Design of Structures II

Lecture 2

Welcome to UGC lecture series in B.Architecture. Now we are going to have a lecture 2 in a unit1. Unit 1 is based on the Design of concrete members and working stress design of beams. In the lecture 1, we have seen so far, what do you mean by concrete, what do you mean by reinforcement concrete, what are the reasons for using steel as a reinforcement material in the case of reinforcement concrete structures, what are the grades of concrete, how do you calculate the amount of powder for the particular batch of concrete, also we have started discussing about what are the various method of design of reinforced concrete elements.

One is working stress design method, second is ultimate load design method, third one is Limit state design method. So far we have seen, working stress design method and ultimate load design method. In the case of working stress design method, they are considered only the concrete and steel as an elastic material. On the contrary, it is not correct, concrete is a more complex material. First i.e, Advantages of working stress method and the second one is, in the case of working stress method, they have used huge amount of fact of safety for, concrete and steel. Though they could design up to their working stress method, they have used huge amounts of fact of safety since there are three for concrete and 1.8 for steel, the design will be safe but it is uneconomical. Also, the stress is developed in the structure i.e the actual stress is developed in the structure, is very much lesser than the theoretical values. So, the assumption i.e the reasons are the assumptions i.e concrete is an elastic material, it is not correct. On the contrary, concrete is more complex material. Next to it, we have seen the Ultimate load design method. In the case of Ultimate load design method, they have used taking the inelastic or plastic behaviour of concrete and steel and they have calculated the ultimate load by using the factor of safety. The ultimate stress is, they are no real values also, in the case of ultimate load design method. Though they have been, they have used their factor of safety to find out the ultimate load, the deflection and cracking methods are not considered so this method is only used to find out the ultimate load after designing with the help of working stress method which is used to calculate the factor of safety. So next, the rational and practical design method, which was found which is called as Limit State method. This limit state method which overcomes the drawbacks of working stress method and ultimate load design method. In the case of working stress method, they have designed only up to their working stresses, so they have used more amount of act of safety and also they have considered the concrete to be an elastic material and the concrete is not correct, it is a more complex material. Also, in the case of ultimate load design method, they started considering inelastic and plastic behaviour of concrete and steel. They have found ultimate load by multiplying with the factor of safety and also the ultimate stresses have no real values. Though they have used the deflection or however, the deflection and tracking efforts were not considered. So, this method i.e the ultimate load method was only used to calculate and ultimate load, after designing with the help of the working stress method, which is used to find out the real factor of safety. So, when you overcome the drawbacks of those two methods, the rational and practical method was found, that is called the Limit state method, in the case of Limit state method, what do you mean my limit state? In the case of lecture 2, the contents of lecture 2 which consist of; Methods of design of RC elements. So far in lecture one, we have seen; working stress method and the ultimate load design method. In the schedule two, we are going to discuss about; Limit state design method. Next one is; we are going to start with; Working stress method of design of structures. In the working stress method design of structures, we are going to have; what are the assumptions which are made in the concepts of designs of working stress method; we are going to begin to analyze the rectangular section and are going to design them, rectangular section using the expression which has been found in the analysis of rectangular section.

I already told you that it is a rational and practical design method i.e the Limit state method. It gives a new approach of statistical property. What do you mean by limit state? That limit state means an acceptable limit for safety and serviceability of the structure before the failure occurs. This is called as a limit state, an acceptable limit for safety and serviceability of the structures before failure occurs. So, there is a concept or design which such limit state is to achieve the acceptable probabilities, so that structure will not become unfit for use and will not reach the limit state. Though these structures and RCC elements can be designed to their ultimate loading conditions, they have added certain factors of safety that is called as a partial safety factor. So, once a structure has been designed to their ultimate load, it starts failing. When the stress in materials reach their respective ultimate stress conditions, it begins to fail. So once, in order to avoid that failure of structure, they have added certain factors of safety that is called partial safety factor. The partial safety factor, here it is; 1.5 for concrete and 1.15 for steel; this is called as partial safety factor. This is not like the case of working stress method, in working stress method the elements are designed to their working stress conditions. They are not designed to the ultimate loading conditions, when you take the factor of safety. The factor of safety was found in the working stress method; 3/4 the concrete and 1.8 steel, so they have used huge amount of factor of safety, that is why this method failed. Though the structures are safe, after designing with the help of working stress method; this method leads to uneconomical. This method i.e the Limit state method, they design their structures to reach their stresses of the materials to their ultimate loading conditions in order to avoid the failure of structures when it reaches the ultimate loading conditions, they are adding the factor of safety i.e called as the partial safety factor. They are adding factor of safety partially i.e 1.5 for concrete and 1.8 for steel. So, in the case of limit state methods; the limit state means the acceptable limit for safety and serviceability of the structure before failure occurs. So, thus the concept or the design with such a limit state, to achieve and acceptable limit for safety and serviceability of the structures, so that the structures will not become unfit for use and will not reach their limit state. In the case of limit state design methods; they have used two limit states; one is limit state of collapse and limit state of serviceability i.e in the case of limit state method, they have added limit state of serviceability i.e the deflection and cracking effects were considered in the limit state method. So, here the statistical property of strength and load can be estimated which will be a limiting state of material in the case of limit state method. The partial safety for that method were introduced to reduce the probability of the failure to zero. That is in the case of limit state method. So, the advantages of limit state method over other methods are; Though this structure which is designed to their ultimate loading conditions, they have added some partial safety factors i.e 1.5 for concrete and 1.15 for steel. So, this structure will not have the probability of failure in the case of limit state method, will be reduced to zero. In addition to that, in the case of working stress method or in the case of ultimate load design method, the deflection and cracking methods were not considered but here in the case of limit state method the deflection and cracking methods are considered. These are all certain advantages over the other two previous methods. Now, we are going to have a detailed look on working stress method.

Before designing a working stress method, we need to know what are the assumptions made in the case of working stress method. So, each and every method which have their own assumptions and finally checking whether their assumptions are correct or not and finally they frame their assumptions. So, in the case of working stress methods also, they made certain assumptions, using these assumptions only the structures will be analyzed. Based on the analysis and the expressions derived, they started designing the RCC elements. So, here the first assumption is; at any cross section, the plane section before bending and remain plane after bending. What does it mean? It means that the strain at any cross section of the wind is directly proportional to the neutral axis. This is something like, it is based on the theory of simple bending. In the case of theory of simple bending, the layers above the neutral layers are subjected to compressive stresses and the layers below the neutral layers are subjected to tensile stresses. Whereas, in the case of neutral layers, there is neither combustion nor tension. So, when you move towards the top, the stresses gradually increase and when you move towards the bottom i.e the neutral layers, it gradually increases and reaches its maximum value. So, the stain at any cross section of the beam is directly proportional to the distance from the neutral axis. This is the meaning of the first assumption i.e at any cross section, the plain section before bending remain plane after bending. The second assumption; All the tensile stresses are internally taken care of by the reinforcement and none by concrete, except as otherwise specifically permitted. This is the second assumption. So, here we all know that in the case of concrete, that concrete is very strong in compression but weak in tension. So, here in the case of a beam, when it is subjected to any kind of force, if it is deformed, the layers above the neutral layers are subjected to compressive stresses, so all the compressive stresses are internally taken care of by concrete since the concrete is very strong in compression. When we go below the neutral i.e the portion below the neutral layer, all these things are subjected to tensile stresses. So, here the concrete is very strong in compression but very weak in tension. So, that is why we have provided an alternative material to resist those tensile stresses i.e the material which is called as steel reinforcement. So, here all the tensile stresses are entirely taken care of by steel reinforcement and none by the concrete except otherwise specially permitted. In some places, concretes are allowed to take certain tensile stresses i.e in the case of water tanks. In some conditions, in some structures only, will concretes be allowed to take some tensile stresses. The third assumption; the stress-strain relationship of steel and concrete, under working loads, is a straight line. The stress-strain relationship of steel is; steel and concrete is a straight line. This is a stress and this is the strain i.e they are taking as a linear part, it is considered as a linear. Stress is directly proportional to the strain, that is why they have considered only upto the elastic limit. This is the point where the material reaches their maximum permissible value. That is why they have designed up to the, that is why the stress-strain relationship of concrete and steel under working load is considered as a straight line. Next, they have used, this we have discussed already in first schedule i.e modular ratio, a well-known mechanics they have used in the case of a working stress method. The modular ratio 'm' = 280/3 sigmacbc; where sigmacbc is permissible compressive stress due to bending in concrete. Maximum compressive stress in concrete in bending i.e the bending stress. The compressive stress is called bending stress. So, where sigmacbc is permissible compressive stress due to bending in concrete. Maximum compressive stress in concrete which is represented as N/mm^2 as given in Table 21 of IS 456:2000. These are all the assumptions made in the case of working stress method, based on these four assumptions, we are going to analyze and find out the expression used to design the size of the section as well as the reinforcement record for it. We are going to have; 2 sections; one is Rectangular sections and the other is flanged section. flanged sections are normally called as T beams or L beams. Now, it is called as. Now, for example, in the case of a building which is supported like this; these are all the locations of columns, how the slab systems can be provided for this one. The slab systems can be provided as supported over the intermediate supports which are in the form of beams by connecting the column and the ends. So, here the slabs are supported on these supports. These supports are acting. When you take the cross section of the slab, this a cross section of a slab, it is supported over this beam and here, these are all called as the beam and this intermediate beams are designed as 't-beams', it maybe designed as rectangular beams. But it is something like, when you take the cross-section, this portion is called as a 'flange' portion or slab portion. The slab portion is called as 'flange' portion and this portion is called as wave portion. So, these intermediate beams can be designed as a t-beam and these edge beams will be designed as; 'l' beam i.e it is something like an inverted letter 'l'. The analysis and design of t and l beam are almost the same. The only difference is the flange portion, in the case of t beam, the flange is on either side of the wave portion. But in the case of l-beam, the flange is only on one side. So, first we are going to have an analysis of a rectangular section. Before that, in the case of beams, there are three different sections; one is 'balanced' sections, second one is 'under reinforced' sections, third one is 'over reinforced' sections.

What do you mean by 'balanced' section? Balanced section means, normally the reinforced concrete members are designed on the basic assumption that the stresses in concrete and steel reach their maximum permissible stresses at the same time. Both the materials are stresses to their maximum permissible value one and at the same time, that stress is called as 'balanced' section. For example, if you have a rectangular section, this is taken as neutral axis of the beam. This is the neutral axis. Here, you consider this as a singular. I will explain later. Here, if you take this as a stress diagram, here the axis passes through, the balance section is known as; Balanced Neutral axis or Critical neutral axis. The depth of this critical neutral axis from the top most extreme fiber to the neutral axis is called as, taken as Xc, Xc is the depth of the Balanced section. What do you mean by the balanced section? RCC members are designed on the basic assumption that, the stresses in concrete and steel till their maximum permissible values are achieved at the same time. Both the values are stressed to their maximum permissible value one and at the same time, that section is called the balanced section and the axis passes through the neutral layer, the axis that passes through this section is known as balanced neutral axis or critical neutral axis and the depth of the neutral axis is denoted by Xc. Xc is the depth of critical neutral axis. So, here both the materials are stresses to their maximum permissible value one and at the same time i.e sigmacbc and sigma st. Now, in the case of other section i.e now we move onto Unreinforced section. Under-reinforced means less steal, if less steel than required for the balanced section is used it is called as under-reinforced section. In such conditions, in this session, the steel is stressed to its maximum permissible value, while the concrete is stressed below it's maximum permissible value. Here in the case of under-reinforced section, since we are using less steel, the concrete area will be more. So, among these two materials, we are using less amount of steel, so when subjected to any kind of forces, the steel reaches its maximum permissible value first. So, here when you take this diagram in such condition, what is the type of failure that would occur in the case of under-reinforced section. Since the steel is thrust to its maximum permissible value, the section which fails due to overstressing steel initially. Type of failure that occurs under-reinforced section is; tension failure or ductile failure. What about the neutral axis of under-reinforced section? Since it is unbalanced section, the neutral axis is situated in the center of gravity of the section. My question is; whether is the neutral axis more upwards or more downwards? Since, we are using less amount of steel, the area of concrete is almost more, so automatically the neutral axis will move upwards. So, this is the neutral axis of the under-reinforced section. So, I am taking x as the actual depth of neutral axis. So, since the neutral axis is present at the cg of the section, the neutral axis moves upwards in the case of under-reinforced section. So, when we compare the actual neutral axis with the critical neutral axis, in the case of under-reinforced section, x is less than Xc. Once you find out the actual depth of your neutral axis, if it is compared with one another, if X is less than Xc, the section will be under-reinforced section. Now, we move onto Over-reinforced section. Now in the case of over-reinforced section, if more steel, over-reinforced means more steel. If more steel than that required for the balanced section is used, that section will be called as over-reinforced section. In such conditions, in this section, the concrete is stressed to its maximum permissible value first, while steel is stressed below its maximum permissible value. So, here in the case of under-reinforced section, steel is stressed to its maximum permissible value while the concrete is stressed i.e actually cbc is less than permissible cbc. In the case of over-reinforced section, here you are using more amount of steel, the concrete area will automatically reduce. So, among both the materials, the concrete is stressed to its maximum permissible value first, while the steel is stressed below its permissible value. What about the neutral axis in this? What about the failure in over-reinforced section? Since the concrete is stressed to its maximum permissible value first, the nature of failure occurs in the over-reinforced section is sudden failure or brittle failure. Why the sudden failure? Since the concrete is a brittle material, it fails suddenly. So here, the nature of failure is brittle failure. What about the neutral axis? Since it is an unbalanced section, the neutral axis is going to be present in the center of gravity section. So, here in the case of over-reinforced section, we are using more amount of steel, automatically the neutral axis moves downward. What about the depth of neutral axis? This is the depth of neutral axis for the over-reinforced section. When you compare X with Xc, X is greater than Xc. If X is greater than Xc, it is called over-reinforced section. These are the three important sections in the case of analysis of rectangular or flanged section. Before analysing any rectangular or flange section, we must know what do you mean by balanced section; under-reinforced section; what do you mean by over-reinforced section. I am going to repeat, in the case of balanced section, both the materials are stressed to their maximum permissible value at the same time i.e one and at the same time, that is why it is called a balanced section. The axis that passes through the section is called balanced neutral axis or critical neutral axis. The depth of neutral axis here is called as, Xc. So, here in the maximum stress of the topmost extreme area is sigma cbci.e permissible value and here in the bottom is sigma i.e in the reinforcement is sigma St. What about in the under-reinforced section? Under-reinforced means less steel is used, if less steel than what is required for the balanced section is used it is called as under-reinforced section. In this section, the steel is stressed to its maximum permissible value first while the concrete is stressed below its permissible value. So, under such conditions, this section will fail initially because of over stress in steel. So, the type of failure that occurs in under-reinforced section is tensile failure or ductile failure. What about the neutral axis? Since it is secured in an unbalanced section, automatically the neutral axis is going to be situated in the center gravity of the section. Since we are using less steel, we are using more amount of concrete, the neutral axis moves towards the top, moves towards the compression side. Here we are taking X as the actual depth of the under-reinforced section, when compared Xc, X is less than Xc. If X is less than Xc, we can conclude that it is under-reinforced section. What about over-reinforced section? If you are using more amount of steel that is called as over-reinforced section. More amount of steel than required for the balanced section is used, that section is called as 'Over-reinforced section'. In this section, the concrete is stressed to its maximum permissible value while the steel is stressed below its permissible value. Under such conditions, this section will fail initially due to over stress in concrete. What about the neutral axis? Since automatically, the neutral axis will move downward. So, take X is the depth of the neutral axis and compare to Xc, here X is greater than Xc. If X is greater than Xc, it is called as over-reinforced section.

Now, these are the three important sections, we need to analyze any rectangular or flanged section. So, here the three sections, we have seen and before that, type of failures, before we conclude these three sections, what is the most important section among these three sections? What is the most safest section? I am saying that the most safest section is the, under-reinforced section. The most safest section is under-reinforced section. The reason being its nature of failure. The nature of failure is tension failure or ductile failure, the tension failure/ ductile failure which shows the failure will not fail suddenly, it is not brittle in nature, it is ductile in nature. It shows the failure, we can easily rehabilitate this section. So, the most safest section among these three sections is under-reinforced section. So, in the case of Limit state method, we have talked about limit-state method, we are going to discuss about it. Though these three sections are based on working stress method, in the case of Limit state method, they are avoiding designing over-reinforced section because of its type of failure. The nature of failure is brittle failure. The brittle failure is a sudden failure. It fails suddenly, it does not show any signs of failure. So, we can't rehabilitate these structures, that is why they have avoided designing over-reinforced section in the limit state method.

Let us summarize what we have discussed so far in the schedule 2, one is the Methods of design of RC elements, we have discussed the concepts of limit state method. Then what are the advantages of limit state method over other two methods. What are the factors of safety they have used in the case of a limit state design method and we have started to discuss working stress method in detail. In this one, we need discuss about the analysis of rectangular section before designing the rectangular section. We have discussed about, the three important sections; balance section, under-reinforced section and over-reinforced section. In these three sections, what about the neutral axis, what about the nature of failure in each section and also, which section will be the most economical and most safest sections, we have finalized.

With regard to the questions, so far we have discussed concept of limit state method, from that I need to ask; Define the term: 'Limit State' and what are the advantages of limit state method over the other two methods. This is very important question and we have discussed three important sections; Differentiate between under reinforced and over reinforced section and then, define the section, we have to define what is under reinforced section, over reinforced section and also next one is explain the nature of failure of every section. What are the nature of failures that occur in the balanced section and over reinforced section and with regard to the references, we need to refer; IS 456:2000 plain and reinforced concrete-code of practice and also, we can refer a well known book written by S.N Sinhai.e Reinforced Concrete design. With this we come to the end of this lecture, Thank you!