Design of Structures II

Lecture 7

Welcome to the UGC lecture series in B.Architecture. Let us have a discussion on Design of Structures II, Unit 1 - lecture 7. In this one, we are going to design the doubly reinforced rectangular section. In the previous lecture, we have seen how to find out the moment of resistance, how to analyze the doubly reinforced rectangular section and how to find out the moment of resistance of the section. Using the expressions of the moment of resistance of the doubly reinforced sections we are going to find out what is the reinforcement required for the doubly reinforced section. This doubly reinforced section normally consists of the reinforcement at the bottom as well as at the top. So, at the bottom it consists of Ast_1 as well as Ast_2. Total Ast = Ast 1 + Ast_2 and at the top it is taken as Asc. Here, how do we find out the reinforcement? In the case of doubly reinforced section, we first need to decide whether the section is a balanced singly reinforced section i.e Design of Doubly reinforced rectangular section. Here our aim is to find out Ast_1, Ast_2 and Asc.

This is one formula which is used to find out the moment of resistance. Another formula is;

$Mr = Ast_1 \sigma st (d - x/3) + Ast_2 \sigma st (d - d')$

Now, to first find out Ast_1; Assume our section is balanced singly reinforced section. When you want to find out the balanced singly reinforced section, we need to first find out Xc.

Once we find out xc, we can find out Ast_1. Once, you find out moment of resistance of balanced singly reinforced section is given;

This is the moment of resistance of the balanced singly reinforced section. Here, this is the moment of resistance of the singly reinforced section. This is the moment of resistance due to compression reinforcement. Once you find out the moment of resistance of the balanced singly reinforced section, we can easily find out what is the area of Ast_1 required for Mr i.e

$Mr = Ast_1 \sigma st (d - xe/3)$

This is the expression required to find out Ast_1 required for a balanced singly reinforced rectangular section and another one is, it can be found from equating these two things i.e C_1 to T_1 i.e compressive force C_1 to T_1 or by equating C_1 to T_1 at the neutral axis.

Using this expression we can easily find out Ast_1. Then to find out Ast_2 and Asc. How to find out Ast_2? The total moment of resistance is this one, we have found the moment of resistance of the balanced singly reinforced section and total M is given in the problem. So, total Moment;

$M = Mr + M1$

M1 is the moment of resistance due to the compression reinforcement and due to Ast_2. So, to find first M1 i.e excess moment.

$M1 = M - Mr$

So for M1, find Ast_2 and Asc. For this excess moment we are going to find out Ast_2 and Asc. So,

$M1 = Ast_2 \sigma st (d - d')$

So from this, this is Mr. If you take this as M, this is M1.

Now, to find Asc; by equating this C_2 and T_2 i.e

$(1.5m - 1) Asc \sigma cbc' = Ast_2 \sigma st$

From that, we can easily find out what is Asc.

This is one expression. These are the expressions used to find out (or) we can also find out using;

$M1 = (1.5m - 1) Asc \sigma cbc' (d - d')$

i.e this expression.

This is the formula to find out the area of steel required for the doubly reinforced section. Now, here to design the section.

To find xc, first we are finding xc, then by equating C_2 T we are finding Ast_1. Then we are finding moment of resistance of the balanced section and we are finding the excess moment, M - Mr, for the excess moment we are finding Ast_2 and also we are finding Asc by equating the area of equivalent tensile steel to the compressive steel above the neutral axis. Now, we need to design the section. Here, they have given the section i.e the first problem - a doubly reinforced section is given, this is reinforcement at the tension zone. So this is Ast which is equal to;

$Ast_1 + Ast_2$

and this is Asc, which is placed at d' from the topmost extreme fibre. Now here, the section is 360 x 750mm i.e

b = 360mm
d = 750mm

Now, the beam has to resist the bending moment of 300 kNm.

M = 300 kNm

and to find the tensile and compressive steel required for σ cbc = 7 and σ st = 190

σcbc = 7N/mm ²
σst = 190 N/mm ²
d' = 50 mm
Ast = Asc

Now first to find out xc.

xc = 247mm

So first by assuming, it is balanced singly reinforced section. So balanced singly reinforced, we have found xc. Now, to find out Ast_1 for balanced singly reinforced section. Before that, we need to find out Mr of balanced singly reinforced section i.e

$$Mr = 360 \times 247 \times \frac{7}{2} (750 - \frac{247}{3})$$

= 207.8 kNm
Now, to find Ast_1 for balanced singly reinforced section. At the neutral axis;

$C_1 = T_1$ i.e

(or)

$Mr = Ast_1 \sigma st (d - Xc/3)$

This is the moment of resistance of the balanced singly reinforced section. We can also use this expression to find out Ast_1.

So here by substituting; we get

= 1638mm ²

Now, to find out Ast_2 and Asc for Excess moment. The excess moment i.e the remaining moment.

M1 = M - Mr

M is given in the problem

= 300 - 207.8

For this excess moment, we are going to design Ast_2 and Asc since it is doubly reinforced section.

= 90.2 kNm

Now, to find out Ast_2;

M1 = Ast_2 σst (d - d') = 693.23mm ²

But total Ast;

$Ast_1 + Ast_2$

= 1638 + 693.23

= 2331.23mm ²

So total Ast. Now, to find Asc;

M1 = (1.5m - 1) Asc σ cbc'(d - d')

(or)

(15m.1) Asc σ cbc' = Ast_2 σst = 1242.14mm ²

So, that is all about the design of the doubly reinforced rectangular section. So here, we have used one worked example to find out the design of the doubly reinforced rectangular section. So here, they have given the size of the beam and the beam has to resist the moment of 300 kNm and they have asked us to design the reinforcement i.e both tensile and compressive steel reinforcement. So here, the stresses in concrete and steels are given in the problem. So we have started designing the section. First we have found the area of reinforcement required for a balanced singly reinforced section. At neutral axis, $C_1 = T_1$ (or) the moment of resistance;

$Mr = Ast_1 \sigma st (d - xc/3)$

we have found the Ast_1 required for it and we have found the excess moment i.e The excess moment is the given moment minus the moment of resistance of the balanced singly reinforced section i.e 90.2. For the 90.2 kNm, we have found Ast_2 and we have found the total Ast and for finding out Asc, we have equated the moment of area of the compression side to the moment of area at the tension side (or) we can use this expression to find out the Asc required for it i.e 1 - 4.14. So here, if you want to find out i.e here this is the total Ast, we can assume the diameter of the reinforcement and find out for example, as in diameter. 25mm diameter, we can find out number of bars required for it.

We can easily provide how many numbers of reinforcements required for it. At the same time here also, assume the diameter of reinforcement. I can also have 16mm diameter bar. So, number of bars is equal.

So, we can easily find out how many numbers we need to provide. So, this is the rectangular section. We can easily provide the reinforcement required for it. If this is Ast, this is Ast and this is Asc and this is the size of the section;

Now, let us summarize this lecture. In this lecture we have discussed about the working stress design method of a doubly reinforced rectangular section. We have worked out one example, in this example they have given the size of section, as well as the stresses in the concrete and steel. They have asked us to design the area of reinforcement required for it. Since, it is a doubly reinforced section, we need to find out the area of steel required at the tension zone as well as at the compression zone. In the case of tension zones, it consists of Ast_1 and Ast_2. Ast_1 is used to find out, the area of reinforcement required for the balanced singly reinforced section and Ast_2 is used to balance the reinforcement which is provided at the compression zone. For finding out Ast_2 we are finding out the excess moment i.e excess moment which is found from the total moment minus the moment of resistance of the balanced singly reinforced section. For that excess moment, we are providing the additional tensile reinforcement at the bottom, that is taken as Ast_2 and for balancing that one, we are provided with the reinforcement at the

top. For M1 also, we have provided the reinforcement at the compression zone i.e Asc. This, Ast_2 is used to balance this Asc, that is called as additional tensile reinforcement i.e Ast_2. So the total Ast is normally called as $Ast = Ast_1 + Ast_2$

This is the way we have designed the doubly reinforced rectangular section by using one worked example and the questions.

In the question here as well, they have asked us to design the section by giving a size of section, as well as the external moment carrying capacity of the beam. So here, the doubly reinforced concrete beam, 250mm vibe and 600mm deep overall, has to resist an external bending moment of 95 kNm. Find the amount of tensile steel and compressive steel required. If covered to the centre of the steel on both sides is 50mm. Here, they have given; σcbc = 5 N/mm ² and σst = 140 N/mm². So here also, first we need to assume our section is a balanced singly reinforced section. We need to first find out what is the Ast required for the balanced singly reinforced section i.e at the neutral axis, $C_1 = T_1$. Find out Area of reinforcement i.e Ast required for the balanced singly reinforced section and we need to find out what is the moment of resistance of the balanced singly reinforced section. Then, normally we know that the moment of resistance of the doubly reinforced section is the moment of resistance of the balanced singly reinforced section plus the moment of resistance due to the compression reinforcement. So here, we need to first find out what is the moment of resistance of the balanced singly reinforced section. The total moment of the problem is given in the problem i.e the moment of doubly reinforced section which must be equal to the moment of resistance of the balanced singly reinforced section plus the moment which is provided for the additional tensile reinforcement and the compression reinforcement. Again we need to find out the excess moment. Excess moment, M1 equal to the total moment that is given in the problem minus the moment of resistance of the balanced singly reinforced section. So for that excess moment M1, we need to find out what is Ast_2. Then for finding out Ast by equating the moment of area on compression side which is equal to the moment of area of tension side i.e

$(1.5m - 1)\ Asc\ \sigma\ cbc' = Ast_2\ \sigma\ st$

So, Asc we can easily find out from this expression. So, totally we can find out Ast_1, Ast_2 and Asc. So, here total $Ast = Ast_1 + Ast_2$ and Asc we have found. So this is the question. With regard to the references, we need to refer; IS456:2000 i.e Plain and reinforced concrete - Code of Practice and we can also refer a book in order to work out more examples i.e Reinforced concrete design by S.N Sinha. Let us come to the end of this lecture, thank you!