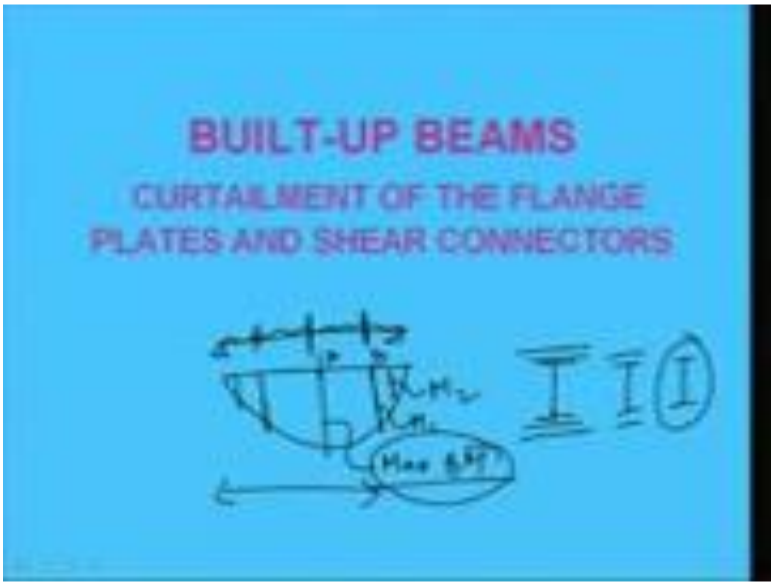
Design of Steel Structures
Prof. Damodar Maity
Department of Civil Engineer
Indian Institute of Technology, Guwahati

Module - 6
Flexural Members
Lecture - 6
Built-up beams Curtailment of the Flange Plates and Shear Connectors

Hello today's lecture will be the continuation of previous lecture. In previous lecture, we have discussed about different aspects of built-up beams; that means, how to make a built-up section for using in beam what type of sections we will be using for beam. Then how the extra plate we are going to use or extra section in terms of rolled section we are going to add with a particular section to withstand the heavy load or to resist the huge deflection due to large span. So, the remaining aspect of the built-up beam will be discussed today's lecture that is the curtailment of the flanges, curtailment of plate flanges that we will discuss and then another important aspect is the shear connector, is basically used to make the whole section behave monolithically. So, these 2 aspects we will try to focus in today's lecture. First will see, why curtailment is required and what is the purpose of making curtailment of flanges and flanges of beams?

(Refer Slide Time: 02:37)



Now, if we see the bending moment diagram of a section say a cantilever beam is there, a simply supported beam is there with some load. Then if we see bending moment diagram we will see, bending moment diagram is like this. So, when this is the maximum bending moment diagram. Now, when we are choosing the section, we are choosing on the basis of this maximum bending moment, maximum bending moment on this basis. Now, say suppose if we see here we will see the bending moment is less, but why unnecessarily we will put the same large section throughout the span of the beam.

So, to reduce the cost of the beam; that means, to reduce the weight of the beam to reduce to make economic the design, what we can do? We can use in such a way that, the section in this position at the middle will be higher and section in this position will be lesser. How can we make it? Say suppose we are making say at the middle section maybe we can make say a I section and then with some plate, at middle section say at A. And say at B we came use say same I section maybe a smaller plate or maybe here we may use 2 plates here, we may use 1 plate and maybe at the end means here we may use only this 1.That means; as moment is going to say this is M1 and this is M2 as moment is going to reduce at different places.

So, considering maximum bending moment if we choose the section throughout the length of the beam then definitely it will not be economic. So, to make economy what we can do, we can choose different section at different position. So, how we can do it? What we can do is that, a basic section we can use throughout the length of the beam then the plate additional plate we can use as per the requirement of the moment. That means; where the moment is high we can use plate and where the moment is less we may not use not use the plate or we may use some thinner plate. So, in this way we can means economize the design. So, how to reduce the section, how to make curtailment of the plates in the flanges that we will means discuss in details.

(Refer Slide Time: 05:45)

How it look? If you see the curtailment of the flange plates, it is basically if you see say suppose, this is a say I section now this is a I section. Now, this along the length if I seen this will look something like this. Now, what I can do. Here I can make a curtail 1 plate; I am going to curtail here then another plate. So, again I can curtail here 1 plate. So, in this way say different plates I am going to curtail. Now, similarly here also we will get similar aspects. So, in this way; that means, 1 plate that is I section and another plate is given from here and another plate is given from here, as moment is increasing towards span.

So, in this way we can introduce some plate that means; along the span if I see say this is the span say suppose like this it is then as bending moment is developing like this. So, the section modules will be required more here and less towards this. So, what we can do generally, first plate we use to provide throughout the span, then again we can reduce the span as say suppose here; that means, here bending moment is little less. So, we can make it; then again say here, we can again provide some other type of plate; that means 1 additional plate.

So, to tackle the means to take care the maximum bending moment. So, this 1 2 3 plates are providing, but after certain distance away from the mid span. So, as bending moment is going to reduce. So, we are cutting down the plate. So, these plates only we are making up to this and then second plate we are making up to this and the third plate we are making up to this. So, the maximum section, we are going to get in the middle, because the maximum bending moment in this particular case is coming at the mid span.

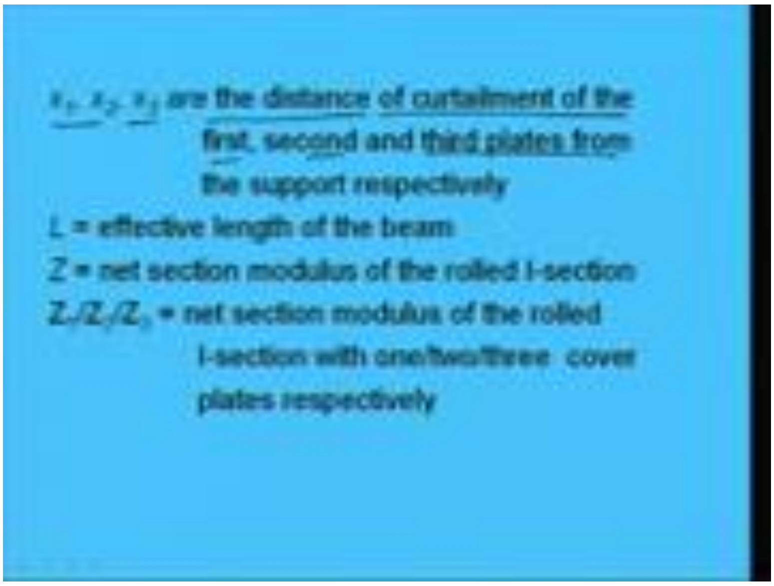
(Refer Slide Time: 09:03)

So, as per IS specification the first cover plate is carried through the full length of the beam. The IS code has told that, we have to carry out throughout the length of the beam, the first cover plate then the remaining plates can be curtailed as applicable for built-up beams fabricated with angle sections for flanges and plate sections for web. However this is not applicable for plated beams. So, IS code has given some specification through which we have to maintain those things.

(Refer Slide Time: 09:43)

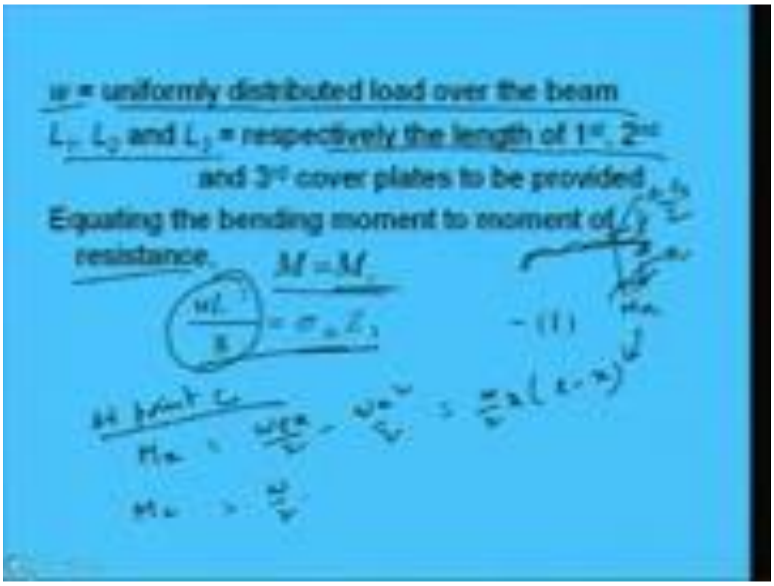
So, now how to find out the length of the curtailment. So, let us see say, if this is a span now, if we see the bending moment. So, this is bending moment; so this is the maximum bending moment maximum at the center. So, this total length I can write. So, what I can do here, 1 plate I can provide here, another plate I can provide and maybe here another plate I can provide. So, this maybe say we can make L1 and this maybe say this is L3 and this is L2 means, L1, L2, L3 we are making and whereas, the total length is L. And let us make the point as like say this is C say this is A point A and this is point B and this is point C; that means, moment is developing at a as MA MB and MC. So, in this way we can now, we can find out the moment at different point.

(Refer Slide Time: 11:33)



How do we find out? If suppose the beam is UDL ly distributed means UDL load is there then let us assume that, x1, x2, x3 are the distance of curtailment of the first second and third plates from the support respectively. So, let us make x1, x2, x3 from distance from the this that this is x1 and this is x2 and this is x3. If we denote and let us assume L is the effective length of the span means total length. And Z is the net section modulus of the rolled I section; that means the original section Z that is net section modulus. And Z1, Z2, Z3 will be net section modulus of the rolled I section with 1, 2, 3 cover plates; that means, Z1 will be Z plus for first cover plate. Z2 will be Z plus first cover plates plus second cover plate like this, we are denoting.

(Refer Slide Time: 12:45)



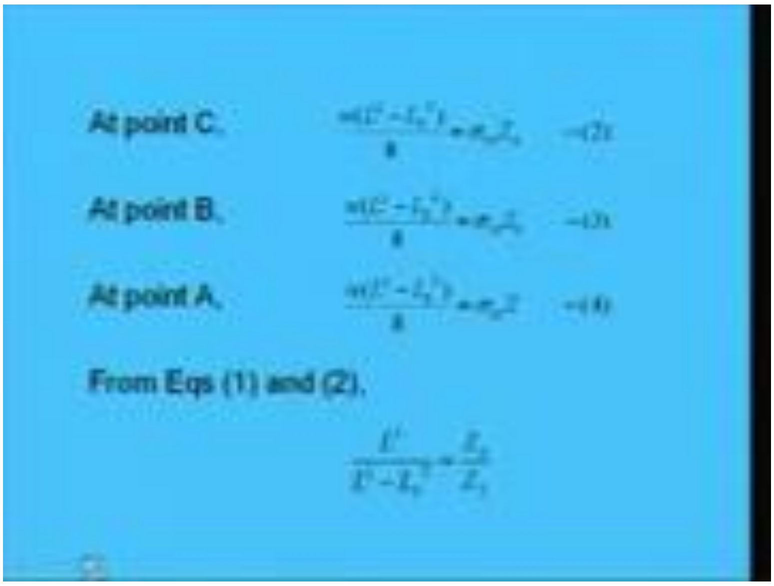
So, with this denotation we and say, W is the uniformly distributed load over the beam is provided. And L1, L2, L3 are respectively the length of first second and third cover plates to be provided; L1, L2, L3 we have shown here this is the first cover plate L1, this is L2 and this is L3. So, if we equate the bending moment of resistance then we can make M is equal to Mr means M is basically WL square by 8 the maximum bending moment which is occurring at the center. And Mr will be moment of resistance that will be sigma bt into Z3 or sigma bc into Z3.

So, from this we can find out the value. Similarly, say suppose at point C what will be the equation means, how we will make it at point C. So, at point C when we are going to make we know moment at any point is wlx by 2 minus wx square by 2. So, I can write w by 2 into x into l minus x. So, this is the equation at any point means, when the bending moment we are going to calculate for simply supported beam, say at x distance Mx will be this. So, now at point C what will happen moment will be MC.

So, that will become w by 2 into x, what will be the x value this x is basically L minus L3 by 2; this will be L minus L3 by 2 because, if we see the equation here means diagram here this is total is L. And L3 is say this is point C; so L3 is this 1 L3 at point C. So, this is this distance will become L minus L3 by 2; because this is L by 2 and this is L3 by 2. So, L minus L3 by 2; so from this we can find out MC is equal to L minus L3 by 2 this is x into l minus x means, l minus l 3 by 2.

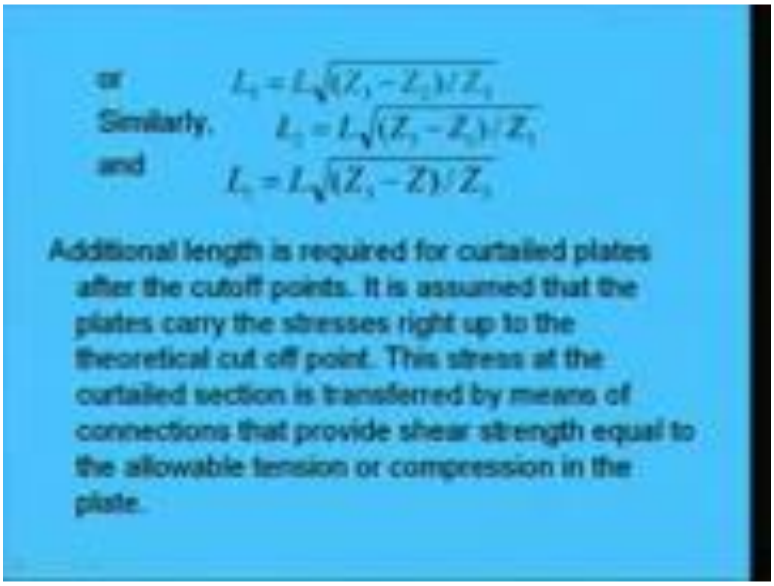
So, now if we derive this we will get w by 8 into l minus l3 here, l minus l3 and here we will get this will become l plus l3 by 2. So, l square minus l3 square by 2. So, this is coming 8.So, finally, MC will become w by 8 into l square minus l3 square.

(Refer Slide Time: 16:06)



So, MC we can find out. So, that MC will become the moment of resistance sigma b2 into Z2. And similarly means at that point what is the section modulus that is we are assuming that Z2. And at point B in similar way we can find out that w MB will become wL square minus L2 square by 8 which will be equal to sigma bt into Z1 and similarly at point A this will become w into L square minus L1 square by 8, which will be equal to sigma bt into Z. So, these are the equations we have. Now, if we equate say equations 1 where this is given wL square by 8 is equal to this and equation 2 this 1 if we make means, if we equate sigma bt because sigma bt is M then we can find out this equation. That means, L square by L square minus L3 square is equal to Z3 by Z2.

(Refer Slide Time: 17:23)



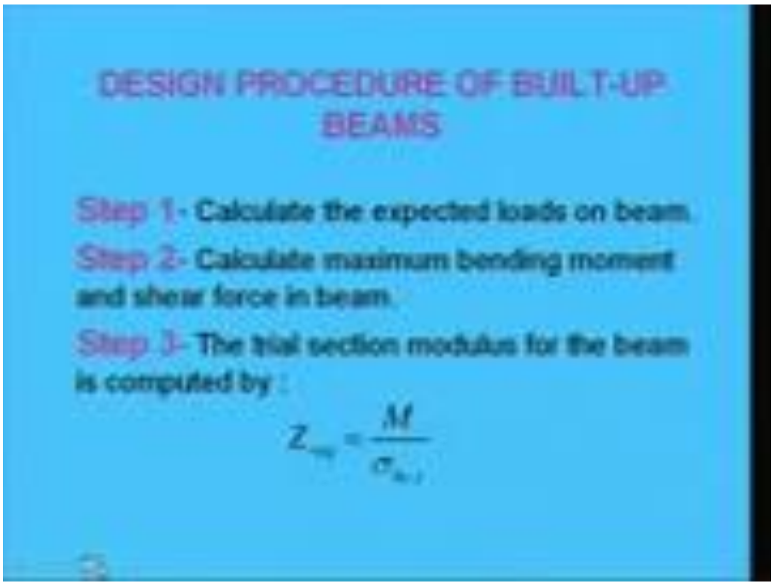
So, in this way we can find out the relation or from this equation we can find out L3 is equal to L into Z 3 minus Z 2 by Z3 square root of see from this I can find out the value of L3; If we rewrite this equation this L square by L square minus L3 square is equal Z3 Z2 from this I can find out L3, which we have derived as like this. L3 is equal to L into square root of Z3 minus Z2 by Z3. Similarly, L2 we can find out, L into Z3 minus Z1 by Z3 and L1 is equal to L into Z3 minus Z by Z3. So, the curtailment length L1, L2, L3 the length of the plate can be decided from these equations, which is on the basis of the section modulus.

What are the total section modulus, what is the required section modulus at different places we can find out that is Z1, Z2, Z3 from the moment point of view because we know moment at every point and that is moment is we can know from the equations. And Z1, Z2, Z3 will be simply M1 by sigma bt M2 by sigma bt and M3 by sigma bt sigma bt or sigma bc. So, from there I can find out the Z1, Z2, Z3 value and we know total length L. So, the moment we know Z1, Z2, Z3 value we can find out, the value of L1, L2, L3 the length of different plate added in the section.

So, additional length is required for curtailed plates after the cutoff points. It is assumed that, the plates carry the stresses up to the theoretical cutoff points; theoretically up to the cutoff points. This stress at the curtailed section is transferred by means of connections that provide shear strength equal to the allowable tension or compression in the plate.

This is important, which you should note. This stress I am repeating once again, this stress at the curtailed section is transferred by means of, connections and provide shear strength equal to the allowable tension or compression in the plate. So, in this way we can decide. Now, the things which we have been decided for designing aspects of for designing of beam means built-up beam now we can summarize, say design procedure of built-up beams.

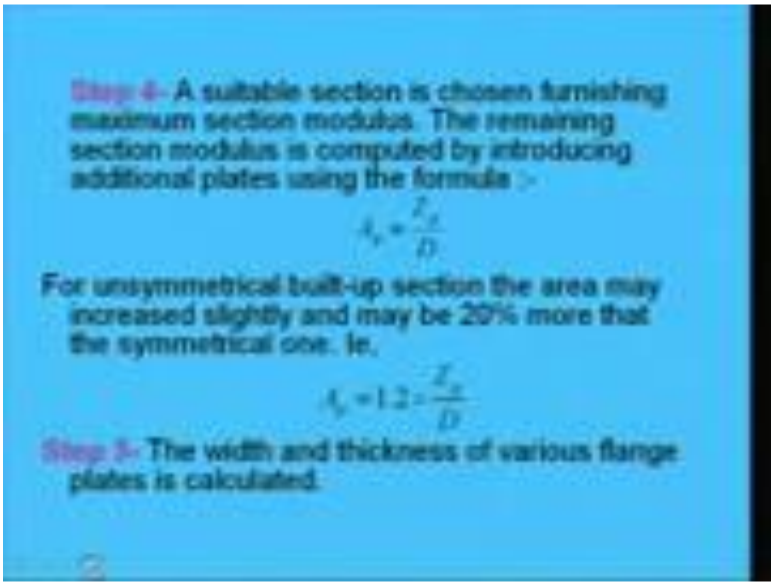
(Refer Slide Time: 20:27)



First step; we can see that we have to calculate the expected loads coming on the beam, then in step 2, calculate maximum bending moment and shear force in beam and next step is, the trial section modulus for the beam is computed; that means, first we will find out the required section modulus, which will be M by sigma bc and or sigma bt. Now, why we are telling trial, because if the section is unrestrained laterally then we do not know what is the permissible bending stress in compression; that means, sigma bc.

So, we have to assume some sigma bc value then we have to find out some approximate section modulus. After that, we have to go for the actual 1 that is why it is told trial means by iteration method by iterative way we have to find out the actual section. So, to start with, what we can do? We can find out the section modulus required with an assumptions of sigma bc in case of unrestrained beam. However for restraint beam as we know sigma bc is equal to sigma bt is equal to point 65. So, we can find out the Z required directly.

(Refer Slide Time: 22:00)

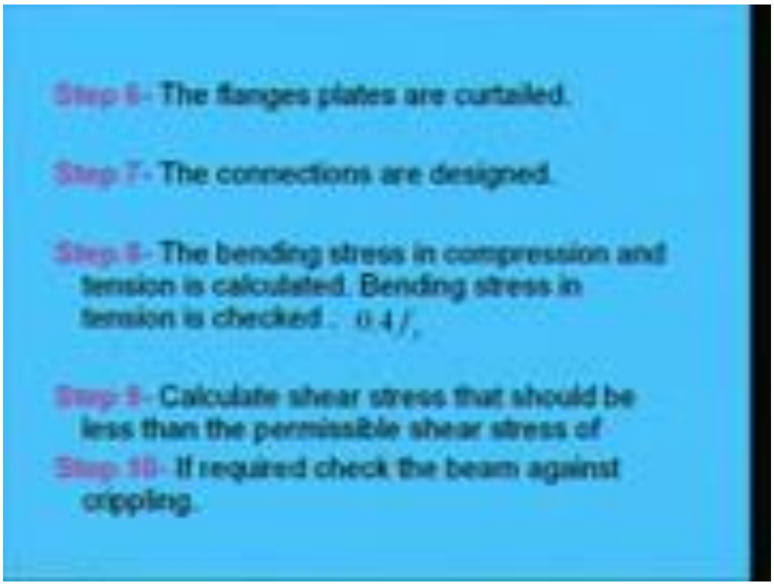


In next step, a suitable section is chosen furnishing maximum section modulus. The remaining section modulus is computed by introducing additional plates using the formula Ap is equal to Zp by D. In last lecture, we have seen how to find out Ap; Ap means area of plate additional plate which will be Zp by D. Now, another thing we have to remember is that for unsymmetrical built-up section means; suppose sometimes we are providing only say 1 plate at the top. So, in this case unsymmetrical built-up section.

So, in this case it is from experience it is seen that, the area has to increase slightly; that means, the area required whatever it is coming will provide little higher side. And in general 20 percent extra additional area we are providing in case of unsymmetrical section. So, for unsymmetric built-up section, the area may increased slightly and maybe 20 percent more, than that the symmetrical 1; that means, Ap will become 1.2 of Zp by D1 point 2 of Zp by D; next what we will do?

Next we will go for step 5: where it is told that the width and thickness of the various flange plates is calculated. So, the moment we get the value of the area of the plate now we can find out the width and thickness. But how do we find out width and thickness, what will be the width because 1 is dependent on another. So, each other is dependent; so now we have to see the codal provision. In code certain provisions are given which we have discussed.

(Refer Slide Time: 24:10)



So, on that basis we have to find out the width and then thickness, then the flange plates is curtailed means curtailment of flange plates we will do to make economize of the design. And how to find out the curtailment length; that means, length of the additional plates that we have to adapt in step 6: Then what we will do. Then another important point is connections, the connections are designed, because when we are going to add some plates definitely we need to connect either by the riveting or by wielding.

So, we have to design the connections properly connections will make the whole sections monolithic and shear will transfer without any failure. Then next step is step 8 in step 8 what we will do. The bending stress in compression and tension is calculated. Now, bending stress in tension has to check which should be below point 4 fy; that has to be checked. This is not this bending stress is given bending stress has to be checked means that 0.66 fy. Now, then calculate shear stress that should be less than the permissible shear stress of 0.4 fy, shear stress is 0.4 fy.

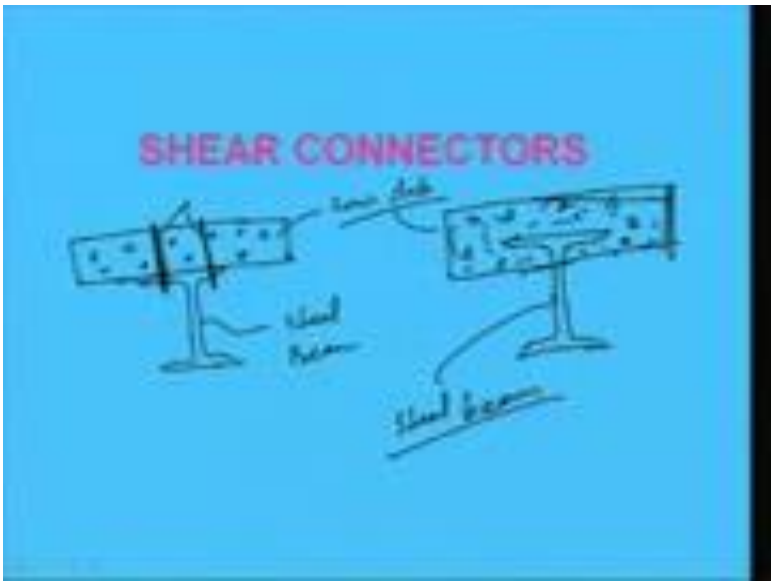
So, we will calculate the shear stress and we have to check whether it is less than the permissible shear stress or not. Then in step 10; if required check the beam against crippling of course, another step is deflection, crippling and deflection. So, if required we have to check against crippling if crippling when because, the when concentrated load is coming or at the support crippling effect occurs. So, that has to be checked. Another thing is the, deflection as we know maximum deflection will be span by 325; allowable maximum deflection is span by 325. So, we have to check whether the developed deflection is less than the allowable or not, if it is not then we have to redesign if it is then fine.

So, these are the steps 10 steps we have to follow for design built-up sections. So, now we will discuss another important aspect that is shear connectors. As in case of built-up members we need to connect the flanges. So, in that case sometimes shear connectors is required basically, when it is required. When steel concrete composite members are used; that means, generally we used to take the advantage of steel and concrete together. As we know, concrete is strong enough under compression whereas, steel is strong enough under tension. And concrete cannot take tension much means negligible tension it can carry.

So, taking the advantage of both the material we can make use a beam in such a way that, where the compression stress due to bending will develop there we will provide concrete and where the tension stress will develop there we will provide steel. So, in that way we can make use of steel concrete composite. So, the built-up section whatever we are discussing 1 is only steel we are going to use, another is we can make use of concrete as well as steel; steel in the tensile part and concrete in the compression part.

So, to make the joint monolithically, to make the section monolithically mechanical device which is called the shear connector is required to join those things, it not only interact between the concrete and steel to make monolithic, but also transfer the shear from 1 to another properly.

(Refer Slide Time: 28:59)



So, how does it look first let us see, say this is a steel beam, I beam; and this is a concrete beam. Now, concrete flanges are used here and this is the steel, say this is steel beam and this is concrete; infect these are mostly slab. So, slab portion are taking means are of use for the development of the compressive stress. So, these have to be designed properly. So, that shear connector has to make in here, in such a way that it can resist the moment horizontal moment between concrete slab and beam and it can transmit the horizontal shear between the 2. So, basically shear connector is mechanical device by which, interaction of a slab interaction of a concrete slab with a steel beam is accomplished in a composite beam construction for buildings and bridges.

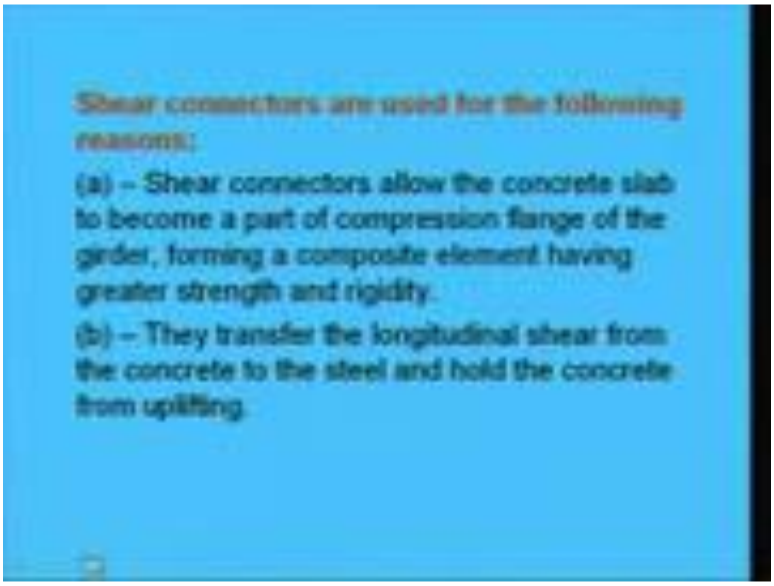
Another type of use of steel concrete composite is done that is like this say, this is the steel beam and it is encased on the concrete slab. This is another type, where also we use; so this is concrete slab and this is steel beam; different type of arrangement has their own advantages and disadvantages. On the basis of requirement, we have to choose a particular type of arrangement.

(Refer Slide Time: 31:30)

Now, if we see the steel concrete composite design, there are 2 codes we used to follow which you can note down; 1is that IS 11384-1985; IS 113 84 1958; code of practice for composite construction in structural steel and concrete this is 1.This is based on limit state design method and its use has been restricted to buildings only for buildings only this code is used. Another code we use for steel concrete composite design that is IRC 22-1986; this is a standard specification and code of practice for road bridges the Indian Road Congress Delhi this code name.

This code is based on working stress method working, stress method and it is applicable for road bridges. So, 1 code is specialized for means applied for road bridges another code is for buildings. The first code that is IS 113 84 is based on limit stress design method and the code IRC 22-1986 is based on working stress design method. So, design philosophy is completely different. So, when you are going for design of a bridge you have to consider accordingly, and when you are going for design of a building steel building you have to design accordingly.

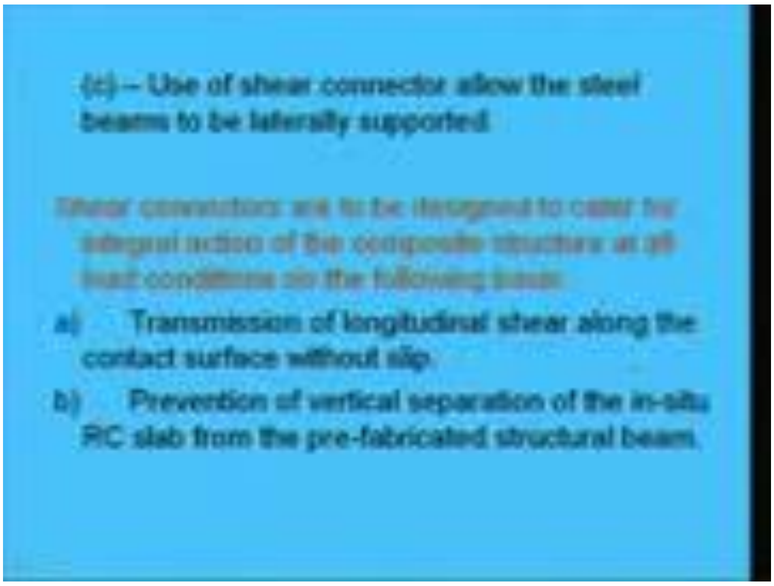
(Refer Slide Time: 33:16)



Now, what are the reasons of shear connector’s use why we are going to use the shear connectors? Mainly this is because; the shear connectors allow the concrete slab to become a part of compression flange of the girder forming a composite element having greater strength and rigidity. As we know, the compressive strength of concrete is very high. So, if we can use as a compression flange the slab of the concrete, if we can use as a compression flange, then we can take the advantage of the property of the concrete. Another is they transfer the longitudinal shear from the concrete, to the steel and hold the concrete from up lifting.

So, the use of shear connectors plays an important role here; that is the, that is the shear connectors transfer the longitudinal shear from the concrete to the steel and hold the concrete from uplifting hold the concrete from uplifting; so these are the 2 things.

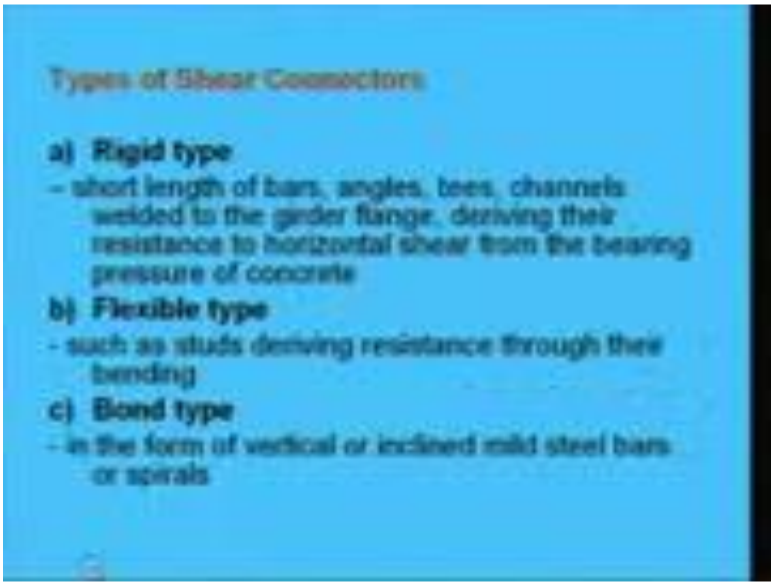
(Refer Slide Time: 34:39)



Another point is, there that is use of shear connector allow the steel beams to be laterally supported. This is also very important, when we are going to use, concrete with the steel beam then automatically it is doing as a laterally supported it is acting as a laterally supported beam. So, in case of laterally supported beam we know the allowable compressive tress in compression in the steel is 165 for fy 250 that is 0.66 fy; that means, the highest strength. But if it is unrestrained, if it is unsupported laterally, then this allowable compressive stress in bending in steel will be less than 0.66 fy and it depends on other factor and we know how to calculate those things

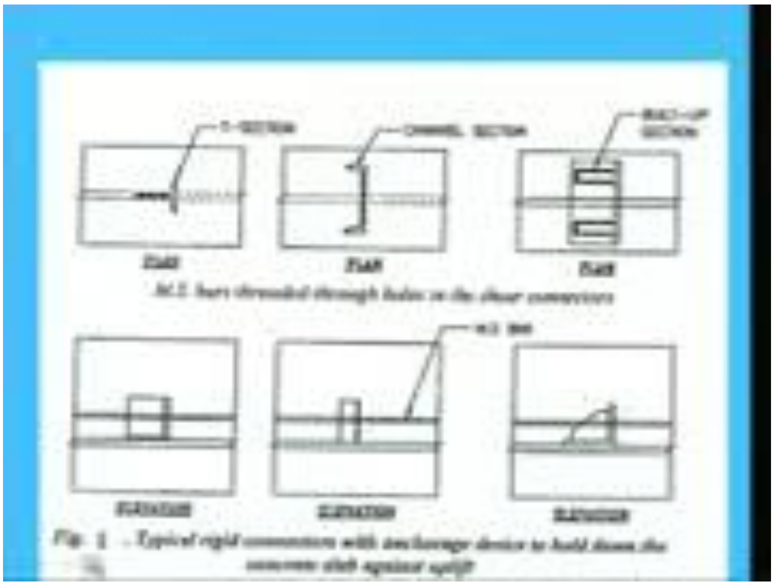
So, this is another advantage of using concrete as a compression flange. Now, shear connectors are to be designed to cater for integral action of the composite structure at all load conditions on the following basis. So, shear connector has to be designed to cater integral action; basically that is transmission of longitudinal shear, along the contact surface without slip transmission of longitudinal shear. Another is prevention of vertical separation of the in-situ RC slab from the pre fabricated structural beam.

(Refer Slide Time: 36:25)



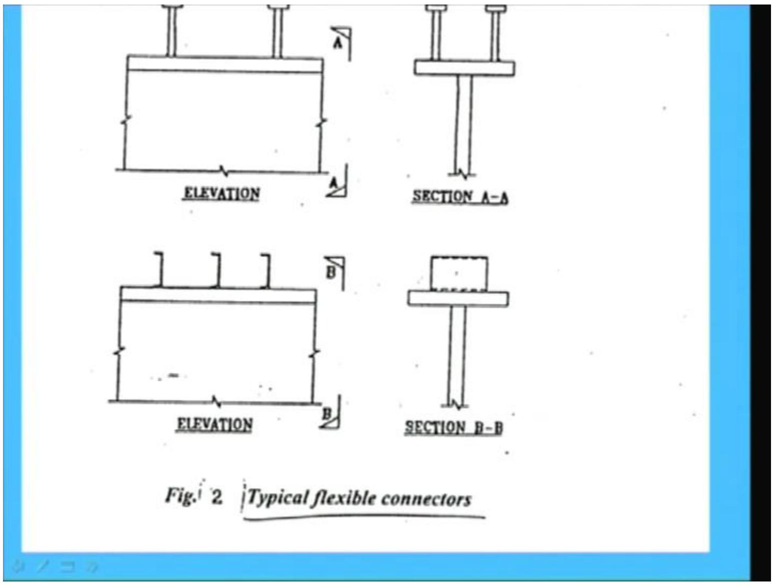
Now, what are the types of shear connectors? As we know there are 3 types of shear connectors we use to make use in the construction that is 1 is rigid type, another is flexible type and then bond type. So, rigid type flexible type and bond type. In case of rigid type generally short length of bars, angles tees channels welded to the girder flange deriving their resistance to horizontal shear from the bearing pressure of concrete. And in case, of flexible type it is generally starts deriving resistance through their bending. And bond type means, in the form of vertical or inclined mild steel bars or spiral.

(Refer Slide Time: 37:29)



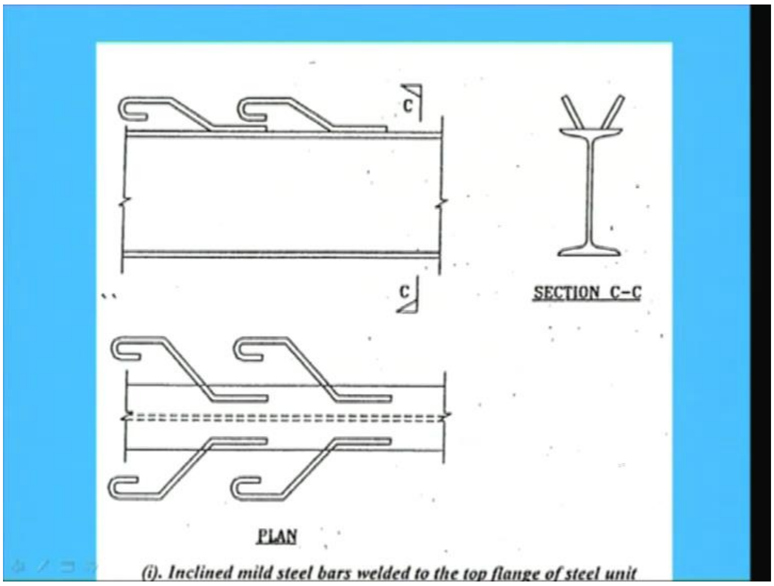
So, three types of shear connector use; one is this. This is typical rigid connection with anchorage device to hold down the concrete slab against uplift. So, this is 1 case; you see, this is the elevation of when this is a plan with T section shear connector, then this will be the elevation. If we use channel section as a shear connector, then it will look like this and again we make use built-up section then it may look like this.

(Refer Slide Time: 38:15)

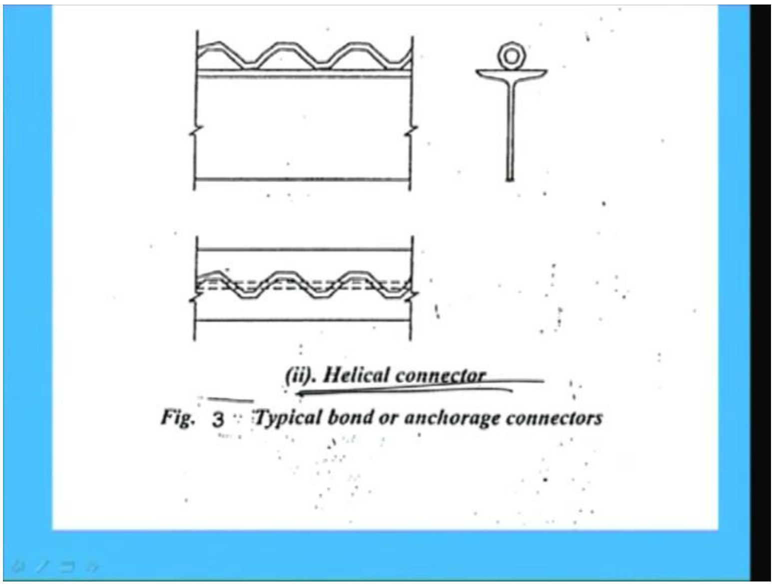


So, these are some typical rigid connectors these are some rigid connector's. Another is flexible connector's flexible connectors look like this. In fact, these pictures you will code where from where I have taken. So, you can use means you can have a look in the code to see in details.

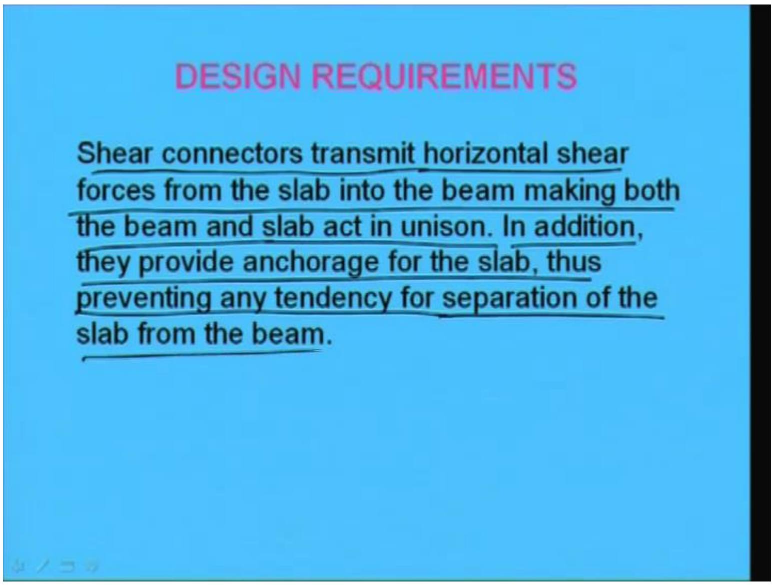
(Refer Slide Time: 38:33)



(Refer Slide Time: 38:44)

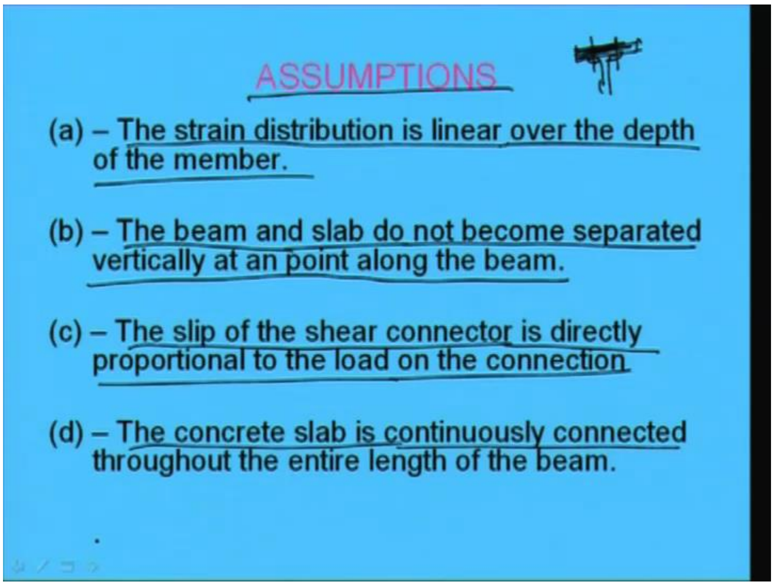


(Refer Slide Time: 38:49)



This is another type that inclined mild steel bars welded means, this is bond type. This is a bond type thing; here it is Helical connectors. So, now we will see the design requirements of the shear connector. Shear connectors transmit horizontal shear forces from the slab into the beam making both the beam and slab act in unity. In addition they provide anchorage for the slab, thus preventing any tendency for separation of the slab from the beam. So, our design requirement is to be in such a way that, it should not means it should act as a monolithically and should not have any separation.

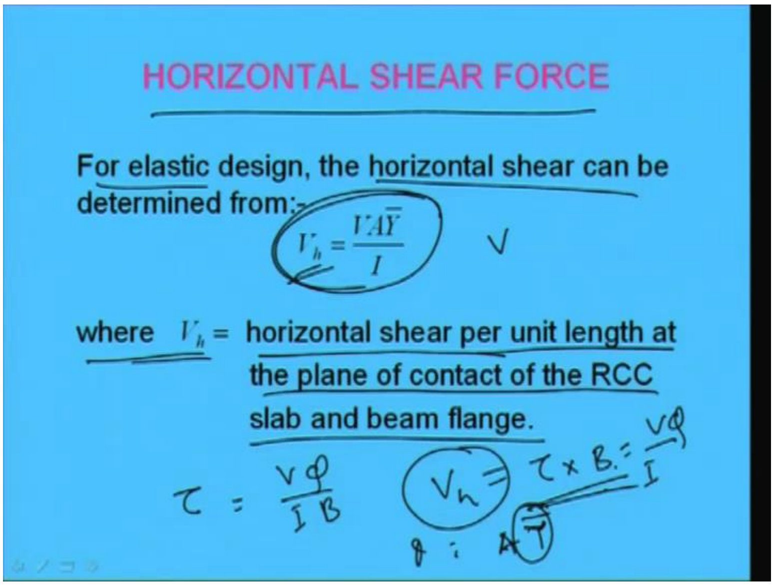
(Refer Slide Time: 39:29)



So, design has been done on the basis of some assumptions means, we have made some simplification for the simple calculation means, for the easy calculation we have made some assumptions. One is the strain distribution is linear over the depth of the member. Then the beam and slab do not become separated vertically, at any point along the beam. So, when the slab is there and beam is there means if this is the section and this is the concrete then there should not be any separation. So, we have to make in such a way that beam and slab do not become separated.

The slip of the shear connector is directly proportional to the load on the connection. And the concrete slab is, continuously connected throughout the entire length of the beam. So, these are the assumptions on the basis of which, we will be going to design a shear connector

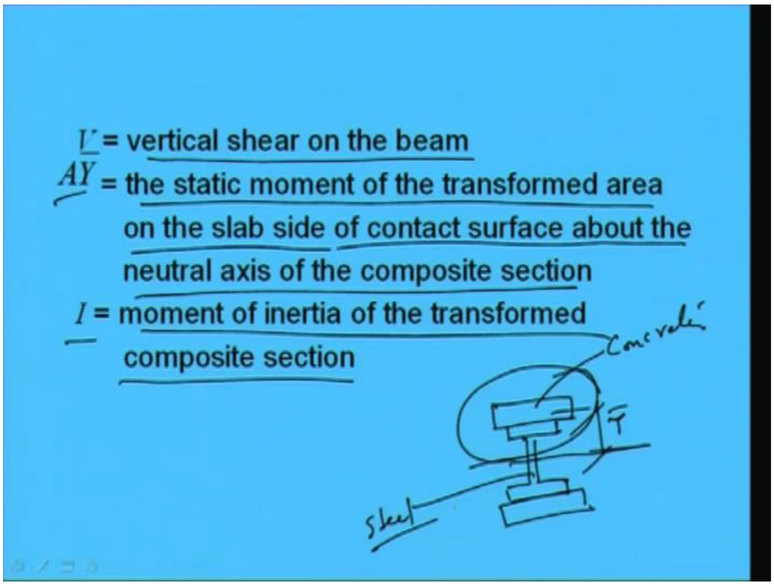
(Refer Slide Time: 40:40)



So, in shear connector from the name itself we understand that, shear force is going to develop. So, we have to take care the shear forces. So, how the shears force is going to develop and how, to resist the shear force means how to tackle those things that we will discuss. Now, that is it comes basically, the horizontal shear force. Now, for elastic design, the horizontal shear force can be written in this way that we have seen earlier. VQ by IB this is means per unit length if we make where let me show here. Vh is horizontal shear per unit length at the plane of contact of the RCC slab and flange

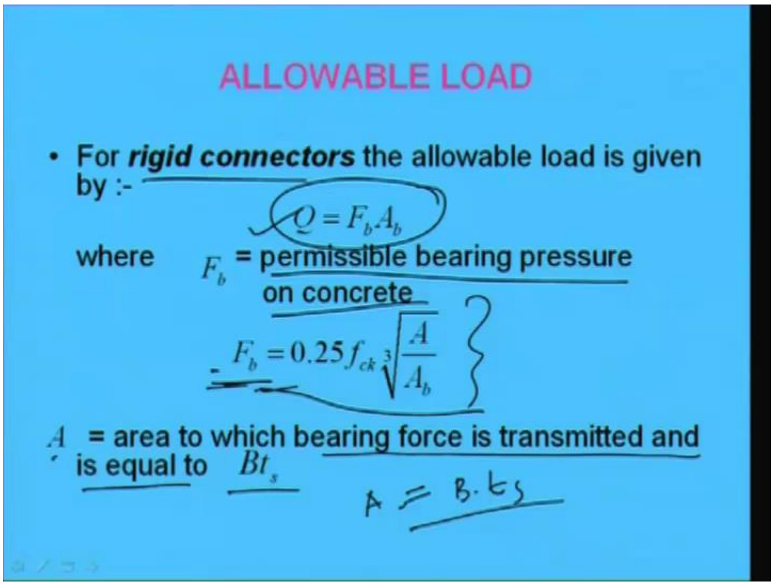
We know shear stress is VQ by IB. Now, Vh is the horizontal shear per unit length means Vh is the tau into B horizontal share per unit length. So, when we are making tau into B. So, what will happen? This Vh will become V by I into Q and Q is nothing but, A into Y bar area of the outer section and to its cg resistance from the section. So, in this way Vh can be find out as VAY bar by I.

(Refer Slide Time: 42:13)



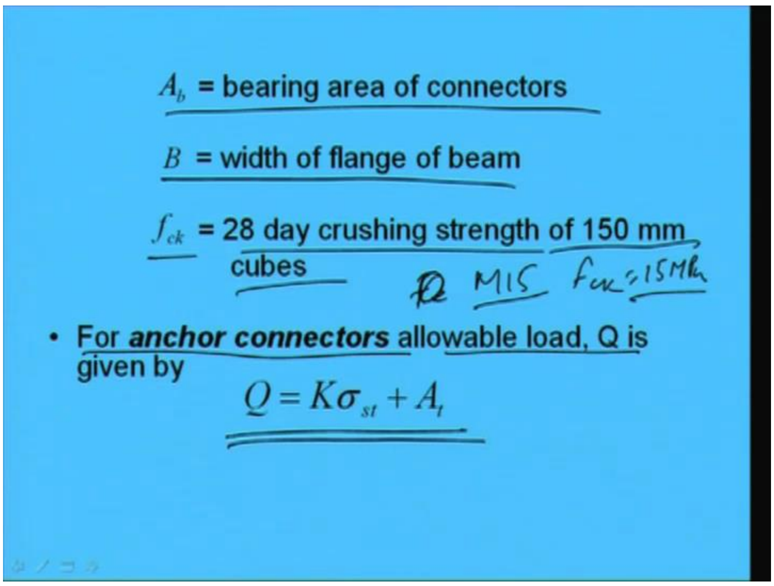
So, V is vertical shear force on the beam. And AY as I was telling AY bar the static moment of the transformed area on the slab side of contact surface about the neutral axis of the composite section. That means, if we have say this is a section and this is say this is I section. Now, when we are going to find out shear stress here, how do we find out? We will find out area and then their cg from here. So, AY I can find out in this position A and Y. And I is nothing but the moment of inertia of the transformed composite section. Remember transformed composite section why I am telling because it has some property say concrete and this is steel. So, when we are finding out the moment of inertia we have to find out either in terms of steel or in terms of concrete. So, transformed moment of inertia. C

(Refer Slide Time: 43:30)



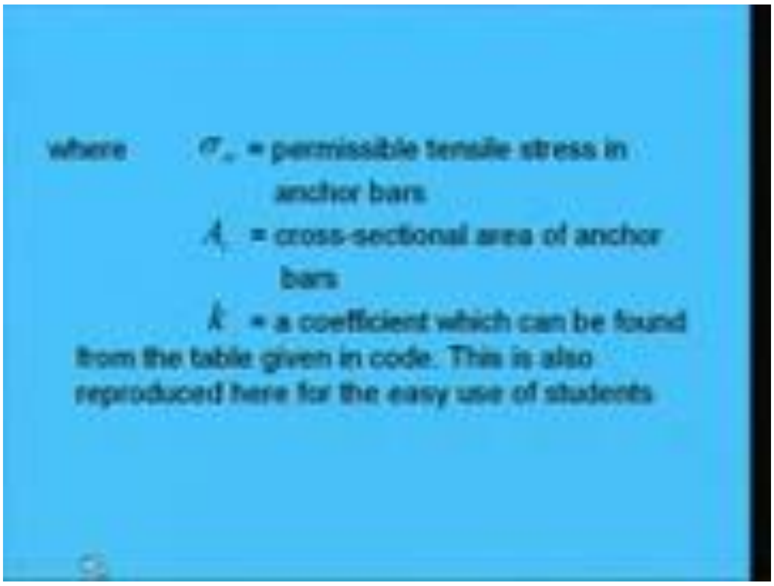
Now, allowable load for rigid connectors the allowable load can be found from this formula that is Q is equal to Fb into Ab where Fb is the permissible bearing pressure on concrete Fb is permissible bearing pressure on concrete. And. So, in this way we can find out. And Fb can be find from this equation that is point 2 five fck into cube root of A by Ab; where A is area to which bearing force is transmitted and is equal to B into ts. So, A can be written as B into ts and Fb which is called the permissible bearing pressure on concrete, that can be find out from here where fck is the characteristic strength of concrete. And then we can find out the load allowable of Q as Fb into Ab.

(Refer Slide Time: 44:40)



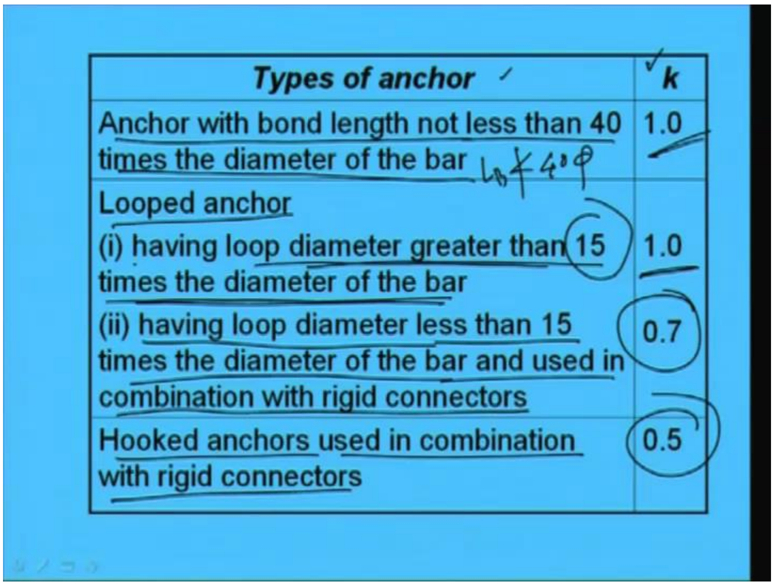
So, Ab is what? Ab is bearing area of the connectors Ab is nothing but, the bearing area of the connectors. And B is the width of flange of beam. And fck as we know the 28 days crushes strength of 150 mm cube. That means, for say if we are using Fe4 F M 15 concrete; that means, fck will become 15 Mpa less standard. So, what we have seen that, for rigid connectors we can find out the allowable load from this formula Fb into Ab. Where Ab is the bearing area and Fb is the permissible bearing pressure which can be found from this formula Fb is equal to 0.25 fck cube root of A by Ab, where A can be find out from this formula that the bearing force which is transmitted and which is equal to B into ts. Now, for anchor connectors the allowable load can be calculated from this formula that is Q is equal to K into sigma st plus At.

(Refer Slide Time: 46:02)



So, what is sigma st? That is permissible tensile stress, in anchor bars permissible tensile stress in anchor bars and At is the cross sectional area of anchor bars. And K is a coefficient which can be found from the table given in the code this is also reproduced here, for the easy use of the students. So, how K is varying which is given in the I am showing here in next table.

(Refer Slide Time: 46:37)

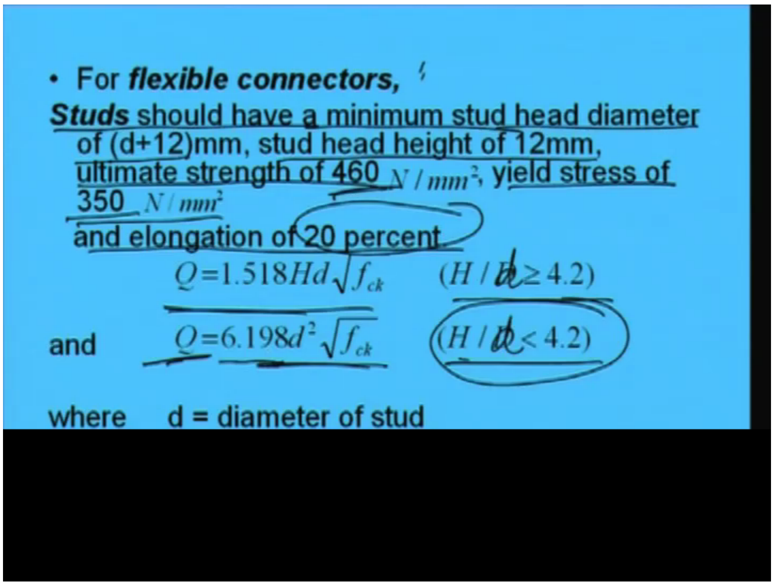


Types of anchor	k
Anchor with bond length not less than 40 times the diameter of the bar $L_b \not< 40\phi$	1.0
Looped anchor (i) having loop diameter greater than 15 times the diameter of the bar	1.0
(ii) having loop diameter less than 15 times the diameter of the bar and used in combination with rigid connectors	0.7
Hooked anchors used in combination with rigid connectors	0.5

So, is for different type of anchor the value of k is given. Like when anchor with bond length not less than 40 times the diameter of the bar anchor with bond length not less than, 40 times the diameter of the bar. If bond length says LB if it is not less than 40 times the diameter of bar, then k we can use as 1; k can be assumed as 1. And for looped anchor if it is having loop diameter greater than, 15 times the diameter of the bar if the loop diameter is greater than fifteen times the diameter of the bar, then we can consider k as 1.

So, similarly if the loop diameter is less than 15 times the diameter of bar and used in combination with rigid connectors then we can use as 0.7.So, in case of looped anchor there are 2 cases. If it is if the loop diameter is greater than 15 times the diameter of the bar then we can use k as 1; otherwise we can use 0.7. In case of hooked anchors used in combination with rigid connector’s k will be becoming 0.5.Hooked anchors used in combination with rigid connectors, if it is then we can use k as 0.5.

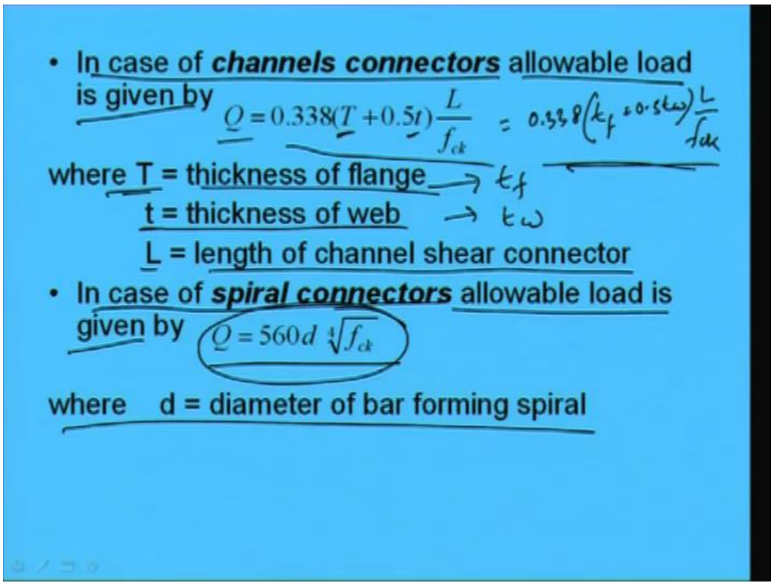
(Refer Slide Time: 48:29)



Now, for flexible connectors; now, studs should have a minimum stud head diameter of d plus 12 mm and stud head height of 12mm ultimate strength of 460; Newton per millimeter square and yield stress of 350 Newton per millimeter square and elongation of 20 percent. So, for flexible connectors the condition is that stud should have a means studs whatever, way you are going to use it should have a minimum head diameter of d plus 12mm; and head height will be 12mm ultimate strength will be 460 Newton per millimeter square and yield stress would be 350 Newton per millimeter square and elongation should be 20 percent.

So, for this we can find out the value the allowable load Q as 1.518 Hd root over fck when, H by d is greater than4 point 2 H by d is greater than or equal to 4.2; this d is this 1. And Q will become 6.198 d square root over fck if H by d less than4.2. So, in this way we can find out the strength. Now, d is nothing but, the diameter of the stud and H is the height of the stud. So, if H is the height and d is the diameter then for H by d less than 4.2 we can find that Q is equal to 6.198 d square into root over fck. And if H by d greater than or equal to 4.2 then this formula will become Q is equal to 1.158 Hd root over fck. These formulas are given in the code.

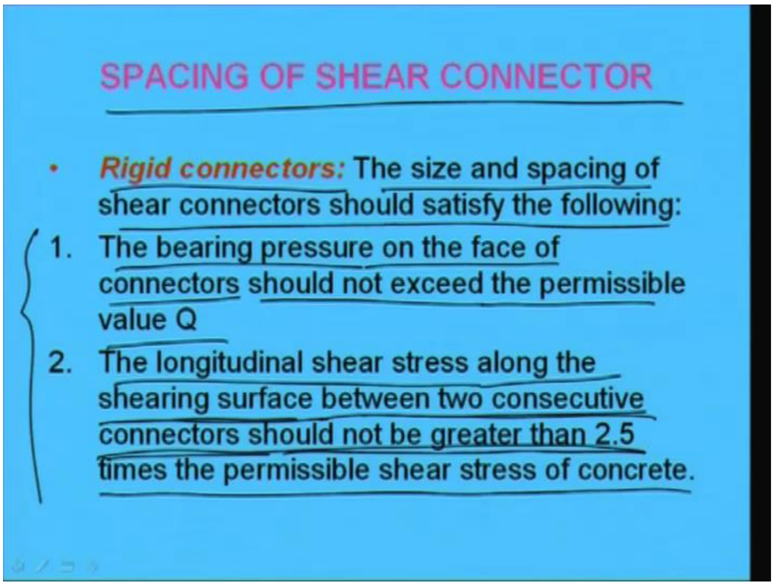
(Refer Slide Time: 50:47)



In case of channel connectors allowable load is given by Q is equal to this. That is, 0.338 into T plus 0.5t into L by fck; this is T and this is t. So, Q is equal to 0.338 into T plus 0.5; t into L by fck; where this T is we know thickness of the flange and this t is known as, thickness of the web. And L is the, length of channel shear connector. So, from this t this is basically, tf; I can write thickness of flange and this is tw. Then this in a better way, if I represent that, I can write tf plus 0.5 tw into L by f ck L is length of channel shear connector.

So, when we are going to use channel connectors the allowable load can be find out from this formula; That is Q is equal to 0.338 into tf plus 0.5 tw into L by fck where L is length of channel shear connector L is nothing, but the length of channel shear connector. In case of spiral connectors, allowable load is given with this formula. That is Q is equal to 560 d into fourth root of fck; where d is diameter of bar which is forming spiral d is nothing but, the diameter of the bar which is forming spiral. So, the allowable load; in case of, spiral connectors will become Q is equal to 560 d fourth root of fck.

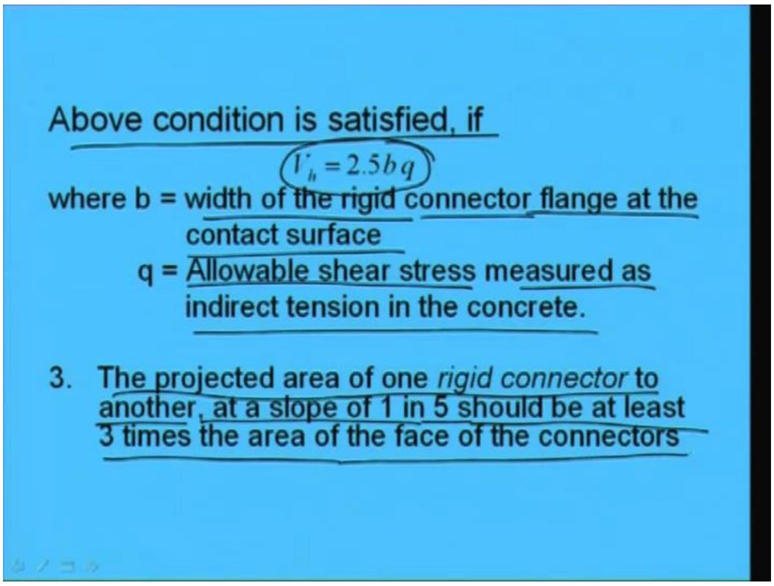
(Refer Slide Time: 53:04)



Next the spacing of shear connector. So, in code will see certain spacing has been given certain spacing has been provided through which we have to maintain and through we have to design the shear connectors. So, in case of rigid connectors it has the following specification has been given in case of rigid connections. The size and spacing of shear connectors should satisfy the following as per the codal provision.

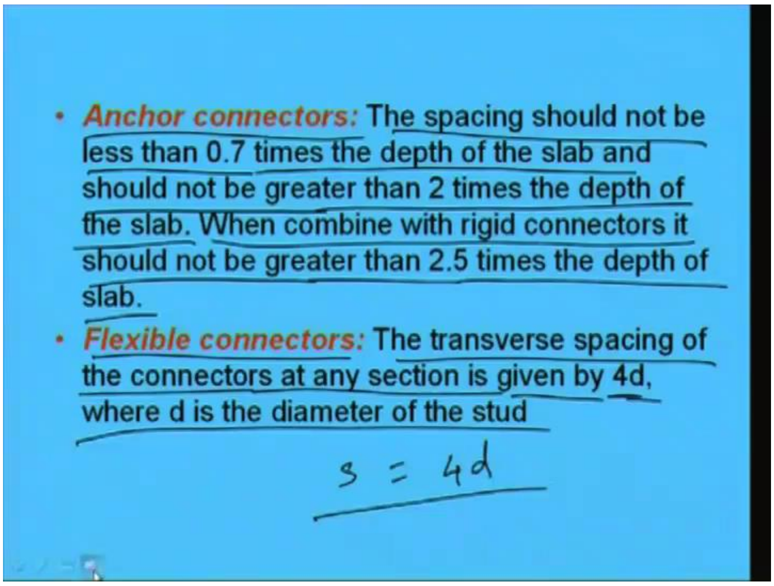
What are those? That the bearing pressure on the face of connectors should not exceed the permissible value Q, bearing pressure on the face of connectors should not exceed the permissible value Q. Then the longitudinal shear stress along the shearing surface between 2 consecutive connectors should not be greater than 2.5 times the permissible shear stress of concrete. So, these things we have to remember. That is the longitudinal shear stress along the shearing surface between 2 consecutive connectors should not be greater than 2.5 times the permissible shear stress of concrete it should not be greater than 2.5 times the permissible shear stress of concrete.

(Refer Slide Time: 54:25)



So, above condition is satisfied if Vh is written as 2.5 into bq. Where b is the width of rigid connector flange at the contact surface, b is the width of the rigid connector flange at the contact surface. And q is the allowable shear stress measured as indirect tension in the concrete; the projected area of 1 rigid connector to another at a slope of 1 in 5 should be at least 3 times the area of the face of the connectors.

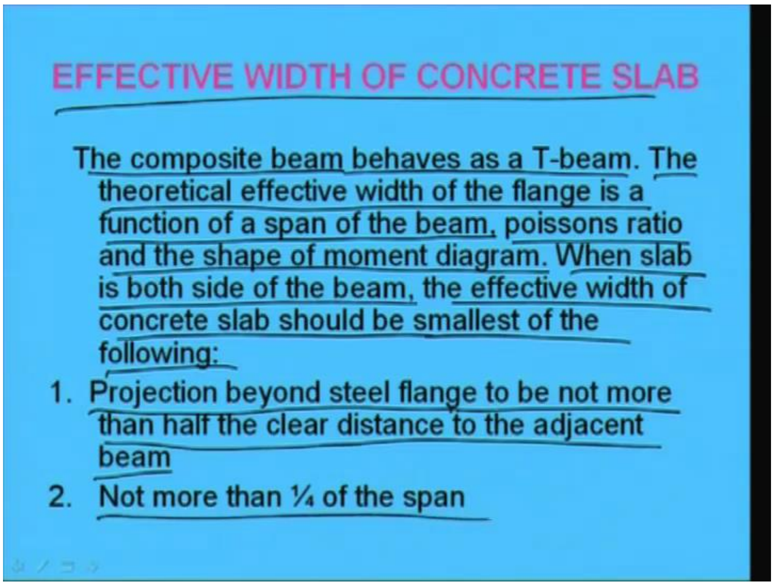
(Refer Slide Time: 55:18)



So, what we are seeing is lot of provisions have been given the code which we have to remember for anchor connectors, let us see here, this told as the spacing should not be less than 0.7 times the depth of the slip and should not be greater than 2 times the depth of the slab. When combined with rigid connectors it should not be greater than 2.5 times the depth of the slab. So, these are to be remembered. And for flexible connectors the transverse spacing of the connectors at any section is given by 4d; where d is the diameter of the stud. So, transverse spacing is given as 4d.

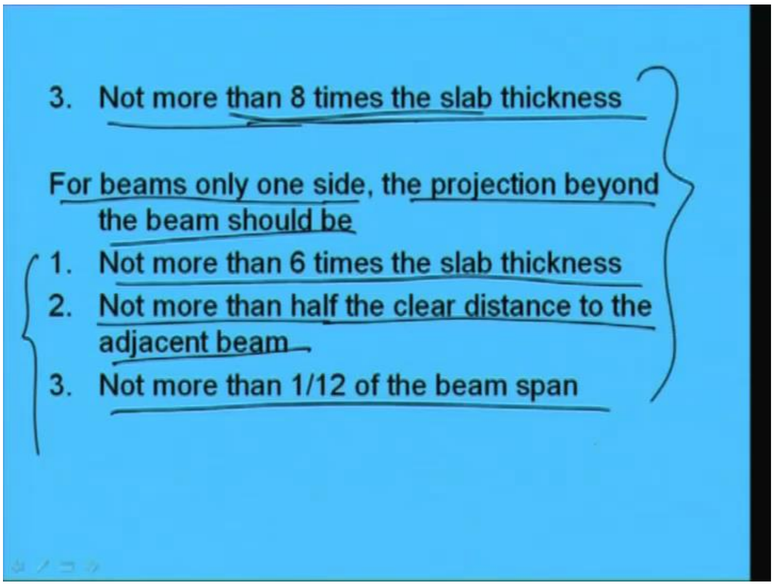
So, what we have seen is that, there are lot of provisions means lot of codal provisions has been given which we have to remember or we have to follow the code while designing a shear connector designing of shear connector is pretty easy. If we have the code in front of us, because the provisions of code the codal guidelines has to be remembered and has to be followed while going for design. If in front of us the code is there then design procedure will be little easier, because we can have a look the code and then we can make it.

(Refer Slide Time: 56:59)



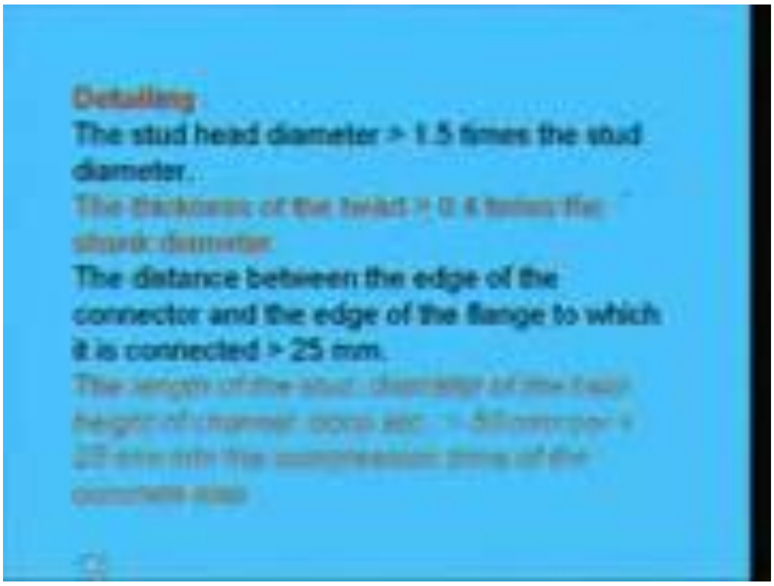
Next is effective width. Now, the effective width of concrete slab that also codal provision is there, the composite beam behaves as a T-beam as we know composite beams behave as a T-beam monolithically. The theoretical effective width of the flange is a function of span of the beam, Poisson’s ratio and the shape of moment diagram. When slab is both sides on the beam, the effective width of concrete slab should be smallest of the following this is also given in the code which can be followed. One is projection beyond steel flange to be not more than half the clear distance, to the adjacent beam and it should not more than 1 fourth of the span and also it should not more than 8 times the slab thickness.

(Refer Slide Time: 58:10)



So, these are the 3 conditions which we have to follow, that is, it should not be more than the half the clear distance of the adjacent beam and should not be more than one-fourth of the span and should be more than 8 times of the slab. So, whichever is less we have to provide? And for beams only 1 side the projection beyond the beam should be least of this. That is, it should not be more than 6 times the slab thickness and should not more than the half the clear distance of the adjacent beam and should not be more than one-twelfth of the beam span. So, these also we have to remember.

(Refer Slide Time: 58:55)



Now, detailing the stud head diameter is should be greater than 1.5 times the stud diameter stud head diameter should be greater than 1.5 times the stud diameter this is 1. Another thing is thickness of head should not be less than 0.4 times the shank diameter. And the distance between the edge of the connector and the edge of the flange to which it is connected should not be less than 25mm. And the length of the stud diameter of the helix height of the channel hoop etcetera should not be less than 50mm and nor it should be greater than 25mm into the compression zone of the concrete slab.

So, what we are seeing it seems little boring that we have to remember lot of codal guidelines while designing a shear connector. But if we have in front of the code then we do not have to remember anything, we will just follow the code and very quickly we can design a shear connector. In fact, in next lecture next or next 2 lecture; I will demonstrate 1 workout example on shear connectors. So, that it can become means it can become easier to understand. So, with this I like to conclude today.

Thank you.