UNIT-I

PRESTRESSED CONCRETE

UNIT-I

INTRODUCTION

Basic Concepts of prestressing

Prestressed Concrete is basically concrete in which internal stresses of suitable magnitude & distribution are introduced so that the stresses resulting from external loads are Counteracted to a desired degree.

In RC members, the prestress is commonly introduced by tensioning the steel reinforcement

ex: Wooden Wheel construction by force fitting of metal bands and shrink fitting of metal tyres on wooden wheel indicates that art of prestressing has been practiced from ancient times.

Terminology:

→ Tendon: A stretched element used in Concrete member of a structure to impart prestress to the concrete. Generally high-tensile steel wires, bars, cable are used as tendons.

→ Anchorage: A device generally used to enable the tendon to impart & maintain prestress in the concrete.

→ Pretensioning: NOTE: High strength Concrete is necessary in prestressed concrete as it offers high resistance in tension, shear, bond and bearing

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SYSTEMS OF PRESTRESSING.

A system of prestressing means the actual process adopted in making a prestressed beam. A system of prestressing involves the process of tensioning the tendons and securing them firmly to the Concrete. Some of the systems commonly followed are

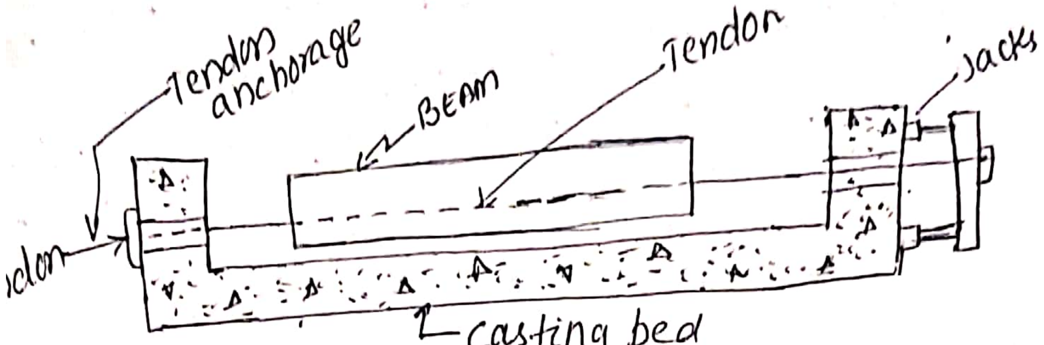
* In this method, the [prestress] is imparted to concrete by bond b/w steel & concrete.

1) Pre-tensioning System (2) post-tensioning System

I. Pretensioning: A method of prestressing concrete in which the tendons are tensioned before the Concrete is placed.

Pretensioning System: In Pretensioning System, the tendons are first tensioned between rigid anchorage blocks cast on ground or a unit mould type pretensioning bed, prior to the casting of concrete in the moulds. The tendons comprising individual wires or strands are stretched with constant eccentricity or variable eccentricity with tendon anchorage at one end and Jacks at the other. With the forms in place, the Concrete is cast around the stressed tendons.

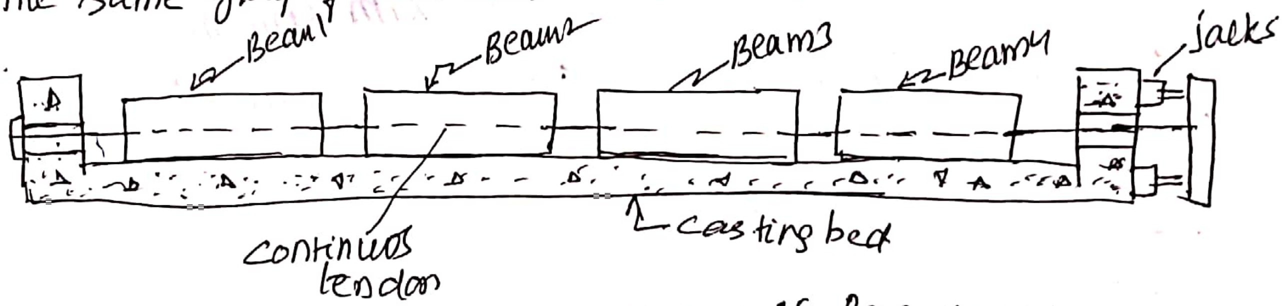
High Early Strength Concrete is often used to facilitate Early Stripping and re-use of moulds. When the Concrete attains sufficient strength, the Jacking pressure is released. The high tensile wires tends to shorten but are checked by the bond b/w Concrete & Steel. In this way the prestress is transfered to the Concrete by bond mostly near the ends of the beam.



Beam with st tendon (PRE-TENSIONING)

For mass production of pretensioned elements, the long line process developed by 'HOYER' is used.

In this method (HOYER SYSTEM) the tendons are stretched b/w two bulk heads several hundred metres apart so that a number of similar units may be cast along the same the same group of tensioned wires.



HOYER'S LONG LINE SYSTEM OF PRETENSIONING

The tension is applied by the hydraulic Jacks or by a movable ~~Machin~~ stressing machine. The tendons when tensioned are anchored to abutments by steel wedges.

The transfer of prestress to concrete is achieved by screw jacks by which all wires (tendon) are simultaneously released after the concrete attains the required compressive strength.

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* Def: Post tensioning: A method of prestressing concrete by tensioning the tendons against hardened concrete. In the method the prestress is imparted to concrete by bearing.

II POST-TENSIONING SYSTEM

Principle:- In post tensioning, the concrete units are are first cast by incorporating ducts or grooves to house the tendons. When concrete attains sufficient strength, the high tensile wires are tensioned by means of jack bearing on the end face of the member and anchored by wedges or nuts. The forces are transmitted to the concrete by means of the end anchorages. and The space between the tendons and the duct is generally grouted after the tensioning operation.

A number of systems of post tensioning is available each protected by patent rights. These systems are adapted for linear prestressing and with some modification for circular prestressing also. Some of the commonly followed systems of post-tensioning are

→ FRESSINET SYSTEM
→ Magnel Blaton System
→ Gifford ~~Udall~~ Udall System
→ Lee-Mccall System

(for details refer: PSC by N. Krishna Raju)

Applications of posttensioning

It is ideally suited for medium to long span insitu work where the tensioning cost is only a small proportion of the cost of the whole job. It may be used with advantage to fabricate large members such as long span bridge decks of the box girder type by prestressing together a number of smaller precast units.

Post tensioning is invariably used for strengthening concrete

Concrete dams, circular prestressing of large concrete tan[ks] and biological shields of nuclear reactors.

Pretensioning

This method is economically adopted in mass product[ion] in factories which make concrete products of limited size. This is so because, handling as well a transporting large produc[ts] are highly expensive and maybe practically impossible if the members are too large.

LOSSES IN PRESTRESS

(1) The initial prestress in concrete undergoes a gradual reduction with time from the stage of transfer due to various causes. This is referred to as "loss of prestress".

Types of losses of prestress:

1) LOSS DUE TO ELASTIC DEFORMATION OF CONCRETE

It depends on the modular ratio and average stress in concrete at the level of steel.

If f_c = prestress in conc. at the level of steel

E_s = modulus of elasticity of steel

E_c = modulus of elasticity of concrete

$\alpha_e = \frac{E_s}{E_c}$ = modular ratio

$E = \frac{\text{stress}}{\text{strain}}$

Strain in concrete at the level of steel $= \frac{f_c}{E_c}$

stress in steel corresponding to this strain $= \left(\frac{f_c}{E_c}\right) E_s$

∴ loss of stress in steel $= \alpha_e \cdot f_c$

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A pretensioned concrete beam 100mm×300mm is prestressed by straight wires carrying an initial force of 150 kN at an eccentricity of 50mm. The modulus of elasticity of steel and concrete are 210 & 35 kN/mm² respectively. Estimate the % loss of stress in steel due to elastic deformation of concrete, if area of steel wires is 188 mm².

sol $P = 150kN$; $e = 50mm$; $A = 3\times10^4 \, mm^2$ & $a = 188mm^2$

$$I = \frac{bd^3}{12} = \frac{100\times300^3}{12} = 225\times10^6 \, mm^4$$

$$\text{Initial stress in steel} = \frac{P}{a} = \frac{150\times10^3}{188} = 800 \, N/mm^2$$

($y = e$ b/c single load)

Stress in Concrete, at the level of steel

$$f_c = \left[\frac{P}{A} + \frac{P.e.y}{I}\right]$$

$$= \left(\frac{150\times10^3}{3\times10^4}\right) + \left(\frac{150\times10^3\times50\times50}{225\times10^6}\right)$$

$$f_c = 6.66 \, N/mm^2$$

∴ loss of stress due to deformation of concrete $= \alpha_e \cdot f_c$

$$= \left(\frac{E_s}{E_c}\right)(f_c)$$

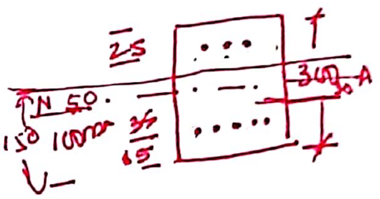
$$= \left(\frac{210}{35}\right)\times 6.66 = 40 \, N/mm^2$$

$$\text{Percentage loss of stress in steel} = \frac{40}{800}\times100 = \underline{\underline{5\%}}$$

*Note: → $\frac{P}{A}$:- Direct stress due to prestress $= P/A$

→ Bending stress " " " $= \frac{P.e}{Z}$ where $Z = I/y$

#2 A rectangular Concrete beam 300mm deep and 200mm Wide is prestressed by means of 15- 5mmϕ wires located at 65mm from the bottom of the beam and 3-5mmϕ Wires located 25mm from the top of the beam. If the wires are initially tensioned to a stress of $840 N/mm^2$, Calculate percentage loss of stress in steel due to elastic deformation of the Concrete only.

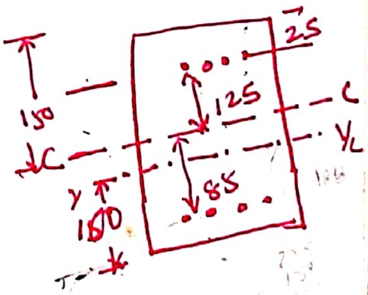


sol $E_s = 210 kN/mm^2$; $E_c = 31.5 kN/mm^2$

position of centroid of the wires from the soffit of beam, bottom

$$y = \left[\frac{(15\times 65) + (3\times \overset{(300-25)}{275})}{(15+3)}\right] = 100mm$$

$\therefore e = \frac{d}{2} - \bar{y} = 150 - 100 = 50mm$



$A_c = 300\times 200 = 6\times 10^4 mm^2$

$I = \frac{200\times 300^3}{12} = 45\times 10^7 mm^4$

Stress x Area

Prestress force $P = 840 \times \frac{18(5)^2}{4} = 300 kN$

Stress at the level of top wires $= \left(\frac{300\times 10^3}{6\times 10^4} - \frac{300\times 10^3 \times 50 \times 125}{45\times 10^7}\right)$ (150-25)

$= 0.83 N/mm^2$.

(150-65)

@ the level of bottom wires $= \left(\frac{300\times 10^3}{6\times 10^4} + \frac{300\times 10^3\times 50\times 85}{45\times 10^7}\right)$

$= 7.85 N/mm^2$

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Modular ratio $\alpha_e = \left(\frac{210}{31.5}\right) = 6.68$

loss of stress in wires @ top $= (6.68 \times 0.83) = 5.55\ N/mm^2$

Loss of stress in wires @ bottom $= (6.68 \times 7.85) = 52.5\ N/mm^2$

% loss of stress

for wires @ top $= \frac{5.55}{840} \times 100 = 0.66\%$

for wires @ bottom $= \frac{52.5}{840} \times 100 = 6.25\%$

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2) LOSS DUE TO SHRINKAGE OF CONCRETE

The shrinkage of concrete in prestressed members results ~~results~~ in the shortening of tensioned wires and hence contributes to the loss of stress.

The shrinkage of concrete is influenced by the type of cement and aggregates and the method of curing used. use of High strength concrete with low w/c ratios results in a reduction in shrinkage and consequent loss of prestress.

* proper curing is reqd in PS members to prevent shrinkage

In case of pretensioned members generally moist curing ~~curing~~ is resorted to in order to prevent shrinkage until the ~~the~~ time of transfer. Consequently, the total residual shrinkage strain will be large in pretensioned members in comparison with post-tensioned members.

As per IS:1343, Loss of prestress due to shrinkage of concrete is given by

ϵ_{cs} = total residual strain

total residual strain $\epsilon_{cs} = 300\times10^{-6}$ for pretensioning

$$= \left[\frac{200\times10^{-6}}{\log_{10}(t+2)}\right] \text{ for post-tensioning where}$$

t = age of concrete at transfer in days

$\therefore$ loss of stress $= \epsilon_{cs}\times E_s$

\# A conc. beam is prestressed by a cable carrying an initial prestressing force of 300 kN. The c/s area of wires in the cable is 300 mm². Calculate the percentage loss of stress only due to the shrinkage of concrete using IS1343 recommendations for the beam

(a) Pretensioned (b) post-tensioned. Assume $E_s = 210 kN/mm^2$ and the age of conc. @ transfer = 8 days.

Sol

initial stress $p_i = \frac{P}{A} = \frac{300 \times 10^3}{300} = 1000 N/mm^2$

(a) $e_{cs} = 3 \times 10^{-6}$

Loss of prestress $= 300 \times 10^{-6} \times 210 \times 10^3 = 63 N/mm^2$

$\therefore$ % loss $= \frac{63}{1000} \times 100 = 6.3\%$

(b) $\varepsilon_{cs} = \left[\frac{200 \times 10^{-6}}{\log_{10}(t+2)}\right] = \left[\frac{200 \times 10^{-6}}{\log_{10}(8+2)}\right] = 200 \times 10^{-6}$

$\therefore$ loss of stress $= 200 \times 10^{-6} \times 210 \times 10^3 = 42 N/mm^2$

$\therefore$ % loss $= \frac{42}{1000} \times 100 = 4.2\%$

Note: creep means deformation under sustained load

3. LOSS DUE TO CREEP OF CONCRETE

The sustained prestress in the concrete of a prestressed member results in creep of concrete which effectively reduces the stress in high tensile steel.

The loss of stress in steel due to creep of concrete can be estimated if the magnitude of ultimate creep strain or creep coefficient is known

I Ultimate creep strain method

If ε_{cc} = Ultimate creep strain for a sustained unit stress

f_c = compressive stress in conc. @ the level of steel

E_s = modulus of elasticity of steel

Then loss of stress in steel due to creep of concrete $= \varepsilon_{cc} \cdot f_c \cdot E_s$

CREEP COEFFICIENT METHOD (IS 1343-1980)

If ϕ = Creep Coefficient
ε_c = Creep Strain
ε_e = elastic strain
α_e = modular ratio
f_c = stress in Concrete
E_c = modulus of Elasticity of Concrete
E_s = modulus of elasticity of steel.

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Creep coefficient $= \left(\dfrac{\text{creep strain}}{\text{elastic strain}}\right) \therefore \phi = \left(\dfrac{\varepsilon_c}{\varepsilon_e}\right)$

$\therefore \varepsilon_c = \phi \cdot \varepsilon_e = \phi\left(\dfrac{f_c}{E_c}\right)$

$\therefore$ loss of stress $= \varepsilon_c \cdot E_s = \phi\left(\dfrac{f_c}{E_c}\right) \cdot E_s = \phi \cdot f_c \cdot \alpha_e$

A concrete beam of rectangular cs 100mm wide & 300mm deep is prestressed by 5 wires of 7mm dia. located at an eccentricity of 50mm, the initial stress in the wires being 1200 N/mm². Estimate the loss of stress in steel due to creep of concrete using the ultimate creep strain method & creep coeff method. use the given data: $E_s = 210\,kN/mm^2$, $E_c = 35\,kN/mm^2$

Sol

$A = 3\times10^4\,mm^2$; $P = 5\times38.5\times1200 = 23\times10^4\,N$

$\alpha_e = \dfrac{E_s}{E_c} = \dfrac{210}{35} = 6$; Creep coeff $= 1.6$ from IS 1343 for pre-ten

$I = 225\times10^6\,mm^4$, $\varepsilon_{cc} = 41\times10^{-6}$ mm/mm per N/mm²

Stress in conc. @ the level of steel $= \left[\dfrac{P}{A} + \dfrac{Pe \cdot y}{I}\right]$

$= \left[\dfrac{23\times10^4}{3\times10^4} + \dfrac{(23\times10^4\times50)\cdot50}{225\times10^6}\right] = 10.2\,N/mm^2$

I Ultimate creep strain method

Loss of stress in steel = $\varepsilon_{cc} \cdot f_c \cdot E_s$

$= (41 \times 10^{-6} \times 10.2 \times 210 \times 10^3)$

$= 88 \, N/mm^2$

% loss = 88%

II Creep coeff - Method

Loss of stress in steel = $\phi \cdot f_c \cdot \alpha_e$

$= (1.6 \times 10.2 \times 6)$

$= 97.92 \, N/mm^2$

4) LOSS OF STRESS DUE TO RELAXATION OF STRESS IN STEEL

The IS code recommends a value varying from 0 to 90 N/mm² for stress in wires varying from $0.5 f_{pu}$ to $0.8 f_{pu}$.

5) LOSS OF STRESS DUE TO FRICTION

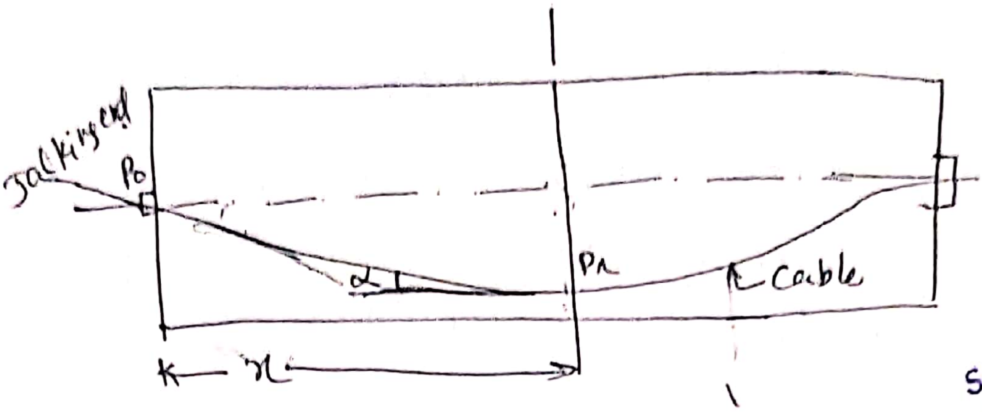
The magnitude of this loss is of the following two types.

@ losses of stress due to curvature effect which depends on the tendon alignment

(B) loss of stress due to the wobble or wave effect (unavoidable misalignment).

The magnitude of prestressing force, P_x at a distance 'x' from the tensioning end is given by

$$P_x = P_0 e^{-(\mu\alpha + kx)}$$



Where P_0 = Ps force at the Jacking end
μ = coeff. of friction b/w cable & duct
α = angle in radians through which tangent of the cable has turned
K = friction coeff. for wave effect
$e = 2.7183$

As per IS, values for μ are selected according to steel movement
and K values.

Generally

(b) LOSS OF STRESS DUE TO ANCHORAGE SLIP

In post tensioning systems, when the cable is tensioned and the Jack is released to transfer prestress to concrete, the friction wedges employed to grip wires, slips over a small distance. The magnitude of slip depends on the type of wedge and magnitude of stress in the wires.

This loss is computed as follows $\Delta = \left[\frac{PL}{AE_s}\right]$

$$\Rightarrow \left[\frac{P}{A}\right] = \frac{E_s \cdot \Delta}{L}$$

Where Δ = slip of anchorage, mm
L = length of cable = mm
A = c/s area of cable = mm²
E_s = modulus of Elasticity, N/mm²
P = Prestressing force in the cable, N.

This % of loss is higher for short members than for longer members. It forms a major portio of the total loss. Hence due care must be given while prestressing a short member.

A conc. beam is post-tensioned by a cable carrying an initial stress of 1000 N/mm². The slip at the jacking end was observed to be 5mm (Δ). $E_s = \cancel{210\ N/mm^2}$ 210 kN/mm². Estimate the percentage loss of stress due to anchorage slip if the length of the beam is ⓐ 30m ⓑ 3m

ⓐ 30m. Loss of stress $= \frac{E_s \Delta}{L}$

$$= \frac{210 \times 5 \times 10^3}{30 \times 1000} = 35\ N/mm^2$$

$$\%\ \text{loss} = \frac{35}{1000} \times 100 = 3.5\%$$

ⓑ 3m; loss of stress $= \frac{E_s \Delta}{L}$

$$= \frac{\cancel{210}^{70} \times 10^3 \times 5}{\cancel{3} \times 1000} = 350\ N/mm^2$$

$$\therefore \%\ \text{Loss} = \frac{350}{1000} \times 100 = 35\%$$

* TOTAL LOSSES ALLOWED IN A DESIGN

A pretensioned beam 200mm wide and 300mm deep is prestressed by 10 wires of 7mm ϕ initially stressed to 1200N/mm² with their centroid located 100mm from the soffit. Find the max. stress in concrete immediately after transfer, allowing only for shortening of concrete.

(ii) If the concrete undergoes a further shortening due to creep and shrinkage while there is a relaxation of 5% of steel stress, estimate the final percentage loss of stress in the wires using the IS code regulations and the following data

$E_s = 210 kN/mm^2$; $E_c = 5700 (f_{cu})^{1/2}$; $f_{cu} = 42 N/mm^2$

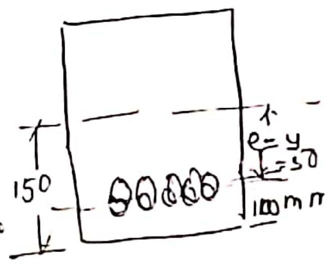
Creep coeff (ϕ) = 1.6 ; Total residual shrinkage strain $\epsilon_{cs} = 3\times10^{-4}$

Sol

$A_c = 200 \times 300 = 6\times10^4 mm^2$

$E_c = 5700(42)^{1/2} = 36,900 N/mm^2$

$I = \frac{200\times300^3}{12} = 45\times10^7 mm^4$



$\alpha_e = \frac{E_s}{E_c} = \frac{210\times10^3}{36,900} = 5.7$; $e = \frac{d}{2} - y = 150 - 100 = 50$

$P = 1200 \times 10 \times \frac{\pi (7)^2}{4} = 462\times10^3 N = 462 kN$

$e = y$

Stress in concrete at the level of steel

$$f_c = \left[\frac{462\times10^3}{6\times10^4} + \frac{462\times10^3 \times 50\times50}{45\times10^7}\right] = 10.3 N/mm^2$$

$\left(\frac{P}{A} + \frac{Pe \cdot y}{I}\right)$

(i) Loss due to elastic deformation of concrete (shortening)

$= \alpha_e \cdot f_c = 5.7 \times 10.3 = \underline{58.8 N/mm^2}$

P_i

$\frac{\pi 7^2}{4}$

* Forces in wires immediately after transfer $= (1200 - 58.8)\, 38.5\times10$

$= 4,410\times10^3 N$

Stress in concrete at the level of Steel

(i) $f_c = \left[\frac{440\times10^3}{6\times10^4} + \frac{440\times10^3\times50\times50}{45\times10^7}\right] = \underline{9.78\ N/mm^2}$

Types of losses of prestress

1. Elastic deformation = 58.8 N/mm²
2. Creep of Concrete $(1.6\times9.78\times5.7)$ = 89.2 N/mm²
3. Shrinkage of Concrete $(3\times10^{-4}\times210\times10^3)$ = 63.0 N/mm²
4. Relaxation of Stress in Steel $\frac{5}{100}\times1200$ = 60.0 N/mm

Total Loss = 271.0 N/mm²

Final Stress in wires = (1200 − 271) = 929 N/mm²

% of Loss = $\left(\frac{271}{1200}\times100\right)$ = 22.58%

A PSC beam 200 × 300 mm is prestressed with wires (area = 320mm²) located at const eccentricity of 50mm and carrying an initial stress of 1000 N/mm². The span of beam is 10m. Calculate the percentage loss of stress in wires if (a) the beam is pre tensioned and (b) the beam is post-tensioned using the following data

E_s = 210 kN/mm² ; E_c = 35 kN/mm²

Relaxation of stress in steel = 5% of initial stress

Shrinkage of Concrete = 300×10^{-6} for pretensioning
200×10^{-6} for post tensioning

Creep coeff: ϕ = 1.6

Slip at anchorage = 1mm

frictional coeff. for wave effect μ = 0.0015 per m

(see back)

DESIGN OF PRESTRESSED CONCRETE SECTION

Design of sections for FLEXURE (BM)

Minimum Section modulus

prestressed sections under the action of flexure (or) should satisfy the limits specified for permissible stresses at the stage of transfer of prestress and at service loads.

Expressions for the min. section moduli required, PS force and the corresponding eccentricity are developed using the four stress relationships established for the two extreme fibres of the section and considering the two critical combinations of prestress and moments.

The general combinations considered are:

1) The max. prestressing force at transfer together with the min. moments sustained by the section and

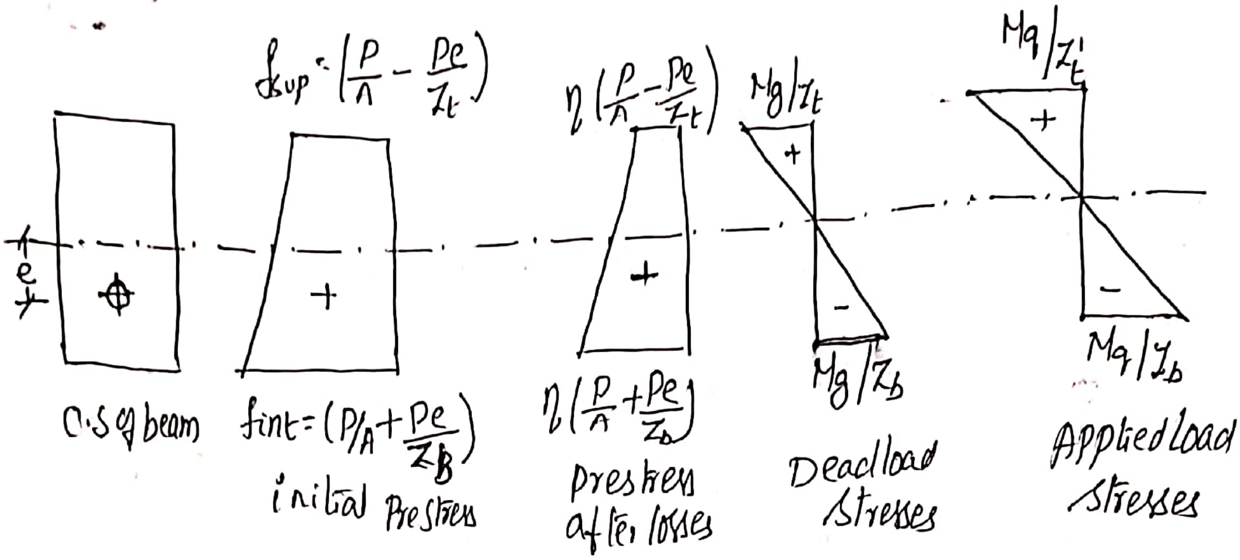
2) The min PS force after all losses in combination with the max design moment for the serviceability limit state

* The four fundamental conditions for stresses at transfer and service loads are as follows:

At tranfer

Top fibres $\left(f_{top} + \frac{M_g}{Z_t} \right) \geq f_{tt}$ — ①

Bottom fibres $\left(f_{bot} - \frac{M_g}{Z_b} \right) \leq f_{ct}$ — ②



Stresses due to Prestress, D.L & applied load

At working load

Top fibres $\left[\eta f_{top} + \frac{M_g}{Z_t} + \frac{M_q}{Z_t}\right] \leq f_{cw}$ — (3)

bottom fibres $\left[\eta f_{bot} - \frac{M_g}{Z_b} - \frac{M_q}{Z_t}\right] \geq f_{tw}$ — (4)

From (1) & (3), we have $\qquad \eta$ = loss ratio

$$\left[\frac{M_q + (1-\eta) M_g}{Z_t}\right] \leq (f_{cw} - \eta f_{tr}) \leq f_{tr}$$

Similarly from (2) & (4), we have

$$\left[\frac{M_q + (1-\eta) M_g}{Z_b}\right] \leq (\eta f_{ct} - f_{tw}) \leq f_{br}$$

Where f_{tr} & f_{br} are the ranges of stress at top & bottom fibres respectively. Hence the design formulae for the required section moduli are

$$Z_t \geq \left[\frac{M_q + (1-\eta) M_g}{f_{tr}}\right] \quad \text{— 5a}$$

$$Z_b \geq \left[\frac{M_q + (1-\eta) M_g}{f_{br}}\right] \quad \text{— 6b}$$

In cases where dead loads in addition to the self wt. acts on a member, these eqns are modified and used as below

$$Z_t \geq \left[\frac{(M_q + M_g) - \eta M_{min}}{f_{tr}} \right] \quad \text{—} \quad \cancel{(5a)}$$

$$Z_t \geq \left[\frac{M_d - \eta M_{min}}{f_{tr}} \right] \quad \text{—} \quad (5a)$$

$$Z_b \geq \left[\frac{M_d - \eta M_{min}}{f_{br}} \right] \quad \text{—} \quad (6b)$$

where M_d = self wt + Permanent DL + LL

M_{min} = Min. moment due to self wt of the member

Prestressing FORCE

Generally the section selected is somewhat greater than the min. given by eqn (5) & (6) and consequently the prestress can lie b/w an upper & lower limit. Any value of the prestress with in these limits may be safely used without exceeding the permissible stresses at the extreme fibres. However the minimum prestressing force required will be obtained by selecting the max. tensile prestress given by eqn (1) at the top fibre and min comp prestr given by eqn (4) corresponding to bottom fibre.

Rearranging these eqns

f_{tt} = @ transfer tensile force

$$f_{sup} \geq \left(f_{tt} - \frac{M_g}{Z_t} \right) \quad \text{—} \quad (7)$$

$$f_{inf} \geq \left[f_{tw} + \frac{(M_q + M_g)}{\eta Z_b} \right] \quad \text{—} \quad (8)$$

Z_t & Z_b corresponds to the actual values of the selection selected.

Eliminating e from the eqns

$$f_{sup} = \left(\frac{P}{A} - \frac{P.e}{Z_t}\right) \text{ \& } f_{inf} = \left(\frac{P}{A} + \frac{P.e}{Z_b}\right)$$

∴ Min. Prest. force = $P = \frac{A(f_{inf} Z_b + f_{sup} \cdot Z_t)}{(Z_t + Z_b)}$

Similarly, eliminating P, from the equations, the corresponding max. eccentricity is given by

$$e = \frac{Z_t \cdot Z_b (f_{inf} - f_{sup})}{A(f_{sup} Z_t + f_{inf} Z_b)}$$

A post tensioned prestress beam of rectangular section 250mm wide is to be designed for an imposed load of 12 kN/m, uniformly distributed on a span of 12m. The stress in the concrete must not exceed 17 N/mm² in compression or 1.4 N/mm² in tension at any time and the loss of prestress may be assumed to be 15 percent, calculate

@ the min. possible depth of beam

b) for the section provided, the min. pos force and the corresponding eccentricity.

Sol/ Imposed load, $q = 12$ kN/m ; $\eta = 100 - 15 = 85\% : 0.85$

$b = 250$ mm ; $f_{ct} = f_{cw} = 14$ N/mm² ; $l = 12$m

$h = d$ mm ; $f_{tt} = f_{tw} = -1.4$ N/mm²

Live load Moment $M_q = \left(\frac{12 \times 12^2}{8}\right) = 216$ kN-m

$\times$

Dead load moment $M_g = \left[\frac{(bd) \times 24 \times 12^2}{10^6 \times 8}\right] = \frac{432\,bd}{10^6}$ kNm

$= 432\,bd$ N-mm

Range of stress at bottom fibre

$f_{br} = (\eta f_{ct} \; f_{tw})$

$= (0.85 \times 17 - (-1.4)) = 15.85\,N/mm^2$

@ Min Sec. modulus is given by

$$Z_b = \left[\frac{M_q + (1-\eta) M_g}{f_{br}}\right]$$

$$\frac{bd^2}{6} = \left[\frac{218 \times 10^6 + (1-0.85)(432\,bd)}{15.85}\right]$$

$b = 250mm$ on simplifying we get

$\underline{\underline{d = 580mm}}$

(b) Section provided $b = 250mm$; $d = 580mm$

$\Rightarrow A = 145 \times 10^3 mm^2$

$Z_b = Z_t = 14 \times 10^6 mm^3 \;\left(\frac{bd^2}{6}\right)$

Self wt Moment $M_g = 432 \times b \times h = 62.5 \times 10^5$ N-mm

$(M_q + M_g) = 2785 \times 10^5$ N-mm.

$$f_{sup} = \left(f_{tt} - \frac{M_g}{Z_t}\right) = \left[-1.4 - \frac{625 \times 10^5}{14 \times 10^6}\right] = -5.9\,N/mm^2$$

$$f_{inf} = \left[\frac{f_{tw}}{\eta} + \frac{(M_q + M_g)}{\eta Z_b}\right] = \left[\frac{-1.4}{0.85} + \frac{2785 \times 10^5}{14 \times 10^6 \times 0.85}\right] = 22\,N/mm^2$$

∴ Min. PS force is given by

$$P = \left[\frac{A(f_{inf} Z_b + f_{sup} Z_t)}{Z_b + Z_t}\right] = \left[\frac{145 \times 10^3 (22 - 5.9) 14 \times 10^6}{28 \times 10^6}\right]$$

$$P = \underline{\underline{1170 kN}}$$

Corresponding eccentricity is given by

$$e = \left[\frac{Z_t Z_b (f_{inf} - f_{sup})}{A(f_{sup} Z_t + f_{inf} Z_b)}\right] = \left[\frac{(14 \times 10^6)^2 \times \{22 - (-5.9)\}}{145 \times 10^3 (22 - 5.9) 14 \times 10^6}\right]$$

$$e = 167.5 mm$$

Q2. A PS road bridge of span 10m consists of a concrete slab 380mm thick with parallel post tensioned cables, in ~~which~~ each of which the force of transfer is 360kN. If the bridge is required to support an uniformly distributed applied load of 25kN/m², with the tensile stress in concrete not exceeding 0.7N/mm² at anytime, calculate the max. horizontal spacing of cables, their distance from the soffit of the slab at mid span and their lowest possible positions at the supports. Assume 20% loss of prestress after transfer.

sol

considering 1m ~~str~~ width of slab

$$A = (1000 \times 380) = 38 \times 10^4 \, mm^2$$

$$I = \frac{1000 \times 380^3}{12} = 455 \times 10^7 \, mm^4$$

$$Z = Z_b = Z_t = \frac{I}{d/2} = \left[\frac{455 \times 10^7}{190}\right] = 24 \times 10^6 \, mm^3$$

self wt of slab $= \cancel{1000}(0.38 \times 1 \times 1 \times 24) = 9.1 \, kN/m$

$$M_g = \left[\frac{9.1 \times 10^2}{8}\right] = 113.7 \, kN\text{-}m$$

$$\frac{M_g}{Z} = \left[\frac{113.7 \times 10^6}{24 \times 10^6}\right] = 4.72 \, N/mm^2$$

$$M_q = \left[\frac{25 \times 10^2}{8}\right] = 312.5 \, kN.m$$

$$\frac{M_q}{Z} = \left[\frac{312.5 \times 10^6}{24 \times 10^6}\right] = 13 \, N/mm^2$$

if P = initial PS force & e = eccentricity, the limiting stress conditions are

$$\left(\frac{P}{A} - \frac{Pe}{Z_t}\right) + \frac{M_g}{Z_t} = -0.7$$

$$\left(\frac{P}{A} - \frac{Pe}{Z_t}\right) + 4.72 - 0.7$$

Also $\eta\left(\frac{P}{A} + \frac{Pe}{Z}\right) - \frac{M_g}{Z_b} - \frac{M_q}{Z_b} = -0.7$

$$0.8\left(\frac{P}{A} + \frac{Pe}{Z}\right) - 4.72 - 13.0 = -0.7$$

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Solving these eqns

$P = 3000 \times 10^3 N$

$e = 106.5$ mm

∴ Distance of cable from soffit at centre (mid point)

$= (190 - 106.5) = 83.5$ mm

Force/cable = 360 kN

∴ Spacing of cables $= \left(\frac{1000 \times 360}{3000}\right) = 120$ mm

Lowest possible position of cable at support is given by $(P/A - Pe/Z) = -0.7$

$$3000 \times 10^3 \left[\frac{1}{38 \times 10^4} - \frac{e}{24 \times 10^6}\right] = -0.7$$

$\Rightarrow e = 69$ mm

Distance of cable from soffit (@ support) $= (190 - 69)$
$= 121$ mm.

#3 × A PSC beam has a symmetrical I section in which the depth of each flange is 1/5th of overall depth and the Web is thin enough to be neglected in bending calculation. At the point of max. BM, the PS Force is located at the Centre of the bottom flange and the Total loss of prestress is 20%. Show that the deadload must be atleast one-seventh of the L.L.

(Not reqd)

Sol over all depth = h ; Thickness of flange = 0.2h
Breadth of flange = b
Assuming b = 1 unit

#4. A pre-tensioned beam, 80mm wide and 120mm deep, is to be designed to support working loads of 4 kN, each concentrated at the third points over a span of 3m. If the permissible stresses in tension are zero at transfer and 1.4 N/mm² under working loads, design the no. of 3mm wires and the corresponding eccentricity required at the mid span section. Permissible tensile stress in wires is 1400 N/mm². The loss of prestress is 20% and the density of concrete is 24 kN/m³.

Sol: self wt of beam $g = (0.08 \times 0.12 \times 24) = 0.23\,kN/m$

section Modulus $Z_b = Z_t = \frac{bd^2}{6} = \frac{80 \times 120^2}{6} = 192 \times 10^3\,mm^3$

Self weight moment $= M_g = \frac{(0.23 \times 3^2)}{8} = 0.26\,kN\text{-}m$

LL moment $= M_q = (4 \times 1) = 4\,kN\text{-}m$

Per. stresses, $f_{tt} = 0$; $f_{tw} = -1.4\,N/mm^2$

tens. stress @ trans; tens stress @ work load

$A = 80 \times 120 = 9600\,mm^2$

Reqd prestress at bottom and top fibres is given by

$$(bot)\ f_{inf} = \left[\frac{f_{tw}}{\eta} + \frac{(M_q + M_g)}{\eta Z_b}\right] = \left[\frac{-1.4}{0.8} + \frac{(0.26+4) \times 10^6}{0.8 \times 192 \times 10^3}\right]$$

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$$\therefore f_{inf} = 26.00\,N/mm^2$$

$$(top)\ f_{sup} = \left[f_{tt} - \frac{M_g}{Z_t}\right] = \left[0 - \frac{0.26 \times 10^6}{192 \times 10^3}\right] = -1.35\,N/mm^2$$

* Min. prestress force 'P' is obtained by the Expression

$$P = \left[\frac{A(f_{inf} Z_b + f_{sup} \cdot Z_t)}{Z_b + Z_t}\right] = \left[\frac{9600(26 \times 192 \times 10^3 - 1.35 \times 192 \times 10^3)}{2 \times 192 \times 10^3}\right]$$

$$\boxed{P = 120785\,N = 120.78\,kN \simeq 121\,kN}$$

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corresponding eccentricity is given by

$$e = \frac{Z_b \cdot Z_t (f_{inf} - f_{sup})}{A [f_{sup} Z_t + f_{inf} Z_b]}$$

$$= \frac{192 \times 10^3 \times 192 \times 10^3 (26 - (-1.35))}{9600 (26 \times 192 \times 10^3 - 1.35 \times 192 \times 10^3)}$$

$$\boxed{e = 22mm}$$

Area of 3mm wire $= \frac{\pi (3)^2}{4} = 7.05 mm^2$

Safe force in each wire $= 1400 \times 7.05 = 9870N$

$\therefore$ No. of wire $= \frac{P}{\text{safe force in each}} = \frac{21 \times 10^3}{9870} = 12.3 \sim 13$ ans

UNIT-II

ps of

ANALYSIS OF PSC BEAMS

Analysis of stresses in a psc beam (memb) is based on the following assumption:

→ Concrete is homogeneous elastic material

→ Within the limits of working stress, both concrete and steel behave elastically.

→ Plane section before bending is assumed to remain plane even after bending. (i.e strain distribution is linear across the depth of the member)

Resultant Stresses

The stresses due to prestressing alone are generally combined stresses due to the action of direct load and bending resulting from an eccentrically applied loads.

Following notation are used for the analysis of PS

P = ps force (+ve if comp)

e = eccentricity of PS force

$M = P.e$ = moment ; A = c/s area of the conc. memb.

I = M.I

Z_t & Z_b = section modulus of the top & bottom fibres

f_t & f_b = ps in concrete developed at top & bottom fibre (+ve when comp & −ve when tensile in nature)

y_t & y_b = distances of the top & bottom fibre from the centroid of the section

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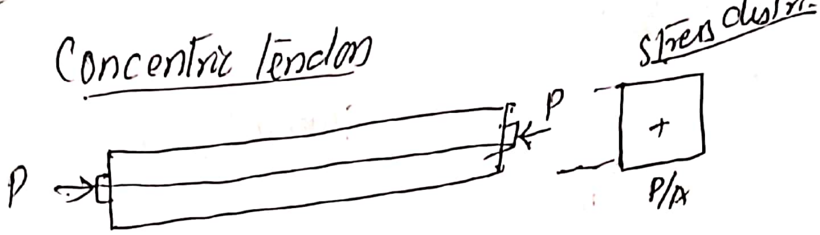
Case I

Concentric tendon



Case II Eccentric tendon

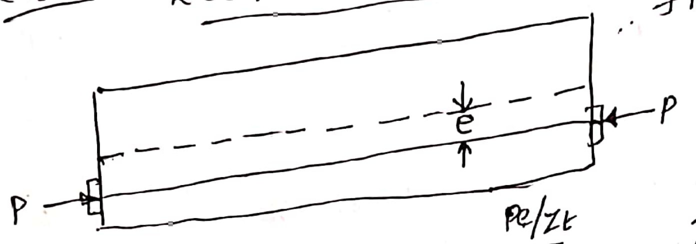
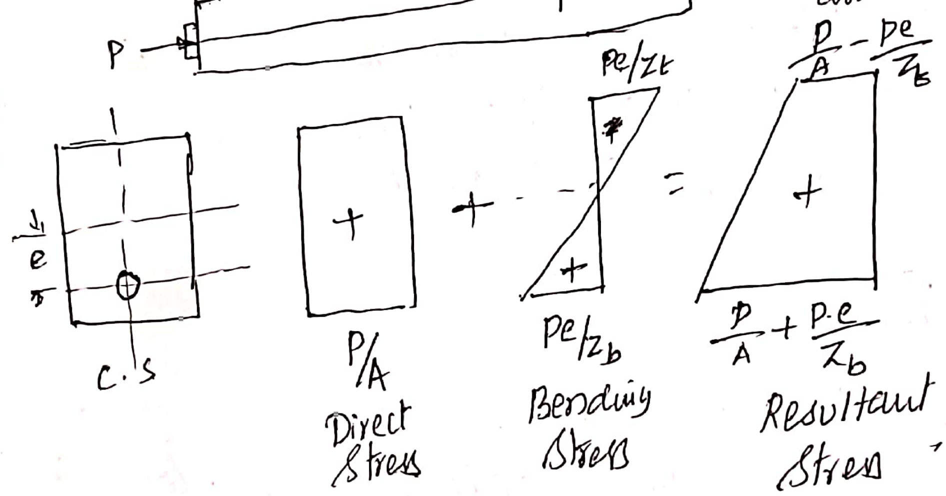
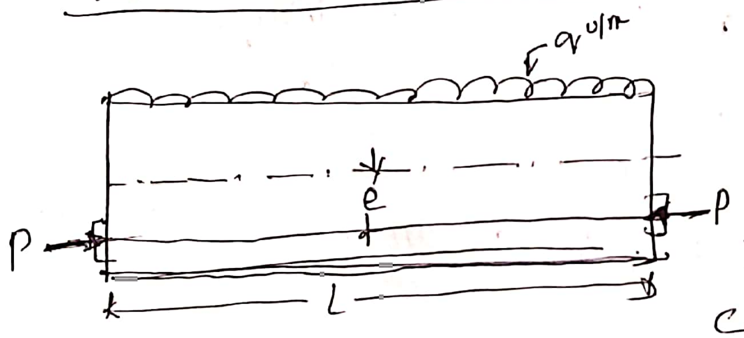


fig: shows a conc. beam subjected to an eccentric PS force 'P' located at an eccentricity of 'e'.



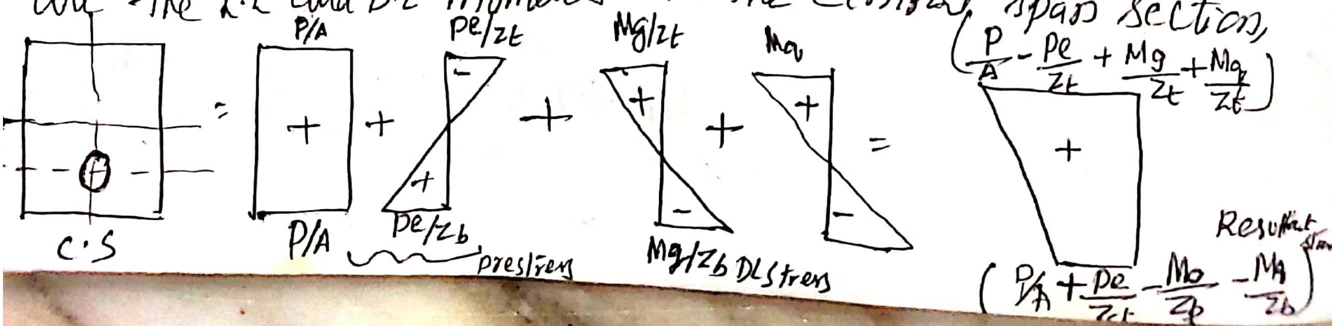
Resultant Stresses at a Section



D.L intensity = g $M_g = \frac{gl^2}{8}$

L.L intensity = q $M_q = \frac{ql^2}{8}$

The resultant stresses in concrete at any section are obtained by superimposing the effect of prestress and flexural stress (q,g) developed due to loads. If M_q & M_g are the L.L and D.L moments at the central span section,



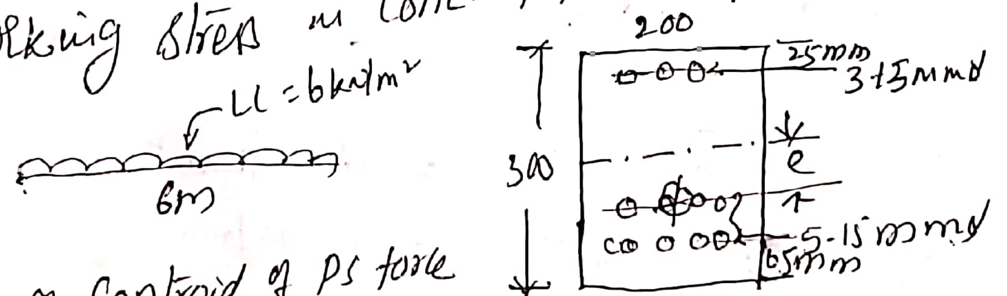
The resultant stresses at top & bottom fibres of concrete at any given section are obtained as

$$f_{top} = \left(\frac{P}{A} - \frac{Pe}{Z_t}\right) + \left[\frac{M_g}{Z_t} + \frac{M_q}{Z_t}\right]$$

$$f_{bott} = \left[\frac{P}{A} + \frac{Pe}{Z_b}\right] - \left[\frac{M_g}{Z_b}\right] - \left[\frac{M_q}{Z_b}\right]$$

A rect. conc. beam of c/s 300mm deep and 200mm wide is prestressed by means of 15 wires of 5mm ø located 6.5cm from bottom of the beam and 3-5mm ø at 2.5cm from top. Assuming the Ps in stress as 840N/mm², calculate the stresses at the Extreme fibres of the mid span section when the beam is supporting its own weight over a span of 6m. If a u.d.l. of 6kN/m is imposed, Evaluate the max working stress in conc. Take density of conc = 24kN/m³

Sol



Dist. of centroid of Ps force from base

$$y = \left[\frac{(15\times65) + (3\times275)}{18}\right] = 100mm.$$

$$e = 150 - 100 = 50mm.$$

$$P = 840 \times 18 \frac{\pi(5)^2}{4} = 3\times10^3\ kN$$

$$A = 300\times200 = 60\times10^3\ mm^2$$

$$I = \left[\frac{200\times300^3}{12}\right] = 45\times10^7\ mm^4$$

$$Z_t = Z_b = \frac{I}{d/2} = \frac{45\times10^7}{150} = 3\times10^6\ mm^3$$

Self wt of beam $= 0.3 \times 0.2 \times 24 = 1.44$ kN/m

$\therefore$ Self wt BM $M_g = \frac{1.44 \times 6^2}{8} = 6.48$ kN-m

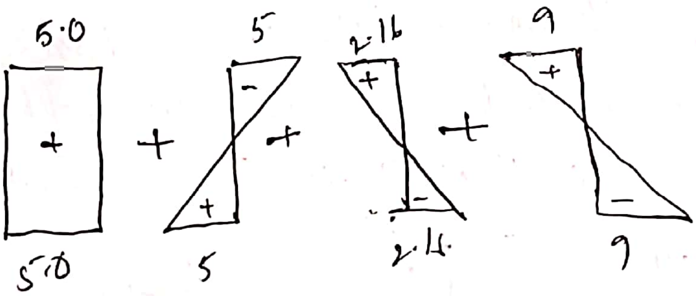
LL moment $M_q = \frac{6 \times 6^2}{8} = 27$ kN-m

Direct Stress $= \frac{P}{A} = \frac{3 \times 10^5}{6 \times 10^4} = 5$ N/mm^2

Bending Stress due to e $= \frac{P.e}{Z} = \frac{3 \times 10^5 \times 50}{3 \times 10^6} = 5$ N/mm^2

Self wt Stress $= \frac{M_g}{Z} = \frac{6.48 \times 10^6}{3 \times 10^6} = 2.16$ N/mm^2

L.L Stress $= \frac{M_q}{Z} = \frac{27 \times 10^6}{3 \times 10^6} = 9$ N/mm^2



$\therefore f_{top} = 5 - 5 + 2.16 + 9 = 11.16$ N/mm^2

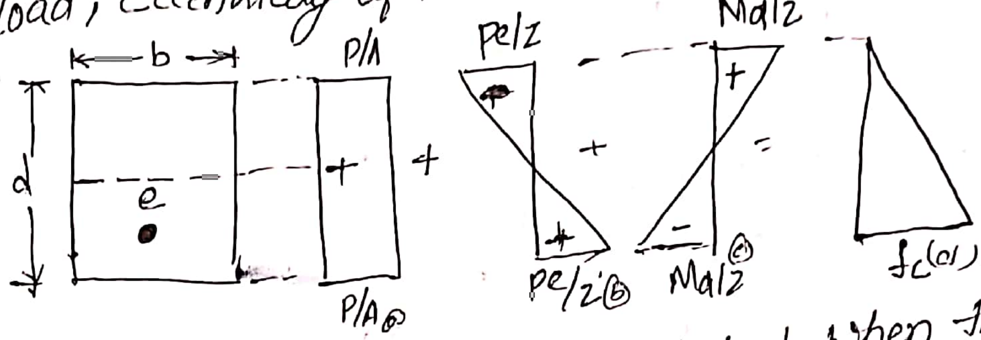
$f_{bot} = 5 + 5 - 2.16 - 9 = -1.6$ N/mm^2

$\therefore$ Max. working Stress $= 11.16$ N/mm^2

PRESSURE LINE (OR) THRUST LINE :-

DESIGN OF PSCB

Let the effective total prestress be P at an eccentricity of e. Let Md be the max BM due to DL alone. The stresses due to direct load, eccentricity of Ps and due to DL moment are shown below



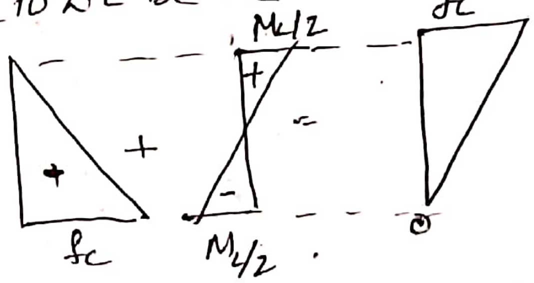
The beam should be so designed that when the LL has not been applied, the resultant stress on the section due to prestress, eccentricity of the Ps and due to DL moment should be as shown in fig (d) so that the max comp stress in the bottom fibre should be f_c (per stress in conc). The stress in the top fibre be zero.

To suit this condition, we have

$$\frac{P}{A} - \frac{Pe}{Z} + \frac{M_d}{Z} = 0 \quad -(1)$$

$$\frac{P}{A} + \frac{Pe}{Z} - \frac{M_d}{Z} = f_c \quad -(2)$$

When LL is applied, BM due to LL be M_L



The beam should be so designed that after the LL is applied, the bending stresses $\frac{M_L}{Z}$ caused by LL should be such that the resultant comp stress in top fibre is f_c and in bottom fibre is zero.

To fulfil this condition

$$\frac{M_L}{Z} = f_c \quad -(3)$$

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But from (2)

$$f_c = \frac{P}{A} + \frac{Pe}{Z} - \frac{M_d}{Z}$$

$$\therefore \frac{P}{A} + \frac{Pe}{Z} - \frac{M_d}{Z} = \frac{M_L}{Z}$$

$$\Rightarrow \frac{Pe}{Z} = \frac{M_d + M_L}{Z} - \frac{P}{A} \quad \text{---} (4)$$

Rewriting (1) & (4)

$$\frac{P}{A} + \frac{M_d}{Z} = \frac{Pe}{Z} \quad - (1)$$

$$(+) \quad -\frac{P}{A} + \frac{M_d + M_L}{Z} = \frac{Pe}{Z} \quad - (4)$$

$$\frac{2M_d + M_L}{Z} = \frac{2Pe}{Z}$$

$$\boxed{e = \frac{2M_d + M_L}{2P}}$$

In designing the beam, it is worth to remember the following formulae

$$\boxed{Z = \frac{M_L}{f_c}}$$

$$\boxed{P = \frac{f_c A}{2}}$$ (Since stress vary from 0 to f_c)

$$\boxed{e = \frac{2M_d + M_L}{2P}}$$

Steps for designing a PSC beam

1) Calculate the LL moment
2) Det. the Section Modulus Reqd from the Condition $Z = M_L/f_c$ choose a Convenient depth
3) $\frac{1}{20}$ or $\frac{1}{25}$ of the span. the determine the

width b from Relation $\frac{bd^2}{6} = Z$

Thus width and the depth are both known.

step 3) Now find PSF 'P' from $P = \frac{f_c}{2} \cdot A$ $(A = b \times d)$

4) find the amount of steel reqd from the relation

$$A_s = \frac{P}{\text{Safe stress in steel}}$$

5) Determine the DL moment M_d

6) Place the Reinforcement at the Eccentricity given by

$$e = \frac{2M_d + M_L}{2P}.$$

#1 A PS conc. beam of uniform rect C.S and span 15M Support a total distributed load DL @ 272 kN Excluding the wt of beam. Determine the suitable dimension of beam and cal. the area of tendons and their position. The per. stresses are $14 N/mm^2$ for concrete (f_c) & $1050 N/mm^2$ (f_{st}) for tendons.

sol step 1 LL BM $= \frac{WL}{8} = \frac{272 \times 15}{8} = 510 kN\text{-}m.$

2) section modulus reqd $Z = \frac{M_L}{f_c} = \frac{510 \times 10^6}{14} = 3.643 \times 10^7 mm^3$

3) Assum $d = \frac{1}{20}$ span $= \frac{15 \times 15000}{20} = 750mm$

$\Rightarrow Z = \frac{1}{6} \times b \times 750^2 \Rightarrow b = \frac{3.643 \times 10^7 \times 6}{750^2} = 388 \simeq 390mm$

∴ Hence the beam section will be 390mm × 750mm

4) PSF $P = \frac{f_c}{2} \cdot A = \frac{14}{2} \times 390 \times 750 = 2047500 N$

Area of tendons $= A_s = \frac{P}{f_{st}}$

$= \frac{2047500}{10500} = 1950 mm^2$

If 6mm φ bar is used ⇒

no of bars/tendons $= \frac{1950}{\frac{\pi(6)^2}{4}} \simeq 70.$

Hence Provide 70 - 6mm φ wires

5. DL of beam $= \overset{1}{0} \overset{b}{\times 39} \overset{d}{\times 0.750} \overset{\times 8}{\times 25000} = 7312.5$ N/m (w)

$$M_d = \frac{7312.5 \times 15^2}{8} = 205664 \text{ Nm} = 205.664 \text{ kN-m}$$

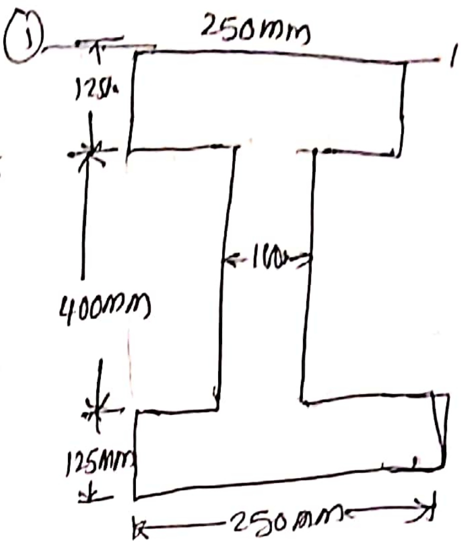
$$\therefore \text{Eccentricity} = \frac{2M_d + M_L}{2P} = \frac{(2 \times 205.664) + 510}{2 \times 2047500} \times 10^6$$

$$\boxed{e = 225 \text{ mm}}$$

Sep-2012

sol

component	Area mm^2	c.g dist. y from 1-1 mm	ay mm^3	ay^2 mm^4	I_{xy} mm^4
Top flange	31.25×10^3	62.5	1.953×10^6	1.22×10^8	$\frac{250\times125^3}{12} = 0.407\times10^8$
Web	40×10^3	325	13×10^6	12.25×10^8	5.33×10^8
Bottom flange	31.25×10^3	587.5	18.36×10^6	107.86×10^8	0.41×10^8
Σ	102.5×10^3		33.31×10^6	121.38×10^8	6.13×10^8



$$\bar{y} = \frac{\Sigma a y}{\Sigma a} = \frac{33.31\times10^6}{102.5\times10^3} \approx \cancel{267\,mm} \text{ from top}$$
325mm (symmetry need not do)

$$Z = \frac{I}{d/2} = \frac{6.13\times10^8}{325} = 1.886\times10^6\, mm^3$$

$$DL = \frac{102.5\times10^3\times24}{10^6} = 2.46\, kN/m$$

DL Moment $M_d = \frac{2.46\times10^2}{8} = 30.75\, kN\text{-}m$

LL Moment $M_L = \frac{12\times10^2}{8} = 150\, kN\text{-}m$

Extreme stress due to DL $= \pm\frac{M_d}{Z} = \frac{30.75\times10^6}{1.886\times10^6} = \pm16.30\, N/mm^2$

extreme stress due to LL $= \pm\frac{M_L}{Z} = \frac{150\times10^6}{1.886\times10^6} = \pm79.53\, N/mm^2$

Let the initial prestress force be P_o; PS force @ transfer $P = 0.75P_o$

Let the eccentricity of tendon $= e$; At transfer, tensile stress in conc $= 1.2\,N/mm^2$

$$\frac{P_o}{A} - \frac{P_o e}{Z} + \frac{M_d}{Z} = -1.2 \Rightarrow \frac{P_o}{102.5\times10^3} - \frac{P_o\times e}{1.886\times10^6} + 16.30 = -1.2 \quad (1)$$

$$\Rightarrow \frac{P_o}{102.5\times10^3} - \frac{P_o e}{1.886\times10^6} = -17.5 \quad (1)$$

At service limit, tensile stress in conc $= 0$ $\quad \frac{P}{A} + \frac{Pe}{Z} - \frac{M_d}{Z} - \frac{M_L}{Z} = 0$

$$\Rightarrow \frac{0.8P_o}{102.5\times10^3} + \frac{0.8P_o e}{1.886\times10^6} - 16.30 - 79.530 = 0$$

$$\Rightarrow \frac{P_o}{102.5\times10^3} + \frac{P_o e}{1.886\times10^6} = \frac{95.83}{0.8} = 119.78 \quad (2)$$

5

on solving (1) + (2)

$P = \cancel{4016.923\ kN}\ 5245512.8\ N$

$e = 24.69\ mm$

$$\text{Number of 7mm } \phi \text{ wires} = \frac{\cancel{4016.923 \times 10^3}\ 5245512.8}{\frac{\pi (7)^2}{4} \times 1200} = 87 \text{ wires}$$

Chk

safe stress in wires

#

Sep-2022 Q: A PSC beam having symmetrical I section is to be designed to support a LL of 12kN/m over an Eff span of 10m. The I section is made up of flanges 250mm wide and 125mm thick and the web is 100mm thick and 400mm deep. The permissible stresses in concrete may be assumed as 13N/mm² in compression and 1.2N/mm² in tension. Assume % losses as 15%. Det. the min. prestressing force and the corresponding eccentricity.

LOSSES

cont..

Prestressing force $= \left(\frac{320\times10^3}{1000}\right) = 320\ kN/mm^2$ $\frac{1000\times320}{1000} = 320kN$

C.S Area $= A = 6\times10^4 mm^2$

Modular Ratio. $\alpha_e = \frac{E_s}{E_c} = \frac{210}{35} = 6$

$I = \frac{100\times300^3}{12} = 45\times10^7 mm^4$

Stress in concrete at the level of steel $= \left[\frac{320\times10^3}{6\times10^4} + \frac{320\times10^3\times50\times50}{45\times10^7}\right]$

$= 7\ N/mm^2$

Various Losses are Compiled in table as below

Type of loss	pre-tensioned beam	post-tensioned
1. Elastic deformation of conc.	$6\times7 = 42\ N/mm^2$	----
2. Relaxation of stress in steel	$\frac{5}{100}\times1000 = 50\ N/mm^2$	$50\ N/mm^2$
3. Creep of concrete	$\phi \cdot f_c \cdot \alpha_e = 1.6\times7\times6 = 67.20\ N/mm^2$	$67.20\ N/mm^2$
4. Shrinkage of Concrete	$\varepsilon_{cs} E_s = (300\times10^{-6}\times210\times10^3) = 63\ N/mm^2$	$(200\times10^{-6}\times210\times10^3) = 21\ N/mm^2$
5. Slip at anchorage	—	$\frac{E_s\Delta}{L} = \left(\frac{210\times10^3\times1}{10\times1000}\right) = 21\ N/mm^2$
6. Friction effect	—	$P_i kL = 1000\times0.0015\times10 = 15\ N/mm^2$
Total loss of stress	$222.20\ N/mm^2$	$195.20\ N/mm^2$
% loss of stress	22.20%	19.52%

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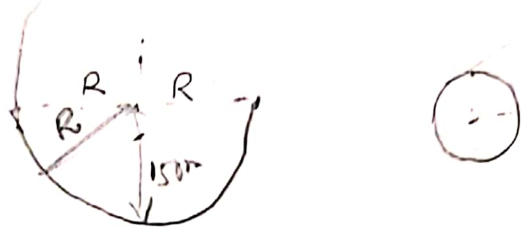
Advantages of Prestressed Concrete



Part A

1) Discuss different types of anchorages used in Pre-stressing system (2017-DEC 2.5M)

2 What is meant by tendon? (2.5M)

3. How do you compute the loss of pre-stress due to wobble Effect (May-2017)

4) What are the assumptions made in PSC. Discuss in detail different pre tensioning & post tensioning methods and advantages of each method with neat sketchy (May/2017) 10M

QUESTION BANK

1) List out different systems of post tensioning (sep 2012)

A) Fressinet System; Magnel Blaton System
Gifford Udall System; Lee Mccall System.

2) A Conc. beam is post tensioned by a cable carrying an initial stress of $1000 N/mm^2$. The slip at the Jacking End was observed to be 6mm. $E_s = 210 kN/mm^2$. Estimate the loss of stress due to anchorage slip if the length of beam is 25m. (sep 2012)

3) A PSC beam having a symmetrical I section is to be designed to support a LL of 12 kN/m over an eff. span of 10m. The I section is made of flanges 250mm wide by 125mm thick and the web is 100mm thick and 400mm deep. The per Stresses may be assumed as $13 N/mm^2$ in comp and $1.2 N/mm^2$ in tension. Assume percentage losses as 15%. Det. the min. ps force and the corresponding eccentricity (sep 2012 15m)

4) * A ~~post tensioned~~ A Prestressed concrete beam 200x300 mm is prestressed with wires (area = $320 mm^2$) located at 50mm from the bottom carrying an initial stress of $1000 N/mm^2$. The Span of beam is 10m. Calculate the percentage loss of stress in wires when the beam is post tensioned*. Assume $E_s = 210 kN/mm^2$; $E_c = 35 kN/mm^2$. Relaxation of stress = 5% of initial stress, Shrinkage of concrete = 200×10^{-6}, Creep coeff = 1.6; Slip at anchorage = 1mm friction coeff = 0.0015/m*. (Dec-2017 : 10M)

A Post tensioned concrete beam 200mm wide 400mm deep is prestressed by 4 cables each with a C.S area of $80mm^2$ with an initial stress of $1200N/mm^2$. All the four cables are straight and located at 120mm from the soffit of the beam. If modular ratio is 6, calculate the loss of Pre stress in four cables due to elastic deformation of concrete for only of the following cases: (May/17 - 10M)

(A) Simultaneous tensioning and anchoring of cables

(4) Successive " of 4 cable one at at a time.