Design of Offshore Structures
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Module - 4
Lecture - 4
Tubuler Joint Design for Static and Cyclic Loads IV

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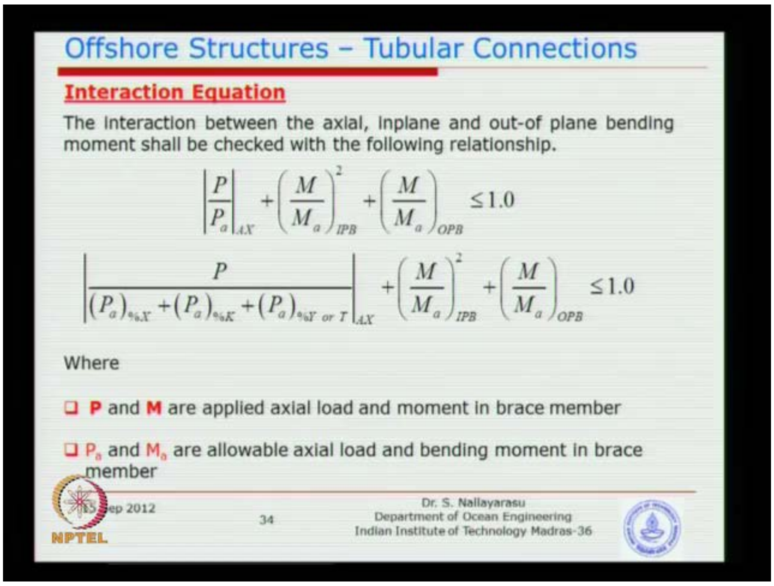

So, last week, we were looking at the design practice, after we have just looked at the combination of loading, actual plus bending and we looked at this first equation is just, basically the combination of actual capacity plus the bending capacity, in plane and outer plane. And in plane, we had the square term, which I think, we were explaining the non-liner capacity, available for both in plane and the outer plan. But the recent studies showed that, the outer plane it's becoming un conservative. So, we have just removed it and also we the second equation, were in, if we have the enhanced capacity or in case of capacity coming from various other options, like x, k or y, you could add them together and then, finally divide by the total applied load, divide by the capacity, you can get the unity check ratio.

So, 1 thing you must easily, can see from here, is the classification of joint, only affects the capacity of actual direction, whereas the movement capacity, not so much. Except some numerical formula are different for different. But otherwise, this formula is usually used, for all most all type of joints and you can find out what is the unity check and if the unity check is less than 1, then it is safe.

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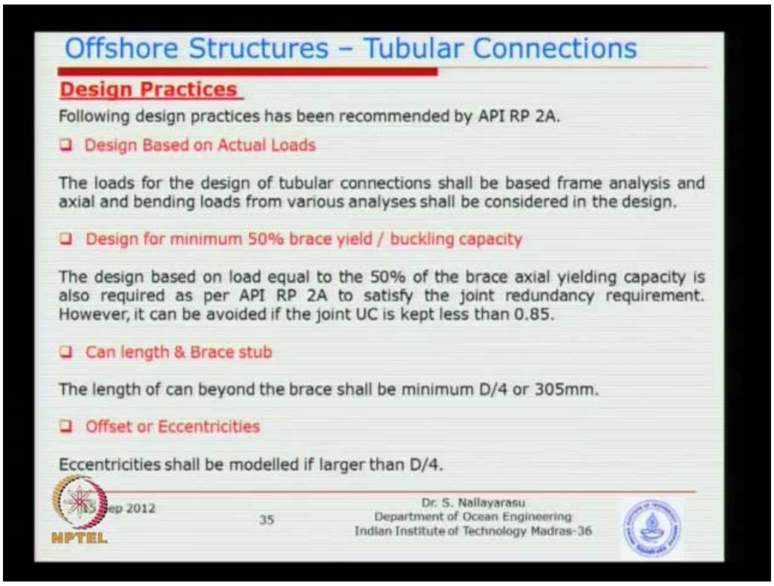

So, this is just a high light of, what we were trying to do for a design, of a tubular joint. But of course, with several restriction and these were the list of, you know the design practice is normally followed. The first 1 was, design based on actual loads, basically. That means, you do the analyses, you get the loads, you try to take the loads from the global analyses and put that into the design equations and see whether, the unity check is less than 1, safe or unsafe. The second requirement, was by the API, as I explained last class, is basically to see that, even if the member stress or member loads are smaller, every small. Since, you have over size the member or you might have actually, put the member which is not, you know required so much.

For example, typical case will be procurement. You buy a pipe, which is bigger than because its available and you put it there, so the loads will be smaller, for that particular size. So, in such cases, basically, you should make sure that, you take the 50 percent of capacity of the member, instead of loads because the load is so small and you do not want to make that joint to fail. So, this called a capacity check and its mandatory and the last 1, basically the design configuration, if you see the sketch, you will understand how it is going be configured. Basically, the length of the section, if you go to the next page, you will see that, how much is to be ex10ded, whether you ex10d full length, that is the best.

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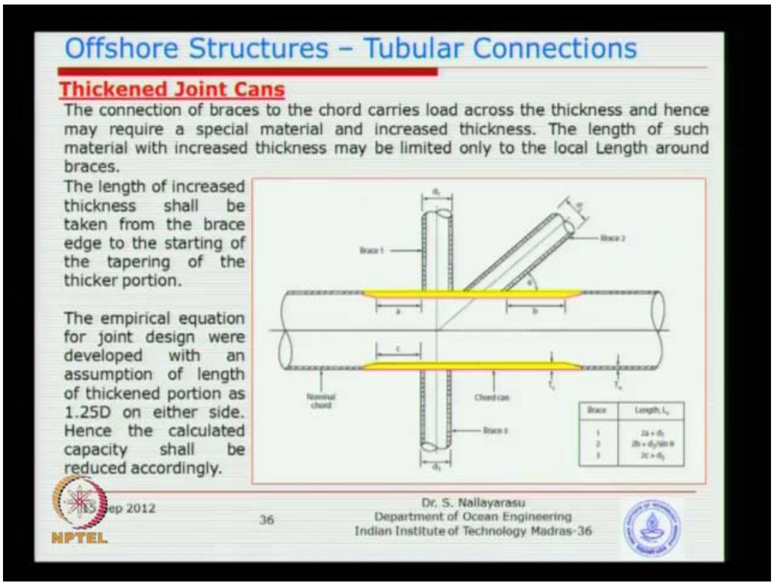

You know basically, but then, you do not have the optimization, because your wall thickness required at the junction, is always going to be bigger because of the local effects, whereas the global effect, the member is not requiring so much thickness. So basically, how much is to be, determined by the minimum requirement and normally, we go for d by 4, as I see from the previous requirements of the code, either the diameter by 4 or 305 m m, whichever is smaller or bigger, must be bigger. Smaller is not correct, so if you find d by 4 is coming as 500, you would use 500, not 305. But, if the d by 4 comes less than 3 0 5, then you must use 3 0 5. So, basically that is. The regarding the eccentricity, will see later basically, if you have the non-concentric joints, than you have to module the eccentricity, to generate the additional movements.

So typically, if you see the yellow color, I hope you can see the color, the yellow color is the increased thickness, just made to resist the local loads. Now, imagine if this whole member, the whole jacket is made up of single thickness, you do not need to worry about this effect of, so called reduced chord length. This, because we have reduced, we have completely everything is same thickness, bigger thickness, then this check is not required. But of course, that is not economical, so we make it has required. Of course, anybody can guess, you to need to provide the thickness up to, at least the footprint of the brace, for sure you need. But that will not help, because the load will try to distribute across the length. So, you need to extend, little bit beyond and that is where, we have this criteria called D by 4 or 3 0 5.

Now, is that enough? This is what we are going to see and basically, it is not enough because all the empirical equations which we derived, we saw that q f, q u and the combination of them to calculate the capacity p a. I think, all of you remember the formula know? So, formula for p a, so formula for m a, so those formulas were deferred developed, based on the assumption that, this length from the, from here to the end are the yellow color, the extended can is 1.2 5 times the diameter. That was the assumptions they made, in the equations. Now, if you provide minimum as 3 0 5 or D by 4, capacity will be smaller or bigger? It will be definitely smaller.

So, there will be a reduction, that you have to apply, to the calculated value of p a. So, that is what we are going to see. There is a reduction formula, if you see this formula, this formula is to calculate the reduction in the capacity, because we are not providing 1.2 5 on this side, 1.2 5 on the other side.

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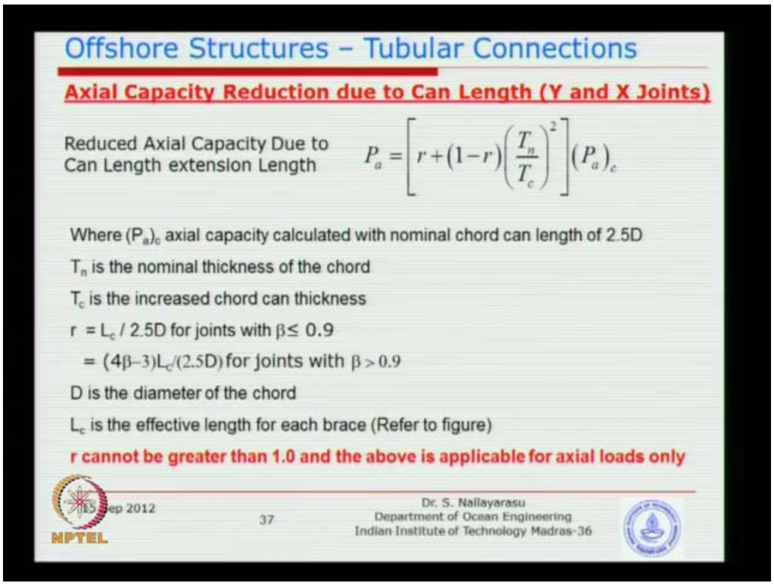

That means, what making him 2 and half times the diameter, we have not providing. Of course, if you go and provide, nobody is going to prevent it. But that is going to be a extra weight, extra steel. So, what we try to provide is, what is mandatory because this 2.5 times the diameter, is not mandatory. It is left to the designer's choice, you can go and provide 2 and half meter, 2 and half diameter. But nobody is going to say anything about it, but it is not going to be economical design. But what is mandatory is, this D by 4 is mandatory. So, once you provide D by 4, that means 0. 2 5 D, isn't it? Instead of 1. 2 5 D, that means you are going to reduce the weight, but then, the consequences of it, you have a reduced capacity.

So, basically using this formula, you can find out, is a very simple, you see here the ratio r is the length of the chord divided by 2. 5 D. So, as long as you have 2. 5 D, what will happen? r will become 1, so you can go there, when once you put r is equal to 1, the second term will disappear, isn't? If the first term is 1, automatically the calculated capacity p a c, just I have given a different symbol, so that you understand. So P a c is a calculated capacity, multiplied by a reduction factor. The reduction factor, always have to be less than, it cannot be greater than 1, for sure. So, it will be less than 1 or equal to 1. When it will become equal to 1? When the length of the chord become 2.5 D, I think very simple idea, also you see, here the parameter on the second side, the second term, you can see the ratio of nominal thickness, to increased thickness.

So, if you go back to this picture, nominal thickness is the black color one, somewhere here, that is the reduced thickness. Whereas, the yellow color 1, is the increased thickness. As long as the ratio is kept to 1, what will happen? Does not matter, whether it is 2 .5 D or 3 D does not matter, because everywhere, same thickness. So, this equation also converge to, the reduction factor should be 1. That means, no reduction. So, as long as you play with these 2 parameters, the longer, thicker, here capacity will enhance and that you can actually, do a plot. We see this plot, the thickness ratio is equal to 1, which is basically, the this line.

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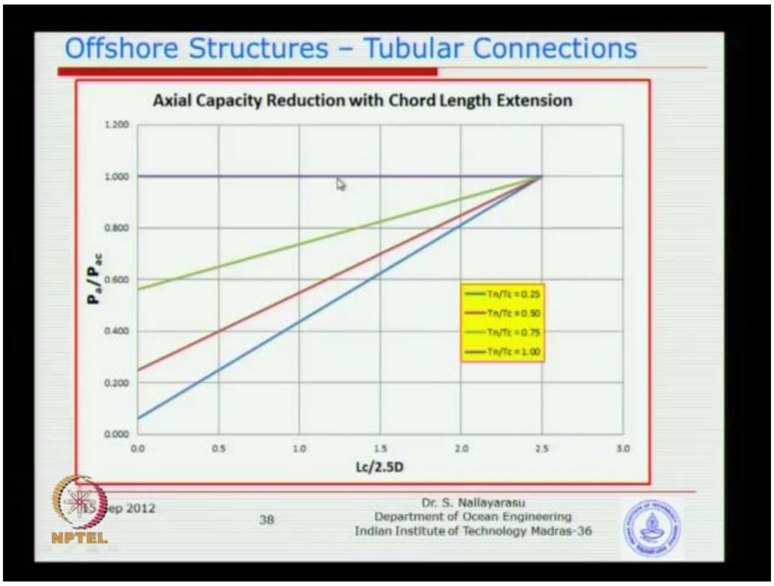

Then, the thickness ratio becomes 1, does not matter, whether it is 2. 5 D, because it is everywhere, the same thickness. So, your reduction factor, are the multiplication factor is 1. As long as you have the thickness is smaller, that means the ratio is smaller, you got a bigger problem. So, you can see that various lines. So, it is always starts from 1 and come down to. So, for example, if I keep the l by 2.5 D is basically, the ratio is 2 and half times, then it is automatically 1 and you reduce it, you can keep on coming down to, lesser value .2, .3. So, this needs to be taken into account, before you go and use this values of P a in this equation, you have to look for the reduction and then, put it here. If you are length, this 2 and half diameter, then you do not need to reduce, directly can use it.

So, this thickened can affect must be carefully calculated. But of course, this is only applicable for actual load, no reduction is suggested by a p i, for moments whether it is in plane and outer plane. This we have already, I think I have explained in the previous class, as well in the starting of this now basically, the reason why we do this is, a you know to create extra reserve strength in the joint.

That means, we design for 50 percent of the brace capacity, in addition to the actual load. Suppose, if your actual load is higher than the 50 percent capacity, is not a problem. But as long as your loads are smaller, but you still designed for 50 percent capacity, just to make sure that the joints are having, additional strength, that means the joints will not fail, before the member fails.

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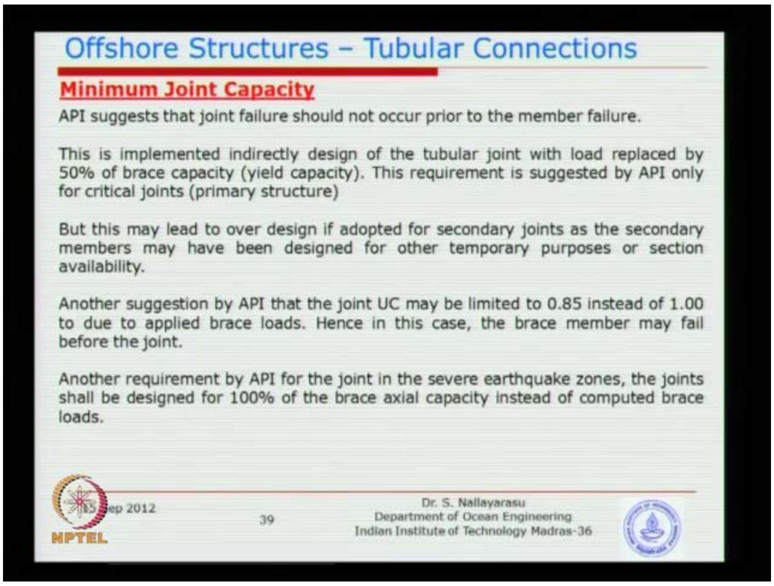

The last one, before we jump onto basically, stiffened joints, sometimes you do experience such type of 3-dimensional joints, unable to classify into any of this categories. Because they are not concentric, they are not going in joining, to a single work point or vicinity of work point and they are separated by, you see here, the separation between the top 2 braces and another brace. And both of them are, all 3 of them are oriented in a 3-dimensional angles.

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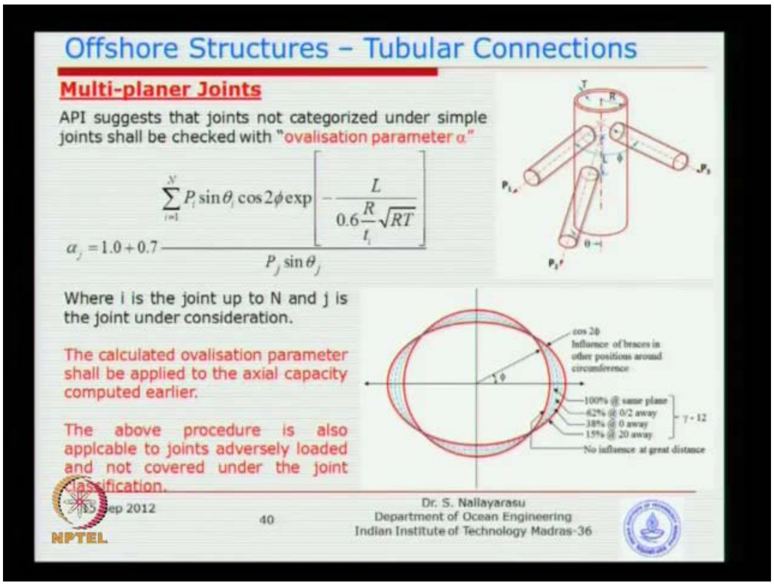

You have 2 of them like this, another one in another way. You are unable to classify because this distance between the top 2 braces and the bottom brace, is quite far and you could not, actually treat them separately also, because they are in the vicinity. They are in a kind of, in between near of them, it would classify. Such type of joints you may experience in some times and all of them, are going to carry the tension or compression. Sometimes, you experience such type of joints, in such type of cases, people where suggesting, down classify into k, y, t joints, you can actually do a 3-dimensional analysis.

Some of the paper published suggest that, so called, the ovalising parameter, that means which of the load is going on to the chord and try to over rise the pipe, so you calculate equal and ovalising in parameters, which will be less than 1 and cumulatively, you can take the effect. But, API only give you suggestion that you can attempt to do this. But, in practice, nobody does this, because it is quite complicated, in a way. So, this is the empirical formula, given by the API, that you can use., so summation of all the loads from, all the braces divided by, the brace in question. For example, j is the brace in question and basically, there are number of braces, from i is equal to 1 to n. So, 3 braces it will be 3 and we are trying to calculate the ovalising parameter, the effect is, if there is no other brace, the effect will be 1 and if there are few more braces, this is the formula that you need to calculate, multiplied by 0.7.

So, it will be incremental to that brace load. But of course, in real design practice, we do not use it, but in the research study especially, when we do the experimental analysis, we try to use this, the effect of 1 brace, on the effect of the chord, due to various other braces in the vicinity. Sometimes, you get into this kind of situation, see here on the left side, you see, you called this is not an x brace.

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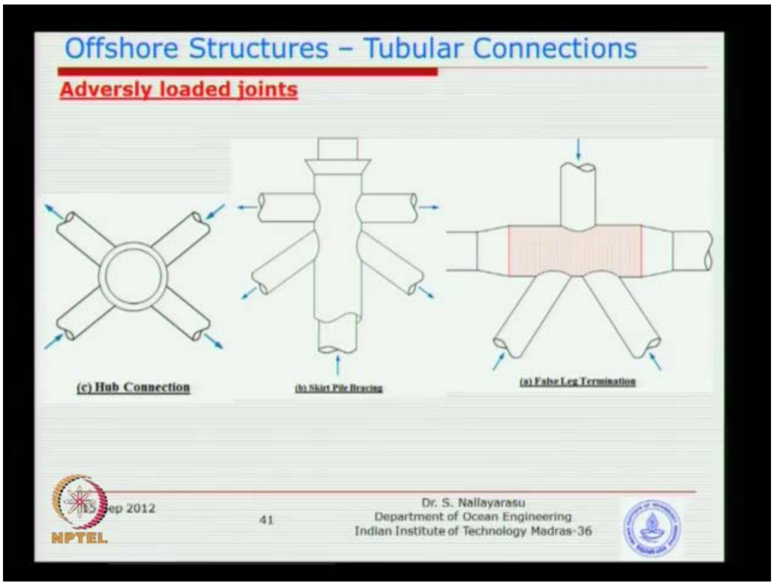

Though, it looks almost like a, almost like a x brace. But you see here, there is a member going through at the center and all 4 of them, giving adverse effect, 2 of them is actually pulling and 2 of them is compressing. And you can neither classify this into, either 1 of the category called k y or t, because the chord member is perpendicular and all the braces are in the outer plane and such type of cases, this ovalising study will be very useful, if you go and do this analysis, by taking chord.

For example, you take this chord and treat 1 brace by 1 brace, which is absolutely not correct. Even anybody can conclude because they are simultaneously applying 2 members on tension, 2 members on compression. So, there will be effect of 4 times, isn't? It will not be taken into account, when you do a classification of s t joint or a y joint and come up with a design and basically, the thickness is 20 m m.

But actually, you may need more than 20 mm because all the loads are simultaneously applied, at anyone in given, instead of time and that is the kind of things, you may experience in some design cases, you may have to check using, this type of cumulative effect. The upset that we were talking about earlier, the last point in the, in here, upset are so called eccentricity. Normally, we try to avoid that, but if you cannot avoid, then what as we try to do is, for example.

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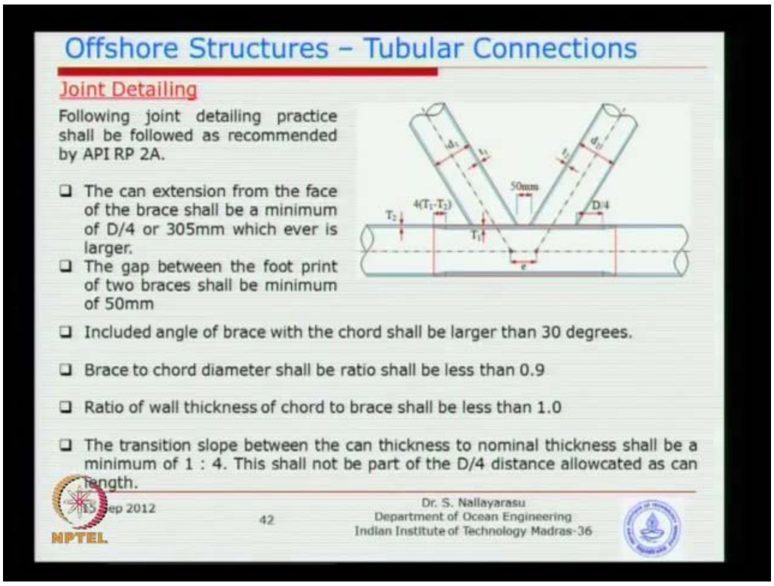

You have this case, where joint is separated by a distance of e. If the distance is quite small, how much is quite small? Basically, the diameter divided by 4, 25 percent of the diameter, then you do not need to really worry about it, because the moment introduced by this, is going to be small, those type of moment is already taken into account, in the empirical equations, whereas if it is exceeding that, then you later considered this moment in the analysis.

Basically, that is the recommendation given by API, which we need to definitely follow, because the empirical formulas, those who have developed have taken into account, only a small adjustment, a distance between the 2 braces delivering the courses. Typical example will be, see this 3 pictures. On the left side, you see here, basically the similar type of joint, 3 times, 3 dots you see the were points, are so-called the intersection of braces and the chord member.

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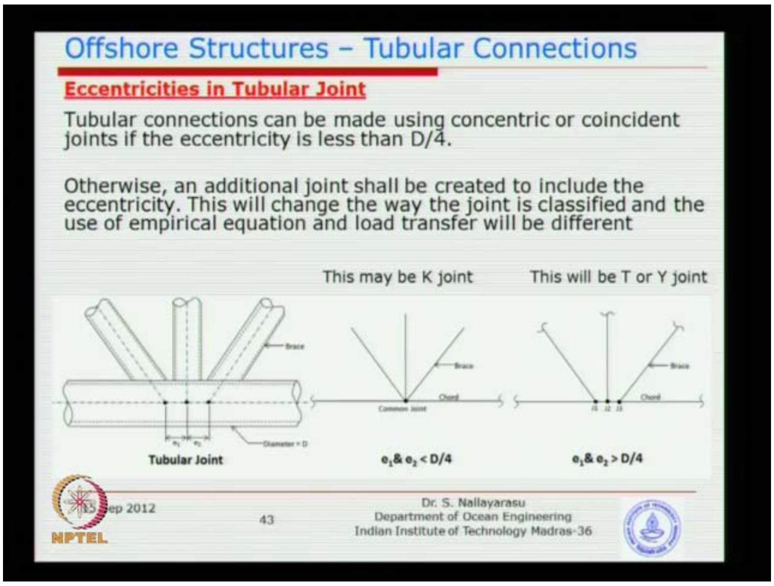

Now, if you see here, if you model like this, is what really happens is, the load carried by 1 of the brace will be cancelled by another brace. That means compressed other one may be tension, which that means, the chord is not experiencing actually the share transfer between 1 brace to other brace. If you model this way, the right-hand side, you will see that the member between this 2 small members, will be experienced large amount of shares, as well bending movement. So, that is why, whenever the diameter by the eccentricity is exceeding D by 4, you should actually design the intersection, are the small members between them to be correctly. So, that is some recommendations, you need note, because it will forget, you may actually under design a chord member. So, the next one is the grouted leg signs.

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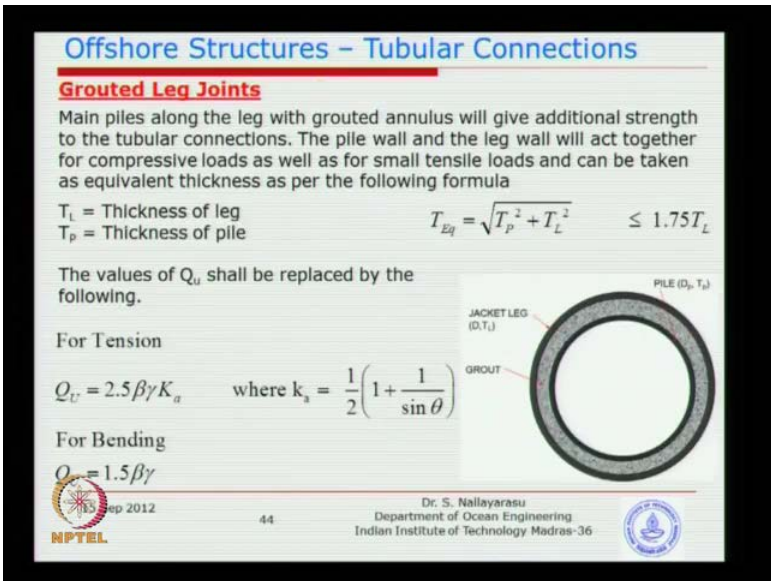

So, far what we have seen, is the joints or the chord members are purely single skin, that means only the pipe is there. Now, I think, you might have understood already the jacket likes, we have the piles going through, and we have either grouting or sometimes, no grouting. So, when you do have, such type of legs grouted, so the grout is filled in the annulus, so you have an external skin cell and internal pile and when you actually apply loading, this not going to behave exactly same. But then, what is the equivalent effect you can take, because there is a pile inside, which is going to provide large stiffness and they are made together, by means of the grout, which is build inside and set and they are going to behave, as a composite member.

So, what we need to do is, the suggestion from API, is to calculate the equivalent thickness, ignoring extent of the grout. I think, you might have studied your mechanics, you can always calculate a, the equivalent thickness, equal section modules equivalent area, by means of, by means of modules of elasticity ratio. So, you can calculate that, because that is the reflective of the stiffness, of the any material.

So, you can calculate, but what API suggests, do not use the strength of the grout, but you can use the advantage of the grout, provided by the composite action of inner pipe and the outer pipe. So, SRS is basically, one of the method suggested by API, basically square root of inner pipe wall thickness less outer pipe wall thickness, will give you an equivalent thickness, which you can use in all your calculations, whatever you have learnt.

So, you have already learned, how to do a design tubular joint. So, instead of only the outer thickness, you will use the equivalent thickness, which is square root of sum of squares of inner pipe and the outer pipe. Now, they were several studies done in the past, proved that, for example, you calculate equivalent thickness and it comes more than 2 times, the outer cell thickness. It is becoming un conservative, some of the experimental studies proved that, do not use the calculated equivalent thickness, if it is bigger than 1.7 5 times the outer wall thickness. That is the limitation, posed by some of the research papers, what API does not give you that limitation. But in practice, we normally limit to 1. 7 5 times the thickness.

So, you replace all your chord thickness, the thickness equivalent calculated here, only difference is the Q u value is, are slightly different from, what you have learnt for single skin joints. I think, Q u for t joint was basically, I think 30 beta, if I am not wrong. You go back to the table, if you go here, let us just quickly look at 30 beta for t r y joints in actual tension, change to something, slightly different here. Because of the composite action, is 2.5 beta gamma times K a. K a, is defined as something like this, for tension and for bending is also, a slightly different formula. So, only these are the changes you are going to make, to the original computation, what you have learnt, the q u values and q f values, only q u values are changed because you have a cell inside a cell, with a annulus filled with a grout.

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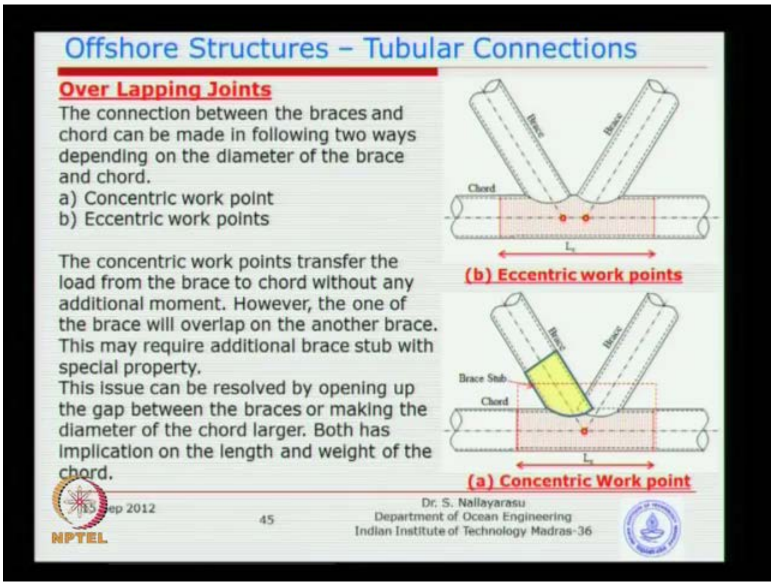

Other than that, no procedure is going to change, because of this change. The last one is basically, the overlapping joints. You can see, from this picture, what you can notice, this these 2 braces are trying to be connected to 1 joint, here. That is what our intention and because the chord size is smaller, we ended up, opening up. Otherwise, you see the bottom picture, I still would like to make it, connect to single point.

That means, no eccentricity, the load is coming from 1 brace, is taken as the cancellation effect, by other brace. The chord does not experience too much of share, there is no unbalanced forces. So, this is good, but then, I have an overlap because the diameter of this chord, is quite small. Now, if I make the diameter cord bigger, like what you see, in the dotted line, isn't it, you make the diameter bigger, then I will get this much gap isn't it. If I make the diameter bigger and bigger, then, there is no overlap. But what will be the consequences the weight of the structure will increase - number 1.

The wave load will increase, so basically to avoid, you can try and see this overlap joints. But the overlap joints, how to design? this is one of the major problem, because so far, what we have learnt is, design of a joint like this, member are not overlapped, individually delivering forces in the form of t junction, y junction or k junction. But here, there is a lot coming from this brace, partly loaded onto the brace, partly loaded onto the chord. Now, the sharing between them, depends on how much is overlap and that becomes, a slightly complicated.

So, what we have, so much learned about all those empirical equations, we may not be able to use them here and API suggests, do not use unless essential. If it is essential, then you look for a separate study, that means you will do a finite element analysis, like what I have shown you, earlier. Try and do that kind of local analysis and the, see whether, you can resolve it. But most of the time, no companies or no owners will actually prefer this, because you see here, this welled, this welled is unable to see after you finish it. Because for the, it is inside another brace, so you cannot inspect it.

The crack happens afterwards, is going to be failing and that is why, overlapped joints are not at all recommended. There were several studies, in nineteen seventies, because this proves to be one great advantage. You see the length of this can, so called the colorful picture, LC. The length is more at the first picture down here, whereas the bottom one, length is slightly less, maybe 10 percent 15 percent, because we have made it to overlap, but at the price of additional material being provided, on this member. So, there is absolutely actually you are not going to save too much.

So, only a perception that you do overlap joint, I will try to say, this much could ultimately the designs becomes complicated and you also have to spend, some more material in compensating because after all, this is not having a special property, that will fail. So, that is why, normally not recommended. Something like this, you can see from here, is a picture that you can easily understand.

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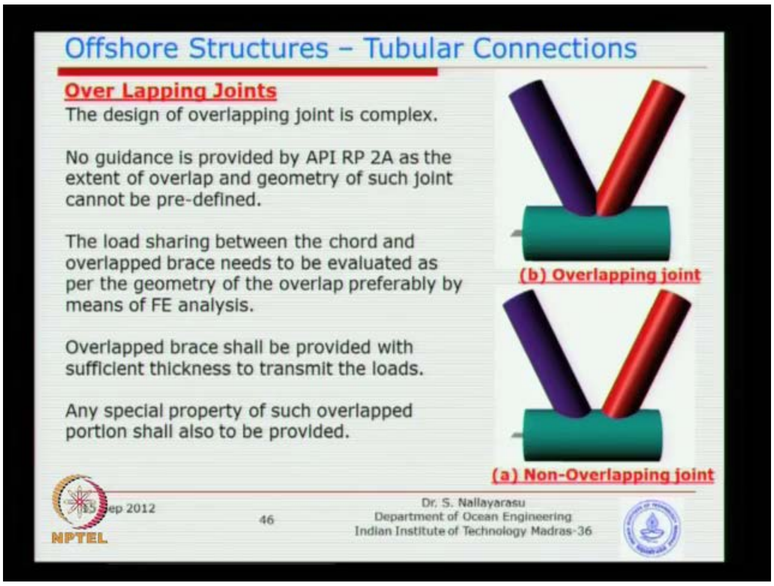

Overlapping becomes problem, because this number, if you make it bigger, then automatically the overlaps goes away. You have to size the braces properly, so that type of overlap does not come up.

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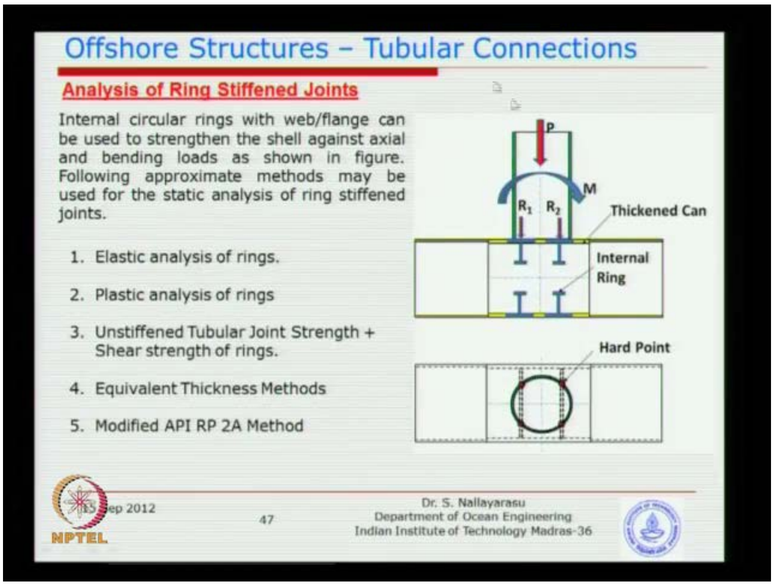

Now basically, the last one in the tubular connection in the static analysis, is basically to design stiffened joint, whatever we have learnt this un stiffened joint and then, we have looked that the can reduction length effect. Then we have looked at this multi planer joints and then basically, the overlapping joints. The last one is the joints, which has been stiffened by, somehow to increase the strength. So, basically what we try to do is, if you have decided the thickness of this, for example, this so-called thickened can, but ultimately, you do not get that kind of thickness or you already have purchased, but the loads have increased.

So, scenario might come in such kind of issues, so how do we make it safe. So, you can always go and provide stiffening inside, as usual any structural member, you can add stiffness, you can stiffen them against any of the failure action. It can be bending, it can be shear, it can be a tarzan, you try to stiffen them. In this particular case, is the stiffening required against, the 3 modes of failure we learned about. One is ovalisation basically, trying to compress from circular session to elliptical section. The third, second one is, basically a general collapsed, just compressing. The third one is, either pull of or just local punching failure. Now, if you see this, if you go and put inside full of concrete.

You just fill the whole member with the concrete, what will happen? Nothing will happen, basically concrete is very good in compression. So, when you try to load something in compression, it will definitely take huge amount of load. But what about tension, when you apply tension, this concrete will not come into that much effect. So that is why, instead of providing concrete, you can actually provide concrete, sometimes you do use that, but then the jacket becomes very heavy, not very good. So, the alternative solution is, provide concentric rings under the load such that, when you try to compress, the ring action will come into picture. As you know very well, rings are very good in taking or sanction the load, distributed by radial, will take a huge compression load, that is why you provide a rings inside and that rings will be scattering for, the all the 3 effects.

It could be punching effect, it could be pulling effect or it could be ovalisation affect and many times, we use this. Unfortunately what happens is, method of analysis is not very clear, because API live it to the designer, does not recommend that much guidance. So, what has happened, over the period of time? People have been using different ideas, but then, the recent API, thus gives some guidance. You could do this, you could do this, but not elaborate enough.

So basically, have just summarized few of the ideas, there are several methods available, can do elastic analysis of ring, using a finite element software or you can use a plastic analysis of analysis of the ring or you can use, the un stiffened tubular joint equation. The third one is very commonly used, you know what is the effect, when the ring is not there. So, do all your calculation, but then, evaluate the strength of the ring and put it inside your API equation and you will get the combined effect. The fourth one is basically, equivalent thickness, very similar to the composite pipe we used, pipe in pipe with the grout.

You can find out, what is the equivalent thickness. That means, thickness of the original chord is say, 20 m m. The additional thickness effect, due to the presence of the rings can be another 10 m m, so you provide 30 m m. You all can substitute the thickness into the conventional joint calculations. The last one, which I had been doing some studies for last several years, come up with modification to the API equation, so that you can easily design it, which will see. Some of the publication is already available. So, the first one, we need to understand, how the behavior the ring. You know, if you provide a ring something like this, without a flange you can see the red color is the ring, position appropriately.

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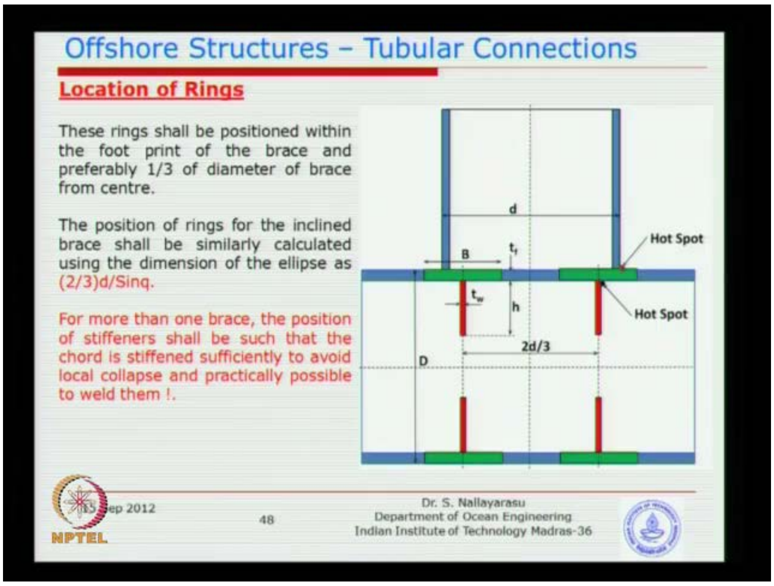

Normally, we position in such a way that, if you see the plan view, something like this, you see here in this, you should understand, the ring should actually be placed within the periphery of the brace. Do not provide outside, not very good because here, the load will transfer at the hard points. You see the red color point, that is the point cross-section or the crossing of the stiffener, with the wall of the pipe or the brace. So, that is where the load will jump because that is where the stiffness is higher. So, you should always provide within the perimeter of the braces and basically, you see here typical idea, is in the practice about two third of the diameter. So, if the braces inclined, accordingly you have to, calculate the elliptical diameter or elliptical dimensional and then provided it. And if you look at the individual stiffener, this is what is going to happen. You know the ring is going to carry a point load, at the point where the intersection is happening with part of the chord is also participating in the whole behavior, is it not?

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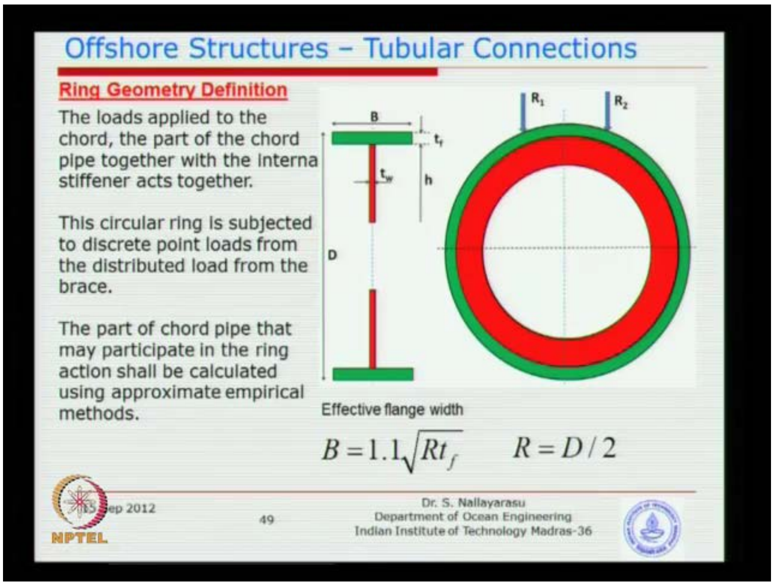

Because, it is not only just the stiffener alone, but also, the green color, what have what I have shown is, some part of the chord itself, is going to be behaving together, with the ring and that equivalent, some empirical formulae is given in practice. So, you can calculate, typically it will come, something like 1.1 square root of r t, is a empirical formula is not derived from somewhere.

So, what we need is a solution to such type of load, with the ring. If you go back and look at the literature, some of the mechanics books, you will find solution to such type of, but very complicated. This type of loading, you see here, you go back, I have just provided the load transfer only at this point. What about the load elsewhere? You could actually decide to divide the total load p divided by 4, isn’t it and each point is carrying one fourth of the load and do it. But this is only true, only if it is a vertical brace and also only 2 stiffness and it is also true only for actual load. What about moment, when you have the moment applied in this equation, you will have 2 points carrying compression load, the other 2 points carrying tension load.

So, you have to submit up and then what about the outer plane moment, one point will carry, combination with actual plus in plane bending plus the outer plane bending. So, you will see that, one of the corner point, this point, is going to carry almost maximum load. All other points will carry slightly lesser, depending on the direction of the movement. So, you need to resolve the forces and then carry out such analysis. Of course, you look at some of a text books, you will find equations to solve. Basically, I think, I have given one of the equation to solve, if this type of formulas given in one of the book Roark ring book.

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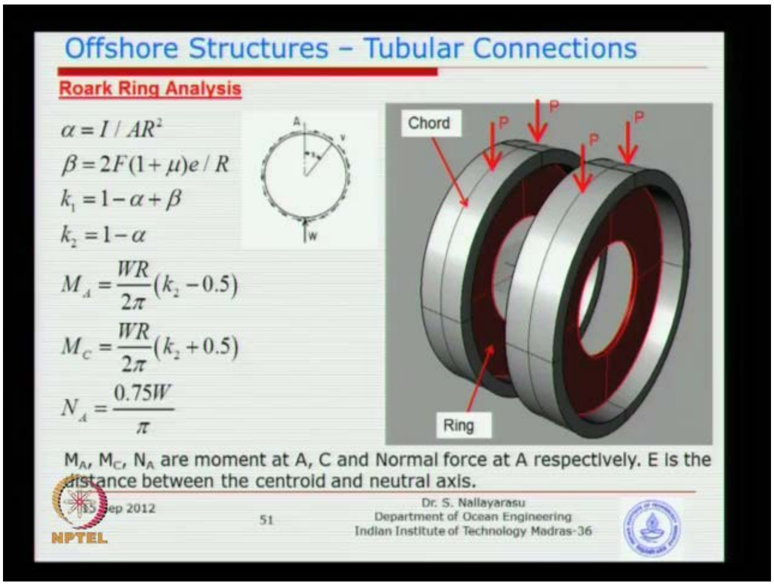

You know, basically it is a Roark formula for stress and strain, it is compilation of all the formulas, you will find such type of solution for calculation of bending moment. Because you can once you find the bending moment, you can always find at the bending stress. So, such type of this is not empirical formula, this is derived from mechanics. Simple bending of circular ring beams, so you can derive it.

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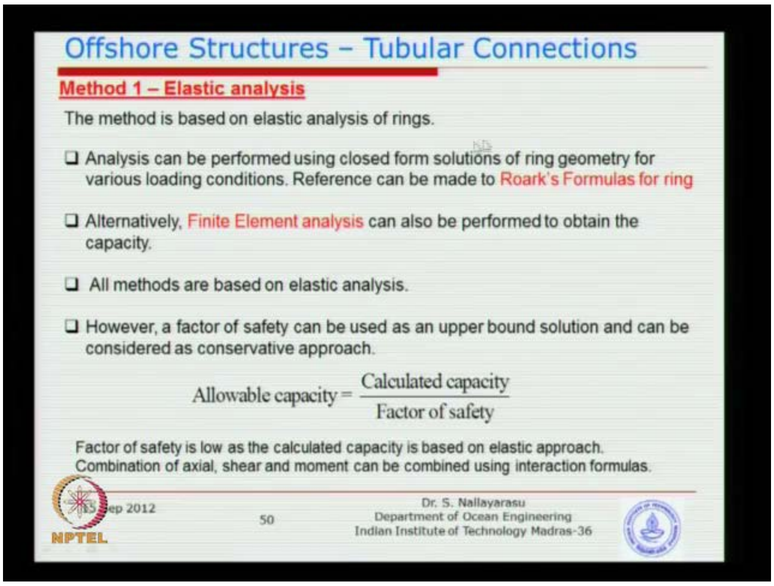

But one of the thing is, only for simple load cases, such ideas are given, if the loads are complicated, then it may be forced to go for finite element analysis. So, you could either use the Roark formula, if they are very simple cases. But if they are complicated, you could use F E analysis, I think some of you might have already been doing. So, you can see that, they can solve any complex problem.

So, the allowable capacity is calculated as, calculate the capacity divided by a gain factor of safety. The reason why, even though we do the elastic analysis, actually when you do elastic analysis you do not need to do, basically a later divide by factor of safety because is within the limit of elastic. But then, you look at elastic means, you can go up to yielding, so that means, definitely need a factor safety to be defined.

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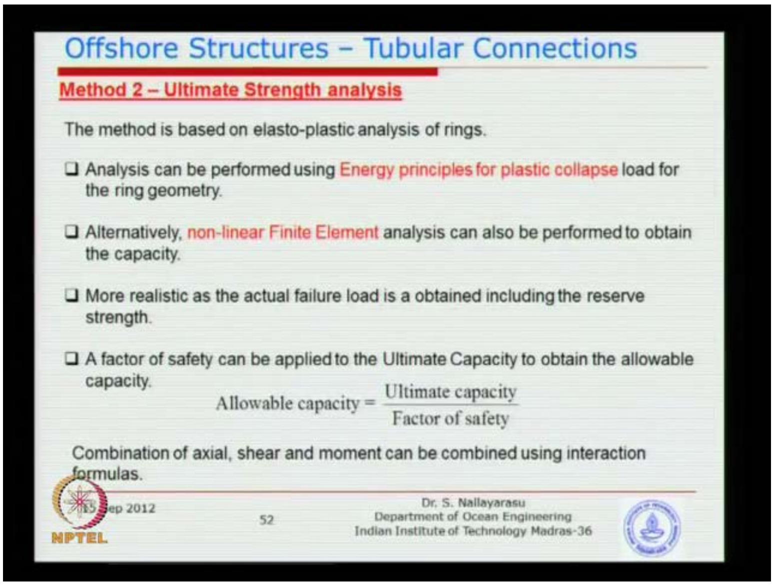

Alternatively, you could also do a elasto plastic, also called the ultimate strength analysis. Some of the software's, A P software's are available, are capable of doing such. Basically, you can load it, until failure and you can divide by larger factor of safety. So the difference between elastic analysis and elasto plastic analysis, the magnitude of the factor safety is definitely going to be different. Here you may use two and half or 3, whereas the elastic analysis, you will use 1. 67 or 1.75. The third one is a very simple one, tubular joint strength which actually we have, learned for last few classes, plus the capacity of the ring.

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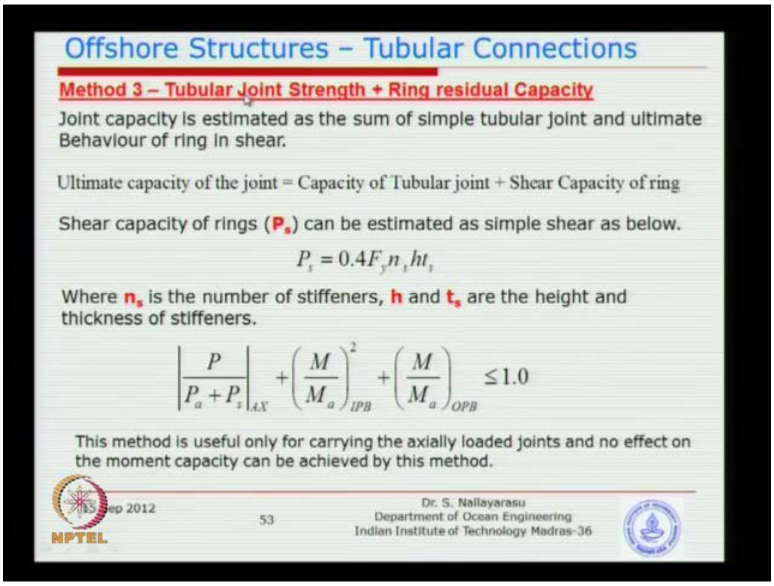

The capacity of the ring is calculated as the simple share capacity, that means if you load, if you cut this stiffener across, the vertical so-called the web of the stiffener will be active, in taking the share. So, basically 0.4 times, the area times the number of stiffness. I think, which we learned about share capacity last time. 0. 4 is the allowable stress factor, multiplied by yield multiplied by area, which is basically the high times the thickness and n is the number of stiffness. So, you go back to your interaction equation, the P a is calculated, as per the API plus P s is the share capacity of the stiffener themselves.

This seems to be very simple method because you do not need to do anything, straightaway use the API equations and then add the capacity of the share of this stiffness and many times, people use this method because it is quite simple, very easy to calculate. Unfortunately, the stiffness does not provide any enhancement on the movement capacity.

So, that is one of the weakness here, though it may provide because if you go back to this sketch, you go back to the sketch, definitely when you apply a in plane moment, one of the stiffener is going to get compression. The other brace is going to get tension and compensating. For sure, it is going to help. But imagine, if you have only 1 stiffener at the middle, yes, it does not have any movement capacity. If you put 3 brace, 3 stiffness, for sure it is going to be effective. The center one will take more actual load and the 2 outer ones, will get the moment load. So, that is one of the weakness, that we find sometimes people do not agree, especially the contractor. The fourth one is, basically using the conventional simplified method of equivalent thickness.

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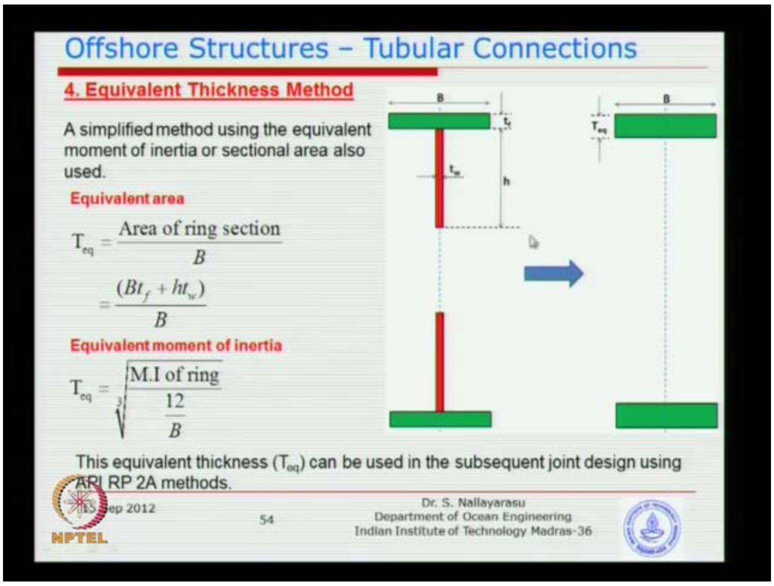

So, the equivalent thickness can be calculated either by the moment of the inertia equivalents or by the method of share area. So, if you see there, the first one, the area of the ring, which is basically, this plus this divided by B, I will get the equivalent thickness. Just because the presence of the red color, the basically the steam, what will be the additional thickness I will get. That is what we are doing. We keep the B same, so you go back to your API calculations, simply replace the thickness with T equivalent, which is seems very simple, but many times, this produces unconservative results because of such a simple.

So, you have to calculate both T equivalent, using moment of inertia and using sectional area and find out whichever is smaller and try to use this. Sometimes, agreeable to some clients, sometime, the last one is very simple also, so we have geometric parameter for the joint, we have geometric parameter the presence of load, which is Q u and Q f and Q r, you find out one more empirical parameter, just because of the presence of the ring.

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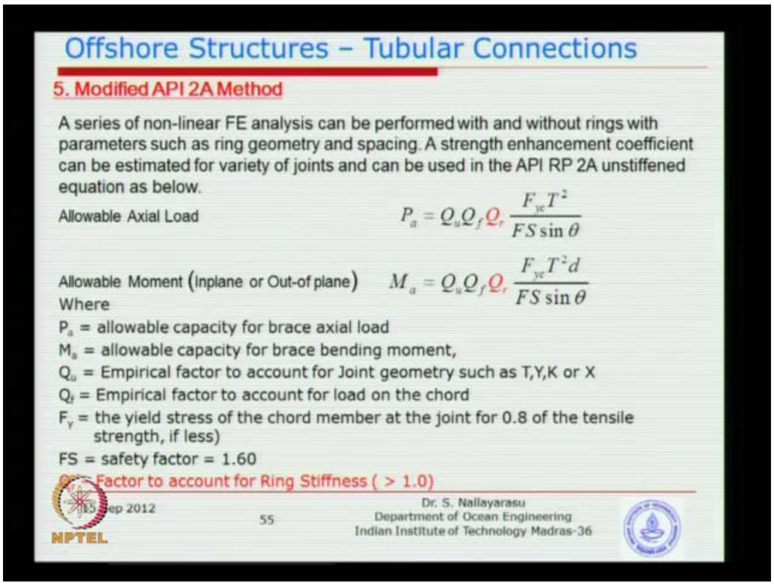

Q r will be 1, if there is no ring and Q r can be a enhancement factor, which some of my students are published few papers, we have carried out test, as well as FE analysis, come up with the similar empirical formula, like what you saw there, the plots of Q u values. Several plots we saw know, with respect to beta, with respect to various other parameters.

So, if you come up with that, you can use this. So basically, one of the paper we have published in one of the journal, which you could use that, just to compute 3 stiffness Q r value is so much, 2 stiffness different. So, you can use that, as the modification factor to enhance the capacity. So, what we have seen here, among the 5 method proposed, the 1 easy-to-use is method 3 and method 4. Normally practice because of their simplicity and you do not need to go on to. Method 1, we used to do this, especially these Roark formulas, early nineties, but then there are very conservative. Because, these ring formulas are really conservative, the moments are very high, it may require at bigger thickness.

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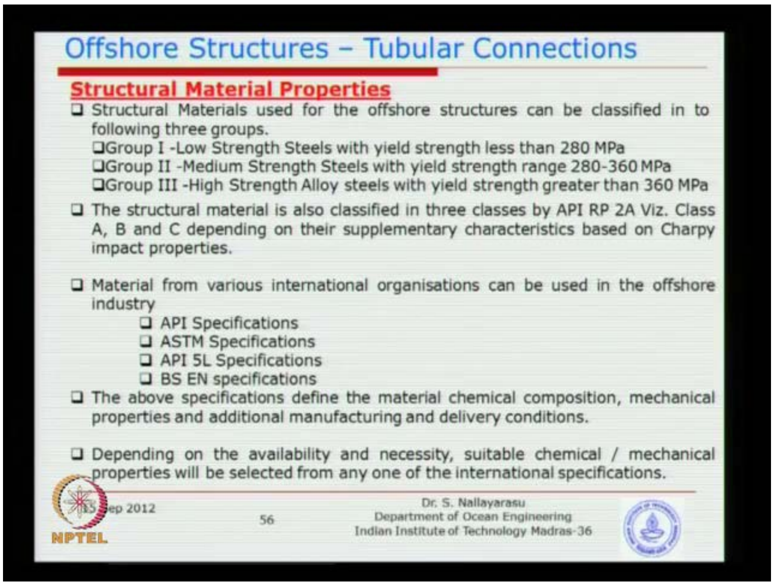

The last one, I think, we just look at the material properties because you have seen the special property at the junction, normally we require, you know the property such that, when you pull the brace, by applying tensile load, the material on the chords should have sufficient across thickness property, that it does not peel of that is what we were looking at the other day, so-called through thickness property.

While doing so, actually you see at the material for the structural applications, API classifying too low strength, medium strength and high-strength, basically the range of yield strength is given 280, 280 to 360 and beyond 360. Normally, beyond 360 is not recommended because of the welding is associated problem there and you have the materials, coming from various specifications, American codes, ASTM, API and British codes and now, ISO codes. Most of the British codes, have now been merged with, the ISO codes, they are called BS EN, And you know and basically, you will find several classes of materials available for ship construction, steel for a, you know basically, the structural applications for off shore structures, on shore structures.

So, you have to select them, suitably. The primary point is, what is recommended by API. You know, you cannot use beyond 400. 400 is a demarcation, given by API, not to go beyond, because they expect more and more welding problems and you will have, especially for the joints of the kind that we are dealing with. Of course, you can use elsewhere, like for example, if you have a bolter connections, nothing to worry.

Whereas, we are having a high shrink welded connections and that is where, we have problem. So basically, the joint locations where we have highlighted as the yellow color, previously a few pictures and that is where, we need basic idea is the material should be properly selected, such that the failure by material behavior does not happen. That means, better material, if it is fails by loading does not matter. So that is where, you have to make sure that the welding and the material supposed to be correct. And one of the property, that we are looking at is, the through thickness property. That means, when you pull across the thickness against tearing, should not happen.

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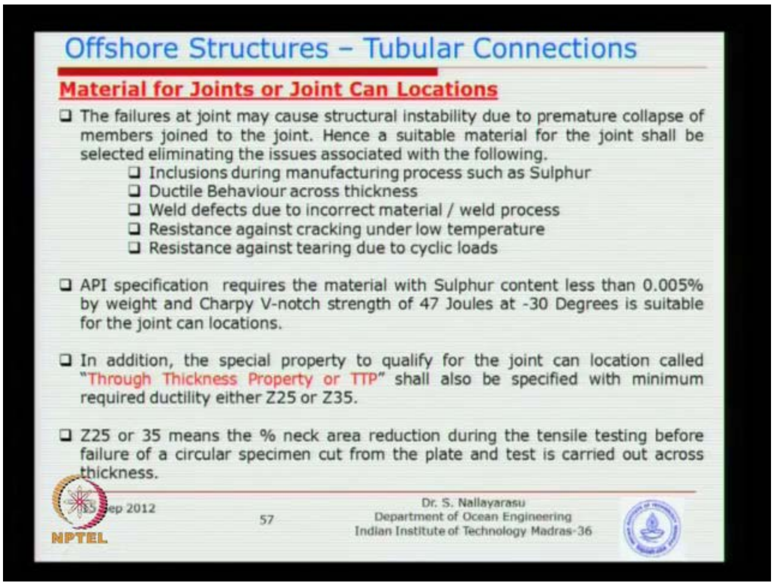

The second thing is, the material toughness at such applications. I think, in the, in the other course will be going in detail. Basically, the toughness of the material, against the impact loading, should be higher. So the energy of impact, is to be registered by the material toughness, which is measure of easy method of, finding out v-norch of a particular specimen, at certain temperature depending on the application, where ever the jacket structures are located.

Normally, API recommends, minus 30 degree testing and you should get 47 joules. So next time, when you go down to our laboratory, we can see how the V-Norch test is performed. And the notation here, basically z 35, z 25 is nothing but, you take the specimen across the thickness and try to pull, until such time the deformation is at least 35 percent. If it fails, earlier than that, that means is the material is not very good.

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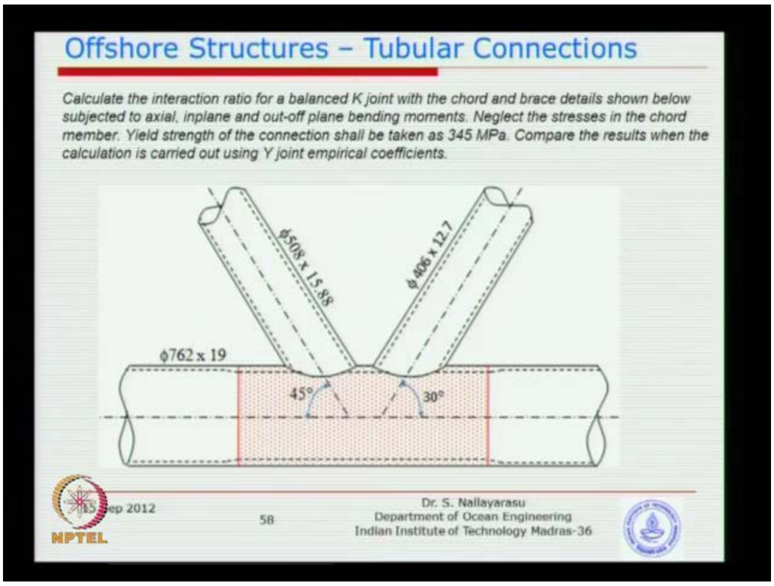

So, basically the neck area, it should get at least 35 percent extension and I have given 2 problems, I think or one problem. Probably, we try to finish this problem, before we finish the class today. So, it is a typical, so all of you understand, what exactly is going on under tubular connection. So, we started with classification empirical formulas and special cases and then, ring stiffened joints. Will just do 1 simple example, just to highlight, the importance of classification and that is what the purpose of this example. So, this one side is, 406 by 12.7, the other side is 508 by 12., 15. 8 8, with a different angles.

So, typical joint, in practice and have the chord thickness and the information is given 762 by 19 m m, basically, somewhere here and with this, what has been asked? Find out the unity check, using the formulas you have learnt, using both methods- y and k joints. You could actually classify them, you have the loads on the next page, I think ,I have just summarized. But if you actually use y joint and if you use k joints equations, how the equation makes the results deferring and of course, you will see that, the y joint, what we have learnt from our conceptualization, y joint is going to be unbalanced, k joint is going to be balanced So, balanced one should result in lower unity check, unbalanced one should result in slightly higher unity check. So, we are going to just see how they are going to come. The data is summarized, of course the loading is given, each brace is 900, 1275.

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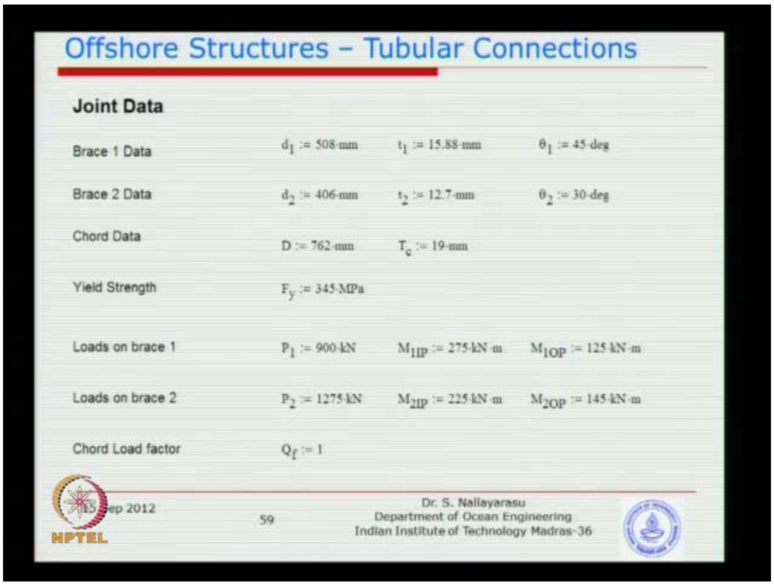

I have just given the actual load, in such way that, behaving as a balanced case because angles are different. Of course, the moments are given slightly different values and there is no load, given for the chord, so chord load factor will become 1. So, to make like little difficult, easy, instead of solving for those and all other information is given there, yield strength is given, brace diameter, chord diameter, wall thickness everything is given.

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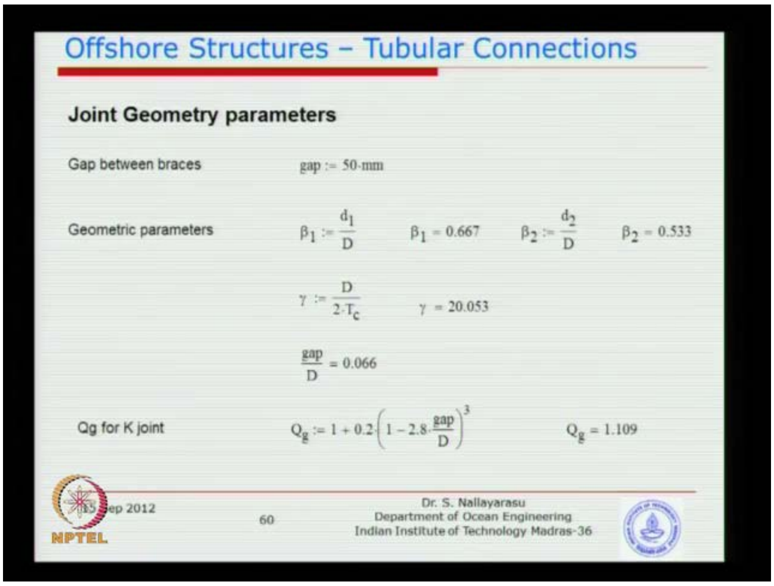

So, once you are given this, you can straight away jump into, calculate the geometric parameters like beta and then gamma and then basically, the Q g factor, which is to be used for k joint. Because, all of them are known and this beta value, you will have 2 beta value. Beta value for brace number 1, beta value for brace number 2, gamma value of course, only 1 gamma value because D by 2 T and the gap is given as 50 m m. So, if you solve, I have just taken brace number 1, which is on the left side.

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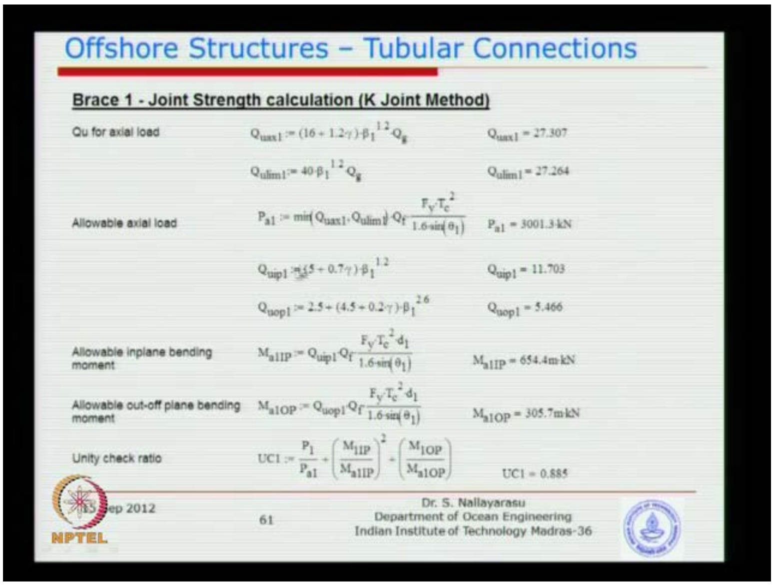

I have just solved for Q u value and then, basically substituted into PPA allowable. I am just putting sub script, so that P a 1, P a 2, you do not get confused. And you also calculate, the allowable movement capacity in plane, allowable capacity in outer plane, substitute into your interaction equations, ultimately you get a 88 percent utilization. Quite safe, isn’t it? So you just to a, all the formulas are available, so it is not a big trouble, substitution of the numbers only.

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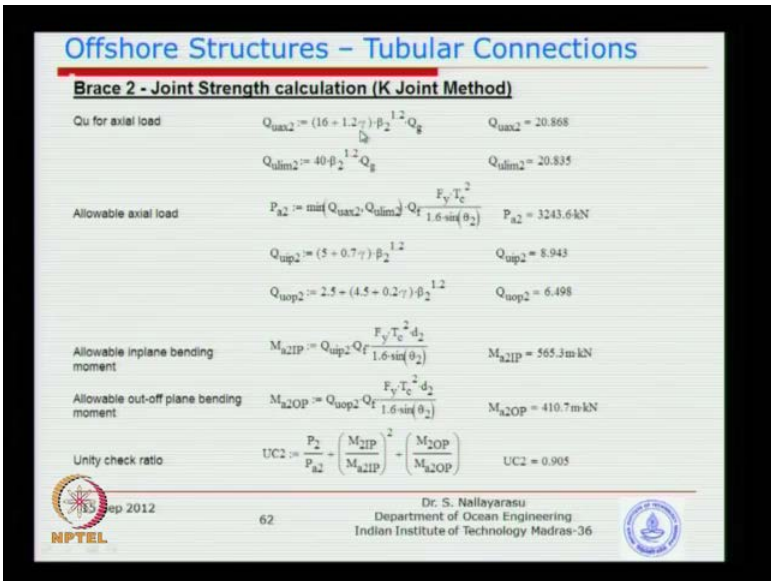

And I go to the brace number 2, you do the same thing, for the k joint. I get the unity check off 0.9, both are same. Only just, I just replace the values of second brace, gamma values and beta values and the loading.

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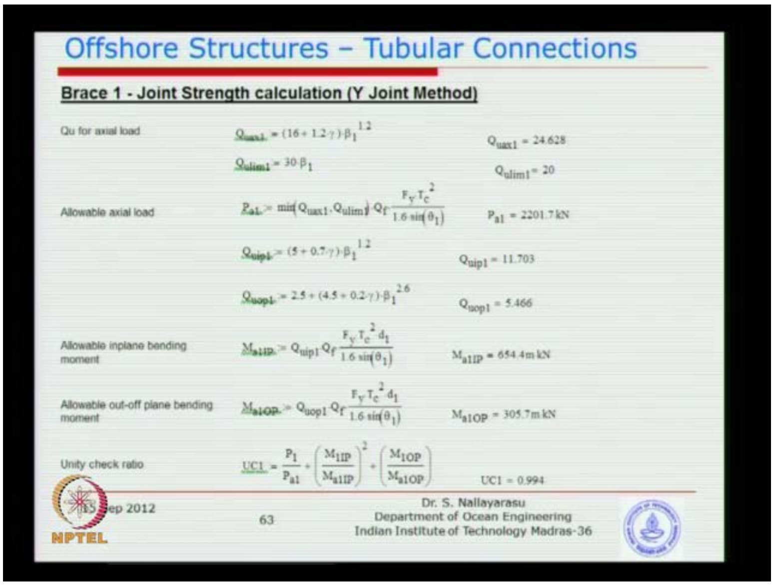

And go to brace number 1, use the y joint method. I get a unity value of 0.9 9 4 and go to brace number 2, 1.025.

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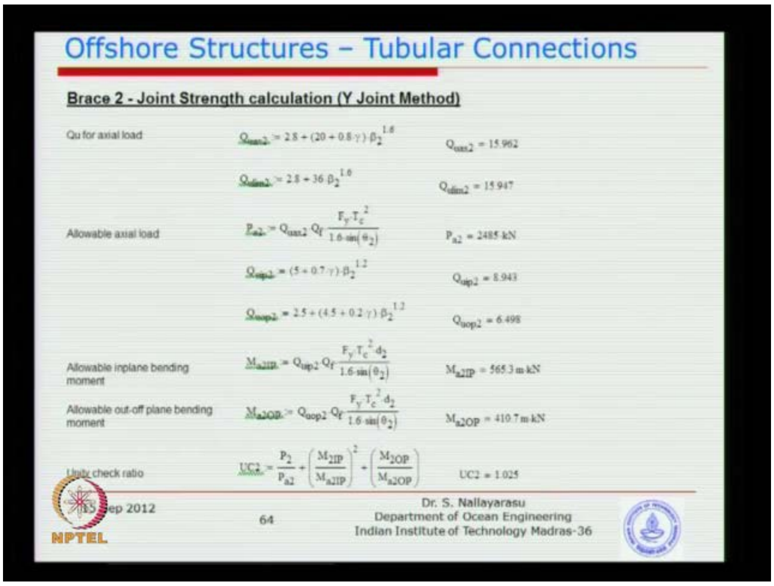

Now, if we go to the summary, just a quick summary to look at.

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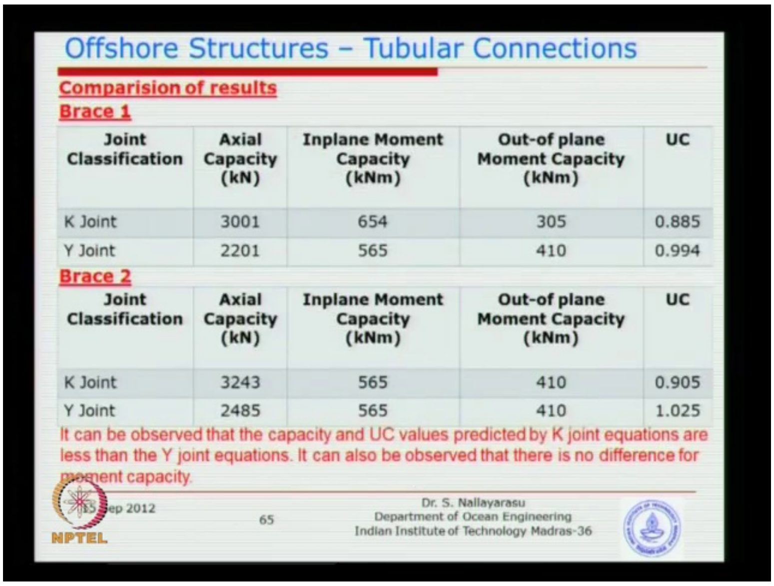

What really happens? I just look at the brace 1, when I use the k joint, I have got 88 percent. I go to the brace y joint, I get a 10 percent higher. So, basically y joint is unbalanced loads, give you a slightly increased unity check, that means more trouble for us. So, if you do not classify the joint according to the loading, you will see that you will be doing a incorrect calculation methods. Similarly, to brace 2, 0.9 becomes 1.0 and typically, just because of your methods of calculations. So, this example gives you an idea, how you do it, number 1, also do a comparison.

So, if you are asked to find out the unity check or if you are asked to find out, what is the capacity of the joint, you just need to go back and just calculate the geometric parameter, go to Q u values and find out the Q u from your r beta values and if it is a k joint, you will have the Q g multiplication there. If it is a y joint, you do not have that Q g. Q f fortunately was given as, 1 because there is no load under chord, otherwise you will have to go back to your Q f equation, substitute all the parameters, find out what is Q f. Then you come back here because basically, you see here, Q u multiplied by Q f multiplied by f y t square divided by 1.6 sin theta. Now, in the examination point of view, what will be given is, basically this table will be given.

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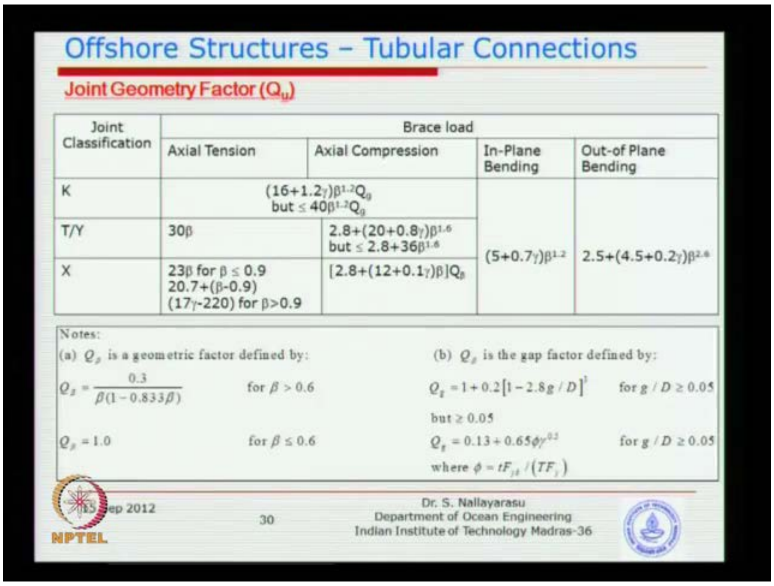

So, you need remember remaining, this table will be given this table for a tubular joint design. This contains only the information regarding Q u and this equations, will be given. You do not need to memorize and when you give, when I give this equation, I will give you this table, because this is no point memorizing this numerical values.

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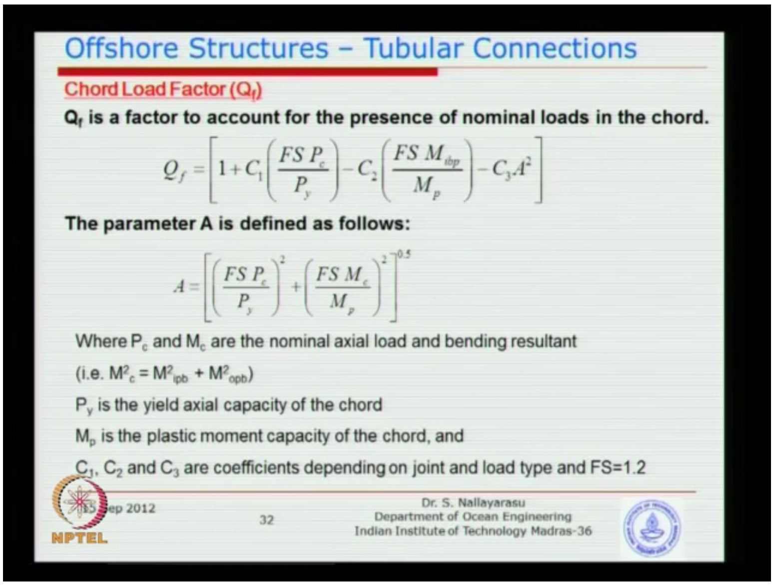

So, this 3 information will be provided and basically, remaining you should remember, especially the, this interaction equation, you should keep it in your mind.

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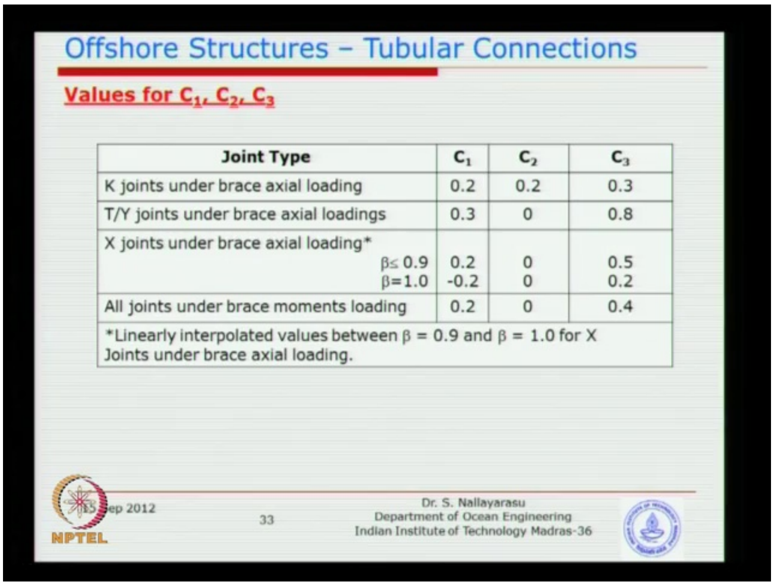

Also, the equations for calculating P a and M a, you should be able to keep it in your mind. Do not ask for it and make sure, that you remember.

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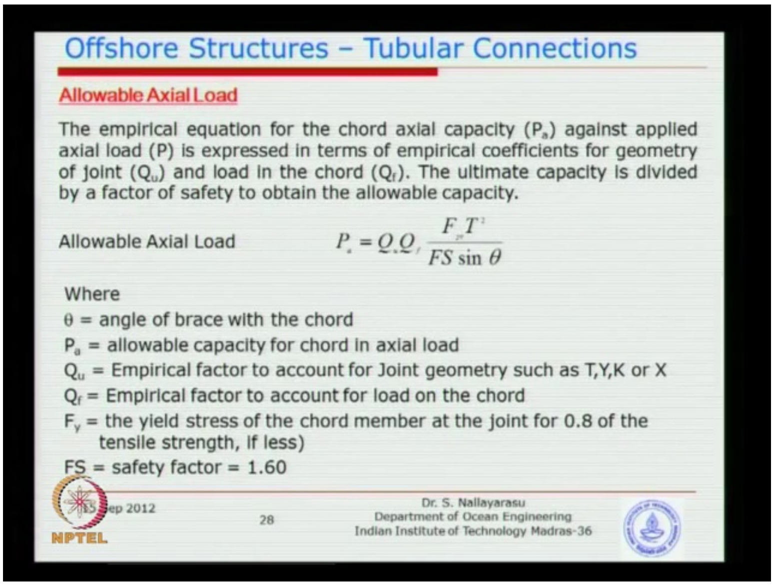

But those 3 big, this table plus Q u f values and associated constants, I will definitely provide in the exam sheet. I think, so whatever we have done so far, is basically the static capacity of tubular joint.