Design of Structures II

Lecture – 20

Here we are having a look on a subject Design of structure II, in the previous lecture we have seen in detail about how to find the moment of inertia of the doubly reinforced flange section. And we have found the moment of resistance for three cases that is when the neutral axis lies inside the flange and two cases when the neutral axis lies outside the flange. And also we have worked problems on this three cases.

In this Lecture we are going to flange or we are going to design the section. In the previous lecture we have find the moment of resistance of the reinforced section. Here we need to have some practice on design of flanged section. Here for designing i.e., for finding the area required for two cases that is when the neutral axis lies within the flange or outside the flange. This will be given as to determine the A_{St} on worked examples for the following cases such as,

- $X_u \leq D_f$
- $X_u \rhd D_f$

We are going to work out two problems that are,

1. Determine the reinforcement required for a T-beam to resist a M_u of 360kNm with the following data. Width of flange = 1500mm; Depth of flange = 100mm; Width of rib = 300mm; Effective depth = 500mm; Materials = M20 and Fe415.

Solution:

Here normally to design a flange section we will use Roorkee design handbook for RCC structure of the flanged section for the structures in this I have taken certain provisions design of the flanged section. Here they have given a singly reinforced rectangular section there is also certain provision designs for the singly reinforced section in Roorkee design. We can also design both singly reinforced and doubly reinforced section by referring the Roorkee design handbook. By referring the table in the handbook we can design the area of reinforced section for the flanged section.

They have given a T-section with the values,

$$M_u = 360kNm; b_f = 1500mm; D_f = 100mm$$

$$b_w = 300mm; d = 500mm$$

The materials are M20 and Fe415. They ask as to find the area of the reinforced section. Here first we need to find whether the neutral axis found inside the flange or outside the flange. So first they ask us to,

i. **Compute** $\frac{D_f}{d}$ & $\frac{b_f}{b_w}$

By doing this one we need to analyze whether the neutral axis found inside the flange or outside the flange and depending upon that we are going to design the section. If it is confirmed that the neutral axis lies outside the flange than that section has to be considered as rectangular section. When the neutral axis lies inside the flange then that section should be designed as a T-section.

$$\frac{D_f}{d} = \frac{100}{500} = 0.2$$

$$\frac{b_f}{b_w} = \frac{1500}{300} = 5$$

ii. **Compute** μ_w**:**

Where, $$\mu_w = \frac{M_u}{f_{ck} b_w d^2}$$

$$= \frac{360 \times 10^6}{20 \times 300 \times 500^2}$$

$$= 0.24$$

iii. **To obtain μ_w from the table flexure 7.6 for the volume of $\frac{b_f}{b_w}$ & $\frac{D_f}{d}$**

So here using the table flexure 7.6 for the values of $\frac{b_f}{b_w}$ & $\frac{D_f}{d}$ that is calculated above as 0.5 and 0.2. Therefore we get the value $\mu_w = 0.334$

iv. **Compute calculated μ_w with obtained μ_w:**

This is to confirm whether the neutral axis lies within the flange or outside the flange. If calculated μ_w is less than the obtained μ_w i.e., $0.24 > 0.334$ it confirms that the neutral axis lies within the flange.

v. **It has to be designed as Rectangular section of size $b_f \times d$.**

vi. **Compute** $\mu_u = \mu_w \times \frac{b_w}{b_f}$

$$= 0.24 \times \frac{300}{1500}$$

$$= 0.048$$

For this we need to compare the percentage of tensile reinforcement that is the constant k.

vii. Compute k:

This is the value k to find out the percentage of reinforcement from the table.

$$k = \mu \times f_{ck}$$
$$= 0.048 \times 20$$
$$= 0.96$$

viii. From table flexure 2.1 B, obtain $P_t = 0.282$

This is the percentage of reinforcement we have found from the flexure 2.1B for the corresponding k is equal to 0.96.

ix. To find A_{St}:

So A_{St} is normally calculated from the percentage of reinforcement that is,

$$P_t = \frac{100 A_{st}}{b_f d}$$

$$A_{st} = \frac{p \times b_f \times d}{100}$$

$$= \frac{0.282 \times 1500 \times 500}{100}$$

$$= 2175 mm^2$$

If you assume the diameter of reinforcement that is diameter bar has 25mm. The number of bar is equal to,

$$= \frac{2115}{\pi/4 \times 25}$$

2. Determine the reinforcement required for a T-beam to resist a M_u of 600kNm with the following data. Width of flange =1500mm; depth of flange = 100mm; Width of rib = 300mm; Effective depth = 500mm; Material = M20 and Fe415.

Solution:

Here in this problem we need to check whether neutral axis lies with the flange or outside the flange. If it is outside the flange the beam has to be designed as a T-section. The data given in this problem are,

$$M_u = 600kNm; b_f = 1500mm; D_f = 100mm$$

$$b_w = 300mm; d = 500mm$$

Materials given are M20 and Fe415 that is $f_{ck} = 20N/mm^2$ and $f_y = 415N/mm^2$. They ask us to design the A_{St}.

i. **Compute** $\frac{D_f}{d}$ & $\frac{b_f}{b_w}$

$$\frac{D_f}{d} = \frac{100}{500} = 0.2$$

$$\frac{b_f}{b_w} = \frac{1500}{300} = 5$$

ii. Compute $\mu_w = \dfrac{M_u}{f_{ck} b_w d^2}$

$$= \frac{600 \times 10^6}{20 \times 300 \times 500^2}$$

$$= 0.4$$

This is the calculated μ_w value which is equal to 0.4. Next we need to obtain the value of μ_w from the Roorkee design handbook and then we need to compare these values to find whether the neutral axis lies within the flange or outside the flange.

iii. Using table flexure 7.6 for the values of $\dfrac{D_f}{d}$ & $\dfrac{b_f}{b_w}$ and obtain the value of μ_w. This is known as the obtained μ_w, which is equal to 0.334.

iv. We need to compare the calculated μ_w with the obtained μ_w. Here calculated μ_w is greater than obtained μ_w i.e., 0.4 > 0.334. So here neutral axis lies outside the flange. And we confirmed that it is designed as T-beam.

v. We need to find out whether it is under reinforce or over reinforce. So obtain μ_w for $\varepsilon = \varepsilon_{\lim}$ which is equal to 0.479. For this they obtained the μ_w value from the Roorkee table as 0.464 from the table flexure 6.4.

vi. Now we compare this μ_w with the calculated μ_w. That is the calculated μ_w is less than the obtained μ_w for $\varepsilon = \varepsilon_{\lim}$ that is 0.479. So it is designed as singly reinforced T-beam.

vii. Now obtain ω_w for μ_w which is equal to 0.4 i.e., from table flexure 7.6 of Roorkee handbook.

$$\omega_w = 0.511$$

viii. Compute the percentage of tensile reinforcement that is compute the area A_{St} for singly reinforced T-beam. Next we need to find out A_{St} ,

$$A_{st} = \omega_w b_w . d \frac{f_{ck}}{f_y}$$

$$= \frac{0.511 \times 300 \times 500 \times 20}{415}$$

$$= 3694 mm$$

This is the way to calculate the area of reinforcement for the singly reinforced T-beam.

Summary:

In this lecture we have seen two problems. In the first one we have seen the neutral axis lies within the flange and in the second problem the neutral axis lies outside the flange. And we have checked it whether it is singly reinforced section or doubly reinforced section. Then we have formed the area of the singly reinforced T-beam. We have designed the T-section by referring the Roorkee handbook. If the neutral axis lies within the flange we can design it a the rectangular beam and if it lies outside the flange we can design it as a T-beam.

Questions:

1. Determine the reinforcement required for a T-beam to resist a M_u of 400kNm with the following data. Width of flange = 1250mm; Depth of flange = 100mm; Width of rib = 250mm; Effective depth = 550mm; Materials = M20 and Fe415.
2. Determine the reinforcement required for a T-beam to resist a M_u of 900kNm with the following data. Width of flange = 1100mm; Depth of flange = 120mm; Width of rib = 275mm; Effective depth = 600mm; Materials = M20 and Fe500.