Re-Modified

CBCS SCHEME

USN | | | | | | | | | | 18CV81

Eighth Semester B.E. Degree Examination, July/August 2022
Design of Prestressed Concrete

Time: 3 hrs.   Max. Marks: 100

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Important Note: 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages. 2. Any revealing of identification, appeal to evaluator and /or equations written eg. 42+8 = 50, will be treated as malpractice.

Module-1

1 a. Distinguish between pre tensioning and post tensioning. **(06 Marks)**

b. List the advantages of PSC over RCC. **(04 Marks)**

c. Explain with sketch Hoyer's long line systems of pre-tensioning. **(10 Marks)**

OR

2 a. Explain concept of Thrust line. **(06 Marks)**

b. A rectangular concrete beam of cross section 300mm deep and 200mm wide is prestressed by means of 15 wires of 5mm diameter located 65mm from the bottom of beam and 3 wires of 5mm diameter, 25mm from top. Assuming the prestress in steel as 840N/mm^2, calculate the stresses at the extreme fibres of mid span section. When the beam is supporting its own weight over a span of 6m. If a uniformly distributed live load of 6kN/m is imposed, evaluate the maximum working stress in concrete. **(14 Marks)**

Module-2

3 a. List different types of losses in post tensioning system. Explain any two. **(06 Marks)**

b. A pretensioned beam, 200mm wide and 300mm deep is prestressed by 10 wires, of 7mm diameter initially stressed to 1200N/mm^2, with their centroids located 10mm from the soffit. Find the maximum stress in concrete immediately after transfer, allowing only for elastic shortening of concrete. 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 Indian Standard Code regulations and following data:

$E_s = 210kN/mm^2$, $E_c = 5000\sqrt{f_{cu}}$. $f_{cu} = 42$ N/mm^2 creep co-efficient (ϕ) = 1.6,

total residual shrinkage strain = 3×10^{-4}. **(14 Marks)**

OR

4 a. Explain:

i) Short term deflection

ii) Long term deflection

iii) Limiting deflection as per IS code. **(06 Marks)**

b. A type-3 post tensioned pre stressed concrete beam of 10m span. The beam is post tensioned using three high tensile bars of 40mm diameter located @ an effective depth of 700mm. The effective cover from each of the vertical face of the beam is 60mm.the effective pre stressing force in each bar after all losses is 600kN. Given, cross section 450mm × 750mm, $\frac{x}{d} = 0.43$,

$\frac{I_c}{b_{d^3}} = 0.081$, $f_p = 1035N/mm^2$, $E_s = 200kN/mm^2$, $E_c = 28kN/mm^2$, compute the width of cracks in the tension zone if the service load moment at mid span is 1040kN-m. **(14 Marks)**

Module-3

5 a. Explain failure modes of beam under flexure. (06 Marks)

b. A post tensioned bridge girder with unbonded tendons is of box section of overall dimensions 1200mm wide by 1800mm deep, with wall thickness of 150mm. The high tensile steel has an area of 4000mm^2 and is located at an effective depth of 1600mm. The effective prestress in steel after all losses is 1000N/mm^2 and the effective span of girder is 24m. If f_{ck} = 40N/mm^2 and f_p = 1600N/mm^2, estimate the ultimate flexural strength of section. (14 Marks)

OR

6 Design a simply supported Type-I pre stressed beam with total moment M_T = 435kN-m including self weight moment of M_{SW} = 55kN-m. The height of the beam is restricted to 920mm. The pre stress at transfer $f_{p_o} = 1035N/mm^2$ and pre stress at service $f_{Pe} = 860B/mm^2$. The allowable compressive stresses are 12.5N/mm^2 at transfer and 11.0N/mm^2 at service. The pre-stressing tendon is 7 wire strand with nominal diameter of 12.8mm and nominal area of 99.3N/mm^2. (20 Marks)

Module-4

7 a. Explain different methods of improving shear resistance of PSC members. (05 Marks)

b. Explain the mechanism of shear failure in PSC beams. (05 Marks)

c. The support section of a PSC beam 150 × 300 is to resist a shear of 100kN. The pre stress at centroidal axis is 5N/mm^2, and f_{ck} = 40N/mm^2. The cover to tension reinforcement is 45mm. Check the section for shear and design suitable shear reinforcement using IS Code recommendation. (10 Marks)

OR

8 a. Differentiate between web shear and flexure shear cracks in PSC members with neat sketches. (06 Marks)

b. A pre stressed I section has the following properties. Area = 55 × 10^{3}mm^2, I = 189 × 10^{7}mm^4, statical moment about the centroid = 468 × 10^{4}mm^3, thickness of web = 50mm. It is prestressed horizontally by 24 wires of 5mm diameter and vertically by similar wires at 150mm centres. All the wires carry a tensile stress of 900N/mm^2. Calculate the principal stress at the centroid when shearing force of 80kN acts upon this section. (14 Marks)

Module-5

9 a. Write a note on anchorage zone stresses. (04 Marks)

b. Explain end zone reinforcement. (06 Marks)

c. The end block of a post-tensioned prestressed concrete beam, 300mm wide and 300mm deep, is subjected to a concentric anchorage force of 832.8kN by a Freyssinet anchorage of area 11720mm^2. Design and detail the anchorage reinforcement for the end block. (10 Marks)

OR

10 a. Explain with neat sketches the following pre-stressing systems:
i) Freyssinet's system ii) BBRV system. (10 Marks)

b. The end block of a post-tensioned bridge girder is 600mm wide by 1200mm deep. Two cables, each comprising 97 high tensile wires of 7mm diameter, are anchored using square anchor plates of side length 410mm with their centres located at 600mm from the top and bottom edges of beam. The jacking force in each cable is 4500kN. Design a suitable anchorage zone reinforcement using Fe-415 grade HYSD bars conforming to IS:1343 code provisions. (10 Marks)

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Module-1

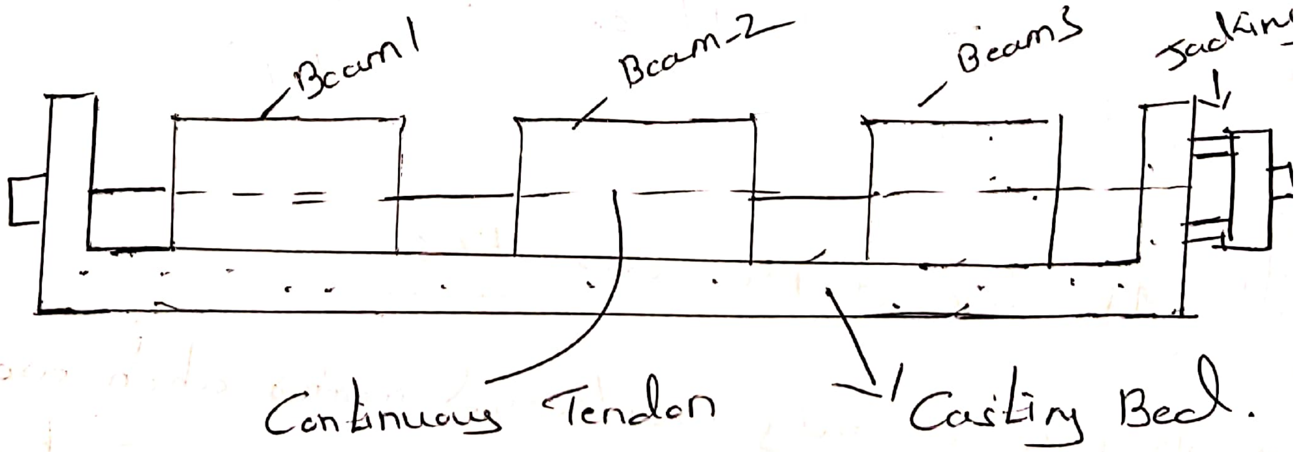
1a.

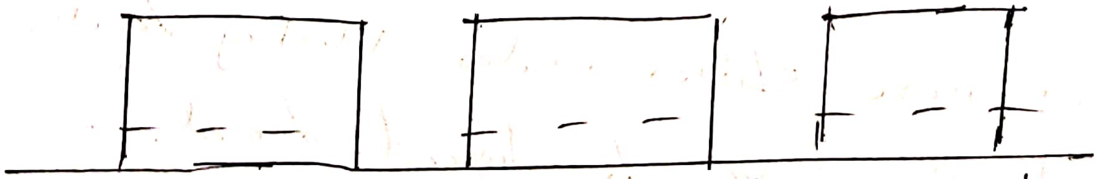
Pre-tensioning	Post-tensioning
1) Loss of Prestress is more	* Loss of Pre-stress is comparatively less
2) Since this method is used for factory production size of member is limited	* Since this method can be employed for Both Pre cast & cast in situ members. size of member may vary.
3) It is cheaper Because there is no Expenditure on rubber core spacer etc.	* It is costly Because of the use of rubber core spacer etc.
4) Tendons can be straight or circular only	* Tendons can be of any shape.

1b Advantages of PSC over RCC

* In case of fully Prestressed member which are free from Tensile stress, the c/s is more effectively utilized.
* It is more stiffer under Working Loads.
* Good Resistance to Impact Load.
* Use of High st steel & concrete results in lighter & slender sections.
* Long span Bridges proves more Economical.

1c For mass production Pre tensioned elements, the long Line process developed by Hoyer is generally used in factory. In this method tendons are streached Between two Bulk heads several hundred meter apart, so that number of similar units may be cast along the same group of Tensioned wires. The wires or strands when tensioned singly or in groups are generally anchored to abutment by steel wedges.

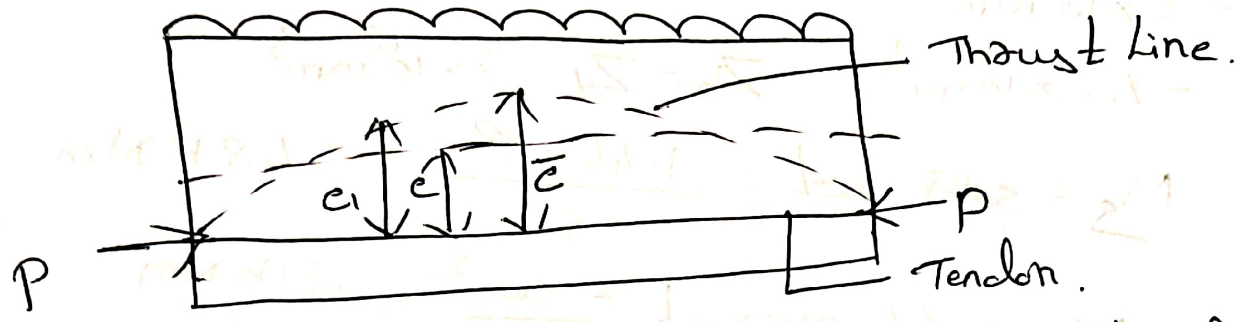




Hoyer's Long Line system PreTensioning.

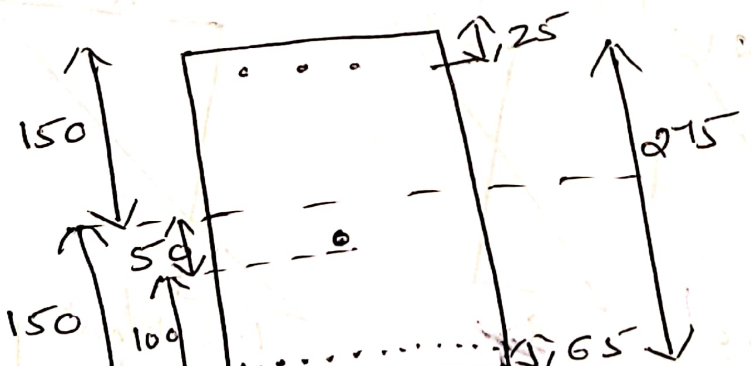
2a

Thrust Line



At any given section of PSC Beam, the combined effect of prestressing force & the externally applied load will result in a distribution of concrete stress that can be resolved to a single force. The locus of point of application of this resultant force in any structure is termed as pressure line.

b



$$\bar{y} = \frac{\left[\frac{\pi \times 5^2}{4} \times 15\right] 65 + \left[\left(\frac{\pi \times 5^2}{4}\right) \times 3\right] 275}{\left[\frac{\pi \times 5^2}{4}\right] \times 15 + \left[\frac{\pi \times 5^2}{4}\right] \times 3}$$

$\bar{y} = 100m$

$P = 840 \times 18 \times 19.7 = 3 \times 10^5 \, N$

$A = 6 \times 10^4 \, mm^2$

$I = 45 \times 10^7 \, mm^4, \quad Z_b = Z_t = 3 \times 10^6 \, mm^3$

$M_g = \text{self wt} = \frac{1.44 \times 6^2}{8} = 6.48 \, KNm$

$M_q = \text{LL moment} = \frac{wl^2}{8} = 27 \, KNm$

$\sigma = \frac{P}{A} = 5.0 \, N/mm^2$

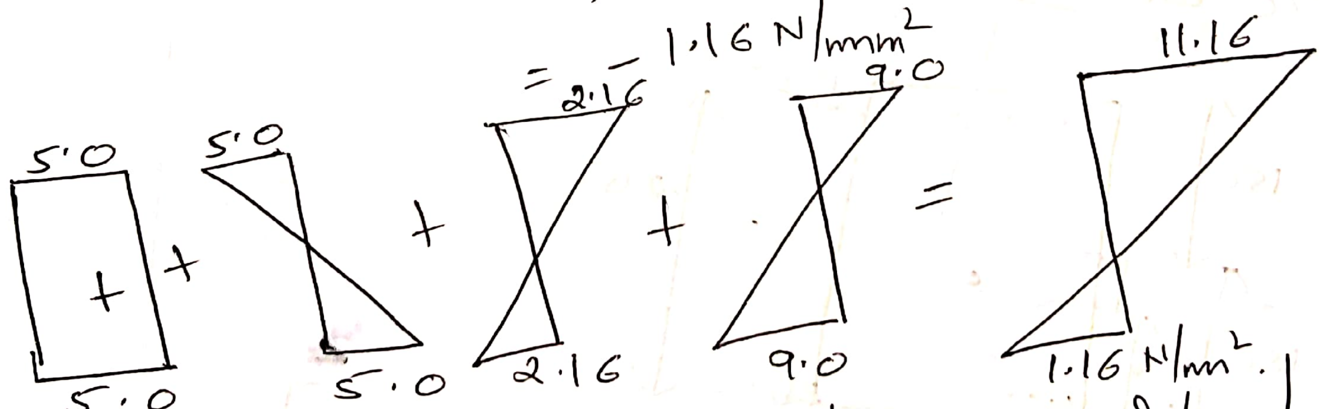
Top fiber stress $= \frac{P}{A} - \frac{Pe}{Z} + \left(\frac{M_g + M_q}{Z}\right)$

$= 11.16 \, N/mm^2$

Bottom fiber stress.

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

$= -1.16 \, N/mm^2$



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Module -2

3a

Types of Losses

1) Losses due to friction
2) Losses due to creep & relaxation of steel
3) Losses due to shrinkage of Concrete
4) Losses due to creep of Concrete
5) Losses due to anchorage slip.

Explaination

1) Loss due to shrinkage of Concrete

Due to shrinkage of Concrete, the Prestress in Tendon is reduced with time, it is Product of E_s & E_c

$$Loss = \epsilon_{cs} \times E_s$$

For Pre Tensioning – 0.003

" Post " – $\frac{0.0002}{\log_{10}(t+2)}$

2) Loss due to creep of Concrete

It is defined as time dependent deformation of concrete under sustained loading

Calculated by

Creep Co-efficient method – $Loss = m \times \phi \times f_c$

m = modular ratio

ϕ = creep co-efficient

f_c = stress in concrete at level of steel.

3b

$A = 200 \times 300 = 6 \times 10^4 \, mm^2$, $e = 140 mm$

$I = \frac{bd^3}{12} = 450 \times 10^6 \, mm^4$

$P_i = P_i \times A_{st} = 1200 \times [10 \times \pi/4 \times 7^2] = 462 KN$

① Elastic shortening = $m = \frac{E_s}{E_c} = 6.480$

$f_c = \frac{P}{A} + \frac{Pe}{I} \times e$ = ~~10.25 N/mm²~~ 27.822

$Loss = m \times f_c = 180.85 \, N/mm^2$

Stress in steel after Elastic shortening $= 1200 - 180.85$
$= 1019.15 \, N/mm^2$

② creep

$f_c = \frac{P}{A} + \frac{Pe}{I} \times e$ = ~~11.650~~ ~~23.6169~~ 8.74 N/mm²

$P = 1019.15 \times [10 \times \frac{\pi}{4} \times 7^2] = 392.214 KN$

$Loss = m \times \phi \times f_c = 90.90 \, N/mm^2$

③ shrinkage $Loss = \epsilon_{cs} \times E_s = 63 \, N/mm^2$

④ Relaxation $Loss = 5\% \times P_i = 60 \, N/mm^2$

Total Loss $= 805.25 \, N/m^2$

% Loss $= 32.90\%$ //

4 a] **Short Term Deflection**

These are governed by bending moment & flextural rigidity of member. Mohr's moment area Table is rapidly available for estimation of deflection due to prestressing force or self wt or imposed load.

$$\Delta = \frac{A\bar{x}}{EI}$$

b] **Long Term Deflection**

Deflection of PSC member may vary due to time Dependent losses such as creep & shrinkage. Deflection produced due to LL DL & Prestressing including all time dependent losses are long term loss.

$$\Delta = \left[\Delta_{DL} + \Delta_{LL} + \Delta_P \left[\frac{P_{eff}}{P_i}\right]\right](1+\phi)$$

3] **Limiting Deflection as per IS code.**

- Final deflection due to all loads including effect of Temperature creep & shrinkage should not Exceed span/250.
- The deflection after the erection of Partitions & application of finishes should not Exceed span/350 or 20mm whichever less.

4b

$P = 1800 kN$, $e = 325 mm$,

$I = 1582 \times 10^7 mm^4$

$Z = 4218 \times 10^4 mm^3$

Bottom fiber stress $= \sigma_b = \frac{P}{A} + \frac{Pey}{I} = 19.2 N/mm^2$

$M_0 = \sigma_b \times Z = 810 kNm$

$M = M_d - M_0 = 230 kNm$

$m = \frac{E_s}{0.5 E_c} = 14.3$

$\frac{x}{d} = 0.43$, $x = 300 mm$. $\frac{I_c}{bd^3} = 0.081$, $I_c = 125 \times 10^8 mm^4$

$\epsilon_s = \frac{mM(d-x)}{E_s I_c} = 0.00053$

$\epsilon_h = \left(\frac{h-x}{d-x}\right) \epsilon_s = 0.0006$

Avg strain $\epsilon_m = \epsilon_h - \left[\frac{b_t(h-x)(a'-x)}{3E_s A_s (d-x)}\right] = 0.0005$

i) crack width under Bar, $W_{cr} = 3 C_{min} \epsilon_m = 0.045 mm$

ii) crack width @ Bottom corner $W_{cr} = \frac{3 a_{cr} \epsilon_m}{1 + 2\left[\frac{a_{cr} - C_{min}}{h-x}\right]}$

$= 0.077 mm$

iii) crack width at soffit mid way b/w two Bars

$W_{cr} = 0.095 mm$

5a

i) Faracture of steel in Tension Zone.

Sudden failure of PSC member without any warning is generally due to fracture of steel in Tension Zone. This tye of failure takes place due to provision of lower percentage of steel in section ∵ or less amount of steel concrete in Tension Zone cracks & steel cannot Bear additional stress.

ii) Failure of underreinforced section.

The member approaches failure due to the gradual reduction of compressive zone Exibiting large deflection & cracks which developed at soffit & progressed towards the compression phase. when concrete area is insufficient to resist resultant compressive force, ultimate flextural failure of member takes place through crushing of concrete.

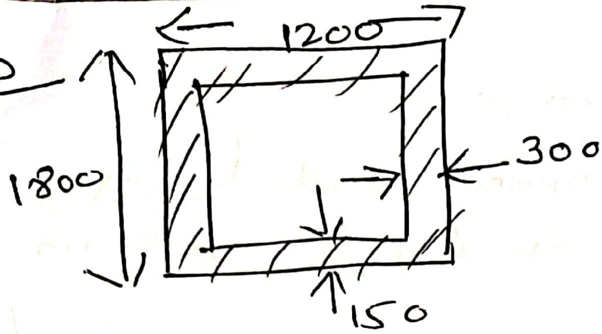
iii) Failure of Bond b/w steel & concrete

This type of failure takes place due to inadequate transmission length at the End of member.

iv) Anchorage failure.

These failure may takes place in End Blocks & If not properly designed in post Tensioned member to resist transverse tensile forces.

5b



$d = 1600 mm$
$A_p = 4000 mm^2$
$f_{pe} = 1000 N/mm^2$
$f_p = 1600 N/mm^2$
$f_{ck} = 40 N/mm^2$
$\frac{l}{d} = \frac{24}{1.6} = 15$

Assuming NA lies in web

$A_p = A_{pf} + A_{pw}$

$0.45 f_{ck} (b_f - b_w) D_f = A_{pf} f_p$

$A_{pf} = 1518.75 mm^2$

$A_{pw} = A_p - A_{pf} = 4000 - 1518.75 = 2481.25 mm^2$

$\frac{A_{pw} f_{pe}}{b_w d f_{ck}} = 0.129$

$\frac{x_u}{d} = 0.427 \Rightarrow x_u = 0.427 \times 1600 = 683.2 mm$
$> D_f$

∴ Assumption is corrite

$\frac{f_{pu}}{f_{pe}} = 1.312 \Rightarrow f_{pu} = 1.312 \times 1000 = 1312 N/mm^2$

$M.R = f_{pu} \times A_{pw} (d - 0.42 x_u) + A_{pf} f_p \left(d - \frac{D_f}{2}\right)$

$MR = 1312 \times 2481.25 \left[1600 - 0.42 (683.2)\right] + 1518.75 \times 1600 \times \left(1600 \times \frac{150}{2}\right)$

$MR = 7.98 \times 10^3 kNm$

6a

1. Lever arm (z) $\frac{M_{sw}}{M_T} = \frac{55}{435}$

$= 12.5\%$

$M_{sw} = 0.125 M_T$

since $M_{sw} < 0.3 M_T$, $z = 0.5h$

$= 0.5 \times 920$

$z = 460mm$

2. Effective Prestress (Pe)

Since $M_{sw} < 0.3 M_T$ $Pe = \frac{M_{IL}}{z}$

$M_{IL} = M_T - M_{sw}$

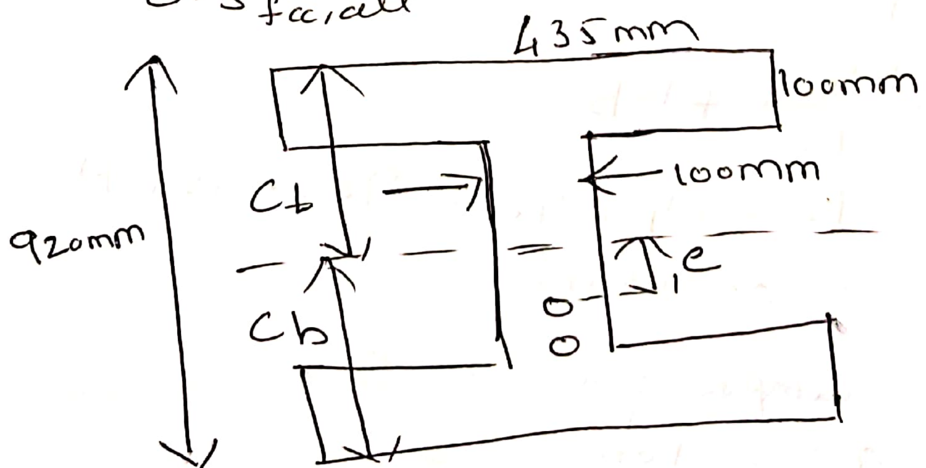
$= 435 - 55$

$M_{IL} = 380 kNm$

$Pe = \frac{380 \times 10^6}{460} = 826 kN$

$Ap = \frac{Pe}{f_{pe}} = 960 mm^2$

$A = \frac{Pe}{0.5 f_{c,all}}$ = Area of Section = $150 \times 10^3 mm^2$



Geometric properties

$A = 2 \times [435 \times 100] + 100 \times 700$

$A = 159000 mm^2$.

$I = 1.780 \times 10^{10} mm^4$

$$r^2 = \frac{I}{A} = 111949.68\,mm^2$$

$$K_t = K_b = \frac{r^2}{c_t} = \frac{111949.68}{460} = 243.36\,mm$$

Design

$$e = \frac{M_{sw}}{P_o} + K_b$$

$$P_o = A_p \times f_{po} = 960 \times 1035$$

$$P_o = 993.6\,KN$$

$$e = \frac{55 \times 10^6}{993.6 \times 10^3} + 243.36 = 298.71\,mm$$

Effective Prestress

$$P_e = \frac{M_T}{e + K_t} = \frac{435 \times 10^6}{298.71 + 243.36} = 802.47\,KN$$

Since P_e is not close to previously estimate P_e in Preliminary design, the values of A_p, P_o & e are recomputed.

$$A_p = \frac{P_e}{f_{pe}} = 933.10\,mm^2$$

$$e = \frac{M_{sw}}{P_o} + K_b$$

$$P_o = A_p \times f_{po} = 965.75\,KN$$

$$e = 300.31\,mm$$

check for Compressive stress

At transfer $A \geq \frac{P_o h}{f_{ccall} \cdot c_t}$

$$= \frac{(965.75 \times 10^3) \times 920}{12.5 \times 460}$$

$$A \geq 154.520\,mm^2$$

b) At Service

$$A \geq \frac{P e h}{f_{ccall} \cdot C_b}$$

$$= \frac{(802.47 \times 10^3) \times 920}{11 \times 460}$$

$$A = 145903.6 mm^2$$

The provided area of section is adequate & the stress are within the allowable limit.

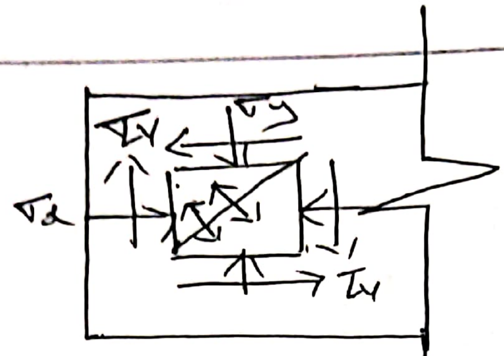
Module-4

7. a

Shear Resistance of PSC member can be Improved by

* Horizontal or axial Prestressing
* Prestressing by Inclined or sloping cables
* Vertical or Transverse Prestressing.

7b In a PSC member shear stress is generally accompanied by direct stress in axial direction of member & if transverse vertical prestressing is adopted.



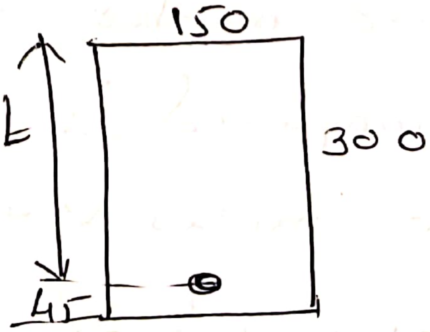
$$\sigma_{max} = \frac{\sigma_x + \sigma_y}{2} + \frac{1}{2}\sqrt{(\sigma_x - \sigma_y)^2 + 4\tau_v^2}$$

$$\sigma_{min} = \frac{\sigma_x + \sigma_y}{2} - \frac{1}{2}\sqrt{(\sigma_x - \sigma_y)^2 + 4\tau_v^2}$$

Direct stress σ_x & σ_y being Compressive magnitude of Principal Tensile stress is considerably reduced. so under working load Both major & minor principal stress are compressive, there by Eliminating risk of Tension cracks in concrete.

σ_{min} develops tensile stress & hence diagnol crack will occur.

These can be Improved by different shear mechanism.



7c

$V_u = 150\,kN$

$d_t = 300 - 45 = 255\,mm$

$\sigma_x = f_{cp} = 5\,N/mm^2$

$b = 150\,mm$

$D = 300\,mm$

$f_{ck} = 40\,N/mm^2$

$f_y = 250\,N/mm^2$

$f_t = 0.24\sqrt{f_{ck}} = 1.52\ N/mm^2$

$V_{cD} = 0.67bD\sqrt{f_t^2 + 0.8 f_{cp} f_t} = 86.5KN$

$\therefore V_{cD} < V_u$

$\frac{A_{sv}}{S_v} = \frac{V_u - V_{cu}}{0.87 f_y d_t}$, $S_v = 145mm$

Providing 2L-8mm Bar

min shear

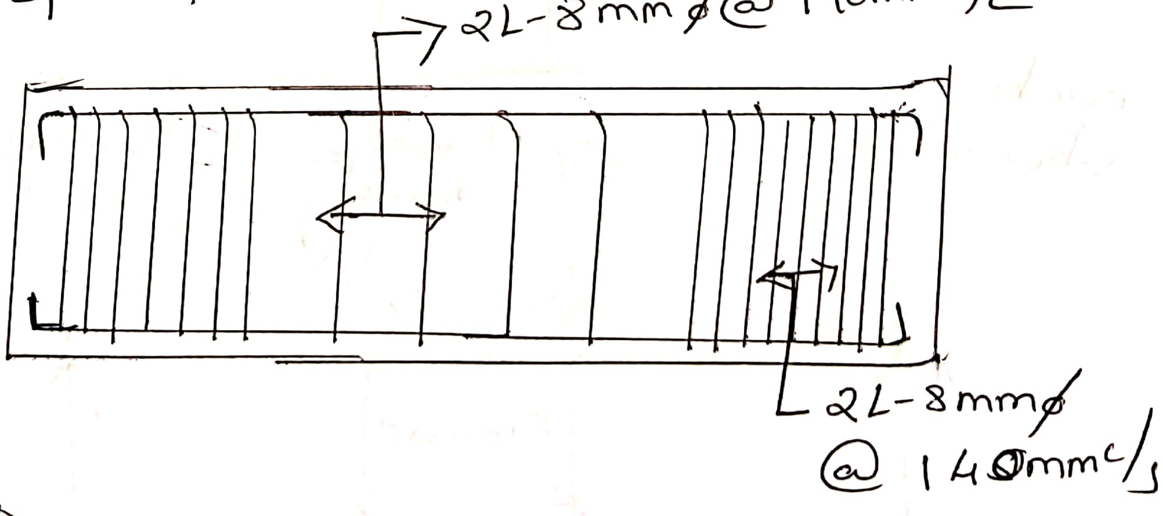
$\frac{A_{sv}}{bS_v} = \frac{0.4}{0.87 f_y}$

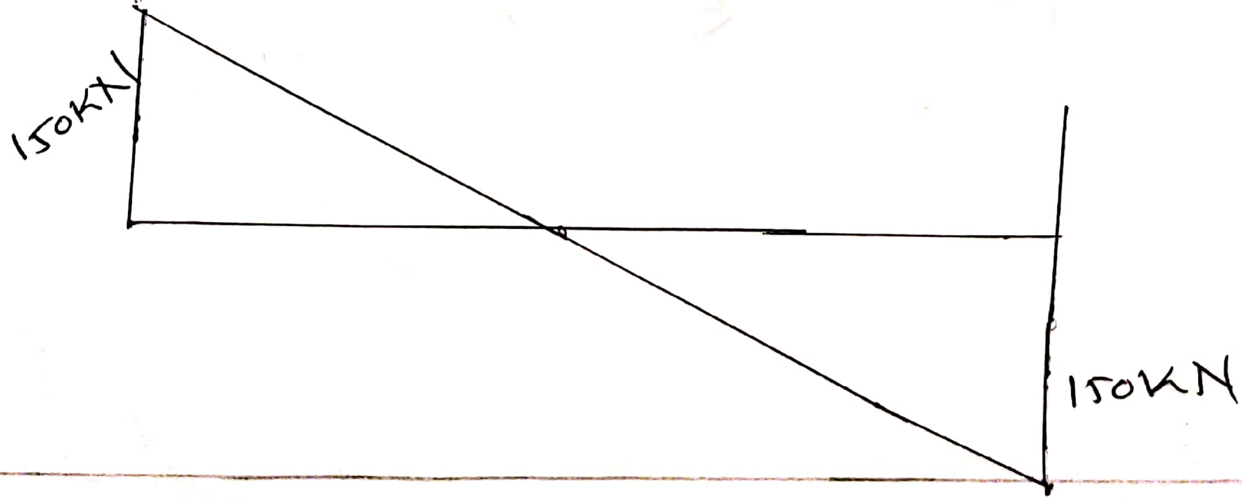
$S_v = 604mm$

max spacing $0.75d = 191mm$

$4b_w = 600mm$

use 140mm spacing at support, 190mm at mid span.





8a

Web shear cracks

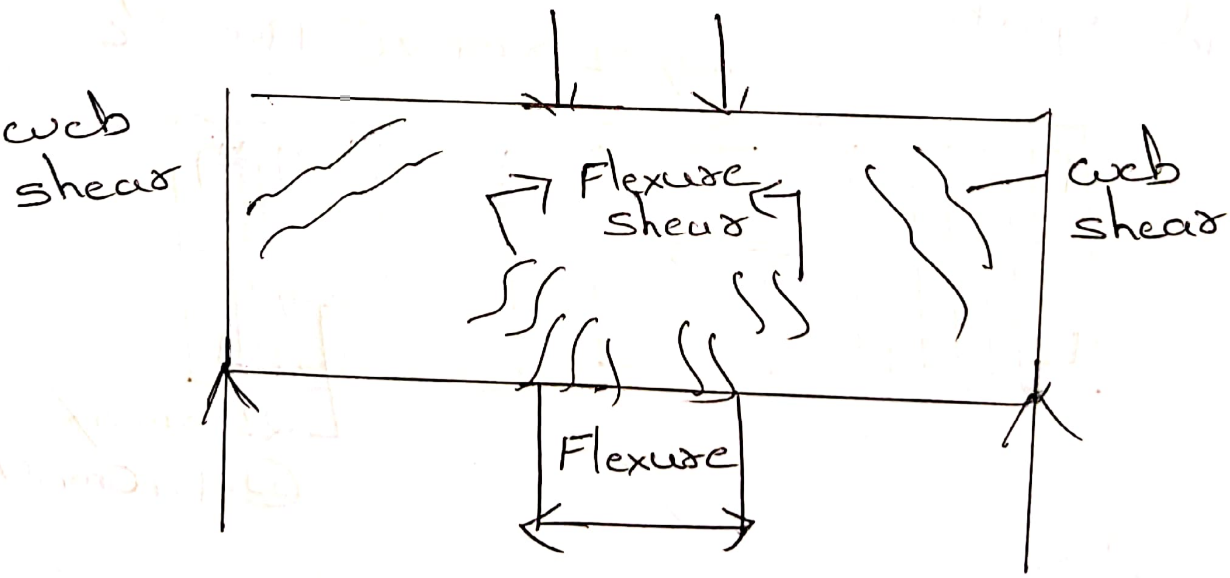
* Generally start from an interior point when local principal Tensile stress exceeds Tensile strength of concrete

* These are likely to develop highly Prestressed Beam

Flextural shear cracks

* These are first intiated by flextural cracks in inclined direction.

* These are developed when combined shear & flextural Tensile stress produce principal stress Exceeding Tensile st of Concrete.



8b

$A = 55 \times 10^3 \ mm^2$

$I = 189 \times 10^7 \ mm^4$

$\tau_v = \frac{Vs}{Ib} = \frac{(80 \times 10^3)(468 \times 10^9)}{(189 \times 10^7) \times 50}$

$\tau_v = 3.95 \ N/mm^2$

Principal stress

$f_{max} \text{ or } f_{min} = \left(\frac{f_x + f_y}{2}\right) \pm \frac{1}{2}\sqrt{(f_x - f_y)^2 + 4\tau_v^2}$

$f_x = \frac{24 \times \left(\frac{\pi}{4} \times 5^2\right) \times 900}{55 \times 10^3}$

$f_x = 7.71 \ N/mm^2$

$f_y = \frac{\left(\frac{\pi}{4} \times 5^2\right) \times 900}{(50 \times 50)} = 2.364 \ N/mm^2$

$f_{max} \text{ or } f_{min} = \left(\frac{7.71 + 2.364}{2}\right) \pm \frac{1}{2}\sqrt{(7.71 - 2.3)^2 + 4(3.95)^2}$

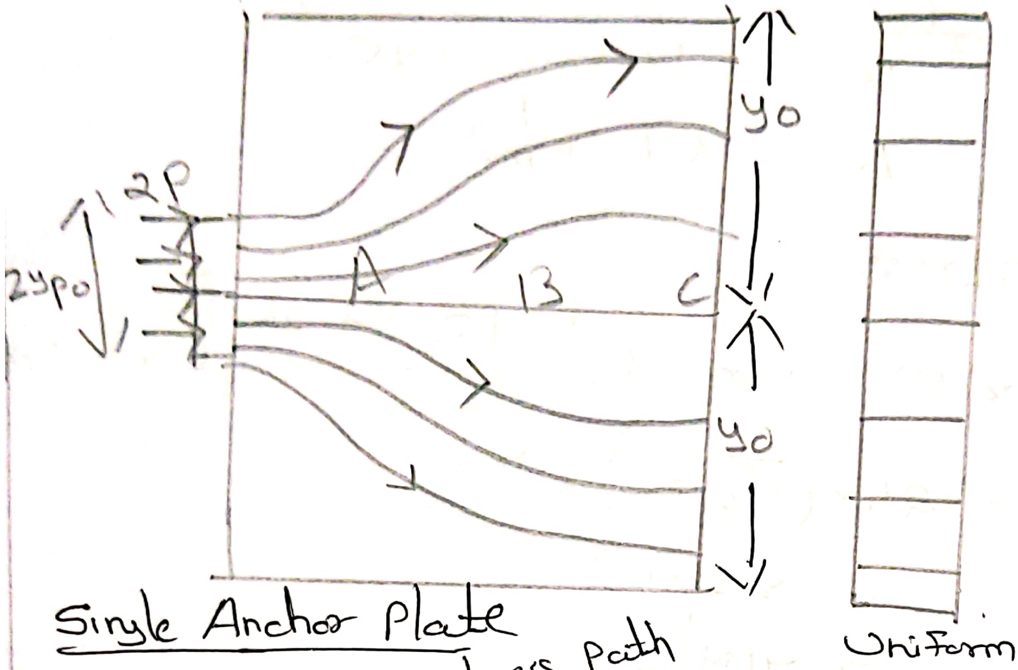
$f_{max} = 9.8 \ N/mm^2$

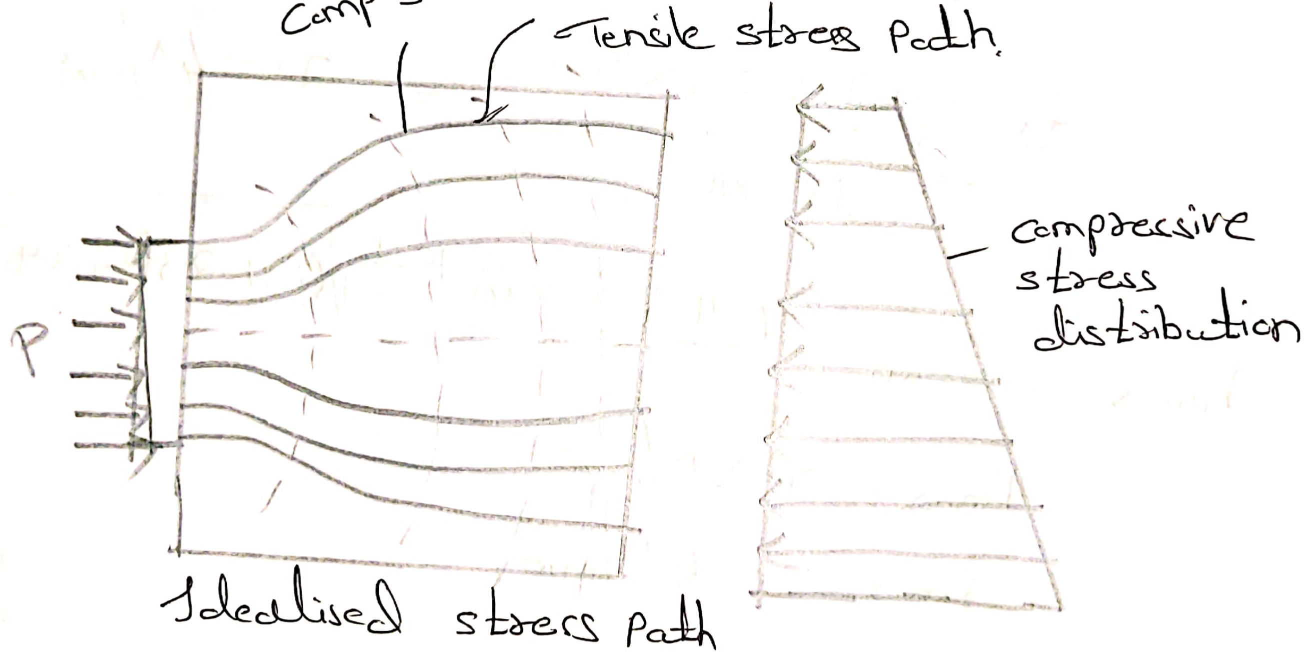
$f_{min} = 0.4 \ N/mm^2$

Module- 5

9a

stress distribution in Anchorage zone.



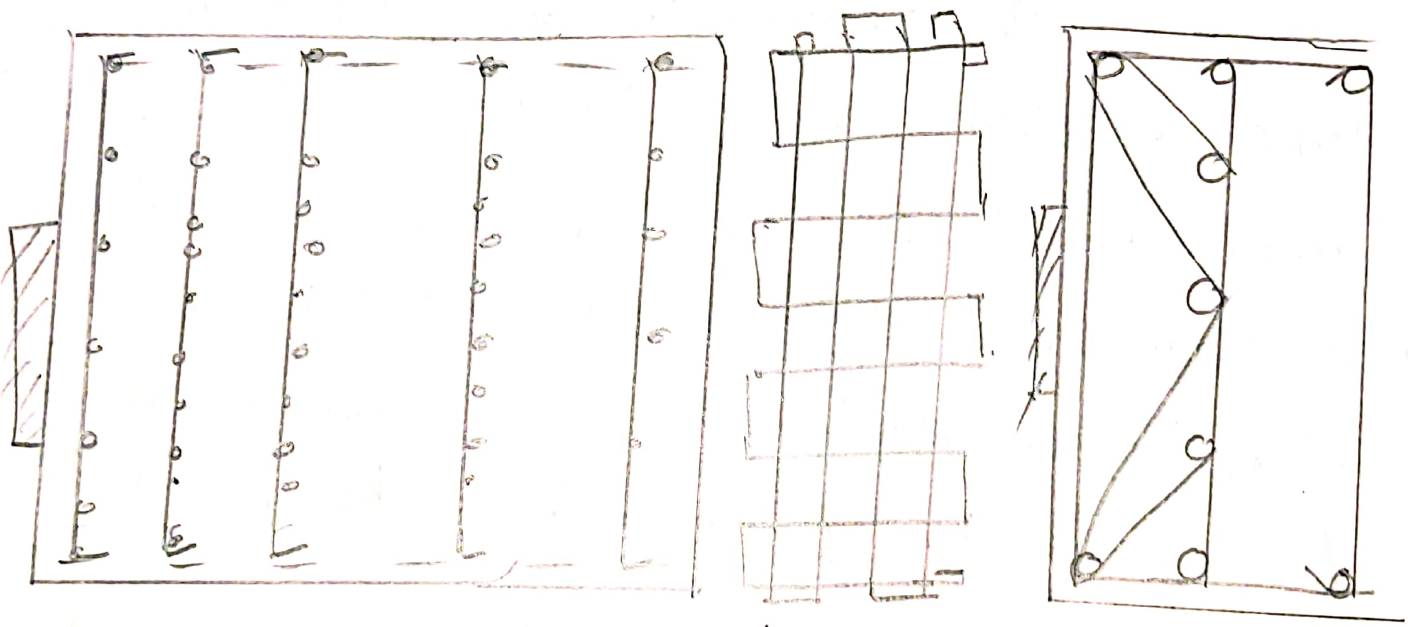


The curvature of strut being convex towards center line of Block induce compressive stress in zone A. In zone B the curvature is reversed in direction & strut End to deflect outwards. In zone C struts are st & Parallel so that no transverse are Induced

7b End Zone Reinforcement

Main Reinforcement should be designed to withstand bursting tension, which is determined by transverse stress distribution on critical axis, usually coinciding with the line of action of largest individual force.

Typical Arrangement of End Block Reinforcement is shown



9c

Compressive stress $\sigma_c = \frac{P}{A} = 9.3\ N/mm^2$

$2y_{po} = \sqrt{\frac{1170 \times 4}{\pi}} = 123mm$

$\frac{y_{po}}{y_o} = 0.41$

Tensile stress $f_{r(max)} = \sigma_c \left[0.98 - 0.825\left(\frac{y_{po}}{y_o}\right)\right]$

$= 6\ N/mm^2$

Bursting Tension $= F_{bst} = P_k \left[0.48 - 0.4\left(\frac{y_{po}}{y_o}\right)\right]$

$F_{bst} = 264 KN.$

$$Ast = \frac{Fbst}{0.87 f_y} = \frac{264\times10^3}{0.87\times415} = 731.20 mm^2$$

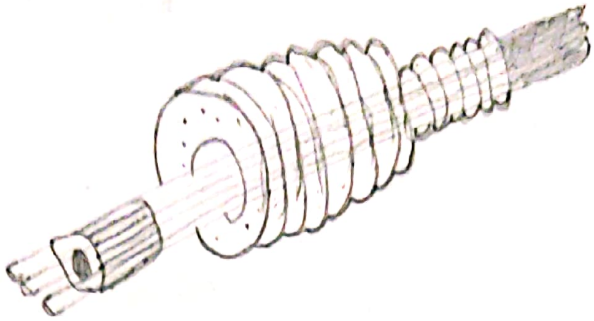
$$\text{No of Bars} = \frac{Ast}{\frac{\pi}{4}\times10^2} = 9.309$$

$\simeq$ 10 No

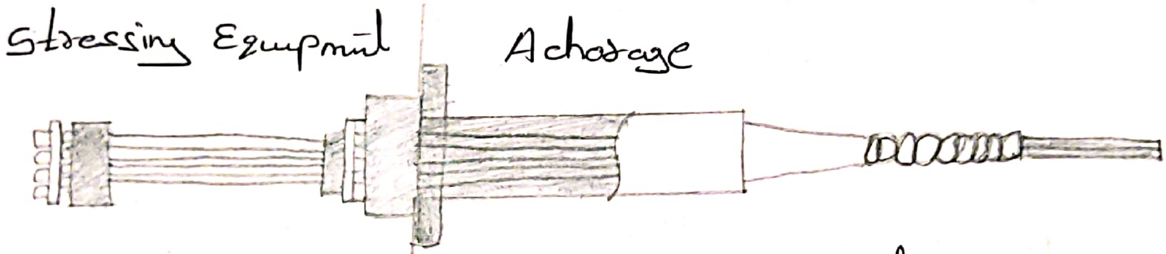
10a i] Freyssinet's System

In Freyssinets system Mats, helics, cloops, or Links are generally provided in perpendicular directions. Helical Reinforcement is more efficient than mat reinforcement. In case where spalling or secondary Tension develops at corners, suitable steel in the form of hair-pin bars should be provided to prevent failure of corner zone.

Consist of a cylinder with a conical interior through which the high-Tensile wires pass & against the walls of which the wires are wedged by Connical plug Lined longitudinally through groves to house the wires as shown below.



viii)



Anchoring of BBRV Tendons

BBRV Post-Tensioning system was developed in 1949 by four Swiss Engineers - Birkenmeier, Brandestini, Ros & Vogt. This system is well suited for transmitting large force. A BBRV Tendon consist of severall parallel length of high-Tensile wires, with Each End transminating in a cold formed Button head with a machined anchorage fixture as shown.

10b

$2y_{po} = 410mm$, $2y_o = 600mm$, $P_k = 4500kN$

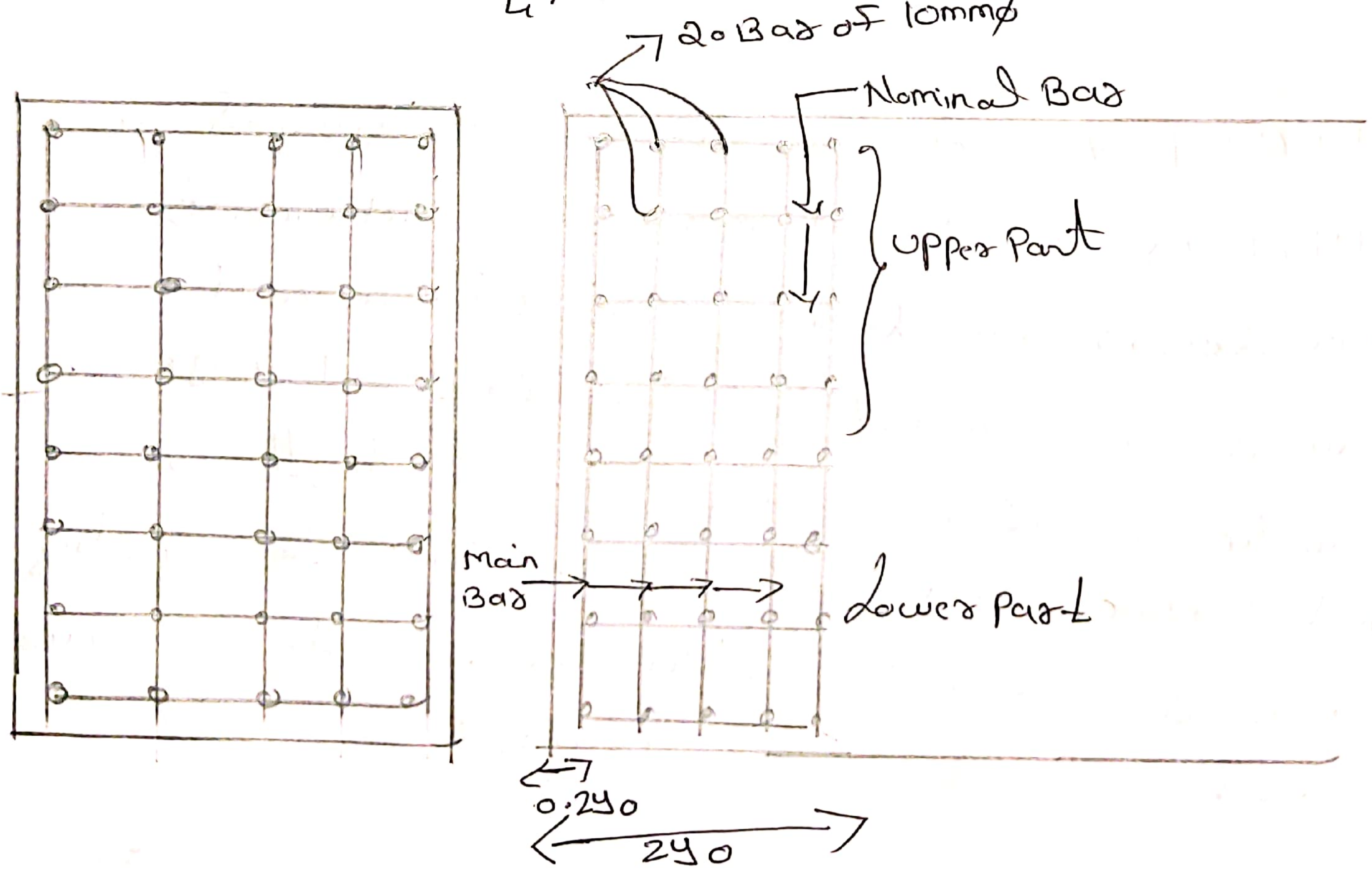
$$\frac{2y_{po}}{2y_o} = 0.683$$

$$F_{bst} = P_k\left[0.32 - 0.3\left(\frac{y_{po}}{y_o}\right)\right]$$

$F_{bst} = 517 kN$

$$A_{st} = \frac{F_{bst}}{0.87 f_y} = 1434 mm^2$$

$$\text{No of Bars} = \frac{A_{st}}{\frac{\pi}{4} \times 10^2} = 20 \text{ Nos.}$$



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