Design of Structures II

Lecture 8

Analysis of Flanged Section 1

For example this a hall which is having a column arrangement like this. These are all the column location of column which has been arranged for the design of slap system. A slap system for the building now how to provide the slap system for this case. Normally we are connecting by column by means of the beam and providing slap over the beams. So here this is the cross section or longitudinal section of the slap which is supported over the beams. These beams are normally designed as lied has tear in the beams. So here the intermediate beams are designed as T beams here the T beams with flange portion is called T beams. That is flange on either side of the web portion and the L beam inverted L that is called as inverted L beam that is called as L beams it's in the shape of inverted L. so here in the case of L beam having the flange only one side the edge beam are designed as L beams or analyzed as L beams.

Only the difference between the two beams are it is in the shape of letter T and it is in the shape of letter inverted L. but in the case of T beam either side of the web portion or either side of the rectangle portion. But here the flange which is having only one side of the web portion. But the analysis and design of these two beams are almost same these two beam are generally called as flanged beams. So the least analysis and design of these two beams are almost same only the different is the flange portion. The case of T beam provided flange on either side web portion but in the L beam the flanges provided on only one side.

So now we are going to start analyzing T section that is flanged section. Here also it is having three section one is balanced section under reinforced section and over reinforced section we have already discuss in detail about these three section anyway I am repeating. Normally the reinforce member design on the basic assumption that the stress in the materials reaches their maximum permissible stress at the same time both the material stress to their allowable stress one in the same time the section will be called as balanced section. In the case of under reinforced section so the under reinforced section normally we are know that from the under reinforce it is less it has less steel. So if less steel than that required for the balanced sectionis provided that is under reinforce section. In this section the steel is stress to maximum permissible value first well the concrete is stressed below the permissible value under such condition this beam will fail initially due to over stress in steel. So the type of failure occur in the case of this under reinforced section is tension failure or ductile failure. Now we come to over reinforced it automatically known as if the beam over the reinforced the steel is provided more. If the steel is provided more than in the required for balanced section will called as over reinforced section.

In such condition in this section the concrete is stress to maximum permissible value first will the steel is below the maximum permissible value. In such condition this section will fail initially due to over stress in concrete so the type of failure which is normally occur in the case of this section is brittle failure or sudden failure. So these two section are called as unbalanced section normally. So in the case of unbalanced section the neutral axis going to situated center of gravity of the section. In the case of under reinforce section the failure of section is a tension failure the steel is stress towards the maximum permissible value first. So here we are using more amount of concrete the neutral axis going to situated center of gravity of the section since it is the neutral axis moves upwards. So here when compare X with Xc here X is less than Xc. But in the case of balanced section

X = Xc Where X is the actual depth of the neutral axis for the unbalanced section Xc is neutral axis for balanced section.

But in the case over reinforced section we are using more steel automatically the concrete area will less. So it move towards the bottom the neutral axis going to situated center of gravity of the section it move towards the bottom. So here

X >Xc

That is the neutral axis portion of the unbalanced as well as balanced section. Once we find out Xc and find X we have compare to X with Xc. If X is less than Xc we need to conclude our section is unbalanced section. If X is greater than Xc we need to concluded our section is over reinforced section. If X is equal to Xc we need to conclude our section is balanced section. Now to find out the moment of resistance of a single reinforce T or L section. Normally the single reinforce the section which is provided the reinforcement the tension zone only is called as single reinforce.

This is T beam this is flange portion or slap portion the projected portion is called as web portion. If the beam is reinforcement at the tension zone thatis called as single reinforce tension zone only is called as single reinforce. Now how to find the moment of resistance T beam so here there are two cases when the neutral axis lies inside the flange. Here the neutral axis when the neutral axis lies inside the flange over the moment of the resistance of the beam. That is a case 1

X less than or equal to Df

It means the neutral axis lies within the flange or just at the bottom of flange that is

X less than or equal to Df

When the neutral axis lies within the flange what is the moment resistance of the beam and when the neutral axis lies out with the flange what will be there moment resistance of the beam that is

X less than or equal to Df

Now are going to look on

X less than or equal to Df

So here this is T beam and b_f is the width of the flange and D_f is the depth of the flange since it is simply reinforce section. The beam is reinforce at the reinforcement at the tension zone. So here d is the effective depth of the beam and b_w is the width of the beam. Now taking central axis for this one for example now this is the stress equivalent stress diagram for balanced section. In the case of the balanced section both the material are stress to their maximum permissible value one at the same time. So the stress at the top most extreme fiber is taking as σ_{cbc} and stress at the bottom most fiber is taking as$\sigma_{\frac{st}{m}}$. So here this is x_c and this will be d - x_c since it is a balance section. By using similar triangle property we can find out what is x_c

$$\frac{x_c}{\sigma_{cbc}} = \frac{\mathrm{d} - x_c}{\sigma_{\frac{st}{m}}}$$

Where as$\sigma_{\frac{st}{m}}$ is the stress in concrete surrounding the tensile steel. So this is we have already discussed in the previous right angular section. How that area of the steel is transfer into the equivalent area of concrete surrounding the tension steel. So this is $\sigma_{\frac{st}{m}}$ the stress in concrete surrounding the tensile steel and if it is A_{st} area of steel m * A_{st} we all known that equivalent area of concrete surrounding the tensile steel. If it multiplied by modular ratio that is m * A_{st} we all known that equivalent area of concrete surrounding the tensile steel.

Now to find out x now first case the neutral axis lies within the flange this stress diagram so here I am taking it as x so this is case (1) X $\leq D_f$ Now to find out x here this is the unbalanced section when the neutral axis lies within the flange depth of neutral axis. Normally in the case of unbalanced section the neutral axis situated the center gravity of the section. So here find out the actual depth of neutral axis we need to equate moment of area on compression side to the moment of area on tension side. Moment of area is we all know that moment of area equal to area into distance of center of gravity from the neutral axis. Distance of center of gravity area from the neutral axis. Moment of area on compression side is equal to moment of equivalent concrete area on tensile side.

Since we have already transfer the area of steel in to the equivalent concrete area surrounding on tensile steel. So we have to equate moment of area on compression side to the moment of equivalent concrete area on tensile side. So moment of area on compression side is area of the compression side that is

b_f * x

Distance of CG of this compression side from the neutral axis is $\frac{x}{2}$ which is equal to moment of equivalent concrete area on tensile side here it ism * A_{st} the distance of CG of tensile steel from the neutral axis is d – x. so this is the way of finding the neutral axis for the first case when

X ≤ D_f

The neutral axis lies inside the flange find out the moment of resistance first one we find out x we have to compare depth of flange when it is finalizes here

X ≤ D_f

The neutral axis lies inside the flange and also check x with theX_c. If X is less than X_c we need to conclude our section is unbalanced section. If X is greater than X_c we need to concluded our section is over reinforced section. Now what is the moment of resistance for under reinforced section?

M_r = T * Z

In the case of under reinforced section the steel is stress to the maximum permissible value. So the failure of section here it is tensile failure or ductile failure. So what is T here T is normally force $A_{st}\sigma_{st}$ that is force is stress into area.

Now here this is the compressive force C which is acting at $\frac{x}{3}$ from the top most extreme fiber and T is the tensile force which is offered by the reinforcement and distance between these two forces is called from Z that is d - $\frac{x}{3}$.

M_r =$A_{st}\sigma_{st}$ * d - $\frac{x}{3}$.

And another formula

M_r = C * Z

Where c is the force that is stress into area. So here area is b_f * x and the stress is since the stress diagram is there triangular one if you take σ_{cbc} stress at the top. The average stress $\frac{\sigma_{cbc}}{2}$ * d - $\frac{x}{3}$

M_r =b_f * x * $\frac{\sigma_{cbc}}{2}$ * d - $\frac{x}{3}$

What is this mean the moment of resistance of the T section the neutral axis lies within the flange? So here this the moment of resistance which is equal to the moment of resistance of the rectangular section. So here we come to conclude that the neutral axis lies within the flange the T beam should be designed as a rectangular size of b_f * d. so when the neutral axis lies within the flange it means that the beam has to be designed as rectangular beam and the beam has to be designed as a T beam.

Analysis of Flanged Section 2

If X is greater than X_c or the X is greater thanD_f the beam has to be designed as a T beam. Now second case T beam and b_f is the width of the flange and D_f is the depth of the flange and b_w is the width of web and since it is simply reinforce section. The reinforcement of the tensile zone is A_{st} and d is the effective depth of the section. Now here the neutral axis lies outside the flange. Now here this is an equivalent stress diagram of balanced section now I am takingσ_{cbc} is the stress at the top most extreme fiber and $\sigma_{\frac{st}{m}}$stress in concrete surrounded tensile stress the balance section both the material has maximum permissible value one in that the same time. And X_c is depth of neutral axis for the balanced section that is critical depth of neutral axis d - X_c is the remaining depth. Now first step to find X_c so since it is balanced section I am using similar triangle property

$$\frac{x_c}{\sigma_{cbc}} = \frac{\mathrm{d} - x_c}{\sigma_{\frac{st}{m}}}$$

So this is the formula to find out X_c or it may be return as

$$\frac{x_c}{\mathrm{d} - x_c} = \frac{\sigma_{cbc}}{\sigma_{\frac{st}{m}}}$$

Now we need to find out actual depth of neutral axis for the section, so here I am taking as an equivalent stress diagram for unbalanced section this is for balanced section and this for unbalanced section. I am taking x is depth of the neutral axis and this will be the d – x so here when the neutral axis lies out the flange the portion above the neutral axis are divided into two portion one will be the flange portion and the remaining will be the web portion. So when the neutral axis lies outside when the beam is in the shape of T section so when x is greater than $D_f$the beam should be designed as T beam. When the neutral axis lies within the flangex is less than or equal toD_f the beam has to be designed or analyses as a rectangular beam. So here to find out x for the unbalanced section the neutral axis is going to situated under the center of gravity of the section so we need to find out the depth of neutral axis by equating the moment of area to compression side to the moment of area to tensile side.

So the moment of area to compression sideto the moment of equivalent concrete area on tensile side. The moment of area to compression sidehaving the two portion above the neutral axis first portion the flange portion that is

$b_f * \ D_f$

This is the area of the flange portion divided the portion above the neutral axis has compression portion. The two portion one is flange portion and another one is web portion. And this is taken as x - D_f and this is one the depth of neutral axis taken as x and the remaining will be taken as x - D_f. So the first one is the flange portion $b_f \ * \ D_f$ and distance of CG of flange portion from the neutral axis here it is. So this $\frac{D_f}{2}$normally the CG of this portion at the center that is $\frac{D_f}{2}$so what is the CG of this flange portion from the neutral axis $\frac{\mathrm{x} - D_f}{2}$this is moment of area of flange portion plus moment of area of web portion

$b_w *$ x - D_f

And CG of the portion is normally occurred as the center of this portion. If this $\frac{\mathrm{x} - D_f}{2}$and this will be again $\frac{\mathrm{x} - D_f}{2}$the depth of portion is x - D_f and the CG at the center $\frac{\mathrm{x} - D_f}{2}$and the CG of this portion fromthe neutral axis $\frac{\mathrm{x} - D_f}{2}$this the moment of area of the flange portion f and this the moment of area of the web portion w so here it is totally moment of area of compression side which is equal to the moment of equivalent concrete area on tensile side

b_f * $D_f(\frac{x - D_f}{2})$ + b_w * x - $D_f(\frac{x - D_f}{2})(\frac{x - D_f}{2})$ = m A_{st}(d – x)

So this is the formula which is find out but here what is say that the moment of area of the web portion to small compare to the flange portion. So the moment of area of the web portion is very smallhence it is neglected

b_f * D_f $(\frac{x - D_f}{2})$ + b_w * x - $D_f(\frac{x - D_f}{2})$ $(\frac{x - D_f}{2})$ = m A_{st}(d – x)

So this equation can be rewritten as

b_f * D_f $(\frac{x - D_f}{2})$ = m A_{st}(d – x)

So this is the formula which is used to find out the depth of neutral axis by equating the moment of area of the web portionto the moment of area of the flange portion. Now we need to find out what is moment of resistance so again we are going to find out moment of resistance of the section. So here in this section X is greater than X_c the neutral axis lies within the flange section. If X is less than X_c it is under reinforced section and the moment of resistance of the section

M_r = T * Z

Before that we considered the flange portion and σ_{cbc} is the actual σ_{cbc} at the top most extreme fiber andσ_{cbc}' is the stress at the bottom of the flange so here we have the stress diagram here it is trapezoidal one and I am considering C be the total compressive force offered by the compression zone which is acting at the CG ȳ. So here the stress diagram is trapezoidal one this σ_{cbc} and this σ_{cbc}'. So here the corresponding tensile force is taken as T and distance between these two forces are (d - ȳ). So we need to find what this taken as D_f I am going to find the moment of resistance

M_r =A_{st} * σ_{st} * (d - ȳ).

Where ȳ = ($\frac{\sigma_{cbc} + 2\sigma_{cbc}{}'}{\sigma_{cbc} + \sigma_{cbc}{}'}$) * $\frac{D_f}{3}$

This is the moment of resistance of the beam and here next one if X is greater than X_c it is over reinforced section

M_r = C * Z

M_r= b_f * D_f ($\frac{\sigma_{cbc} + \sigma_{cbc}{}'}{2}$)* (d - ȳ).

This is the equation we have derived. So where ȳ is

ȳ = ($\frac{\sigma_{cbc} + 2\sigma_{cbc}{}'}{\sigma_{cbc} + \sigma_{cbc}{}'}$) * $\frac{D_f}{3}$

So this is the way of finding the moment of resistance of the flanged section when the neutral axis lies outside the flange the beam has to analyze as the flange portion or flange section.

That also about the moment of resistance of the flange portion.