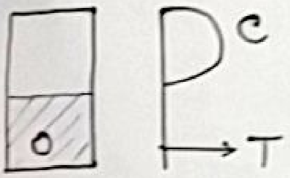
সেকান্দার স্যার

Lec-1

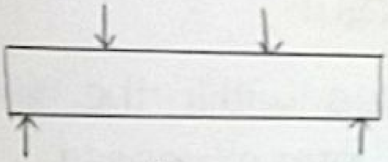
Prestressed Concrete

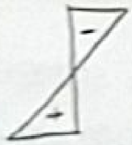
Concrete — Reinforced concrete
— prestressed concrete

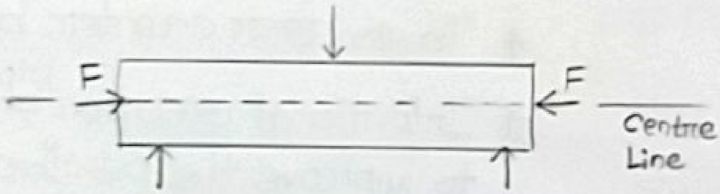
* Reinforced concrete কিছু কিছু ক্ষেত্রে suitable না।
যেমন- Long span structural system (bridge) এ.



বেশ খানিকটা concrete waste হয়ে যায়। (beam এর) তাই নিচের concrete থেকে T সরানোর ব্যবস্থা করা হয়।





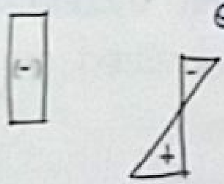


$f = \frac{My}{I}$

$(+) \rightarrow T$
$(-) \rightarrow C$

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

$-\frac{F}{A}$: prestress; $\frac{My}{I}$: stressed from external loading



a) $\frac{F}{A} > \frac{My}{I}$
b) $\frac{F}{A} = \frac{My}{I}$
c) $\frac{F}{A} < \frac{My}{I}$

$\rightarrow$

$$f_{top} = -\frac{F}{A} - \frac{M y_{top}}{I}$$

$$f_{bottom} = -\frac{F}{A} + \frac{M y_{bottom}}{I}$$

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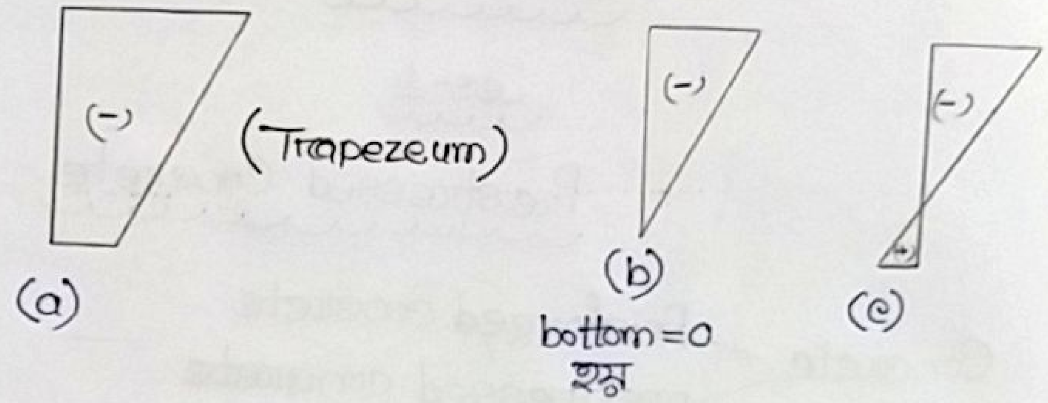
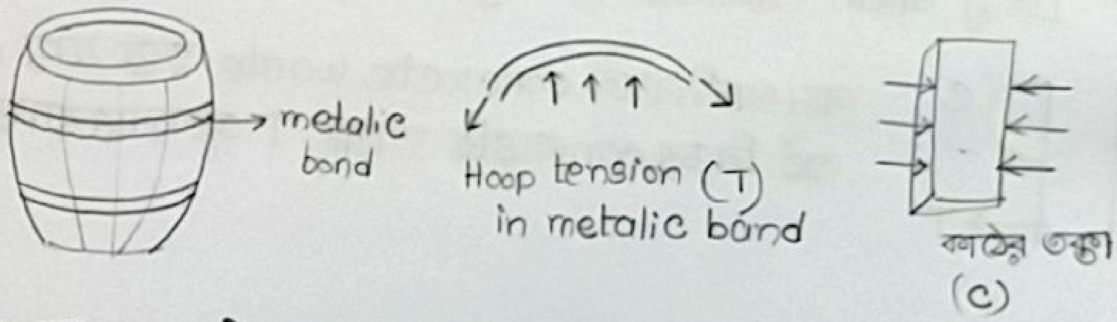
for (a),

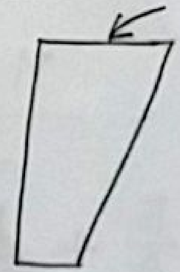


* prestressed is applied here concentrically (member এর axis বরাবর (c.g)).



* Tension টাকে counter balance করা।
* Intentional creation of stresses within the system to improve the performance – pre-stressed.
* Application of (internal stresses) [→ F/A] on such magnitude and distribution that the [stresses resulting from external loading] [← $\frac{My}{I}$] will be counter balanced to a desired degree.

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



F ↔ বেশি হয়ে গেলে compression বেড়ে যাবে। ফলে তখন concrete compression এ fail করতে পারে। তাই F কে অতটাও বাড়ানো যাবে না।

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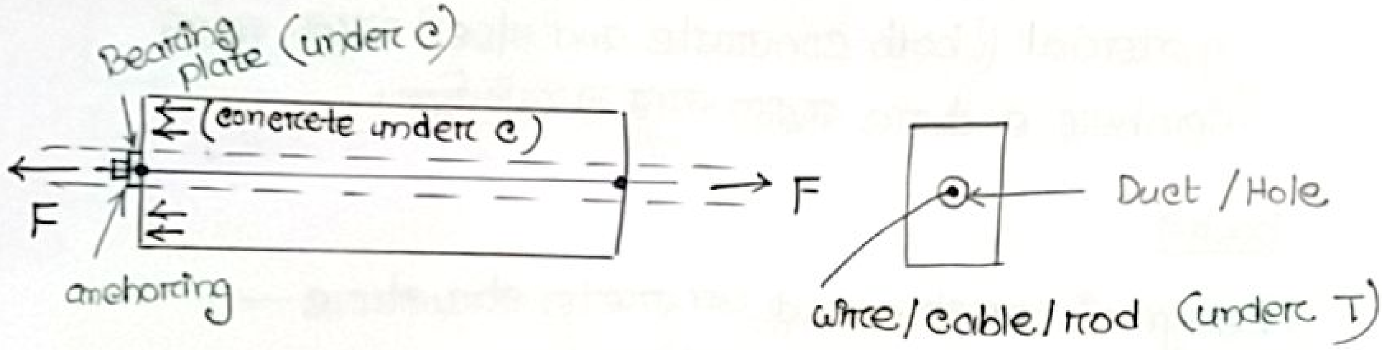
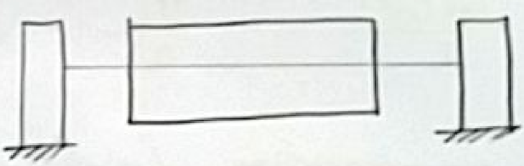
* Prestressed is applied by applying tension in steel.



প্রথমে steel এ T দেয়া হয়। Then anchorage করা হয়। এখন, rod গুলো আবার আগের অবস্থায় ফেরত যেতে চায়, কিন্তু anchorage এর জন্য যেতে পারে না, বাধা পায়। ফলে bearing plate ও concrete এ C কাজ করে। অর্থাৎ, এখানে prestressed transform হয় bearing এর মাধ্যমে। (post-tension - method P.T.P.C.M) member তৈরির পর steel এ T দেয়া হয়েছে

আরেকটি method,

pre-tension - method (member তৈরির আগে steel এ T দেয়া হয়)



এখানে bond এর মাধ্যমে stress transfer হয়।

আগে steel এ T দেয়া হয়। then beam cast করা হয়। Beam strength gain করার পর, 'T' ছেড়ে দেয়া হয়। তখন steel আগের জায়গায় ফেরত যেতে চায়, কিন্তু concrete allow করে না, তখন concrete এ C develop করে বাধা দেবার জন্য। তাই এখানে bonding এর কারণে stress develop করে।

** যদি member এর c.g তে F apply করা হয়, তবে member এর efficiency কমে যায়।

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** prestressed concrete এর জন্য high strength material (both concrete and steel) লাগে, নইলে member endure করতে পারে না বেশিদিন।

Books

Design of prestressed concrete structure —
T.Y. Lin (S.I symbol) → 3rd/4th Ed.

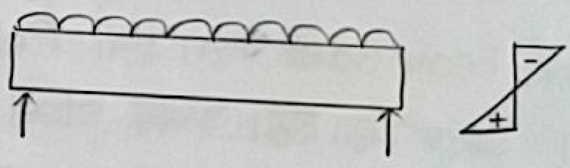
Lecture-2

□ Concepts of Prestressing:

There are 3 concepts.

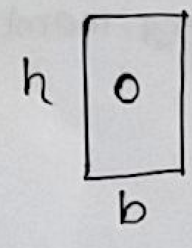
□ 1st Concept (বেশি apply হয়)

prestressing apply করা হয় to transform concrete into an elastic material.

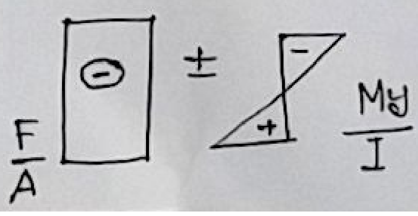


$\frac{My}{I}$ compression – (−ve)
tension – (+ve)

• due to tension concrete doesn't act as elastic, ductile material. তাই reinf. use না করা হয়ে, আমরা Tension সরাবো prestress দিয়ে।

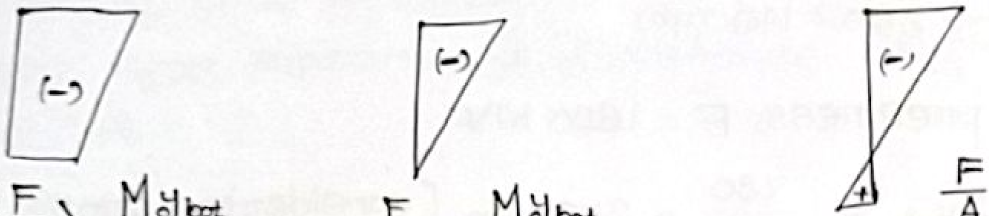


$$f = -\frac{F}{A} \pm \frac{My}{I}$$

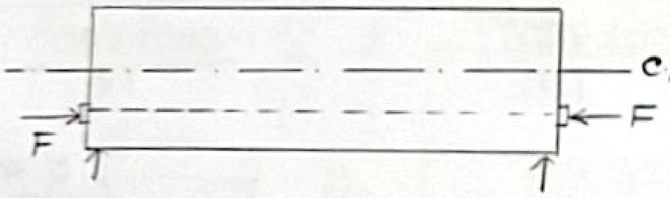


$$f_{top} = -\frac{F}{A} - \frac{My_{Top}}{I}$$ } এটা problem করে

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

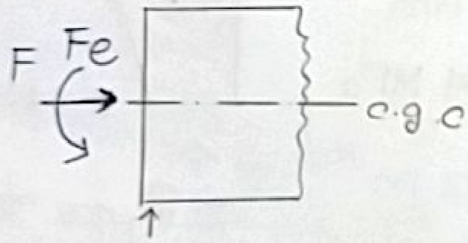


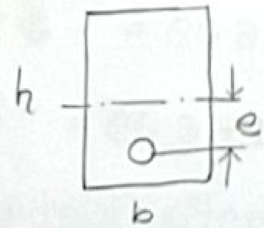
$\frac{F}{A} > \frac{My_{bot}}{I}$ $\qquad$ $\frac{F}{A} = \frac{My_{bot}}{I}$ $\qquad$ $\frac{F}{A} < \frac{My_{bot}}{I}$

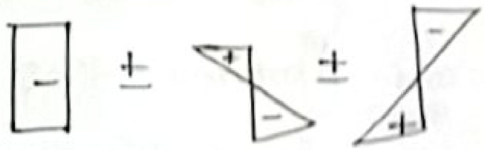


যদি prestress এর rod c.g তে না নিয়ে একটু নিচে দেয়া হয়,

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



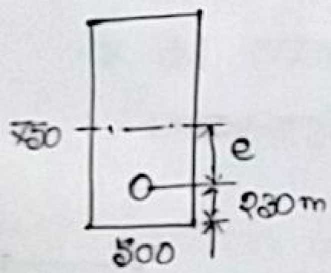


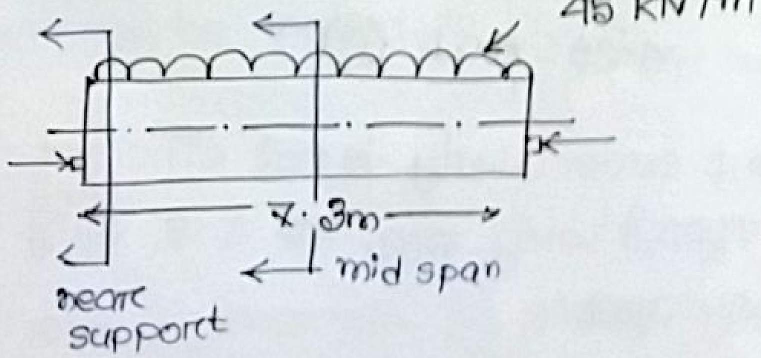


$$f_{top} = -\frac{F}{A} + \frac{Fey_{top}}{I} - \frac{My_{top}}{I}$$

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

P-16





effective prestress = initial prestress − loss

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

$e = \frac{750}{2} - 230 = 145$ mm

Effective prestress, $F = 1620$ KN

$y_{top} = y_{bot} = \frac{750}{2} = 375$ mm (considering gross area)

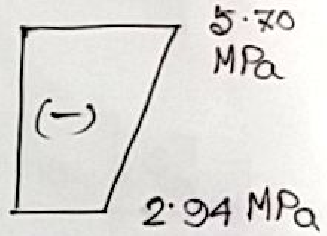
$$f = -\frac{1620 \times 10^3}{500 \times 750} \pm \frac{1620 \times 10^3 \times 145 \times 375}{\frac{500 \times 750^3}{12}} \pm \frac{299.76 \times 10^6 \times 375}{\frac{500 \times 750^3}{12}}$$

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

at mid span

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

$f_{bottom} = -4.32 - 5.01 + 6.39 = -2.94$ MPa



এই figure আঁকতে হবে exam এ.

The system is now elastic, ductile, cz no Tension.

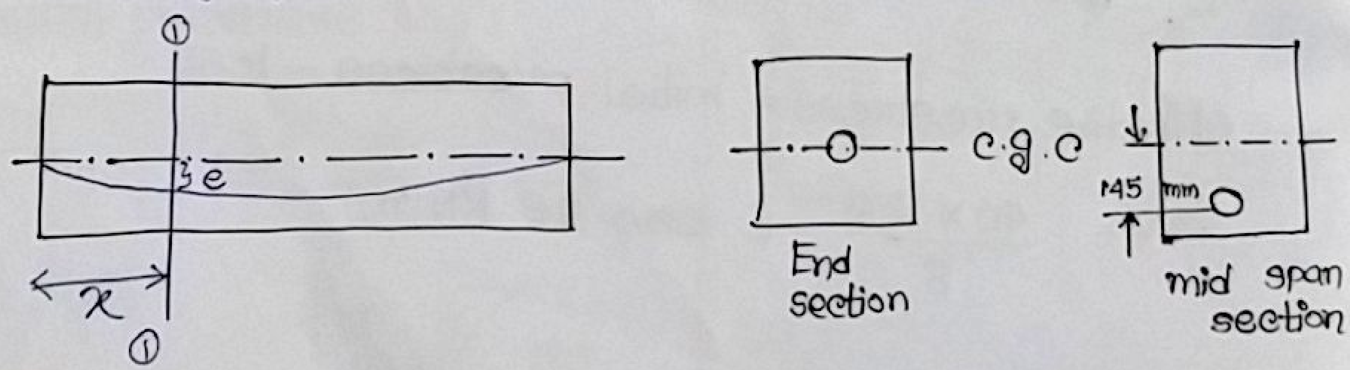
Near support,

$M = 0$

$\therefore f_{top} = -4.32 + 5.01$ (T)

$f_{bottom} = -4.32 - 5.01$ (C)

* constant eccentricity is not efficient. যেহেতু M, X-section অনুযায়ী vary করে, তাই e ও vary করানো হলে efficiency বাড়বে।



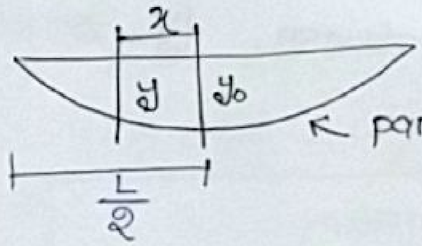
Q. Compute fibre stresses at top, bottom section near mid span, near support, at a distance x from left support.

→ For x distance,

e at section ①-① বের করব।

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

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



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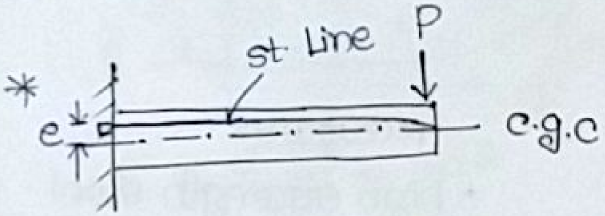

compute fibre stresses at support.

formula same. f_{top}, f_{bottom} বের করে নিতে হবে।

* Q. হয়তো ω বের করতে হবে।

compute ω which can be applied to produce zero tension at bottom fibre at midspan.

(A) $f_{bottom} = 0$ ধরব

• the section will remain uncrack at midspan, what is ω?

(A) তখন, $f_{bottom} = f_r$

কারণ, নিচে (bottom) এ Tension কাজ করে, আর concrete tension নিতে পারে না। তাই bottom এ crack হবে।

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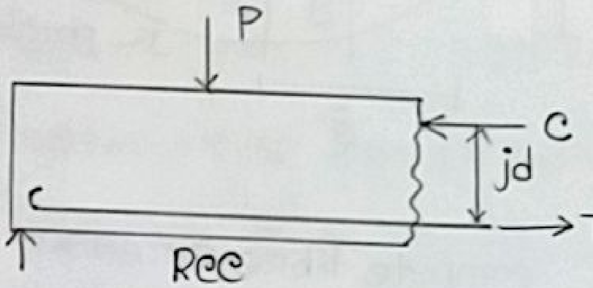
Lecture-3

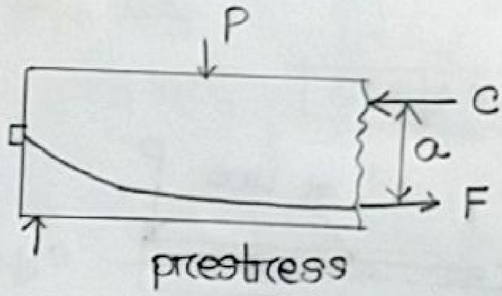
2nd Concept:

Prestressing for combination of high strength steel with concrete.

Normal use $f_y = 60$ KSi
prestress, $f_y = 150$ KSi



• normal steel



• high strength steel

• যদি $P=0$ (no external load),

$T = C = 0$, $(f_s, f_c) = 0$ } no external load, no stress

but, jd (sectional property) remains constant.

• 'M' change হলে, f_s, f_c change হয়।

• এখানে stress change হবে।

$M = 0 = C \cdot a = 0$

$= F \cdot a = 0$

$F = C \neq 0$ [cz, আমরা already stress দিয়ে রেখেছি]

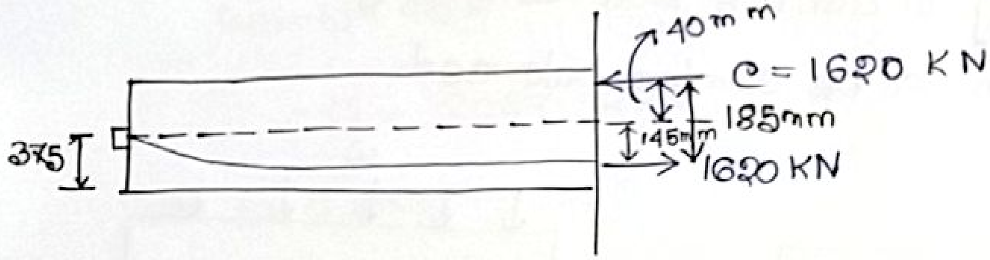
Here $a = 0$

তখন, F ও C এর line of action same হয়।

• 'M' change হলে normally F, C change হয় না। তবে overloading হলে হতে পারে।
change হয় শুধু location of 'C'.

• 'C' এর location জানলে stress বের করা যায়।

Math (গত দিনের) → using 2nd Concept:



$M = C \cdot a$

$\therefore a = \frac{M}{C} = \frac{299.76 \times 10^6}{1620 \times 10^3}$

$= 185 \text{ mm}$

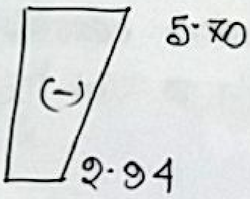
$f = -\frac{C}{A} \pm \frac{C \cdot ey}{I}$

$= \frac{-1620 \times 10^3}{500 \times 750} \pm \frac{1620 \times 40 \times 375}{\frac{500 \times (750)^3}{12}}$

$= -4.32 \pm 1.38$

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

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

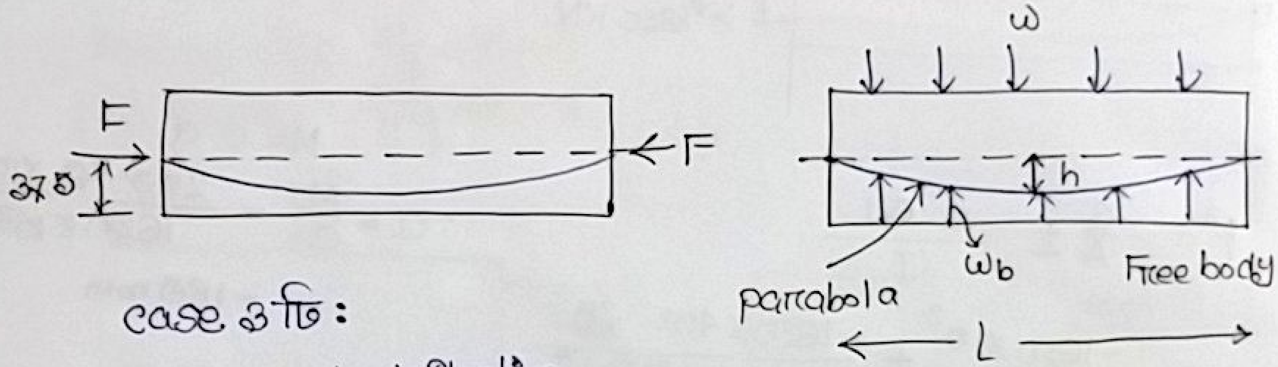


3rd Concept:

কিছু কিছু math এর জন্য এই concept ভাল।

" Prestressing to achieve load balancing."

External load must be counter balanced.



case ৩টি:

1) $w_b < w$ ↓ deflection

2) $w_b = w$ — no deflection

3) $w_b > w$ ↑ deflection

- Deflection and crack shall be within limit

- Fh change করে আমরা deflection টাকে change করে ফেলতে পারি।

$$F.h = \frac{w_b l^2}{8}$$

$$\therefore \boxed{w_b = \frac{8Fh}{l^2}}$$ If the distribution is parabolic

where h = sag

w = external load

w=0 হয়ে গেলে, beam টা উপরে উঠে যাবে। এটাকে বলে hogging ⌒.

(Math)

$$w_b = \frac{8Fh}{l^2}$$

$$= \frac{8 \times 1620 \times (145 \times 10^{-3})}{(7.3)^2}$$

$$= 35.3 \text{ KN/m} < w = 45 \text{ KN/m}$$

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Q. what excess external load must be applyied to balance it (i.e. $w_b = w$ হয়)? বা কত prestressing দিতে হবে যাতে ($w_b = w$) হয়।

$$w_b = w = 45 = \frac{8F \times 0.145}{(7.3)^2}$$

$$\therefore F = 2067.28\ kN$$

বা, h = ? কত হতে হবে ?

$$M = \frac{(w - w_b)l^2}{8} = \frac{(45 - 35.3) \times (7.3)^2}{8} = 64.6\ kN.m$$

$$f = -\frac{F}{A} \pm \frac{64.6 \times 10^6 \times 375}{I}$$

$$= -\frac{1620 \times 10^3}{500 \times 750} \pm$$

$$= -4.32 \pm 1.38$$

('C' এর জন্য)

$$f_{top} = -4.32 - 1.38 =$$

$$f_{bottom} = -4.32 + 1.38 =$$

যদি $w_b = w$ হয়, তবে, $f = \frac{F}{A}$ হয় (rectangle হয়)

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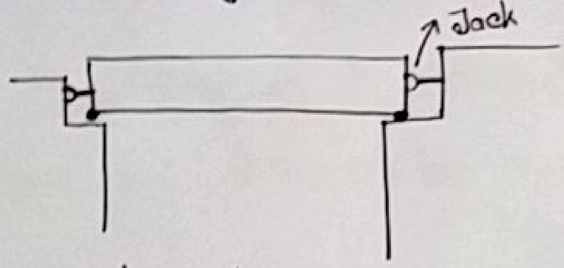
Im Theory

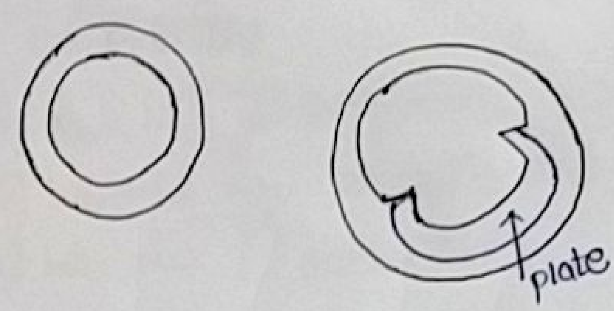
Classification and Types:

1) Externally or internally prestressed:



• external খুব কম হয়, বেশিরভাগই internal হয়।

2) Linear or circular prestressing:



3) pre-tensioning and post-tensioning:

pre tensioning – member cast করার আগে pretension দেয়া।
post " → " " " পরে " "
(example – bridge)

4) End anchored or Non-end anchored tendons:

End anchored – post tensioning (not necessarily)

Non-end anchored – pretensioning
আগে tension দেয়া হয়, then member cast করা হয়। then sufficient strength achieve করলে দুই side এ কেটে দেয়া হয়। so, end is non anchored.

post tension – anchored
post tension – non-anchored

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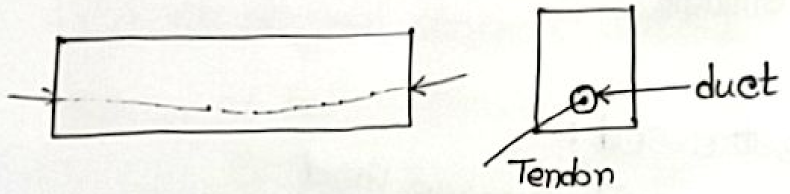
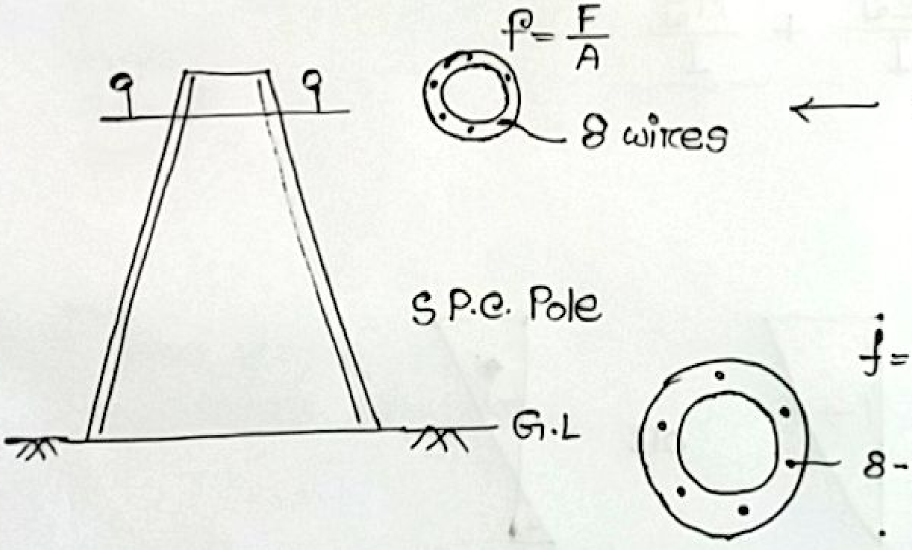
Lecture - 4

(5) Bonded or unbonded tendons:

- Pre-tension members are generally bonded
- Post " " " " unbonded, but can also be bonded



To protect from corrosion. grouting করা হয়। grouting করলে → bonded
" না " → unbonded



← এখানে A ছোট. যা পর্যাপ্ত না এই f (compressive stress carry করার জন্য।

এই ক্ষেত্রে

Top: 4 টা bonded, 4 টা unbonded.

আরও কিছু দূরে (নিচে): 6 টা bonded, 2 টা unbonded

Bottom: 8টাই bonded

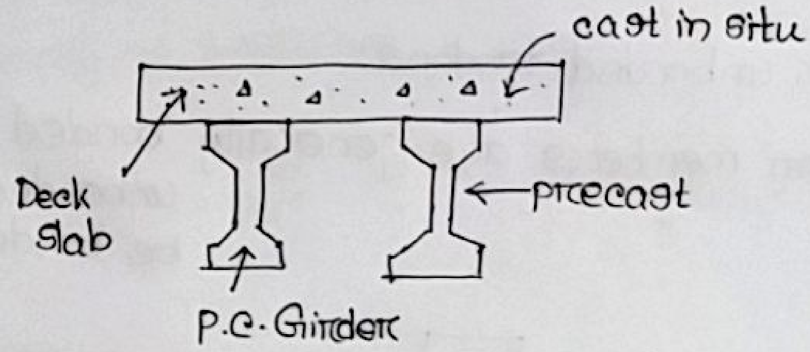
(6) Precast, Cast-in-place, composite constructions:

- Cast in place → structure যেখানে তৈরি হবার কথা, member গুলো সেখানেই cast হচ্ছে।
- precast → construction site এ member তৈরি হয় না।

এক্ষেত্রে
- Transportation অনেক important matter
- Handling
- Erection

এই stress গুলো check করতে হবে

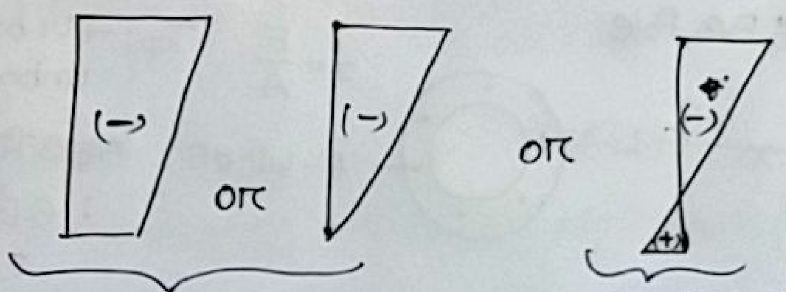
• Composite : pre-cast + cast-in-situ



(খ) Partial and Full Prestressed :

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

Effective prestress (under $\frac{F}{A}$); service load (for $\frac{My}{I}$)



Full prestressing (Tension allow করা না হলে)

partial prestressing (Tension allow করা হলে, upto service load)

• Over loading হয়ে গেলে full prestressing আর থাকে না, partial prestressing হয়ে যায়।

• Partial prestressing করাটাকে অনেকে prefer করে, cz এটা more cost effective হবে এবং more ductile হবে।

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M.S steel (mild steel) % elongation > 15 %

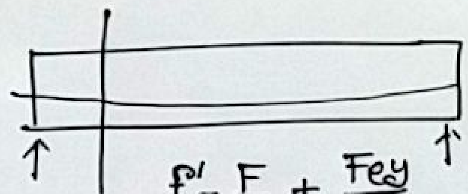
High strength steel → % elongation < 6 %

□ Stages of Loading: (V.Imp for exam)

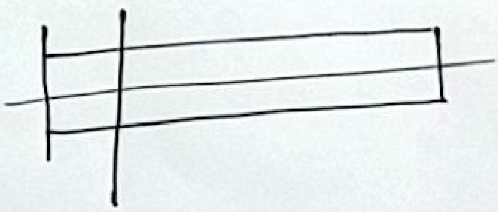
- এটা RCC তে কখনই ছিল না। কিন্তু P.C. এ এটা থাকবেই।
- RCC তে ৩টি stage এ loading হয়।
- P.C. তে সবগুলো stage ই critical.
- P.C →
  1) initial stage
  2) intermediate stage (সব member এ নাও থাকতে পারে)
  3) final stage

  সব member এ must থাকবে

[Next দিন – C.T (৩টা concept)
যে কোনটা apply করে stress বের করব]

• 

$f' = \frac{F}{A} \pm \underline{Fey}$

• 

f° দেয়া থাকবে, M বের কর

- compute the UDL that will produce 1st crack. or the section will remain uncrack.

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Lecture-5

Stages of Loading:

– For any prestressed concrete design there must be initial and final stages.

- **Initial:**

– Before prestressing:

- Tp & shrinkage এর জন্য rod দিতে হবে।
- support condition ঠিক করতে হবে।

– During prestressing:

- কতটুকু Tension apply করব সেটা বলে দিতে হবে।

ACI code

smaller of these ২
- Max → $0.80 f_{pu}$
- Max → $0.94 f_{py}$

$f_{pu} = 1860$ MPa (বেশি use হয়) (high strength steel এর ultimate strength)
= 1724 MPa
= 1670 MPa

f_{py} = yield strength.

- তবে manufacturer যেটা বলে দেয় সেটার বেশি use করা যাবে না।

- Allowable Compressive stress $= 0.6 f'_{ci}$ · i ← initial
  Tension " $= 0.25\sqrt{f'_{ci}}$
- Concrete এর strength বাড়তে থাকে, আর prestress কমতে থাকে time এর সাথে।

– During service load condition (at transfer of prestress)

Compression → $0.45 f'_c$
Tension → $0.5\sqrt{f'_c}$

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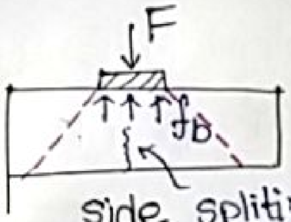
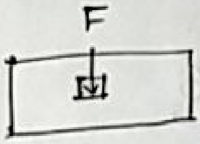




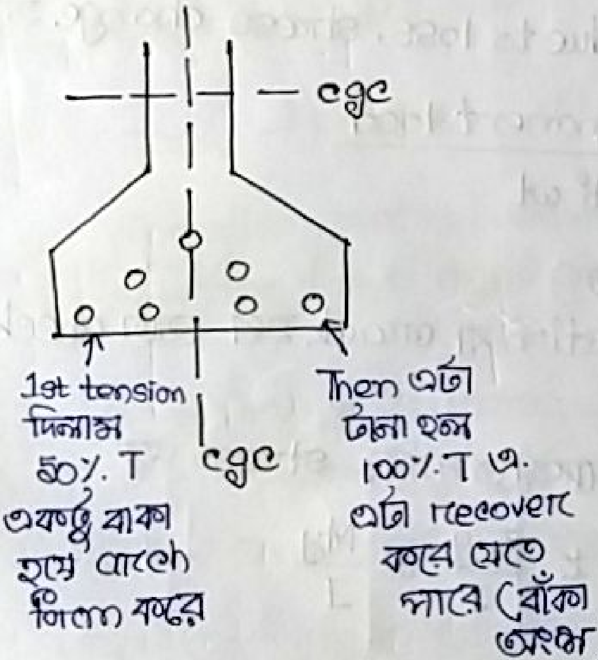
f_b = Bearing stress
এটাও check করে দেখাতে হয়।

অল্প জায়গায় বেশি load কাজ করলে এভাবে dispersed ভাবে load ছড়িয়ে যায়।

- Prestress is applyied gradually. 20 টা Tendon এ tension দিতে হলে সবগুলোতে একবারে না দিয়ে অল্প কিছু দেয়া হয়।

— Decentering and Retensioning:

Tension এ আছে, আবার Tension দেয়া। বড় বড় construction এ fully tension দেয়া হয় না, ধাপে ধাপে দেয়া হয়।



Cambering/Hogging
— prestress এমনভাবে apply করা হয় যেন (-ve) deflection হয়

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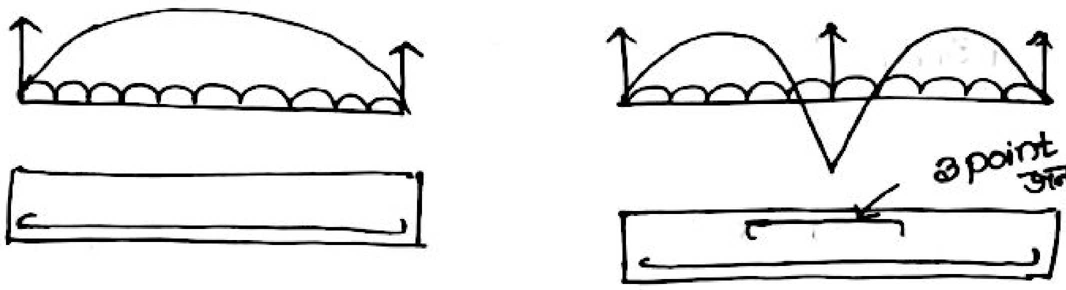
Lecture-6

□ Intermediate Stage:

precast + cast-in-situ (×)

Composite construction → RCC + prestress এ Intermediate stage পাওয়া যায়।



a point uplift এর জন্য -ve M zone এ steel থাকতে হবে

□ Final Stage:

F → effective prestress (due to loss, stress change হয়ে গেছে)

a) • Sustained load → permanent load
- self wt
- FF
- PW

এই load এ কতটুকু deflection বা crack হবে সেটা check করা।

b) • Working load / Service load → status দেখতে পারি, stress এর

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

c) • Cracking load →

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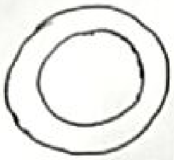
 pc pipe

d) Ultimate load:
$$M_u = \phi M_n$$
$$P_u = \phi P_n$$
$$V_u = \phi V_n$$
} Calculated ultimate

PC Vs RC

১। PC→ high skilled labour, high strength material

১। serviceability:
২। safety
৩। Economy

PC→ X-section কম
RC→ X- " বেশি

[১] · Deflection – PC ভাল

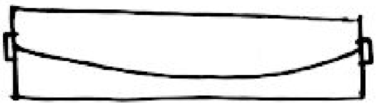
· crack – PC ভাল

· Vibration control, stiffness দরকার → RC ভাল
(water tank, retaining wall) → যেখানে volume · দরকার

[২] PC→ has to go through safety test from the begining
So, safety ensurance বেশি।

RC→ compercatively কম

· PC এর fire ও corrosion resistance কম।



C. cover বেশি PC তে

৩ PC → not economic unless there is repeatation.

• expensive হলেও অনেক ক্ষেত্রে PC দিতেই হয়।

Lecture-7

Chapter-2

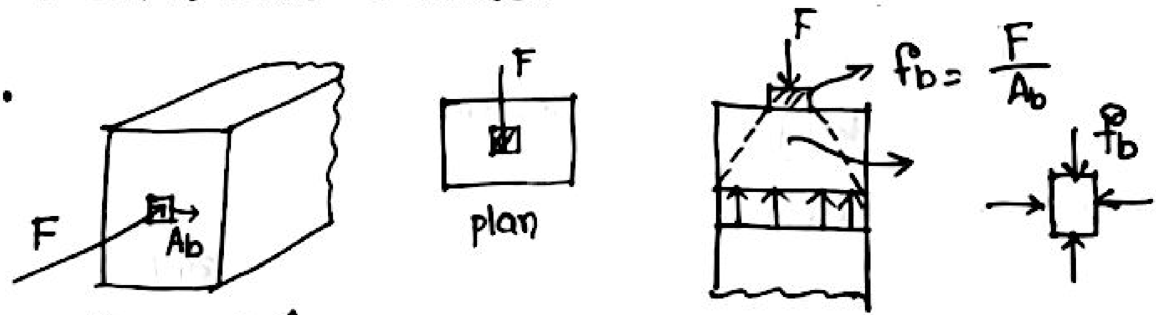
☐ Materials:

1) Concrete (high strength)
2) Steel
3) Auxiliary Materials (duct, grout, anchoring system)

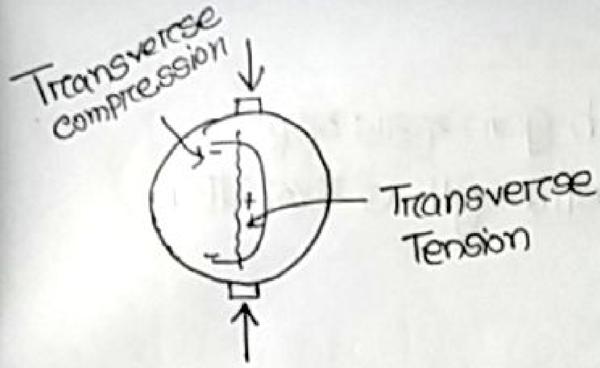
Q. Why high strength concrete?

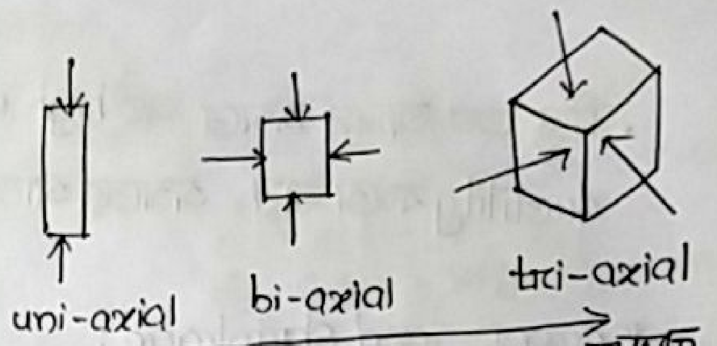
$f'_c = 5000$ psi to 8000 psi

• prestress concrete এর একটা significant loss of prestress থাকবেই, it can't be avoided.

• 

Demand of compressive strength high. cz big force, small area. তাই high strength concrete লাগেই।





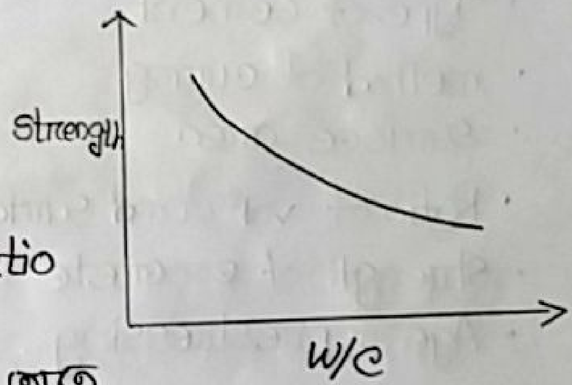
Stress (বেশি load নিতে পারে)

- High strength concrete এর creep, shrinkage কম cz Ec বেশি।
- Compressive strength বেশি, তাই Tensile strength ও বেশি পাওয়া যাবে।

Q. How to get high strength concrete?

Quality control করতে হবে।

- method of mixing
- " " curing
- good proportioning



- But mainly depend করে w/c ratio এর উপর।
- w/c কমালে strength বাড়ে, কিন্তু তাতে করে workability কমে যায়।

তাই admixture use করা হয়, এটা strength ঠিক রাখে, workability বাড়ায়।

$f'_c \rightarrow$ 28 days cylinder strength

$f'_{ci} \rightarrow$ compressive strength of concrete at the time of prestressing (8 hour ও হতে পারে, 1→3 day ও হতে পারে) by→ quick setting cement + elevated Tp and pressure) একে steam curing বলে

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• কিন্তু এত অল্প সময়ে এই high strength gain করার সময় ductility কমে যায়, সময়ের সাথে সাথে strength ও কমে যায়।

* Creep and shrinkage:

• Creep and shrinkage হল main culprit in reducing the strength of concrete.

• But high strength concrete এ এই ২টা property কম, তাই সুবিধা।

- Type of aggregate
- w/c ratio
- Type of cement
- method of curing
- surface area
- Ratio of volm and surface area
- strength of concrete
- Age of prestressing

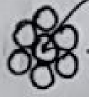
} এই factor গুলোর উপর creep & shrinkage depend করে।

* বেশি পরে prestressing করলে ভাল। cz, by that time creep ও shrinkage কমে যায়, loss কম হয়।

□ Steel:

steel পাওয়া যায় → 1) wire
2) strand
3) steel bar (for external prestressing)

• 12.7 mm 7-wire strand
$A_{sp} = 98.7 mm^2$



dia বড়
– 7-wire strand (twisting অবস্থায়)

• 15.2 mm 7 wire strand
$A_{sp} = 140 mm^2$

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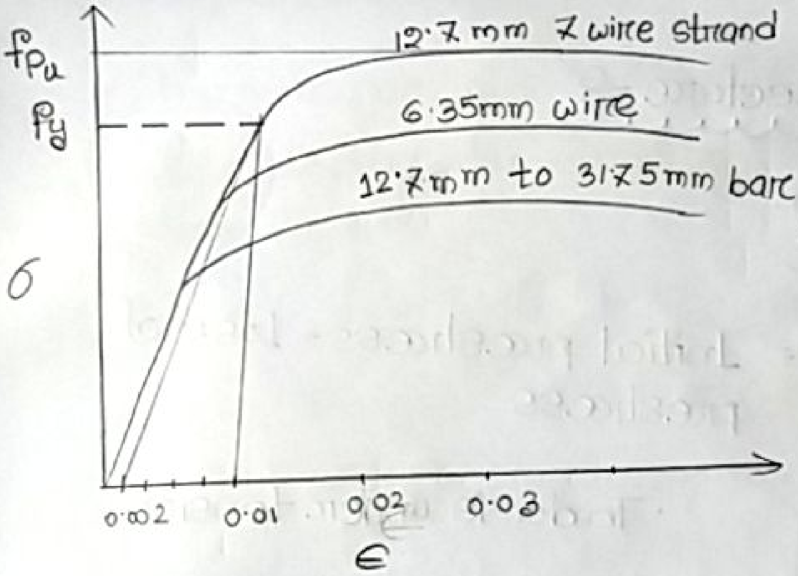


P-54

stress strain curve

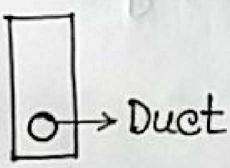
f_{pu} = 1860 MPa (1862 MPa)
= 1720 MPa (1724 MPa)

Q. Why high strength steel?

- Carbon content বাড়ালে strength বাড়ে, কিন্তু % elongation কমে যায়।
- minimum % elongation 12-15% হতেই হবে।
- prestress concrete less ductile compared to RCC.

* যখন কোন material yield show করে না, তখন, use
- set → (0.1%, 0.2%)
- total strain (1%, 0.9%, 1.5%)

☐ Auxiliary materials:
- Grout:



Duct বেশি flexible
হলে buckling হতে পারে।
তাই rigidity প্রয়োজন হয়।

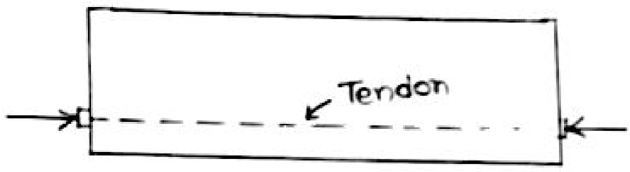
Grout

Anti-shrinkage admixture লাগবে।

Lecture - 8

Loss of Prestress :

- Effective prestress = Initial prestress − Loss of prestress



- Tendon is under tension

- যেকোন কারণে যদি Tension এর জন্য corresponding elongation কমে যায়, তবে যতটুকু elongation কমবে ততটুকু stress loss হয়ে যাবে।

  2" টেনে লম্বা করেছি → 100%

  0.5" shorten → 25% will be reduced of stress

Q. Explain, what are the factors for responsible for loss of prestress.

∴ Tendon এ Tension, but concrete এ 'C'. এরা ২জন bonded. তাই concrete short হয়ে যাওয়ায় Tendon ও short হবে। ফলে loss হবে → Loss due to elastic shortening of concrete.

time independent [
- Loss due to elastic shortening of concrete :
- Loss due to anchorage take up :

- Creep of concrete :] Time dependent
- Shrinkage " " :] সময়ের সাথে সাথে বাড়ে, কিন্তু শেষের দিকে বৃদ্ধি কমে যায়।
- Steel relaxation :] Time dependent

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- Loss or gain due to bending of member:

Bending এর ফলে deformation হয়ে লম্বা হয়ে গেলে member, gain হবে stress.

- Loss due to Friction:

Friction depend করে → length of Tendon [length বাড়লে, friction বাড়ে]

→ Surface function of material

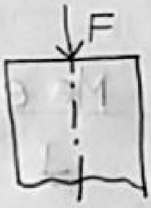
— Curvature effect [Curvature বেশি হলে friction বেশি]

বড় বড় bridge এ ২ side টেনে (একসাথে) Tension দেয়া হয়, তাতে energy কম লাগে।

☐ Loss due to elastic shortening:

Due to the application of F, concrete unit shortening,

$$\epsilon_c = \frac{f_c}{E_c}$$



Let, $e = 0$

$$\therefore \epsilon_c = \frac{F/A}{E_c}$$

$\epsilon_s = \epsilon_c$ (since they are bonded)

$$\therefore \epsilon_s = \epsilon_c = \frac{F}{A E_c}$$

Loss due to elastic shortening $= \Delta f_s = E_s \epsilon_s$

$$= \frac{F}{A} \cdot \frac{E_s}{E_c}$$

$$= \frac{F}{A} \cdot n$$

if $F \to F_i \to$ initial prestress $\to A_t = A_g + (n-1) A_s$

if $F \to F_o =$ Force at transfer $= 0.9 F_i \longrightarrow A_g$

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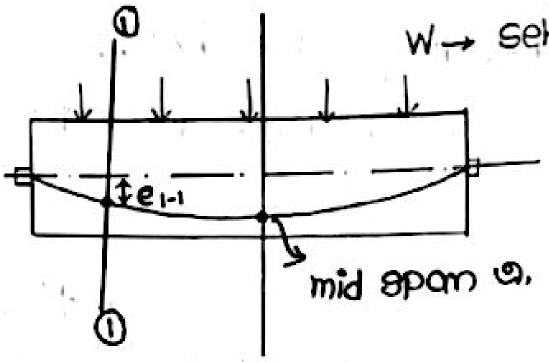


mid span এ, Elastic shortening = Δf_s = ?

$\Delta f_s = n \cdot f_c$

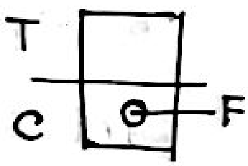
∴ ঐ point এর f_c বের করব। একে বলে f_{cir} = Stress in concrete at c.g.s due to prestress.

- অর্থাৎ f_c বের করতে হবে ঐ point এর।

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

Find $F_{cir} = f_{bottom\ y=e}$ = ?] 'C' = +ve, 'T' = −ve

$$f_{cir} = \frac{F}{A} + \frac{F.e.e}{I} - \frac{M_u.e}{I}$$



∴ $\Delta f_s = n \cdot f_{cir}$

For section ①-①

$$f_{cir} = \frac{F}{A} + \frac{F\, e_{1-1} \cdot e_{1-1}}{I} - \frac{M_{a\,1-1} \cdot e_{1-1}}{I}$$

- যদি simply supported হয়, তবে, $M_a = \frac{wL^2}{8}$

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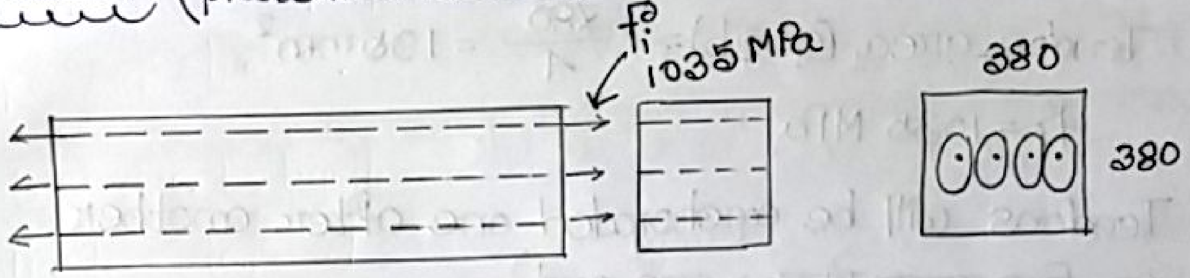
P-93

Problem (pretention member)



$A_{ps} = 780 mm^2$

$n = 6$

$F_i = \underbrace{1035}_{f_i} \times \underbrace{780}_{A} = 807.3 KN$

$$\Delta f_s^o = \frac{nF_i}{A_t} \text{ or } \frac{nF_o}{A_g}$$

$$\Delta f_s^o = \frac{6 \times 807.3 \times 10^3}{380 \times 380 + (6-1) \times 780} = 33 MPa = \frac{nF_i}{A_t}$$

$$\Delta f_s^o = \frac{nF_o}{A_g} = \frac{6 \times (0.9 \times 807.3)}{380 \times 380} = 30 MPa$$

Q. Calculate the stress in steel after the elastic shortening of has taken place.

∴ stress in steel after elastic shortening
$= (1035 - 33)$ or $(1035 - 30)$.

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Problem (Post Tension member) ($e=0$)

Tendon area (each) $= \frac{780}{4} = 195 \, mm^2$

$f_i = 1035$ MPa

Tendons will be anchored one after another
(একদিক থেকে টানব → one end)

- ৪টি Tendon এর elastic shortening এ loss = 0

1	2	3	4	Tendon
0 + (1)	0	0	0	
(+1) ↑	+1	+1		
(+1)	+1			

যখন ৩ নং anchor করা হয়েছে → (+1)

(+1) যখন ২ নং কে anchor করেছি

(+1) → যখন 4 নং anchor করা হয়েছে

$$\Delta f_{s_1} = \frac{\overbrace{(1035 \times 195)}^{F} \times \overset{n}{6} \times 3}{\underbrace{380 \times 380}_{A_g}} = 25.2 \text{ MPa}$$

← ৩ বার loss হয়েছে 1 নং Tendon

$$\Delta f_{s_2} = \frac{2}{3} \times 25.2 = 16.8 \text{ MPa}$$

$$\Delta f_{s_3} = \frac{1}{3} \times 25.2 = 8.4 \text{ MPa}$$

$$\Delta f_{s_4} = 0$$

$$\therefore \Delta f_{s,avg} = \frac{25.2 + 16.8 + 8.4}{4} = 12.6 \text{ MPa}$$

(50% of 1st one)

- অর্থাৎ, $\boxed{\Delta f_{s,avg} = \frac{\Delta f_{s_1}}{2}}$

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- 1st টা anchor করার সময় $f = 1035$ MPa ছিল। যখন 2nd টা anchor করছি তখন আর $f = 1035$ MPa থাকে না, cz loss এর কারণে 1035 কমে যাবে 8.4 MPa পরিমাণ, কিন্তু আমরা প্রতিটা Tendon এর জন্যই $1035 = f$ use করেছি। (এটা একটা) (কারচুপি) !!!

But এটা acceptable.

* Pretension member এ loss বেশি compared to post tension member.

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Lec-9

Time dependent losses:

Loss due to creep of concrete:

Factors affecting creep:

1) Type of concrete
2) " " aggregate
3) Humidity
4) w/c ratio
5) age of concrete at which prestress is applied

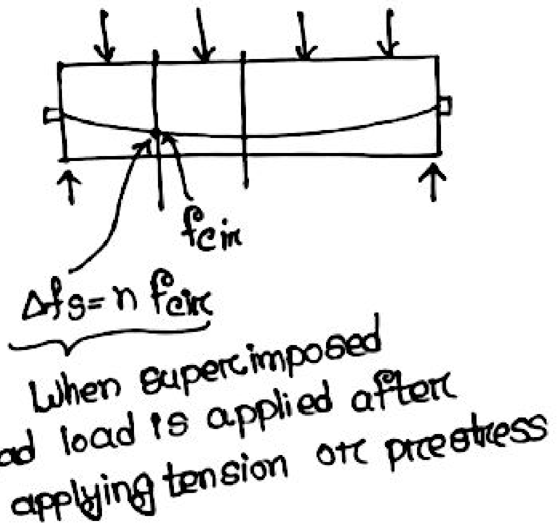
For bonded tendon

$$\text{Loss due to creep (CR)} = K_{cr} \frac{E_s}{E_c} \left[f_{cir} - f_{cds} \right]$$

$K_{cr} = 1.6$ for post tension member
$= 2$ " pretension "

∴ pre-tension member এ creep loss বেশি হয় compared to post tension member.

$f_{cir} \rightarrow$ stress in concrete at c.g.s due to prestress



supercimposed dead load এর জন্য,

$$f_{cds} = \frac{My}{I} = \frac{M_{SIDL} \cdot e}{I}$$

SIDL → Super imposed dead load.

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Loss due to shrinkage:

$$\epsilon_{sh} = 550 \times 10^{-6}\left(1 - 0.06 \frac{Vol^m}{surface}\right)(1.5 - 0.015 \text{ Relative Humidity})$$

∴ surface area বেশি হলে shrinkage বেশি হবে।

- Humidity বেশি হলে shrinkage কম হবে।

$$\epsilon_{sh} = 8.2 \times 10^{-6}\left(1 - 0.06 \frac{V}{S}\right)(100 - RH)$$

$$\Delta f_{SH} = 8.2 \times 10^{-6} K_{sh} E_s \left(1 - 0.06 \frac{V}{S}\right)(100 - RH)$$

K_{sh} = 1.0 (for pretension member)

= depends on time span betn the end of curing and the time of application of prestress (for post tension member)

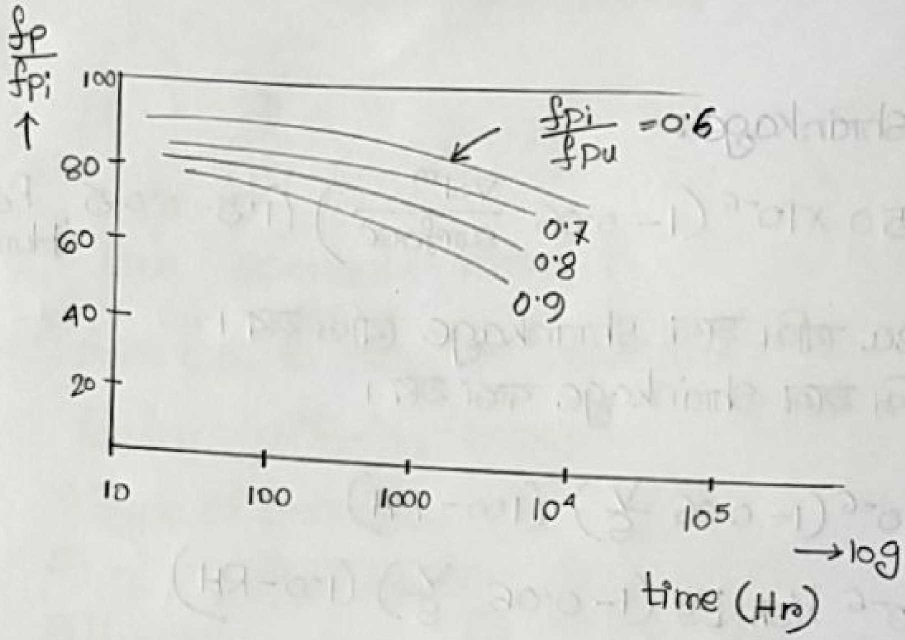
P-101

time	1	3	7	30	60
Ksh	0.92	0.85	0.77	0.58	0.45

∴ পরে টানা ভাল, cz Ksh কমতে থাকে সময়ের সাথে। Ksh কমলে SH ও কমবে।

Steel relaxation:

$$\frac{f_p \text{ (prestress at time } t)}{f_{pi} \text{ (initial prestress applied)}} = 1 - \frac{\log t}{10}\left(\frac{f_{pi}}{f_{pu}} - 0.55\right)$$



- কম prestressing – কম loss, বেশি prestress – বেশি loss

$t_1 \rightarrow$ time of prestressing

$$\therefore \frac{f_p}{f_{pi}} = 1 - \left(\frac{\log t - \log t_1}{10}\right)\left(\frac{f_{pi}}{f_{pu}} - 0.55\right)$$

$t \rightarrow$ এই time এ prestress জানতে চাই (variable)

$\therefore$ Loss $= f_{pi} - f_p$

☐ Loss due to anchorage take up (post tension member)

For

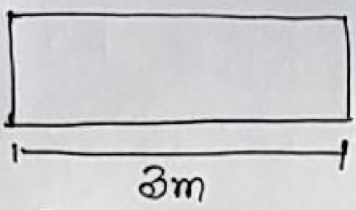
- এই loss টা অ্যাঙ্করনির্ভর হয়।
- 2·5mm slip is allowed

ANC (Loss due to anchorage take up)

$$ANC = \Delta f_s = \frac{\Delta a}{L} E_s$$

Δa = slip = 2·5mm

L = length of member

Q. 

what is ANC ?

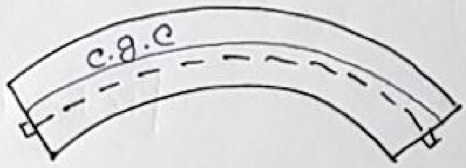
$E_s = 210000$ MPa

$\therefore ANC = \frac{2.5 mm}{3 \times 1000} \times 210000 = 17.5\%$

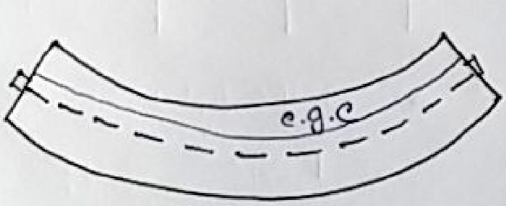
If $L = 30m$, $ANC = \frac{2.5 mm}{30 \times 1000} \times 210 = 1.75\%$

$\therefore$ member Length বাড়লে Loss কমে।

☐ Loss or gain due to bending :



{ span ছোট, member এর S.W কম
Fibre ছোট হচ্ছে, loss.



{ span বড়, member S.W বেশি
Fibre বড় হচ্ছে, তাই gain

$\Delta f_s = n f_c$ at c.g.c

$= n \left[\frac{My}{I} \right]$ (where $y = e$)

× ☐ Frictional loss: Tendon বেশি লম্বা হলে, বেশি frictional loss.
bend বা curvature " হলে, " " " .

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