PRESTRESSED CONCRETE STRUCTURES

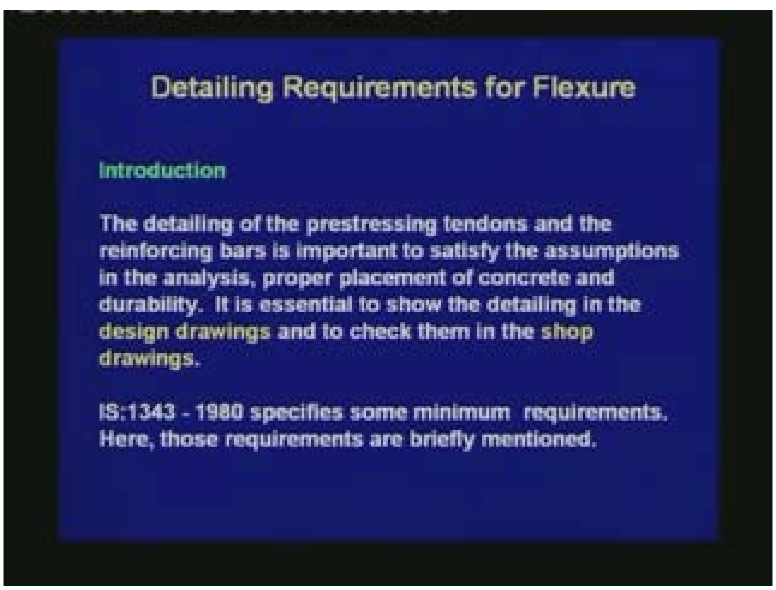
Amlan K. Sengupta, PhD PE
Department of Civil Engineering
Indian Institute of Technology Madras

Module - 4: Design of Members

Lecture – 22: Detailing Requirements

Welcome back to prestressed concrete structures. This is the sixth lecture of module four on Design of Members. In this lecture, we shall study detailing requirements for flexure. We shall also study the detailing requirements for shear and torsion to get a complete picture of the detailing requirements.

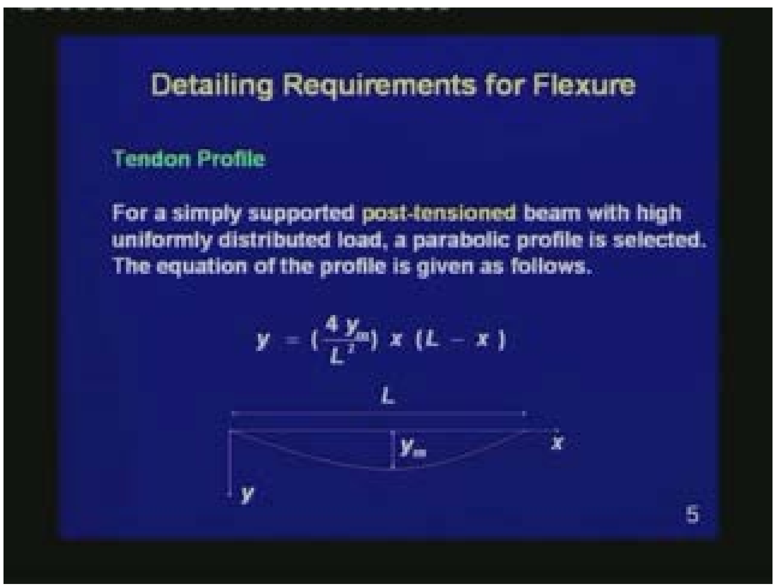
(Refer Slide Time: 01:46)



The detailing of the prestressing tendons and the reinforcing bars is important to satisfy the assumptions in the analysis, proper placement of concrete and durability. It is essential to show the detailing in the design drawings and to check them in the shop drawings.

The code IS: 1343-1980 specifies some minimum requirements. Here, those requirements are briefly mentioned. Till now, we have studied the design of the prestressing steel and the location of the prestressing steel. But, it is also very important to show those design results in the drawings. The detailing of the other reinforcement is equally important and these detailing have to be shown in the design drawings so that a person who is fabricating the steel cage does not have any doubt during the fabrication.

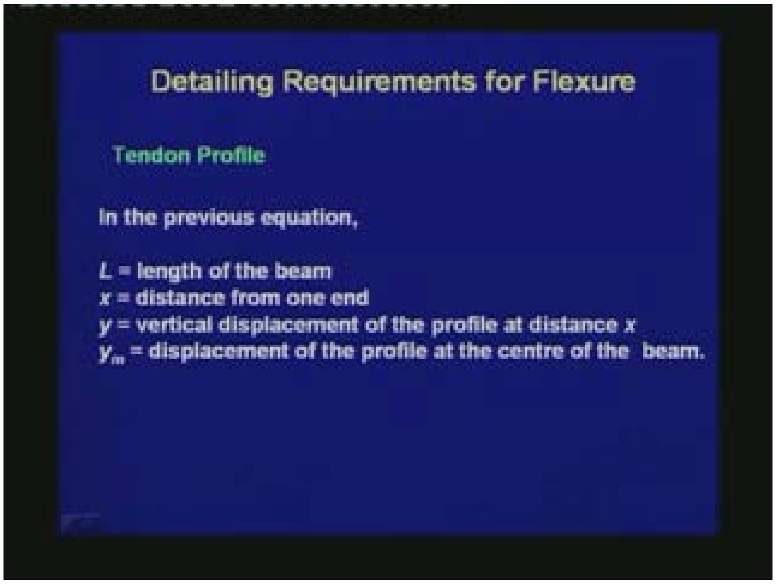
(Refer Slide Time: 03:29)



First, we are studying about the tendon profile in a beam. For a simply supported post-tensioned beam with uniformly distributed load, a parabolic profile is selected. The equation of the profile is given as follows.

$y = (4 y_m / L^2) x (L – x)$

(Refer Slide Time: 04:30)



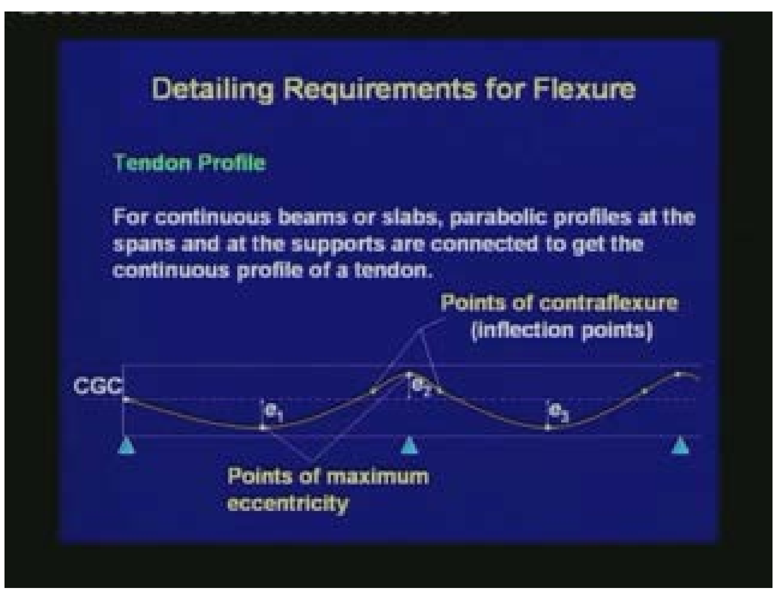
Here, L is the length of the beam, x is the distance from one end, y is the vertical displacement of the profile at distance x, y_m is the displacement of the tendon from the ends at the middle.

Thus, the first thing we need to know while placing the tendon is what is its vertical location with respect to a reference height. The equation helps us to determine this vertical location of the tendon along the span of the beam.

(Refer Slide Time: 04:52)

In this photograph, you can see the parabolic tendon profiles in a simply supported bridge girder. The location of a tendon during the fabrication of the reinforcement is extremely important. The ducts are placed within the reinforcement cage as per the design drawings. Then, the strands are passed through the ducts which finally will be very close to the design assumptions.

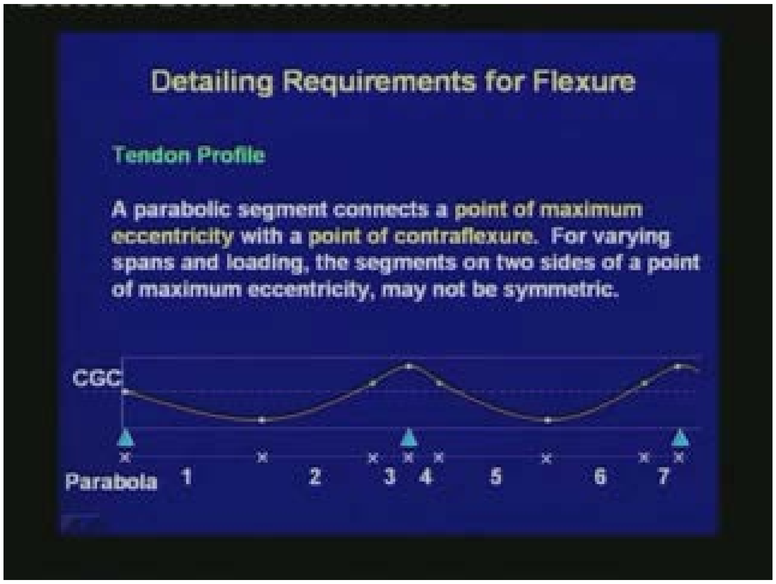
(Refer Slide Time: 05:38)



For continuous beams or slabs, parabolic profiles at the spans and at the supports are connected to get the continuous profile of a tendon. We shall discuss about continuous beams and slabs in different modules. Here, we are just mentioning about the tendon profile in such systems.

In a continuous beam, the tendon has parabolic profiles in the spans, and as well as over the supports. The parabolic profiles in the span are much longer than the parabolic profiles over the supports. There are some key points in laying out this profile. First, for the edge of the end span, the CGS is located at the CGC. As we move towards the middle of the end span we have the point of maximum eccentricity. Then, as we move towards the first support we have a point of contraflexure or an inflection point, where the tendon changes its curvature. Then, we move on to the support point where the tendon has the maximum eccentricity above the CGC. Again, as we come down, the CGS has a point of contraflexure, and at the middle of the interior span it reaches the point of maximum eccentricity.

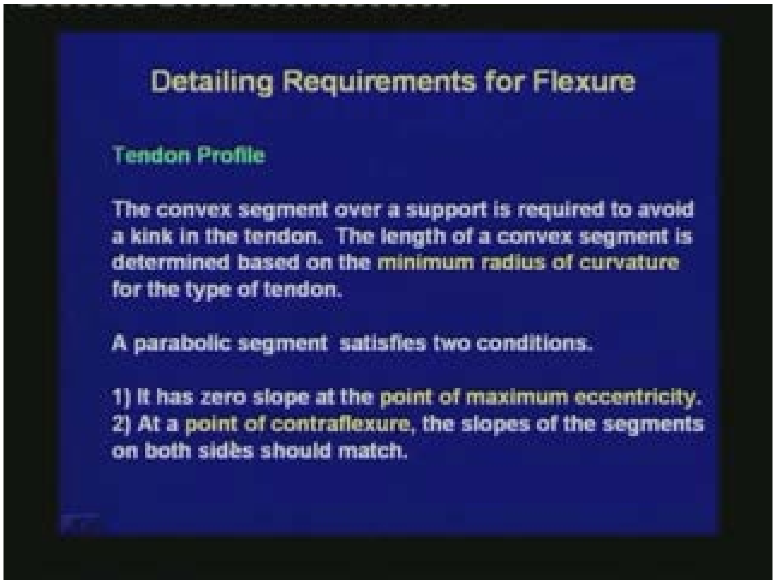
(Refer Slide Time: 07:46)



Now, each of these key points is connected by parabolic segments. A parabolic segment connects a point of maximum eccentricity with a point of contraflexure. For varying spans and loading, the segments on two sides of a point of maximum eccentricity may not be symmetric. In this sketch, we have one parabolic segment from the edge to the critical section of the end span. We have a second parabolic segment from the critical section at the end span to the first point of contraflexure. Then, we have a third parabolic segment from the first point of contraflexure to the critical section over the support. Like that, we have the fourth, fifth, sixth and seventh segments. All these can have individual equations based on the locations of the point of contraflexure and the locations of the point of maximum eccentricity.

The important feature is that at a point of contraflexure, the two parabolic segments on the two sides should have the same slope. Also, at a point of maximum eccentricity, the two parabolic segments on the two sides should have the same slope, which is zero.

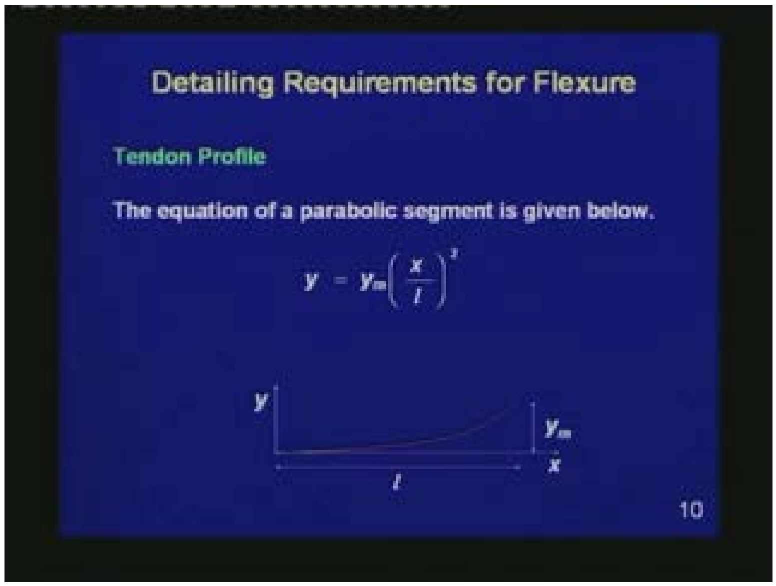
(Refer Slide Time: 09:42)



The convex segment over a support is required to avoid a kink in the tendon. We cannot have a sharp kink in the tendon, that is why we need to provide a small parabolic segment over the support. The length of a convex segment is determined based on the minimum radius of curvature for the type of tendon. Thus, from the parabolic equation, we find out the radius of curvature and the radius of curvature over the support should satisfy a minimum value for the type of tendon that is being used.

A parabolic segment satisfies two conditions. It has a zero slope at the point of maximum eccentricity. At a point of contraflexure, the slopes of the segments on both sides should match. These are the two boundary conditions which determine the constants of the parabolic equation.

(Refer Slide Time: 11:03)

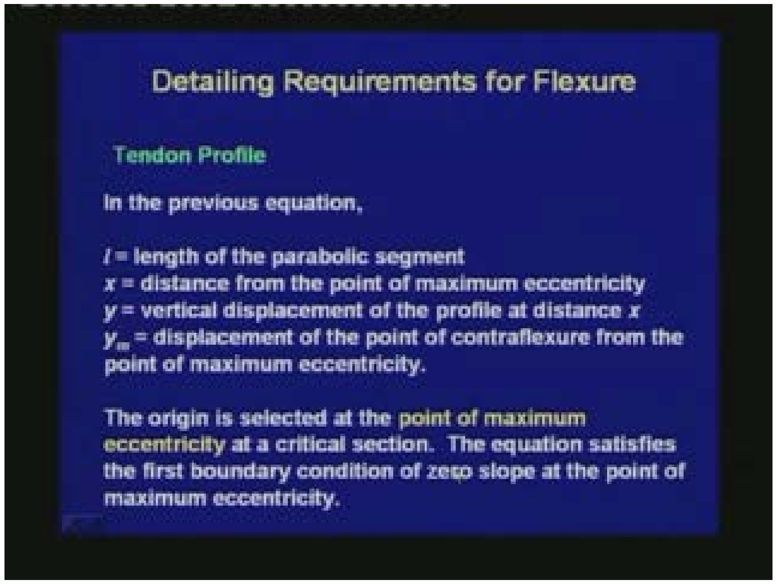


Next, we are writing the equation of the parabolic segment which connects the point of maximum eccentricity with a point of contraflexure.

$y = y_m \, (x/l)^2$

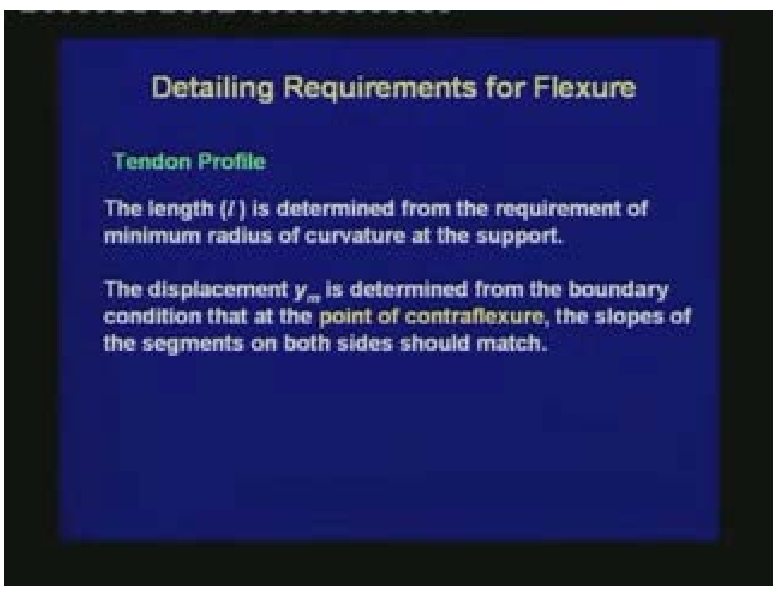
In this equation, y is the vertical displacement of the CGS from the level of maximum eccentricity, *l* is the length of the parabolic segment and x is the distance from the point of maximum eccentricity. The maximum value of y at x = *l* is denoted as y_m.

(Refer Slide Time: 11:50)



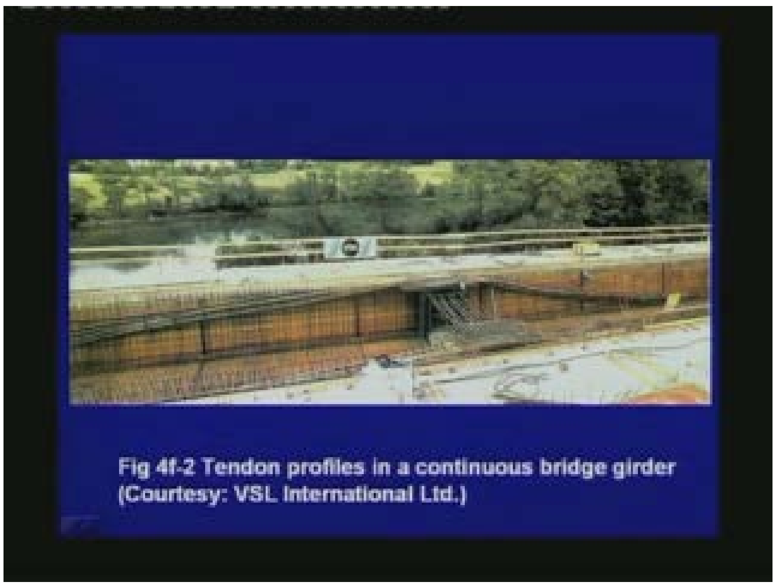
The origin is selected at the point of maximum eccentricity at a critical location. The equation satisfies the first boundary condition of zero slope at the point of maximum eccentricity.

(Refer Slide Time: 12:25)



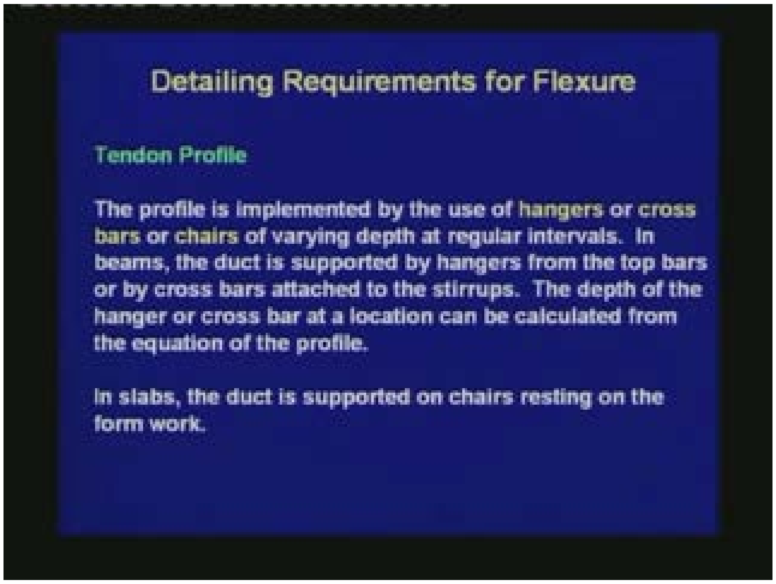
The length *l* is determined from the requirement of minimum radius of curvature at the support. That means, we have to have a minimum length of the parabolic profile over the support so as to satisfy the requirement of minimum curvature. This locates the point of contraflexure. Once we determine that, we can determine the complementary length of the parabolic segment in the span. That length is substituted in the expression of the parabolic curve. The displacement y_m is determined from the boundary condition at the point of contraflexure, where the slope of the segments on both sides should match.

(Refer Slide Time: 14:33)



This figure shows the tendon profiles in a continuous bridge girder. Here, you can see that the tendons have come up near the support and they satisfy the minimum requirement of curvature. Again, beyond the support they go down to satisfy the maximum eccentricity as per the design in the span.

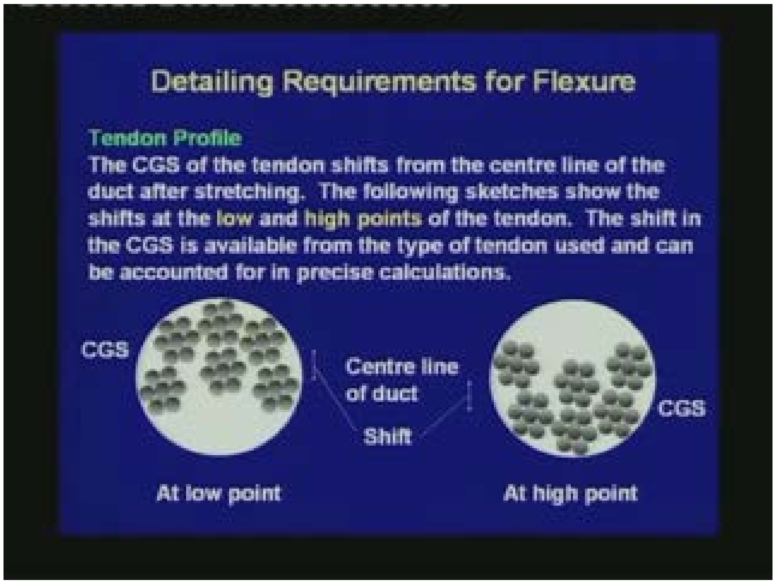
(Refer Slide Time: 15:15)



The profile is implemented by the use of hangers or crossbars or plastic supports called chairs, of varying depth at regular intervals. In beams, the duct is supported by hangers from the top bars or by cross bars attached to the stirrups. The depth of the hanger or the crossbar at a location can be calculated from the equation of the profile. In slabs, the duct is supported on chairs resting on the form work.

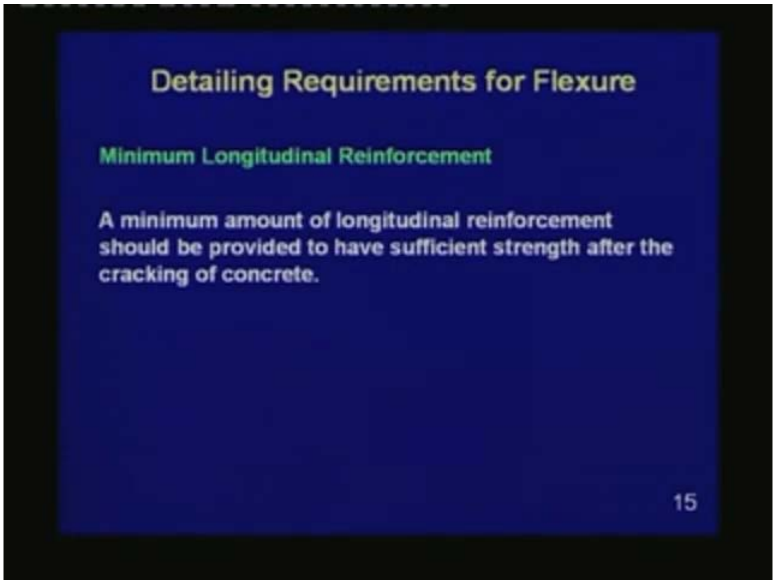
Thus, once we have the equation of the parabolic profile, we can calculate the vertical locations of a tendon along the length of the beam. These values should be mentioned in the design drawings, so that the person who is laying out the duct should not have any ambiguity regarding the layout.

(Refer Slide Time: 16:44)



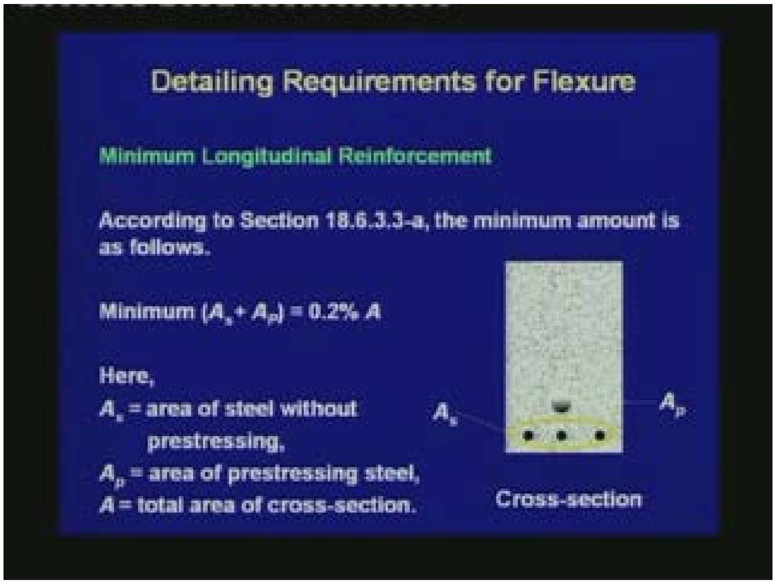
Another feature in the tendon profile is that, the CGS of the tendon shifts from the centre line of the duct after stretching. The following sketches show the shifts at the low and high points of the tendon. The shift in the CGS is available from the type of tendon used and can be accounted for in precise calculations. That is, although we may have placed the duct as per the requirement, once the tendons are stretched the CGS of the tendon may not lie in the centre line of the duct. At a low point, after the stretching the tendons touch the upper surface of the duct and hence the CGS shifts upwards. Whereas, at a high point, the tendons touch the bottom surface of the duct and hence the CGS shifts downwards. This shift may be included if we want precise locations of the CGS.

(Refer Slide Time: 18:07)



Next we are moving on to the requirements of reinforcement. The first one is the minimum longitudinal reinforcement. A minimum amount of longitudinal reinforcement should be provided to have sufficient strength after the cracking of concrete. Although, the prestressed concrete members are expected to crack at a much higher load, after it cracks, it should not reach its strength, immediately. In that case, again the failure will be quite sudden. Hence, the code describes a minimum amount of reinforcement such that the ultimate strength is greater than its cracking strength by a certain amount.

(Refer Slide Time: 19:10)

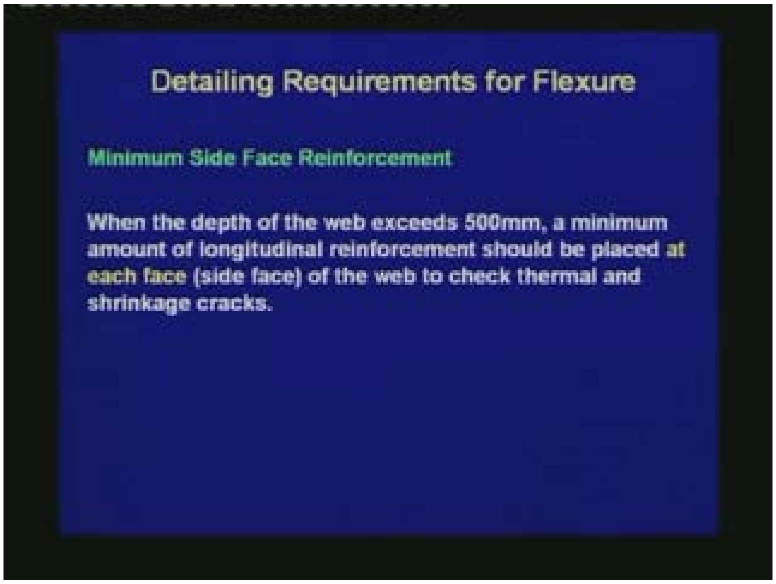


According to Section 18.6.3.3-a, the minimum amount is as follows. The minimum amount is given as the summation of the amount of prestressing steel and the amount of additional flexural steel. The minimum (A_s + A_p) should be equal to 0.2% of the total cross-sectional area. Here, A_s is the area of the steel without prestressing, if we have it for additional flexural strength in a partially prestressed member. A_p is the area of the prestressing steel and A is the total area of cross-section. Remember that, here A_s does not include the temperature or shrinkage reinforcement which are not designed for flexural capacity.

Note that the minimum amount of longitudinal reinforcement is independent of the cracking strength of the concrete. Hence, if we are using high strength concrete we have to be cautious about using this expression. The code limits the maximum strength of the concrete to 60 N/mm^2, and this equation is applicable up to that grade of concrete.

The minimum reinforcement can be reduced to 0.15% of the area of the section, if high yield strength deformed bars are used as non-prestressed reinforcement. Thus, the code gives us a flexibility to reduce the minimum amount of steel if we are using high strength deformed bars.

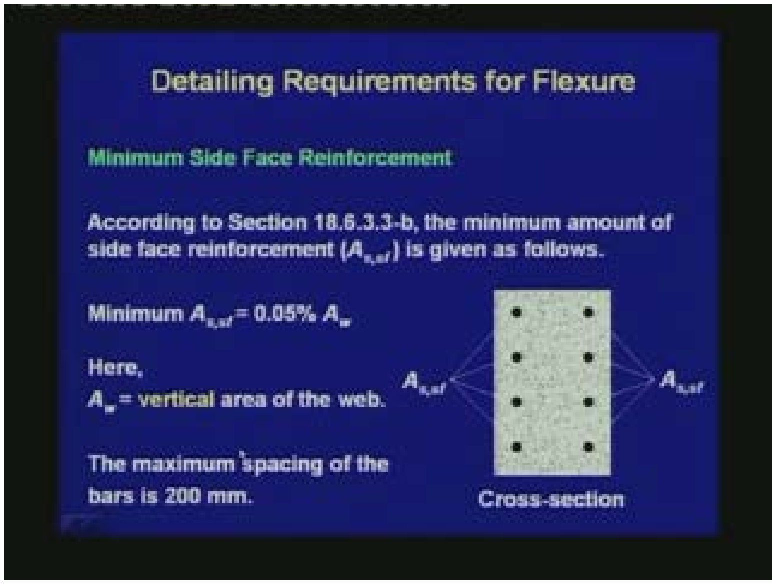
(Refer Slide Time: 22:10)



Next, we are studying about the minimum amount of side-face reinforcement. When the depth of the web exceeds 500 mm, a minimum amount of longitudinal reinforcement should be placed at each face, which is called a side face of the web, to check thermal and shrinkage cracks.

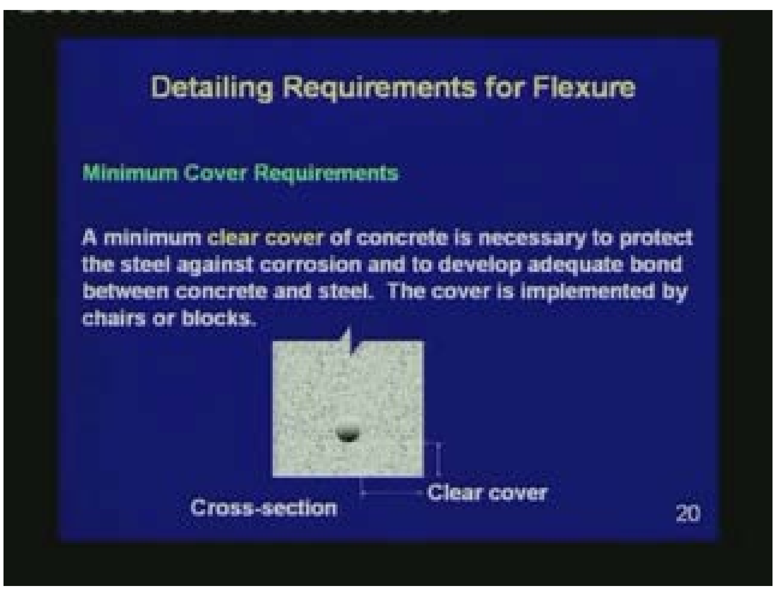
When the web is deep, the flexural steel is concentrated at the bottom near the span, and at the top near the supports for a continuous beam. According to Section 18.6.3.3-b, the minimum amount of side face reinforcement, which we shall denote as $A_{s,sf}$ is given as follows.

(Refer Slide Time: 23:10)



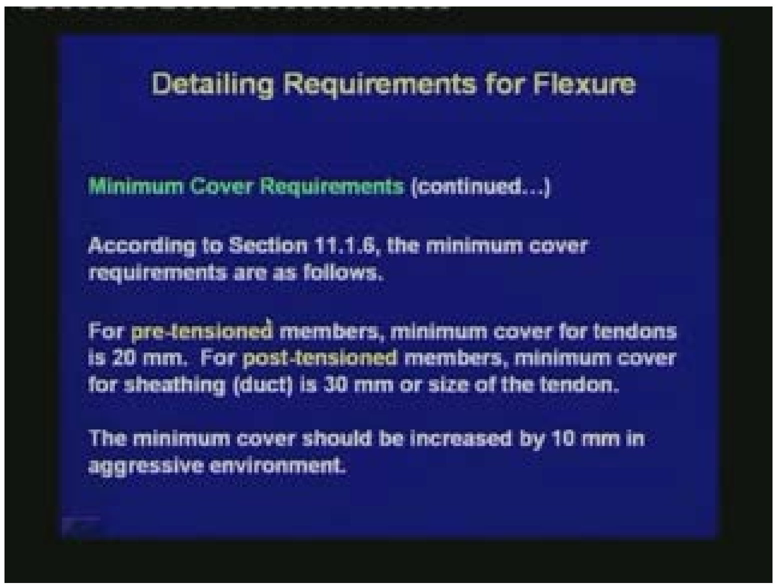
The minimum $A_{s,sf}$ is equal to 0.05% of A_w, where A_w is the vertical area of the web. In each face, the amount of longitudinal steel should be 0.05% of the area of the web. Another requirement is that the maximum spacing of the bars is 200 mm. The side face reinforcement is also known as skin reinforcement.

(Refer Slide Time: 24:05)



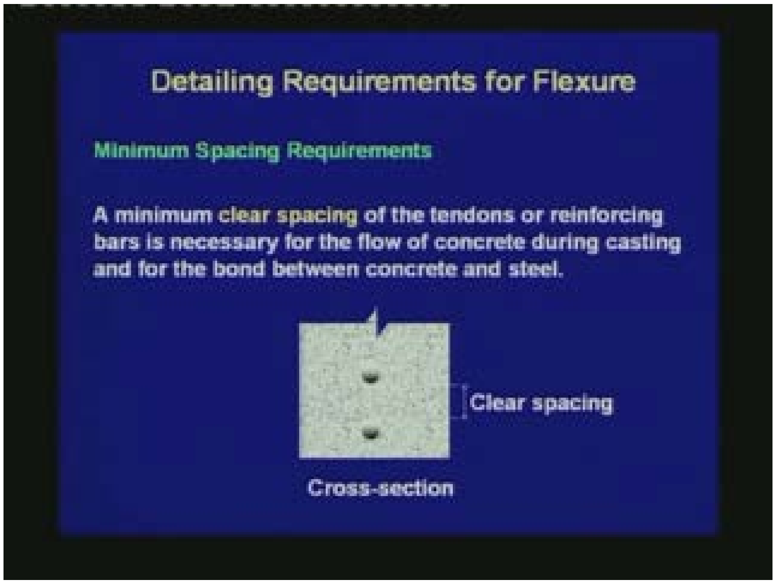
The next requirement is the minimum cover. A minimum clear cover of concrete is necessary to protect the steel against corrosion and to develop adequate bond between concrete and steel. The cover is implemented by chairs or mortar blocks. We have to remember that when we talk of cover, it is not just the cover below the steel, but it is also the cover on the two sides of the steel. The requirement of the code is based on a clear cover, which means it is from the nearest face of the duct to the edge of the concrete section.

(Refer Slide Time: 25:01)



According to Section 11.1.6, the minimum cover requirements are as follows. For pre-tensioned members, minimum cover for tendons is 20 mm. For post-tensioned members, minimum cover for the sheathing (duct) is 30 mm or size of the tendon. The minimum cover should be increased by 10 mm in aggressive environment. If the environment is aggressive or extreme, then the code recommends having increased cover to check the corrosion of the prestressing tendons. Remember that the corrosion of a prestressing tendon has much adverse effect as compared to the corrosion of a non-prestressed reinforcement.

(Refer Slide Time: 26:35)

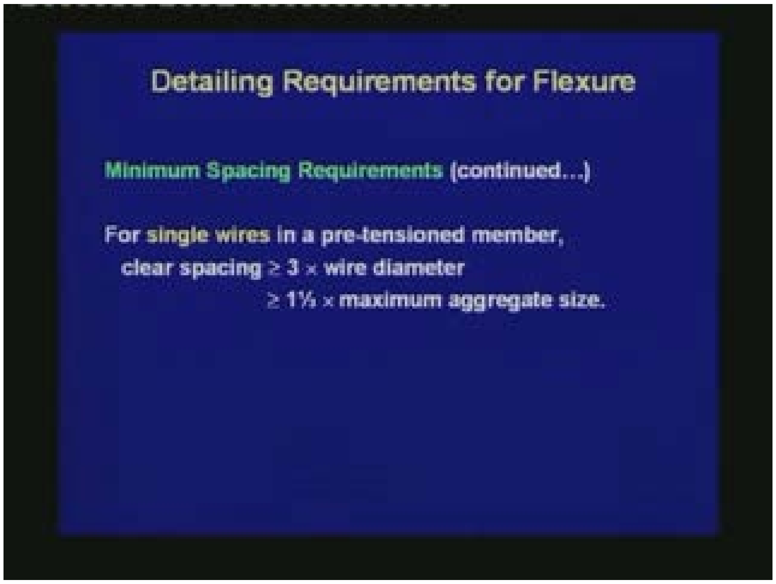


Next is the minimum spacing between the tendons. A minimum clear spacing of the tendons or reinforcing bars is necessary for the flow of concrete during casting and for the bond between concrete and steel. When we are talking of the clear spacing between the ducts, it is the spacing between the surfaces of the ducts.

(Refer Slide Time: 27:08)

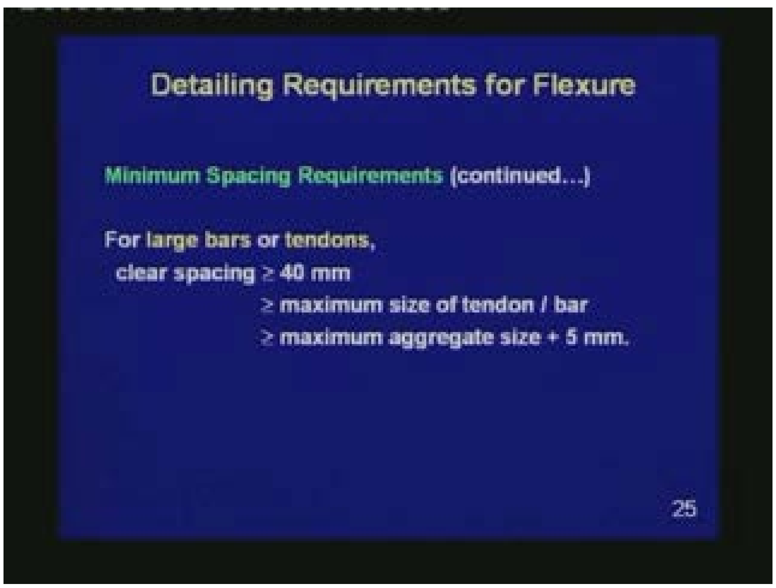
According to Section 11.1.7, the minimum spacing requirements are as follows.

(Refer Slide Time: 27:18)



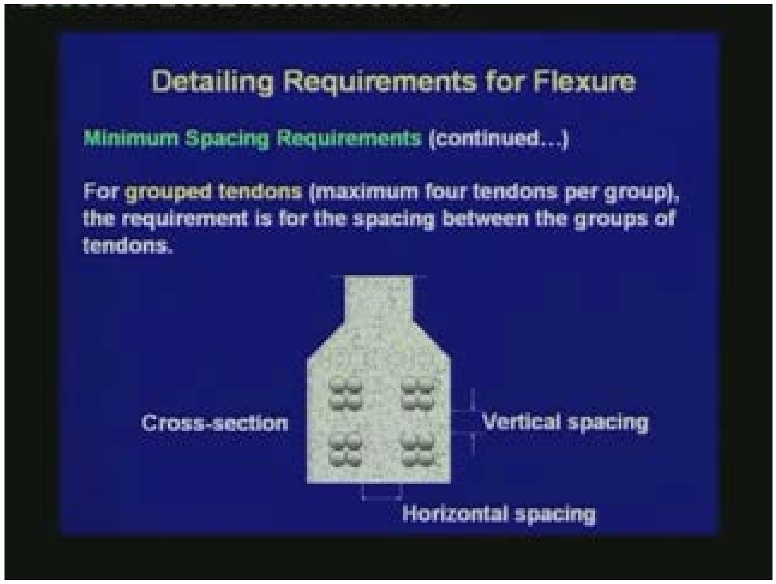
For single wires in a pre-tensioned member, the clear spacing should be greater than 3 × the wire diameter. It should also be greater than 1⅓ × the maximum aggregate size.

(Refer Slide Time: 27:38)



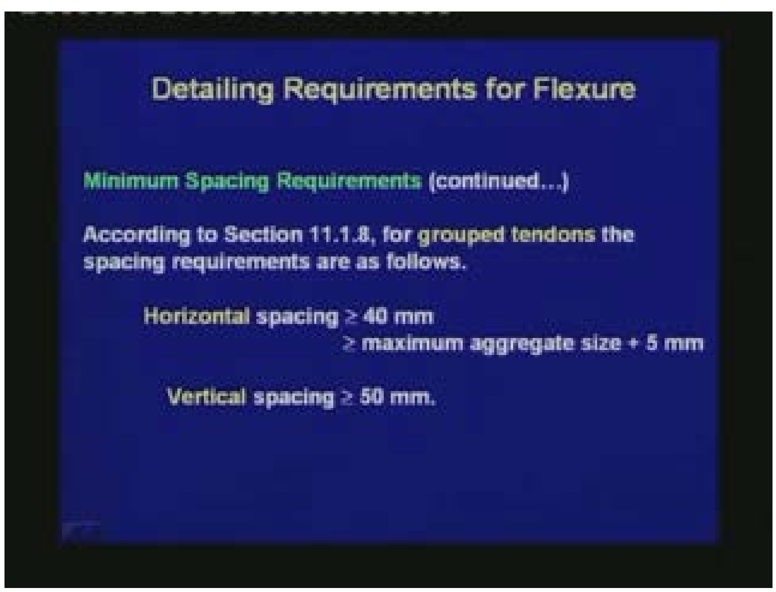
For large bars or tendons, the clear spacing should be greater than 40 mm. It should also be greater than the maximum size of tendon or bar, and it should also be greater than the maximum aggregate size + 5 mm.

(Refer Slide Time: 28:16)



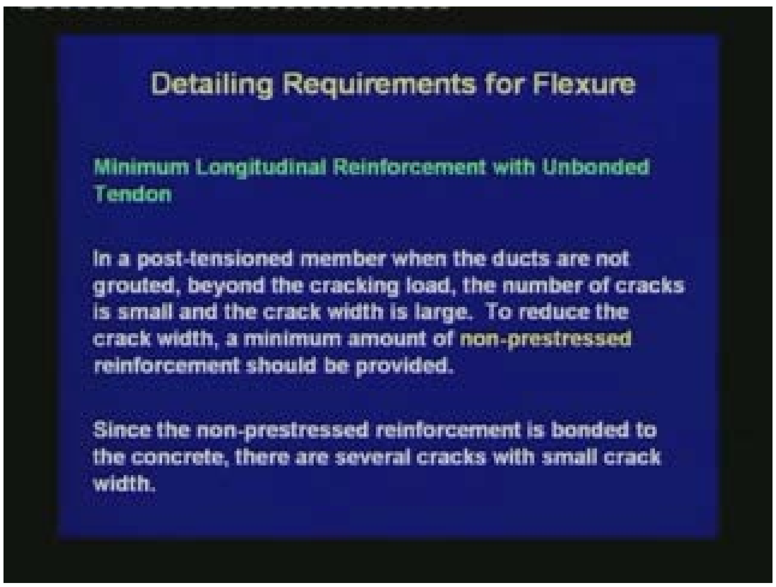
If we are grouping the tendons, then the requirement is for the spacing between the groups of tendons. The code allows having maximum 4 tendons in a group. In this sketch, we have shown 4 groups of tendons, where in each group there are 4 tendons. When we are referring to the spacing we are referring to the spacing between the groups. There is a requirement for a vertical spacing, and there is a requirement for a horizontal spacing.

(Refer Slide Time: 29:01)



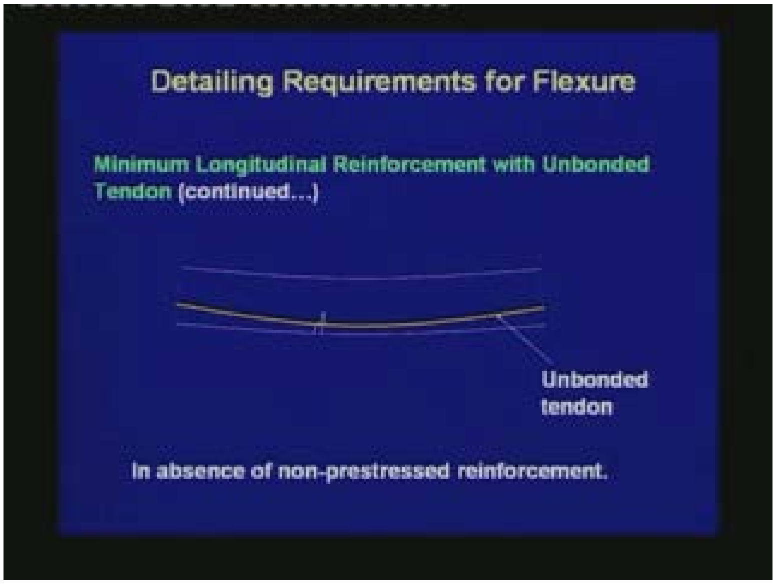
According to Section 11.1.8, for grouped tendons the spacing requirements are as follows. The horizontal spacing should be greater than or equal to 40 mm or it should be greater than or equal to maximum aggregate size + 5 mm. The vertical spacing has to be greater than or equal to 50 mm. It is preferred that the tendons are placed in a one vertical plane.

(Refer Slide Time: 29:46)



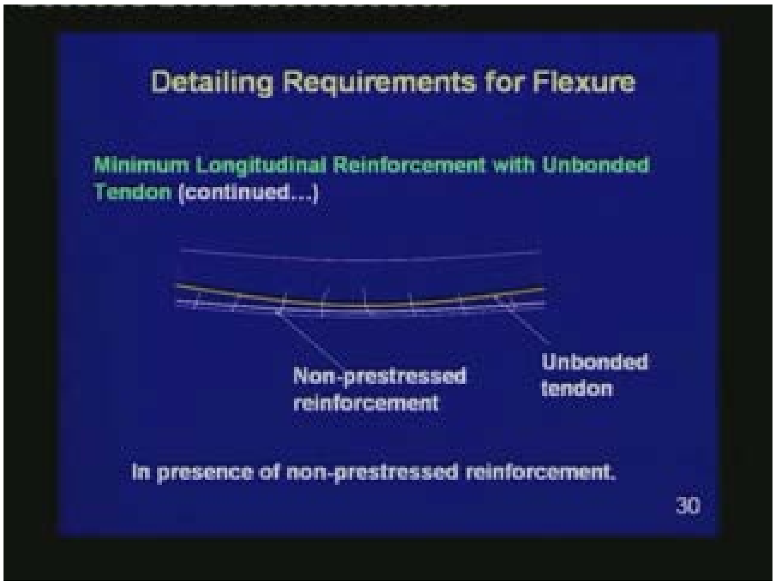
Next, we are studying about the minimum longitudinal reinforcement with unbonded tendons. In a post-tensioned member when the ducts are not grouted, beyond the cracking load, the number of cracks is small and the crack width is large. To reduce the crack width and to distribute the cracking, a minimum amount of non-prestressed reinforcement should be provided. Since, the non-prestressed reinforcement is bonded to the concrete there are several cracks with small crack width.

(Refer Slide Time: 30:25)



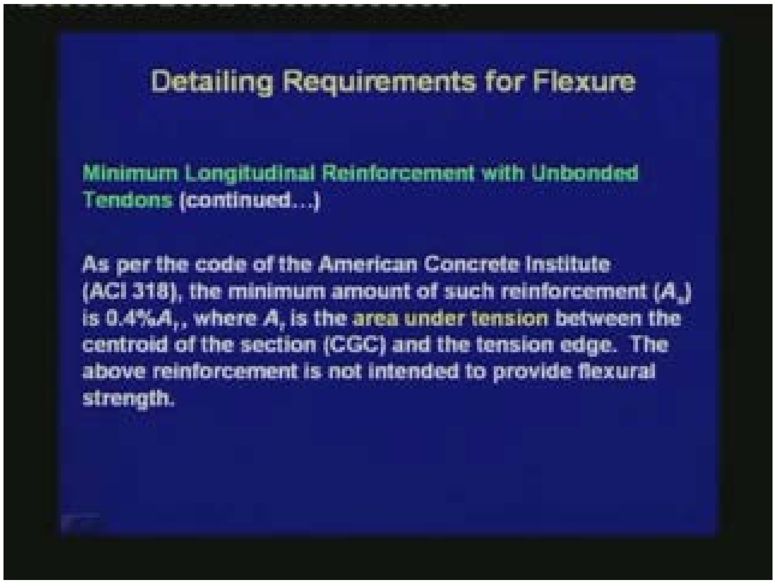
This is a sketch where the member does not have any non-prestressed reinforcement. In that situation, when the load increases beyond the cracking load, then we can observe that there is a single large crack with a substantially large crack width. This is detrimental for the tendon and hence this is not allowed by the code.

(Refer Slide Time: 30:57)



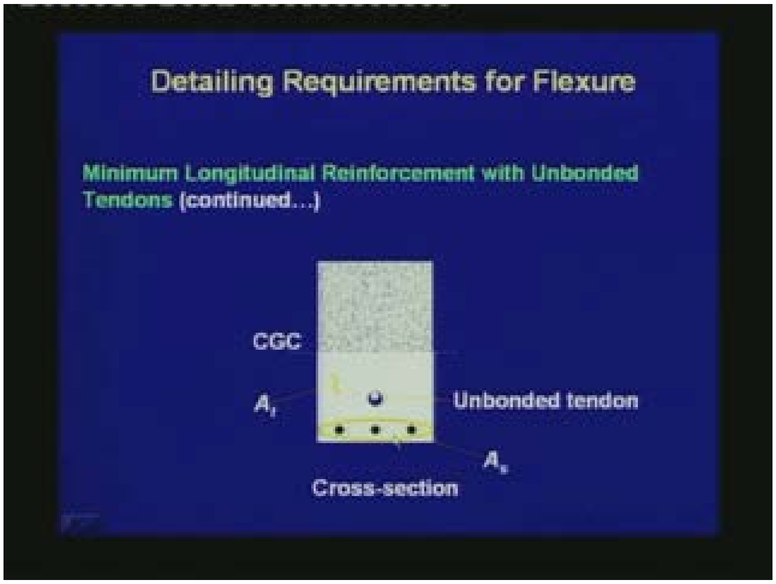
We should have a minimum amount of non-prestressed reinforcement which will help to distribute the crack along the span of the beam and the crack width will get reduced. This is a much better situation regarding the durability and the performance of the beam, as compared to the beam without any non-prestressed reinforcement.

(Refer Slide Time: 31:27)



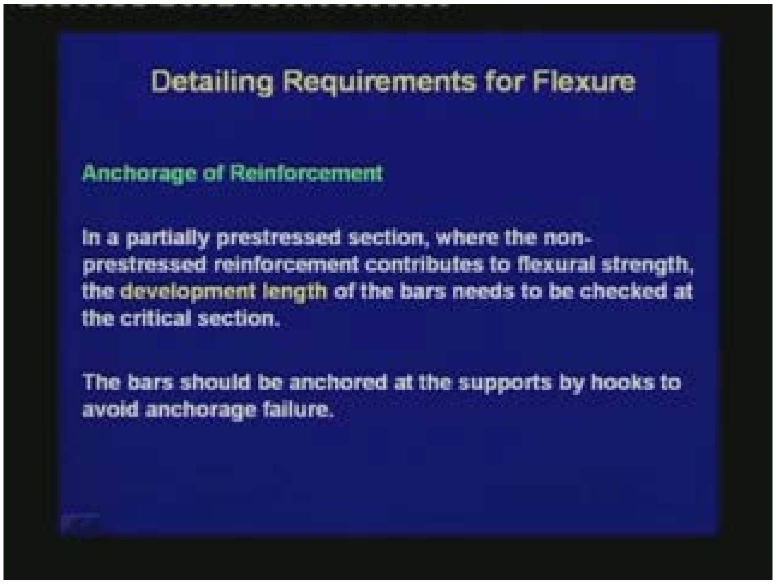
As per the code of the American Concrete Institute, which is ACI 318, the minimum amount of such reinforcement is 0.4% A_t, where A_t is the area under tension between the centroid of the section (CGC) and the tension edge. The above reinforcement is not intended to provide flexural strength.

(Refer Slide Time: 32:00)



The way this reinforcement is calculated is that, we are considering the area which is under tension and that area is given by the part which is between the CGC and the extreme tension face. We are denoting that area by A_t. The minimum amount of non-prestressed reinforcement is equal to 0.4% of A_t.

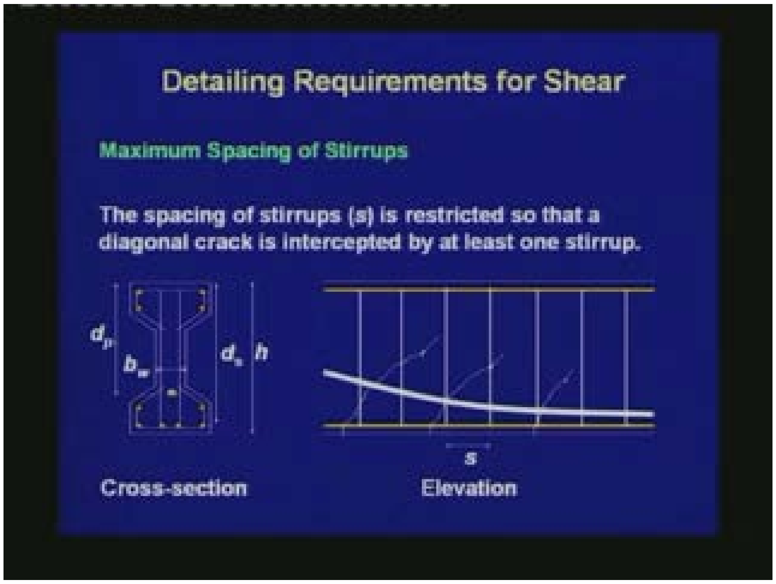
(Refer Slide Time: 32:48)



Our next requirement is the anchorage of reinforcement. In prestressed concrete section, if it has non-prestressed reinforcement which contributes to flexural strength, the development length of the bars needs to be checked at the critical section. We had talked earlier that, a prestressing tendon develops the strength through the bond in case of a pre-tensioned member, or through the anchorage in case of a post-tensioned member. But, the non-prestressed reinforcement in a partially prestressed member should have adequate development length, and that is measured from the critical section. In this lecture, we are not going into the details of calculating the development length because that is covered in a course of reinforced concrete.

The requirement of development length is satisfied by providing adequate embedment length or hooks at the ends. The bars should be anchored at the supports by hooks to avoid anchorage failure due to pull out of the bars.

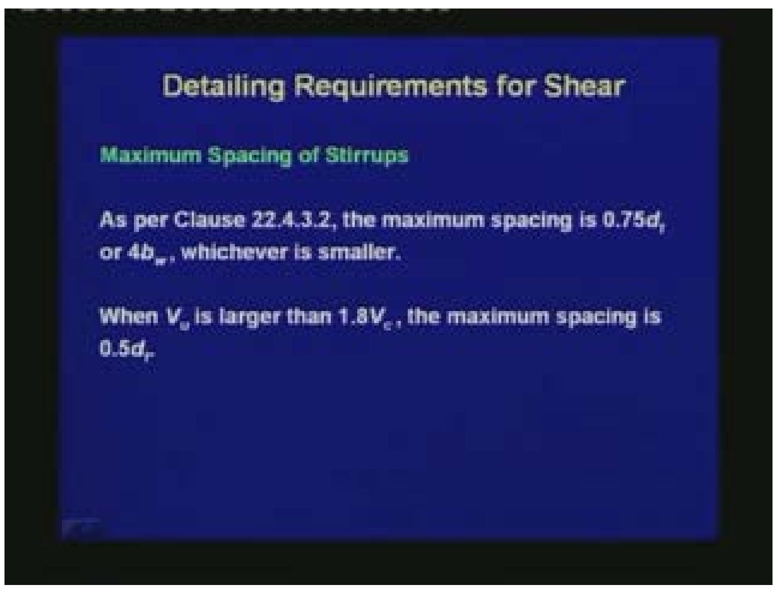
(Refer Slide Time: 34:53)



Next, we are moving on to the detailing requirements for Shear. The detailing requirement for the stirrups in IS: 1343-1980 are briefly mentioned. We shall study the analysis and design for shear in a subsequent module. Here, we are discussing the detailing requirements to have a total picture of the detailing of reinforcement in a prestressed concrete member. The first requirement of the design of stirrups in a prestressed concrete beam is the maximum spacing. The maximum spacing is mentioned because it restricts the growth of the cracks. The spacing of the stirrups, which is denoted as ‘s’ is restricted to a maximum value, so that a diagonal crack is intercepted by at least one stirrup.

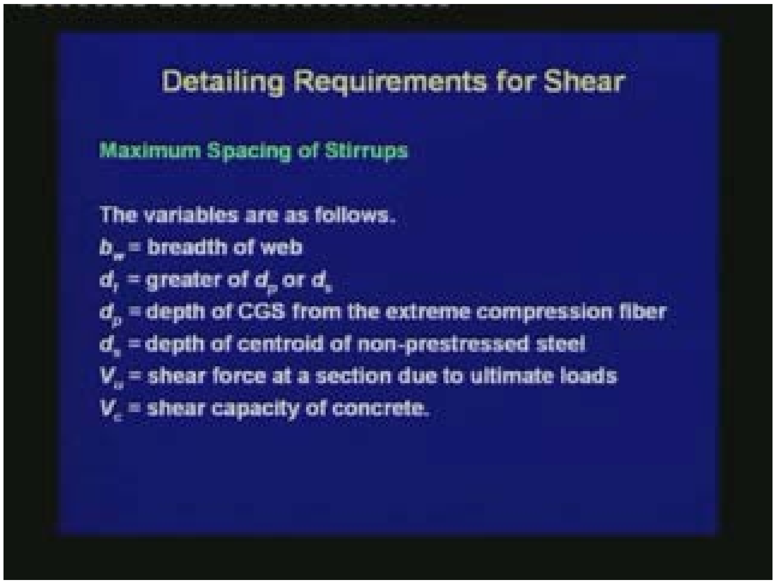
The cross-section of a typical I-girder is shown. These are the variables that we will be using: d_s is the depth of the centroid of the non-prestressed steel; d_p is the depth of the CGS; h is the total height and b_w is the width of the web. In the elevation we see that due to shear or a combination of flexure and shear, the cracks tend to be diagonal. We have to provide stirrups in such a way that there is at least one stirrup to intercept the diagonal crack, and hence the spacing of the stirrups is restricted to a maximum value.

(Refer Slide Time: 36:58)



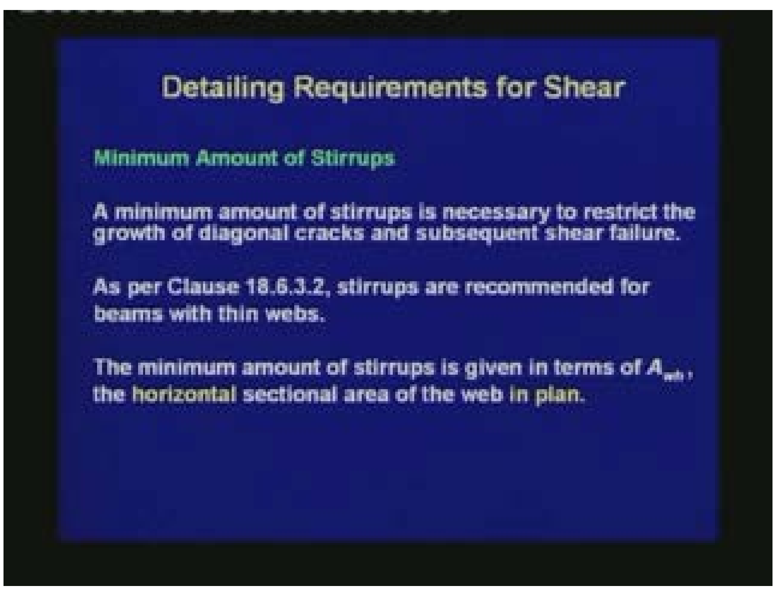
As per Clause 22.4.3.2, the maximum spacing is $0.75d_t$ or $4b_w$, whichever is smaller. When V_u, the shear demand at a section due to ultimate loads is larger than $1.8V_c$, where V_c is the capacity of concrete, the maximum spacing is reduced to $0.5d_t$.

(Refer Slide Time: 37:17)



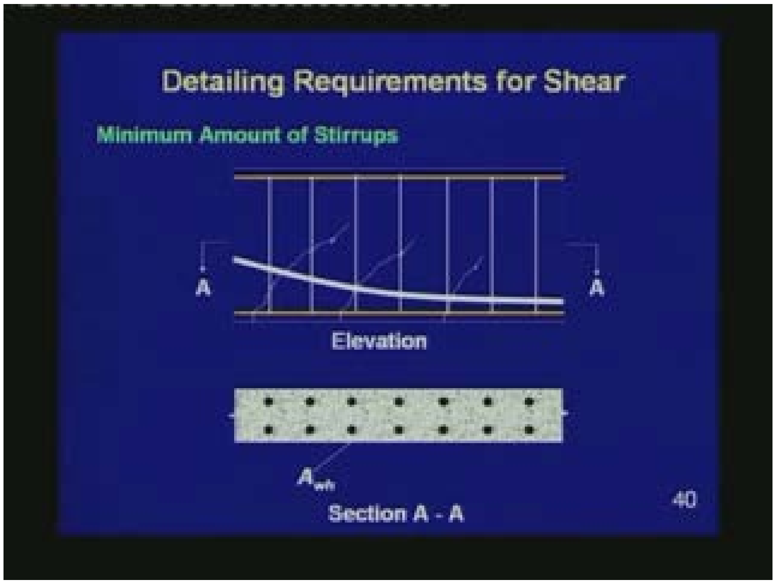
Here, d_t is greater of d_p or d_s, that means whichever reinforcement is at the bottom, we calculate the distance of that reinforcement and we denote that as d_t.

(Refer Slide Time: 38:30)



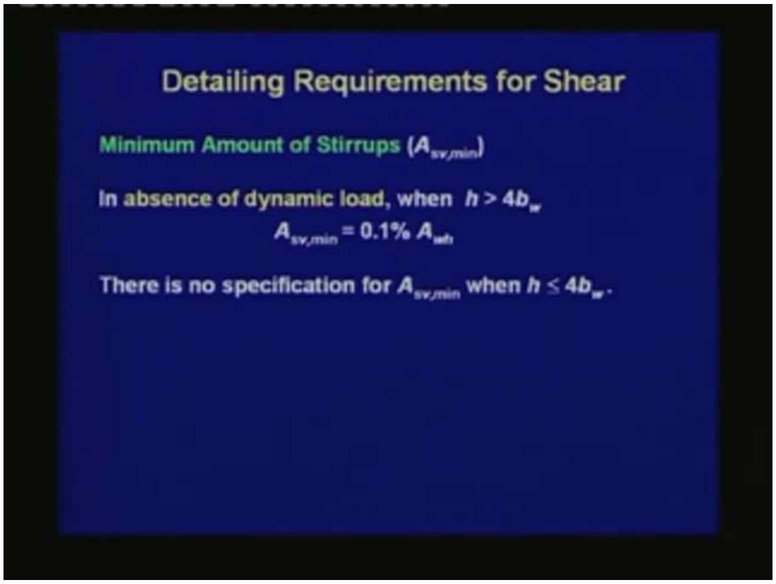
A minimum amount of stirrups is necessary to restrict the growth of diagonal cracks and subsequent shear failure. As per Clause 18.6.3.2, stirrups are recommended for beams with thin webs.

(Refer Slide Time: 39:09)



Although, for low value of a shear demand the shear capacity of the concrete may be adequate, it is recommended that we provide shear reinforcement at least for beams with thin web. The minimum requirement of the amount of shear reinforcement is based on the horizontal area of the web, which we are denoting as A_{wh}. The horizontal area is explained by the sketch. If we take a section through the web, then A_{wh} is the area in the plan. Based on this area, we calculate the minimum amount of stirrups that should be provided. The minimum amount of stirrups is denoted as $A_{sv,min}$. In presence of dynamic load, the minimum amount of stirrups is 0.3% of A_{wh}. It can be reduced to 0.2% A_{wh}, when the total height (h) is less than $4b_w$. With high strength bars, the amount of reinforcement can be reduced to 0.2% A_{wh}; it can be even reduced to 0.15% of A_{wh}, when $h \leq 4b_w$.

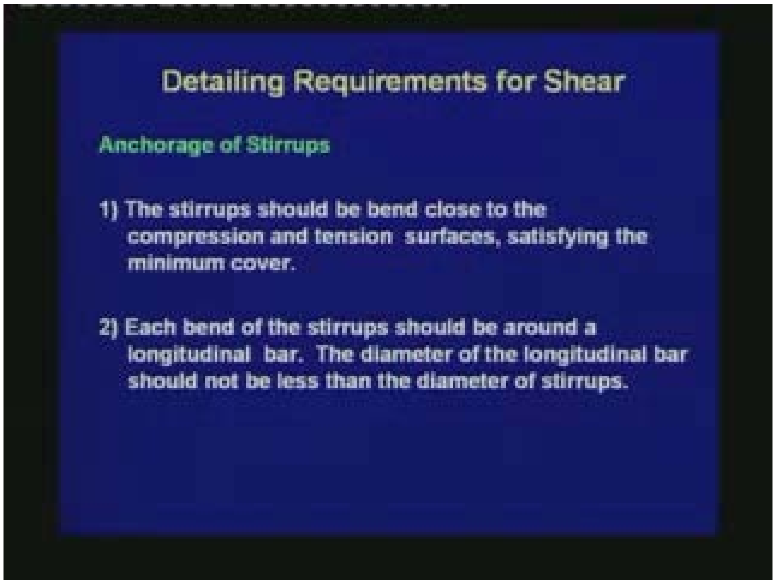
(Refer Slide Time: 40:50)



In absence of dynamic load, when $h > 4b_w$, the minimum amount of stirrups is equal to 0.1% A_{wh}. There is no specification for the minimum amount of stirrups when $h \leq 4b_w$. But it is recommended that some minimum amount of stirrups is provided, especially if the breadth of the beam is small.

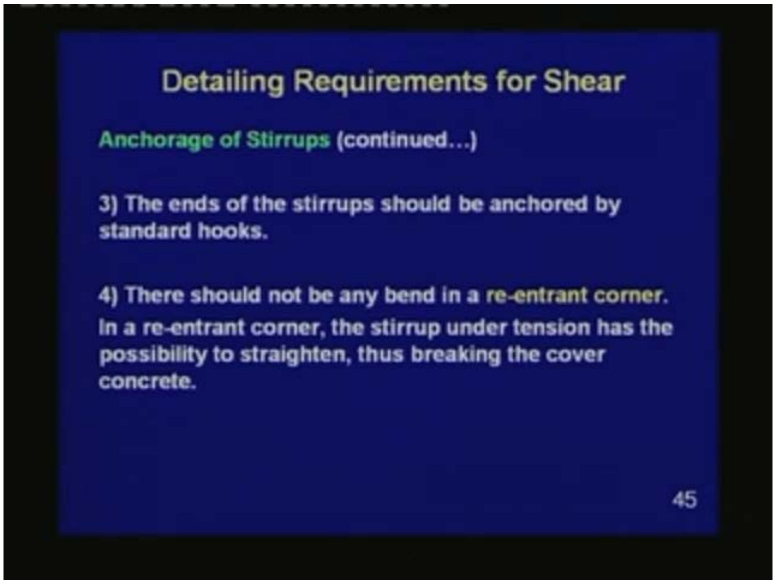
The stirrups should be anchored to develop the yield stress in the vertical legs. As we anchor the longitudinal steel to develop the capacity, similarly the stirrups should be anchored with hooks at the top so as to develop their strength in the vertical legs, under ultimate loads.

(Refer Slide Time: 42:05)



The stirrups should be bent close to the compression and tension surfaces, satisfying the minimum cover. This is the first requirement of anchoring the stirrups. Next, each bend of the stirrups should be around a longitudinal bar because that longitudinal bar will hold the stirrups at the place. The diameter of the longitudinal bar should not be less than the diameter of the stirrups, that means, the longitudinal bar should be stiff enough to check the movement of the stirrups, or opening of the hooks.

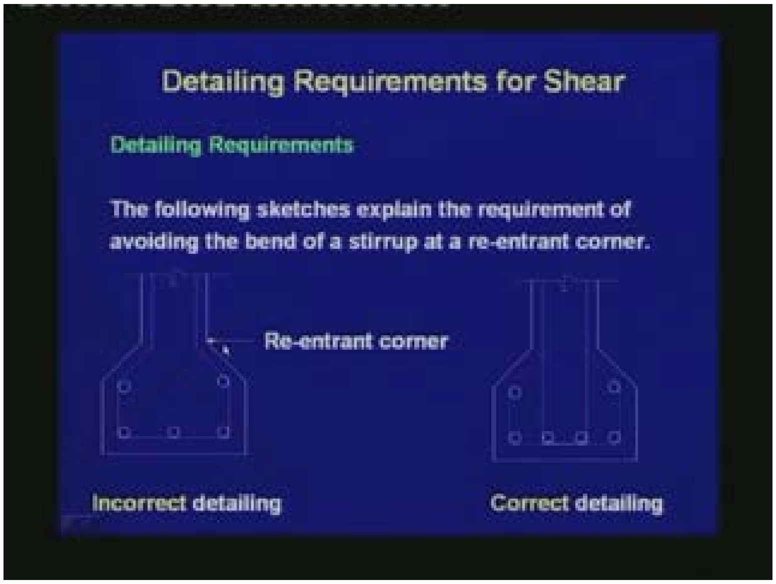
(Refer Slide Time: 42:47)



The end of the stirrups should be anchored by standard hooks. The standard hooks are given in the special publication SP34 of the Bureau of Indian Standards. A standard hook has a certain minimum radius of curvature, and a certain length beyond the bend so that the stirrups are held in place, and they do not move during the increase of the load.

The fourth requirement is that there should not be any bend in a re-entrant corner. In a re-entrant corner, the stirrup under tension has the possibility to straighten, thus breaking the cover concrete.

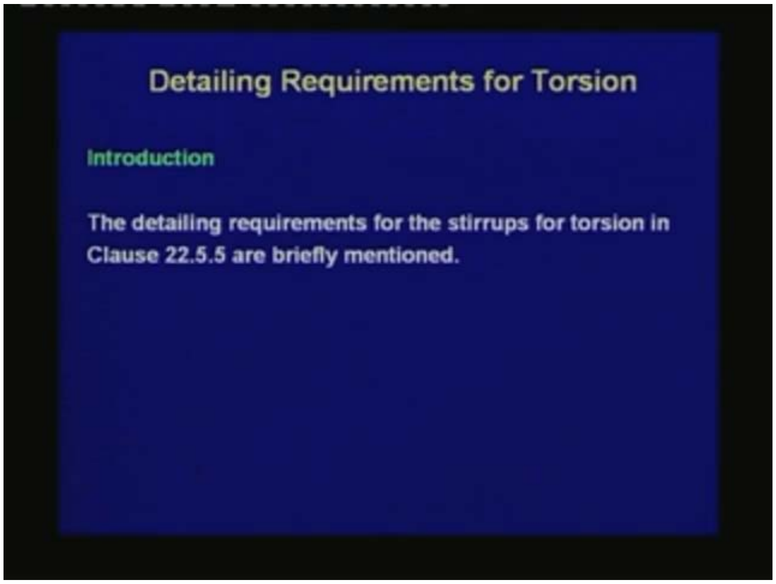
(Refer Slide Time: 44:01)



Let us understand, what is meant by a re-entrant corner? In this figure, the point where the arrow shows is a re-entrant corner. If we provide a stirrup to match the side of the web, when the stirrup is under tension, it will try to straighten and it can break the cover concrete near the re-entrant corner. Hence, it is not permitted to have a bend near a re-entrant corner. We should have individual stirrups, such that the stirrup at the bottom is straight in the re-entrant corners. We provide a separate stirrup in the web. The sketch on the left is an incorrect detailing where the stirrup has a bend at the re-entrant corner. The correct detailing is that we have separate stirrups, and we should not have any bend in any one of them near the re-entrant corners.

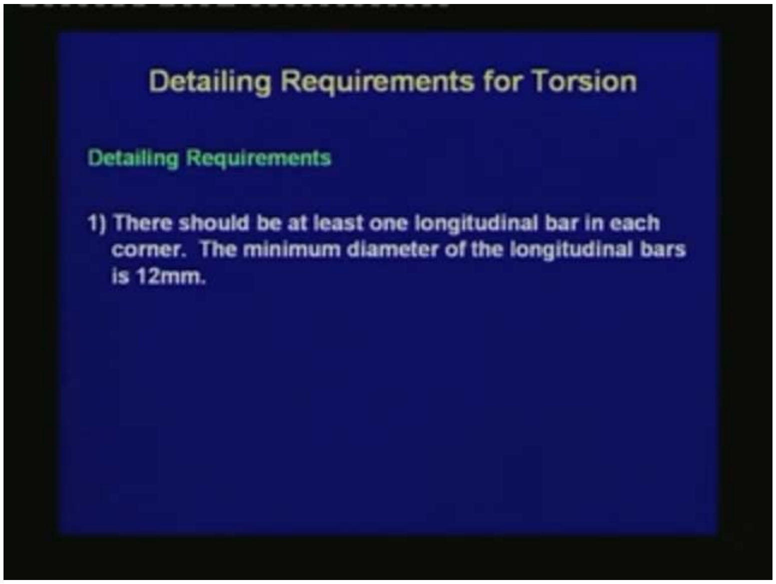
We move on to the detailing requirements for torsion.

(Refer Slide Time: 45:18)



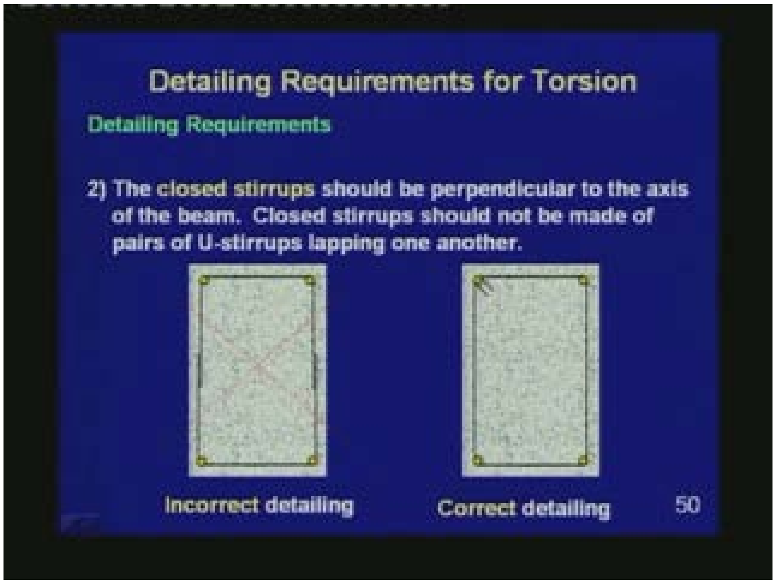
The detailing requirements for the stirrups for torsion in Clause 22.5.5 are briefly mentioned.

(Refer Slide Time: 45:35)



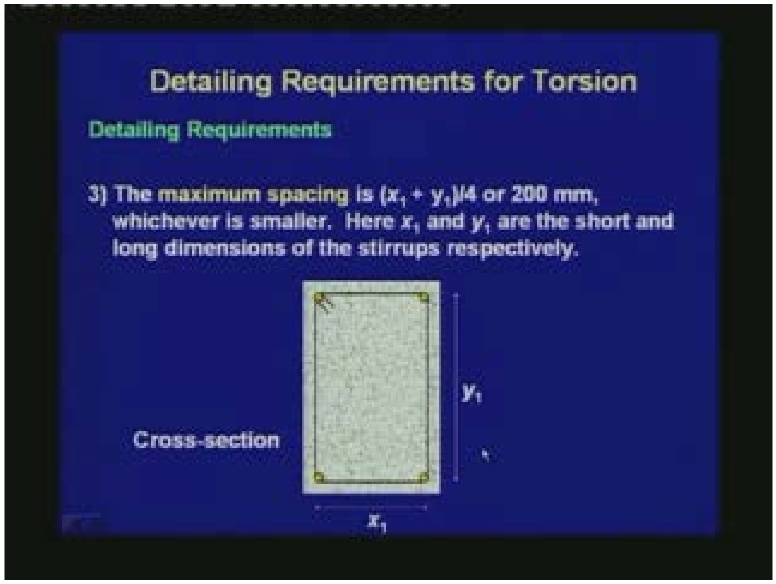
There should be at least one longitudinal bar in each corner. The minimum diameter of the longitudinal bars is 12 mm. Here, we see a requirement similar to the stirrups for shear that wherever we are bending the stirrups, we should provide a longitudinal bar that is stiff enough to hold the stirrup in place. For torsion design, the minimum size requirement is stringent as compared to the stirrup design for shear.

(Refer Slide Time: 47:00)



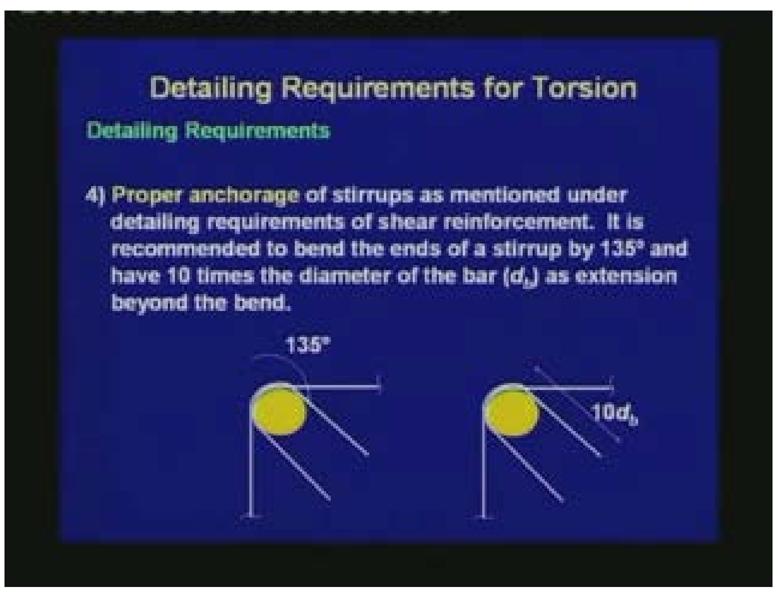
For torsion, we provide closed stirrups to carry the circulatory shear. We shall come to the design of these closed stirrups in the module of the analysis and design for torsion. The closed stirrups should be perpendicular to the axis of the beam and the closed stirrups should not be made of pairs of U stirrups lapping one another. That means, on the left hand side this is an incorrect detailing, where the closed stirrup has been made by lapping two U stirrups; this is not permitted. The correct detailing is that, we make the closed stirrup by a single piece of bar with proper hooks at the ends.

(Refer Slide Time: 47:10)



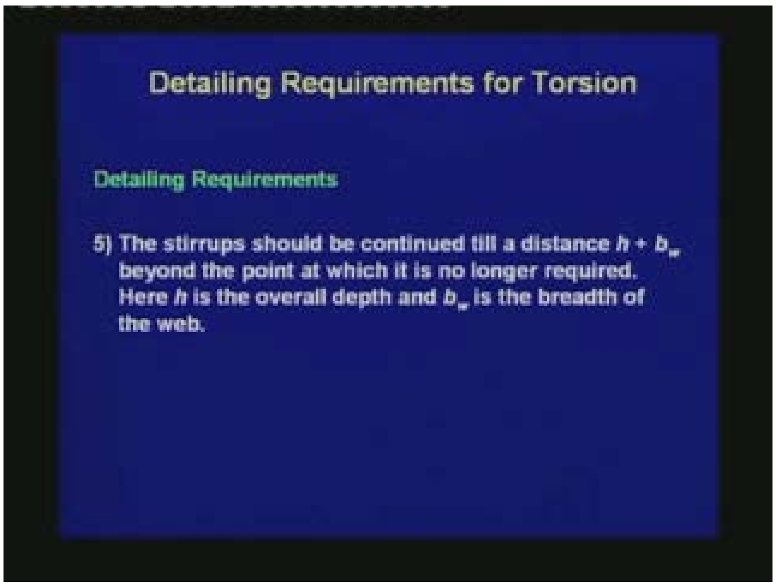
The maximum spacing of torsion reinforcement is $(x_1 + y_1)/4$ or 200 mm, whichever is smaller. Here, x_1 and y_1 are the short and long dimensions of the stirrups, respectively. In this sketch, x_1 is the horizontal dimension and y_1 is the vertical dimension.

(Refer Slide Time: 47:53)



The fourth requirement is the proper anchorage of stirrups as mentioned under the detailing requirements of shear reinforcement. As we had shown the importance of anchorage of the stirrups for shear reinforcement, similar provisions also apply for the reinforcement for torsion. It is recommended to bend the ends of a stirrup by 135° and have 10 times the diameter of the bar (d_b) as extension beyond the bend. That means, the ends of the bar should extend within the core concrete.

(Refer Slide Time: 50:02)

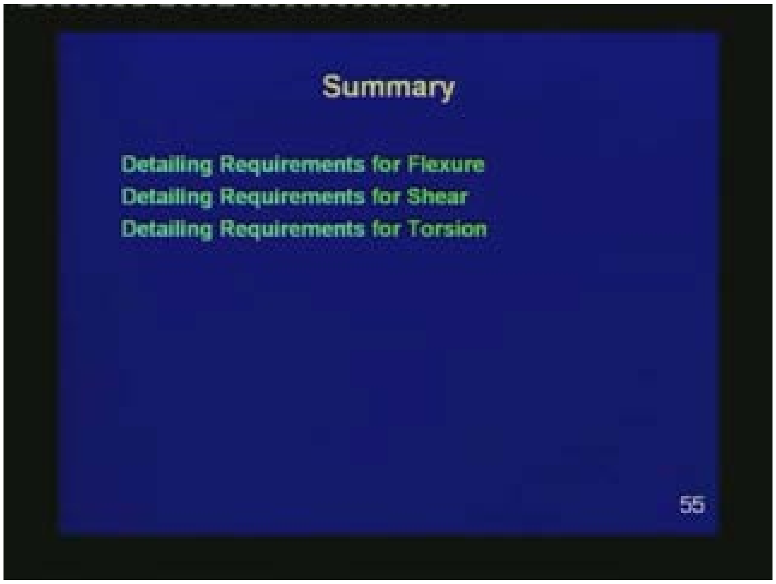


The stirrups should be continued till a distance h + b_w, beyond the point at which it is no longer required by the analysis. Here, h is the overall depth and b_w is the breadth of the web. This requirement is based on the truss action for torsion resistance.

(Refer Slide Time: 50:14)

Here, this is a photograph of the detailing of the steel in a prestressed concrete member. We can see the importance of showing the detailing in the design drawings because the persons who are fabricating the steel should not have ambiguity in placing the steel and the prestressing ducts properly. The prestressing tendons are laid out in a parabolic profile which should be shown properly in the design drawings. The minimum amount of longitudinal reinforcement and stirrups should be provided; the maximum spacing of the reinforcements should be satisfied and the anchorage details of the reinforcements should also be satisfied. Once the proper concrete cage has been made, it should be inspected to check the compliance with the code, and then only the concrete should be poured.

(Refer Slide Time: 51:35)



In today's lecture, we studied the detailing requirements of a prestressed concrete member. We studied the detailing requirements for flexure, shear and torsion. For flexure, the primary importance goes in laying the tendon properly. For a simply supported beam, the tendons are parabolic in nature. The ducts are laid in the proper heights with the help of hangers or cross bars or chairs. The designing of the profile gets more involved in a continuous beam, where the tendon comes down in the span and goes up over the supports. In that type of continuous profile, we have to identify the points of maximum eccentricity at the span and at the supports. We have to identify the points of contraflexure, and then we join a point of maximum eccentricity with the point of contraflexure by parabolic segment.

We have also seen that after the stretching, the CGS of the tendons shifts from the centre line of the ducts. If we need precise calculations then we can consider the shifts in our design checks.

Next we learnt about the requirements for longitudinal steel. The first requirement is that we have to have minimum amount of longitudinal steel such that the strength is higher than the cracking load of the member. We have also said that in case of unbonded tendons, we need to provide some longitudinal reinforcement to check the growth of cracks. This longitudinal reinforcement is not intended to carry flexure, and this reinforcement is distributed near the bottom face to distribute the formation of the cracks and the cracks will have smaller width.

There is another minimum requirement of longitudinal reinforcement; that is the side face reinforcement. If the depth of the web is large then we have to provide minimum amount of steel in the two faces, with maximum spacing between the bars. This steel is intended to check the thermal and shrinkage cracks.

The next set of requirements was regarding the spacing between the tendons. There should be a clear spacing for the flow of the concrete and the development of the bonds. We had seen the requirements for the individual tendons and for group tendons. Another important requirement is the minimum cover which should be provided not only at the bottom of the beam, but also at the sides. The minimum requirement is based on the environment. If the environment is aggressive or extreme, then we need to increase the cover.

Next, we moved on to the detailing requirements for shear. The shear reinforcement which is the stirrups, should be provided within a maximum spacing such that, each diagonal crack is intercepted by at least one stirrup. A minimum amount of shear reinforcement is necessary to check shear failure.

We also studied the detailing of torsional reinforcement, the anchorage of closed stirrups by providing adequate hooks at the ends. With this, we are ending the design of members. In our next module we shall move on to the design of members for shear and torsion.

Thank You.