Design of Connections in Steel Structures
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Module - 3
Lecture - 17
Design of Simple Double Angle Connections

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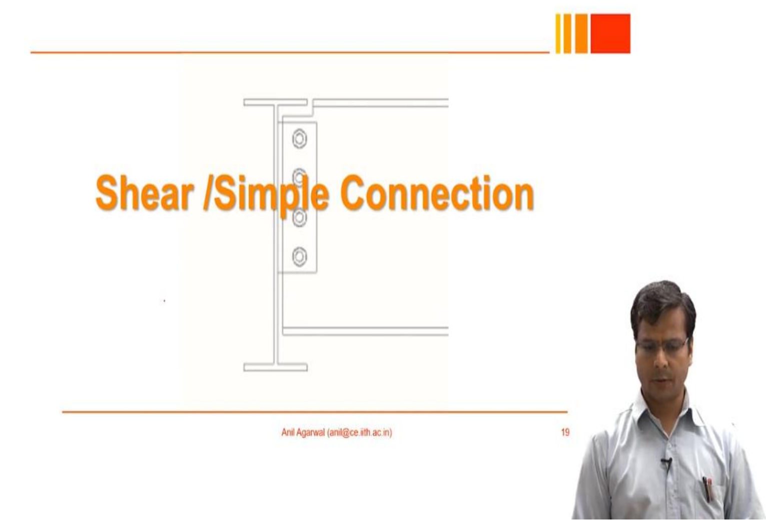

So, now we will talk about some of the design issues with regard to designing of shear or simple connections. So, here is a typical schematic of a simple connection.

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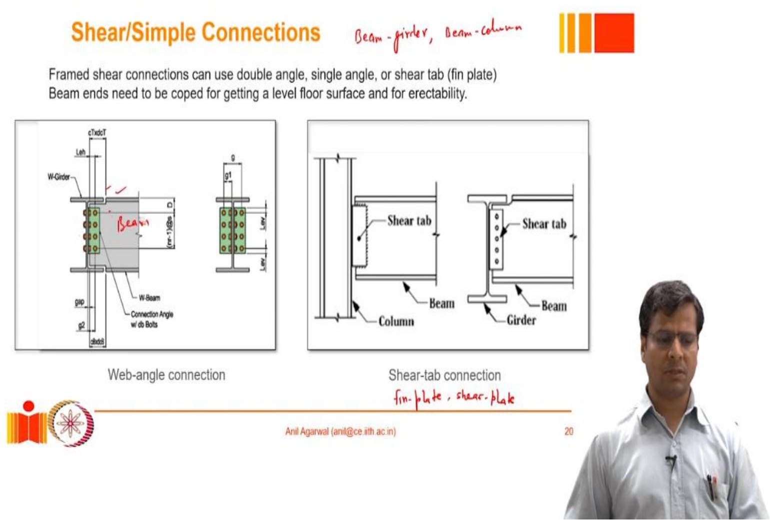

As we had discussed, the first, the 2 major varieties which are often used as a simple connection are the ones where we use either web angles, either 1 or 2; or otherwise we may even use a shear-tab or shear-plate. Sometimes it is referred to as shear-tab; sometimes it is referred to as fin-plate or even a shear-plate. These are different names for this type of a connection. So, I think we have discussed this in somewhat detail.

So, both these connections, shear type connection as well as web angle connection, they could be utilised when we want to join a beam to a girder. So, it can be used for beam-girder condition or beam-girder joint. It can also be used to connect a beam to a column or a girder to a column; the same thing. So, they are more versatile in that way. Because only the web is being connected, so, we do not need many other things.

Now, when we use them to connect a beam to a girder like in this case, so, this one is a beam and let us call this as girder because girder is able to carry the load of the beam, so, girder must be the stronger member in comparison to the beam, because it is carrying the entire load of the beam, maybe some other load also along with that. So, if this is a beam to girder connection, often you would require a floor system above it which will require us to have a flat surface above the beam.

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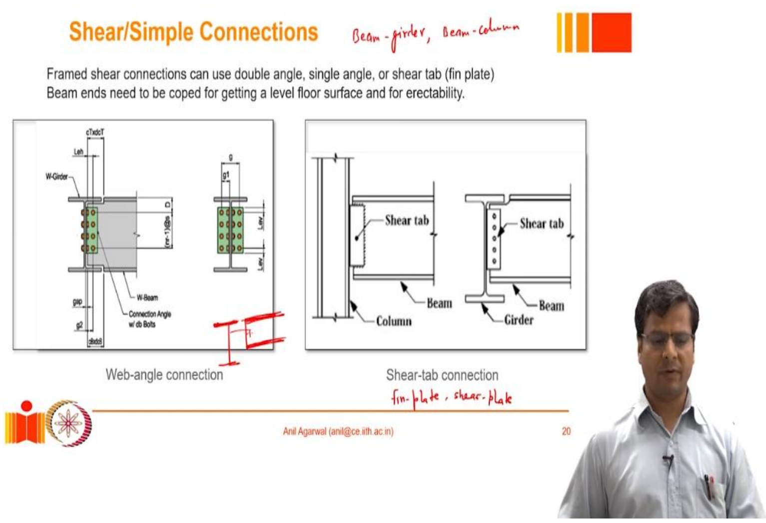

It will be difficult if we wanted to connect this girder to another beam which is let us say this tall, and its flange is at the same level as the flange of the girder, then, if we want to bring it here, we will not be able to bring the web of the beam close to the web of the girder. And the eccentricity will be very large, and we cannot provide this kind of a shear connection.

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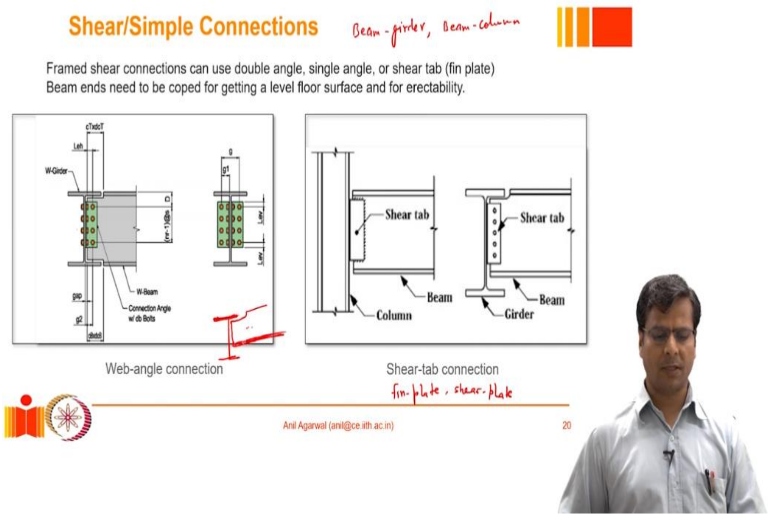

Therefore, in order to facilitate that, often we cope a part of the beam. So, if the beam is not as deep as the flange, we may just cope the top flange.

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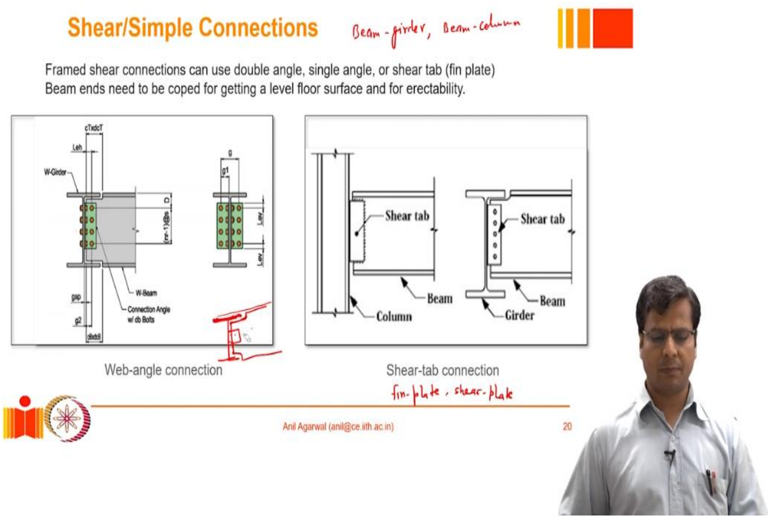

If it is almost as deep as the girder, then we may have to cope both ends. So, this is called coping of the beam. And typically, the motivation for that is so that we can get a flat surface above it. And we can bring the webs close together so that they can be joined in shear. If we are going for a column to beam connection, then there are slightly somewhat other challenges are there.

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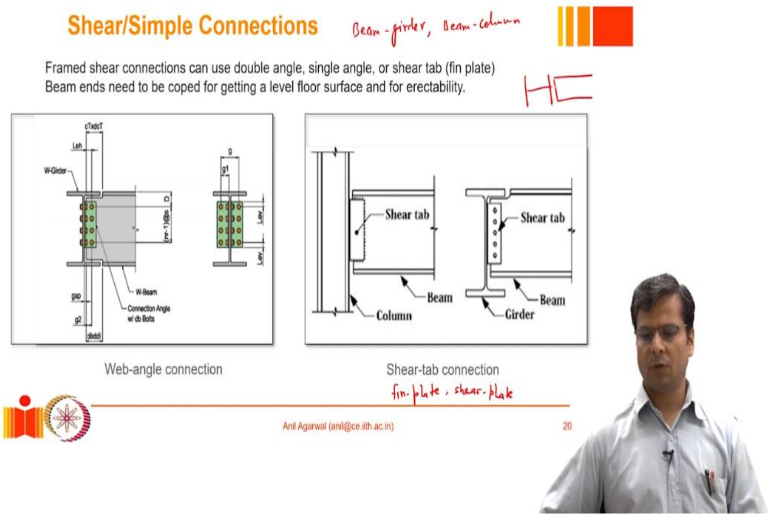

So, let us say we have a column which is an I section and we want to connect a beam to this column. So, right now I was showing a flange.

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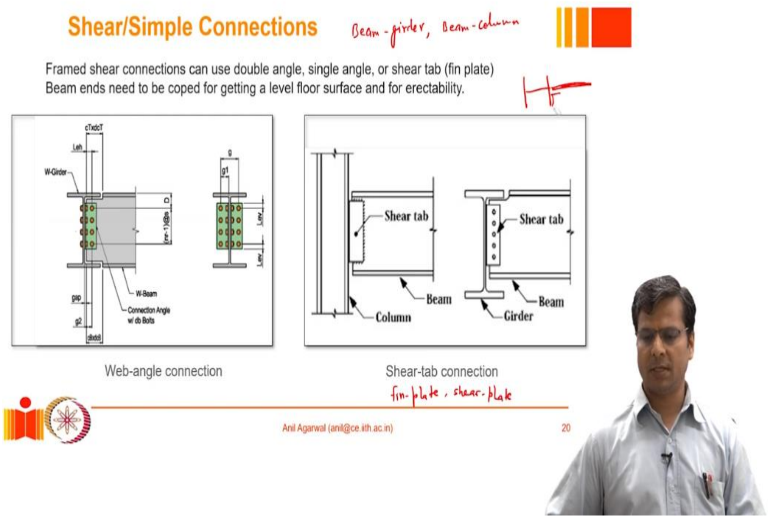

Now, let me show the web of the beam. So, web of the beam is right here. And if you want to use an angle to connect it, I can simply connect it without having to worry about any coping in the beam. So, it is an easy way to do it.

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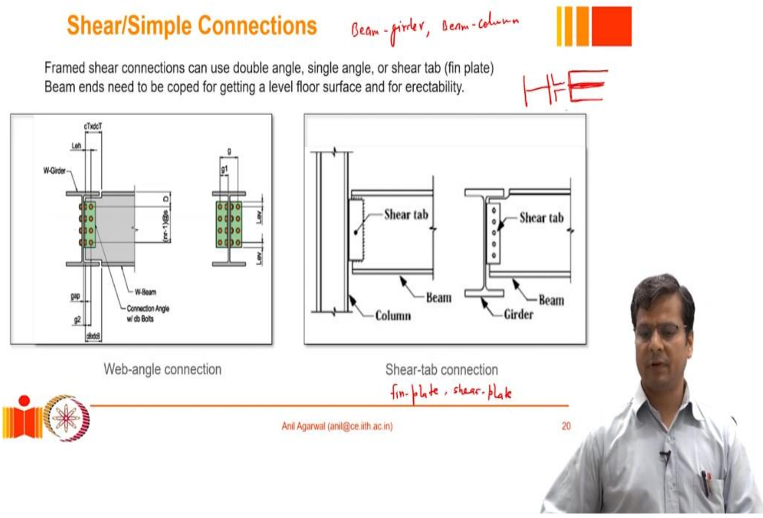

However, if I want to use a double angle, now you may realise, if I put a double angle and typically what would happen is that, this double angle will be welded to the column at the shop. So, this column would come to the site with these double angles welded to the column, maintaining the exact distance between them, what is required to fit the web of the beam. So, web of the beam can barely fit this gap; that is the idea.

And so, this is the web and this is the flange of the beam, the flange width of the beam; and this needs to fit inside. But at the site, we do not have space to pull the beam back and then slide back in. That is very difficult. Usually, we have to lower the beam at the site, which makes it very difficult to place.

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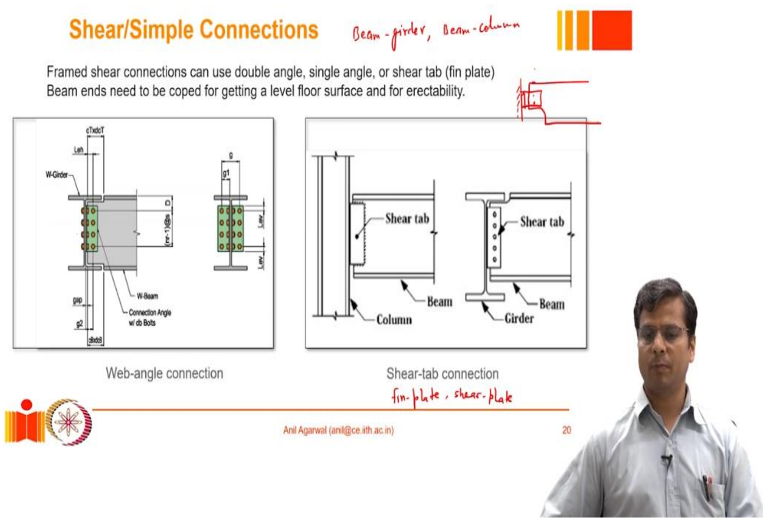

In such a situation, often the bottom flange of the beam has to be coped so that if we have angles here and especially if it is a double angle connection, you can lower the beam to this position between the 2 angles; and there is a column here. So, there the coping requirement is for the bottom flange even though the top flange does not require any coping, because the floor is not continuing over the column. If the orientation also could be different in certain cases;

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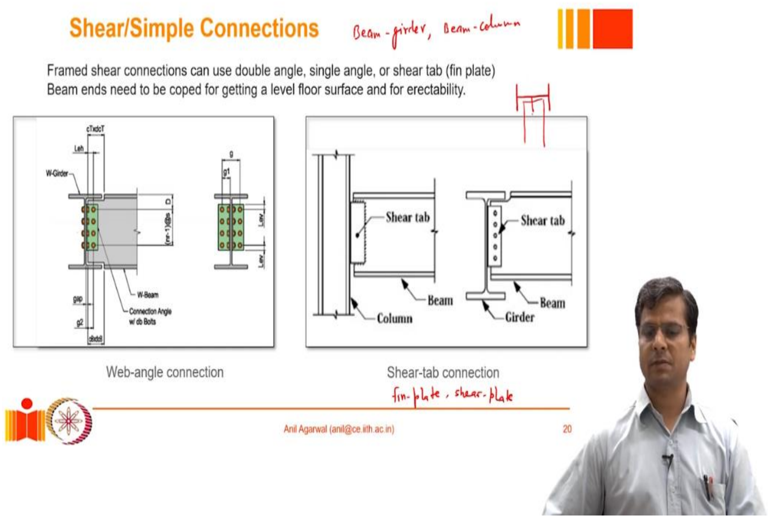

So, in some cases, for example, I may want to connect a beam, bring a simple connection, I want to provide a simple connection here. Now, in such a situation, it is perfectly fine. The beam width is less than the column depth. It is fitting perfectly fine; no issues.

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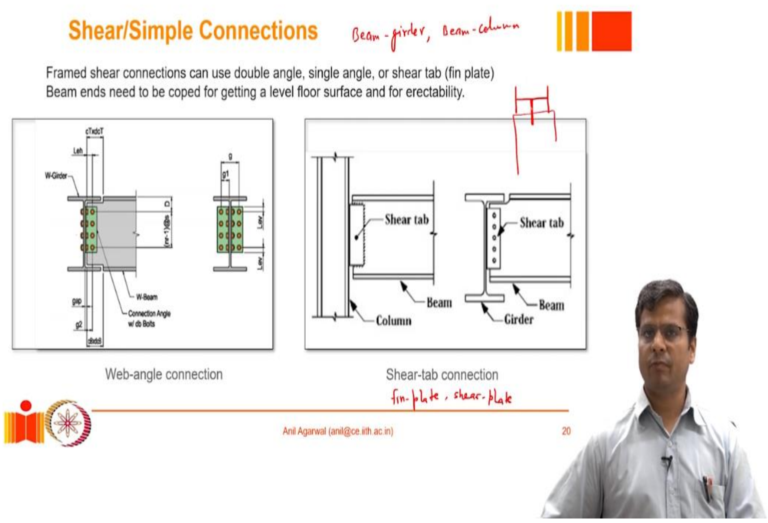

But sometimes, there may be a situation where I want to provide a simple connection; it could be an angle or it could be just a thin plate connection. And I want to provide a beam which is wider than the depth of the column. If that is the situation, I cannot bring the beam all the way back. So, either we cope the top flange again completely, like what is shown here;

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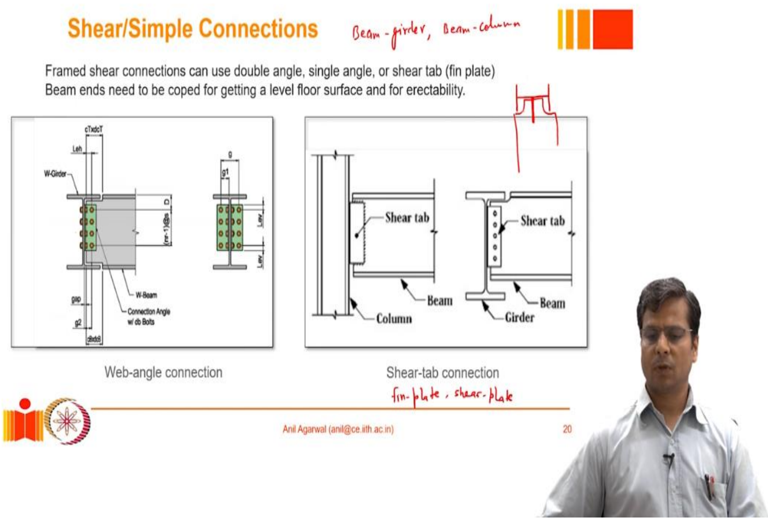

Or sometimes, we do not cope it completely but we cope it from the sides. So, that it allows some space for the column flanges. So, these are some of the additional considerations that we have to pay attention to when we provide shear simple connections which may include a shear-tab or single or a double angle connection.

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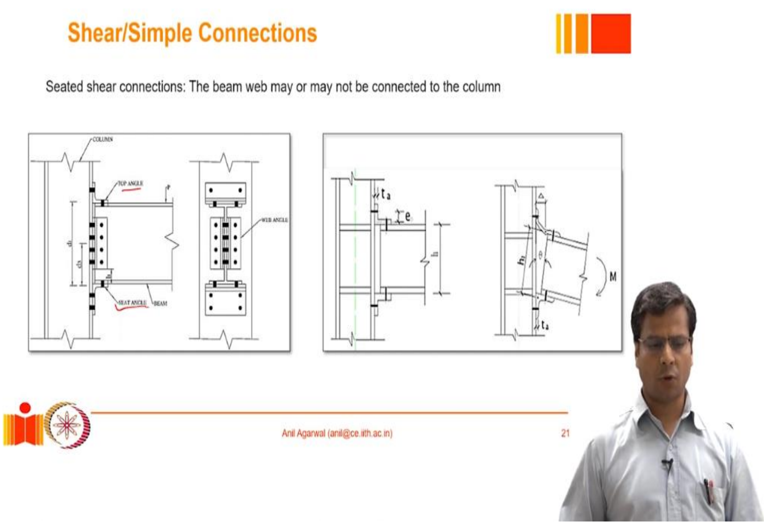

When we go for a seated connection, there are again 2 varieties. We can go for seated connection where there are seat angles provided at the bottom as well as there is a top angle provided. And in addition to that, we may decide to provide some angles to transfer the shear through the web. But typically, in such a scenario, the seat angle would be carrying most of the shear force, and the participation of the web angles will be relatively minor. Top top angle usually does not participate in load transfer; it just is present there to provide lateral stability to the beam so that the beam does not start rotating sideways.

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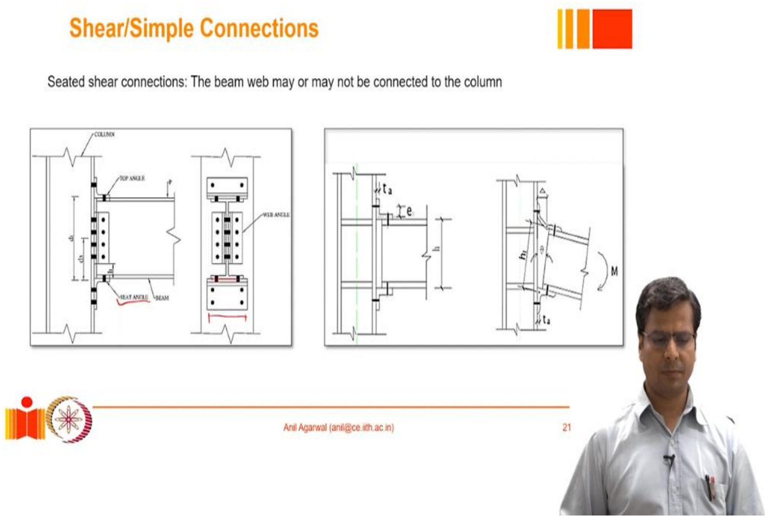

In such a situation, you might notice that the angle is almost the same width as the beam flange.

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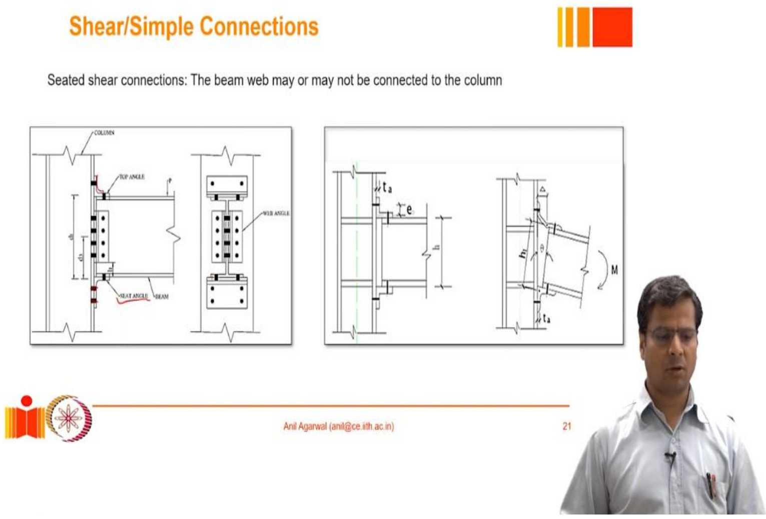

And this leg of the angle could be either bolted or welded to the flange. But typically, this angle is not welded to the flange because again;

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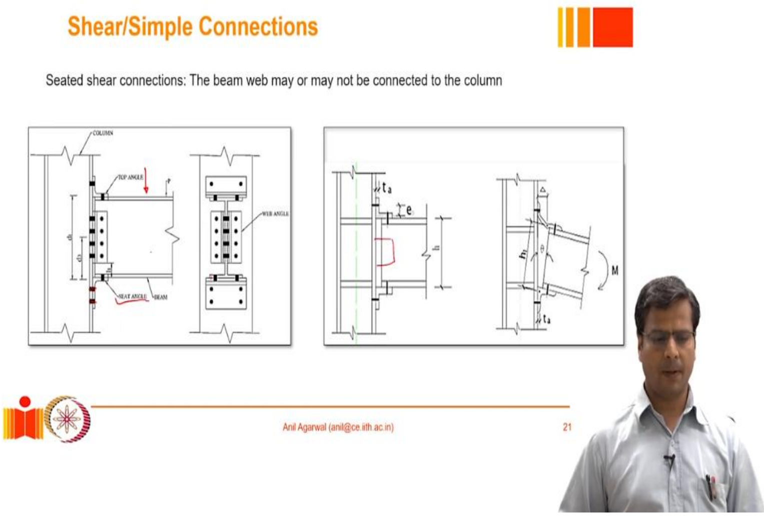

Because of the consideration of lowering the beam in place. So, once we want to lower the beam in place, we do not want this angle to be there to prevent its movement. Another variation of this connection would be where we do not provide any web angle, and again, that also works equally well.

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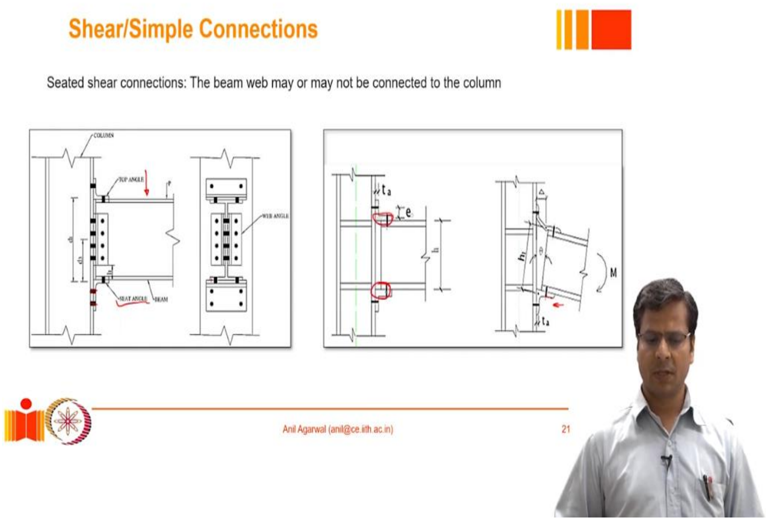

And in these cases, as I had discussed before that these angles, even though they offer lot of resistance when we push them this way; so, in a seated angle connection, as we had discussed that even though the connecting elements are sitting close to the beam flange, still it does not offer or it does not behave like a rigid connection;

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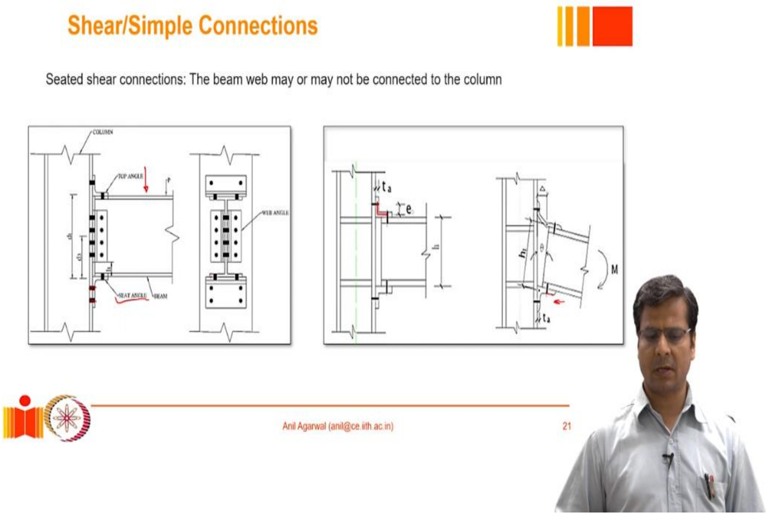

Because these angles themselves are very flexible when we pull them.

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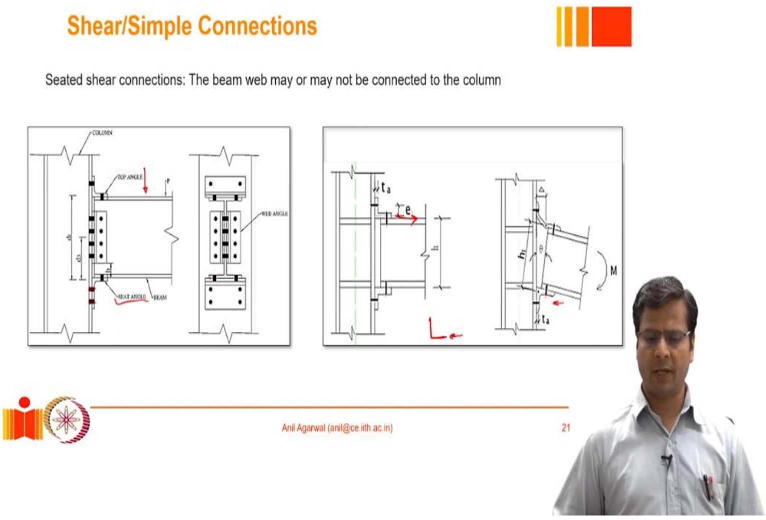

So, if we push this angle in, it would offer very high level of resistance.

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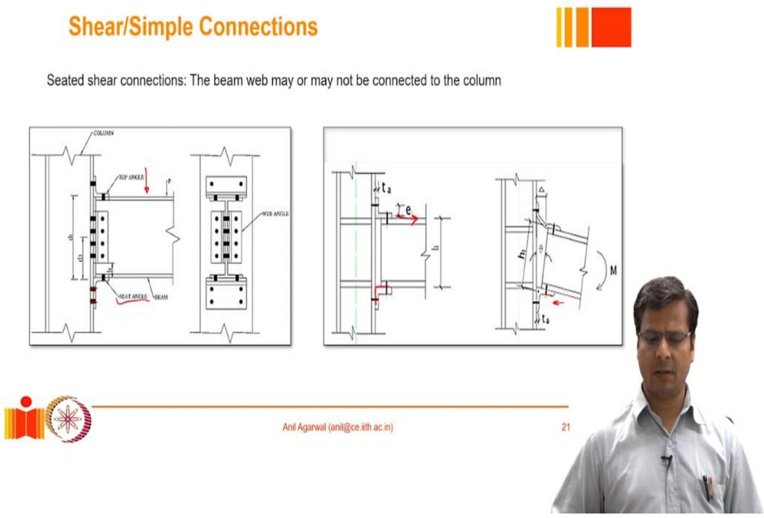

Likewise, that is what is happening in this angle.

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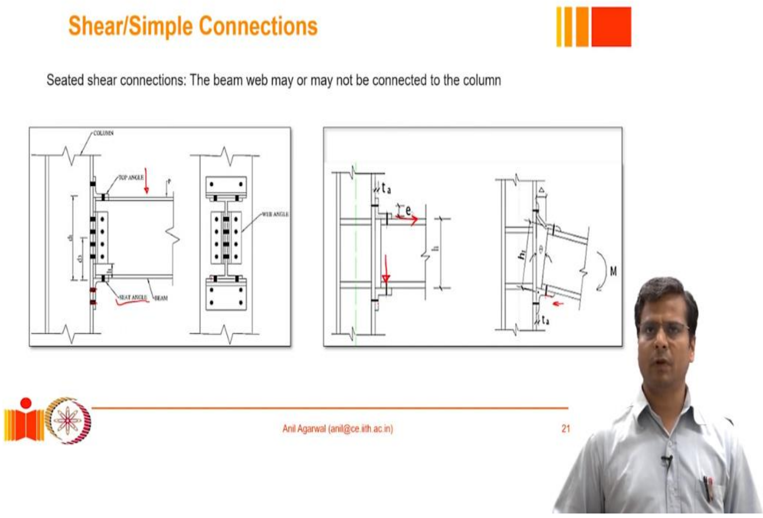

If we push this angle downward, it offers very high level of resistance; it has a very high stiffness.

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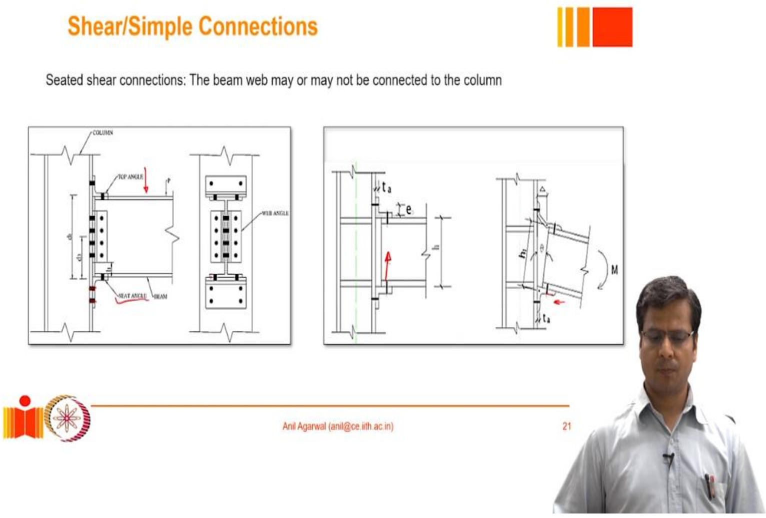

However, when we push it in this direction, or that is the same case as if we pull this angle in this direction.

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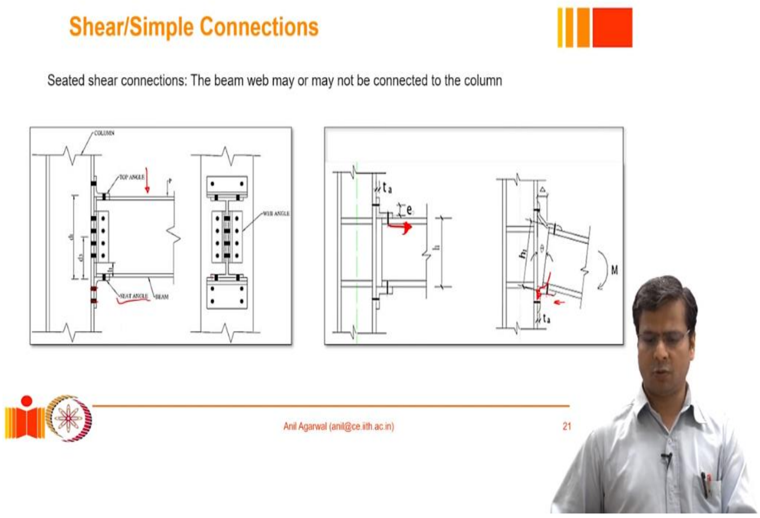

These angles in this such scenario are very flexible and they do not offer lot of resistance. And therefore, as a result, this connection starts to behave like a simple connection. And most of the shear force gets transferred to the bottom through the bottom flange.

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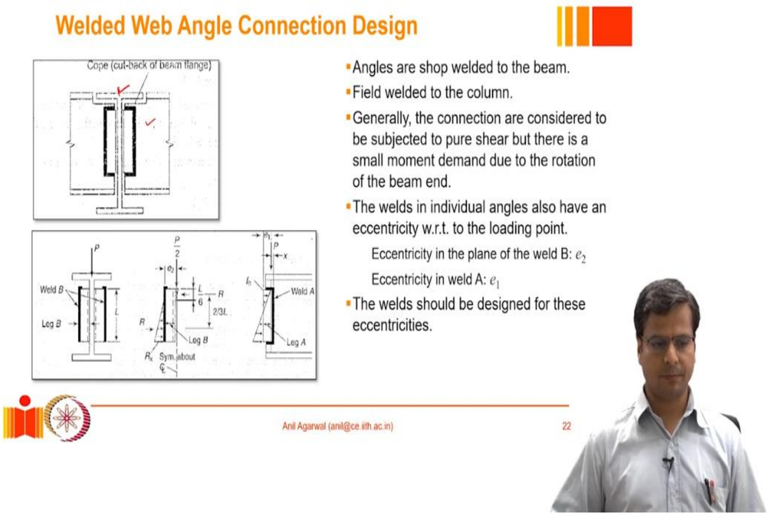

Now, when it comes to web angle connections, so, we will talk about only the type of connections which are available in the Indian Standard IS 800 which I specified there. The other types of connections which I have mentioned before, we can follow International Standards such as American Standards or European Standards to design them. In this discussion, we will restrict ourselves to only the ones that are present in Annexure F of IS 800.

So, there is a possibility that we can provide a double angle connection wherein the angles are welded to the supporting element which is the girder here, and also welded to the supported element which is the beam here. So, this is a beam to girder connection.

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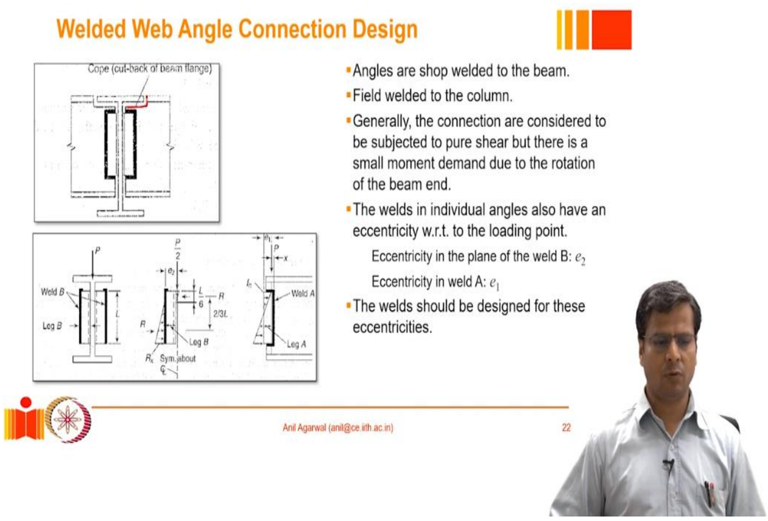

And as we had discussed, there will be a coping requirement in a beam to girder connection, because we want to develop or we want to have a flat surface at the top.

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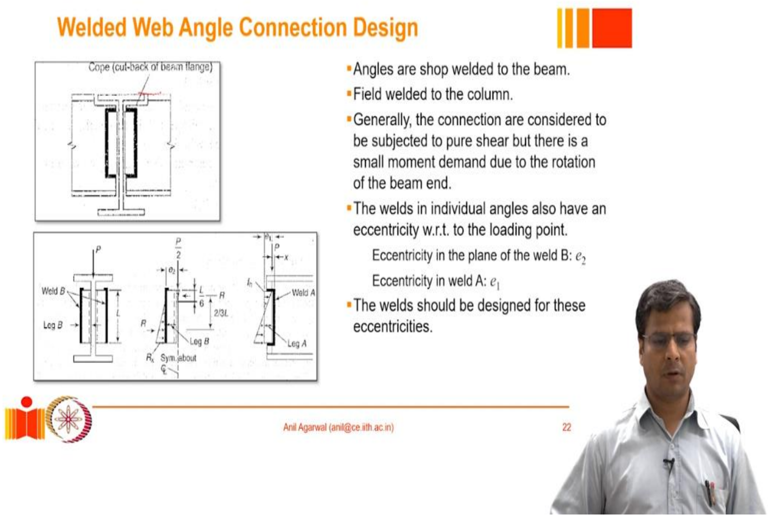

So, we typically would have, if it is a welded-welded connection beam, we are more likely to have the field welding to be done at the column, between the angle and the column, and shop welding will be done between the angle and the beam. So, angle will come to the site where already welded to the beam. And then, at the site, it will be welded to the column. There is always, as we had mentioned that all the connections that we may call them as simple connections, but they still have some level of moment resistance because we can never connect a member exactly at one dot, at one point; it always has to have some level of;

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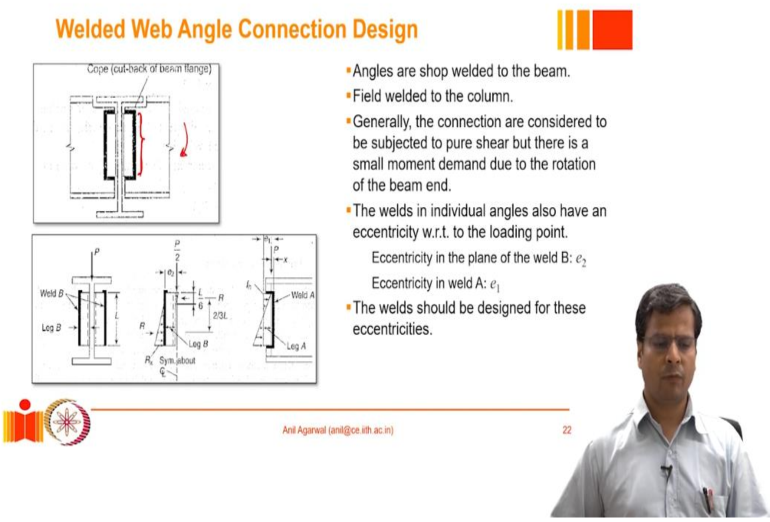

So, this is an example of a double angle connection wherein the angle is welded both to the beam as well as to the girder. In such a situation, you might notice that typically, these angles are shop welded to the beam, and then they are brought to the site, and then they are site welded to the girder. Same thing could be true for the columns as well. As we had mentioned before that even though we may idealise these connections as if they are simple connections, they are never actually truly simple; they are always transferring some level of moment.

And the reason for that is that they do not have 0 dimensions; they have finite dimension, and transferring any moment or allowing for any rotation in the beam would introduce some level of moment demand in these connections, because the beam itself is not perfectly rigid, it is a flexible member.

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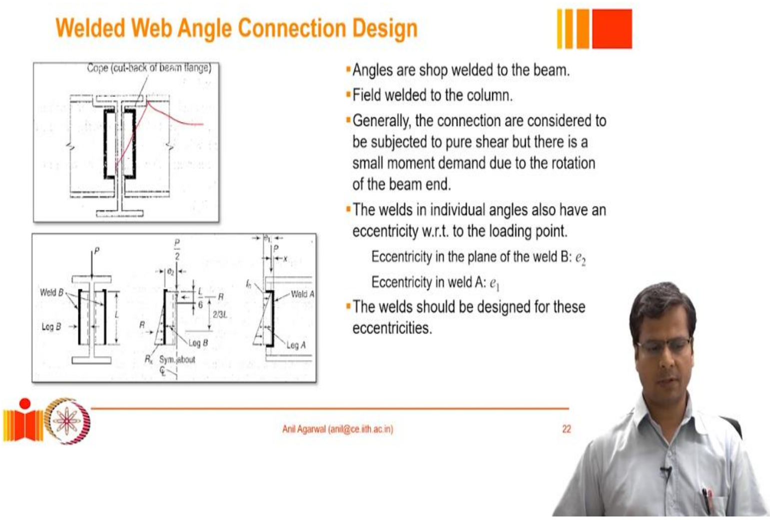

So, if the beam rotates because of the load that are applied to it, it will also introduce a level of moment demand on the connection and it has a tendency to resist that. Also, the other factor that can control the or that can introduce a moment is the eccentricity in the connection. In fact, this is much more significant, this eccentricity effect. So, what we can imagine is that;

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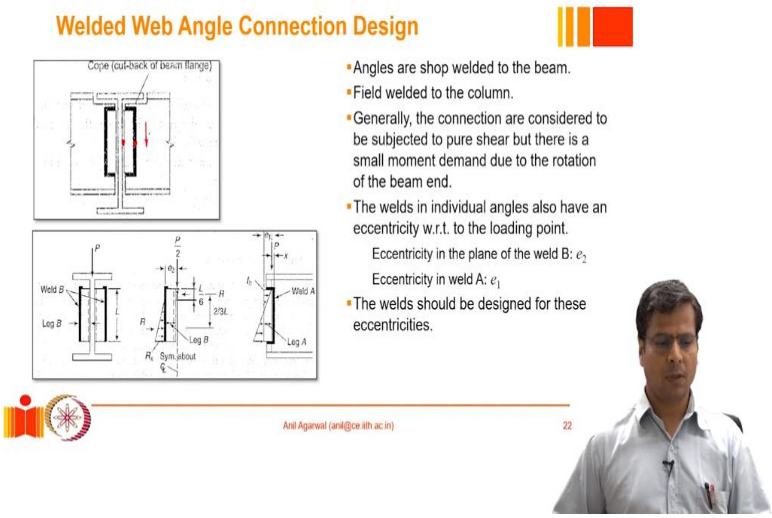

Imagine that this angle is welded at this location as well as this location. So, there are 2 locations where this angle is welded at both ends. And the force is getting transferred by the beam closer to this edge or this location. Now, this has to be transferred to this location.

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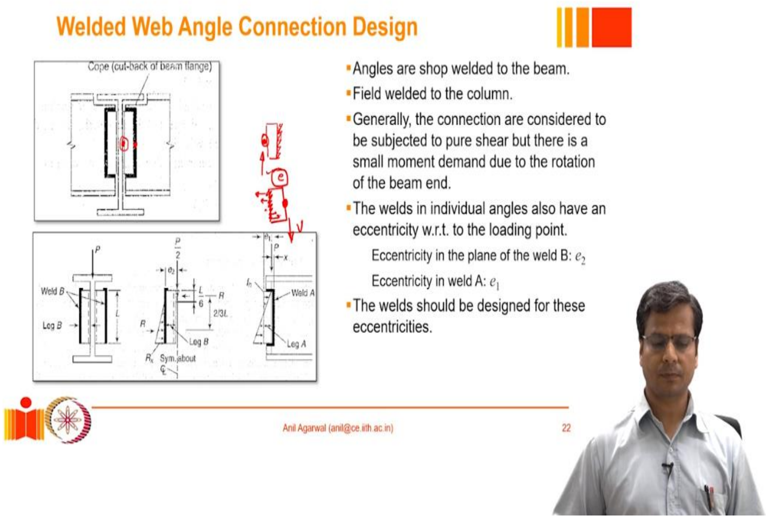

Now, if we say that one of these locations are fully pinned, then what we are saying is that this much of shear has to be resisted by this flange, by this girder; and over here, this weld is pinned, but over here it is getting some reaction from here. So, basically, when we design this weld on the right hand side, we have to consider this eccentricity. Similarly, when we want to design the connection, the weld on the left hand side, we have to make some assumption about what is happening in the weld on the right hand side.

And if we make an assumption that this is behaving as if it is not having any flexural stiffness, that means it is a pinned connection, then we will be applying a force V here. And in between, we will be having a lever arm, that eccentricity is acting as a lever arm which basically means that we will have, in order to resist this moment which is acting clockwise direction, this weld has to apply a force in this way to resist this moment which is appearing because of this eccentricity. So, this gives rise to some level of moment demand in the weld of a simple connection also.

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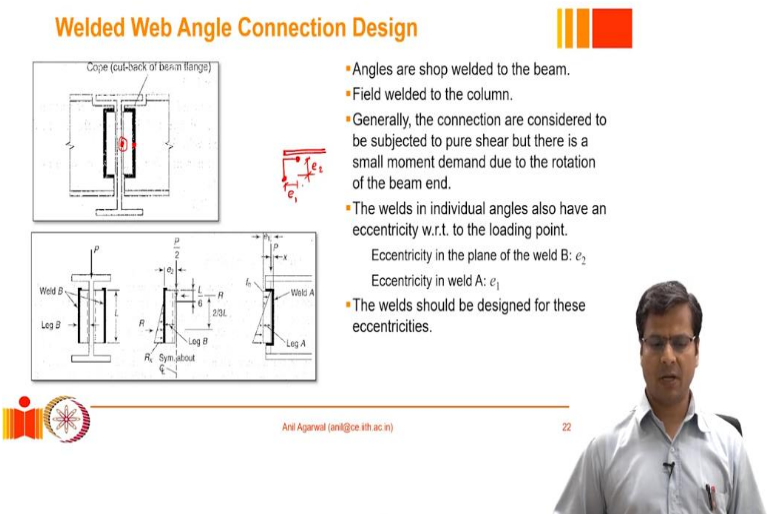

Likewise, there is other plane; if I look from the top, this is the web of the beam and this is that angle. So, we were just looking at this eccentricity which we will call e_1; but also there is another eccentricity which is e_2. If it is not an equal legged angle, then e_1 and e_2 need not be same. And in such a situation, both e_1 and e_2 need to be accounted for, and those respective moments have to be accounted for.

And the demands, moment demands because of these eccentricities need to be calculated. The good news is, typically, as long as these eccentricities are within 50 millimetres to 75 millimetres, we do not have to worry too much about these, because the connection can be considered as rigid enough, the angle can be considered rigid.

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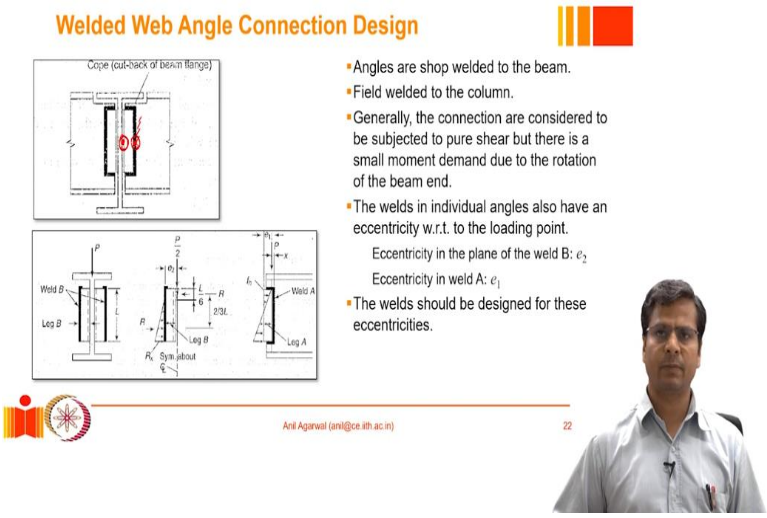

And the assumption that we had made that these two, when we are calculating the demand at this weld, we are assuming that this weld behaves like a pin connection. But that is not really true, and that is a very conservative assumption. And because of that, typically we do not have to account for this moment effect. But if we need to, then we know the process to follow. And to be on the conservative side, sometimes some designers prefer to do that. In fact, the textbook by Doctor Subramanian also recommends the same method to be utilised.

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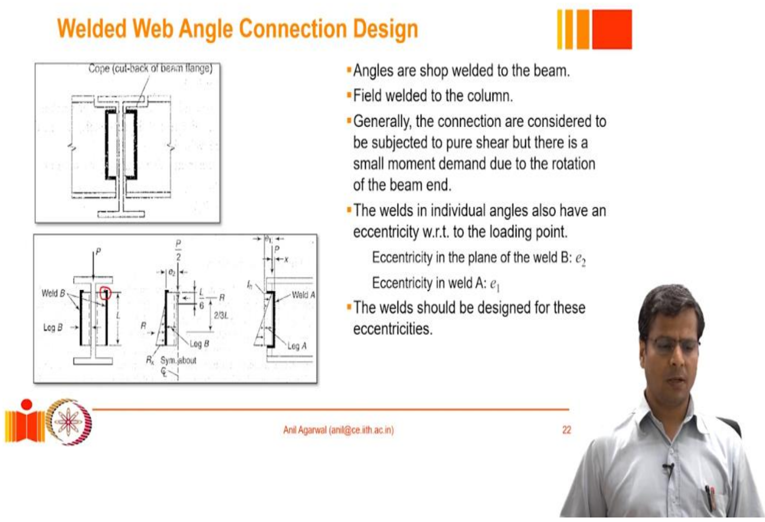

Here also, you might notice that in such situations, we should always provide a return weld at the top. We have discussed this topic when we were talking about the dimensional restrictions and the termination of a weld. We have talked about this that the return weld is essential near the top of this kind of a weld.

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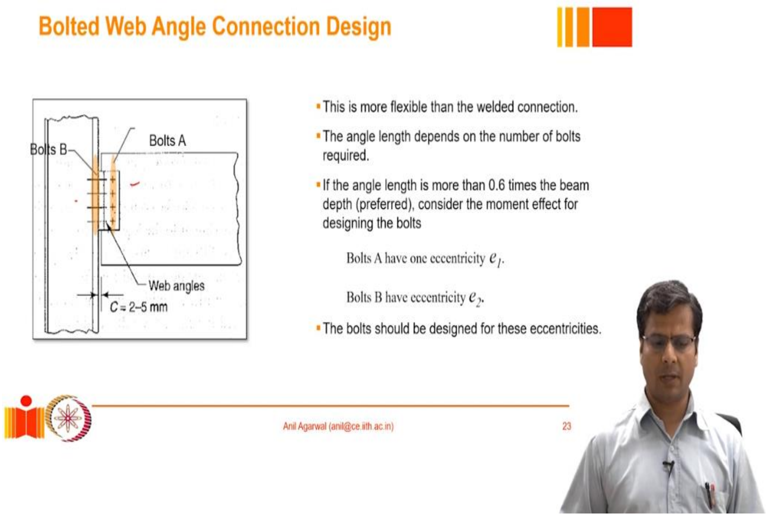

If we talk about web angle connections with bolts, so, this is an example where we might have all bolts connected; where we are using only bolts to connect a beam to a column using a web angle. So, it could be single angle or a double angle connection. Again, the design of this connection is relatively simple if we do not account for the eccentricity.

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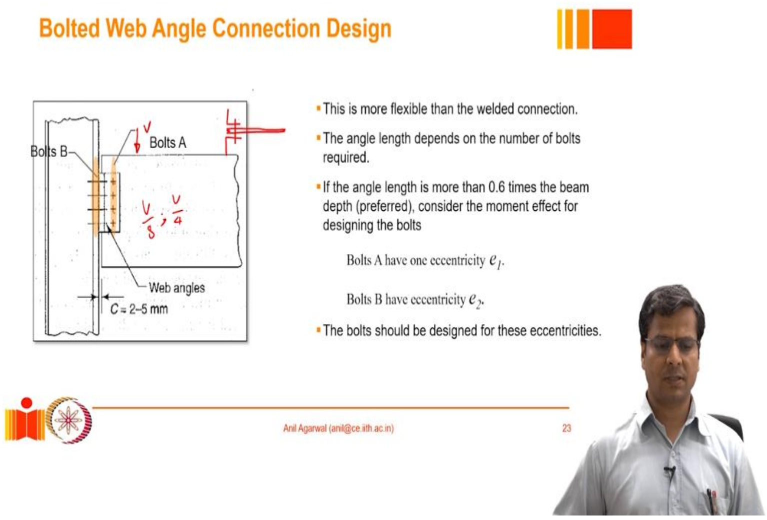

We have a certain load V. And on this surface, we have 4 bolts. So, V divided by 4 is the demand on each bolt. If these bolts are acting in single shear; when would they act in single shear? When we have a single angle connection. Again, looking from the top, this is the web of the beam if it is a double angle connection. This is a bolt passing through both angles and the web of the beam.

Then, when this beam is being pushed downward, this bolt will be subjected to a double shear. If it is a double shear, then we have to divide it by 8. Otherwise, we have to divide it by 4 if it is a single angle.

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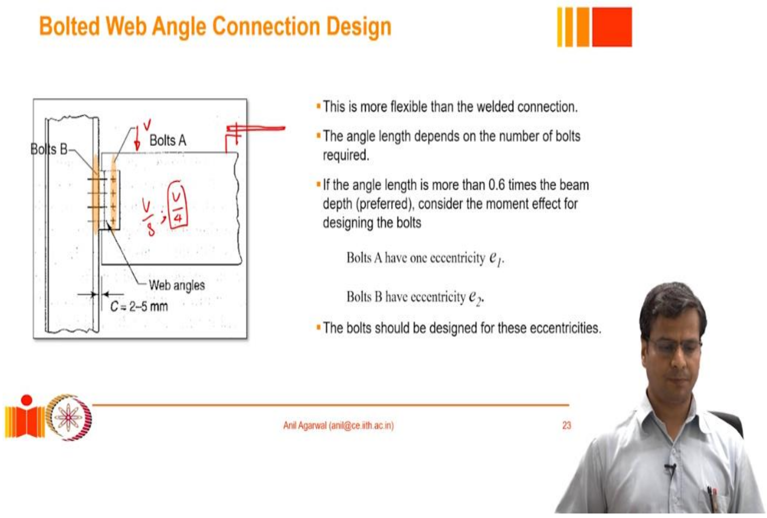

So, if it is single angle connection, we will use V by 4. So, we do that and that gives us the demand in each bolt, and then we know how to design a bolt if we know all the dimensions. We know the bolt diameter; we know the material used in the bolt; we know the material of the angle; we know the material used in the web; and all the edge distances, everything is known; we can design this bolt; we have learnt that already.

So, that is good enough. Typically, when we provide this kind of a connection, we leave some distance between the beam and the column. The reason for leaving this distance is so that it allows for a rotation of the beam without it coming into contact with the column.

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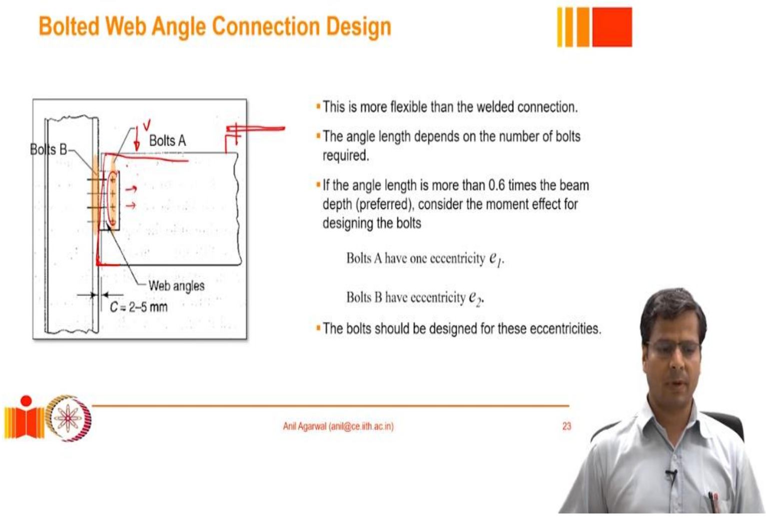

Because, if it comes into contact, let us say the beam starts to rotate because of the light loads. Then what would happen is that, the top flange of the beam, bottom flange of the beam would come into the contact immediately if there was no gap. And then it will start offering a lot of resistance and these bolts will also be subjected to very large tension force demand, which is not really the purpose of these bolts. So, in order for that, so that it does not happen, we have to keep some gap here so that it can rotate freely without producing a lever arm and the lever arm rim is very small.

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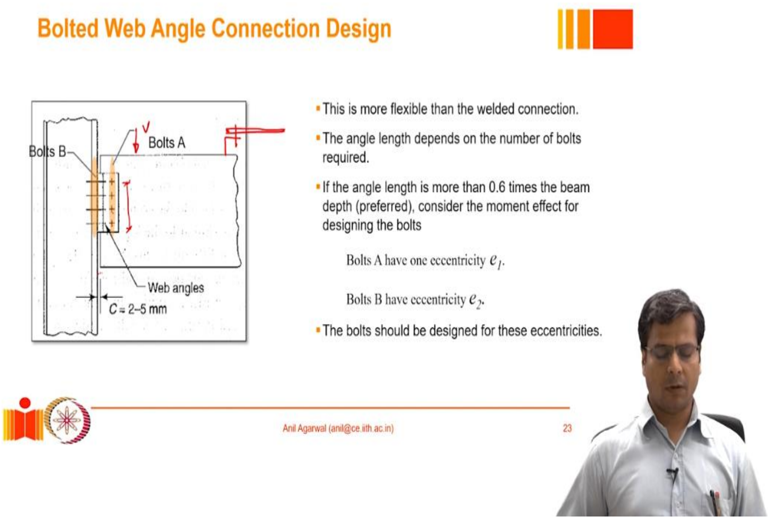

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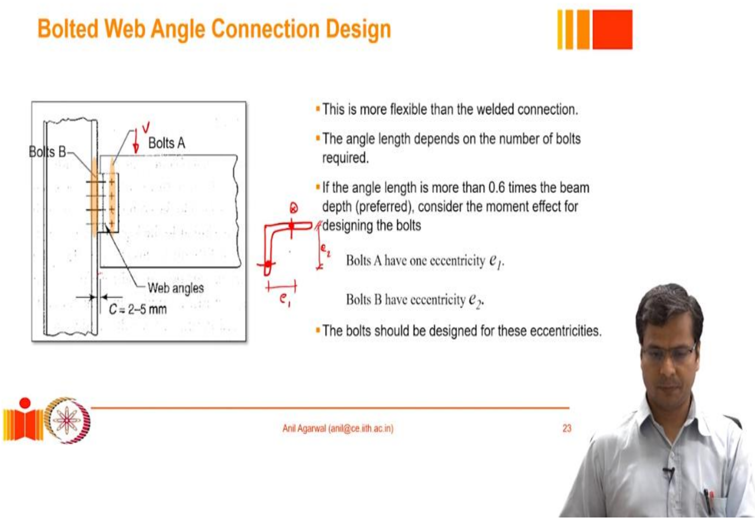

Now, again here, in this angle, if you look from the top, there is a row of bolts here and there is a row of bolts here. And this row of bolts is being pushed downward at this location and we are resisting it at this location. So, there is an eccentricity effect here. And this eccentricity can again give rise to a moment demand, not only in the angle, but also for these individual bolts.

And to be on the conservative side, it is okay to design for this eccentricity. But again, if the eccentricity is within 50 to 75 millimetres, we can ignore it. Also, as we had discussed, when the beam starts to rotate because of the external loads;

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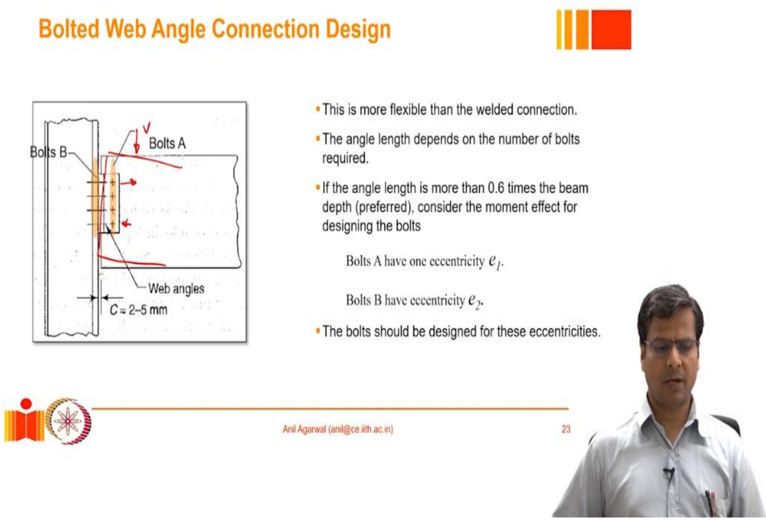

Because of that rotation also, you will observe that there will be an additional shear force demand on these bolts. The top bolts will be pulled outward and the bottom bolts will be pushed inward. And that will introduce an additional force demand on these bolts.

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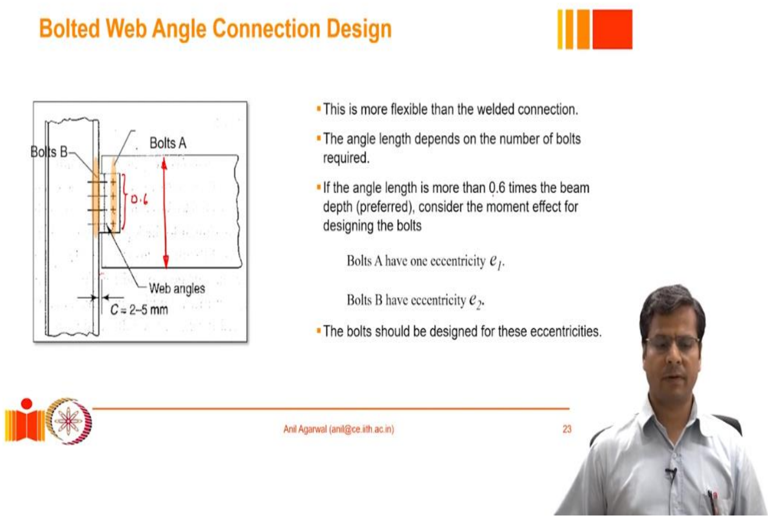

General rule of thumb is that, if the bolt depth, that is this length, it is equal to or greater than 0.6 times the depth of the beam; if that is the case, then we should consider this eccentricity effect and we should account for this additional moment that is appearing in the bolt.

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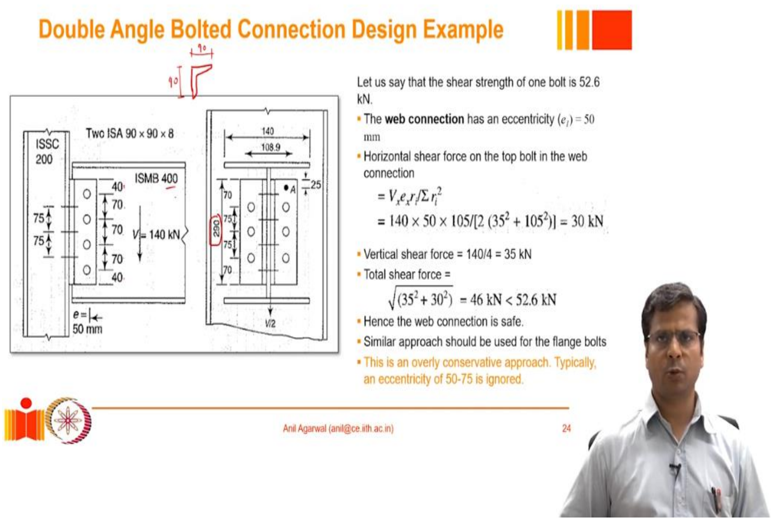

So, let us do one example on a bolted double angle connection. The example is pretty straightforward. You can see this beam. ISMB 400 beam is taken. It is subjected to a shear force demand of 140 kilonewton. Of course, at the ends, this is meant to be a simple connection, so, we do not have any moment acting at the end. And this beam is supported by a column which is an ISSC 200 column.

In addition to this beam and column, we have used two ISA angles of 90x90x8. So, basically, these angles have these dimensions. So, each leg of this angle is 90 millimetre and the thickness is 8 millimetre. The angle length is shown here, which is 70 + 70 + 70 + 40 + 40. This is the total length of the angle, which is equal to 290 millimetres. And if we see, 290 is quite significant when we compare it to 400 millimetres.

So, 60% of 400 would have been 240. And since the angle is relatively long, we should probably consider the eccentricity effect. So, let us see how to include the effect of eccentricity in such a connection. So, if there was no eccentricity, we would have calculated the demand, force demand on each bolt as follows.

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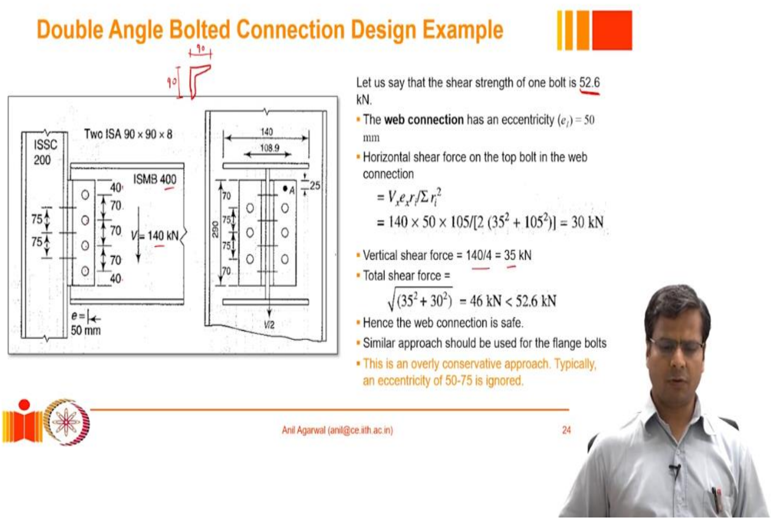

And the demand on each bolt can be calculated as 140 divided by 4. So, that is 35 kilonewton. So, it seems like the capacity is governed by the bearing distance of the plate; and therefore, only 4 need to be counted. So, 35 kilonewton is the shear force demand on a single bolt.

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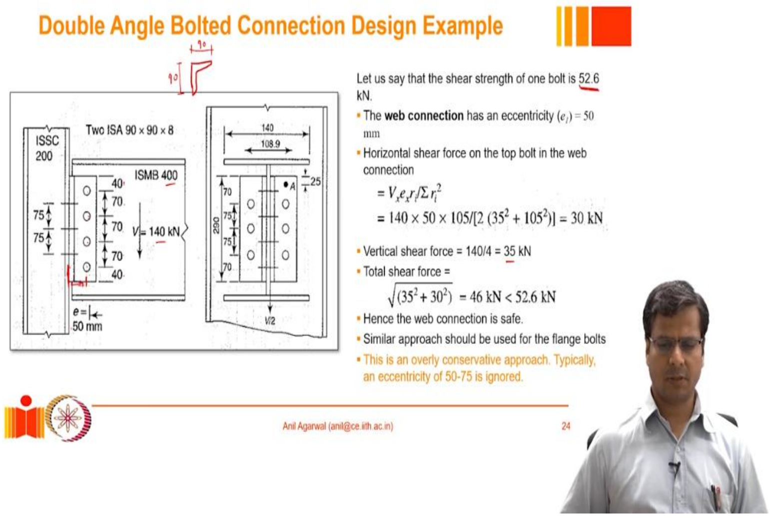

Now, we know that the eccentricity between this plane and this location, that is where the force transfer is happening through the angle is 50 millimetres. So, if this eccentricity is 50 millimetres, we can calculate how much moment or how much additional force will be acting on each bolt.

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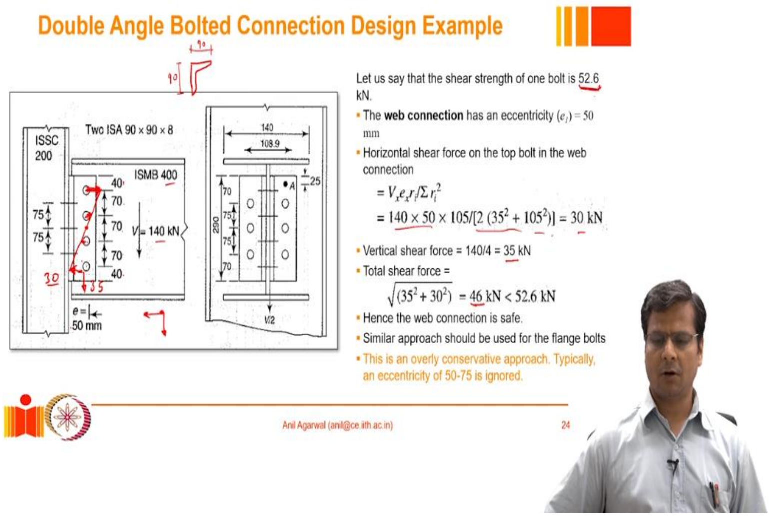

So, the neutral axis of this bolt group will be somewhere here and we can calculate how much additional force will be present in each bolt like so. So, the bolts which are the farthest will be resisting more force or will be contributing more towards resisting the moment, and their contribution towards resistance of the moment will be proportional to their distance squared from the centroid.

So, by using that principle that we have already learnt how to use when a set of bolts are provided to us and there is a load which is producing a twisting moment. So, we use that same principle here and we can calculate the additional force that is acting on the farthest bolt. So, the top and the bottom bolt will be subjected to an additional force demand by using this principle, an additional force demand of 30 kilonewton.

What we had calculated already because of the direct force, that was a 35 kilonewton force acting in the downward direction; and there is a sideways force of 30 kilonewton because of this moment which is due to this eccentricity. A total force demand by combining the two will turn out to be 46. Basically, we are just taking the two vectors 30 and 35, and we are taking the resultant force which is 46 kilonewton.

Now, we can compare whether this is sufficient or this is within the design strength of such a bolt. So, the design strength of this bolt has been given as 52 kilonewton. Therefore, we can conclude that this connection is safe. As I had mentioned before, this is an overly conservative approach typically because the actual eccentricity or actual moment is not really this much, because even this connection does not behave like a pin connection.

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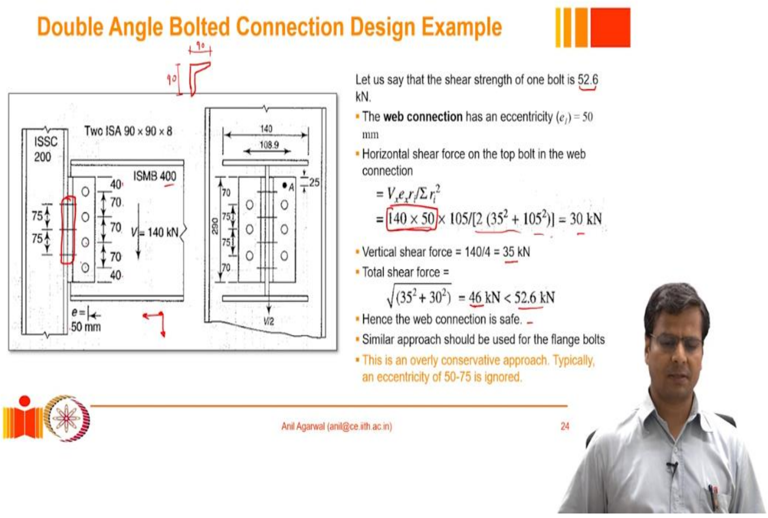

In this assumption, when we are calculating the moment demand, we are multiplying 140 with 50; 50 is the eccentricity.

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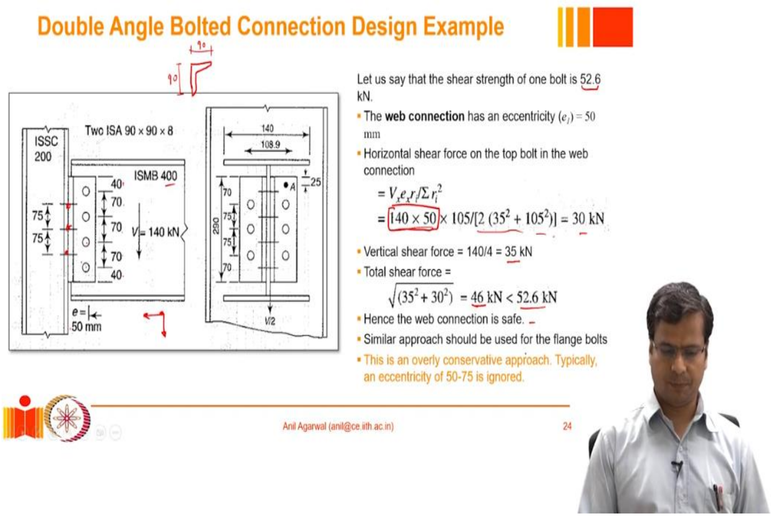

So, we are assuming that there is no moment resistance at this end, but that is not really the case. And therefore, this is a conservative assumption.