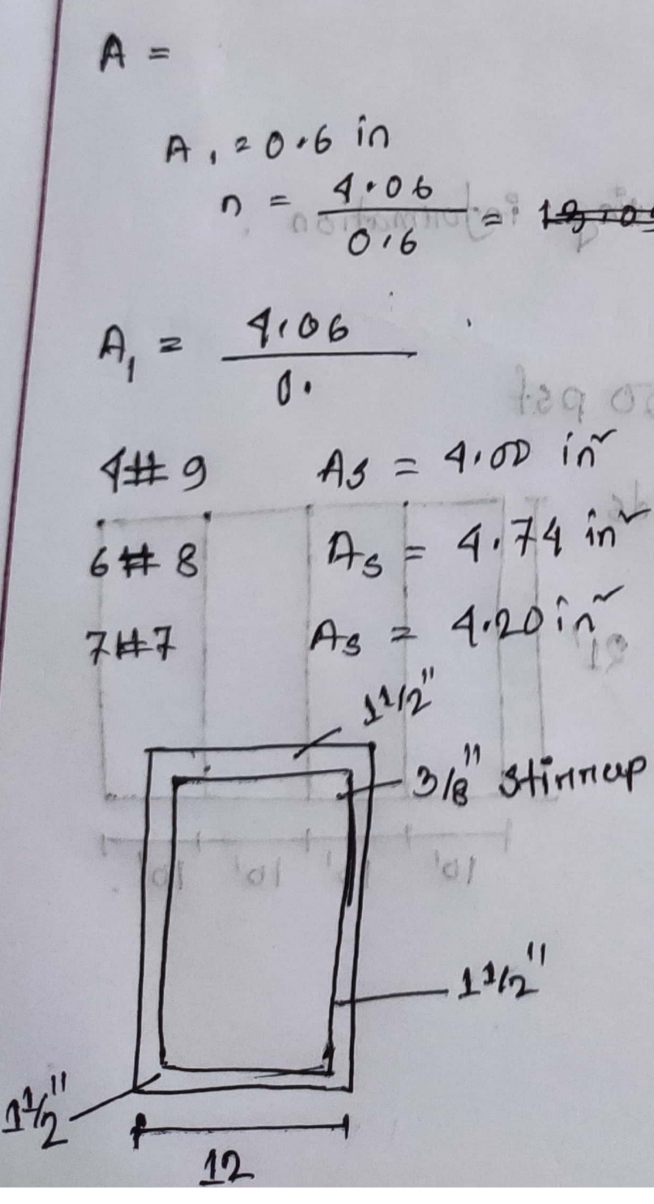
$$n = \frac{4.06}{0.6} = \sout{13.09}\ 6.71 \approx 7$$

$$A_1 = \frac{4.06}{0.}$$

4#9 $A_s = 4.00 \text{ in}^2$

6#8 $A_s = 4.74 \text{ in}^2$

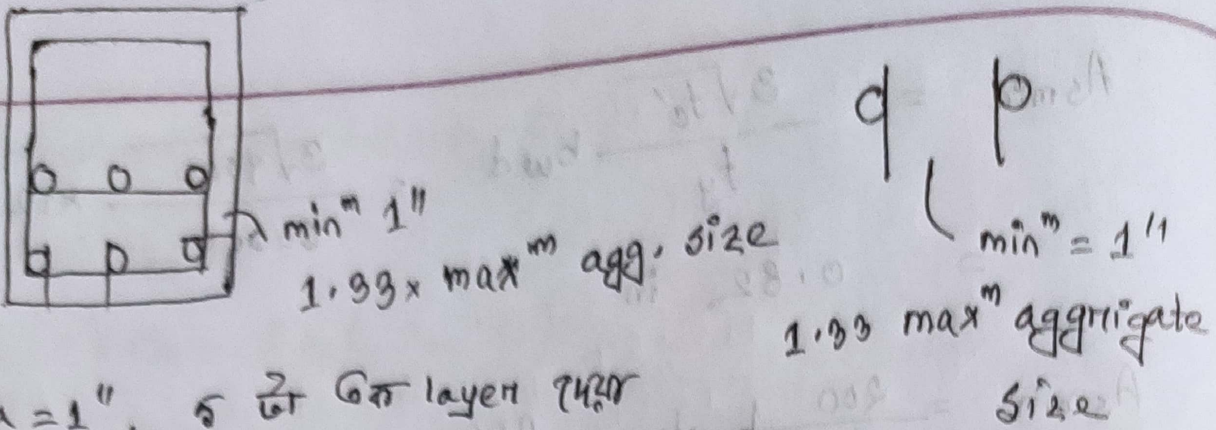
7#7 $A_s = 4.20 \text{ in}^2$



$b - 2\times1.5 - 2\times \phi_s \rightarrow$ stirrup

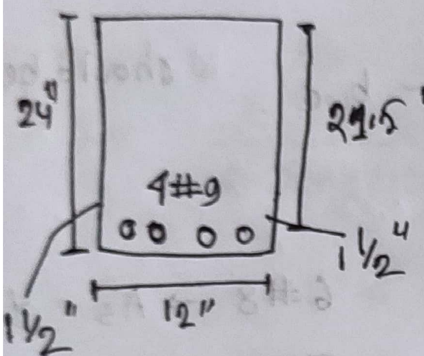
$= 12 - 3 - 0.75$

$= 8.25$ in.



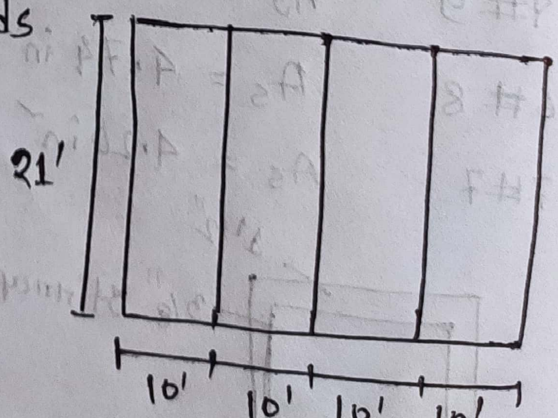
dia = 1'', 5 টা এক layer এ দেওয়া যাবে না। কারণ 5×1 + ফাঁকা জায়গা (4 টা) × 1 = 9 > 8.25

এক layer এ সর্বোচ্চ 4 টা bar দেওয়া যাবে।



Design a beam using the following information.

1. Slab thickness = 6''
2. live load on the floor = 50 psf
3. beams are fixed at both ends.
4. f_c' = 3000 psi
5. f_y = 60,000 psi
6. Design method WSD.



Qualitive beam moment diagram:

05.06.2022

$U_d = \frac{V_{max}}{\Sigma_0 j d}$

$\Sigma_0 = n \pi d$