01·03·2016.

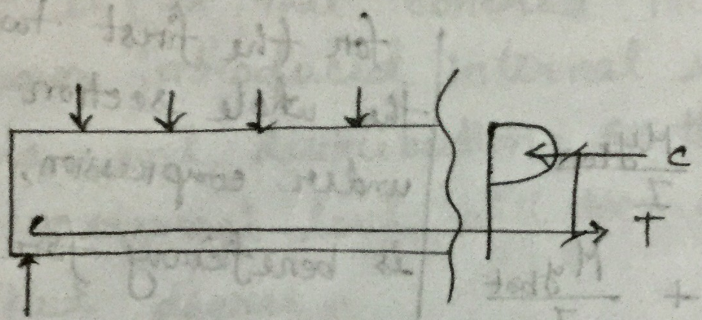
Sikandar Sir

Prestressed Concrete

Textbook:

- Design of Prestressed Concrete Structure by T.Y. Lin — 3rd Edition (SI System निव)

- Why prestressed concrete?



RCC → It is most inefficient cz reinforced concrete, the lower portion of the NA is of no use. So it can not be used everywhere specially in case of heavy loading.

So prestressed concrete is used.

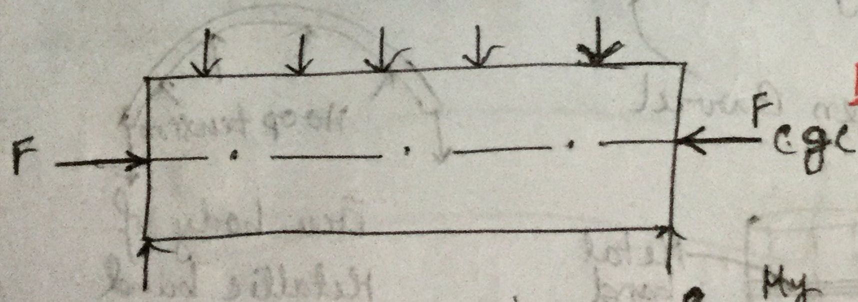
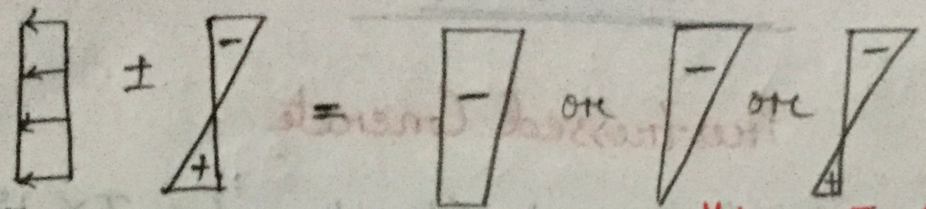


Fig: Concentrically applied prestress.

previous, $f = \frac{My}{I}$ only.

but for compression, $f = -F/A \pm \frac{My}{I}$

resultand may be 3 types of ways



F/A $\frac{My}{I}$ $F/A > \frac{My_{bot}}{I}$ $F/A = \frac{My_{bot}}{I}$ $F/A < \frac{My_{bot}}{I}$

At first –

$$f_{top} = -F/A - \frac{My_{top}}{I}$$

$$f_{bot} = -\frac{F}{A} + \frac{My_{bot}}{I}$$

for the first two cases, the whole section will be under compression, So this is beneficiary for concrete use.

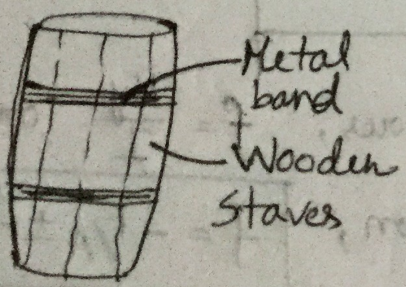
⇓

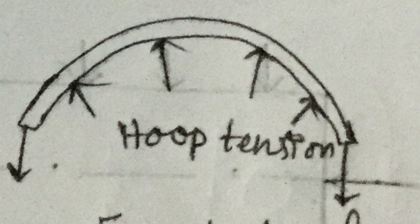
This F force is called

Prestressed ←

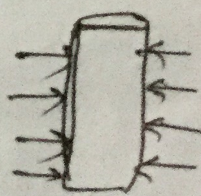
(fig from book)

Wooden Barrel.





Free body of Metallic band



So the band counter balance the liquids tension inside it.

• What is prestressed concrete?

—It is intentional creational of permanent stresses in structural members to improve its performance/behaviour.

— It is that concrete in which there have been introduced internal stresses of such magnitude and distribution so that the stresses due to external load will be counterbalanced by a desired degree.

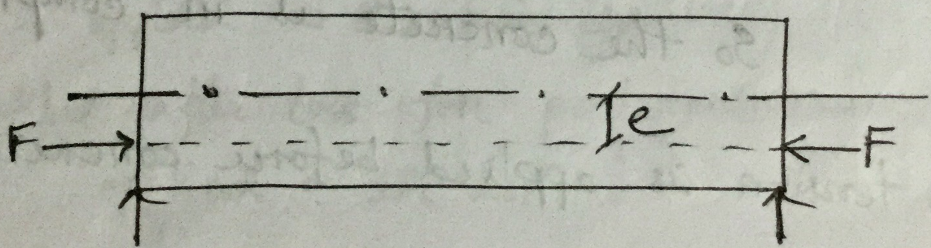
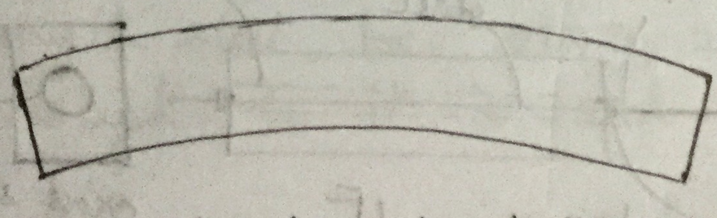


Fig: eccentrically applied prestress

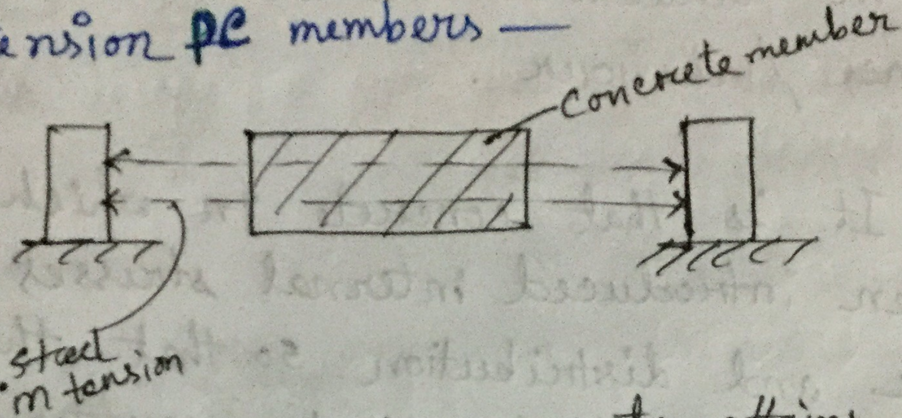


So that ~~downde~~ deflection given by the external loads can be counterbalanced by this upward deflection.

• How the preestress is applied —

Mainly preestress is done by steel tension

1. Preetension PC members —



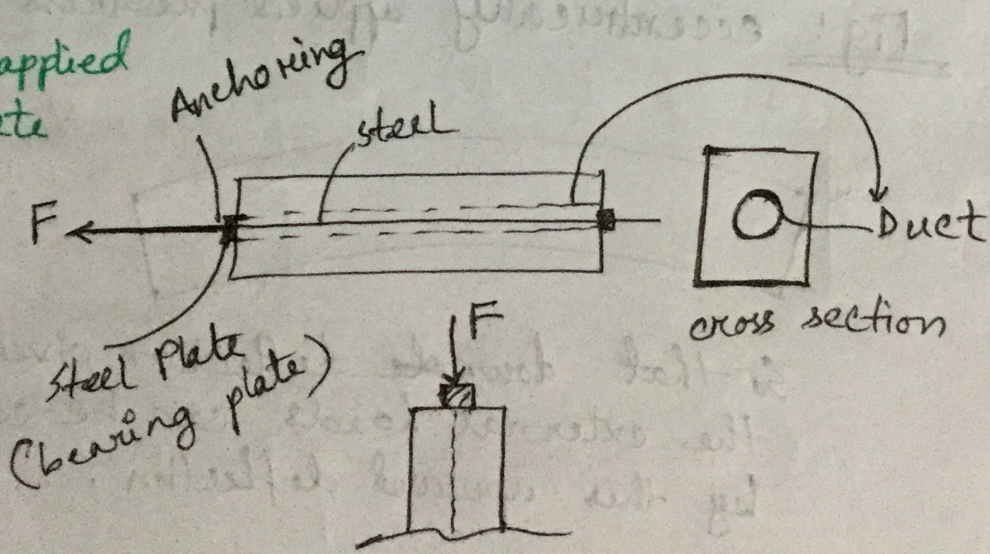
After this concrete attains its strength, then the steel wire will be cut off. The steel want to go to its original place.

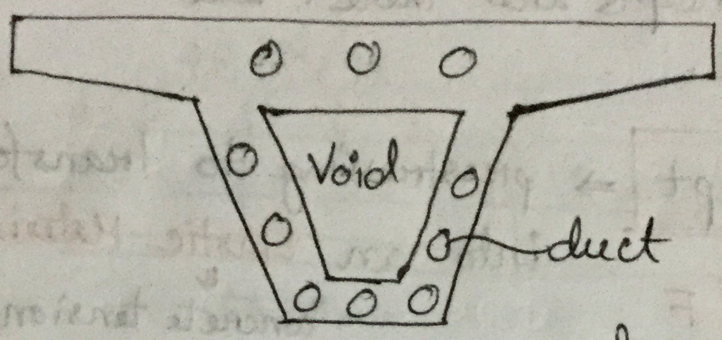
But as steel & concrete are bonded So the concrete is in compression.

• Here tension is applied before concrete casting.

2. Posttensioned PC members —

• tension is applied after concrete casting





Post tensioned PC member.

In previous times —

$f_y = 32$ to 36 ksi

then for this steel

applied = 30 ksi (approx.)

but after loss for post tension

applied = 12 ksi

But now, $f_y = 415$ MPa

& $f_{pu} = 1860$ MPa

High strength steel. loss হলেও যা applied হবে that's enough. So it is used.

⇓

cz loss is unavoidable in all cases.

• Prestressing —

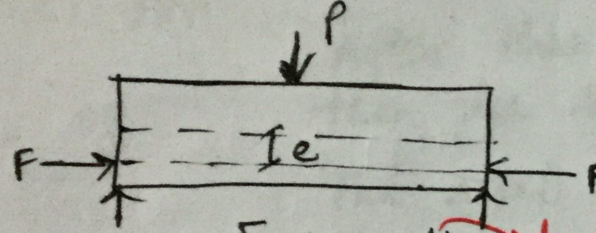
— Three concepts are there. But the end product must be same.

1. **1st concept** → prestressing to transform concrete into an Elastic Material

↓ eccentricity of F

⇓ concrete tension-এ অবশ্যই brittle material হিসেবে কাজ করে

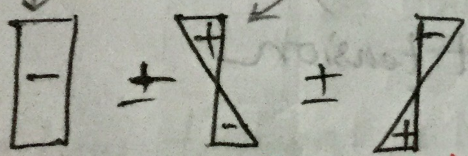
⇓ So একে Elastic Material-এ transfer করে



$$f = F/A \pm \frac{Fey}{I} \pm \frac{My}{I}$$

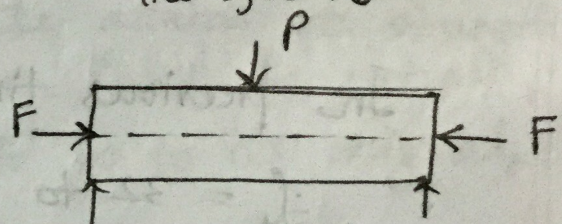
→ due to external load

Eccentric TENDON

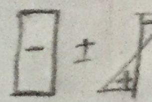


due to prestressing

due to external load



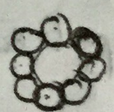
$$f = F/A \pm \frac{My}{I}$$



Concentric TENDON

⇓

● wire



— 9 wire Strand

⇓

কয়েকটি wire নিয়ে Strand হয়

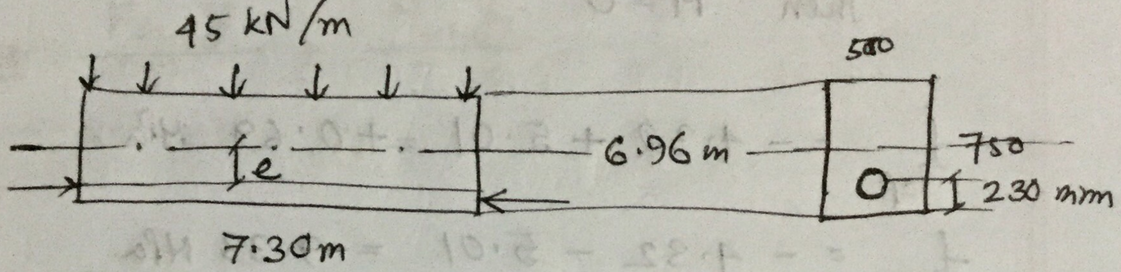
middle wire টা মোটা হয়,

⇓

কয়েকটি strand নিয়ে একেকটি TENDON.

∴ wire → strand → tendon

Problem-1



$F = 1620$ kN. Stress at midsection = ?

Effective prestress = Initial prestress − loss

Considering gross area —

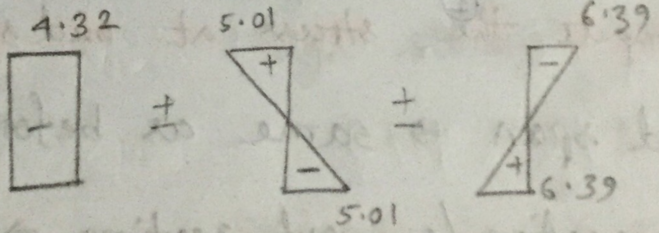
$$M = \frac{45 \times 7.3^2}{8} = 299.76 \text{ kN-m}$$

$e = 375 - 230$
$= 145$ mm

$$f = -\frac{1620 \times 10^3}{500 \times 750} \pm \frac{1620 \times 10^3 \times 145 \times 375}{\frac{500 \times 750^3}{12}} \pm \frac{299.76 \times 10^6 \times 375}{\frac{500 \times 750^3}{12}}$$

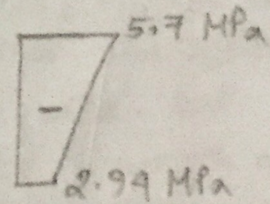
যদি gross area না নিতাম তাহলে $[A_g - (n-1) A_s]$ হত

$$= -4.32 \pm 5.01 \pm 6.39$$



$$\therefore f_{top} = -4.32 + 5.01 - 6.39 = -5.70 \text{ MPa}$$

$$f_{bot} = -4.32 - 5.01 + 6.39 = -2.94 \text{ MPa}.$$



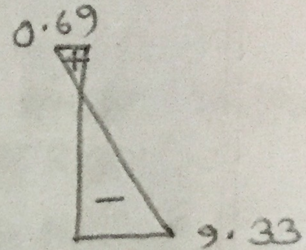
Resultant Stress Distribution at MID SPAN.

Q. Same problem. Stress at support section = ?

Then $M = 0$

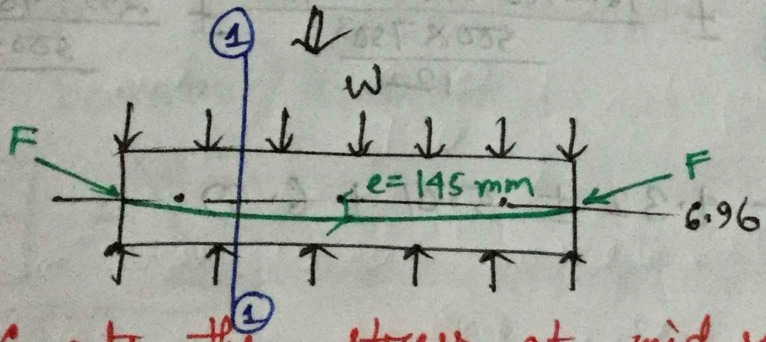
$\therefore f_{top} = -4.32 + 5.01 = +0.69$ MPa.

$f_{bot} = -4.32 - 5.01 = -9.33$ MPa



Resultant Stress Dist^n at SUPPORT

- So at support → tension सदैव it is not required.



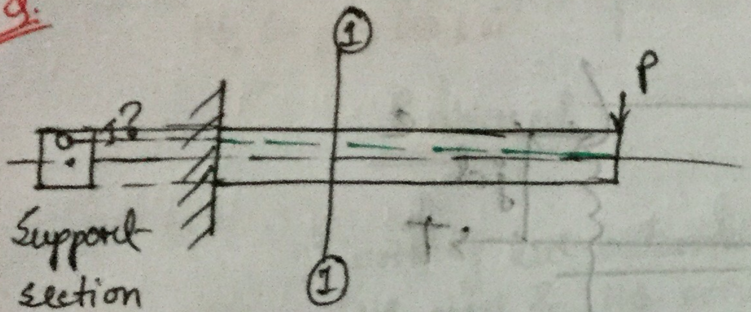
Q. Compute the stress at mid span & support section.

- Mid span ⇒ same as before
- End section / support section ⇒ $M = 0$; $e = 0$.

Q. Compute stress at section 1-1:

$$f = F/A \pm \frac{F e_{1-1} y}{I} + \frac{M_{1-1} y}{I}$$

Q.



Stress at section 1-1 ??

2. 2nd Concept ⇒ It is the combination of high strength steel and high strength concrete.

⇓

Why?

⇓

first-এ খনি থেকে যে iron পাওয়া যেত সেটা দিয়ে যে steel হত, সেটা f_y = 32 to 36 ksi সেটা দিয়ে prestressing করলে loss হওয়ার পর যা থাকে তা inadequate. But loss is unavoidable. So strength of steel বাড়াতে বাড়াতে এখন আমরা use করি

$$f_{pu} = 1860 \text{ MPa} \approx 150 \text{ ksi}$$

⇓

So এখান থেকে loss হলে matters little.

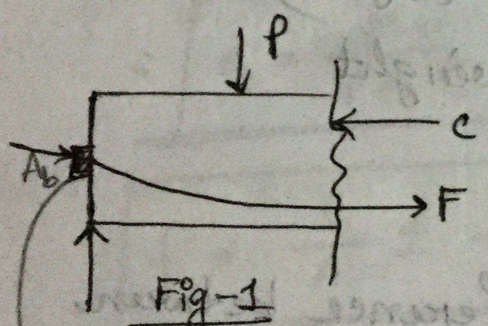


Fig-1

$$F_c = \frac{F}{A_b}$$

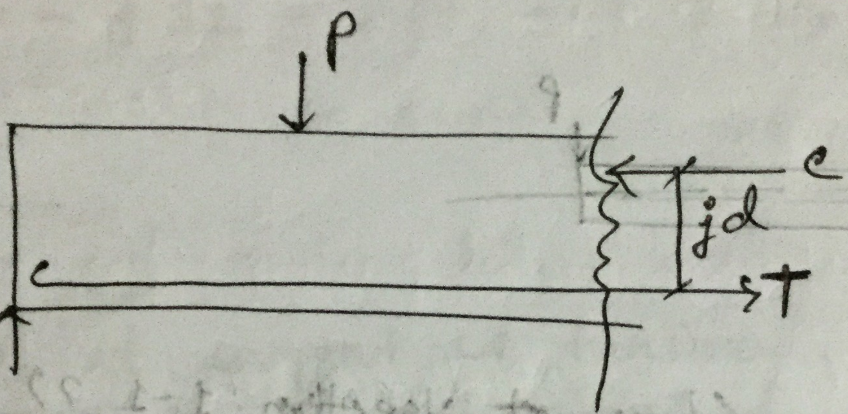
⇓

it is very high stress as area is very small. So high strength concrete is used. ⇚ but এই high strength steel এর সাথে interact করার জন্য high strength concrete লাগে otherwise l_d অনেক বেশি লাগে

- In 6d, $f'_c = 43$ MPa or > 6000 psi is used.

⇓

But বেশি high strength করা যাবে না cz এর ductility & % elongation কমে



Suppose $P = 0$. and neglect self weight

here $C = 0$, $T = 0$ } not prestressed.

But in prestressed concrete, (fig-1)

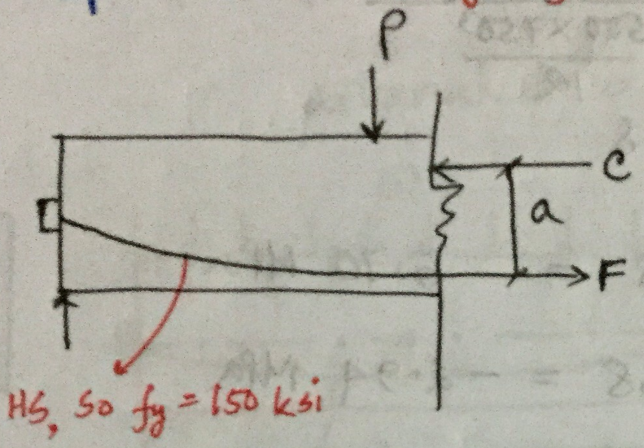
if $P = 0$, neglect self weight

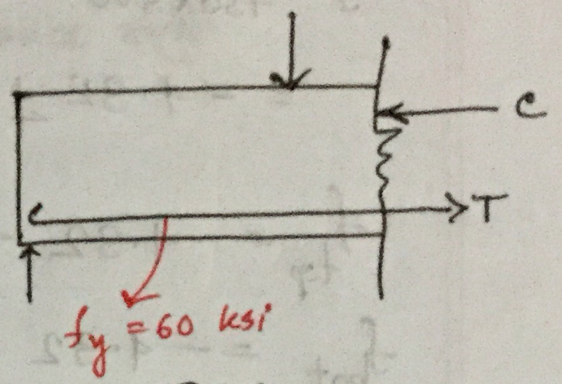
$C \neq 0$, $F \neq 0$

→ This is the main difference between prestressed & reinforced concrete.

15.03.2016

• 2nd Concept – (eccentricity of C)





Prestressed

⇓

nothing but a combination of HS steel & HS concrete & with the change of P/Moment C & F are not changed or change is negligible.

RCC

⇓

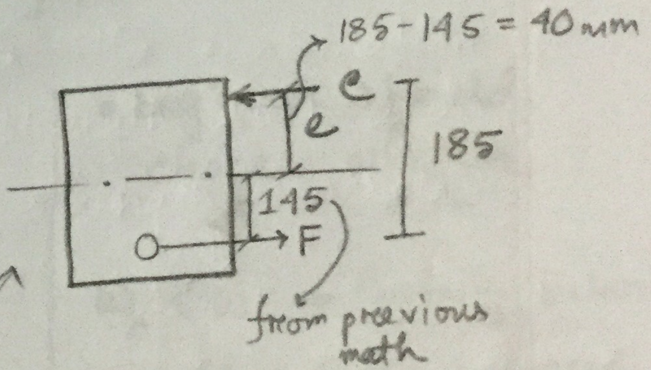
with the change of P/Moment, C & T changes

$F = C$

$\Rightarrow Fa \text{ or } Ca = M$

$\therefore a = \dfrac{M}{F \text{ or } C}$

$\therefore f = \dfrac{C}{A} \pm \dfrac{Cey}{I}$



• Previous Problem

$F = 1620 \text{ kN}, \; M = 29.76 \text{ kN-m}$

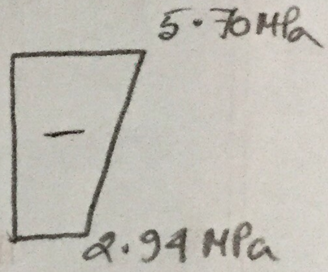
$a = \dfrac{29.76 \times 10^6}{1620 \times 10^3} = 185 \text{ mm}$

$\therefore f = \dfrac{-1620\times10^3}{750\times500} \pm \dfrac{1620\times10^3\times40\times375}{\frac{500\times750^3}{12}}$

$= -4.32 \pm 1.38$

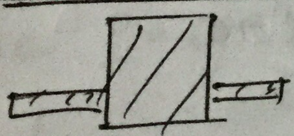
$\therefore f_{top} = -4.32 - 1.38 = -5.70$ MPa

$f_{bot} = -4.32 + 1.38 = -2.94$ MPa



- If RCC σ, we want to use $f_y = 150$ ksi

Section Uncracked



$f_s = n f_{ct}$, Let $n = 9$ & $f_{ct} = 300$

$\therefore f_s = 9\times300$

$= 2700$ psi

If $f_s = 24000$ psi

$\therefore$ only 10% is used which is not effective

⇓

So we must crack the section.

⇓

So we can not use HS steel in RCC.

3rd Concept (Prestressing to achieve Load Balancing) -

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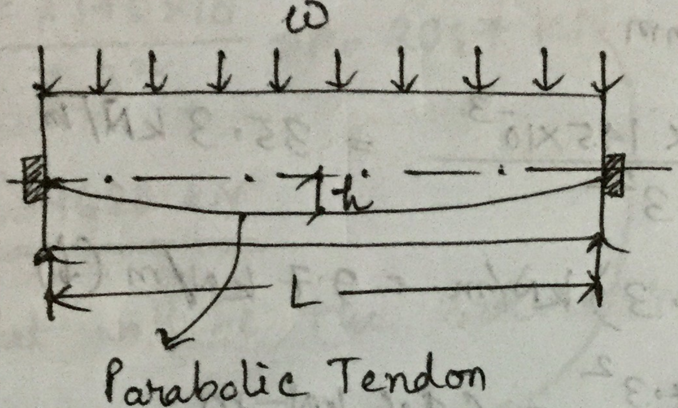
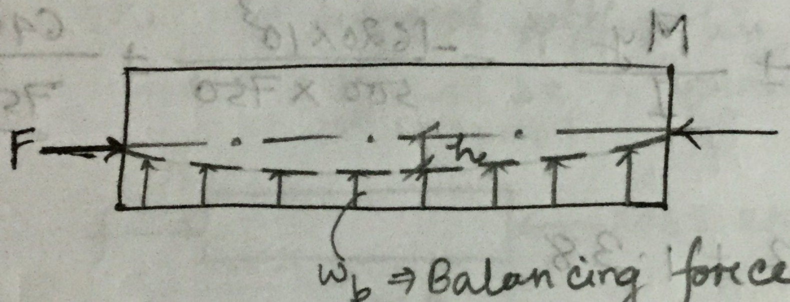
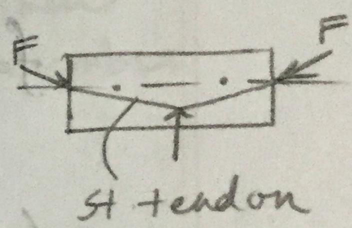
External load balance করবে





or



$$\frac{w_b L^2}{8} = F \cdot h$$

$$\therefore \boxed{w_b = \frac{8Fh}{L^2}}$$

2 variables.

⇓

By this we can control deflection

et in this case section goes up.

- Engineer should choice whether

⇓

$w_b < w$ ⇒ Partially balanced

$w_b = w$ ⇒ Equally balanced

$w_b > w$ ⇒ Over balanced

Previous problem

$M = 299.76$ kN-m

$F = 1620$ kN

$h = 145$ mm

$$w_b = \frac{8 \times 1620 \times 145 \times 10^{-3}}{7.3^2} = 35.3 \text{ kN/m}$$

$$w_{net} = (45 - 35.3) \text{ kN/m} = 9.7 \text{ kN/m} (\downarrow)$$

$$\therefore M_{net} = \frac{9.7 \times 7.3^2}{8} = 64.6 \text{ kN-m}$$

$$f = -\frac{F}{A} \pm \frac{My}{I} = -\frac{1620 \times 10^3}{500 \times 750} \pm \frac{64.6 \times 10^6 \times 375}{\frac{750^3 \times 500}{12}}$$

$$\Rightarrow f = -4.32 \pm 1.38$$

$f_{top} =$

$f_{bot} =$

• Extra —

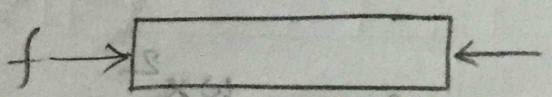
$W_b = \frac{8Fh}{L^2}$ what will be F to balance?

$45 = \frac{8 \times F \times 145 \times 10^{-3}}{7.3^2} \Rightarrow F = 2067$ kN

This F > 1620 kN

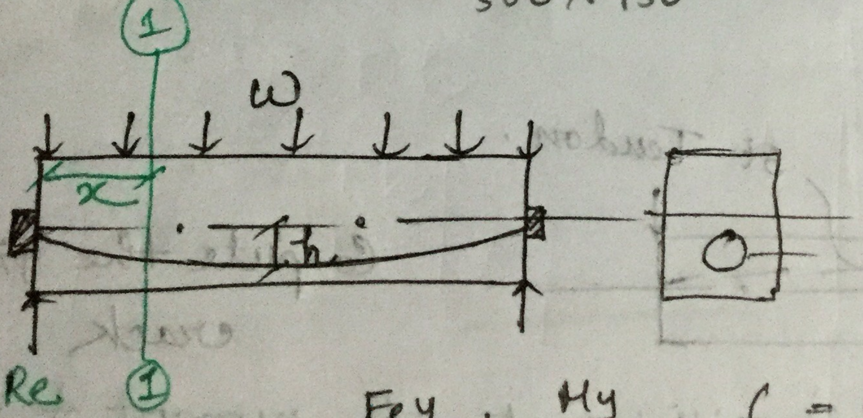
• Then what will be the stress in concrete?

As stress from w is completely balanced with this force. Then it will be a purely axia member.



$\therefore f = \frac{2067}{500 \times 750}$

•



$f = F/A \pm \frac{Fey}{I} \pm \frac{My}{I}$; f_p = Given

Q. Compute the load w that can be applied on the beam which will produce the first crack in the beam.

Moment highest যেখানে i.e. midspan-এ হবে।

$$\because f_{bot} \nearrow f_p = -\frac{F}{A} - \frac{F e\, y_{bot}}{I} + \frac{M y_{bot}}{I}$$

⇓

M = unknown = ?

⇓

Then from $M = \frac{wL^2}{8}$ we determine w.

w থেকে must self weight minus করে দিব।

অনে বলতে পারে section ①-① -এ হিসাব কর।

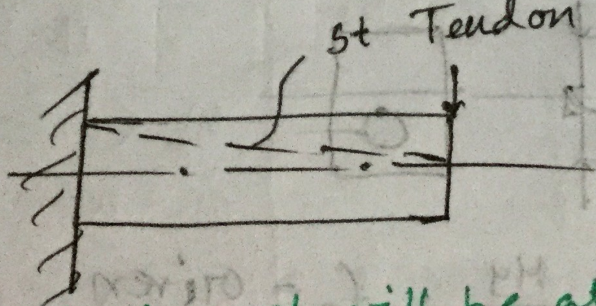
⇓

Then f_{bot} ঠিক থাকবে শুধু just e change হবে

& M_{1-1} change হবে।

⇓

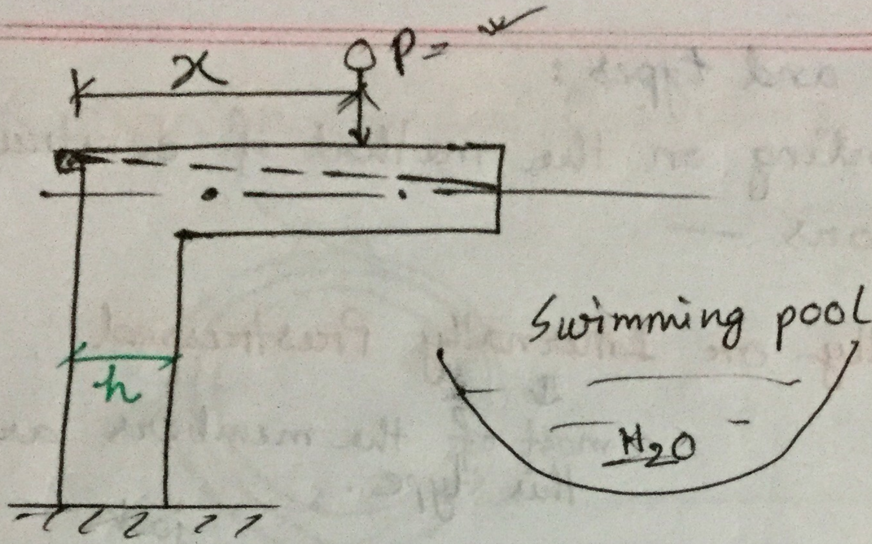
Then $M_{1-1} = R_e \cdot x - \frac{wx^2}{2}$

- 

Compute the first crack

Here first crack will be at the support & we will write, $f_{top} = -\frac{F}{A} - \frac{F e\, y_{top}}{I} + \frac{M y_{top}}{I} \rightarrow = ??$

$$M = PL + \frac{w_{self} L^2}{2}, \quad P = ?$$



What will be x so that diving plate will not crack? / tension will not allowable

⇓

Then $f_{top} = 0$.

$M = P\left(x - \frac{h}{2}\right)$ ⇒ হওয়ার কথা

⇓

or, $M = P(x - h)$

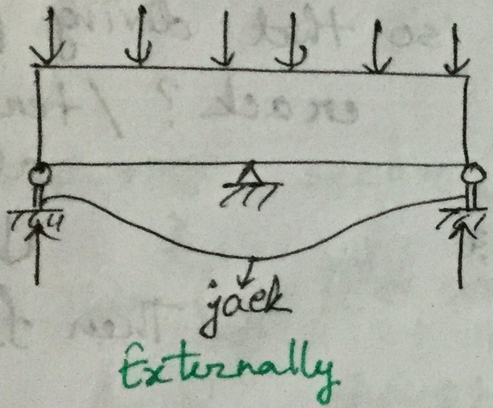
কোনটার কারণে crack না হবে

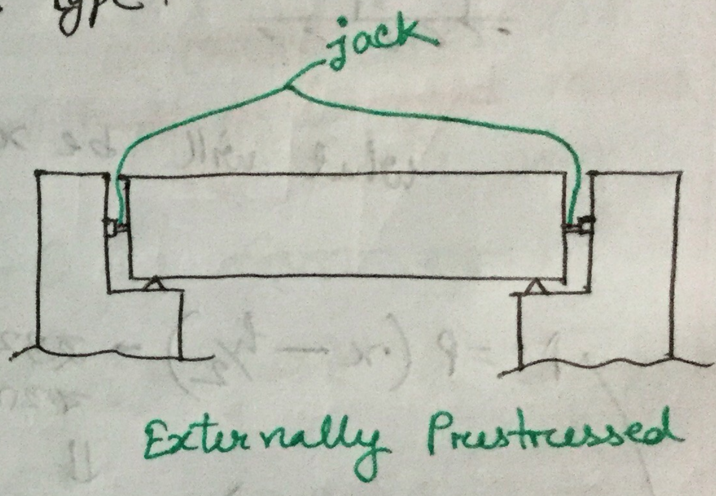
29.03.16

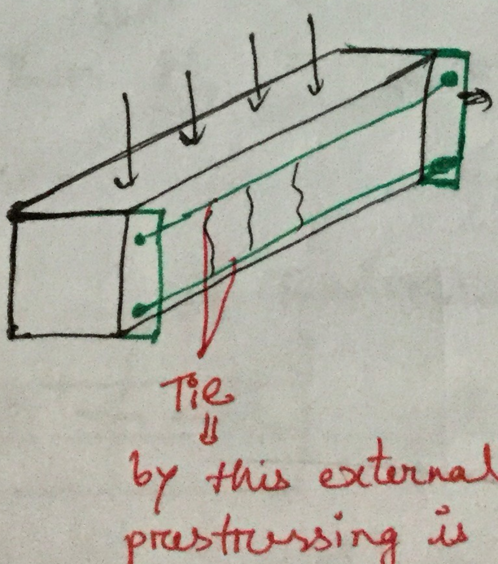
Classification and types :

• Depending on the method of construction and other factors —

1. Externally or Internally Prestressed
⇓
most of the members are of this type.

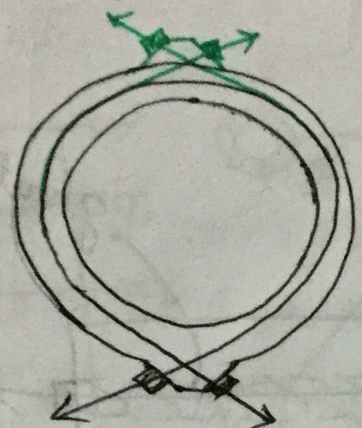






crack হলে যদি external pressure দিলে crack মিলে যাবে।
⇓
This is called external prestressing

2. Linear or Circular Prestressing



but এভাবে অনেক energy লাগবে ⇒ This is circular prestressing

3. Pretensioning & Posttensioning

Pretensioning ⇒ give tension before concrete casting

⇓

Imp. Stresses or Force will be tranfered through <u>bonding</u> bet^n steel & concrete at the ends

Posttensioning ⇒ apply tension after concrete attains its required strength

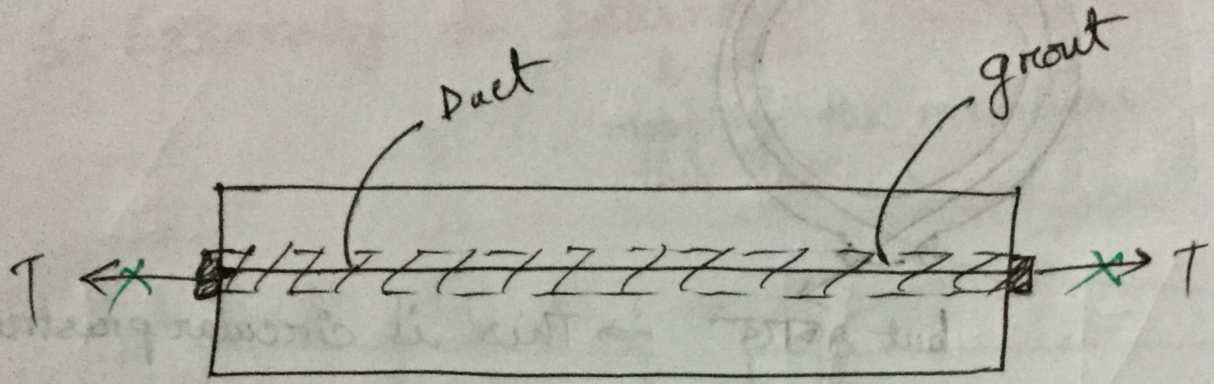
⇓

Imp. stress/Force will be transfered through <u>BEARING</u> at the ends

4. End anchored or Non-end Anchored Tendons —

⇓

all post tension members



post tension member

⇓

after giving grout if we cut the outside T, then stress will be transferred by bonding, not bearing

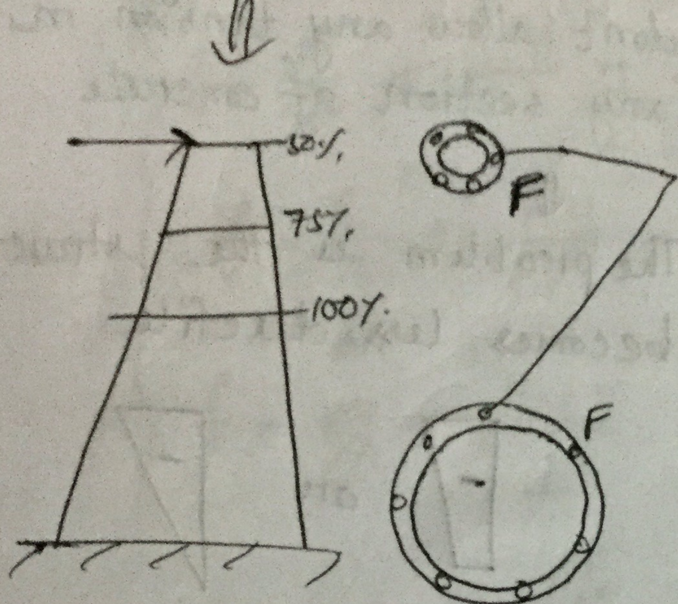
⇓

This is special case & not so preferrable.

5. Bonded or Unbonded Tendons

- post tension members ⟶ bonded / unbonded
  - bonded ⇓ if grouting is done
  - unbonded ⇓ if grouting is not done
- pre tension member ⇒ must BONDED (*)

• but সময় সময় unbonded হতে পারে

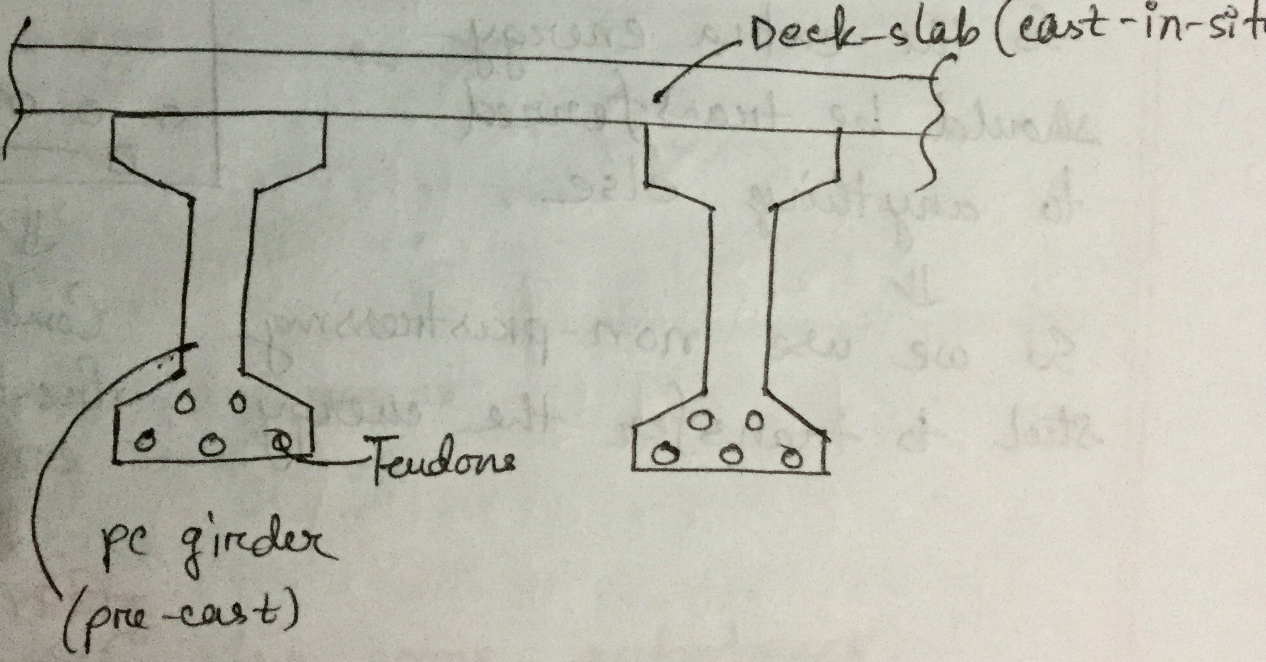


Tendons → এখানে force দুটি আলাদা x-sect^n দিয়ে যায়। উপরের area ছোট হলে অনেক সময় force transfer হতে পারে না।

⇓

Then unbonded রাখা যেতে পারে

6. Precast, Cast-in-place, Composite Construction

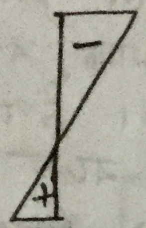


Total bridge system ⇒ Composite system

" " Construction ⇒ Composite Construction

7. Partially or Fully Prestressing —

Partially ⇓ allow tension in concrete



$f_{ct} \leq f_{r}$

⇓

Further it is decided to make $f_{ct} > f_{r}$

⇓

So the extra energy should be transferred to anything else ⇒

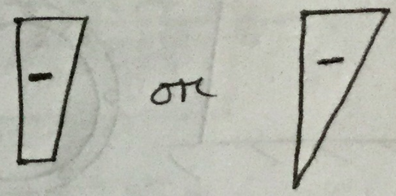
⇓

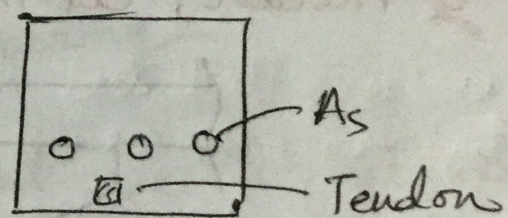
So we use non-prestressing steel to transfer the energy

Fully ⇓ don't allow any tension in any section of concrete

⇓

The problem is the structure becomes less ductile.





⇓

Combination of Prestressed & non-prestressed concrete

⇓

স্ট্রাকচার it will become more ductile & more cost effect.

29.03.2016

CT – Tuesday (Computation of stresses in any concept)

$$f = \frac{F}{A} \pm \frac{Fey}{I} \pm \frac{My}{I}$$

or

$$f = \frac{C}{A} \pm \frac{Cey}{I}$$

or

$$f = F/A \pm \frac{M_{net} Y}{I}$$

Loading Stages →

In case of normal concrete, only one loading stage
⇓
But in PC, there are multiple stages of loading

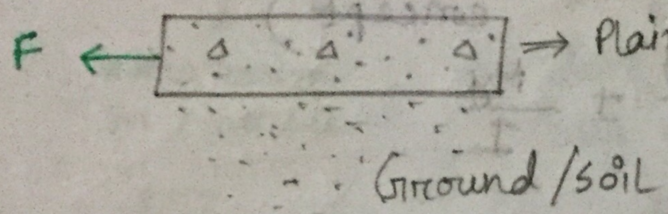
- Initial Stage
- Intermediate Stage
- Final stage

for any PC, these two stages must be there
⇓
Intermediate stage may/may not be there depending on type of PC and construction.

- There are also some substages.

1. Initial stage —
   - Before prestressing
   - During "
   - At transfer of prestress
   - Decentering & Retensioning

- **Before prestressing**



এভাবে just ফেলে রাখলে concrete will try to shrink
So we have to provide reinforcement

- **During prestressing**

F_{pu} = tensile strength of steel (max^m)

According to ACI

$F = 0.80 f_{pu}$ or $0.94 f_{py}$ — whichever is less but this can not (✗) exceed the value recommended by the manufacturer.

Also after the anchorage & Stress at transfer $\not> 0.70 f_{pu}$

Here, at service load condition in flexure, we allow,

- $f_c = 0.45 f'_c$
- Tension $= 0.50 \sqrt{f'_c}$

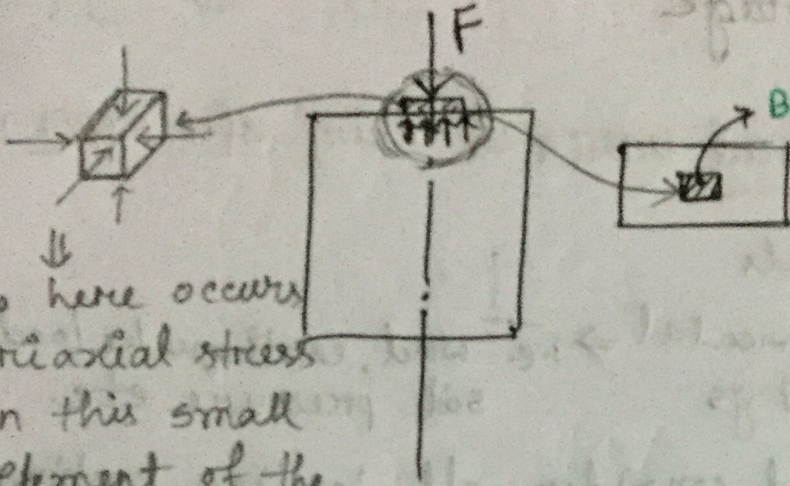
} ⇒ SI unit

f'_c = 28 days cylinder strength

At initial stage ⇒

Comp $= 0.60 f'_{ci}$; f'_{ci} = cylinder strength at initial stage.

Tension $= 0.25 \sqrt{f'_{ci}}$ ⇒ except at the ends of simply supported beam.



So here occurs triaxial stress in this small element of the bearing plane

⇓

So we have to be careful about stress at transfer.

Here high comp. stress occurs. But this concrete has to sustain this high compression. This may also exceed the f_c'.

i.e. $f_c > f_c'$.

⇓

So at transfer stress is kept below $0.70 f_{pu}$. So that concrete can't crush.

2. Intermediate stage

⇓

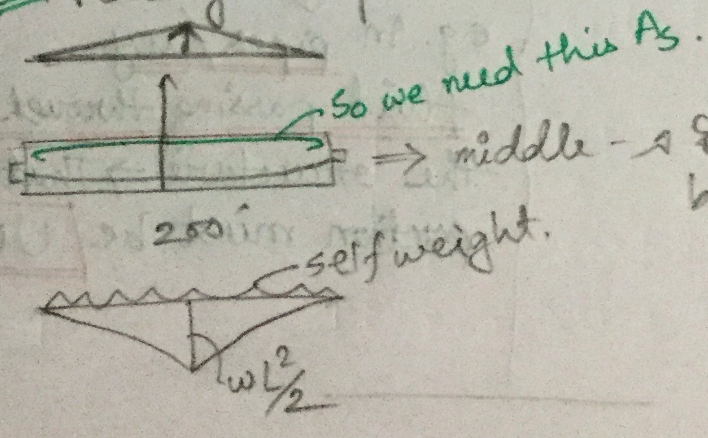
This is needed only for precast members.

- The main problems of this precast members are –

   i. Transportation

   ii. How to erect / Erection

   iii. Placing in position



⇒ middle - এ দিয়ে তোলালে it will be broken.

3. Final stage

⇓

External load লাগাবে & reinf কাজ করবে।

⇓

1. Live loads

2. Environmental loadings ⇒ i.e. wind, earthquake loads, soil pressure etc

So here we should consider all loading combinations including gravity load & others.

i. Sustained Load ⇒ always থাকবে ⇒ for this load & comp. there must be creeping & deflection

ii. Working " ⇒ LL so we use 3 concepts to find out σ & ε.

⇓

Then F should be effective prestress → formula-এর F

iii. Cracking "

iv. Ultimate "

working load × Load factor

if we allow tension & allow crack width specially in serviceability requirement

⇓

we must check if it will be in allowable limit

⇓

e.g. in pipes / any fluid passing through the structure ⇒ That portion must be UNCRACKED.

2 things are very imp.

1. crack width

2. deflection.

3. Final stage

⇓

External load থাকবে & reinf কাজ করবে।

⇓

1. Live loads
2. Environmental loadings ⇒ i.e. wind, earthquake loads, soil pressure etc.

So here we should consider all loading combinations including gravity load & others.

i. Sustained Load ⇒ always থাকবে ⇒ for this load & comp. there must be creeping & deflection

ii. Working " ⇒ ∟ so we use 3 concepts to find out σ & ε.

⇓

Then F should be effective prestress → formula-এর F

iii. Cracking " → if we allow tension & allow crack width specially in serviceability requirement

⇓

we must check if it will be in allowable limit

⇓

e.g. in pipes / any fluid passing through the structure ⇒ That portion must be **UNCRACKED.**

2 things are very imp.
1. crack width
2. deflection.

iv. Ultimate " → working load × Load factor

PC Vs. RC

1. Serviceability → • mainly deflection → Immediate / Long term
   • Crack

   According to ACI
   crack width ≯ 0.4 mm for interior member (in normal env. condition)
   crack width < interior for exterior members.

   ⇓

   deflection can be controlled by Prestressing

   ⇓

   So for Long span members, Prestressed concrete ≫ better than normal concrete
   Then the crack width will also decrease

   ⇓

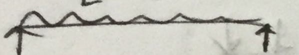
2. Safety

3. Economy

   ⇓

   direct comparison-এ prestress is not economic than RC.

L = 50'



⇓ RC দিলেই হবে। but if L = 200' then PC will be economic as RC-র depth অনেক বেড়ে যাবে।

Prestressed concrete-এ construction time-এ যে test হয় তাতে load / stress অনেক বেশি। So এই load-এ যদি survive করে, then it is expected that service load-এও ঠিক survive করবে।

- Materials–
  1. Concrete
  2. Steel*

12.04.201

Materials

PC

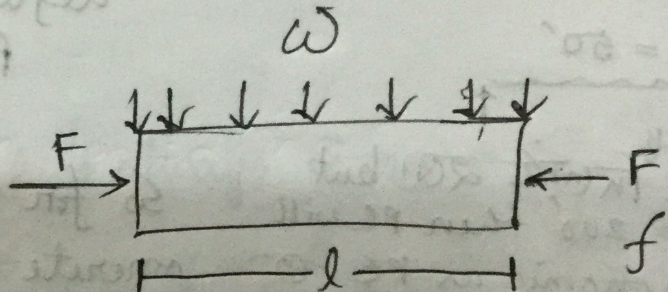
- Concrete
- Steel

→ High Strength

Some others materials ⇒ Such as Grouting

⇓

- Creep
- Shrinkage



$f = \frac{5}{384} \cdot \frac{wl}{E}$

Problem is F

cz it is subjected to constant compression.

⇓

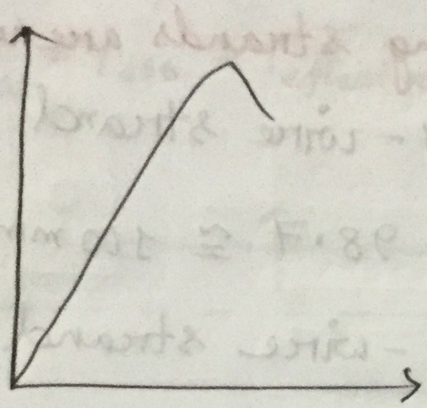
Sustained load

(PC is such a sustained load)

- Factors effecting creep ⇒
  - W/C ratio
  - Type of Concrete Conduit / Duct
  - Type of Aggregate
  - Stress Level
  - Surface-Volume ratio
  - Age of loading

- Concrete (High Strength)

$f'_c = 6000/7000$ psi



- w/c ratio কমালে workability কমে যাবে।

etc - - - -

- Steel (High Strength)

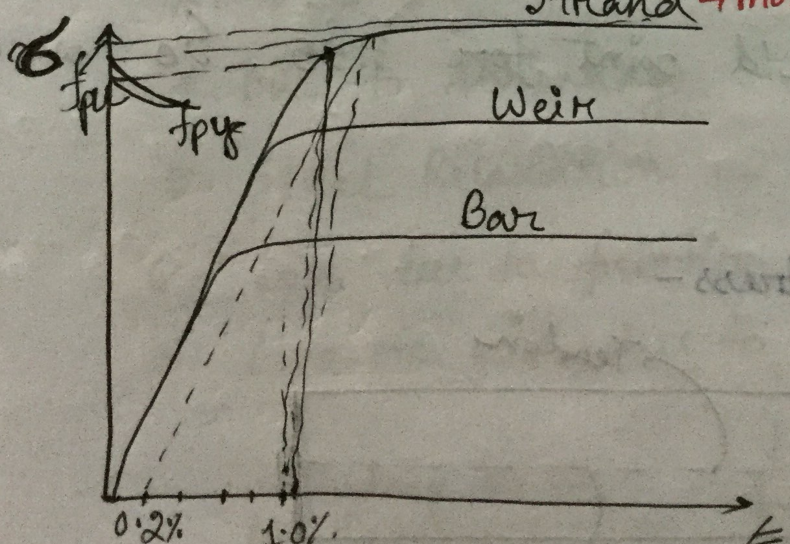
f_y = 120 to 150 ksi

if f_y = 32 to 36 ksi ⇒ loss of prestress

খনিতে আগের অনেক বেশি পাওয়া গেছে—

- Carbon
- Manganese
- Silicon

} Alloying.



Strand → mostly used (normally in bigger construction)

⇒ 7 weir Strand.

Weir → Strand → Tendon or Cable

- 12.7 mm 7-wire strand

$A = 98.7\ mm^2$

• Usually following strands are used—

1. 12·7 mm 7-wire strand

Area = 98·7 ≅ 100 mm^2

2. 15·2 mm 7-wire strand

Area ≃ 140 mm^2

• Bars —

⇒ Usually 12 mm to 32 mm

• The ultimate tensile strength, f_{pu}

Imp. • Yield Stress, f_{py} ⇒ defined by two methods

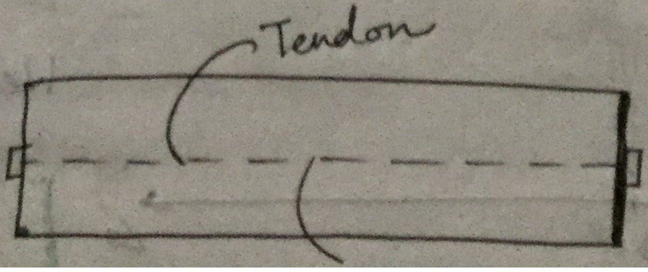
→ Offset Method (0·2% offset)

→ Total Strain (1%)

• There is no yield point for HSS. So we define it.

• fibre glass —

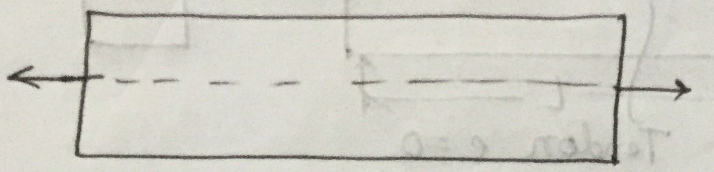
• Loss of Prestress—



26.04.2016

Loss of Prestresses :

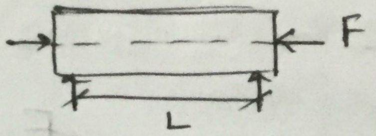
$$F_{initial} - Loss = F_{effective}$$



- যদি কোনো কারণে concrete এর shortening হয়
তাহলে steel-ও shorten হবে।
So এখানে loss হবে।

⇓

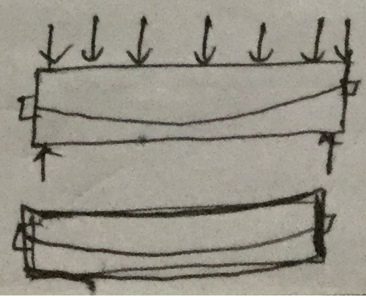
So concrete should not be shortened.



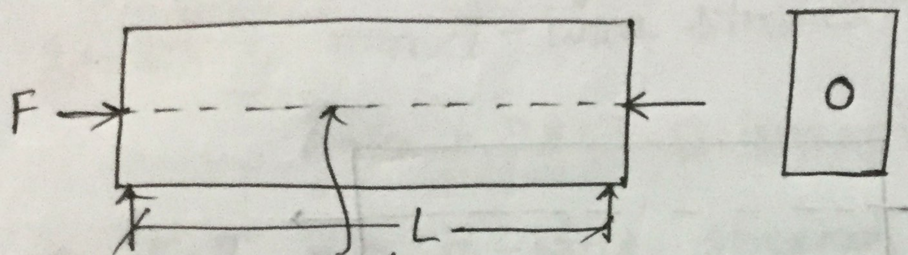
- Causes of concrete shortening –

1. Elastic shortening
2. Due to anchorage-take-up
3. Due to creep.
4. Due to shrinkage
5. Steel Relaxation
6. Loss due to friction
7. Loss or gain due to bending of member

Bending এর জন্য lengthening হচ্ছে so gain ⇐



Loss due to elastic shortening : (for Pretension Member)



$$\Delta L = \frac{FL}{AE_c}$$

$$\therefore \text{strain}, \epsilon_c = \frac{\Delta L}{L} = \frac{F}{AE_c} = f_c/E_c$$

$$\Rightarrow \epsilon_c = \epsilon_s = \frac{\Delta f_s}{E_s}$$

$$\Delta f_s = \frac{E_s}{E_c} f_c = n f_c = n \frac{F}{A}$$

← Force/stress after transfer.

F_i = Initial prestress

∴ The amount transferred ~~after~~ $F_0 < F_i$

The prestress after transfer = F_0 ∴ $F_0 = 0.9 F_i$

- When we use F_i, then, $A = A_c + nA_s$ → i.e. we will use transformed section.
- " " " F_0, then, $A = A_g$.

$\therefore$ Loss due to elastic shortening,

$$\Delta f_s = n\frac{F_o}{A_g} \text{ or } n\frac{F_i}{(A_c + nA_s)}$$

Problem-1

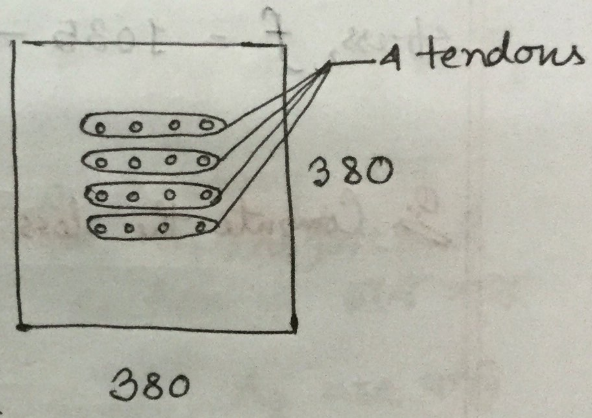
Span = 12.2 m

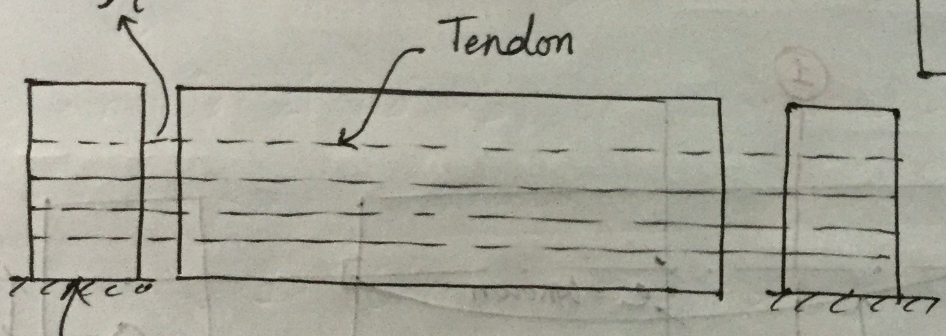
$e = 0$

4 tendons

$A_{ps} = 780\ mm^2$

$f_i = 1035$ MPa





Bulkhead → unyielding support যার সাথে tendon বাঁধা থাকে।

$\therefore F_i = f_i \times 780 = 1035 \times 780\ N = 807300\ N.$

Now, $A_t = A_c + nA_{ps} = 143620 + 6 \times 780$ | $n = \frac{E_s}{E_c} = 6$ (given)

$$\therefore ES = \frac{nF_i}{A_t} = \frac{6 \times 807300}{143620 + 6 \times 780}$$

$= 33$ MPa.

Alternative

Now, Again, $ES = \frac{n F_o}{A_g} = \frac{6 \times 0.9 \times 807300}{380 \times 380}$

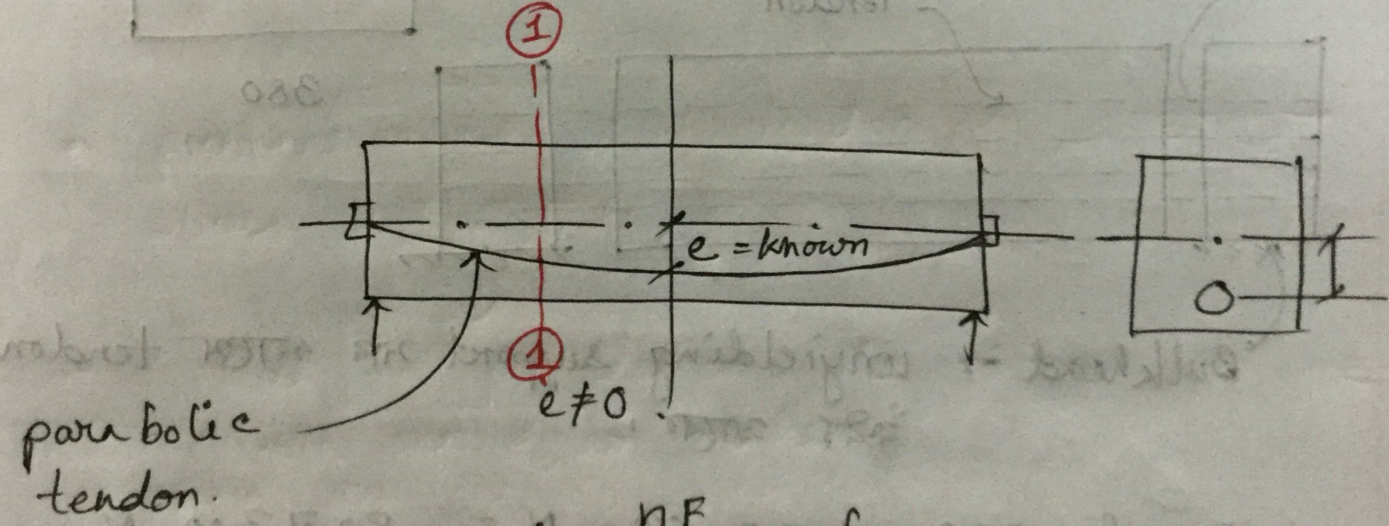
$= 30$ MPa.

(Considering gross area)

Q. Compute the stress in steel after ES / after transform of prestress.

stress, $f = 1035 - (33 \text{ or } 30)$

Q. Compute the loss of ES at mid section.



$ES = \Delta f_s = \frac{nF}{A} = nf_c$

Here $e \neq 0$.

$\therefore f_{cir}$ = stress in concrete at location of c.g.s. due to prestressing.

So in this case, $ES = nf_{cir}$.

• Cz exam-এ যেখানে loss বের করতে বলবে সেখানের f_c বের করতে হবে।

$$f = \frac{F}{A} \pm \frac{Fey}{I} \pm \frac{My}{I}$$

• In prestressing, there will be self-weight.

$\Downarrow$

$\omega_G = \cdot 38 \times \cdot 38 \times 1 \times 25$ kN/m

$$\therefore f_{bot} = -\frac{F}{A} - \frac{Fey}{I} + \frac{My}{I}$$

$$\therefore M_G = \omega_G L^2/8$$

$$\therefore f_{cir} = -\frac{F}{A} - \frac{Fe \cdot e}{I} + \frac{M_G e}{I} \; ; \left[as \;\; y = e\right]$$

$$\boxed{f_{cir} = \frac{F}{A} + \frac{Fe^2}{I} - \frac{M_G e}{I}}$$

⇒ This F may be F_o or F_i

$\Downarrow$

I ও change হবে যদি transformed section-এ চলে যায়

$\Downarrow$

যদি A_g use করি then I-ও gross M.O.I হবে।

$\Downarrow$

It will be better to take A_g.

but তখন লিখতে হবে (considering gross area)

$$\therefore \Delta f_s = n f_{cir}.$$

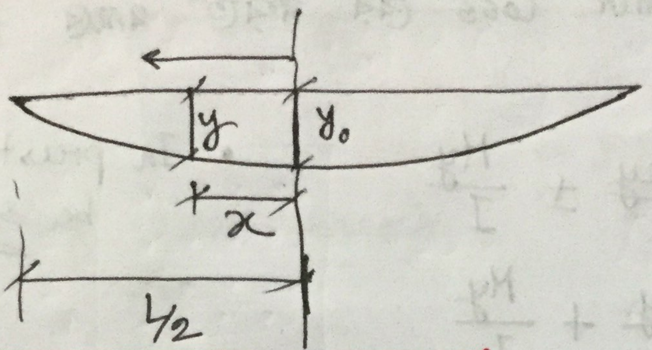
Q. Find out ES at section ①-①.

then,

$$f_{cir} = \frac{F}{A} + \frac{Fe_{1-1}^2}{I} - \frac{M_{G,1-1} e_{1-1}}{I}$$

$$M_{G_{1-1}} = \frac{\omega_G L x}{2} - \frac{\omega_G x^2}{2}$$

e_{1-1} ⇒ বের করব (from pg 144) by eqn.



$$y = y_0\left[1-\left(\frac{x}{L/2}\right)^2\right]$$

- exam-এ support থেকে distance x' দেওয়া থাকলে এই eqⁿ-এর x হবে —

$$x = \left|x' - L/2\right|$$

- pretension-এ চারটি tendon কে একসাথে stress দেওয়া হয়।

⇓

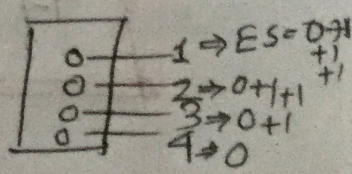
But in post tension, the stress will be given one after another.

⇓

So Here F is obtained after anchoring i.e. after elastic shortening.

⇓

So, for 1 tendon in posttension member,

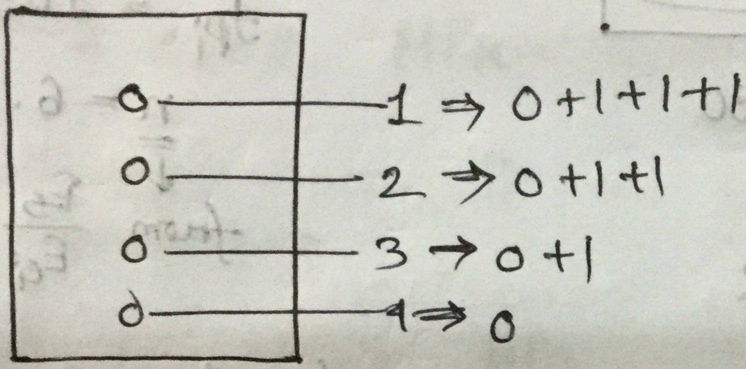


Loss due to ES = 0

∴ এখন প্রথম টানের প্রথম বাদে বাকিগুলিতে Loss হবে।

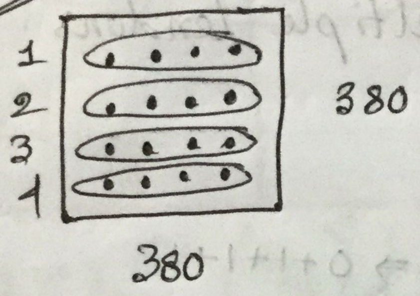
⇓

This is for multiple tendons.



Example-1
(Pretension member)
Previous example

- But if it is post tension member, what will be ES ?

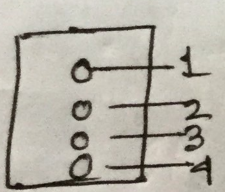


$A_{ps} = 780\ mm^2$ (4-tendons) each

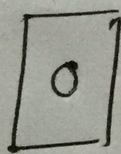
$f_{p_i} = 1035$ MPa 195 mm

$n = 6.$
↓
from $\frac{E_s}{E_{ci}}$

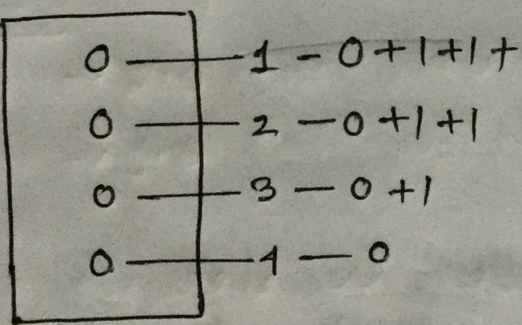
$ES = \Delta f_s = n f_{cir}$
↓
stress in concrete at cgs due to prestress.



⇒ if only one tendon



⇒ **ES = 0**



Imp: So n numbers of tendon হলে

1st tendon will (n−1) times shortening
2nd " " (n−2) " "
3rd " " (n−3) " "

and so on.

- for ① tendon ⇒

if F_0 then $F_0 = 0.9 F_i$

$$n \frac{F}{A} = n \frac{195 \times 1035}{A(380 \times 380)} \times 3$$

(n = 6; 3 ↳ how much time it will shorten)

$$= 25.2 \text{ MPa}$$

- For ② tendon ⇒

$$\frac{25.2}{3} \times 2 = 16.8 \text{ MPa}$$

- For ③ tendon ⇒

$$\frac{25.2}{3} \times 1 = 8.4 \text{ MPa}$$

$$\therefore \text{Average} = \frac{25.2 + 16.8 + 8.4}{~~8~~\ 4} = ~~16.8~~\ 12.6 \text{ MPa}$$

Ans.

Time Dependent Losses :

- Creep
- Shrinkage

} ⇒ Combined effect of these two are quite significant.

- Steel Relaxation.

Creep

- Water cement ratio
- Type of concrete → heavy / light weight
- Vol^m / surface ratio (v. imp.)
- Stress condition
- Humidity → ↑, shrinkag/creep ↓.
- Exposure condition

- Loss due to creep ⇒

$$CR = K_{cr} \frac{E_s}{E_c} (f_{cir} - f_{cds})$$

where, K_{cr} = creep coefficient.

⇒ 2.0 for pretension member

⇒ 1.6 " posttension "

* f_{cds} = Stress in concrete at cgs due to all super-imposed dead load which will be applied after prestressing.

Shrinkage

- Vol^m/surface ratio.
- Relative humidity
- Shrinkage strain, $\epsilon_{sh} = 550 \times 10^{-6}(1 - .06\, V/S)(1.5 - .015\, RH)$

or, $$\epsilon_{sh} = 8.2 \times 10^{-6}(1 - .06\, V/S)(100 - RH)$$

∴ Shrinkage loss,

$$SH = E_s \epsilon_{SH}$$

Again $SH = E_s K_{sh} \epsilon_{sh}$

K_{sh} ↓ a factor for pretension/Posttension member.

~~K_{sh}~~ Time after end of Moistening to application of prestress.

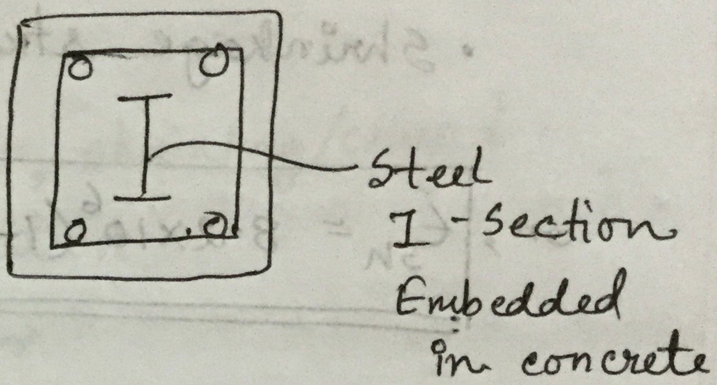
	1 day	7 days	30 days
∴ K_{sh} =	0.92	0.77	0.58

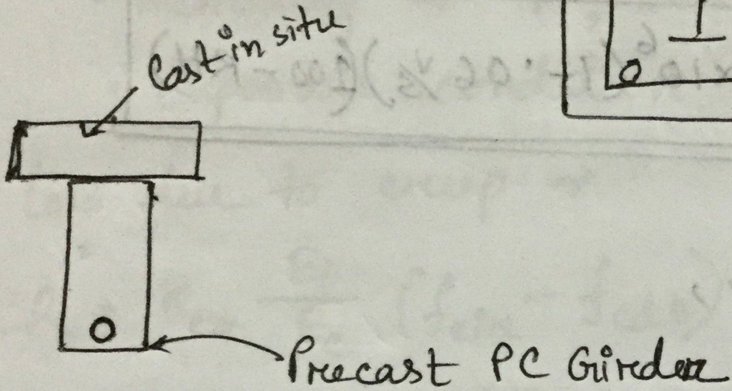
10.5.2016

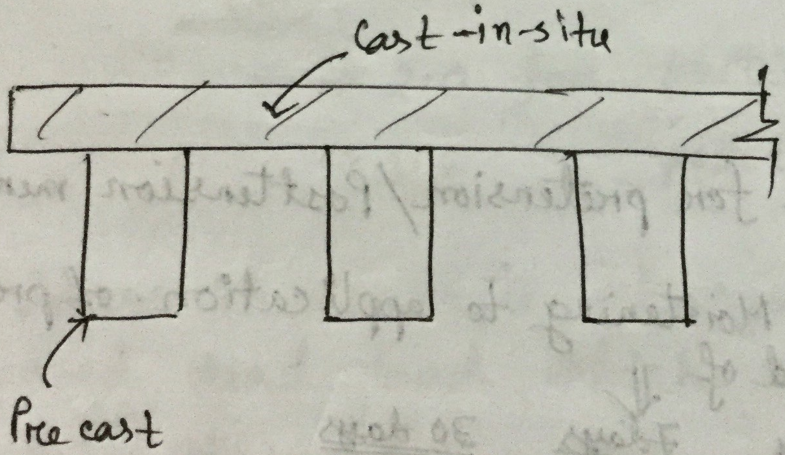
COMPOSITE SECTIONS

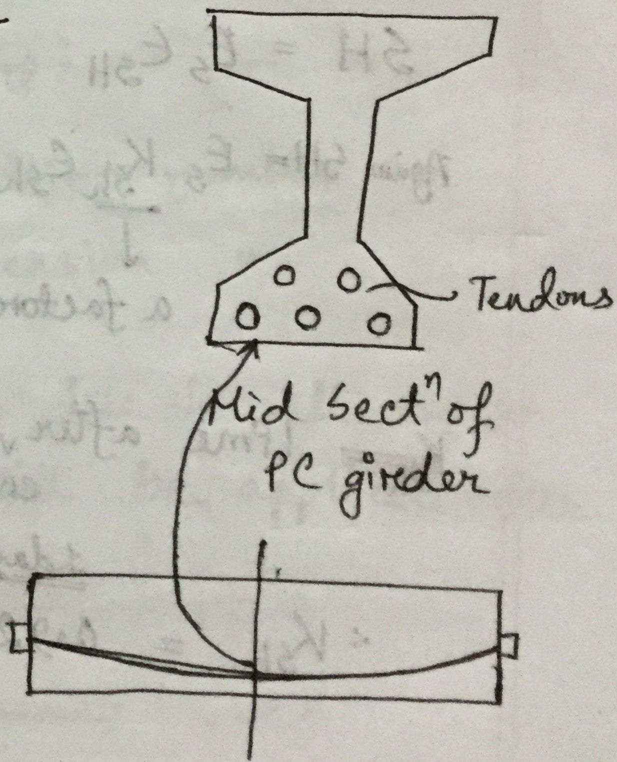
$$f = \frac{F}{A} \pm \frac{Fey}{I} \pm \frac{My}{I}$$

- Composite sections are made for reducing X-sectional area.

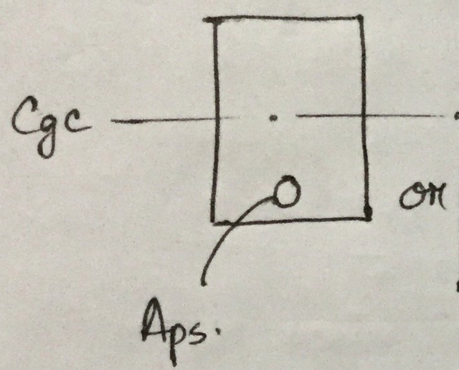








• For Precast Portion–



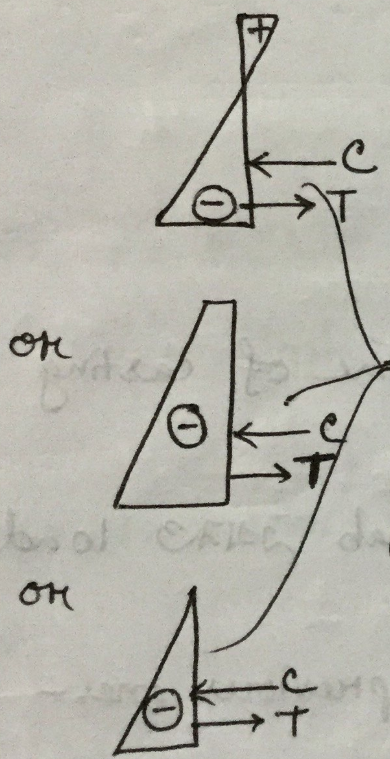
$$f = \frac{F_o}{A} \pm \frac{F_o e y}{I} \pm \frac{M_a y}{I}$$

or $$f = \frac{F_o}{A} \pm \left(\frac{M_a - F_o e}{I}\right) y$$

⇓

from this

f_{top} & f_{bottom}



→ depends on F_o

$(F_o, F_o e, M_a)$

or (F_o, W_G) — W_G: Self wt.

• This is initial Prestress.

• then after that there will be losses.

• After losses, F_o will be replaced by F

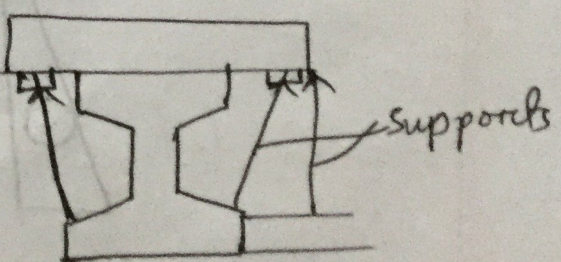
⇓

∴ $(F + W_G)$

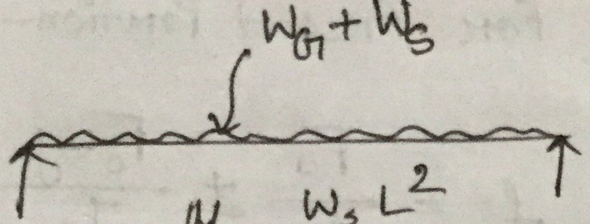
⇓

After all these, effective stress will be there & the section is then ready for transportation.

⇓

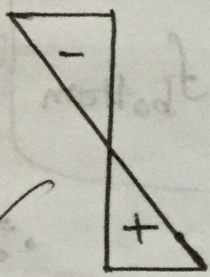


• But river bed থেকে এভাবে support দেওয়া যায় না।



$$M_s = \frac{W_s L^2}{8}$$

W_G = self wt. (girder)
W_s = " " (slab)

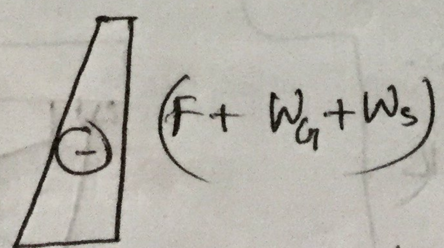


$(W_s) \Rightarrow$ After / at time of casting of slab.

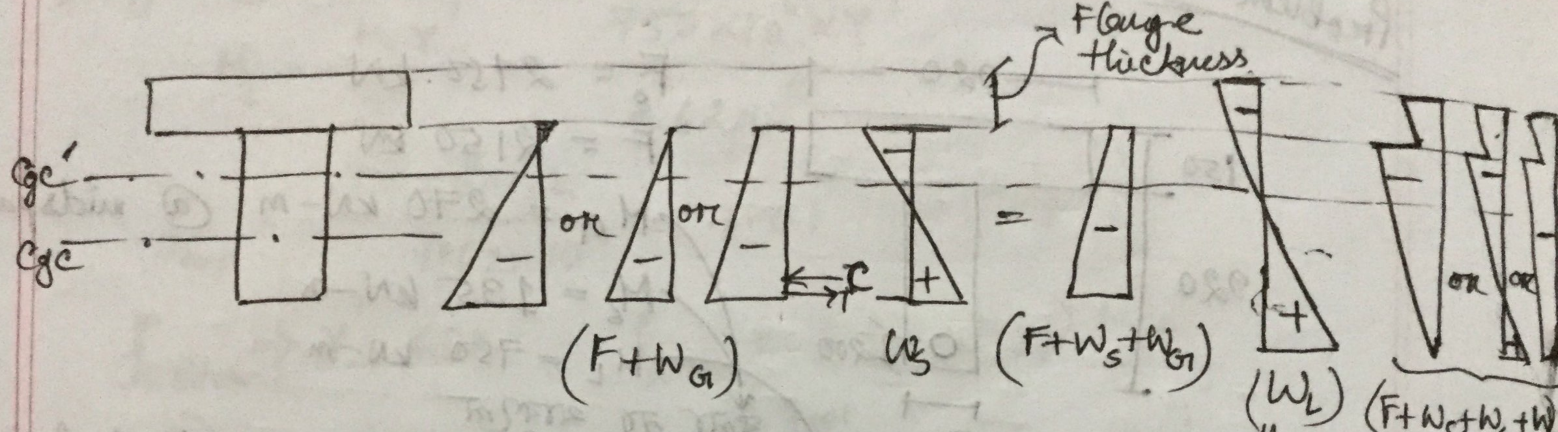
$$f = \frac{M_s y}{I}$$

↳ I_{Girder} cz slab এখনও load নিবে না!

- Adding this dia with the previous ones—



$$f = \frac{F}{A} \pm \frac{Fey}{I} \pm \frac{(M_G + M_s)y}{I}$$



on composite section

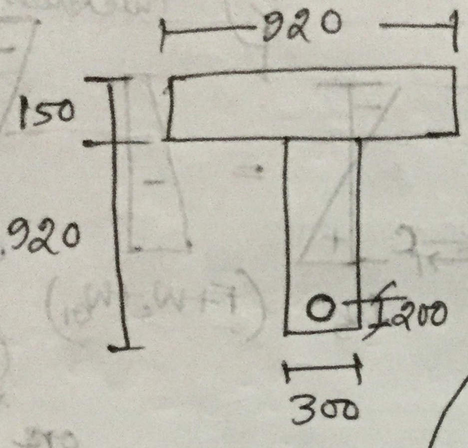
$$f = \frac{M_L Y'}{I'}$$

where, Y' = Position of NA of composite section

I' = MOI of Composite section

- Composite section - এর পর only Live load আসবে।

Problem-1



$F_o = 2450$ kN

$F = 2150$ kN

$M_G = 270$ kN-m @ midspan

$M_S = 135$ kN-m

$M_L = 750$ kN-m

বলা না থাকলে

$M_G = \frac{w_G L^2}{8}$ where w_G = self wt of girder

& $M_S = \frac{w_S L^2}{8}$,, w_S = " " of slab

Load বলা থাকলে W_L & then

$M_L = \frac{w_L L^2}{8}$

• where, L = span

$A_{ps} = 2400$ mm^2

$f_{pu} = 1850$ MPa

$f'_c = 35$ MPa

$I = ?$ 1.95×10^{10} mm^4

$I' = ?$ 4.62×10^{10} mm^4

$A = ? = 2.76 \times 10^5$ mm^2 ~~(given)~~

$A' = ?$ 4.14×10^5 mm^2

$Y = ?$ 460 mm

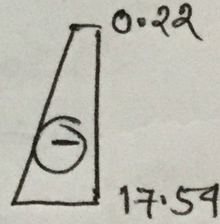
$Y' = ?$ 432 mm

Stage-① $(F_o, F_o e, M_G)$

$f = \frac{F_o}{A} \pm \left(\frac{M - Fe}{I}\right) Y$

$f_{top} = -F_o/A \pm$

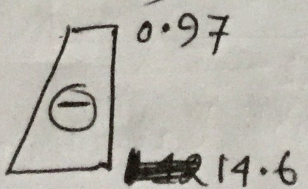
$f_{bottom} = -$



Stage-② (F, Fe, M_G)

$f_{top} =$

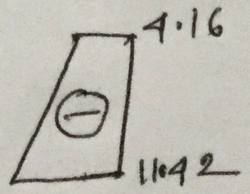
$f_{bottom} =$



Stage-③ (After casting slab) $\{F, Fe, (M_G + M_S)\}$

$f_{top} =$

$f_{bottom} =$

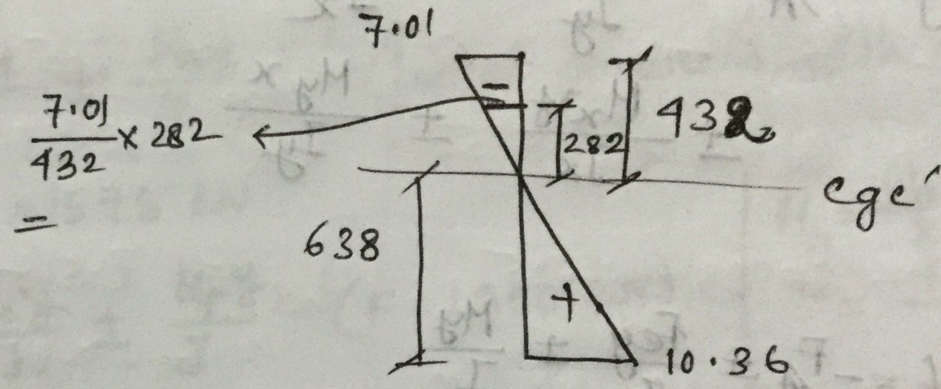


Stage - (4)

$$M_L = \frac{M_L Y'}{I'} = \frac{750\times10^6 \times Y'}{4.62\times10^{10}}$$

$$\therefore f_{top} = \frac{750\times10^6\times432}{4.62\times10^{10}} = 7.01 \text{ MPa (Comp.)}$$

$f_{bottom} \Rightarrow Y' = 638 \quad \therefore f_{bottom} = 10.36$ (ten.) MPa.



432 − 150 = 282

Extra

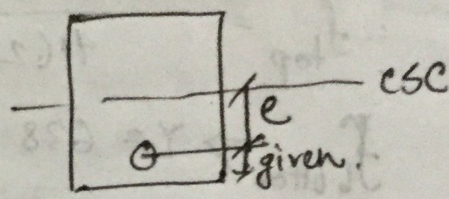
Q. This math without moment.

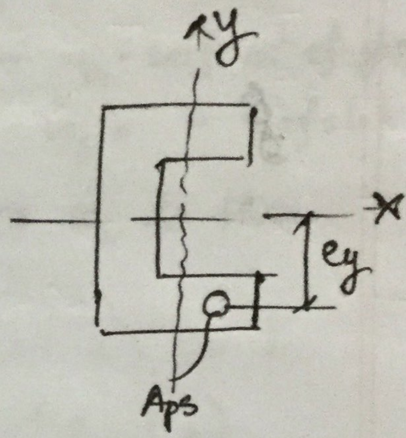
17·05·2016.

Analysis of Section for Flexure

$$f = \frac{F}{A} \pm \frac{Fey}{I} \pm \frac{My}{I}$$

$$f = -F/A \pm \frac{Fe_x \cdot x}{I_y} \pm \frac{Fe_y \cdot y}{I_x} \pm \frac{M_x y}{I_x} \pm \frac{M_y x}{I_y}$$





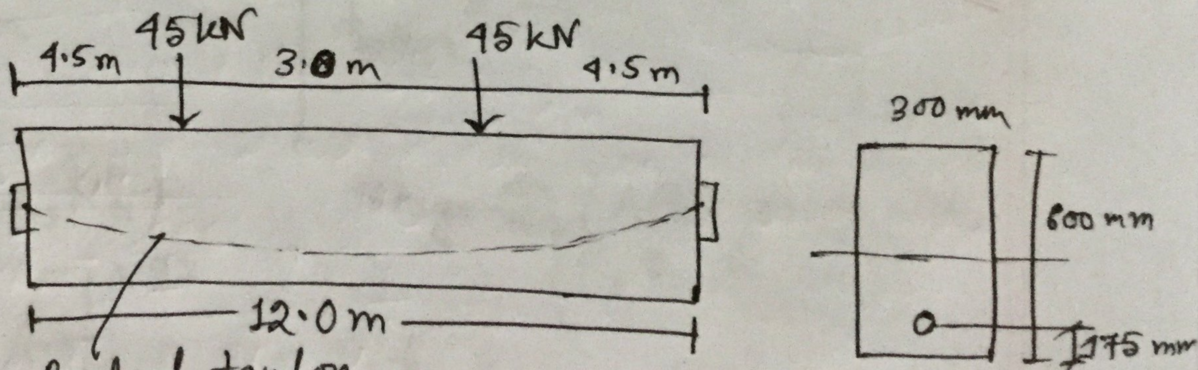
$$f = -F/A \pm \frac{Fey}{I} \pm \frac{My}{I}$$

$$= F/A\left(1 \pm \frac{ey}{r^2}\right) \pm \frac{My}{I}$$

where, $r = \sqrt{\frac{I}{A}}$

$$= F/A \pm (Fe \pm M)\frac{y}{I}$$

Imp. Problems



Post tension Bonded tendon

(two point loading)

$F_0 = 1575$ kN (Prestress @ transfer i.e. initial prestress)

$F = 1350$ kN

$w_G = 4.5$ kN/m (In addition to self wt.)

⇓

self wt. দেয়া না আবশ্যক

must calculate self wt.

(a) $f = -\frac{F_0}{A} \pm \frac{F_0 e y}{I} \pm \frac{M_G y}{I}$: (initial prestress with no live load)

& $F_0 = 1575$ kN

(b) $f = -F/A \pm \frac{F e y}{I} \pm \frac{M_T y}{I}$ ($F = 1350$ kN)

$M_G = \frac{w_G L^2}{8} = \frac{4.5 \times 12^2}{8} = 81$ kN-m $= 81 \times 10^6$

$I = \frac{300 \times 600^3}{12} = 54 \times 10^8$ mm⁴

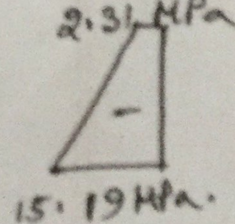
(a) $f = -\frac{1575 \times 10^3}{600 \times 300} \pm \frac{1575 \times 125 \times 300 \times 10^3}{54 \times 10^8} \pm \frac{81 \times 10^6 \times 300}{54 \times 10^8}$

(Considering gross area)

$= (-8.75 \pm 10.94 \pm 4.5)$ MPa

$\therefore f_{top} = -8.75 + 10.94 - 4.5 = -2.31$ MPa

$f_{bot} = -8.75 - 10.94 + 4.5 = -15.19$ MPa.



ⓑ

$$f = -\frac{1350\times10^3}{300\times600} \pm \frac{1350\times10^3\times125\times300}{54\times10^8} \pm \frac{283.5\times10^6\times300}{54\times10^8}$$

$$= \left(-7.5 \pm 9.38 \pm 15.75\right)\ \text{MPa}$$

$$M_T = M_G + M_L$$

$$= 81 + 45\times4.5$$

$$= 81 + 202.5$$

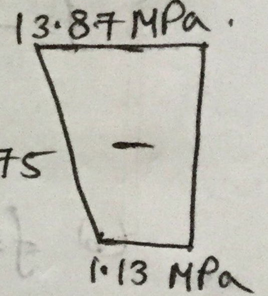
$$= 283.5\ \text{kN-m}$$

$$\therefore f_{top} = -7.5 + 9.38 - 15.75$$

$$= 13.87\ \text{MPa}$$

$$f_{bot} = -7.5 - 9.38 + 15.75$$

$$= -1.13\ \text{MPa}$$



Extra

Midspan না হয়ে @ any section

Then M = changed.

Stress in concrete @ CGS (f_{cir})

Then $\boxed{\Delta f_s = n f_{cir}}$ = Stress in steel due to the applicat^n of bending also.

$$f_{cir} = -\frac{F}{A} - \frac{Fee}{I} + \frac{Me}{I}$$

for ⓐ $F \Rightarrow F_o$ & $M \Rightarrow M_G$

" ⓑ $F \Rightarrow F_{eff}$ & $M \Rightarrow M_T$.

Given, A_{ps}, f_o, f_{eff}.

$\therefore F_o = A_{ps} \times f_o$

& $F = A_{ps} \times f_{eff}$.

Suppose, $f_o = 1400$ MPa

$f_{eff} = 1200$ MPa

The calculate change in stress, f_{cir} for ⓐ & ⓑ two cases.

Then, $\Delta f_s = n f_{cir}$ ⇒ এটা আগের [illegible] & [illegible]. ~~এর সাথে~~

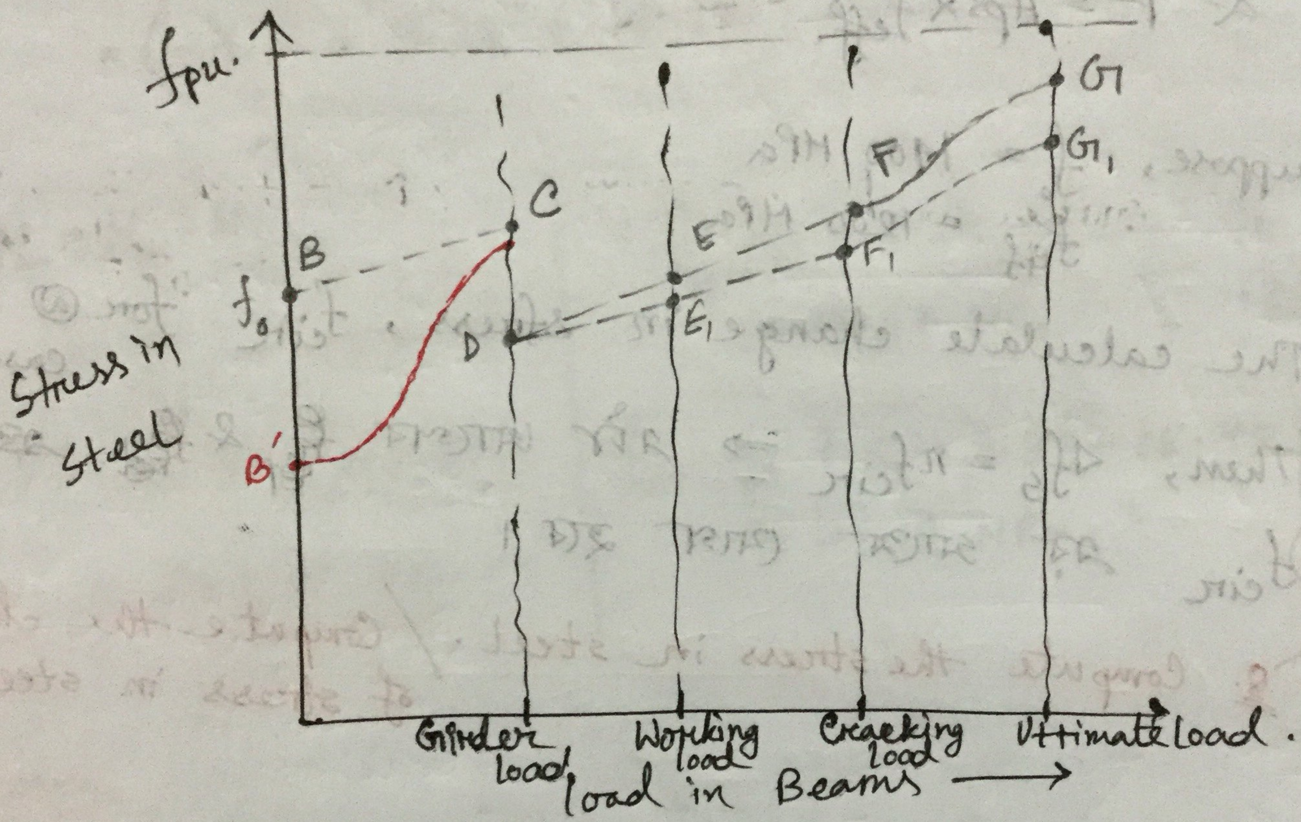
f_{cir} এর সাথে যোগ হবে।

Q. Compute the stress in steel. / Compute the change of stress in steel. ($n f_{cir}$)

The loads ⇒

- Initial load ⇒ (F_o, W_G)
- Working " ⇒ (F, W_G, W_L)
- Cracking " ⇒ (F, W_G, W_L, but sect^n cracked)
- Flexure → Last stage & factored load & f'_c, f_y হবে।

• Depending on the type of loading, how the stress in steel changes –



BC ↑ ⇒ due to self.wt.

CD = loss (time dependent but এখানে concentrated ধরে নিচ্ছি)

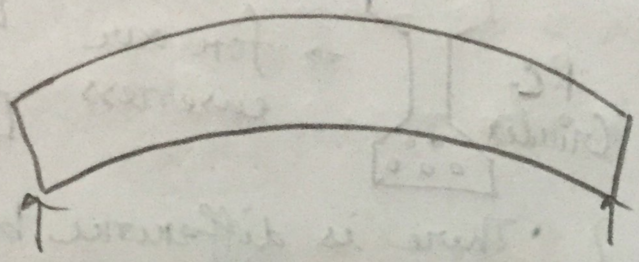
DEF = Bonded tendon

DE_1F_1 = Unbonded tendon

concrete crack করে গেলে the stress is transferred to steel & so there will be a jump

FG = Bonded, F_1G_1 = unbonded.

V.Imp. Q. Briefly explain the change of stress in steel due to different types of loading with neat sketch.



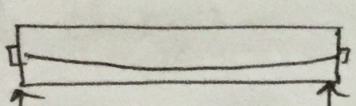
- Girder load কম হলে B'CD ⇒ then the rest of the graph is the same.

Ch-6

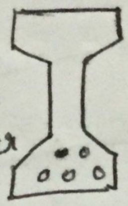
Preliminary Design of Sections for flexure

31.05.2016

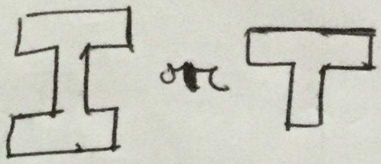
- Normally girders are simply supported.



P.C. Girder



⇒ for our easeness



or

\# Two things are imp in PC ⟶

a. Initial Stress (F_o, F_oe, W_G)

b. Final stress (F, Fe, W_T)

Initial: f'_{ci}, E_{ci} ⟶ $f_{ci} = 0.6 f'_{ci}$

Final: $W_G + W_L$ ⟹ f'_c, E_c ⟶ $f_c = 0.45 f'_c$, $f_{r} = 7.5\sqrt{f'_c}$ ⟹ if tension is considered.

- There is difference betn normal concrete & prestressed concrete
- for design ⇒ $f_c = 0.45 f'_c$

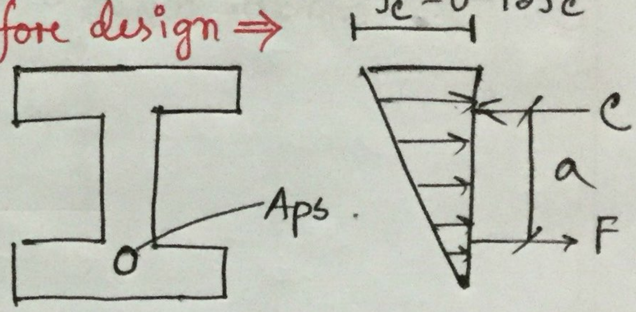
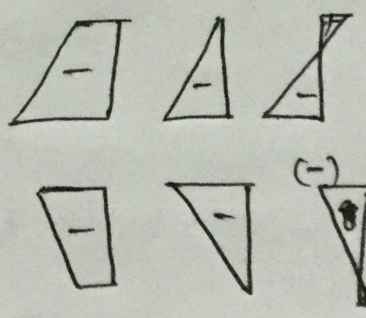


Fig-1

$$f = -\frac{F}{A} \pm \frac{F_o e y}{I} \pm \frac{M_G y}{I}$$

$$f = -\frac{F}{A} \pm \frac{F e y}{I} \pm \frac{M_T y}{I}$$



Check: $f_c \leq 0.60 f'_{ci}$ & same check for tension.

$f_c \leq 0.45 f'_c$ Check & same check for tension

\# Design: —

(*) We will start design with the Working Moment (M_T) i.e. from final stress.

We can write, $M_T = Fa = Ca$

& $F = A_{ps} F_{se}$; $C = \frac{1}{2} f_c A_c$

(F_{se} ↳ effective prestress)

Now $F = C$

- Question is, what about a?

RC	PC
$M = 0$	$M = 0$
$f_c = f_s = 0$	$f_c, f_s \neq 0$
$a = Jd \neq 0$	$a = 0$ ⇒ i.e. Line of action same / যেখানে tendon সেখানেই C

- First, assume $a = 0.65h$ / $\frac{2}{3}h$.

Problem

$M = 435$ kNm
$h = 920$ mm
$f_{se} = 860$ MPa
$f_c = 11$ MPa

- If $f_c' =$ given then, $f_c = 0.45 f_c'$ must be calculated & use f_c in calculations.

Now, $M_T = Fa$

$\Rightarrow a = \frac{M_T}{F}$

$\Rightarrow F = \frac{M_T}{a} = \frac{435 \times 10^6}{0.65 \times 920} = 727$ kN

Now, $727 = A_{ps} \times 860$

$\Rightarrow A_{ps} = 845\ mm^2$

$\therefore A_c = \frac{727 \times 10^3}{0.5 \times 11} = 132 \times 10^3\ mm^2$

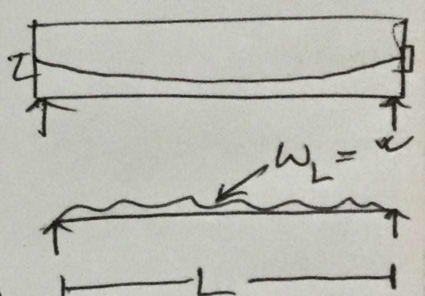
$\therefore C = \frac{1}{2} f_c A_c$ & $T = A_{ps} f_{se}$

$\left(\frac{f_c + 0}{2}\right)$ ⇓ in fig-1

At final stage →

- $f_{se} = 860 + loss$

Extra

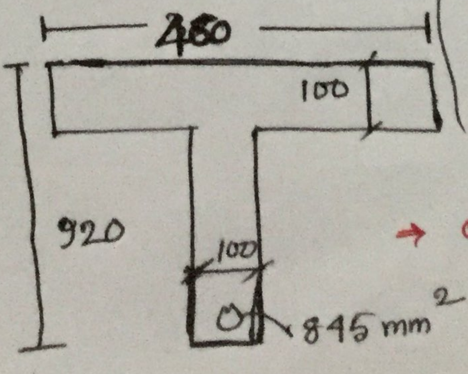


w_L = excluding self weight.

So we have to assume self weight.

⇓

RC-এর মতোই self weight ধরে নিব but section will be smaller than RC.



→ check with required $A_c = 132 \times 10^3\ mm^2$

⇓ but it will be checked in the final design. ⇒ So for now it will be okay

• In exam, h = not given.
So Let us assume,

h = 75% of corresponding RC section

or $h = K\sqrt{M}$, $K = 1.5$ to 2.0 and M = total Moment (k')
(inch)

• $a = 0.65h$ (not always right) cz $a \rightarrow$ depends on $\frac{M_G}{M_T}$

Preliminary Design

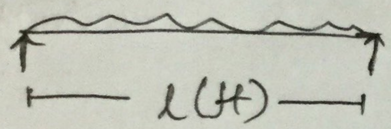
07·06·2016

- Sometimes,

  Depth of Girder = ? unknown.

Then 1. $h = k\sqrt{M_T}$ ← Total moment in k'
(k → 1·5 to 2·0)

or 2. h = 70% to 80% of the corresponding depth of R.C Member.

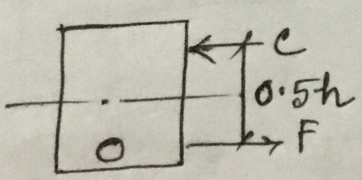


3. $h = l$ in inch

Preliminary design depends on—

$\frac{M_G}{M_T} \Rightarrow$ small

then $F = \frac{M_L}{0.5h}$ ← $M_T - M_G$



Previous Problem :—

$M_T = 135$ kN-m

$M_G = 50$ kN-m

$f_{se} = 860$ MPa

$f_c = 11$ MPa

$h = 920$ mm

Make a preliminary design

Sol^n : $F = \frac{M_T}{0.65h}$ after determining $\frac{M_G}{M_T}$

$F = \frac{M_L = M_T - M_G}{0.5h}$

} Whichever is large (for the section)

Now, $F = \frac{M_T}{0.65h} = \frac{435 \times 10^6}{0.65 \times 920} = 727$ kN

and $F = \frac{M_L}{0.5h} = \frac{(435-50) \times 10^6}{0.5 \times 920} = 837$ kN

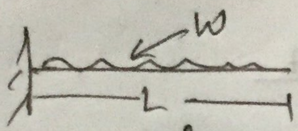
$\therefore F = 837$ kN.

$\therefore A_{ps} = \frac{F}{f_{se}} = \frac{837 \times 10^3}{860} = 973.26 \text{ mm}^2$

$A_c = \frac{F}{0.5 f_c} = \frac{837 \times 10^3}{0.5 \times 11} = 6727.27 \text{ mm}^2$

Cantilever. **Simply Supported**

1.



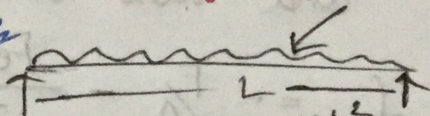
$$M = \frac{wL^2}{2}$$

$$f = -\frac{F}{A} \pm \frac{Fey}{I} \pm \frac{My}{I}$$

$f_{top} = ⊖ ⊖ ⊕$

$f_{bot} = ⊖ ⊕ ⊖$

2.

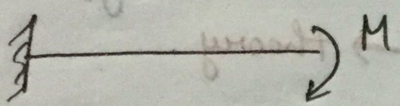


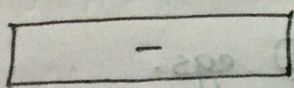
$$M = \frac{wL^2}{8}$$

$f_{top} = ⊖ ⊕ ⊖$

$f_{bot} = ⊖ ⊖ ⊕$

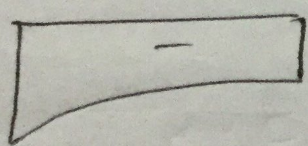
3.





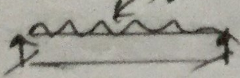
(neglecting selfweight.

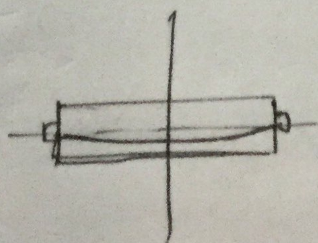
BMD

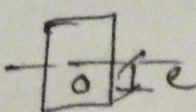


(considering self weight)

4.







M = given, all given

w = ?

Compute the load which will produce the first crack?

— midspan-এ first crack হবে।

and also bottom → first crack হবে।

$$f_{bot} = -\frac{F}{A} - \frac{Fey_{bot}}{I} + \frac{My_{bot}}{I}$$

⇓

M = determined.

therefore, $w = \frac{8M}{L^2}$

⇓

$w' = w - \text{selfweight}$

→ final answer.

5. Math from Loss (due to elastic shortening)

Imp• What are the sources? → theory.

$\Delta f_s = n f_{cir}$

→ stress in concrete @ cgs.

6. Composite section