Design of Structures – II

Lecture – 21

In the previous lecture we have seen the analysis and design of rectangular beam at singly as well as doubly reinforced section and analysis and design of singly as well as doubly reinforced section. We have seen in detail about how to calculate moment of resistance of the rectangular singly and doubly reinforced. Also we have seen how to calculate moment of resistance.

Here in this lecture we are going to design the continuous beam using IS coded coefficients by means of limit state design method. In this case first we need to determine load acting on the beam and need to determine moments using IS code coefficients. And then need to determine the effective depth of section, to determine the Ast requited and to check the depth of the section 'd' for deflection.

I need to first explain how to design, this is the coded table for bending moment coefficients at varies places for varies types of loading condition in the case of IS 456:2000. We are also going to solve some problems based on this coded coefficients. Before that first we need to know about the behavior of the continuous beam. Let us take a continuous beam with the columns. This is called as five span continuous beams. Then how to find out the bending moment for this cases, that is there are several coded provisions for finding out the bending moment at varies cases of continuous beams in IS 456:2000. Here we need to know the behavior of the continuous beam when it is subjected to uniformly distributed load which is WkN/m. Due to this load the beam will defect like this.

This is the deflection nature of the continuous beam. The portion in between the supports which is getting deflected downwards and the portions exactly over the supports deflected upwards. Here this deflection beams which resembles bending moment diagram of a continuous beam. The moment developed over this point is called as Sagging moment. Sagging moment are normally positive bending moments.

And the bending moment due to the deflection of beam is known as the hogging moments and these moments are normally negative bending moment. The moment in between the support is known as span moments. And the moment exactly over the supports are called as support moments.

In the case of span moment there are two different moments which are end spans and interior spans. So now we are going to find out the moment at the middle of end spans. And the moment at the middle of the interior spans. Now coming to supports moments, this two supports are called as support next to end supports and this two supports are called as interior supports. So we are going to find the bending moment at the support next to the end support and to the interior support. Normally the bending moment at end support if it is fully supported the bending moment will be zero. If you have the further construction above the beam then the beam will be deflected upwards normally. Since a partial resistance is developed at the end. So due to this partial resistance at the end there is a bending moment at the top. This partial bending moment is very small which is equal to $\frac{Wl^2}{24}$.

So the IS coded coefficient is given certain moment coefficients for this four bending moment along with the certain conditions. The conditions are in the case of continuous span, the condition span should have more than minimum of three spans. In addition to that the load must be uniform throughout the entire length of the beam. If there is any variation in the load or as well as in the span, we need to find this using any one method which are available. But if the spans are not differ more than 15% of the longest than the coded coefficient can be used to find out the bending moment and also the load should not be varied more than 15%.

If in the case of the varying span meets the varying load then how to calculate the bending moment at the load. That is average of this bending moment and average of bending moment from the two different spans has to be taken in the account for finding the moment at the support. When the moment which is transferred to this span to the support we need to find out the moment which is transferred from this span to the support. And average of this two moment to be taken as the moment at this support. This is the coded coefficient given in the IS 456:2000.

And if you are using this coded coefficient that is the moment coefficient for finding the bending moment at varies places the redistribution moment should not be taken place. This is the introduction about the deflection nature and moment how to find out the moment for the continuous beam there are four moments we are going to find. And how to find the depth of the beam among this four bending moment we need to select the maximum bending moment. For the maximum bending moment we are going to find out the effective depth of the beam. But in the case of writing reinforcement we need to find out the reinforcement for these four moments and has to be placed at the respective places.

Now this is the coded moment coefficient given in the code book. So here there are span moments and support moments and they have given the dead load and the impose load. Some impose load are considered as dead loads for example when the class room. If stage where created where the slab is fixed that has to be taken as the impose load which is considered as dead load. But normally the load which are not fixed with the slab are called as impose load otherwise called as the dead loads. We are all the movable loads and considered as live load. There are moments given for the dead and the live load correctly. Near the middle of fence span the moment coefficients are given.

First we will see the moment coefficient means, here for example in the case of the simply supported beam which is subjected to the uniformly distributed load. The span here it is lw and the bending moment is equal to which is normally $\frac{Wl^2}{8}$. This 1/8 is called the moment coefficient for the bending moment. And again it has to be multiplied by the total load wl and then by l, therefore we can get the value $\frac{Wl^2}{8}$. This is the way of calculating the moment using coded coefficients. Here W_d is the dead load and the total dead load is W_dL, that has to be multiplied by the effective span l.

For the bending moment at the middle of the moment due to the death load and the live load is $\frac{W_d l^2}{16}+\frac{W_d l^2}{12}$. And the support moment at support next to the end support is $-\frac{W_d l^2}{10}-\frac{W_l l^2}{9}$ and at other interior supports is equal to $-\frac{W_d l^2}{12}-\frac{W_l l^2}{9}$.

Now we are going to use this moment coefficients in solving problems.

1. Design the size find the reinforcement required for a for span continuous beam of effective span 4m subjected to a total live load of 25kN/m. Use M20 and Fe415 as materials.

   Solution:

   There is a four span continuous beam is given in the problem. The span of beam is 4m and they have given the live load on the beam as 25kN/m. And they have given M20 and Fe415 as the materials.

   i) **Load Calculations:**

   First we need to calculate the dead loads self head of the beam. For finding the self head of the beam first we need to assume the beam. Normally the assumption will be based on the deflection control l/d ratio which the ratio for continuous beam is 20. So from this we can easily find what is the depth of the beam has to be 26 and depth of the beam will be l/26.

$$\frac{l}{d}=26$$

$$d=\frac{l}{26}$$

$$= \frac{4000}{26}$$

I am assuming the height of the beam as 230 x 450mm overall and the self height of the beam that is equal to the size of beam into the respective unit weight of the section. This will be given as,

$$= 0.23 \times 0.45 \times 25$$

$$= 2.59 kN / m$$

So live load is given in this problem that is W_l which is 25kN/m.

ii) <u>Moment Calculations:</u>

(a) <u>Span moments.</u>

In the span moment we are having the moment at the middle of end span. That is given as $= \frac{1}{12} W_d l^2 + \frac{1}{10} W_l l^2$. That is the moment we have seen. By substituting the values we get,

$$= \frac{1}{12} \times 2.59 \times 4^2 + \frac{1}{10} \times 25 \times 4^2$$

$$= 43.451 kNm.$$

The next moment is moment at the middle of interior span. That is equal to,

$$= \frac{1}{16} W_d l^2 + \frac{1}{12} W_l l^2$$

$$= \frac{1}{16} \times 2.59 \times 4^2 + \frac{1}{12} \times 25 \times 4^2$$

$$= 35.92 kNm.$$

b) Support Moments.

This is moment at the support next to end support. That is given by,

$$= -\frac{1}{10} W_d l^2 - \frac{1}{9} W_l l^2$$

$$= -\frac{1}{10} \times 2.59 \times 4^2 - \frac{1}{9} \times 25 \times 4^2$$

$$= -48.58 kNm.$$

Next we need to find moment at other interior supports. That is given by,

$$= -\frac{1}{12} W_d l^2 - \frac{1}{9} W_l l^2$$

$$= -\frac{1}{12} \times 2.59 \times 4^2 - \frac{1}{9} \times 25 \times 4^2$$

$$= -47.89 kNm.$$

Normally in the case of among four span the maximum bending moment must normally occurs at the support next to the end support. Now this value should be selected to find the effective depth of the beam.

iii) Effective depth of beam:

We have assumed the depth of the beam as 230 x 450mm. So by equating we get,

$$M_{u\max} = M_{u\lim}$$

$$M_{u\,max} = 1.5 \times 48.58 = 72.87 kNm.$$

$$M_{u\,lim} = 0.138 f_{ck} bd^3 = M_{u\,max}$$

$$d = \sqrt{\frac{M_{u\,max}}{0.138 f_{ck} b}}$$

$$= \sqrt{\frac{72.87 \times 10^6}{0.138 \times 20 \times 230}}$$

$$= 338.80 mm.$$

So overall depth of the beam D is equal to (338.80+30+20) 378.80 which is less than 450mm. Hence the beam is safe against flexure.

iv) <u>To find A_{st}:</u>

Now we have kept D is equal to 450mm and d is equal to 410mm for the first bending moment,

$$M_u = 1.5 \times 43.45 = 65.175 kNm$$

And we need to find the value of A_{St} and here $M_u < M_{u\,lim}$, we need to provide the reinforcement.

<u>Summary:</u>

In this lecture we have seen thoroughly about the design of continuous beam using IS coded coefficient. We have found the size of beam and then we have found the area of bending moment for four places. So we need to provide the reinforcement in the respective places. And also we have seen the arrangement of reinforcement of continuous beam.

Questions:

1. Design beam and the area of reinforcement required for a five span continuous beam of effective span 5m subjected to a total live load of 23 kN/m. Use M25 and Fe500 as Materials.

Reference:

- IS 456:2000 plain and reinforced concrete code of practice
- Reinforced concrete design by S.N. Sinha