Module -5

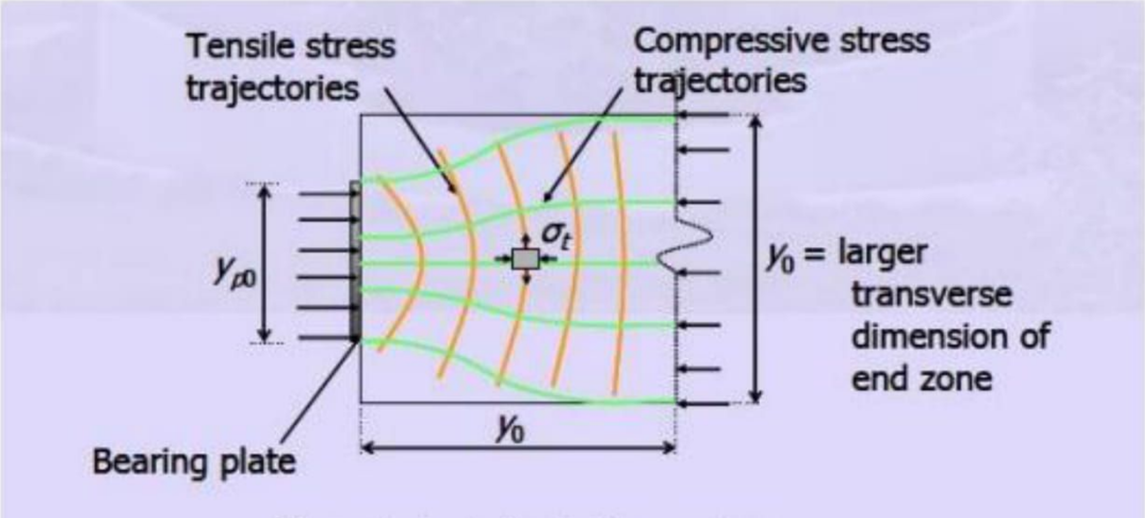
Anchorage zone stresses and design of anchorages. Composite Sections: Types of composite construction - Analysis of composite sections - Deflection –Flexural and shear strength of composite sections.

In prestressed concrete structural members, the prestressing force is usually transferred from the prestressing steel to the concrete in one of two different ways. In post-tensioned construction, relatively small anchorage plates transfer the force from the tendon to the concrete immediately behind the anchorage by bearing. For pretensioned members, the force is transferred by bond between the steel and the concrete. In either case, the prestressing force is transferred in a relatively concentrated fashion, usually at the end of the member, and involves high local pressures and forces. A finite length of the member is required for the concentrated forces to disperse to form the linear compressive stress distribution assumed in design.

The length of member over which this dispersion of stress takes place is called the transfer length (in the case of pretensioned members) and the anchorage length (for post-tensioned members). Within these so-called anchorage zones, a complex stress condition exists.

Transverse tension is produced by the dispersion of the longitudinal compressive stress trajectories and may lead to longitudinal cracking within the anchorage zone. Similar zones of stress exist in the immediate vicinity of any concentrated force, including the concentrated reaction forces at the supports of a member.

The anchorage length in a post-tensioned member and the magnitude of the transverse forces (both tensile and compressive), that act perpendicular to the longitudinal prestressing force, depend on the magnitude of the prestressing force and on the size and position of the anchorage plate or plates. Both single and multiple anchorages are commonly used in post-tensioned construction. A careful selection of the number, size, and location of the anchorage plates can often minimize the transverse tension and hence minimize the transverse reinforcement requirements within the anchorage zone. The stress concentrations within the anchorage zone in a pretensioned.



Stress trajectories in the end zone

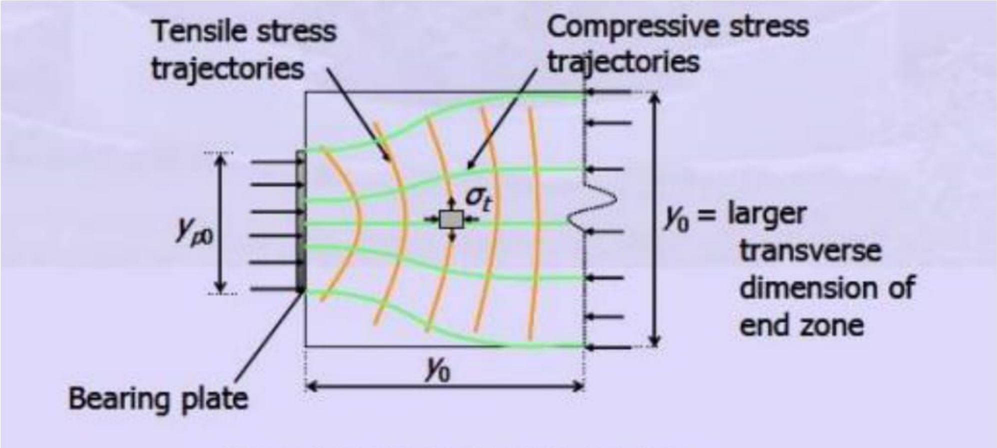
Bursting force: A portion of a pre-stressed member surrounding the anchorage is the end block.

End block

Bursting force

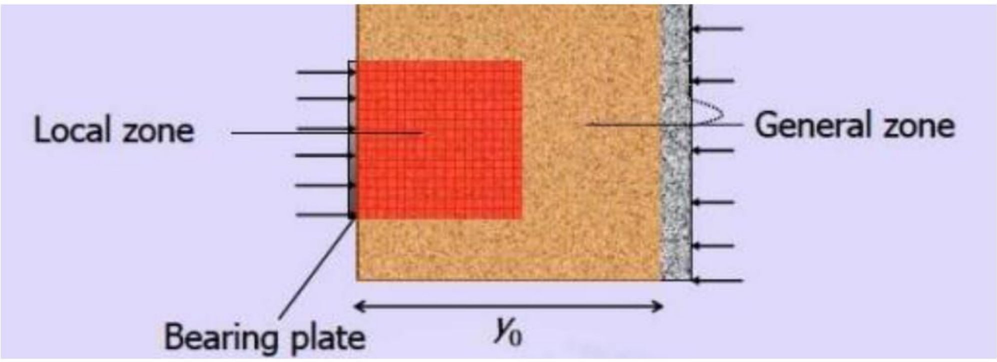
A portion of a pre-stressed member surrounding the anchorage is the end block. Through the length of the end block, pre-stress is transferred from concentrated areas to become linearly distributed fiber stresses at the end of the block. The theoretical length of this block, called the lead length is not more than the height of the beam.

But the stress distribution within this block is rather complicate.



Stress trajectories in the end zone

The larger transverse dimension of the end zone is represented as yo. The corresponding dimension of the bearing plate is represented as ypo. For analysis, the end zone is divided into a local zone and a general zone.

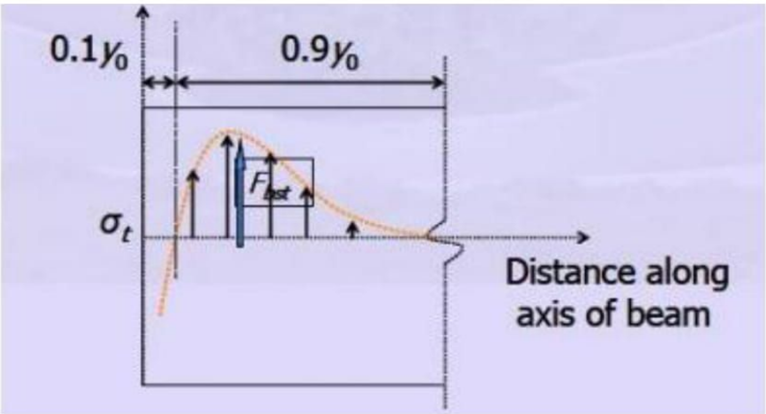


The local zone is the region behind the bearing plate and is subjected to high bearing stress and internal stresses. The behavior of the local zone is influenced by the anchorage device and the additional confining spiral reinforcement.

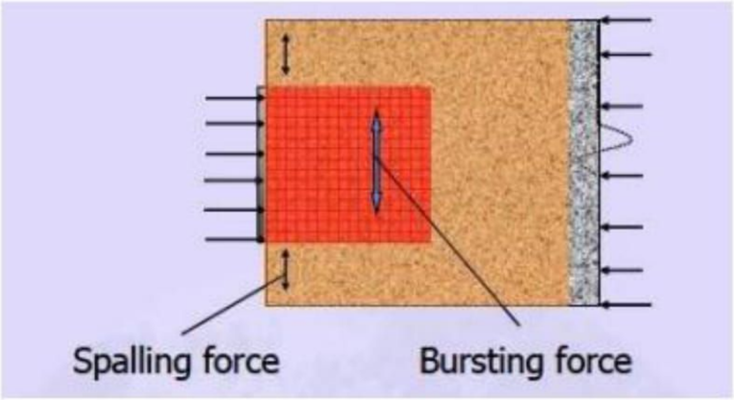
The general zone is the end zone region which is subjected to spalling of concrete. The zone is strengthened by end zone reinforcement.

The transverse stress (?t) at the CGC varies along the length of the end zone. It is compressive for a distance 0.1yo from the end and tensile thereafter, which drops down to zero at a distance yo from the end.

The transverse tensile stress is known as splitting tensile stress. The resultant of the tensile stress in a transverse direction is known as the bursting force (Fbst).



Besides the bursting force there is spalling forces in the general zone.



Fbst for an individual square end zone loaded by a symmetrically placed square bearing plate according to Cl 18.6.2.2 is,

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

Where, PK = pre-stress in the tendon;

y po = length of a side of bearing plate;

yo = transverse dimension of the end zone.

It can be observed that with the increase in size of the bearing plate the bursting force Fbst reduces.

End Zone reinforcement

Transverse reinforcement - end zone reinforcement or anchorage zone reinforcement or bursting link - is provided in each principle direction based on the value of Fbst. The reinforcement is distributed within a length from 0.1yo to yo from an end of the member.

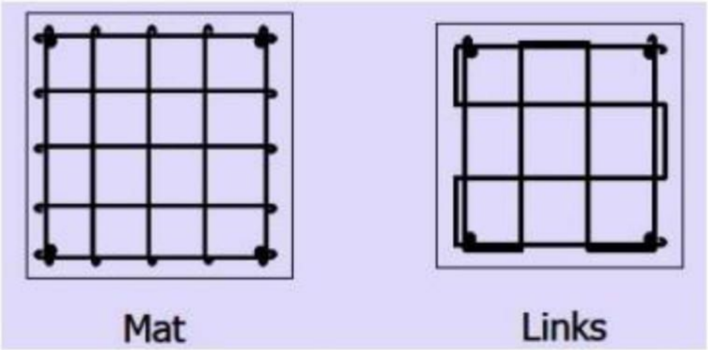
The amount of end zone reinforcement in each direction Ast

The parameter represents the fraction of the transverse dimension covered by the bearing plate.

The stress in the transverse reinforcement, fs = 0.87fy.

When the cover is less than 50 mm, fs = a value corresponding to a strain of 0.001.

The end zone reinforcement is provided in several forms, some of which are proprietary of the construction firms. The forms are closed stirrups, mats or links with loops.



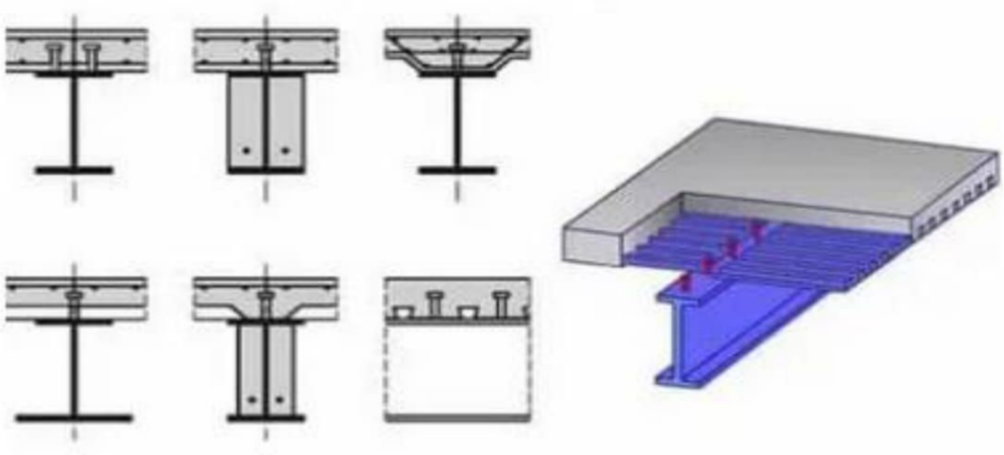
Composite Construction

Many applications of prestressed concrete involve the combination of precast prestressed concrete beams and in situ reinforced concrete slabs. Some examples of such composite construction. An in situ infill between precast beams while an in situ topping . The former type of construction is often used in bridges, while the latter is common in building construction. The beams are designed to act alone under their own weight plus the weight of the wet concrete of the slab. Once the concrete in the slab has hardened and provided that there is adequate horizontal shear connection between them, the slab and beam behave as a composite section under design load. The beams act as permanent formwork for the slab, which provides the compression flange of the composite section. The section size of the beam can thus be kept to a minimum, since a compression flange is only required at the soffit at transfer. This leads to the use of inverted T-, or 'top-hat', sections.

Types of composite construction

Composite Beams

Composite beams are constructed from two or more different types of materials such as steel and concrete, and various valid cross sections have been utilized



Composite beam

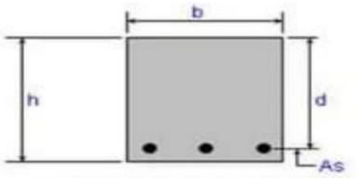
Based on Cross-Section Shapes

Several cross sectional shapes of beams are available and used in different parts of of structures. These beams can be constructed from reinforced concrete, steel, or composite materials:

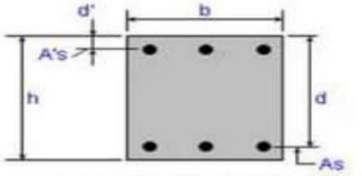
Reinforced concrete cross sectional shapes include:

Rectangular beam

This type of beam is widely used in the construction of reinforced concrete buildings and other structures.



Singly Reinforced Section



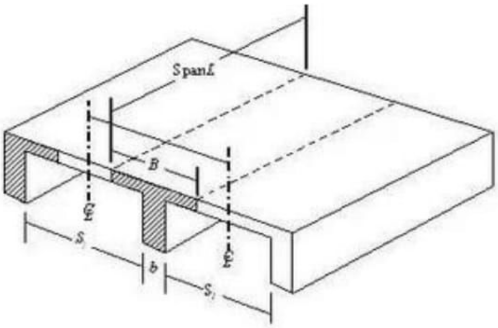
Doubly Reinforced Section

Rectangular Reinforced concrete beam

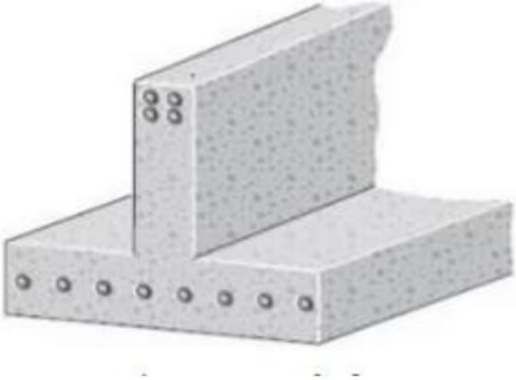
10. T-section beam

This type of beam is mostly constructed monolithically with reinforced concrete slab. Sometimes, Isolated T-beam are constructed to increase the compression strength of concrete.

Added to that, inverted T-beam can also be constructed according to the requirements of loading imposed.



T-beam



Inverted T-beam

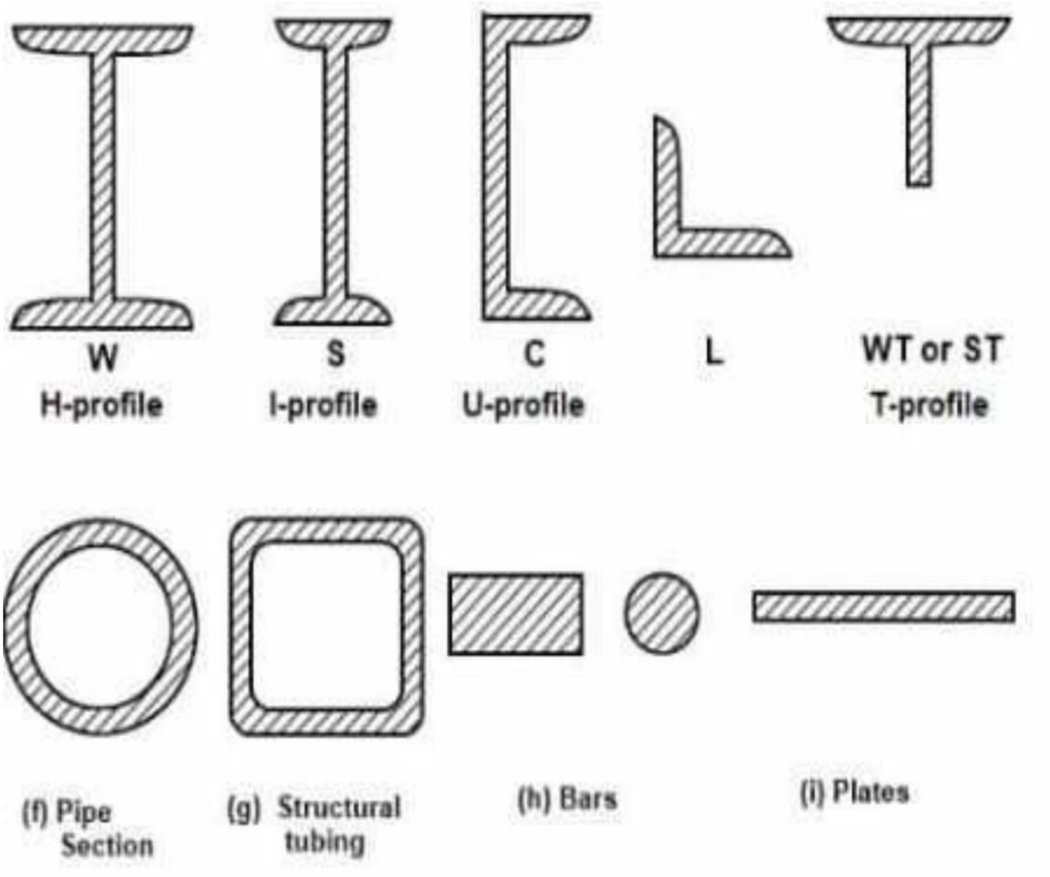
11. L-section beam

This type of beam is constructed monolithically with reinforced concrete slab at the perimeter of the structure, as illustrated in Fig. 10.

Steel cross sectional shapes include:

There are various steel beam cross sectional shapes. Each cross sectional shape offer superior advantages in a given conditions compare with other shapes.

Square, rectangular, circular, I-shaped, T-shaped, H-shaped,C-shaped, and tubular are examples of beam cross sectional shapes constructed from steel.

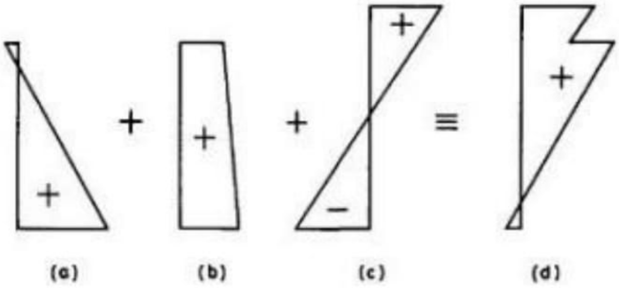


Analysis of composite sections

The stress distributions in the various regions of the composite member are shown in Fig. The stress distribution in Fig. 10.2(a) is due to the self weight of the beam, with the maximum compressive stress at the lower extreme fibre. Once the slab is in place, the stress distribution in the beam is modified to that shown in Fig., where the bending moment at the section, Md is that due to the combined self weight of the beam and slab.

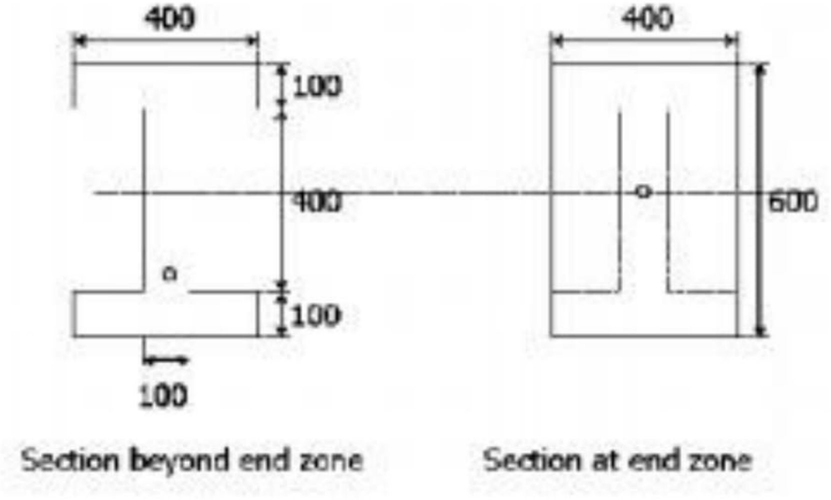
Once the concrete in the slab has hardened and the imposed load acts on the composite section, the additional stress distribution is shown in Fig.. This is determined by ordinary bending theory, but using the composite section properties.

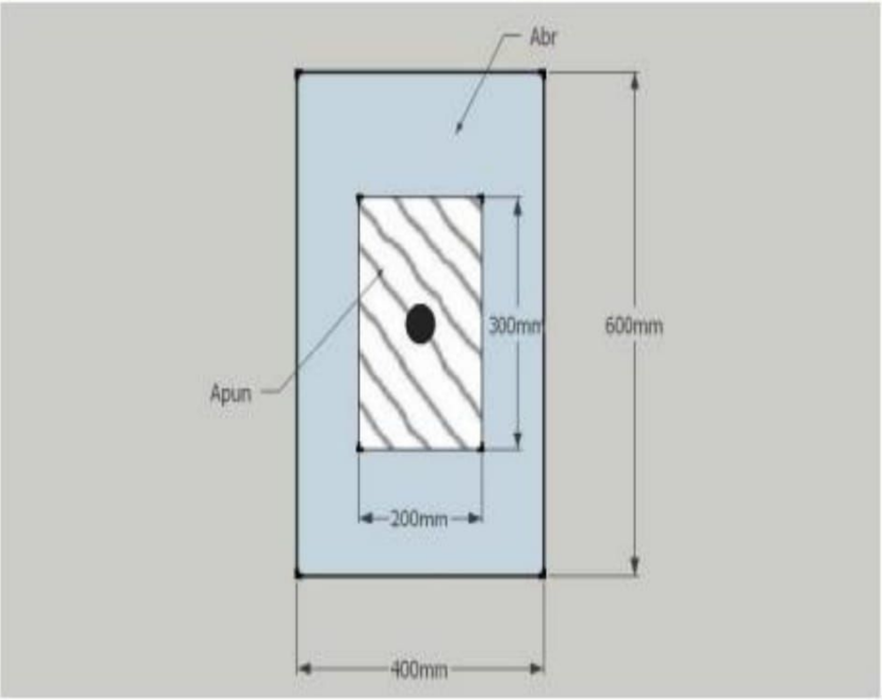
The final stress distribution is shown Figure



Bearing plate & End block

Design the bearing plate and the end zone reinforcement for the following bonded post-tensioned beam. The strength of concrete at transfer is 50 MPa. A pre-stressing force of 1055 kN is applied by a single tendon. There is no eccentricity of the tendon at the ends.





Bearing Plate

Assume area of bearing plate to be 200 mm x 300 mm

$$f_{br} = \frac{P_K}{A_{pun}}$$

P_K = 1055 kN

A_{pun} = 200 x 300 = 60000 mm^2

$f_{br} = \frac{1055\times10^3}{60000}$ = 17.58 MPa

A_{br} = 400 x 600 = 240000 mm^2

$$f_{br,all} = 0.48 f_{ci}\sqrt{\frac{A_{br}}{A_{pun}}}$$

$$= 0.48 \times 50\sqrt{\frac{240000}{60000}} \qquad = 48 \text{ MPa}$$

$$\leq 0.8 \times f_{ci} = 40 \text{ MPa}$$

$$f_{br} \leq f_{br,all} = 40 MPa$$

End Block

In vertical direction

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

$$= 1055\left[0.32 - 0.3\frac{300}{600}\right] \qquad = 179.35 \text{ kN}$$

In horizontal direction

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

$$= 1055\left[0.32 - 0.3\frac{200}{400}\right] \qquad = 179.35 \text{ kN}$$

$$A_{st} = \frac{F_{bst}}{0.87 f_y}$$

$$= \frac{179.35 \times 10^3}{0.87 \times 250} \qquad = 824.60 \text{ mm}^2$$

Provide 10 mm 2L stirrups in both directions as F_{bst} is same in those

$A_w = \frac{\pi \times 10^2}{4} = 78.54\ mm^2$

No of stirrups $= \frac{824.60}{2 \times 78.54} = 6$ Nos

Provide $\frac{2}{3}^{rd}$ A_{st} from 0.1 y_o = 60 mm to 0.5 y_o = 300 mm and $\frac{1}{3}^{rd}$ A_{st} from 0.5 y_o = 300 mm to y_o = 600 mm, both vertically and horizontal.