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Module - 04
Lecture - 03
Tubular Joint Designed for Static and Cyclic loads III

The last week I think we were looking at the tubular the connection behavior. So, we will just introduced the design in this few classes.

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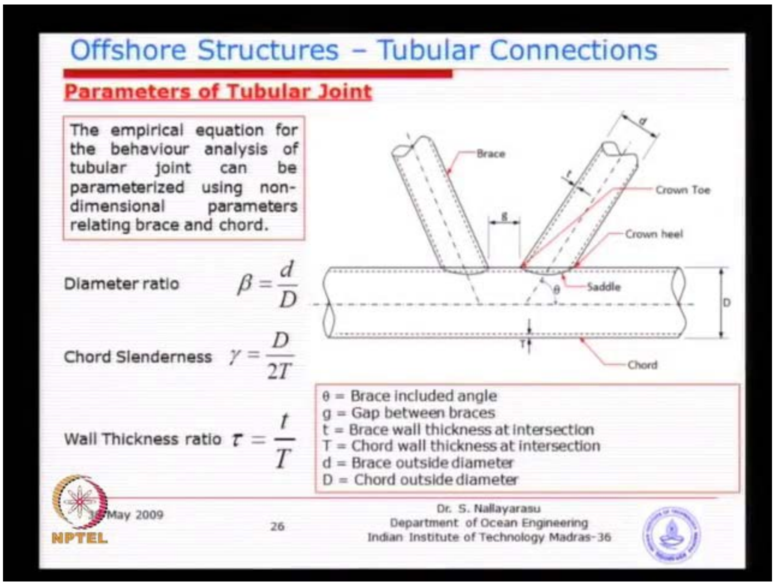

So, if you look at this picture, you can see the major parameter that are selected for computation of the capacity is the diameter ratio which is quit important. If you see the behavior the ratio of the brace diameter to chord diameter becomes large that means near 1 both. So, there will be a different type of failure. If it is small there will be a different type of failure. If you take case of the beta is less than 0.2 very small that means very big chord small brace diameter. So, what will happen when the load is applied, it will poking through that tubular, means the failure will be almost local. So, if you just make 1 diagram

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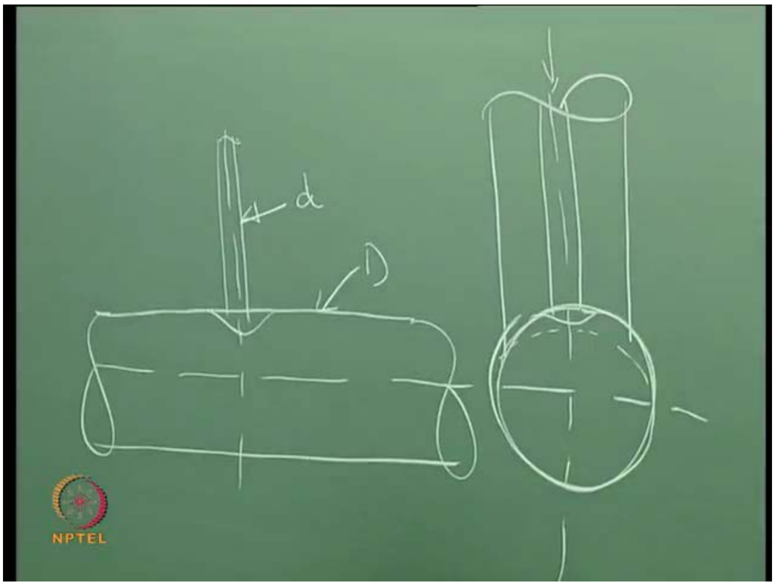

If you this idea and if this brace is quite small is going to be actually failure, very much in local if you do a cross section. Something like this, if to this your diameter of brace, if you just imagine such a small diameter brace only carries little bit of load. This kind of imagination will get in many places because the normally do not want to oversize the brace unless is required, but the chord. This could be jacket like you know the leg is designed for some other purpose, you know by making it to have the pipes going through the legs.

So, you might have a very big leg, but the brace could be quite small typical the example will be the brace will be 500 mm, but the jacket could be 2 meters. So, you just come to 0.25 you know 1 4. So, that is the kind of situation where you can see the behavior could be almost local. There is no chord failure is not going to failure like the novelization because the load is quite small. This you might have studied if you have take in the canary redesign punching shear in a column to slab column to ground slab or column to rub slab.

You might have studied at as certain distance from the column surface d by 2 distance you see the critical section for failure by sheer. So, which is called the local punching shear that means the plate or the slab in that the local size visibility is not going to deform. It is just going to go down straight away failure is immediate and which is what we should avoid. So, one behavior is the diameter ratio is small behavior is or the failure pattern the idea of the load at which the connection will fail is going to be different, when the diameter ratio is may bigger.

So, you just go to the same picture you make it somewhere here. So, if you put node again, you see here this is going to be a pattern of failures slightly different because this is overlies the pipe because the distribution is larger taking into account. The larger length of the pipe. So, you could easily now understand why they have selected that diameter ratio also one of the important parameter because the failure pattern is going to change. Once the failure pattern changes the capacity at which is going to fail also changes. It would be lower I am not concluding that whether d by d ratio is small is going to take lesser load or d by ratio is higher is going to take higher load.

I am not concluding that what, what we trying to make sure is the parameter is selected as the larger influence on the capacity of the joint because is going to affect the type of failure that may occur prior to failures. So, that is one of the parameter then we go to the second parameter is the diameter to wall thickness ratio of the chord itself, I think we can easily imagine you take is half. Basically, d by 2. So, r by t, radius to thickness. So, if you look at that parameter. The larger the diameter you make I am sure keeping the wall thickness it becomes slender cylinder in the sense is going to be filled by local buckling.

Very easy to understand which we have studied in our member design. So, d by T smaller is better, but how smaller is going to become rigid. So, that is why the second parameter is also important to see whether it fails by buckling are fails by other means of bending. The third parameter is not so important in the design of. Basically, static capacity we will see in the equation they will never use this, but this will be very useful in terms of saddle. Later on we will see in the next 2 classes. The stress concentration at the interface between there are thickness of the chord to thickness of brace. So, that really matters, but as the parameter, that is also identified during the initial stage of A P I development.

If you look at the previous chord the tau parameters also was there, but recently it was founded this is not influencing the capacity in static loading. So, that is why you will just not see that there what other parameters are there. The other parent parameters are. Basically, that angle at which the brace comes and joints the chord, which is definitely going to affect. For example, if you take a angle of ninety degree, the total vertical load. It becomes ninety degree means in the brace is perpendicular to the chord.

The load applied on the brace is fully going to deform this pipe. In this way it will make the angle say 45 degrees. I am sure you can easily understand the component normal to the chord is less is getting less more the angle. It will come near to equal to the actual load on the brace. So, what happened to the reminder of the load. Then you have 45 degree, some load goes normal to the chord. Some load goes as a actual or in line force to the chord. In line force I think it is not a problem you can take large amount of load because big diameter is there.

So, the angle is definitely going to affect that capacity because the amount of normal component goes to the pipe is going to be reduced. Than if you have 2 braces joint together I think we discuss this one has earlier also die effect of 2 chord 2 braces delivering force on the same location is going to have a cumulative effect which you see this, the parameter called gap. The larger you make to make the g parameter, say 1 meter then there is no question of any over lapping stress from 1 brace to other. Whereas, if you make it smaller than there will be definitely be a effect of 1 of the brace is overlapped on to another brace.

That means this location of the chord is going to be subjected to higher stresses, but how why depends on what is the load supplied what is gap available, but what they do not want, this g you make it bigger. Our intention is gone if you look at by this time you should have seen some joint some jacket on configuration. You do not want to make that g parameter 1 meter then the point is lost, our priming will not come properly. So, you need to keep it close the, but as much gap needs to be there because you need to wealthy because when you look at the wealthy both wealthy will overlap, weld overlap means is not very good because of the heat generated during wetly 2 times 3 times.

For example, you make this one. So, close that this wetly is overlapped on to this wealthy, next 2 times we heat 2 times we are going to degrade the material and then failure may occur that locations. So,. Basically, I think you can see g also place the major role only for this type of k joints, but whereas, for T and y joints you do not have such parameters there. So, basically, you see this table is giving you an idea of what is the upper and lower limits of the parameters used in the generation of empirical formula for the design purpose.

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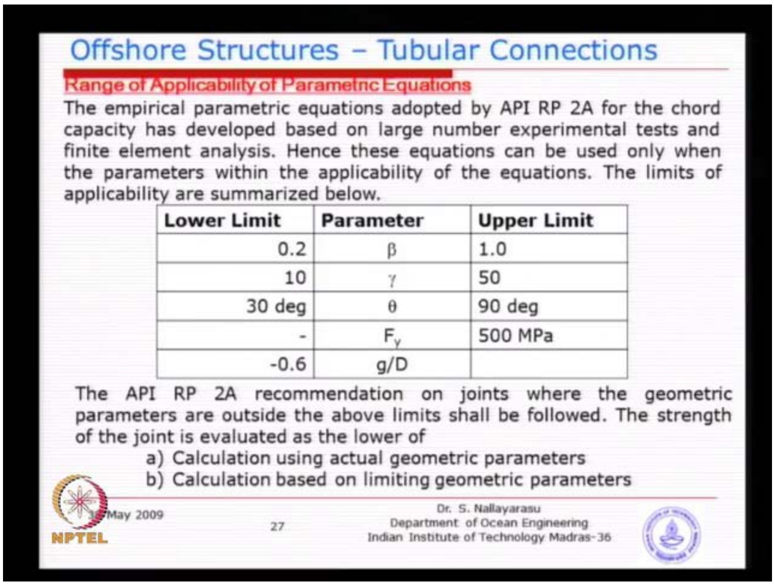

So, this is what the experiments done the P analysis was done on the several joints in almost nearly 1000 testing they have done. If you look at the joint industry project report we have done 1000 joints fabricator tested in the laboratory. This can lot of money out of which within this parameter the main thing is 0.2 the lower to the maximum one, but the normally in practice we do not want to go to beta value of 1 because you will see, when diameter is equal to this diameter, these points become very difficult to weld, weld in the seen it will enlarge location.

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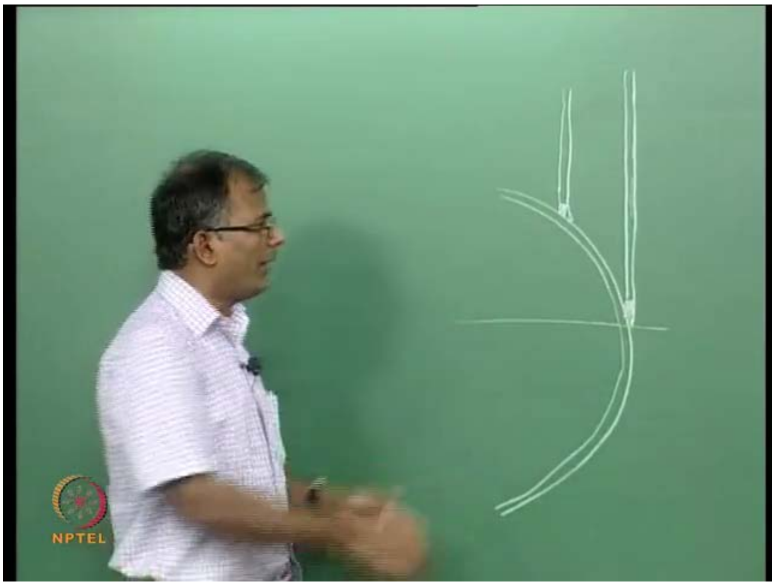

In a. Basically, that is your chord you may have a wall thickness something like this. The brace also going to be this is your central time. If you take plate like this. Now, you see here this wealthy hope our love you can see this wealthy becomes very very difficult. Whereas, that same thing diameter is smaller you normally do not have a. You can weld it properly here, whereas, here this is singular point where the surface of the brace on the chord is almost matching.

So, that is why the d by d ratio of 1, theoretical those experimenter in the equation we normally in practice do not keep it to 0.9 maximum. Then the tau parameter or gamma parameter this is. Basically, 10 to 50 angle between 30 to 90. Yield I think I explained other day, the higher the yield is no good for welding as well we do not have experiments are we do not have a equation satisfy. The gap cannot be less than 0.6 minus that means overlap can be allowed, but not beyond minus 0.6.

Now, you see here, but the bottom I have given what is the recommendation if you violate this. Basically, you can normally not violate this, but if you have situation where you are unable to go for a better solution is still allow, slightly beyond or the limits. Then calculate the capacity based on the actual that means whatever the parameter you have on calculate the parameters using the table here that means the extreme limits limited by the equations, you see whichever the lower capacity will be here capacity of joint. Now, how do we calculate the capacity. Basically, simple.

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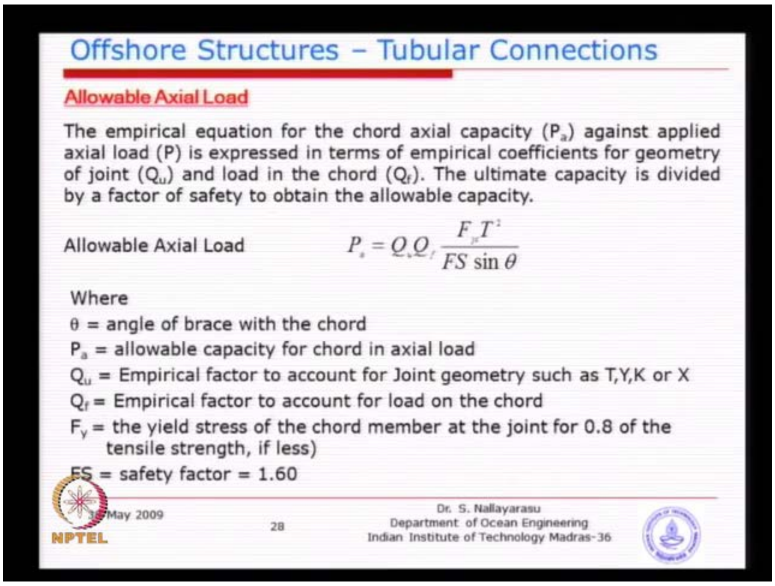

So, we have a notation you can see their allowable actual load that the chord can take prior to failure. So, basically, P allowable, this coming from P ultimate divided by factor of safety. So, basically, P ultimate calculated as Q F Q u and then. Basically, F y the third wall thickness divided by sin theta Now, this is ultimate. So, that is why you see the at the bottom we have a factor of safety defined. So, basically, if you have a joint like this what could be the load that you could applied, the chord can take prior to failure. Basically, your ultimate actual load divided by factor of safety we have the allowable load on the joint without failure.

So, basically, this F s in this particular case there was lots and lots of arguments. In fact several papers in published region times whether 1 point this is correct or higher is better. Now, remember this go back our member design, we were looking at allowable actual stress usually for a short column not cylinder. I hope you remember what is the value. Basically, allowable actual stress. If the column is non cylinder small height is it 0.6. So, if you convert the 0.62 factor of 1.67 listened. So, almost symbol or like sub, there is a difference in the allowable stress design we took the yield as the limiting value yield multiplied by 0.6 will give the allowable actual stress.

I think most of you might have done in the exam also. There you limited the whole thing to yield point and then you brought down to 0.6. Whereas, in this we have this is beyond yield and we have gone to first crack and, but a yield we actual acting somewhere in between. So, you see here if you go back to our load displacement curve we are not limiting our. We are not limiting our capacity at yield we are going beyond, but not at the first crack. So, we have take slightly higher capacity, but divide by a same factors F T F 1 0.6.

So, lots and lots of debate was there, in fact several papers argued it should reduce to. Basically, the same as methodology adapted for tubular. That means increase the factor of safety to 2 and half, but then by the number of arguments over then the reason A P I adapted in fact previous a P I factor of safety to now, may have reduced to 1.6 utilizing additional centre available in the tubular form, which I think you, you might have noticed we derived a elastic capacity versus a elastic capacity in bending and actual. So, you could see the increased strength because of the circular section.

So, basically, because of that finally, the joint committee adapted factor of safety of 1.6. So, suppose if I ask you to find out ultimate capacity what will do you will not divide by the factor of safety, you understand the idea know. Now, you look at this formula there are primarily 3 are 4 parameters involved Q u Q F, F y I think all of you must understand what is F y, F y is the yield strength of chord sometimes not very often the chord material and the brace material. Sometime we use different strength, but most of the jackets we have all material same, but in case if you have then you should take the chord yield strength remember.

This is allowable capacity of the joint preventing failure of chord not the brace, that is why you have to use the chord yield strength multiplied by T square that means the thickness of the chord. So, the bigger thickness you make is going to just the commonsense the stronger you make it is going to carry higher load. Now, these 2 parameters very easy to easy to understand because thickness and the yield of the chord pipe. Now, you have the other 2 parameter. First parameter called the Q u which is typically to account for a geometry of the joint T join k joint. The behavior is going to different.

So,. Basically, to account for the geometry and the load confirmation the second parameter called Q F is to account for any stresses chord itself. For example, if I take the joint if I go back to this picture, if I have the load on this brace as well if I load on this chord the brace load going to comprised. For example, and if we have the tension load and the chord. What will happen the failure would be earlier than expect, but if you have a compression load on the chord and you have a load from the brace you can actually see the failure will not be as early as earlier case. So, influence of the load on chord is going to actually are increase the effect.

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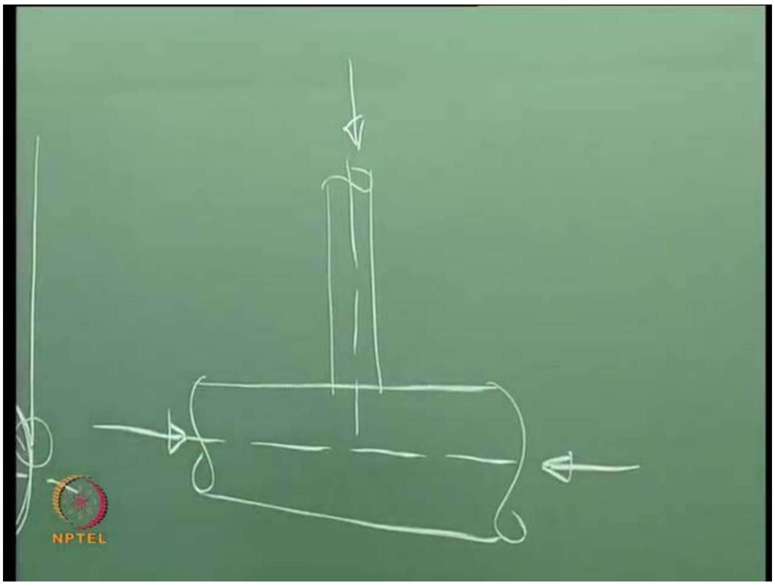

Basically, it because if you have something like this and you take a T joint you put 1 compression load. Very simple idea that local buckling will be prevalently from happening because you cannot a compression loading exactly at the joint and the other 1 is also compression loading. So, depending on magnitude of the load that is going to be applied onto the chord itself, is going to have an influencing on the capacity whether it will fail free mature are it will fail at the ultimate load. So,. Basically, this, is the 2 parameters to account only for the joint configuration and the load path classification.

Take into account this so somebody done experiment have come up with empirical formula. Basically, based on the results of the studies. You will need to that similarly, in this you will be given a empirical formula to account for it. Now, these 2 numbers need not be less than 1, the way that the empirical formula is set up, it will be large numbers not just like less than 1 or less than 2 something like this because this number ranges from almost big big numbers will come.

So, you do not you do not have idea that sometime empirical formula will limit to 0 to 1 2 to five. So, here is a different type of arrangement. So, we need to just see how we can get the values of Q u and Q F. Similarly, allowable moment, how much moment you can applied at this joint. Basically, what is the type of moment that you can apply.

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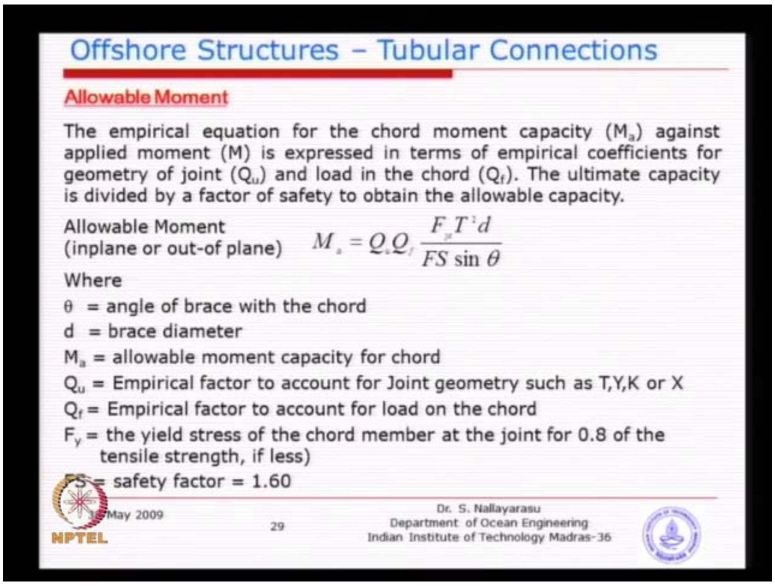

Here to avoid failures similar typical formula, only thing is you have been you are seen this the right-hand side of the equation d is added. So, you can easily understand the larger diameter the moment can be register by better way listened. For example, if I go back to this picture the original picture. Here if I have a moment here the it is resisted by at couple reaction from the 2 sides of the pipe listened. So, bigger the diameter the d couple the effect will be better.

So, that is why you can see here d is multiplied because to take into account stability to get. If you do not have that d is very small what will happened it will immediately fail. So, the smaller the diameter capacity at failure could be smaller. So, that the idea beyond reminding term remind same only thing is Q u and Q F for a moment equation should be different, you know that is the idea whereas, when you look at the actual capacity the equation for this also will different. So, we got 2 distinctive idea allowable actual and allowable moment capacity all the remaining parameters, reminds even in this you have F s you have sin theta you have yield strength you have the wall thickness. So, basically, I think using this you can desired. Now, whether joint is capable of taking the load are failing before. So, for this that done.

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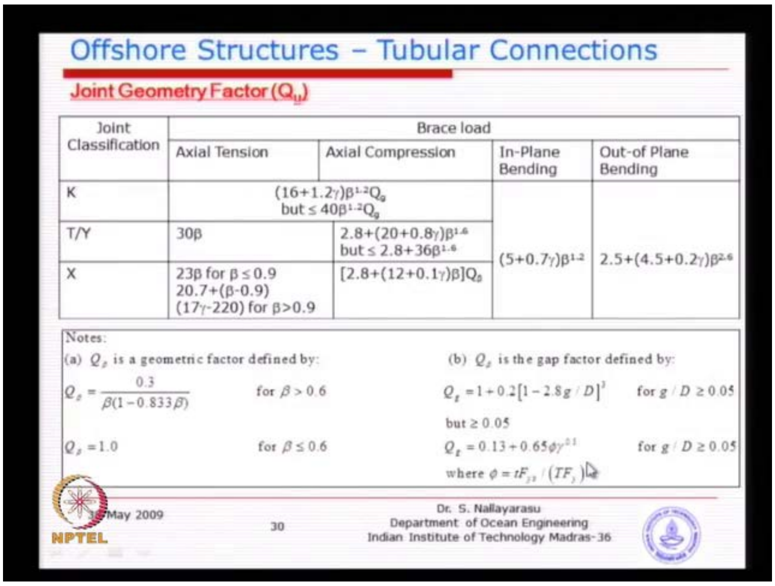
Offshore Structures – Tubular Connections

Joint Geometry Factor (Q_u)

Joint Classification	Brace load			
	Axial Tension	Axial Compression	In-Plane Bending	Out-of Plane Bending
K	$(16+1.2\gamma)\beta^{1.2}Q_g$ but $\le 40\beta^{1.2}Q_g$		$(5+0.7\gamma)\beta^{1.2}$	$2.5+(4.5+0.2\gamma)\beta^{2.6}$
T/Y	30β	$2.8+(20+0.8\gamma)\beta^{1.6}$ but $\le 2.8+36\beta^{1.6}$		
X	23β for $\beta \le 0.9$ $20.7+(\beta-0.9)$ $(17\gamma-220)$ for $\beta>0.9$	$[2.8+(12+0.1\gamma)\beta]Q_\beta$		

Notes:

(a) Q_β is a geometric factor defined by:

$Q_\beta = \frac{0.3}{\beta(1-0.833\beta)}$ for $\beta > 0.6$

$Q_\beta = 1.0$ for $\beta \le 0.6$

(b) Q_g is the gap factor defined by:

$Q_g = 1 + 0.2[1 - 2.8g/D]^3$ for $g/D \ge 0.05$

but ≥ 0.05

$Q_g = 0.13 + 0.65\phi\gamma^{0.5}$ for $g/D \ge 0.05$

where $\phi = tF_{yb}/(TF_y)$

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Basically, first let us understand how the formulas for geometric parameter so called the joint effect the geometry of joint. So, Q u is given for different types of joint. For example, if you go to the left side we have k type of joint we have y and x type of joint y and T is almost a mix up only the angle is slightly different. You see here for types of loading patterns it as axial tension you have axial compression you have in plane and out of plane bending of. Hope, all of you understand what is in plane and out of plane you know in the plane of the joint something like this is in plane. The perpendicular to the basis out of plane, this is out of plane.

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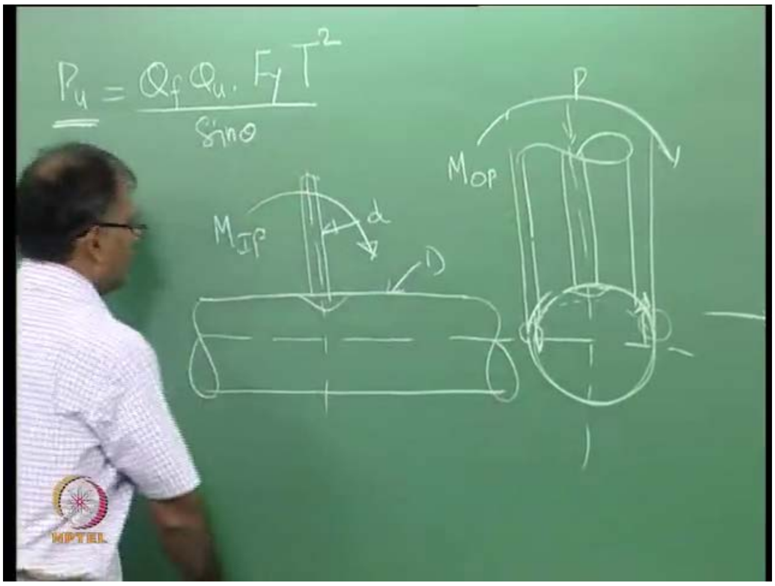

So, let me just if the brace is like this, this is moment in plane moment out of plane. So, you have to this make sure that, whenever he you look at the joint the chord running along braces are seen that is in plane. The moment is in plane and. Basically, the out of perpendicular to that, but the chord is called out of plane. You will have 2 component moments of course, third 1 torsion with normally we do not including in the design. So, basically, you see here tension compression in plane out of plane of 4 category of load and 4 categories of joint configuration.

We got a empirical formula will just spend 1 minute on 1 of them. Basically, you look at the T joint simple 1 thirty times beta, beta is varying from 0.2 to nearly 1 and I said do not go to 1 limit to 0.9. So, you can see here this is going to be varying anywhere between probably 0.6 all the way to 24 25 something like this. So, this number. So, basic idea is it is not something like in empirical parameter between 0 and 1 such. So, this will be different numbers for difference. So, larger the d by d ratio you could see that in the T joints it can take larger capacity that is what the conclusion we are trying to make.

So, because if you look at this formula as longest the Q value is increasing the capacity going to increase. So, you need to just understand which parameter is going to help us. Similarly, Q F based 2 parameters multiplicative and the bigger you make more the capacity is going to be listened. So, you should know which parameter is put in of course, the best parameter in here is T square, the higher you make you are sure going to get bigger capacity square of it listened. Instead of 20 you make it 50, you will suddenly get the very big capacity.

So, like this in the empirical formula, you have got the other loading patterns. Similarly, for k joints, you got another parameter coming is called the gap parameter. So, Q g, this Q g defined as you see here on the right-hand side is a parameter relating the gap and diameter the more the gap you gave it becomes isolated y joint. The smaller gap that you give. Basically, it becomes a balanced g joint and unbalanced T r y joint. So,. Basically, that is taken into account. So, the parameter involved is the gap.

If the gap is 75 then you can substitute and get it and the other parameter is Q beta for the x joint. So, first is the T y joint, highly related to beta and gamma and. Basically, k joint related to the gap parameter h joint related to the Q beta parameter. Two more additional parameter coming in just to make sure. So, basically, if you look at the whole calculation Q u Q F Q beta and Q g. So, of course, Q g is used for only k joint, then Q beta is used only for x joint.

So, these are the 4 category that you have to look at. This particular table I will if it is required for examination point you can print it and give you do not have really memorize, but at then you should know how to use it. Basically, each load is different. So, formula is same for example, if I go to this whether it is tension or compression this is same formula, what will be replace is the, the Q value corresponding to tension are corresponding to compression and which type of joint you are going to. For example, when you are designing a T joint you will take Q u corresponding to this.

If the loading is the tension you will take 30 beta, if the loading is compression you will take this formula. You understand the idea know. So, is table only bigger the basic idea is parameters are going to be calculated corresponding to the joint type, corresponding to the load type in a whether it is. So, similarly, you can also look at the in planes bending on out of plane bending far moment capacity. So, we can see. So, we can have a large number of combination of things that can happen. I just plotted some of this parameter in fact most of them. So, if you look at this side, left side is the Q u value.

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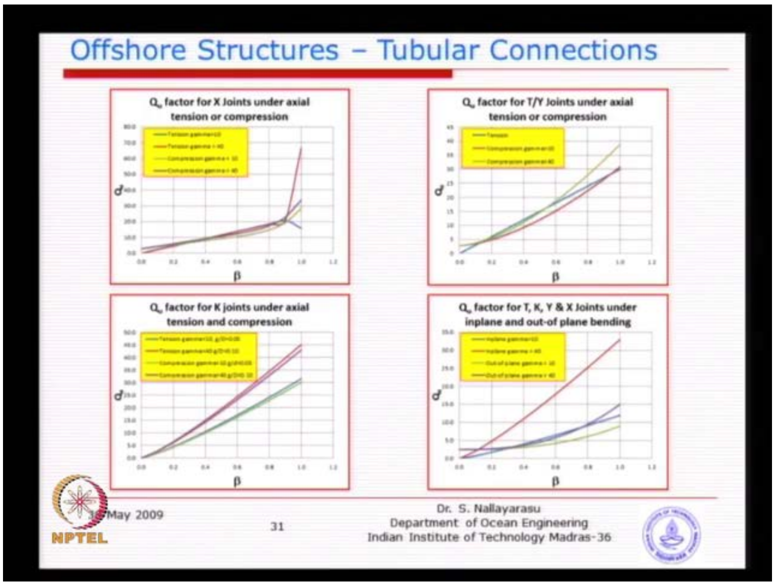

That means the vertical axis is Q u value and the horizontal axis I have just plotted to beta for different values of gamma. You know if you look at for example, axial x-joint it is depended on 2 parameters. One is beta and the other 1 is gamma, you know 2 parameters are involved. Basically, if are tension and compression you got different formulas and in plane bending out of plane bending to different formulas. I will just plotted for the sake of trying to find out what would be the range of 2 values that you will get. Just if you look at the right hand first the Q value for a T joint there are 3 color you can see tension compression. In the compression we have 2 different values of gamma.

Gamma is your d by 2 t. So, basically, you can see is band of values, the blue color is. Basically, the tension is almost linear because 30 time beta. Whereas, if you look at the compression is just varying nonlinearly because is varying by to the power 1.6. You see here. So,. Basically, nearly a non-linear variation, but the values of range you can see 0 to up to somewhere around 35 for the compression loading for tension loading you have about 30.

So, just give an idea of how this values vary with respect to beta. You can see beta is the primary parameter you can see whereas, with respect to gamma. For example, if you go to this 1 in fact the, the gamma value 10 the gamma value 40 is this color red color versus. So, basically, you can see here larger or smaller the variation very small. Similarly, I have plotted for 4 phases where x joint tension and compression T joint and compression and the last 1 is common to all of them. If you go back to table you will see that irrespective of type of joint in plane and out of plane moments are same. Whether it is T joint at P joint does not matter. So, basically, that is what we see here in this diagram. So, this parameters can be easily calculated as longest you can classify the joint and go to the table pickup the right equation and then calculate.

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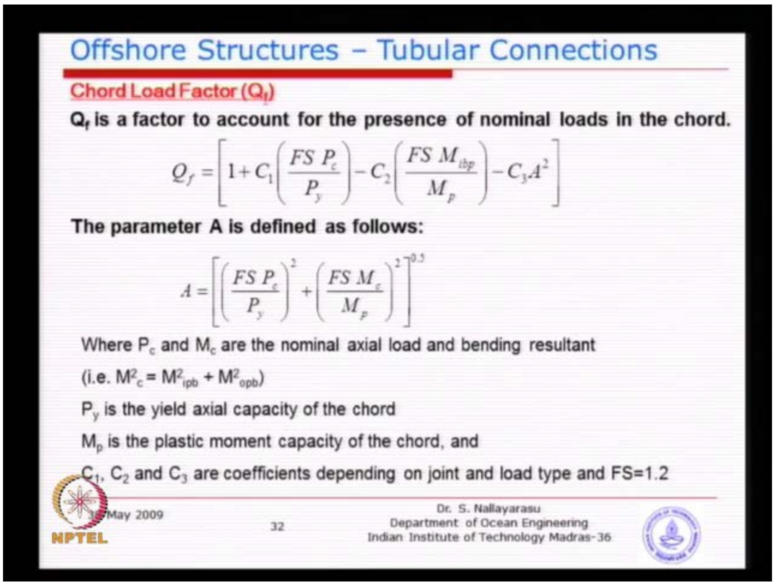

Now, Q F the effect of chord load that means more than stress on the chord pipe you are going to have a earlier failure attributes failure. Is a little bit complicated would say it is empirical formula very difficult to predict and that is how they have developed. So, you can see there are several terms. First 1 is just base capacity that means if there is no chord load what will happen, it will become Q u for Q F become 1 you must remember if I give you word no load on the chord, then you do not need to calculate and get the value listened.

If there is no load ultimately Q F should become 1. If more load is there what will happen the Q F values always have to be less than 1 to remember do not calculate and get g F value 10 20 like this something must be definitely wrong. The purpose of this is the reduction factor. Basically, you see here this is an enhancement factor, Q u is an enhancement factor always going to be greater than 1, you saw that numbers and Q F factor always going to be less than less than 1. Surely 1 is the maximum when the load is not there in the chord and the more load, if you applied on the chord is going to have some effect whether it is tension are compression this stresses going to be additive. So, basically, little bit complicated formula, but easy to calculate because most of the empirical.

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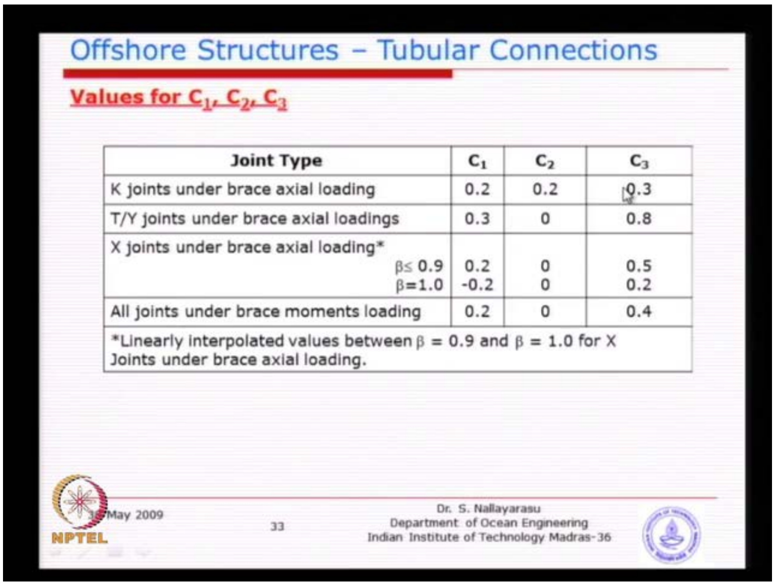

Joint Type	C_1	C_2	C_3
K joints under brace axial loading	0.2	0.2	0.3
T/Y joints under brace axial loadings	0.3	0	0.8
X joints under brace axial loading* $\beta \le 0.9$	0.2	0	0.5
$\beta = 1.0$	-0.2	0	0.2
All joints under brace moments loading	0.2	0	0.4
*Linearly interpolated values between $\beta = 0.9$ and $\beta = 1.0$ for X Joints under brace axial loading.			

We need to understand that terms, there are 3 constants to be taken the constant are available for a P I given for different loading type different joint type. So you can just see most of the numbers are point-two-point 3 like this. These are all calibration coefficient with respect to the chord capacity. Then the parameter called a, a is defined as the collapse flow to the yield load. So, basically, the P c and m c is calculated using this s r s formula. Basically, m c can be calculated if you have in plane moment and out of plane moment this remember you have to very careful. This is not the moment and the load on the brace this is the load and moment on the chord. So, you should be very very careful do not take the load applied here and calculate the Q F value.

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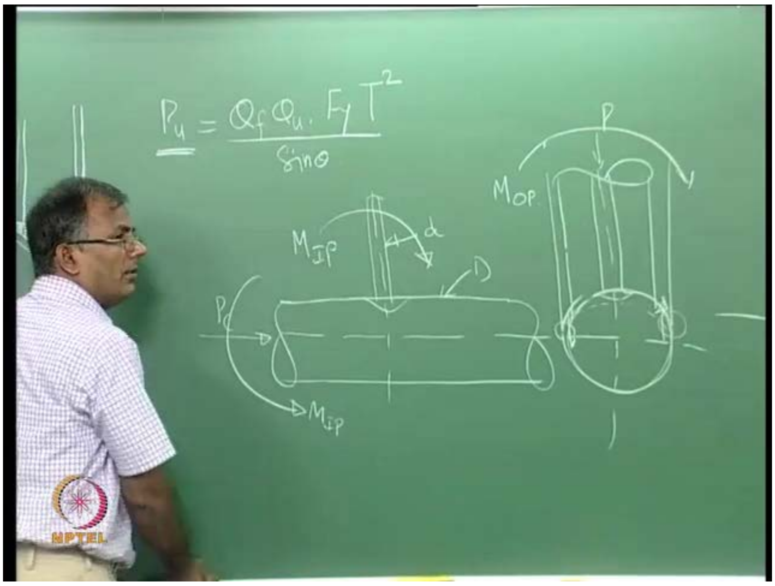

You how to find out what is the load applied on to the, you have to look for this load, load on the chord member not the brace. So, basically, sometimes we get confused of take the brace load and applied which is not correct. So, you have just look for the load on the chord the moment and chord. So, P c is an m c are the nominal axial load and bending moment resultant. Basically, resultant this we have 2 moments know in plane moment and out of plane moment this chord can carry and this s r s sum of square's of square root of both components. So, you can get it P y is the yield axial capacity of the chord, I think what is yield axial capacity. I think you have discussed in 2 classes before that capacity of tubular member until yield is P y, how you calculate a distant multiplied by sectional area I think we discussed about this many many days back.

So, you have to calculate the axial capacity by. So, yield capacity yield time area and m P is the plastic moment capacity of the chord. So, this also be discussed and c 1 c 2 coefficients are going to obtain from the table in the next space, but you see here reduced the factor of safety of 1.2 instead of 1.6. Basically, there is because this parameter is only taken is not a capacity. So, the factor of safety is parameter is 1.2. So, using this formula everyone of them available except P y and m P, that is what we are going to calculate.

So, very simple. So, this m P this appear here appear here P y is appear here remainder all given m c can be calculated as longest the moments given and then P c is the load applied on the chord which is will be given to you.

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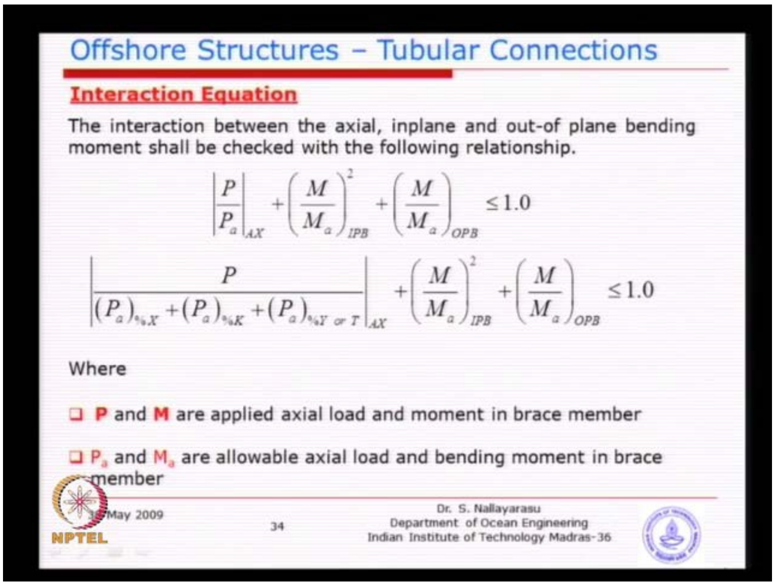

So, now finally we come to, when we desired to find out the loads are applied we have already found the capacity. Capacity in terms of axial we have found, which is P a equal to Q u Q F we have already capacity. Similarly, moment you may have 2 components in plane and out of plane. Basically, you see here moment applied over moment allowable this is moment applied divided by moment allowable this is in out of plane this is in, in plane and. Basically, this is the axial very similar to if you remember I think how do it be the unity check.

P by P a is remember F divided by F a that is what we did listened linear. Then we had F b divided by capital F b which was the ratio of the applied bending is to allowable bending is and then we added the second component the out of plane, but you see here 1 funny thing you have the square term for the in plane bending. That is what we will see why we have in fact there will square here also, but the after long long deliberation.

The non-linear advantage in not being allowed to be taken for out of plane bending because there is no much redundancy on this side because if you look at this, there could be differential distribution of stresses going from longitudinal direction which is basically the in plane moment. Whereas, the out of plane moment square weak. So, basically, the second order term are the square term as not been allowed only for out of plane, but in plane advantages taken in fact if you just go back 10 years this is see the old formula which is these 2 is not there being the square term is not there because earlier empirical studies proved that the capacity is like that.

Now, with the improved test and improved lot of computational using F e m it is. Now, concluded that we could take an advantage of second-order. In fact we will see what is this second-order first order if you can derived relationship than you can compare you will find that this is really true and. Basically, that is why square term only for in plane, but not for out of plane Now, if you just see here of the bottom for the clarity I have this put it for you remember.

I think the previous class we are talking about classification of joints I think we did that we have y and T unbalanced joints r k balanced joint and then we have x joint. Now, if you take a typical joint you may get a combination of done 50 percent k for 1 brace 50 percent T or y for same brace. The next brace should be 100 percent k which is got the we had. Now, how do be the compute the capacity because we have classified a joint which is just few mints precise, but after classification you calculate the capacities of each category.

For example, he take only 1 k joint 1 of the brace is k the other brace is 50 percent k and 50 percent y typically. So, how do we calculated in the capacity of joint. So, you need to come back calculate the axial capacity using k axial capacity using y and multiply the ratios 50 50 means 0.5-0.5 easy 37 and then put dot at the bottom. If it is 100 percent of k, it does not matter full capacity will come. So, we are trying to do is be which are to purred in this, but of course, this lot of arguments is this correct is that behavior going to be just like this.

Maybe not sometimes as early as 15 years back there was several papers on discussion whether it should be this way are it should be the ratio of each of the category, P dived by P allowable capacity with respect to k plus P, P allowable of the y capacity both will lead to different results lots lots of arguments ultimately pa adapted.

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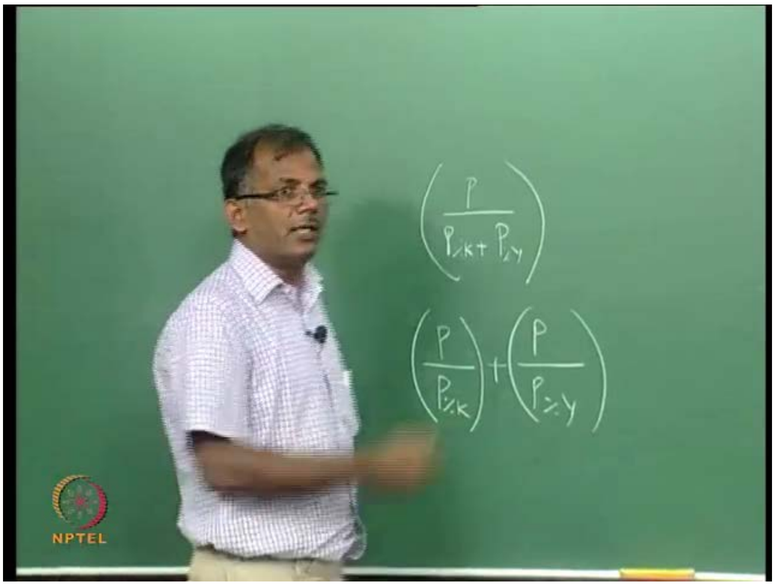

Hope I think we have understood my explanation. Basically, you have P divided by P percentage of percentage of k plus percentage of y. Basically, the capacity of joint just. Now, we have put you could also have actually P divided by P percentage of k plus cumulative addition you will get slightly different result which is ultimately A P I desired to go for the second one, but you see here joint classification has by this time you should the understood joint classification as influence only on axial load, of course, the secondary effects also you will see because when you go to the table for getting the values Q u, you will still select what type of joint what type of load, but directly you can see here. Primarily the load path dependency is only on axial load, but not on moments.

So, that you need to just show to the graph this ideas. So, that we can do the simple problems. So, basic idea is we should know how to calculate P allowable we should know how to calculate the m allowable and classification 3 things. If you know the 3 things you can come back and check the combined if it is less than 1.

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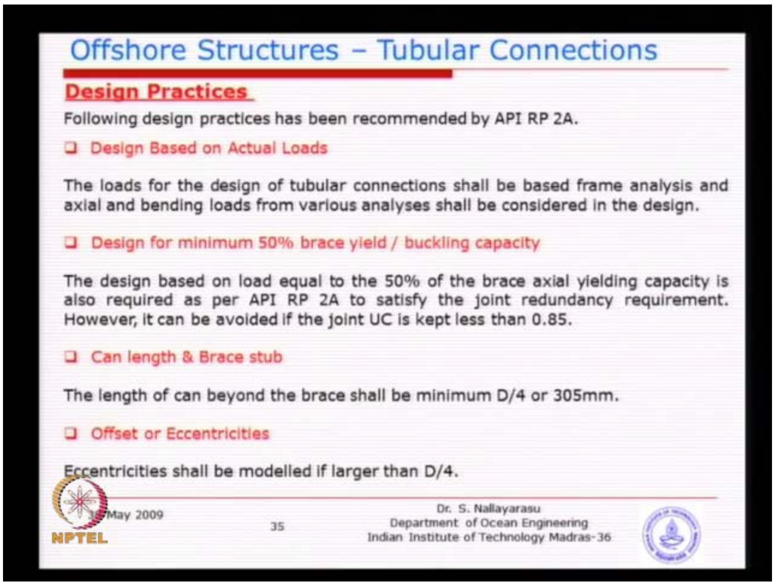

Suppose, do not have moment no issues P divided by P a should be less than one. So, the next 1 after doing this what exactly we are trying to do a design practice implementation design based on. So, loads that means when you make a structure you have a global analysis using computers nowadays becomes manatees because structures become so big carrying out manual design our manual analysis could be taking a longer time.

So, mostly you do a three-dimensional frame analysis most of you might have studied in the next courses. Basically, 3 dimensional frame analysis and whatever loads that you get from the brace member, you design for it which is what normally required in fact on. So, building bridges you normally design for the, but A P I minimum ask for you designed for that in addition you look at the capacity of the brace.

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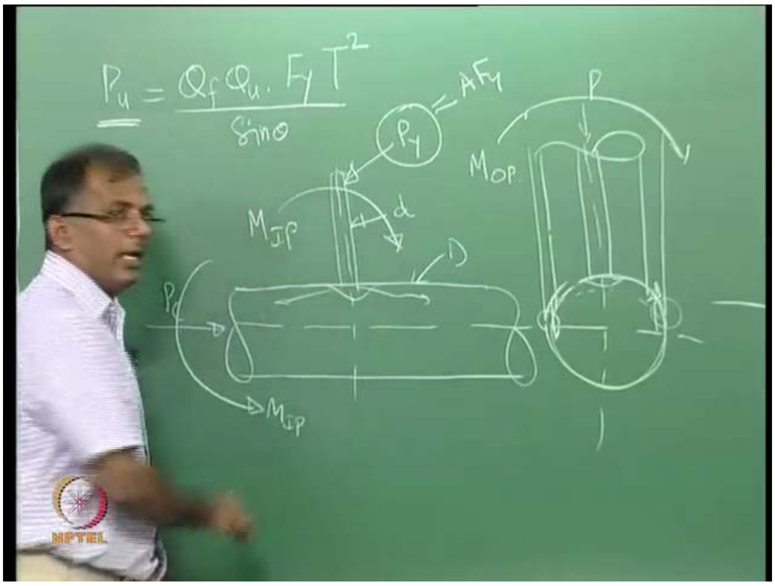

Now, we are looking at that so called P y which is equal to area times F y. Now, you global analysis of structure is carried out, you find out the load is something a P and also calculate that capacity of the brace member k 50 percent and check which is governing. That means if the 50 percent of the axial load capacity is higher, then the joint must be designed for this percent 50 not the axial load, but then there is some problem here why should be designed like this because the brace is only having smaller load.

Why not reducing the brace size, is what the question you will ask because the load is small why should make the brace is bigger. There are several situation for example, material availability. Sometime what happens is the contactors, they try to make a bigger pipe. So, that is what available with them rather than what you have designed for you might have designed for 500 mm the maybe actually put a 600 mm see the I do not have that material. So, that could be 1 potential possibility. The second possibility same brace for example, I think by this time you have clear idea of how the jacket fabricated.

Jacket is fabricated in horizontal condition, but finally, install in a vertical condition. Now, during the horizontal condition the transportation installation the brace maybe subjected to a large bending whereas, in vertical situation in final stage, it may be getting only actual. So, during the earlier temporary stage you may need a bigger diameters, but actually in the final service condition you may require a smaller diameter, but then you cannot go and change it, can you change it is not feasible.

So, you designed for temporary condition which is larger diameter whereas, in the service condition you need a only smaller diameters. Unfortunately we cannot change. So, such a situation arises. So, you will have a situation where the load is smaller, but the capacity higher. Now, why do we do this why this A P I is looking for, this is very simple relative stiffness. We need only to carry 100 times of in the brace, but we have made a bigger brace which can carry 500 tons, typically some example.

Now, you have system responding the larger stiffness, you will see that the load capture especially during large displacement, especially earthquake, during storms the bigger the brace even though earlier time the brace supposed to carry smaller load to try to attack more loads. That might put the joint in danger. So, A P I have deliberative this 1 for long long time. Finally, in fact there was there was condition in earlier A P I you should design for 100 percent especially for large area.

Like if you if you structure is located in seismic prone zone, then you design for 100 percent capacity irrespective of what load it carries which is sometimes very difficult. So, the recent changes. Basically, designed for fifty percent of capacity and design for axial load whichever is giving higher is the governing case. The third one is basically, the length of the you know special material. If you back to our earlier sketches.

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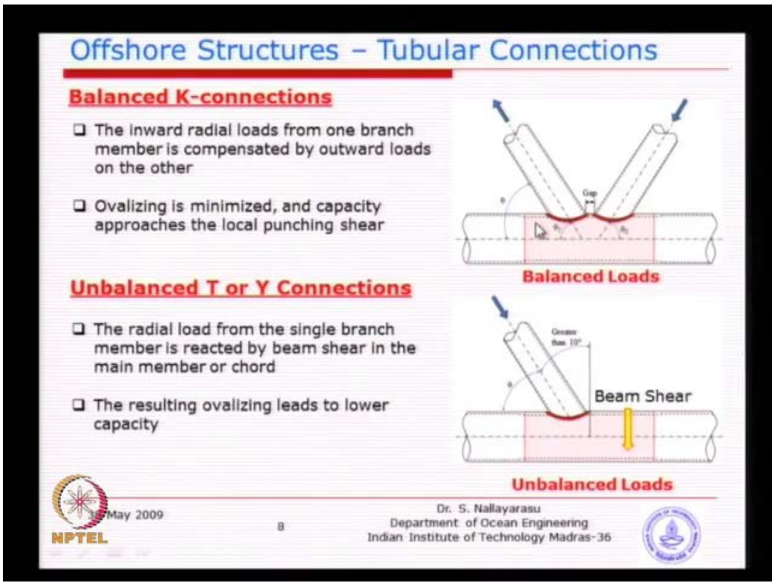

Somewhere I have given you some this kind of what should be the length that you should actually have it in your design whether you want to have longer is better are shorter. The shorter is not very good because you may not actually distribute load properly, but the longer is also not. So, good because thicker material special material more money. So, you need to have certain guidelines how much minimum should be given. So, A P I is giving you e c guidelines as a longest follows that. So, basically the idea is extended by 1 fourth of the diameter of the chord or 305, this is 1 4 whichever is maximum. So,. Basically, if d by 4 is larger then you must be put d by 4 not 305.

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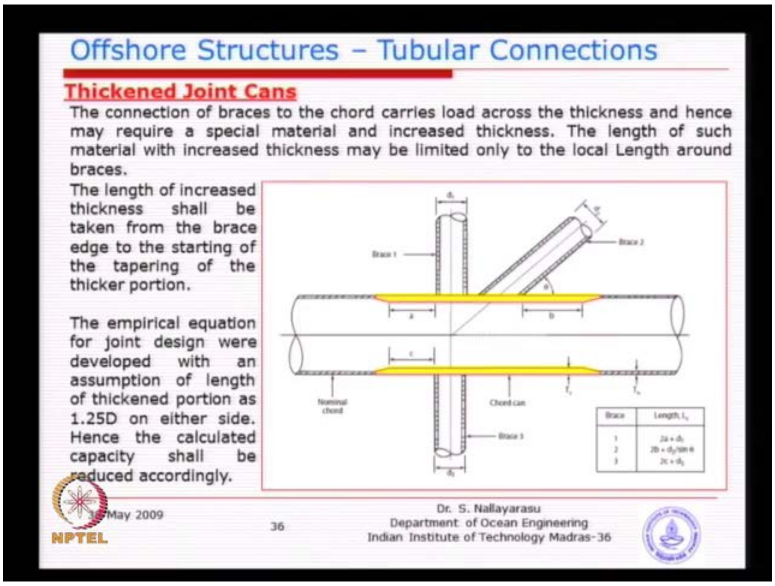

Basically, this will give an idea, but then if you look at this picture that is to be calculated from edge to the full thickness not to the tapped thickness because sometime tapped thickness should be losing another 100 mm 200 mm. So, basically the distance a is the one.

We are talking about should be diameter by 4 or 305 whichever is not smaller larger. The eccentricities shall be modeled the if larger d by 4. Suppose, if you go back to the picture here if the in this particular case the work point is are common whereas, sometimes you have I think previously you have seen if that joint at the 2 location is only to model the eccentricities as longest less than d by 4.

Now, this thickness joint basic idea is how much is better. Just now we saw minimum character of 305 or d by four, but that is only an minimum condition, but in order to use this full capacity whatever the capacity this capacity the all the experiments are carried out by assuming that the distance between the thick and material.

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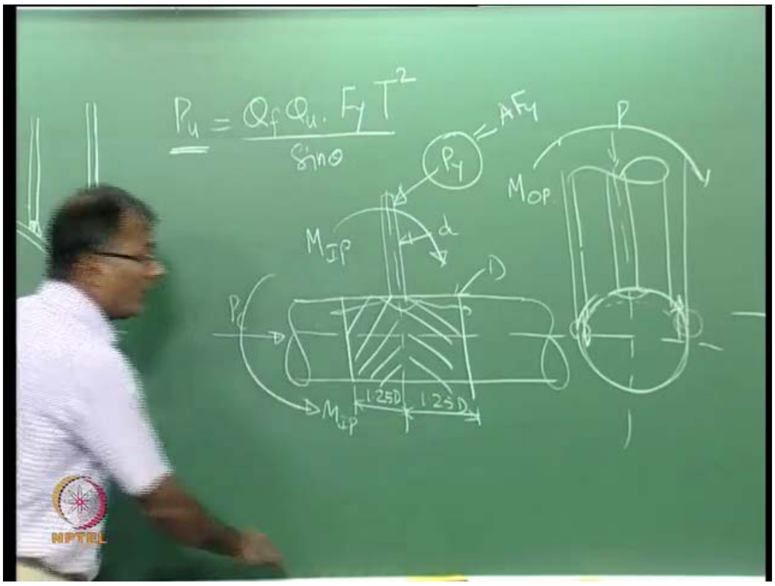

This was taken as 1.25 times diameters. This is what the assumption they have made in the finitely analysis and the previous experiments back. Now, the A P I says because the reduction of cost is essential you only go for 305 or d by 4.

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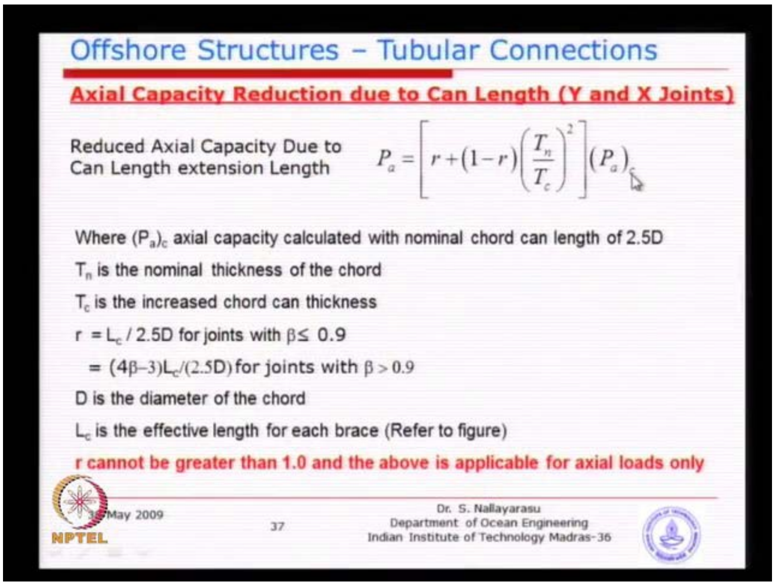

Now, in order to taking into account the need to do a reduction the capacity. Basically, the last previously calculated capacity from those equations called P a calculator, is multiplied by a reduction factor. Basically, must be less than 1 as long as your cans thickness larger store totally 2 and half diameter if you provided than it will become one, but if it less than 2 and half diameters than gradually the capacity will reduced. In a non-linear equation with respect to the nominal thickness to the local thickness. So, what is T c T c is basically the increased thickness witches.

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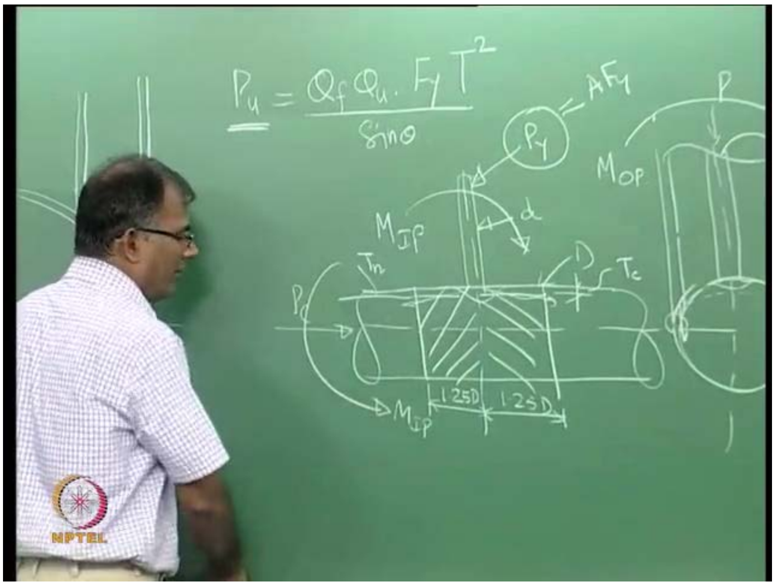

Basically at this location this location we have a T c and l square we have T nominal. So, at the distance away it is. Basically, nominal, nominal thickness and location at which the joint is located is increase. The thickness is called the increase chord thickness. So, you look at this r value this is l c l c is nothing but the total length calculated by this arrangement. Basically, you will add this length plus diameter plus this length.

So, this type of joint you have both side T c time 2 c plus diameter for the bottom the top 1 you see here 2 a, a is here 1 more a can allow can here plus the diameter, but for the inclined brace you just divide for the sin theta to get the elliptical foot print. I think most of you understand the geometric. So, you have a diameter coming in. So, the length of the for the major axis dimensional of the ellipse can find out by just an simple angle theorem.

So, you can see here each brace you need to find out what is the left side what is the right side and added. That will become the l c as longest the l c bigger alleging 2.5 diameter then it is not a problem because the reduction will not be there. Just to show you quickly before we finished I just plotted the those equations you can see here.

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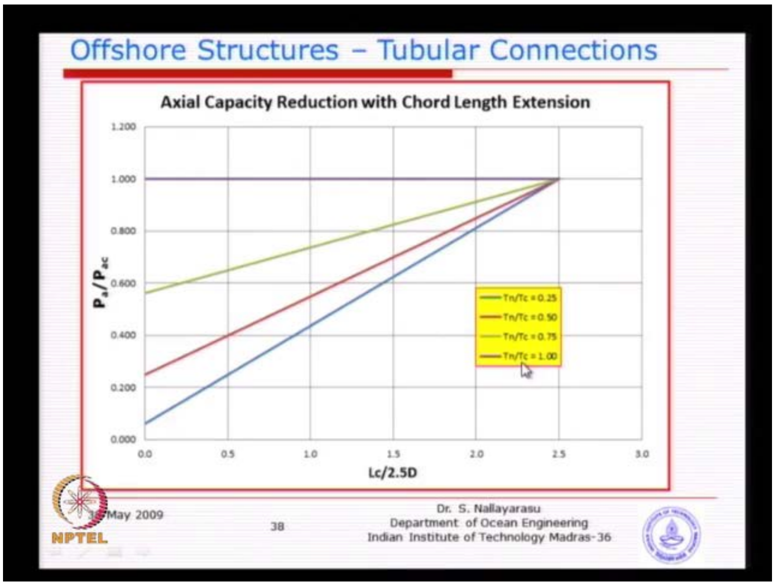

The first 1 the top 1 then the thickness are same that means that nominal thickness and the chord thickness both same that means equal to 1. There is no reduction the load is P a is equal to P a calculator listened as longest the reduction is there. For example, I make thickness is 1 fourth you can see the blue line you can see from 1 it comes down drastically with respect to the, the length of the chord divided by 2 and half. So, as longest you have 2 and half diameter is length automatically every 1 of the reaches 1 listened. So, this parameter very important because the normally provide. So, much length.