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CE 413

(8)

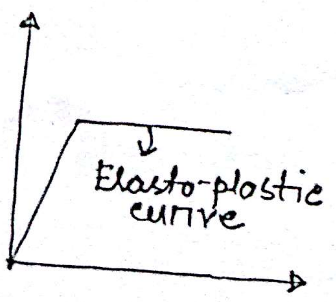
Load-Moment Interaction Diagram : (for Composite Section)
[Like RCC but have a steel I section]

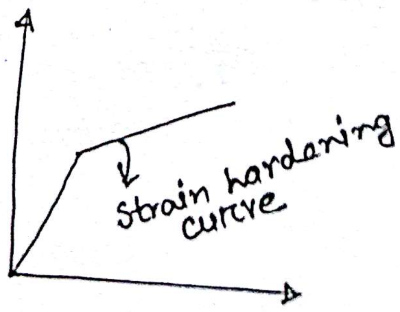
* Plastic stress distribution method is only applicable for compact section. (FEC, thick plate PEC, CFT compact limit এ থাকলে)

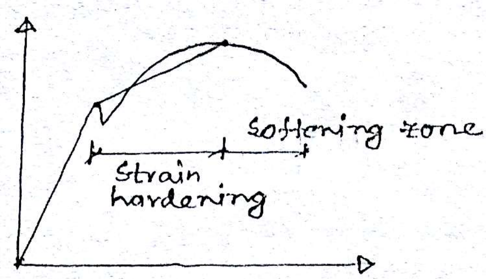
* Strain compatibility method is applicable for all section. (compact, non-compact)

- AISC Interaction equations

Strain Compatibility Method







Plastic stress distribution method :

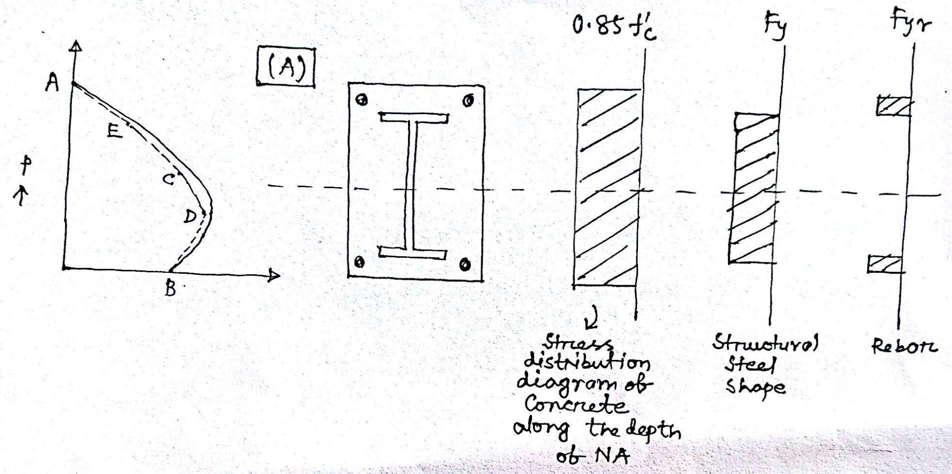
* Deep beam (depth বেশি হলে) এর deflection বেশি হয়, so plain section remains plain থাকে না।

* Fig C-11.1 ⇒ for FEC column (I section have strong & weak axis)

- A → pure compression
- B → pure bending
- C → compression zone এ আছে যার moment capacity B এর সমান
- D → C এর capacity র অর্ধেক
- E → NA এর location এর জন্য আসে এই point

** Draw interaction diagram and explain. (Exam এ আসতে পারে)

* Plastic stress distribution / Rigid-plastic method :



- $P_A = 0.85 A_c f'_c + A_s F_y + A_r F_{yr}$

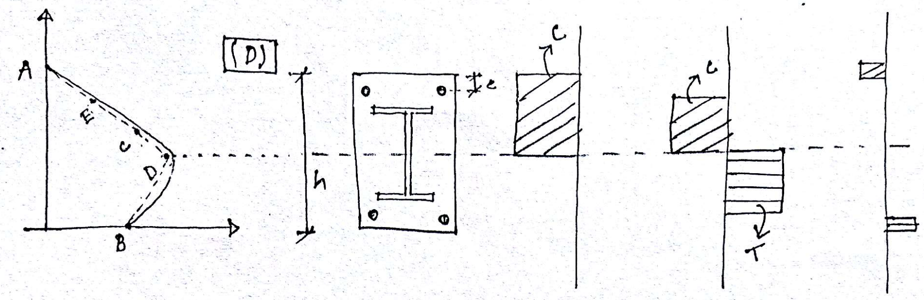
  $A_c \rightarrow (A_g - A_s - A_r)$

- $M_A = 0$ [এতটুকু পর্যন্ত বের করলে হবে]

** also consider the effect of global buckling (Slenderness) বললে P পর্যন্ত বের করতে হবে।

⇒ EI_{eff}, P_e etc বের করে $P_{nominal}$ capacity বের করতে হবে। } factor দেয়া থাকলে $P_{design/allowable}$ পর্যন্ত বের করতে হবে।

• D point এ ধরে নিচ্ছি NA মাঝখানে



Stress distribution for point D

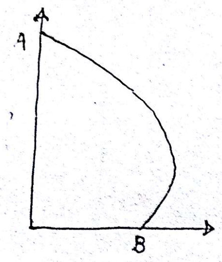
• $P_D = \dfrac{0.85 A_c f'_c}{2} + 0$

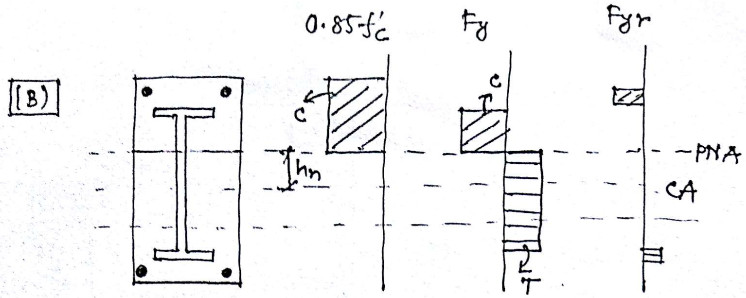
• $M_D = Z_s F_y + \left[A_{sr}\left(\frac{h}{2} - c\right)\right] F_{yr} + \left(\frac{bh}{2} \cdot \frac{h}{4}\right) 0.85 f'_c$

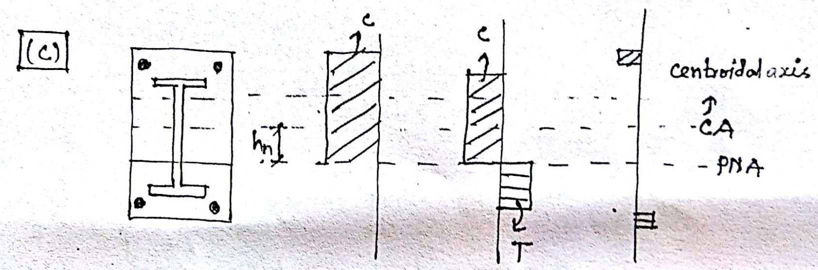
* I section (Steel) এর section modulus ?
Concrete rectangular section এর section modulus. } (Assignment)

• $M_D = Z_s F_y + Z_r F_{yr} + \dfrac{Z_c}{2}(0.85 f'_c)$

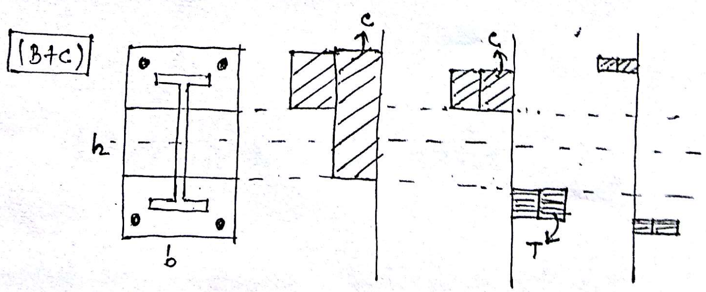
• h = total depth of the section
• c = bar এর cover (2.5″)
[দেয়া না থাকলে assume করতে হবে]







- $P_B = \Sigma P_i = 0$
- $P_C = \Sigma P_i \neq 0$
- $P_C + P_B = P_C$
- $P_C = 0.85 f'_c A_c$



** Draw stress distribution diagram for different points of Load-Moment interaction diagram. (Imp. for exam)

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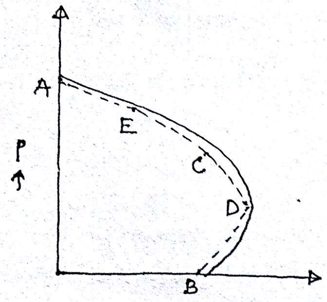
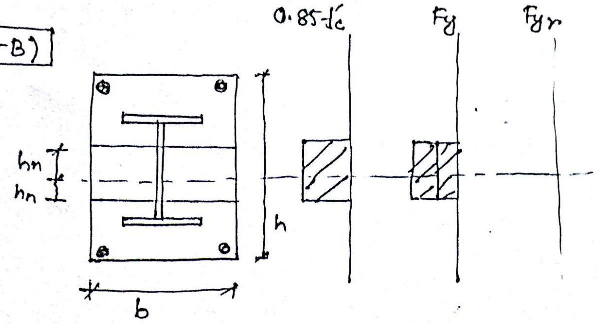
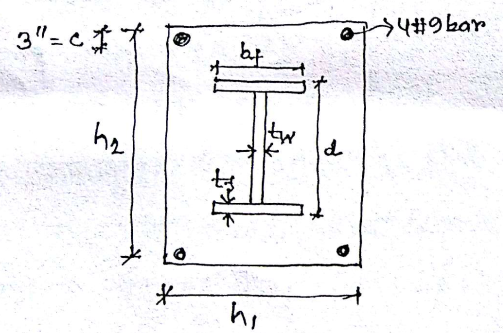


(C-B)



- $P_C - P_B = P_C$
- $P_C = 2h_n(.85f'_c b + F_y)$
- $h_n = \dfrac{.85f'_c A}{2(.85f'_c b + F_y)}$

☐ Problem:



Given,

$h_1 = 15''$ $f_y = 50$ ksi

$h_2 = 21''$ $f'_c = 5$ ksi

$b_f = 5''$ $E_s = 30\times10^3$ ksi

$t_f = 0.4''$ $E_c = 3600$ ksi

$d = 8''$

$t_w = .25''$

Formulate the P-M diagram for strong & weak axis of the given FEC.

(a) Plastic Stress distn (Code-2)

(b) Strain compatibility (Code-3)

(c) Interaction equation (Code-1)

[* Full math assignment, mid term এর পর জমা দিতে হবে]

Solⁿ:

* Strong axis থেকে A, B, C, D point পাব and weak axis থেকে E point পাব। (In P-M diagram)

[A]

- $P_A = 0.85 A_c f'_c + A_s F_y + A_{sr} F_{yr}$
  $= 1787^K$
  } nominal capacity without considering slenderness effect
- $M_A = 0$

* Slenderness effect consider করলে EI_{eff}, P_e etc. বের করে P_n পর্যন্ত বের করতে হবে। Slenderness effect consider করলে load আরও কমে যাবে। Design factor দ্বারা গুণ করলে আরও কমবে।

[D]

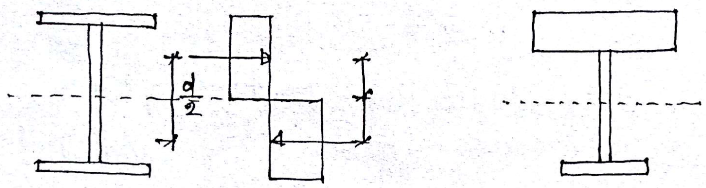
- $P_D = 648^K$

* Force (Area × Stress) * Moment arm about NA or CA নিয়ে M_D বের করব।

- $M_D = \left(\frac{A_s}{2} F_y\right)\frac{d}{2} + \left\{\frac{A_c}{2} \times 0.85 f'_c\right\} * \frac{h}{4} + (A_{sr} F_{yr})\left(\frac{h}{2} - c\right)$

↓

[* section modulus থেকেও বের করা যায় but I section ছাড়া অন্য section দিলে Z জানা difficult হবে]



* unsymmetric section হলে $\frac{d}{2}$ হবে না, তখন top & bottom আলাদাভাবে calculate করতে হবে।

B&C

* B point এর NA, CA থেকে h_n (distance between CA & PNA) উপরে and C point এর NA, CA থেকে h_n নিচে।

* h_n না জানলে area বের করতে পারব না, area না জানলে force পাব না। so P_c & M_c calculate করতে পারব না, so (B+C) & (C-B) করতে হবে to find P_c & $M_c(h_n)$ respectively.

- $P_c = 0.85 f'_c A_c = 1297K$ ↓ from (B+C) [কোন slenderness effect & design factor consider করি নাই]
- $P_B = 0$

- $P_c = 0.85f'_c A_c = \{(2h_n * b) \cdot 85 f'_c\} + (2h_n * t_w) * F_y * 2$

  $\downarrow$ from (C-B) ... $\downarrow$ (2 blocks)

  $\Downarrow$

  solve করলে h_n পাব

- $M_c = M_B = ?$ (assignment)

* M & P of A, B, C, D point (assignment)

* Slenderness effect apply করব 4 point এ। Slenderness consider করলে P এর value কমে যাবে।

Assignment : (Midterm এর পর Monday জমা দিতে হবে)

* only Plastic stress distribution method about strong & weak axis (LRFD method)

• ২টা P-M diagram

- without slenderness & φ factor
- with slenderness
- design factor দ্বারা গুণ

} In each P-M diagram

length = 16 ft

F_y = 50 ksi

F_{yr} = 60 ksi

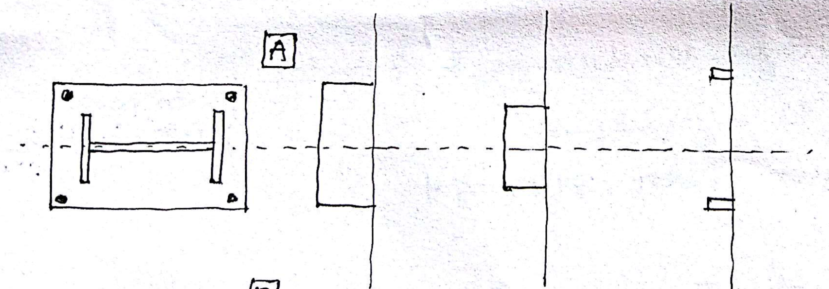
Composite Column Models

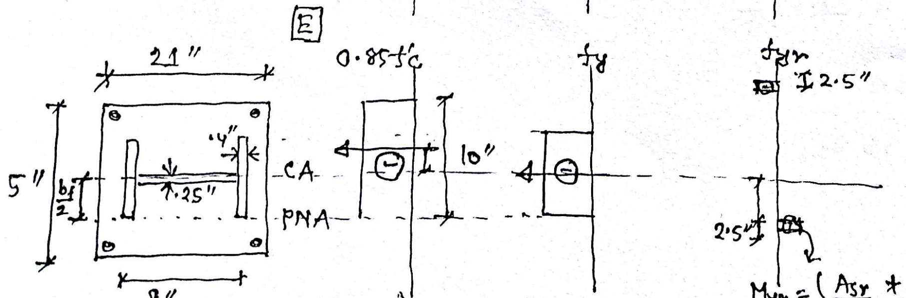
P-M interaction anchor points

⇒ Eq^n গুলো মুখস্থ করার দরকার নাই।

Plastic capacities about weak axis :

* NA হচ্ছে $\frac{b_f}{2}$ তে for E point





$M_{yr} = \left(\frac{A_{sr}}{2} * F_{yr}\right) * (7.5 - 2.5)$

$A_s = 5.8 \, in^2$ $\quad M_c = 860 * 2.5$

- $P_{con.} = 0.85 f'_c * (\overbrace{10 \times 21 - 2 \times 1 - 5.8}^{A_c})$

  (2×1 → 2rebar, 5.8 → A_s)

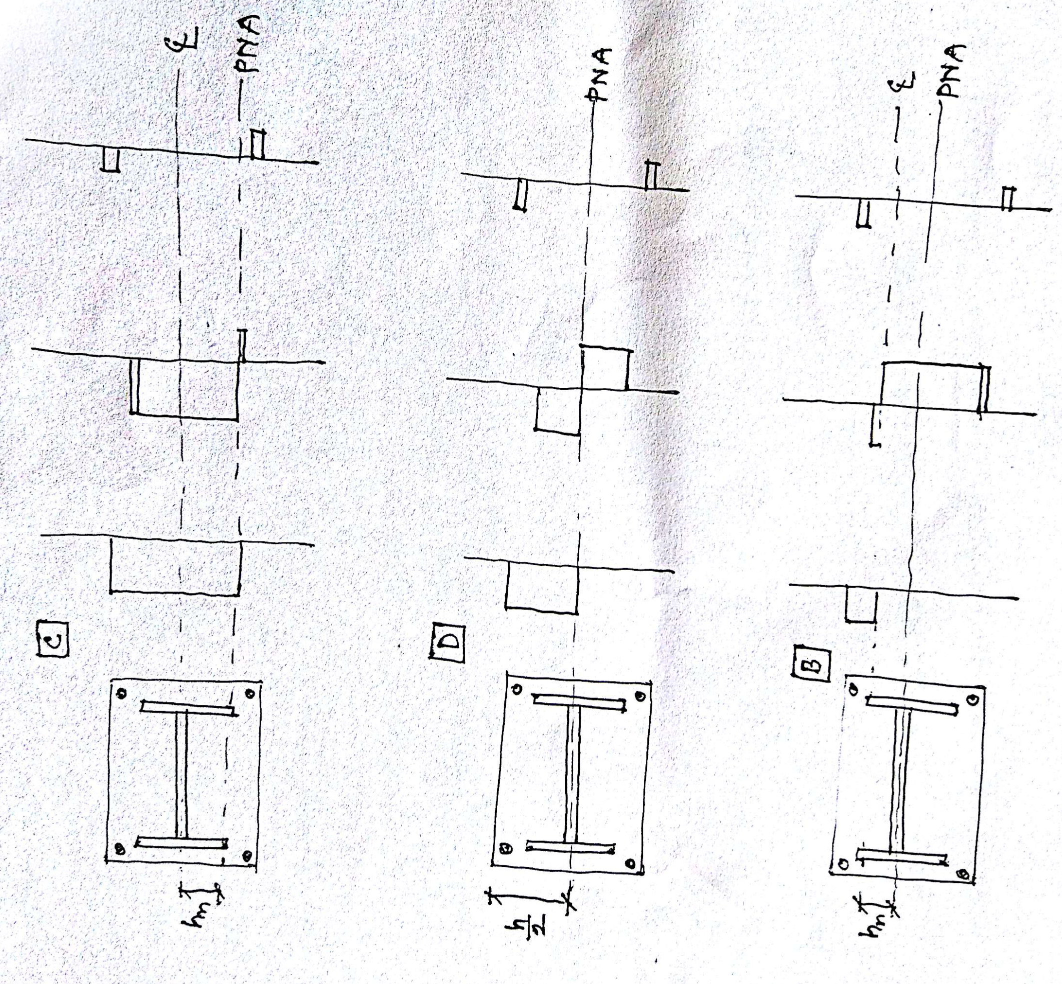
- $P_{steel} = A_s F_y + \frac{A_{sr}}{2} F_{yr}$ → 0 (ascancel each other)

- $P_E = P_{con.} + P_{steel} = 1150^k$

* Steel এর force CA এর respect এ center দিয়ে pass করে, so কোন contribution আসবে না।

- $M_E = 2750$ k-in

** I section এর যেসব formula দেয়া আছে applicable only for that section. Section different হলে formula different হবে।


PNA
C
h_n
PNA
D
h/2
PNA
B
h_n

Tubular section :

* Built up section → round part consider করতে হবে না

Circular section :

* B & C point এর জন্য আসবে না exam এ

** Draw stress-distribution diagram : (Imp. for exam)

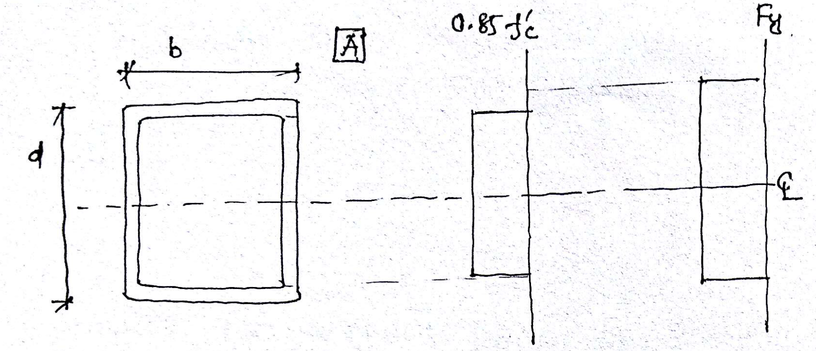
- Square, Rectangular, Circular, FEC column with I section, PEC (compact & non-compact) etc. section আসতে পারে।

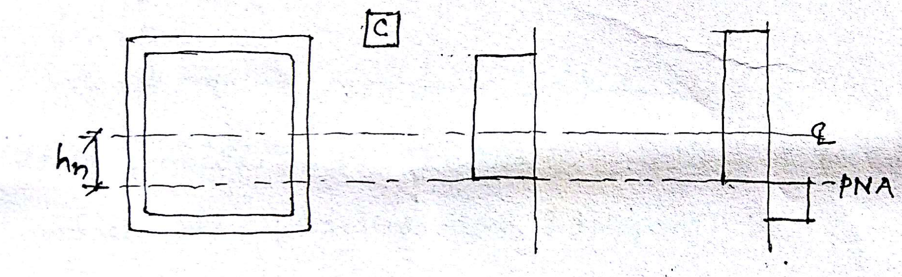
PEC :

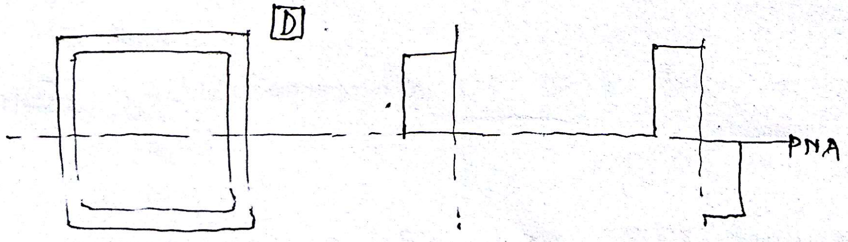
→ non-compact হলে strain-compatibility method দিয়ে করতে হবে।

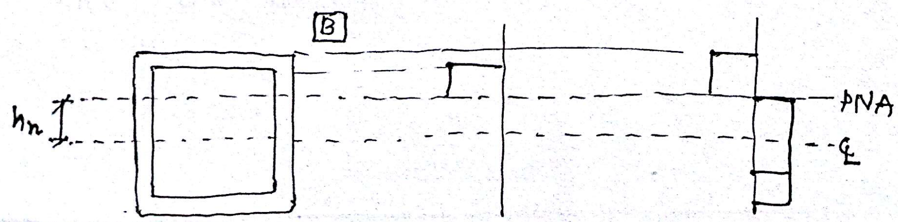
→ compact হলে FEC column এর মত করা যাবে।

Tubular section : (Stress-distⁿ diag.)

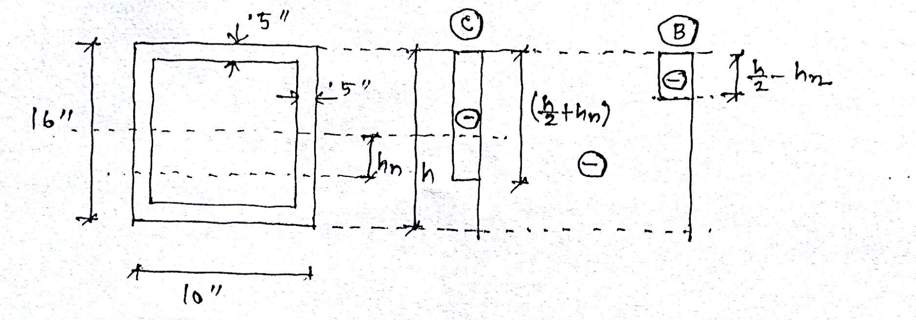








Problem :



$F_y = 50$ ksi

$F_{yr} = 60$ ksi

$f'_c = 5$ ksi

$E_c = 3600$ ksi

$E_s = 30000$ ksi

[* tubular circular column হলে $0.95 f'_c$ হবে।]

Soln :

(B) + (C) $\Rightarrow$ $P_B^{\nearrow 0} + P_c = P_c = 0.85 f'_c A_c$

(C) − (B) $\Rightarrow$ $P_c - P_B = 2 A_s F_y + 2(0.85 f'_c h_n b)$

$P_{con} = 0.85 f'_c * b * (\frac{h}{2} + h_n)$ [for (C)]

$P_{con} = 0.85 f'_c * b * (\frac{h}{2} - h_n)$ [for (B)]

$\Rightarrow 0.85 f'_c A_c = 2 A_s F_y + 2 * 0.85 f'_c b h_n$ [solve করলে h_n পাব]

thin plate হওয়ায় A_c ignore করেছি। So centerline dimension দিয়ে calculation করছি।

$M_C = M_B = ?$ (do yourself)

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* Plastic Stress Distribution Method থেকে বেশি math আসবে।
↓
Method II
(not applicable for non-compact section)

* Method III - Strain compatibility method

Method I - Interaction eqn :

- Uses AISC Beam-column Interaction Eqn
- Strong & weak axis bending
- Requires only pure axial, pure moment capacities (P_o, M_n)
- Conservative designs
- Can use existing Design Guide 6 (conservative answers)

* AISC interaction equations :

* For $\frac{P_r}{P_c} \geq 0.2$,

$$-\frac{P_r}{P_c} + \frac{8}{9}\left(M_{rx} + M_{ry}/M_{cy}\right) \leq 1$$

* For $\frac{P_r}{P_c} < 0.2$,

$$-\frac{P_r}{2P_c} + \left(M_{rx}/M_{cx} + M_{ry}/M_{cy}\right) \leq 1$$

- P_r = required axial compressive strength
- P_c = available axial compressive strength
- M_r = required flexural strength
- M_c = available flexural strength ($\phi_b M_n$ or M_n/Ω_b)
- $\phi_c = \phi_b = 0.9$

* uniaxial bending :

- Strong axis বসালে → $\frac{M_{ry}}{M_{cy}} = 0$
- Weak " " → $\frac{M_{rx}}{M_{cx}} = 0$

* col^m ok check করতে বললে value বসিয়ে < 1 কিনা দেখতে হবে।

[Math পরে করাবে।]

Floor System

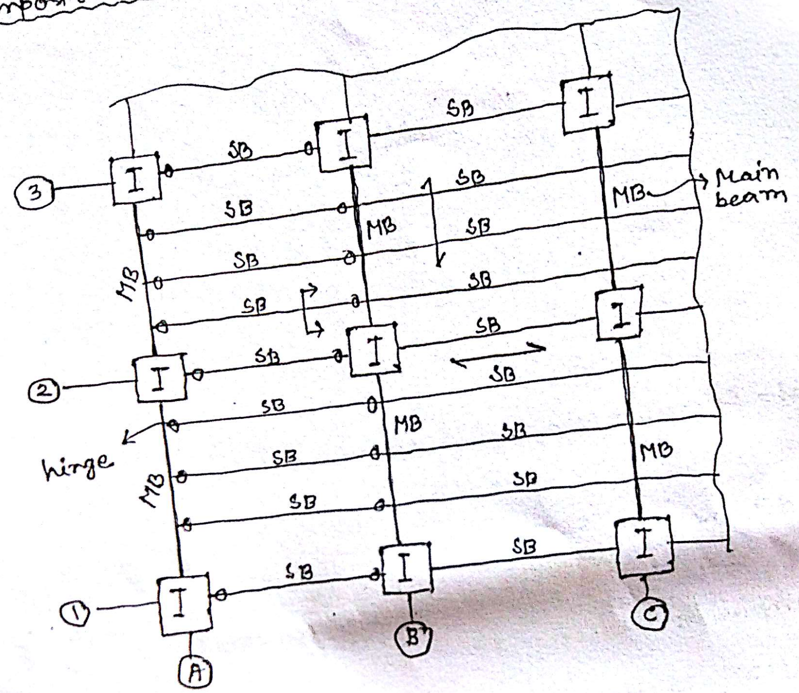
Steel - Concrete composite structural system :

* Composite system ⇒ Steel beam + RCC deck
(deck এর নিচে beam নাও থাকতে পারে)

* composite action না হলে beam and slab আলাদা আলাদা design করতে হবে।

Non-composite action এর design করলে secti. বড় লাগে।

Composite Beam and slab system:

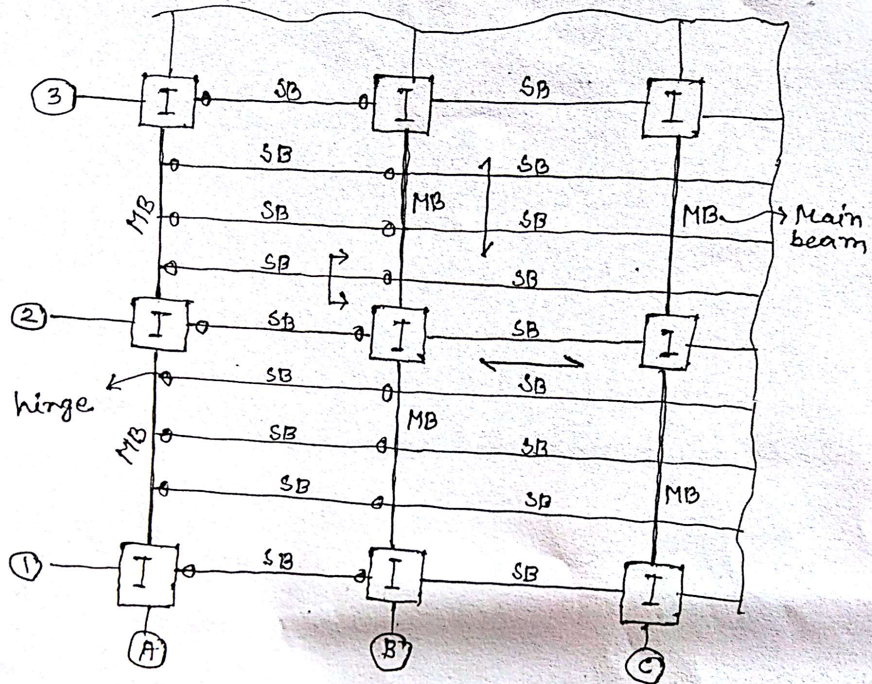


* Secondory beam ঘন ঘন দেওয়া হয়। SB তে simply supported connection দেওয়া হয়। so moment transfer হয়না।

* Moment connection → flange & web both connected থাকবে

*

Composite Beam and slab system:



* Secondary beam ঘন ঘন দেয়া হয়। SB তে simply supported connection দেয়া হয়। so moment transfer হয় না।

- Moment connection → flange & web both connected থাকবে

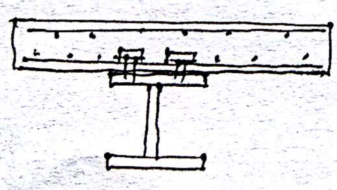
• Main beam এ hinge দিলে system unstable হয়ে যাবে।

* Load transfer

• SB → MB → column

* MB এ load বেশি আসবে। so MB fixed connection দিব। (Moment resisting connection)

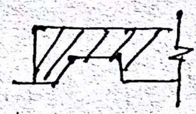
• Secondary beam / Intermediate floor beam

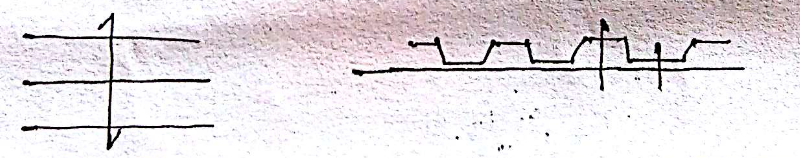


* Corrosive env. / Fire hazard যেখানে বেশি সেখানে fully encased beam use করা হয়।

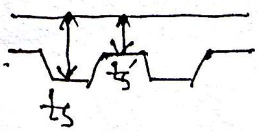
* Steel deck থাকলে slab এর নিচে উপরে 2 layer rod দিই for serviceability criteria. 2 layer rod ও দেয়া হয় thickness বেশি হলে।

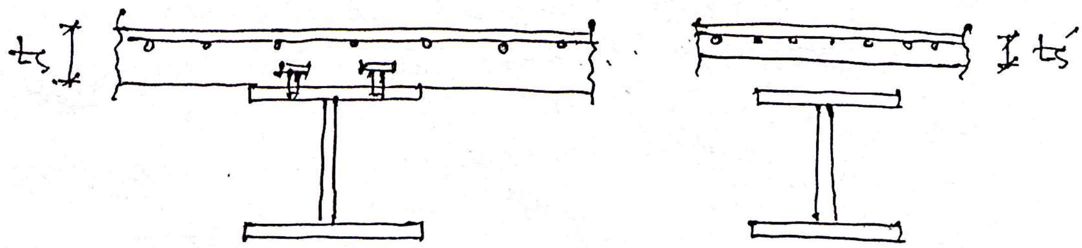
* Deck rib ⊥ to the beam এর design এর সময় slab এর effective thickness নিব। but load calculation এর সময় avg. thickness নিতে হবে।



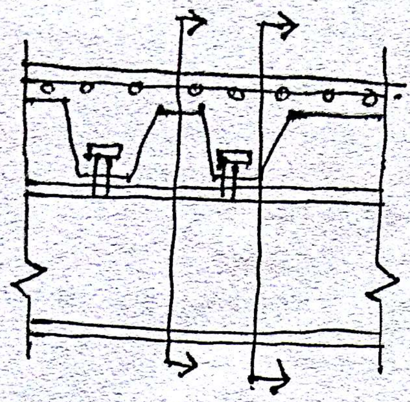


* Rib ⊥ to SB
but ∥ to MB

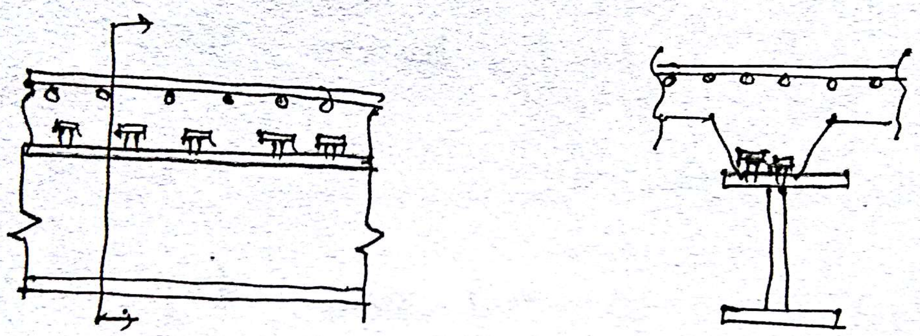




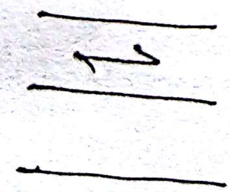
Secondary beam



SB



Main beam



* Rib ⊥ to MB
but ∥ to SB

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Composite Beam & Slab system :

* concrete strength gain করার আগে পর্যন্ত পুরো weight steel beam নিবে at construction stage.

* construction LL 20 - 40 psf ধরে নেওয়া হয়

* Beam wt + Deck wt + shear connector wt + Concrete slab wt + construction LL ⇒ এই সব load steel beam নিবে at construction stage. so only steel এর I section design করলে হবে।

* LL 50 - 60 psf in service condition

* DL ⇒ Floor finish, Partition wall, Fall ceiling & miscellenious load (10 - 20 psf) etc. extra আসবে at final stage. (concrete strength gain করলে)

• at final stage → steel section + concrete

* full composite action → no internal slip between steel & concrete. (economic)

* No " " → only I section ধরে design করবে. so I section এর size বড় লাগবে।

* 70-80% composite action ধরা better as shear connector এর খরচ বেশি হয়।

Advantages of Composite Floor System

Disadvantages " " " "

Construction methods :

* Shored & Un-shored
  ↓ ↓
  Propped Unpropped

* Un-shored construction হলে beam এর নিচে support থাকে না, so beam এর span হবে column to column.

* shored হলে beam এর span কমে যাবে। so moment কম আসবে, size কম লাগবে।

* large span হলে beam এর shored construction economic হয়।

* বেশিরভাগ ক্ষেত্রেই construction stage এর beam এর size govern করে।

Design of Composite Beams

22/04/17/Sat

Design of Composite Beams :

⇒ Strain hardening consider করছি না, Ultimate strength fy ধরে নিই।

⇒ Serviceability limit state থেকে thickness পাব।

Design of simply supported composite beams :

- Stage ২ → pre-composite stage
- Stage 3 → composite stage

* Secondary beam এর সাথে column এর connection fixed / hinge হতে পারে।

* Secondory beam connected with column → Edge beam (like SB or load কম/বেশি হতে পারে wall থাকলে)

Scanned by CamScanner

* Secondary beam এর সাথে main beam এর normally hinge connection দেয়া হয় as shear connection দিতে সুবিধা হয়।

* AISC Design guidelines for composite beams :

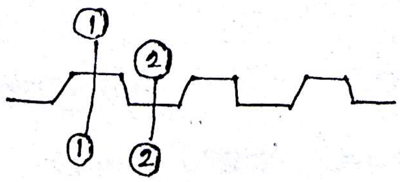
* H_s → দুইটার মধ্যে max^m টা govern করবে

* Slide 37 :

• max^m $8t_s$ → thickness of slab

and min^m $6d_s$ or $4d_s$

• $d_s \le 2.5\, t_f$ → flange thickness



* For rib ∥ to main beam ⇒ sec 1-1 নিব for moment calculation and sec 2-2 নিব for load calculation.

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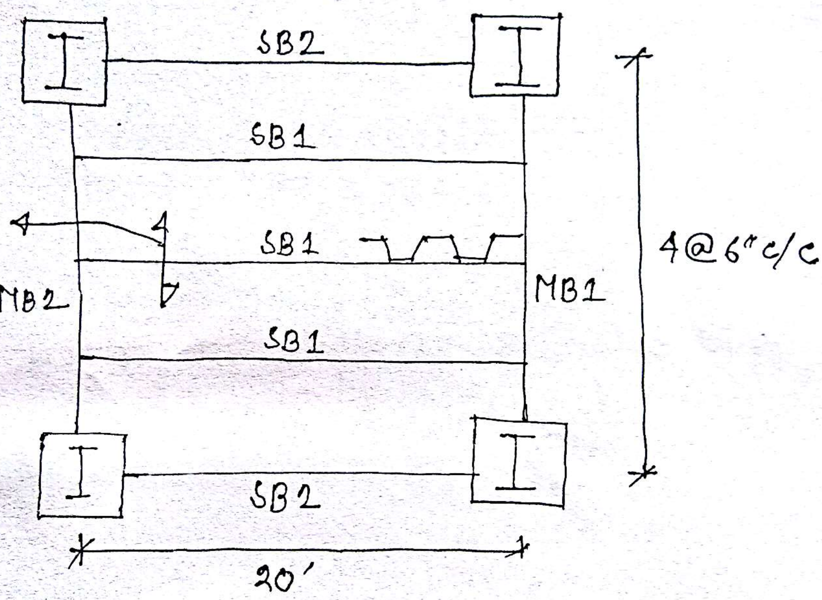
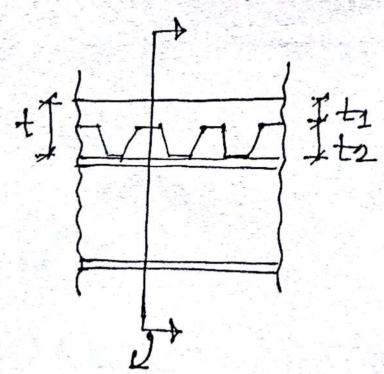
AISC Design Guidelines for Composite Beams:

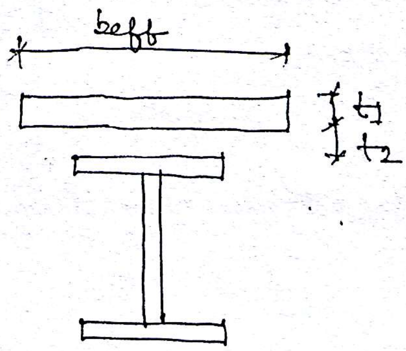
Flexure:

* For b_{eff} ⇒ Interior beam (check 2 criteria)
  Exterior beam (check 3 ")



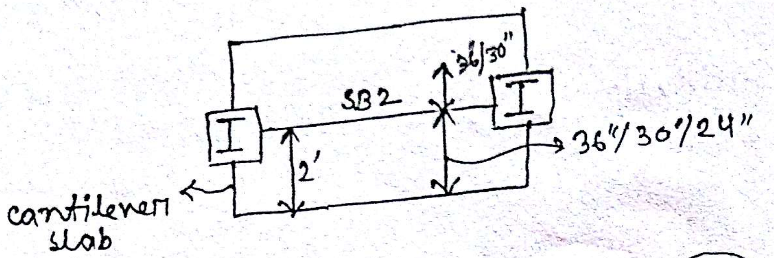


for flexure weakest section নিবে

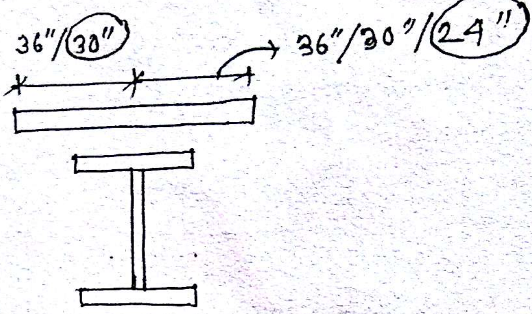


* $b_{eff} = \frac{1}{4} l_{span} = 60''$
  $= c/c \text{ distance} = 72''$ } min^m টা নিবে

$\therefore b_{eff} = 60''$



Edge beam এর আগে cantilever part থাকলে both side আলাদা calculate করতে হবে



$\therefore b_{eff} = 30 + 24 = 54''$

* Rib perpendicular & parallel এর সাথে effective width এর কোন সম্পর্ক নাই।

2a. Positive Flexural Strength

2b. Negative Flexural Strength

* Negative bending এর ক্ষেত্রে only steel section consider করব as concrete is poor in tension. as negative bending এ top tension & bottom compression হয়।

* Lateral torsional buckling prevent করার জন্য bracing দিতে হবে।

Slide 16 → shear connector capacity eq^n

* No. of connectors = $\frac{\text{Total shear}}{\text{one shear connector capacity}}$

- A_{sa} = single connector area

** R_g & R_p value → table or বলা থাকবে। না দেয়া থাকলে $R_g = R_p = 1$ assume করতে হবে।

** concrete is laid on steel beam, no metal deck বলা থাকলে,

$R_g = 1$, $R_p = 0.75$ assume করতে হবে।

Slide 49 :

- W_r → width of the beam
- h_r → height " " "

- thru deck → একসাথে connector punch করে লাগালে

Partial composite section:

⇒ 100% composite action achieve করা যায় না, so 70–80% composite action assume করা হয়।

- S_{tr} → transformed section modulus

- $\frac{V_h'}{V_h}$ → percent of composite action

- V_h = total shear to be resisted

- V_h' = যত shear pass করাতে চাই

$$* \; S_{eff} = S_s + \left[\frac{V_h'}{V_h}\right]^{1/2} (S_{tr} - S_s)$$

Design procedure:

Design of serviceability:

⇒ Long term load এ concrete এর deflection বেড়ে যাবে।

Limits for deflection:

* construction stage এ deflection satisfy না করলে prop দিব or beam এর section বাড়াব or beam টা combering করে দিব।

CE 413

(15)

Elastic Analysis of Composite Beam:

(Full Interaction Analysis)

Assumptions:

1. No slip at steel/concrete interface
2. Material linearly elastic
3. Corenete in tension is neglected

* Transformed Section → Bauindent Steel Section
  → " concrete "

↓

modular ratio, $n = \frac{E_s}{E_c}$

↓

(Short term)

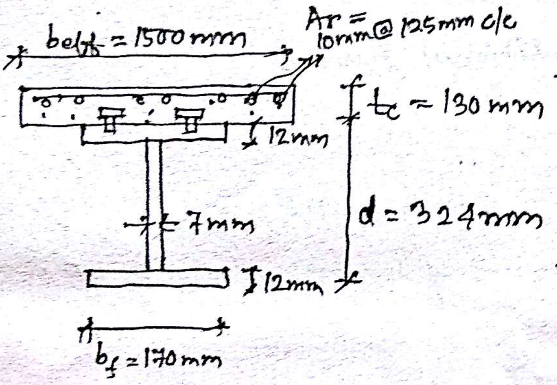
* Long term এ creep এর কারণে corerete এর E_c কমে যায়, so n বেড়ে যাবে for long-term effect

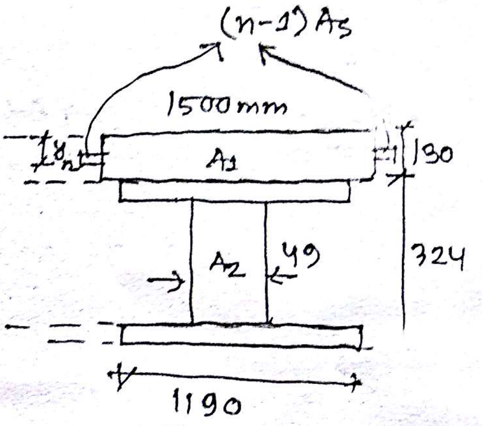
* Short-term modular ratio → $n = \frac{E_s}{E_c}$

* Long- " " " → $n_l = \frac{E_s}{E_{cl}}$ (usually $n_l = 3n$)

↓ Effective modulus of concrete

Transformed Section in (+) Bending:





Given,

$E_s = 200$ GPa

$E_c = 28.6$ GPa

$F_y = 300$ MPa

$f'_c = 25$ MPa

$n = \frac{E_s}{E_c} = \frac{200}{28.6} \approx 7$

• Structural I section:

$A_s = 6180\ mm^2$

$I_s = 115.1 \times 10^6\ mm^4$

$E_s I_s = 200 \times 10^6 \times 115.1 \times 10^{-6}$

* Steel এর stiffness বেশি, so flange width বাড়াব, so $b_f \times n$ করতে হবে।

* 1500 mm এ total As বের করে (n-1) As বের করব। (neglect ও করা যায়)। Ar দেয়া থাকলে rebar ও convert করতে হবে।

• Neglecting Ar: → Additional rebar

Transformed steel area $= nA_s = 7 \times 6180 = 43260 \text{ mm}^2$

" Moment of Inertia $= nI_s = 7 \times 115.1 \times 10^6$
$= 806 \times 10^6 \text{ mm}^4$

$y_n = 106.2 \text{ mm} < 130 \text{ mm}$ ∴ Concrete section is cracked

$$(I_{nc})_{\text{transformed section}} = \frac{1500 \times (130)^3}{12} + (1500 \times 130)\left(\frac{130}{2} - 106.2\right)^2$$

$$+ 806 \times 10^6 + 43260\left(130 + \frac{324}{2} - 106.2\right)^2$$

$$= 2905 \times 10^6 \text{ mm}^4$$

$E_c I_{nc} = 28.6 \times 2905 \times 10^6$ → composite section

$E_s I_s = 200 \times 115.1 \times 10^6$ → Steel only section

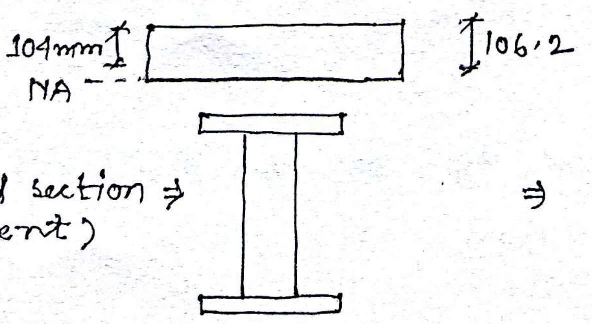
$$\frac{E_c I_{nc}}{E_s I_s} = 3.6$$

⇒ Composite section stiffness is 3.6 times greater than non-composite section.

* Deflection ratio $= \frac{1}{EI} = \frac{1}{3.6} = 0.28$

⇒ Composite section deflection is 28% less than non-composite section.

* NA concrete এর উপরে. so concrete এর কিছু থাকবে tension, so crack হবে।



Cracked section ⇒
(Assignment)

⇒ $E_c I_{nc} = ?$

* Comp. area X Moment arm + Tension area X Moment arm করলে y_n বের করব about NA for cracked section.

* Cracked & uncracked এর effect composite section এ negligible. so uncracked ধরেই design করি।

Comment:

① Flexural rigidity of cracked section is only 0.3% less than that of uncracked section as the cracked section is adjacent to the neutral axis.

∴ cracking can be ignored in composite section in ⊕ bending.

② $\frac{E_c I_{tc}}{E_s I_s} = 3.6$

∴ composite flexural rigidity is increased by 360%.

∴ deflection reduced by 28% of the steel beam of similar span.

* Assignment:

• Solve the problem using equivalent steel section.

(beff কে n দিয়ে ভাগ দিব)

First yield capacity of the composite beam: M_y

$f_y = 300$ MPa

$E_s = 200$ GPa

$\varepsilon_y = 0.0015$ mm/mm

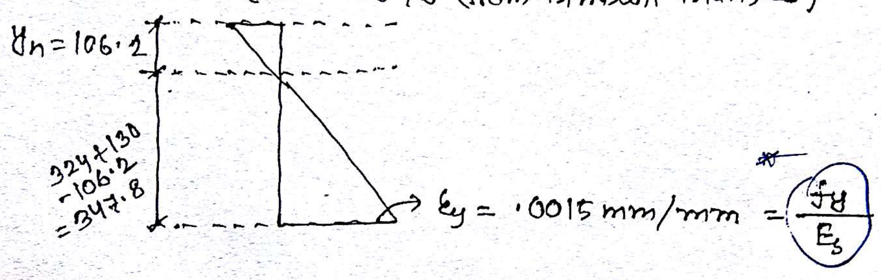
$f'_c = 25$ MPa

$f_c = \varepsilon_c E_c$

$= 13.1$ MPa

$\approx 0.5 f'_c$

$\varepsilon_c = .00046$ (from similar triangle)



$f_{c\,all.} = 0.5 f'_c = 12.5$ MPa

$$\frac{\varepsilon_y}{y} = \frac{1}{\rho} = \frac{0.0015}{347.8}$$

($\frac{1}{\rho}$ → curvature)

$$* \quad \frac{M}{EI} = \frac{1}{\rho}$$

$$* \quad M_y = \frac{EI}{\rho} = (E_c I_{nc}) \frac{1}{\rho} = (28.6 \times 10^3 \times 2905 \times 10^6 \times 4.31 \times 10^{-6})$$

$$= 363.9 \text{ N-mm}$$

(M_y → composite section এর M_y)

Yield Moment Capacity of only steel section:

* $\sigma_y = \frac{Mc}{I}$

* $M_{ys} = \frac{\sigma_y \times I_s}{c} = \frac{300 \times I_s}{\frac{324}{2}} = 213.15$

↓ yield moment for steel section

$\frac{358}{213} = 1.67 \rightarrow 1.7$

⇒ Composite section এর Moment capacity 1.7 times greater than non-composite section.

⇒ NA concrete এর মধ্যে সীমাবদ্ধ থাকলে, Local buckling হবে না as web/flange এ compression আসে না।

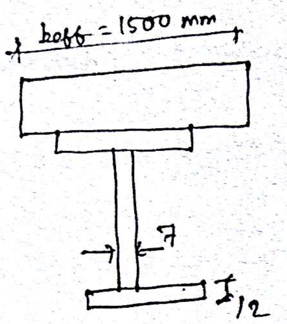
⇒ NA web/flange এ আসলে steel এর-ই part subjected to compression, তাহলে ensure করতে হবে either compact section or

⇒ Beam টা composite action এ আছে ensure করতে পারলে top flange এ compression আসলেও problem নাই।

⇒ construction stage এ top flange এ compression আসলে, top flange এ bracing দিতে হবে।

** Before the attainment of composite action, the top flange of the beam in compression must be adequately braced.

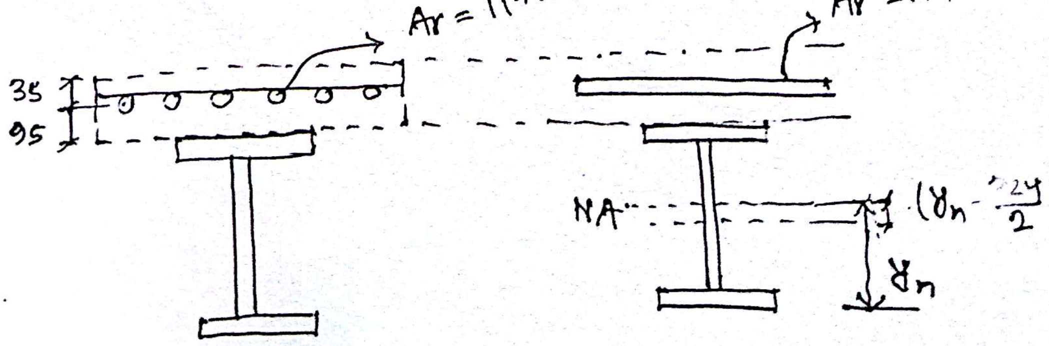
Transformed section in Negative Bending:
(Problem from Bradford book)



- support এর কাছে (−)ve bending → Top tension, bottom compression
- midspan " " (+)ve " → Top compression, bottom tension

⇒ ⊖ Concrete in tension is neglected.
⇒ can be analysed as steel beam

Soln:



$A_s = 6180\ mm^2$

$I_s = 115.1 \times 10^6\ mm^4$

• First Moment of area about the N.A. w.r.to lower fibre of the bottom flange :

$$1170\,(324+95-\bar{y}_n) = 6180\,\left(\bar{y}_n - \frac{324}{2}\right)$$

$$\therefore\ \bar{y}_n = 203\ mm$$

• Second Moment of area,

$$I_{ns} = 115.1 \times 10^6 + 6180\left(\frac{324}{2} - 203\right)^2 + 1170\,(324+95-203)^2$$

$$= 180.1 \times 10^6\ mm^4$$

$$\frac{180.1 - 115.1}{115.1} \times 100 = 56\,\%$$

[* (−) bending এ benefit (+) bending এর চেয়ে কম as (−) bending এর composite section less stronger than (+) bending composite section.]

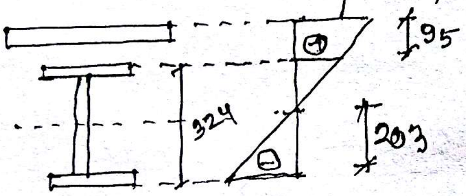
** Comment on the ans or what are the assumptions of analysis ? (Imp. for exam)

• First yield capacity of the composite section in (−) bending :

- first yield of the bottom of fibre of the steel section in compression

$f_y = 300 \ N/mm^2$

$\varepsilon_y = 1.5 \times 10^{-3} \ mm/mm$



$\varepsilon_{bottom} = 1.5 \times 10^{-3} \ mm/mm$

$f_{ys} = 400 \ N/mm^2$

$\varepsilon_{ys} = \frac{400}{200 \times 10^3} = 2 \times 10^{-3}$ [So top fibre এ yield হয় নাই only bottom fibre এ yield হয়েছে

$\frac{1}{\rho} = \frac{M}{EI}$

$\Rightarrow \frac{\varepsilon_y}{y} = \frac{M}{EI}$

$\Rightarrow M = \frac{\epsilon_y}{y} * EI$

$= \frac{1.5 \times 10^{-3}}{203} \times 200 \times 10^3 \times 180.1 \times 10^6$

$= 266.2$ kN-m

- ⊕ Bending :

  $M_y = 358$

- ⊖ Bending :   } compare with M_ys

  $M_y = 266$

[* ⊕ bending এর composite section এর efficiency ⊖ bending এর composite section এর চেয়ে বেশি।]

* Non-compact হলে local buckling হবে so math different হবে।

* Bottom flange is adequately braced against buckling ধরে নিই যাতে bottom fibre yield করে না।

* Compact section হলে yielding আগে হবে; buckling হবে না।

** Here assumption:
⇒ section is compact, so local buckling হচ্ছে না।

[* Next week Monday CT]

Ultimate strength of fully Composite section:
(collect PDF)

Assumptions

Two cases:

- Case 1 – steel section full in tension

- case 2 – slab full in tension, steel beam some part tension, some part compression

** With / without deck math আসতে পারে in exam. [see previous year term ques]

- $C_s \rightarrow$ Total compressive force resisted by steel

- $\frac{C_s}{f_y} \rightarrow A_{sc}$

- $A_{ST} = A_s - A_{sc}$

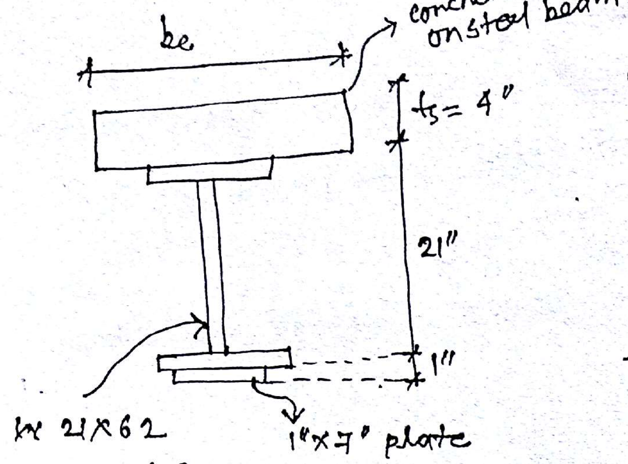
* Either compact or adequately braced against buckling দিবে চাইবে, non-compact করবে না।

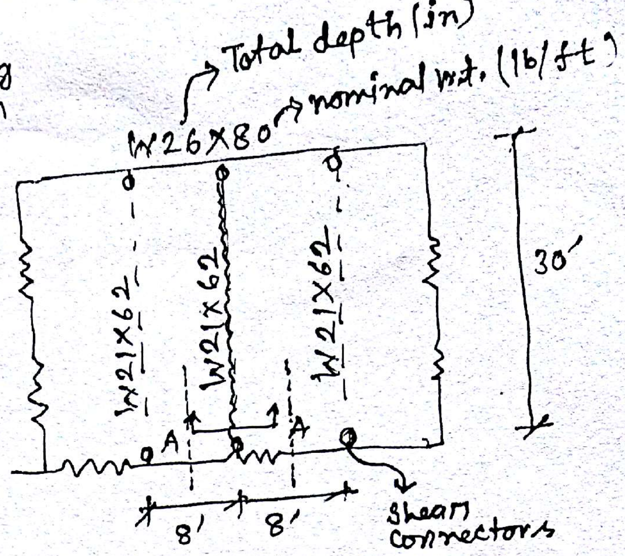
08/05/17 / Mon

CE 413

(17)

Problem:





W 21X62

$A = 18.3\ in^2$

$I = 1330\ in^4$

Sec A - A

Compute the stresses in the composite section for unshored construction → ① Precomposite stage, ② Composite stage

(কোন support / prop used হয় নাই)

$f'_c = 3\ ksi$, $n = 9$

Loading conditions:

PW = 60 psf

FF = 30 psf

Service LL = 60 psf

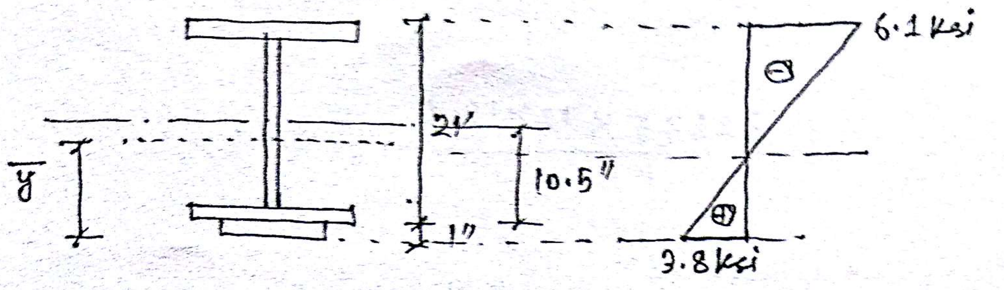
Construction LL = 20 psf

Miscellaneous DL = 10 psf

(... ceiling)

Solⁿ :

① **Pre-composite stage :** (only steel section নিবে as concrete strength gain করবে না in this stage)



$A_{s_1} = 18.3 \text{ in}^2$, $A_{s_2} = 1 \times 7$

$I_{s_1} = 1330 \text{ in}^4$, $I_{s_2} = \dfrac{7 \times (1)^3}{12}$

$\bar{y} = 8.45$

$\bar{I}_s = 1943 \text{ in}^4$

$M = \dfrac{wL^2}{8}$ [as shear connectors are simply supported]

• Precomposite stage :

[concrete slab এর load beam এর udl এ convert করলাম]

$\left(8 \times \frac{4''}{12}\right) \times 150$

DL : Concrete → $12.5 \times 4 = 50 \text{ psf} \times 8 = 400\#/'$

Steel → $\frac{7 \times 1}{144} \times 490 + 62 = 86\#/'$

DL = 486 #/'

LL : $(20 \times 8) = 160\#/'$

Construction LL = 20 psf

DL + LL = 646 #/'

[Here, ASD method is followed. LRFD বললে 1.2 DL & 1.6 LL করতে হবে।]

$\therefore M = \dfrac{646 \times (30)^2}{8} = 72675$ #-ft

$\sigma_{top} = \dfrac{Mc}{I} = \dfrac{72675 \times 12 \times 13.5}{1943} = 6.1$ ksi

$\sigma_{bottom} = \dfrac{72675 \times 12 \times 8.46}{1943} = 3.8$ ksi

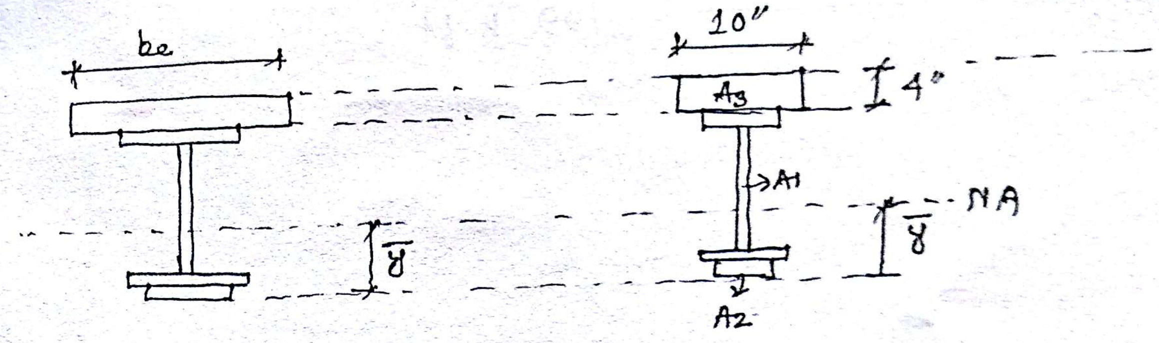
* $\Delta = \dfrac{5}{384} \dfrac{wL^4}{EI}$ (max^m deflection due to distributed load in simply supported beam)

[** two point load & concentrated load at mid
এর formula ও দেখতে হবে।]

$\therefore \Delta = \dfrac{5}{384} * \dfrac{646/12 \times (30 \times 12)^4}{30 \times 10^6 \times 1943} = 0.2''$

$\dfrac{L}{240} = \dfrac{30 \times 12}{240} = 1.5'' \Rightarrow$ Limit (max^m)

② Composite stage:



$be = \frac{1}{4}(\text{span}) = \frac{30}{4} = 90''$ (govern)

$= c/c \text{ distance} = 8' = 96''$

$\bar{y} = 17.96''$

$I = 6633 \text{ in}^4$

• Composite stage:

DL: Concrete → 400#/'

Steel → 86#/'

PW → (60×8) = 480#/'

PF → (30×8) = 240#/'

Misc. DL → (10×8) = 80#/'

1286#/'

LL: 480#/'

1766#/'

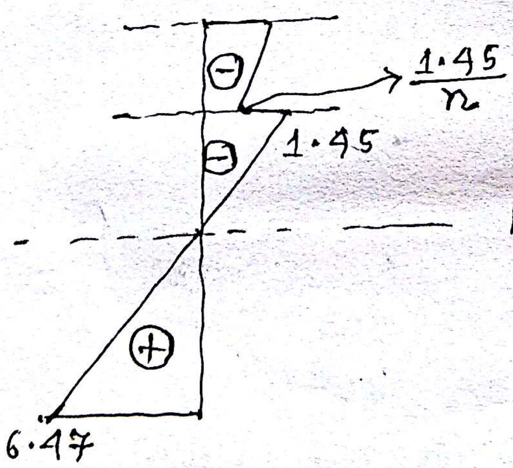
$$M = \frac{1766 \times 30^2}{8} = 199 \text{ k-ft}$$

Steel:

$$\sigma_{bottom} = \frac{199 \times 12 \times 17.96}{6633}$$

$$\sigma_{top} = \frac{(199 \times 12) \times (22 - 17.96)}{6633}$$

$$\Delta = \frac{5}{384} \times \frac{(1766/12) \times (30 \times 12)^4}{30 \times 10^6 \times 6633} = 0.16''$$



Composite Stage

concrete:

$$\sigma_{top} = \frac{(199 \times 12) \times 8.64}{66.33 \times n} = 0.32 \text{ ksi}$$

$$\sigma_{bottom} = \frac{1.45}{n}$$