UNIT-VI

Q11. Write short notes on the investigations carried out on anchorage zone stresses.

Answer : Model Paper-I, Q7(a)

1. The anchorage zone stresses in a pre-tensioned beam is analysed theoretically by 'Guyon'.
2. His analysis plays a very prominent role and gets involved in the effect of superposition of individual loads which are acting in series along the cable.
3. The effects of individual loads attained are useful for acting on external loads across the free end of a rectangular plate.
4. These individual loads are distributed along the anchorage length of cable and is based on a relationship, i.e., bond stress (assumed) V_s distance from the free end.
5. After performing the analysis part, the results which are obtained will indicate that the stresses present in post-tensioned beam depends upon the bonds present in between them. If better bonds are present, then the stresses comes very close to it.

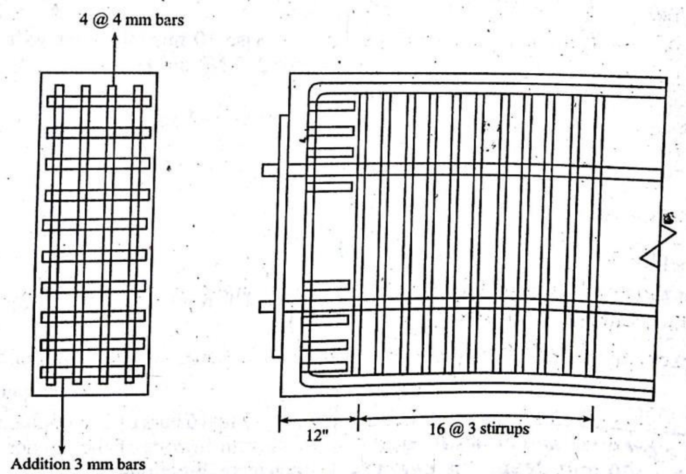

Figure: Anchorage Zone Stresses at End Blocks

Q12. Explain the steps involved in the approximate method of design of end blocks.

Answer : Model Paper-II, Q3(a)

Approximate Method of Design of End Blocks

The compressive stresses of concrete ahead of the anchorage devices, location and magnitude of the bursting force and the edge tension forces can be estimated when the accurate analysis is not available.

Limitations

1. The longitudinal extent of the concrete member which is rectangular in cross-section is atleast equal to the largest transverse dimension of the cross-section.
2. The member within or ahead of the anchorage zone will not have any discontinuities.
3. The main plate of the member in the anchorage zone has minimum edge distance of atleast 1.5 times the corresponding lateral dimension (a) of the anchorage device.
4. The anchorage zone consists of only one anchorage device or group of anchorage devices which are closely spaced.
5. If the centre to centre spacing of the anchorage devices will not exceed 1.5 times the width of these devices in the direction in which it is considered is treated as closely spaced devices.
6. If the anchor force points towards and away from the centroid of the section, the centre line of the member will not be greater than 20° and 5° respectively will be the angle of inclination of a tendon.

(i) Compressive Stresses

The basic anchorage devices which satisfies the below condition will have no additional check of compressive stress of concrete.

$$f_b \leq 0.7\, \phi\, f'_{ci} \sqrt{A/A_g}$$

$$f_b \leq 2.25\, \phi\, f'_{ci}\,,\ n/t \leq 0.08 \sqrt[3]{E_b / f_b}$$

At the interface between the local zone and the general zone of the special anchorage devices ahead, the concrete compressive stresses are given by,

$$f_{ca} = K.\ \frac{0.6P_u}{A_b} \times \frac{1}{1 + l_c . \frac{1}{b_{\text{eff}}} - \frac{1}{t}} \qquad \text{... (1)}$$

$$K = 1 + 2 - \frac{S}{a_{\text{eff}}} \times 0.3 + \frac{n}{15} \quad (\text{For } S < 2\, a_{\text{eff}}) \qquad \text{... (2)}$$

$$K = 1\ (\text{For } S > 2\, a_{\text{eff}})$$

The product of the correction factor in each direction is used, if a group of anchorage are closely spaced in two directions.

The anchor bearing plate area, A_{plate} or the bearing area of the confined concrete in the local zone, A_{conf} will be the effective bearing area, A_b.

The terms in the equations (1) and (2) are expressed below,

f_{ca} – Compressive stress of concrete ahead of the anchorage device.

= Correction factor for closely spaced anchorages.

A_b – Effective bearing area.

a_{eff}, b_{eff} – Lateral dimension of the effective bearing are measured parallel to the larger dimension of the cross-section and the smaller dimension of the cross-section respectively.

l_c – Longitudinal extent of confining reinforcement for the local zone, but not more than the larger of 1.15 a_{eff} or 1.15 b_{eff}

P_u – Factored load of tendon.

t – Thickness of the section.

S – Center-to-center spacing of multiple anchorages.

n – Number of anchorages in a row.

Limitations of Compressive Stresses

1. Area of the plate (A_{plate}) should not be taken larger than the area of the confined bearing (A_{conf}), if A_{plate} controls.
2. The maximum dimension of A_{conf} should be greater than two times the maximum dimension of A_{plate} or three times the minimum dimension of A_{plate}, if A_{conf} controls.
3. The area of the duct should be deducted while determining 'A_b'.

(ii) Bursting Forces

The values of bursting force, T_{burst} and the loaded surface distance, d_{burst} are given by,

$$T_{burst} = 0.25\, \Sigma P_u .\ 1 - \frac{a}{h} + 0.5\, P_u \sin\alpha \qquad \text{... (3)}$$

$$d_{burst} = 0.5\,(h - 2e) + 5e \sin\alpha \qquad \text{... (4)}$$

If more than one tendon is used in the above equations the stressing sequence in a specified manner is considered.

Where,

ΣP_u – Sum of the total factored tendon loads for the stressing arrangement considered.

a – Lateral dimension of the anchorage device or group of devices in the direction considered.

e – Eccentricity of the anchorage device or group of devices with respect to the centroid of the cross-section.

h – Lateral dimension of the cross-section in the direction considered.

α – Angle of inclination of the resultant of the tendon forces with respect to the center line of the member.

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(iii) Edge Tension Forces

- If the center to center spacing for multiple anchorages is less than 0.4 times the depth of section, the spalling forces will not be less than 2% of the total factored tendon force in any case.
- The more detailed analysis is required such as strut-and-ties models or other analytical procedures to find out the spalling forces for larger spacings.
- The spalling and longitudinal edge tension forces are induced when the location of centroid of all the tendons is considered to be outside the keen of the section.
- The longitudinal edge tension forces can be taken as spalling force and this force should not be less than 2% of the total factored tendon force in any case.
- The axial flexural beam analysis at one half the depth of section away from the loaded area enables to determine the longitudinal edge tension force.

Q13. Explain magnel's method of analysis of end blocks.

Answer :

The points load due to anchorage on one side and the normal and tangential distributed loads from linear direct stress and shear stress distribution from the other side are the stresses developed in the deep beam which is considered as end blocks.

The forces and stresses acting on the end blocks and at any point on the horizontal axis parallel to the beam respectively are shown in the figure.

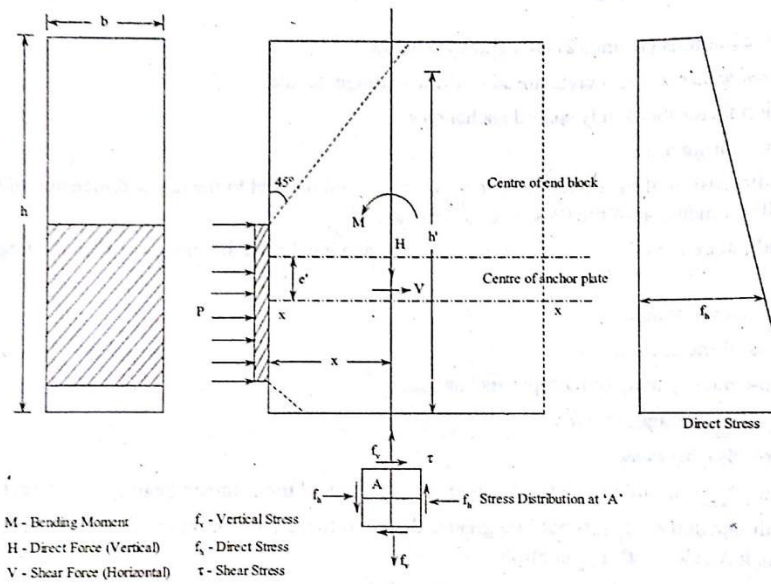


Figure: Forces Acting on the End Block

The stress distribution across the section is given by,

$$f_v = k_1\left(\frac{M}{bh^2}\right) + k_2\left(\frac{H}{bh}\right)$$

$$\tau = k_3\left(\frac{V}{bh}\right)$$

$$f_h = \frac{P}{bh}\left(1+12\frac{e'^2}{h'^2}\right)$$

Where,

k_1, k_2, k_3 – Constants, vary depending upon the distance from end blocks of beam.

f_v – Direct stress.

Consider the depth of section intercepted between the dispersion lines at required point on the horizontal axis and assuming that the point loads disperses at 45°.

The principal stresses acting at a point are given by,

$$f_{max} = \left(\frac{f_v + f_h}{2}\right) + \frac{1}{2}\sqrt{(f_h - f_v)^2 + 4\tau^2}$$

$$f_{min} = \left(\frac{f_v + f_h}{2}\right) - \frac{1}{2}\sqrt{(f_h - f_v)^2 + 4\tau^2}$$

$$\text{And } \tan 2\theta = \frac{2\tau}{f_v - f_h}$$

The principal tensile stress distribution on the required axis and the suitable reinforcements that are designed to resist the tension is 'Bursting Tension'.

Q14. Explain Guyon's method of analysis of end blocks.

Answer : Model Paper-III, Q6(b)

Zone of Transmission

The length of beam within which the dispersion of the pre-stressing force takes place is called 'zone of transmission'.

The distribution of stress in the transmission zone can be analysed by the following,

1. The tensile forces are developed in the transverse direction to the axis of concentrated force. These are called 'Bursting Forces'.
2. The adjacent surface to the anchor plate is also subjected to tensile force at the end section. These are called 'Spalling Forces'.
3. The pre-stressing force 'P' is applied through the anchor plate which is placed at the centre of the end beam as shown in the figure (i).

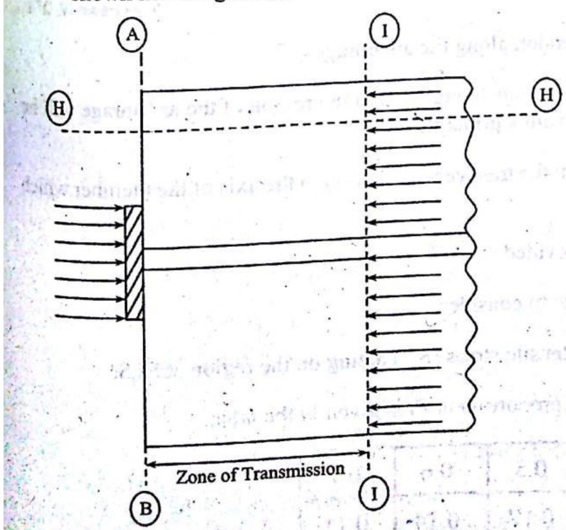


Figure (i)

Let AB be the end face of the beam.

$I - I$ be the end zone of the transmission.

Consider any horizontal $H - H$. The transverse stress and shear stress are subjected to the horizontal section.

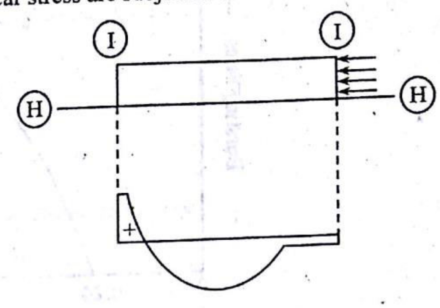


Figure (ii): Transverse Stresses

4. Due to the horizontal, vertical and shear stresses, the trajectories of principal stresses are as shown in the figure (iii).
5. The transmission length is influenced by depth of the anchor plate.

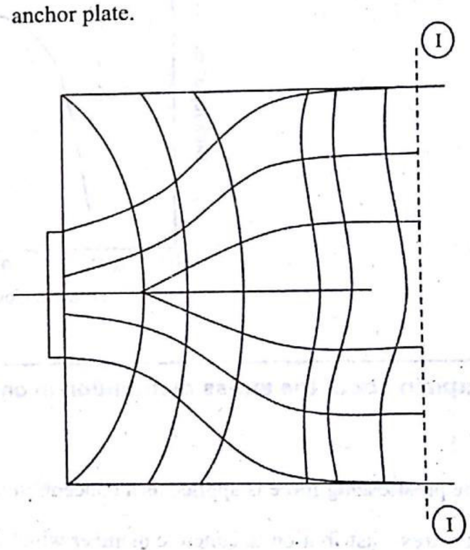


Figure (iii): Trajectories of Principal Stresses

6. Depending on the ratio of depth of anchor plate to the depth of beam, the transmission length and bursting force can be obtained.
7. Generally, the transmission length is taken as equal to the depth of beam.
8. The bursting force with the depth of beam 'd' and the depth of anchor plate 'd'' is given by,

$$P_b = 0.3P\left[1 - \frac{d'}{d}\right]$$

The distribution of bursting stress for $\frac{d'}{d} = 0.8$ and $\frac{d'}{d} = 0.5$ are shown in the below figures.

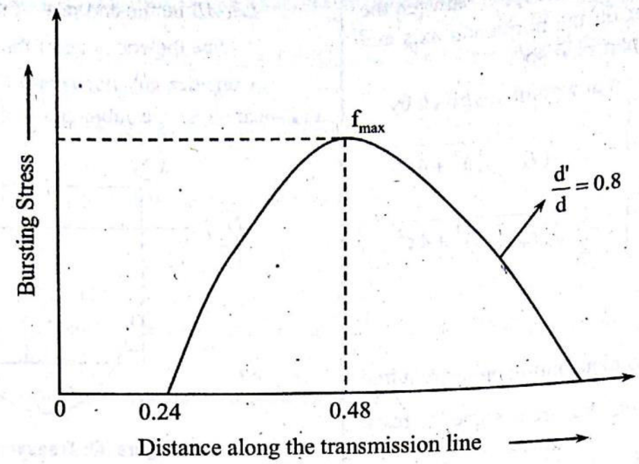


Figure (iv)

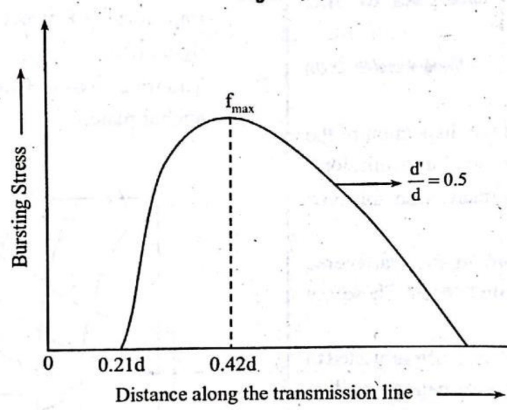


Figure (v)

Q15. Explain about the stress distribution in end blocks.

Answer :

Model Paper-IV, Q7(b)

1. The prestressing force is applied as a concentrated force in a tendon along the anchorages.
2. The stress distribution in concrete member which is away from the anchorage and in the region of the anchorage will be uniform reasonably and complex respectively. This is by St.Venant's principle.
3. The tensile stresses which tend to split the concrete are placed in the transverse direction to the axis of the member which is the more important effect for the design.
4. The tensile stresses must be contained by the reinforcement provided.
5. The resultant of bursting tensile stresses (F_{bst}) are more accurate to consider.
6. The region is extended from $0.2y_0$ to $2y_0$ for assumed bursting tensile stress (F_{bst}) acting on the region at SLS.
7. The values of design bursting tensile forces in end blocks with proportion to Pi is given in the table.

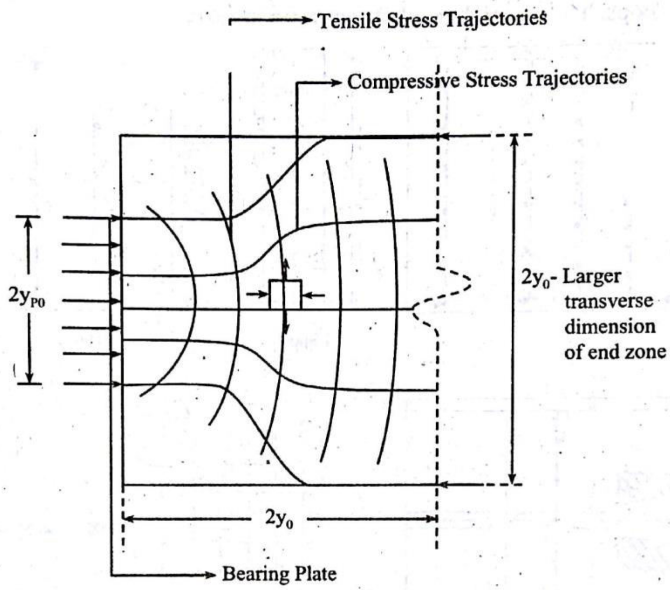
y_{P0}/y_0	0.2	0.3	0.4	0.5	0.6	0.7
F_{bst}/Pi	0.23	0.23	0.20	0.17	0.14	0.11

The above relations can be defined by,

$$F_{bst} = Pi\left[0.32 - 0.3\left(\frac{y_{P0}}{y_0}\right)\right]$$

If $\frac{y_{P0}}{y_0} \leq 0.3, \frac{F_{bst}}{Pi} = 0.23$

$\frac{y_{P0}}{y_0} \geq 0.3, \frac{F_{bst}}{Pi} = 0.11$



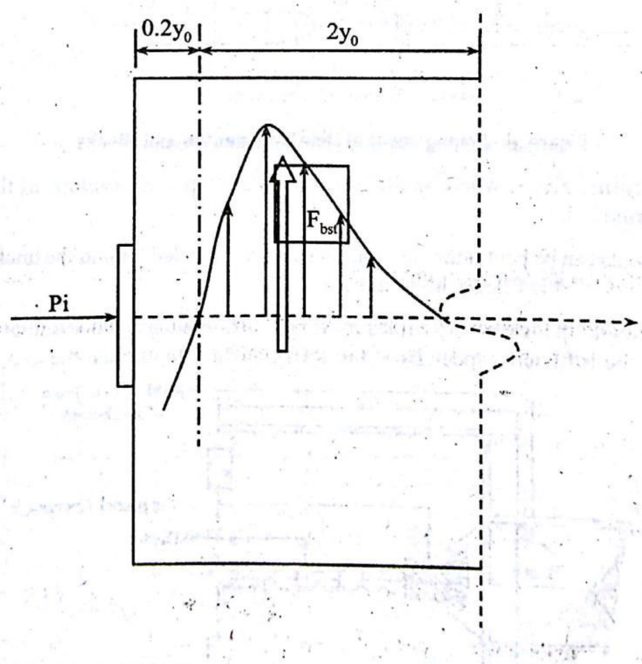


Figure: Distance along Axis of Beam

y_0 – Half the side of the end blocks

y_{P0} – Half the side of the loaded area.

Q16. Explain about the anchorage zone reinforcement.

Answer :

- By using the transverse stress distribution, the designed anchorage zone in the main reinforcement should withstand the bursting tension and coincides with the line of action of the largest individual force on the critical axis.
- The arrangement of reinforcement for freyssinet type of anchorages in end blocks is shown in figure (i) and the links or loops, helics, mats are placed in the perpendicular directions of the reinforcement.
- When compared to mat reinforcement, the helical reinforcement is more efficient and it is tested by Zielinski and Rowe.
- With the deformed bars, loops, hooks or right angle bends are necessary in the case of short bond lengths.

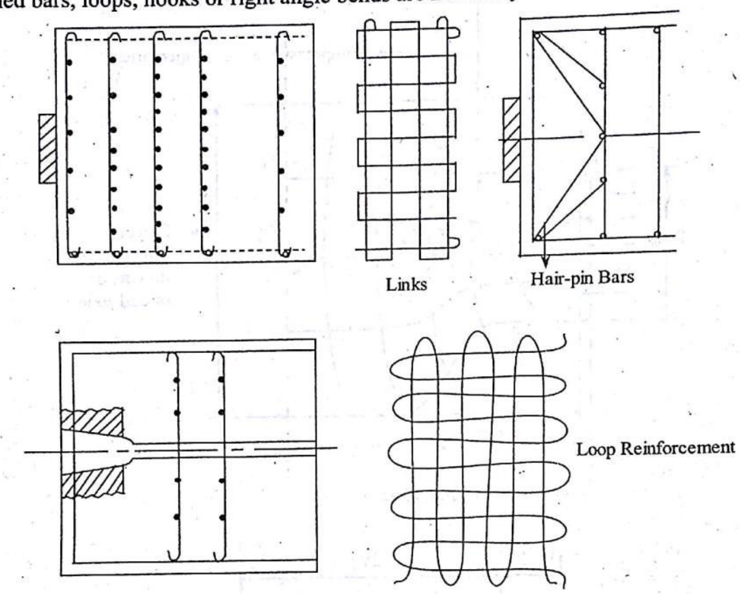


Figure (i): Arrangement of Reinforcement in End Blocks

- To prevent the failure of corner zones, where spalling or secondary tension develops at the corners, the hair-pin bars of suitable steel should be provided.
- The secondary reinforcements can be bent if the suitable packets are provided behind the anchorages and after the operations of prestressing is done, the pocket is filled with mortar.
- While designing the formwork, the use of cap cables must be considered and the space provided for fixing and handling of the hydraulic jack must be sufficient especially at the soffits of the beam when the cap cables are used.

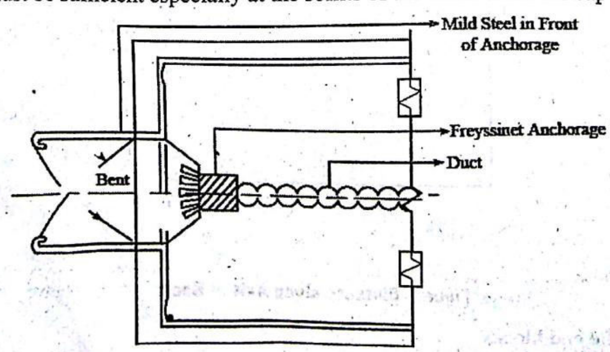


Figure (ii): Pocket Behind Anchorages

- In case of end blocks, the steel cage should be provided to overcome the overlapping of it with bearing plates when they are placed close to the edges of the block.

- During stressing to prevent the spalling of concrete at the corners due to the different elastic modulus of plane containing the reinforcement, this precaution must be taken.

- The cost of end anchorage steel is low when compared to the entire structural members. So, Morice advices that it is better to provide extra reinforcement in doubtful situations.

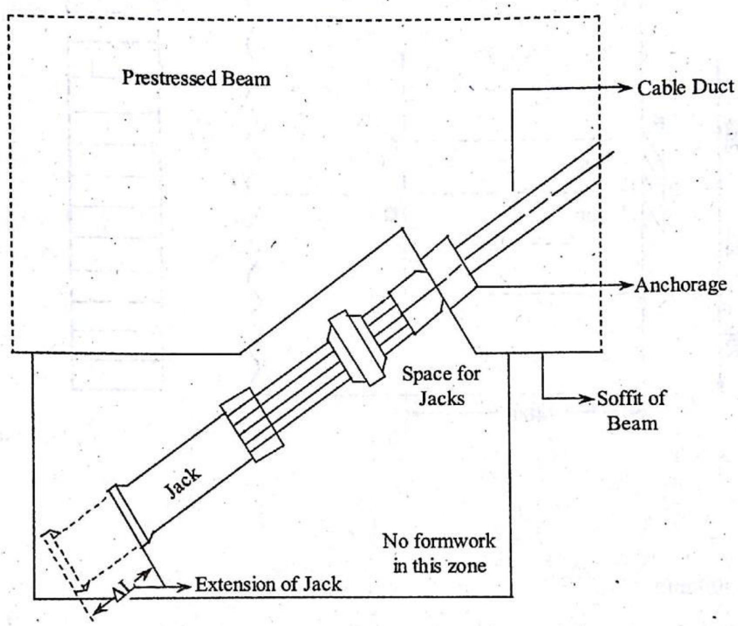
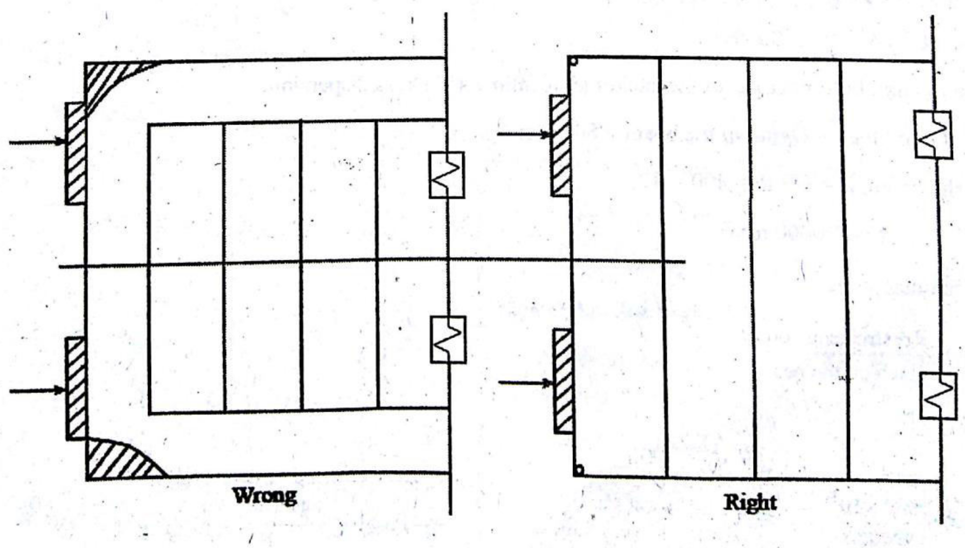


Figure (iii): Provision for Jack at Soffit of Beam



---- arrangement of Steel Cage in Anchorage Zone