Design of Offshore Structures
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Module - 3
Lecture - 5
Steel Tubular Member Design 5

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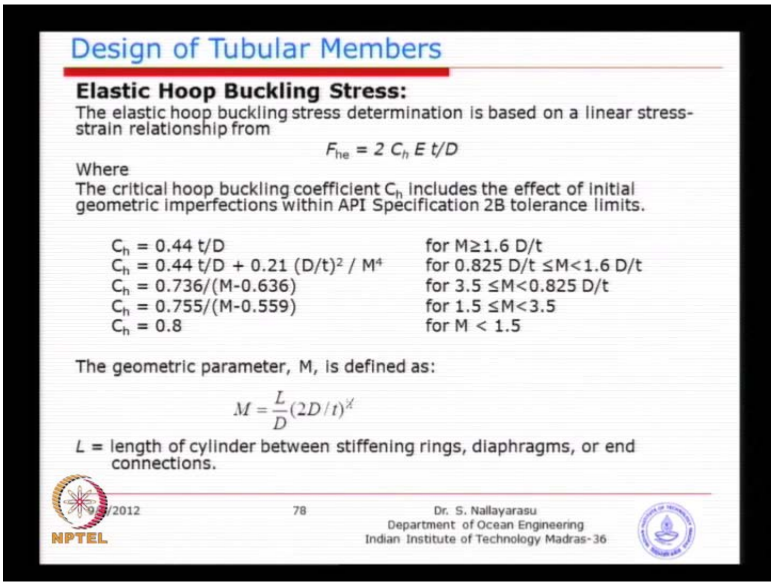

So yesterday we were looking at basically the elastic buckling stress for tubular cylinder subjected to the hydrostatic pressure. The geometric parameter which is defined as basically the ratio of length to diameter multiplied by square root of 2 D by t which gives you an indication that how is the relative size of the member with respect to the length that is going to affect the hydrostatic pressure and associated local buckling. Now this F h e is basically in the elastic stage, which could be potentially larger. As soon as the elastic stage is exceeded then it will form a wavy form, which the allowable stress will come down that is why you see here you know the elastic part especially related to buckling, elastic buckling will be highest stress, elasto plastic will be going down.

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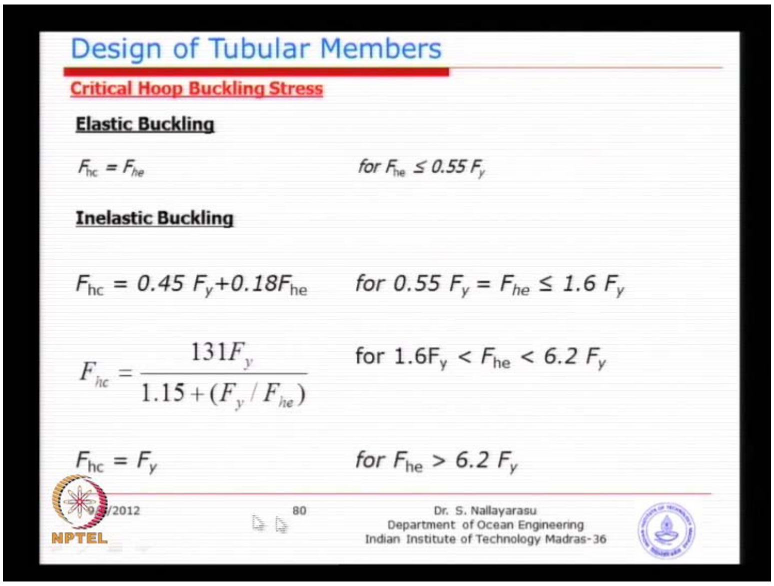

So, basically we need to find out using the elastic stress, you find out the elasto plastic or inelastic buckling which will be lower than the the elastic stress. The reason why we find the elastic is initially any member against buckling, it will be very strong. Once you start a over buckling basically the waveform then it starts giveaway very fast, so that is why you might normally understand most of the time we have elastically, elasto plastic in the linear bending basically or tensioned you normally see there the elasto plastic is higher than the elastic. Whereas, here is exactly opposite, so the elasto plastic stage you will see that the the allowable stress or the capacity will be lower.

So, basically you find out the elastic stage using the buckling coefficient C h which is defined as you know five or six stage equation relating to the geometric parameter, which is defined as M. And this m initially if you do not have a rings is the length of the member between the supports and it starts providing rings then that will become the spacing between the rings. So, is basically a trying to so as soon as you have the reduced M value which as less as one and half or less you could see that the coefficient in the buckling or elastic hook buckling becomes 0.8, and then it starts increasing you could see that the value goes very small.

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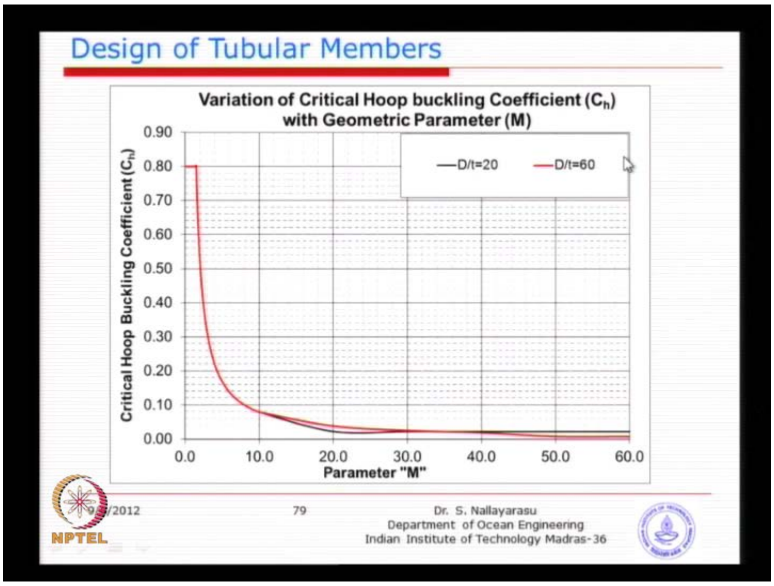

That is what we saw in this particular graph, basically it reduces very very drastically vertically down when the geometric parameter exceeds one and half, as soon as you reach somewhere around five itself, it reaches the value of ten percent you can see here. But after that it becomes very flat. In fact, if you look at this graph what I wanted to demonstrate is basically the difference between the D by t ratio of 20 and D by t ratio of 60. I just put two graphs, you do not see any difference when the M value is lower basically from zero to probably ten, but there is a small value that actually has some effect on the the C h coefficient. But otherwise, I think mostly the C h value independent on D by t predominantly, it is dependent on the length to diameter ratio.

So, once you find out this elastic then you can go back to the elasto plastic which is basically called critical hoop buckling stress, this is the one that we are going to use for as a allowable buckling stress against hydrostatic collapse. So, basically, you you find out the applied hoop stress using the formula p d by two t compare that with this critical hoop buckling stress as long as the critical hoop buckling stress is higher. Remember this is not allowable stress, we have to find allowable stress from here; this is buckling stress we have to divide by a factor of safety, which can be defined.

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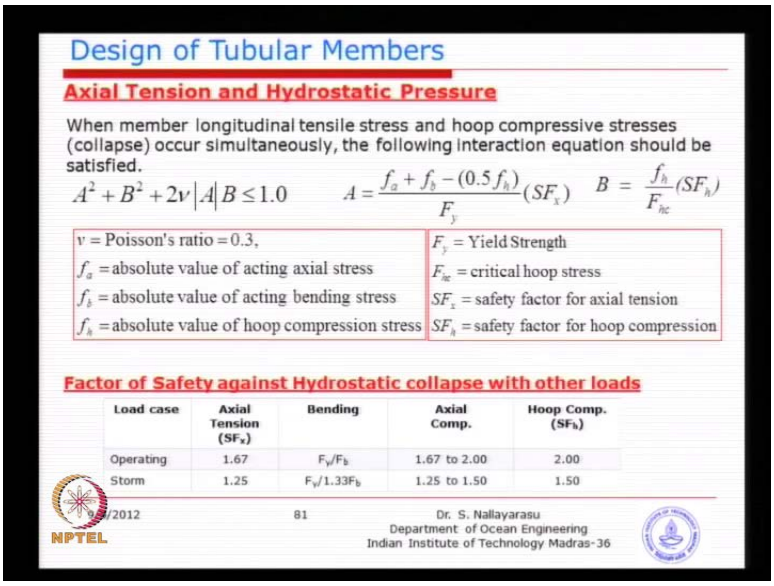

So, just we are going to look that aspect just do not look at the top portion, look at the bottom one. We have got a factor of safety defining, the basically the four combination of stresses that is going to occur. So, if you look at the last one, the last one is the the hoop compression due to external hydrostatic pressure. A factor of safety of 2.0 is required for normal situation, and reduced factor safety of one and half is acceptable when a storm case is storm waves are subjected to. So, basically when you calculate the the critical hoop buckling stress divided by a factor of safety of 2 will give you the allowable hoop buckling stress which you will compare with the applied hoop buckling stress or applied hoop stress of p d by two t.

The table also gives you additional information regarding factor of safety related to the basically the combination of hoop stress with other loads - axial tension, bending and axial compression. So, you can see here a typical factor of safety of 1.67 which will yield 1.6 as the allowable stress. So, basically tension and compression basically is a similar 1.67, but actually the code gives a range if someone wants to have a slightly increase the factor of safety to to have 2.0, but minimum is 1.67. And for bending, the ratio of F y divided by the allowable bending stress, which you have already have calculated can be taken as again you will get into same like 1.67.

For storm, basically you have a slightly reduced factor of safeties very similar to our normal condition like storm versus operating, we have basically 1.67 and increase the allowable stress by 1.33, you can see here, the same thing only we are doing in that particular case. So, basically slightly higher risk is taken for storm waves are normal situation is basically a reduced factor of safety is not allowed.

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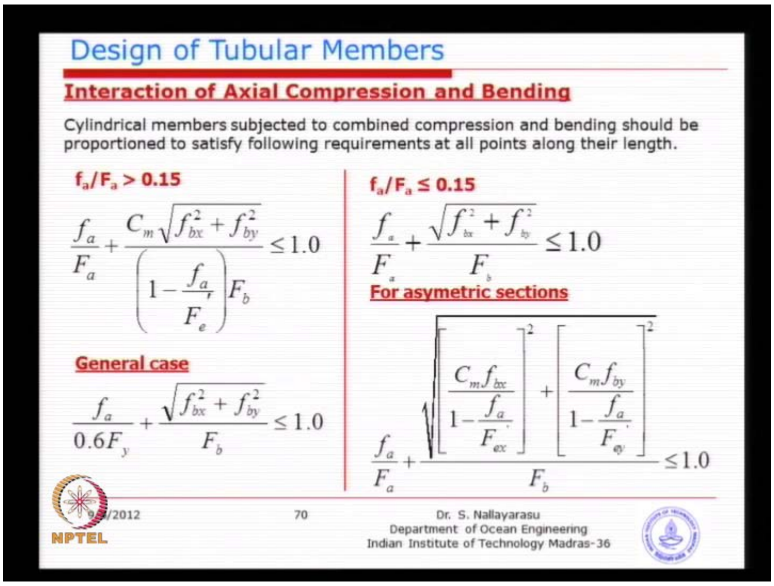

Now, you see here previously when we look at I think yesterday only we were looking at the combinations in this four groups of combinations, we had axial stress combined with bending stress in all situations. Only thing is slightly different scenarios were taken, the the general case and then where you have reduced or smaller axial load, and this one is slightly higher axial load inducing additional magnification of moment, and the last one asymmetric sections where the bending in the x and y size directions are different.

Now this is only combining axial loads and bending loads. Now what we are going to just quickly look at when you have the stresses arising from hoop stress and bending and actual, because the hoop is added. For example, you have a cylindrical structure when you have a tensile force as well you apply the hoop stress coming from the hydrostatic pressure is going to add problem. And if your compressive force and basically you have a external hydrostatic pressure it actually helps us. So, basically you can see the interaction is going to be slightly different and the stress direction is 90 degrees, you know actual and bending in the same direction whereas, the hoop is going to be the in the different direction.

So, basically we need to see how the interaction. It is not going to be a same linear interaction what we had F a by allowable axial stress plus we are not going to do that. Basically you can see here is an non-linear interactions A square plus B square plus two times we have the Poisson's ratio multiplied by AB. So, this is the interaction formula proposed in the API code and we need to calculate the coefficients A and B using there is combine stress formula. So, the A is basically the ratio of f a plus f b minus half the hydrostatic stress which you calculate using p d by two t, basically the hydrostatic pressure multiplied by diameter divided by two times of wall thickness and corresponding allowable stresses factor basically S F x is given here. If it is tension is this, if it is compression is this.

And then the B factor is a pure ratio of f h divided by f h c. This f h c is the one that we just now calculated here, basically the critical buckling stress due to hoop. So, you take that, that is the allowable buckling stress because you have factor of safety applied there. So, basically that is the idea. So, once you know A and B, you can substitute into this equation including the factor of safety is defined for axial, basically the whether it is axial tension or axial compression and basically the hydrostatic is divided by the corresponding the buckling stress; calculate it in the earlier step multiplied by the associated you know the factor of safety. So, you could find this factor is less than one then the combined effect of axial tension or compression plus bending plus hoop stress is safe.

In any case, we need to make sure that this also separately checked basically the direct proposition of applied hoop stress divided by critical buckling stress is producing the factor of safety are minimum two. So, that is the most important that this factor of two must be achieved, independent of before you going to the interaction. Interaction is basically a combined effect, of course yes, but as long as if you can satisfy this probably you will get this also automatically.

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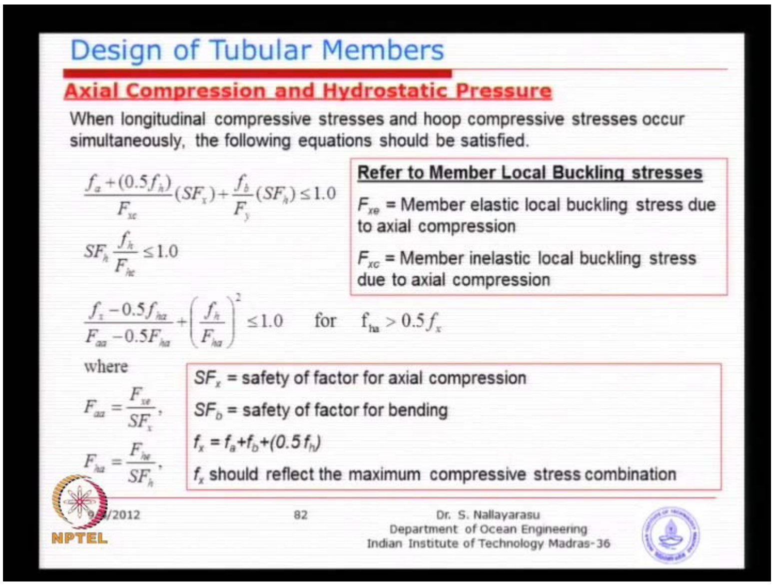

And basically that is tension then axial compression slightly modified formula. So, here you see f a plus half hydrostatic pressure divided by F x c which we just calculate in the earlier stage, you know this is member buckling. So, you should remember the difference between for parameters we discussed also yesterday F x c, F x e which is corresponding to member buckling due to actual load F h c and F h e is the hoop buckling due to hydrostatic pressure. So, this you should not get confused. In fact, some time you get a confusion why this is coming here. Because here the axial compression is going to create problems for basically the axial loads that is why you have the allowable the axial buckling stress, and then you combined with the f b which is a bending stress divided by the yield and must be less than one. This is one formula.

The second formula is the direct checking of hoop, basically hoop stress applied hoop stress divided by allowable hoop stress which is basically the critical buckling stress divided by factor of safety. So, when you divided it goes up, so it is a simple idea. And then the third formula, basically whenever the f h a is greater than 0.5 f x which f h a is defined here. So, just a see counts of checking required to make sure that both compression and tension effects are checked with respect to combining hoop with the axial loads. Most important is the tension will create more problem, compression may actually cancel the effects, because when you are trying to do this that the cylinder tries to expand whereas the hydrostatic pressure is trying to act opposite. Now this F x e and F x c this is what I was mentioning, this is coming from the previous for the member, not just the local hoop buckling stress, so you you should substitute the right terms; otherwise will get into big problem.

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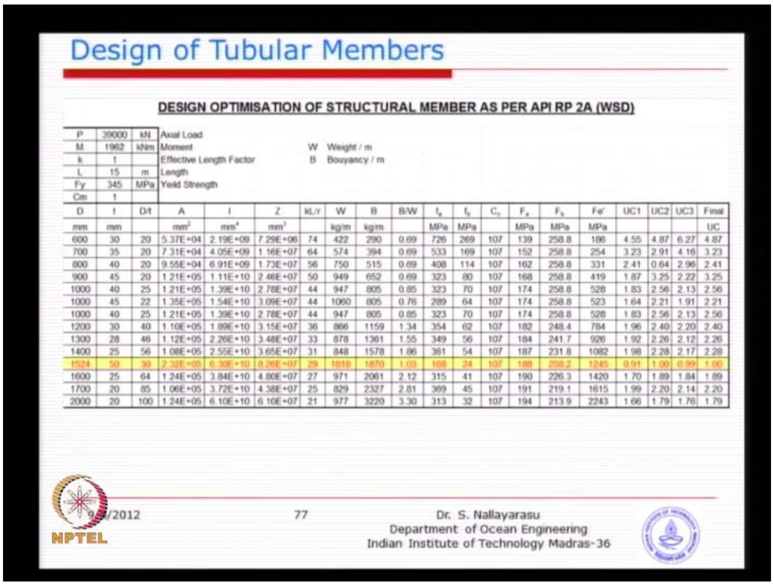

P	39000	kN	Axial Load
M	1962	kNm	Moment
k	1		Effective Length Factor
L	15	m	Length
Fy	345	MPa	Yeild Strength
Cm	1		

D	t	D/t	A	I	Z	kL/r	W	B	B/W	f_a	f_b	C_c	F_a	F_b	Fe'	UC1	UC2	UC3	Final
mm	mm		mm²	mm⁴	mm³		kg/m	kg/m		MPa	MPa		MPa	MPa	MPa				UC
600	30	20	5.37E+04	2.19E+09	7.29E+06	74	422	290	0.69	726	269	107	139	258.8	186	4.55	4.87	6.27	4.87
700	35	20	7.31E+04	4.05E+09	1.16E+07	64	574	394	0.69	533	169	107	152	258.8	254	3.23	2.91	4.16	3.23
800	40	20	9.55E+04	6.91E+09	1.73E+07	56	750	515	0.69	408	114	107	162	258.8	331	2.41	0.64	2.96	2.41
900	45	20	1.21E+05	1.11E+10	2.46E+07	50	949	652	0.69	323	80	107	168	258.8	419	1.87	3.25	2.22	3.25
1000	40	25	1.21E+05	1.39E+10	2.78E+07	44	947	805	0.85	323	70	107	174	258.8	528	1.83	2.56	2.13	2.56
1000	45	22	1.35E+05	1.54E+10	3.09E+07	44	1060	805	0.76	289	64	107	174	258.8	523	1.64	2.21	1.91	2.21
1000	40	25	1.21E+05	1.39E+10	2.78E+07	44	947	805	0.85	323	70	107	174	258.8	528	1.83	2.56	2.13	2.56
1200	30	40	1.10E+05	1.89E+10	3.15E+07	36	866	1159	1.34	354	62	107	182	248.4	784	1.96	2.40	2.20	2.40
1300	28	46	1.12E+05	2.26E+10	3.48E+07	33	878	1361	1.55	349	56	107	184	241.7	926	1.92	2.26	2.12	2.26
1400	25	56	1.08E+05	2.55E+10	3.65E+07	31	848	1578	1.86	361	54	107	187	231.8	1082	1.98	2.28	2.17	2.28
1524	50	30	2.32E+05	6.30E+10	8.26E+07	29	1818	1870	1.03	168	24	107	188	258.2	1245	0.91	1.00	0.99	1.00
1600	25	64	1.24E+05	3.84E+10	4.80E+07	27	971	2061	2.12	315	41	107	190	226.3	1420	1.70	1.89	1.84	1.89
1700	20	85	1.06E+05	3.72E+10	4.38E+07	25	829	2327	2.81	369	45	107	191	219.1	1615	1.99	2.20	2.14	2.20
2000	20	100	1.24E+05	6.10E+10	6.10E+07	21	977	3220	3.30	313	32	107	194	213.9	2243	1.66	1.79	1.76	1.79

Now, before going to the ring, I just want to show you one table which you will realize this is one of the just a simple spreadsheet. Normally when you try to say design means you need to have right parameters selected for the particular aspect of design; that means, this particular case we got multiple answers. The loads are given basically the moment and the applied actual load is given to you. Now you got see here we could work out many different types of answers of combinations of diameter and the wall thickness. And in this case we started with the say typically 600 as the minimum diameter may be you might be given range of diameters to work with you should start like that.

Now when you have 600 starting point, you can see here the last one I have just program the whole equations what will discuss for the last three classes. You know basically from starting from axial stress, allowable axial stress, bending stress and then the hoop, so all of them together, I have just put it in here in each shell. And what is to be noted here, you just look at this column onwards k L by r, you can see here most of the k L by r is less than typically bar 80. And that is what we were talking about primary structure, we try to keep the k L by r less than 80, and then you look you look at the weight starting from 400 kg all the way up to 1800 kg.

So, let us the next one is the buoyancy, and the third one is the ratio of buoyancy to the weight. See ultimately, what we are looking at the any structure which has got heavier than the buoyancy or the weight is more than the buoyancy is not very good, because ultimately you end up, you have to provide additional buoyancy for the structure to be floating during the installation time. So, as long as if you at least make the buoyancy to weight ratios equal to one, then at least the weight itself is self sufficient for the buoyancy, additional buoyancy requirements will be smaller.

So, the primary purpose is to make sure that you come up with reduced weight number one for the same answer you know basically weight means cost and weight means also additional buoyancy. At the same time satisfying other conditions like k L by r and D by t ratio, remember D by t ratio is a concern whenever you design a primary structure, you cannot have a larger D by t ratio, because you do not want the buckling to govern the design. So, looking those thing in your mind, look at the weight and buoyancy and at the same time calculate all these stresses in the line and finally, conclude whether the unity check ratio is less than one.

So, you have a multiple actually you have multiple targets to satisfy that is why sometime we call it this design optimization, cannot be a single parameter optimization. You may have a multiple goals, but then you cannot find single answer, that satisfy all of them. You may have different answers depending on which parameter is a primary and which parameter is a secondary. So, you will just many of the you know commercial software are available for structural optimization as long as you select the right parameters put it in. So, it is a function of for example, if we look at you can write the equation of unity check as a function several parameters, you can get may be ten or fifteen parameters, in the order of priority you try to satisfy one by one.

So, the as long as you said the first parameter which are the first parameter you select for satisfaction you will you answer will be different. So, basically you make a multiple answers then you can write a goal, if you have said three or four answers then you write a goal which I want to select. Then you can so many of the optimization programs work on that basis, but of course, is the simple one is the simplest spreadsheet that you can write yourself to make sure that your goal can be achieved. Basically, I think most of the time if you write your own code you will understand what is exactly going on.

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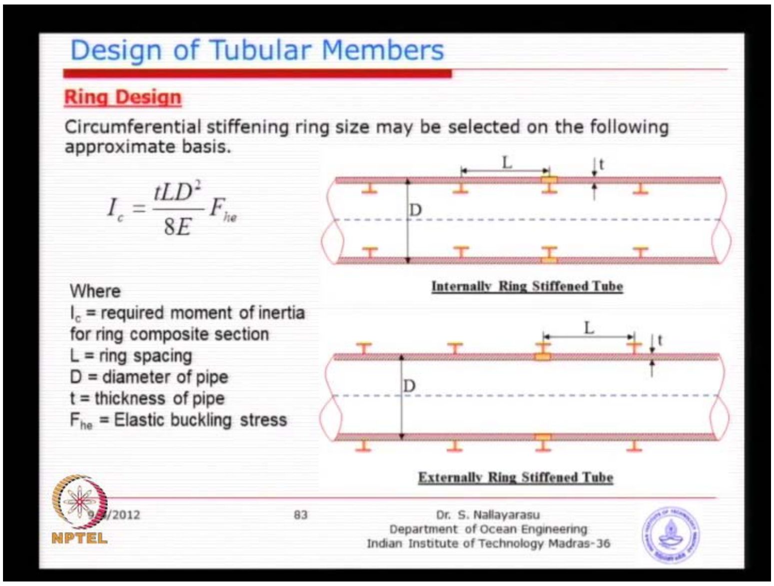

The last one before we finish the discussion on the member design, see whenever you have this hydrostatic pressure is always the problem. So, we try to not to increase a thickness of the member, instead many times this proves to be a alternative design by providing cylindrical or circular rings around the tubular members. In order to prevent the wave form to developed; that means, the local collapsing. You know why the local collapsing happens basically local collapsing happens not just primarily due to hydrostatic pressure, but also due to the fabrication imperfections, you know anyone, one location you may have a small imperfection which can on set of buckling once that forms then you will see that the next session starts to buckle.

So, in order to prevent, you can see here what is being done, you can see we can either provide internal stiffening by means of ring, just a plate or you can have a external stiffening this proves to be a economical solution then simply increasing the thickness by double. For example, 20 mm becomes 40 mm, instead you will realize once you do one calculation for a particular problem, then you will find increasing thickness is not a economical solution, because if you spread the steel that you have spent. For example, you take the steel and just spread between two space, you will find it is maybe smaller steel compared to increasing the steel by q millimeter extra. So, what API suggest, you could provide this stiffening only for the hydrostatic pressure effect, it is does not help in any other load transfer especially axial and bending does not help, because it is only a discrete rings provided to prevent the local collapse.

So, if you are thinking, I am applying axial load more then you should actually increase the wall thickness. So, remember the rings cannot help you in bending, rings cannot tell you in axial stress, shear stress, because they are any direction any location shear can happen. So, this is only to prevent so you should not get in your mind, I will provide rings, I can carry more axial load or bending. This is only for preventing the local collapse of the wall and purely for that purpose, and that is does not help in any other form. So, the moment of inertia of the ring required to satisfy a certain conditions.

Remember when we did the F he, so let me go back to the so-called F he, what was used here. When we calculated F he, we have a geometric parameter called M and the geometric parameter is proportional to the length of the member between the supports is not it. So, based on that the assumption, we have calculated the F h e. Now we are going to calculate the momentum of inertia of the rings required in proposition to what was the previously assumed the length between supports or the distance between the rings.

Basically, it is proportional to, so if you have assumed the ring spacing is 5 meters, you calculated the F h e associated with 5 meter as the centre, the centre of rings. And that stress will be calculated and used here multiplied by the parameters mentioned here is L. In this case, L will become not the member length, it becomes the spacing between the the rings. And D square is divided by 8 E all that you multiplied you get moment of inertia of the section required which is basically the section including as some part of the shell itself. So that is why I have put a little highlight that you would realize the ring together with a part of the shell is behaving as a ring itself.

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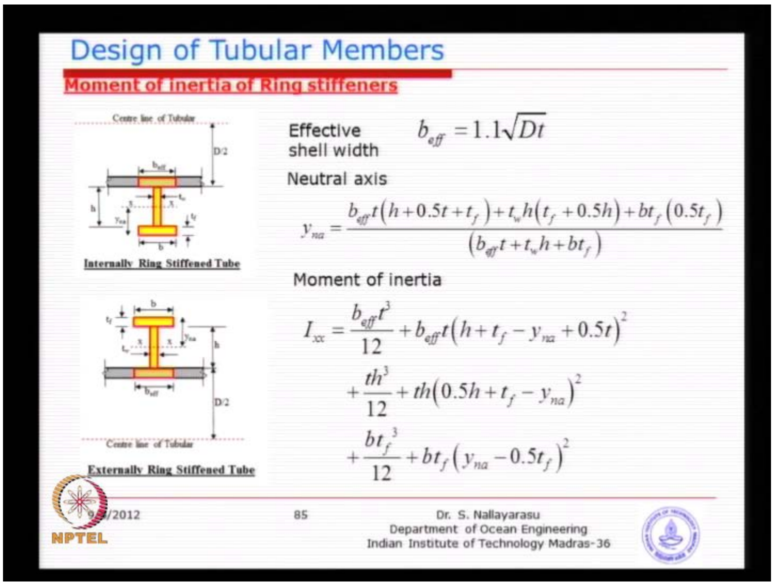

So, the moment of inertia calculation just simply do according to your second movement of area you find out the neutral axis and then find out the movement of inertia about its own axis. So, basically that is why I have put the so-called x x, you see there is simply calculate. As long as the provided momentum of inertia is greater than the moment of inertia required by this calculation, then your assumption of three thinks is valid. You assumed a ring spacing of L while doing the member chuck you know F h e, F h e was assuming a spacing of L and using that L you have come up with moment of inertia and that moment of inertia a satisfied by providing sufficient wall thickness of the web and the flange here. Using this formula you calculate the actual moment of inertia provided and what is the moment of inertia required in this particular case.

So, basically it goes back to the member check. As long as you assume five meter, you have to provide five meters as a spacing, but you should not stop there. You should provide the spacing five meter with a sufficient moment of inertia required, so that the rings will not fail. In some cases what happened, you know if you provided a ring which are cylinder you only have a one thing satisfied, spacing is satisfied, but this strength is not satisfied. So, instead of the ring satisfying or ring supporting the tubular, the tubular will support, because the rings are very very long or wobbly. So, it should be hanging around, does not help the tubular itself. And that is why you need to proportion the rings stiffness and their moment of inertia according to what is required by basically the allowable stress that you have calculated previously.

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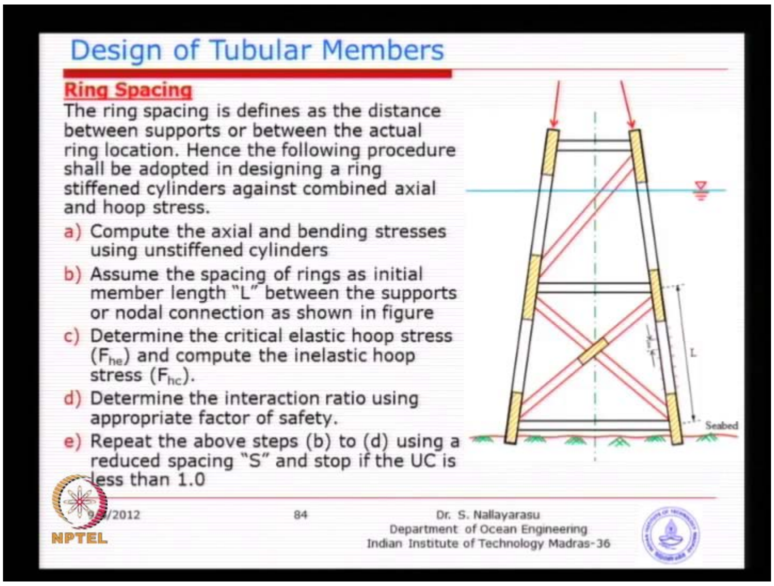

The next thing is just a simple procedure basically I have just listed down, the ring spacing. What is you know perfect design, is again very difficult to determine. You will come up with numerous number of combination, for example, L was fixed say five meter, if somebody will fixed L is four meter you will get a different answer. So, you can see that the for the same problem, you will have many different answers maybe three answers, four answers, five answers. Now we need to fix a goal, what is our primary goal, primary goal is to reduce the weight - number one.

Number two you must make sure that it is workable, I cannot have a ring spacing of a every 50 millimeter, you would not be able to physically fit in. So, you will need to see whether it is possible to fabricate. So, half a meter one meter depending on what is the configuration you are using, so these are the constraint you additionally put that. The third thing, you have cell wall thickness of 20 mm, you cannot have a thickness of your stiffener 50 mm; you possibly cannot do a welding, because 20 mm width or 50 mm, you will not be able to do the welding. So, you can see one by one you collect all the constraints you put it there, the number of answers will come down to probably one or two maximum, and that is where you are going to be tested. Basically you need to find the right answer, given the constraints.

So, if I give you a few constraints, you need to look at which one to be supposed to be used as a first priority, and then look for a right answer, and that is what the question that you are going to get tomorrow. It is not that simply you have all the equations and then I can simply take the calculator and substitute and answer is there, that secretary also can do, you need not engineers do to. So, basic idea is the design means trying to find out the right answer for the given constraints. If the constraints are not given, everyone will come with different answer and ultimately I may not be able to correct it. So, you will be given constraints in the real design also, many times you will get the actual constants should be given, so that you can work out.

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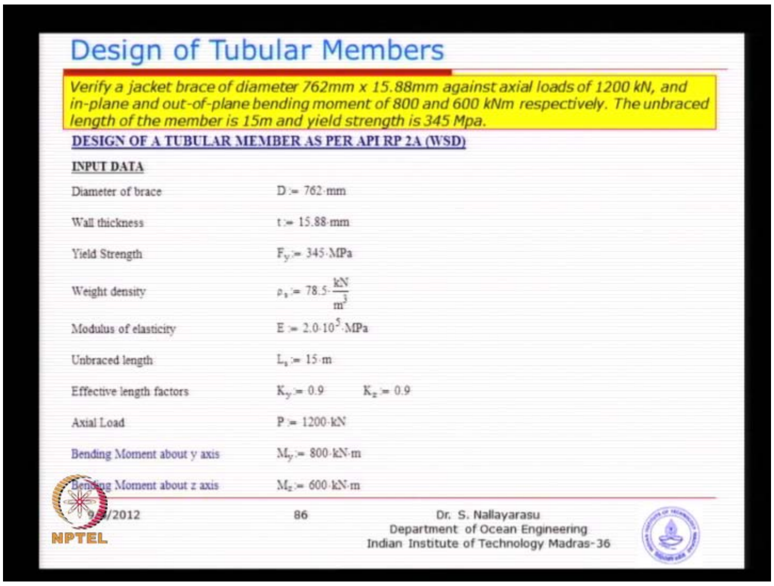

I have given you two problems here, basically one is the design of a simple circular cylinder; I think most of you might have seen, if you have enough time to read. It is just collection of what we discussed over the last three four classes; basically, all the information is given in the. In fact, this is a very simple problem. Verify a jacket brace of diameter 762 by some wall thickness load is given moments are given and unbraced length is given and yield strength is given. So, it is a very simple forward problem. You do not need to do anything actually. You take the equations and just fill in the values and use your calculator, you will get the answer, is not it. Because there is nothing else to be done, but only one thing you need to make sure understand jacket brace.

So, the word you need to note down, because you need to assume a reasonable key factor. So, you should not ask where is my K factor. So, basically the K factor table will be given if required. So, you need to understand the reading the words is very important, because is just have your answer there only. So, you will you read jacket braces K factor is 0.9 or 0.8 depending on whichever the situation and select that K factor that is what I have taken.

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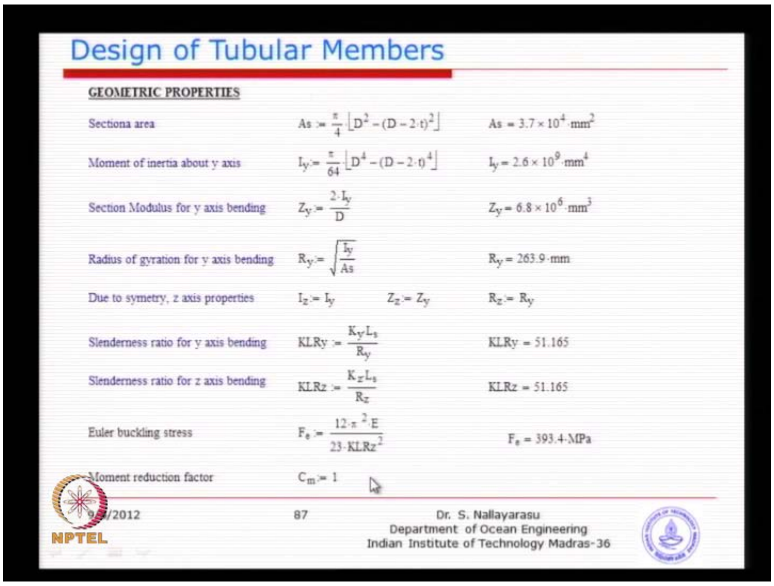

And then proceeds with a simple procedure of trying to find out. So this page you see so many formulas, you will not be given this formula for the exam purpose. So, you trying to find out the sectional properties of tubular, I am sure for every engineer you need to have keep it in your mind is not it. So, you do not ask how to calculate the moment of energy of tubular section.

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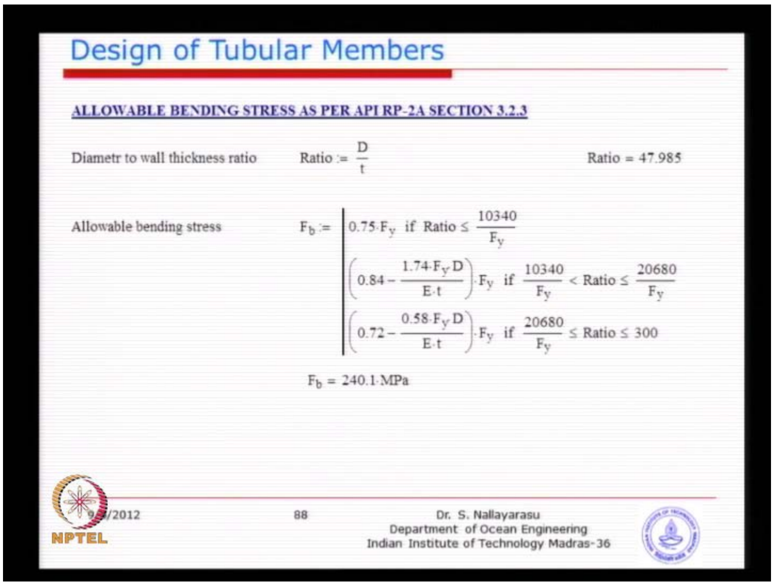

In here this formulas is little complicated, there is no reason why you should memorize. So, the allowable bending stress, allowable axial stress the formulas will be given in the backside of the question paper. So, you do not really need to worry about it. So, basically you see here allowable bending stress is directly dependent on the D by t ratio. So, you calculate the allowable stress.

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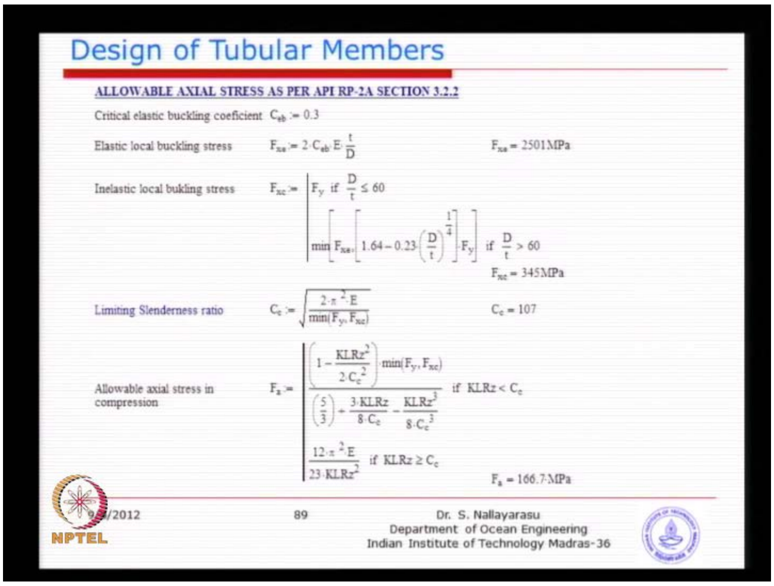

And then we have the allowable axial stress, prior to allowable axial stress, you need to calculate the whether to verify whether the member is local buckling is having effect or not. So, what I have done is I have just taken the procedure from API, assume the local buckling coefficient, find out the elastic buckling stress and find out in elastic local buckling stress, and compare this with the yield stress. If it is less than the yield stress then that will be taken. In this particular case, I think local buckling is not at all governing because the D by t ratio is quite good. And basically find out the limiting cylinderness a ratio which was again you would see here at the bottom in the formula, it may not be there. But in here I have selected to put the comparison between the buckling stress and the yield stress, so that I can take if the buckling stress is smaller then automatically you will be taken and then you calculate the allowable stress after this which comes to be 166.

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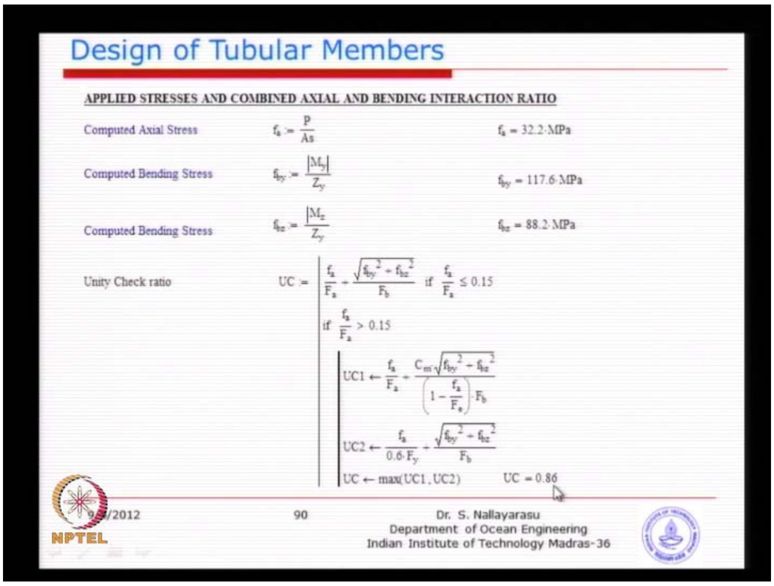

And then, you go for applied stresses, I think you have the applied axial stress load divided by area, and then computed bending stress for x and y directions or y and z directions. Sometimes you may have x and y depending on axis system. And then you find out the the three are unity check formulas, the fourth one not required because a is a symmetric sections, we do not have the the fourth one. And simply find out what is the so automatically here we have a computed code desires, but when you are doing calculations one by one you have just do it and then take the highest ratio that will be the governing case do not take the smallest one and then provide. So, this type of problem is very easy to do, because there is nothing else to think. What you need is take the formula and feed the values and you will get the answer, you understand idea know. So, if I give you I think at the end of this slides I have given five problems; if you have time, you should have practice.

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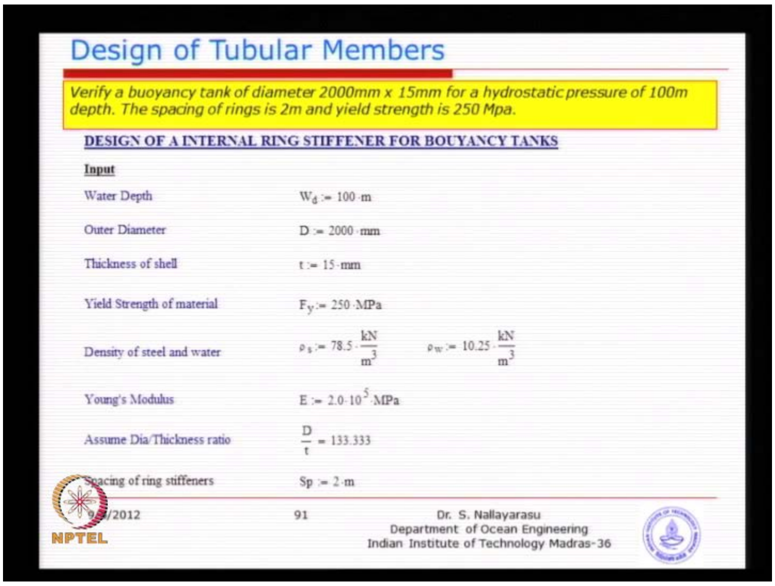

So, basically that the next problem is that is design of a internal ring stiffener for a buoyancy tank. You know buoyancy tank, I think we have seen some pictures, I think in the early days of introduction. Basically buoyancy tanks are large diameter tanks attach to the jacket, so that the jacket will float. In case if the jacket does not have enough buoyancy, you know basically we fit it in and then we can remove them at a later stage when it is not a required because after the filling is done. That means, the primary purpose you must understand is not lower transfer the primary purpose is to hold this basically the the air inside without any break or buckling. There is no actual load no bending load going to come here, because is just sacrificial tank fitted on to the structure is not going to carry any load.

That means, here we are not going to have any interaction between axial load, bending load or here only purely hydrostatic pressure; that means, the problem because very simple. So, in this particular case, you are given a diameter of 2000 millimeters - 2 meters quite big, 15 millimeter wall thickness, hydrostatic pressure of 100 meter water depth, so you can see is quite deep. And then the spacing of rings is suppose to be 2 meter. You should not go less than 2 meter, and you can see from this number 15 millimeter is given, you cannot have stiffener thickness greater than 15. I think if you have studied or probably I will explain one of the days when you are trying to weld thicker plate to thinner plate, the thinner plate will burn away during the heating process. So, you cannot have the second plate which is going to be welded bigger than the parent plate typically practically not possible to weld. So you could see that you should have the stiffener less than 15 mm, and then the yield strength this already given. You cannot select the headed strength of 340, 350, because you have no choice. So, see three or four constraints are given.

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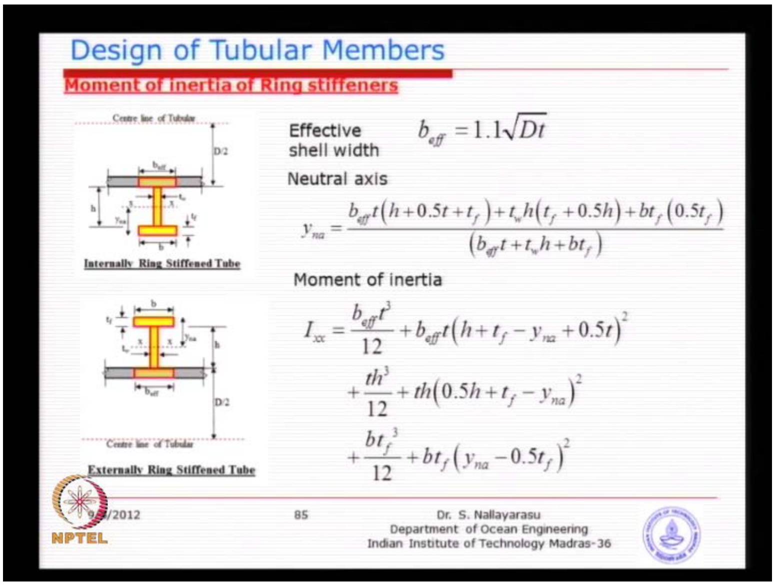

Now, you have only two choices you either can have ring only something like this without the flange, you see here this is the flange, this is web this is the shell which is behaving as a part of the flange, another flange. So, you have two choices either, you can have this web only or if not sufficient you can provide additional flange. Now this web you are very much constraint by the thickness; if you have 15 mm parent thickness, the web also can be maximum 15 millimeter. The outstand, how much we can go, if it is too bigger or so, no use. So, we need to look at the cylinderness of that basically that will be the guidance we need to look at. So, if we look at the D by t ratio of that five peace one thirty three quite large. You know normally for structural members, we have about 60, less than 60, so this is definitely larger than 60. So, it goes in to cylinder range, surely we need to provide rings, and you have the spacing given to us 2 meter.

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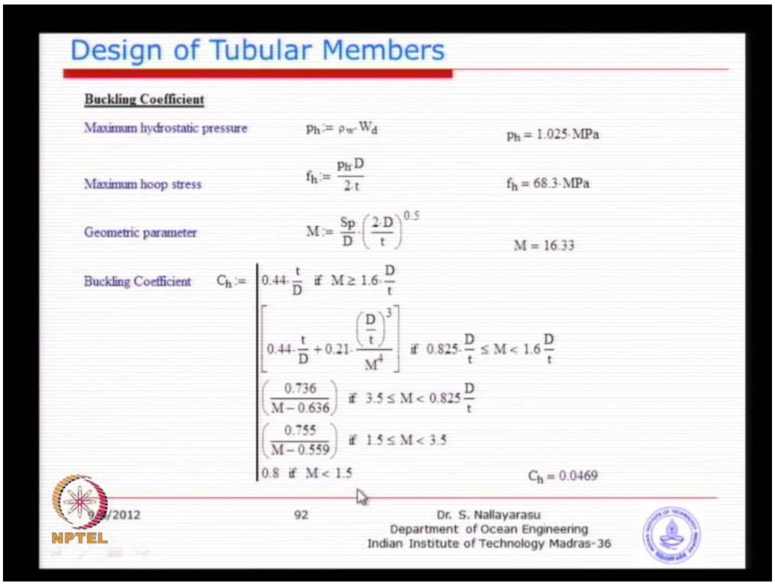

So, simply calculate your hydrostatic pressure and applied hoop stress basically P D by 2 t, which is 68 megapascal, and then find out the geometric parameter which I think we discussed earlier in this morning, and find out the coefficient of buckling basically using this five stage formula. As long as you know, where is the M value you do not need to check every one of them by looking at that formula, you can see where I am going to fall in; you do not need to do everyone of them and then finally decide is not it. As long as you know the value of M, you can straight a way where the value of M is going to be so may be here or may be here then use that formula to calculate the when you are doing here formula solving in the exam, do not have to go through every one of them. There will not be enough time.

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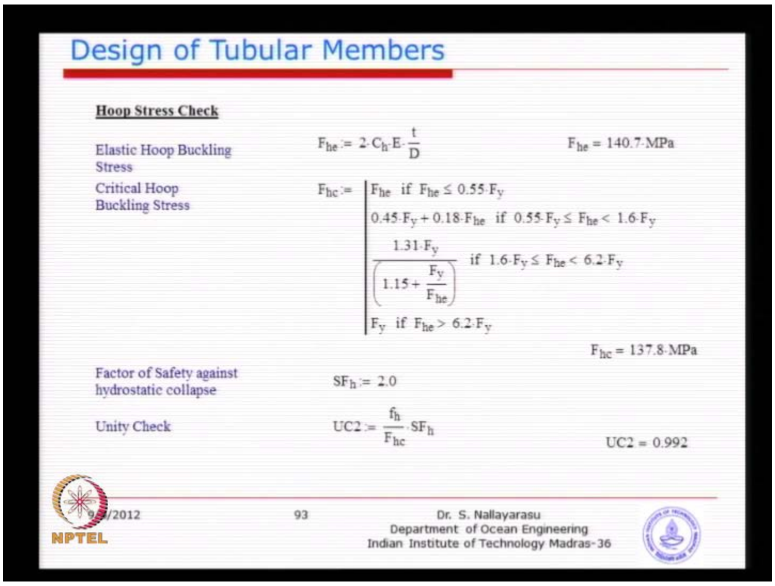

And then you find out all your the elastic hoop buckling, and the inelastic or critical hoop buckling. And then use the factor safety of 2, because there is no other lower only pure hydrostatic and simply find out the unity check which is 0.99, is not it. Now what we have done is we have assumed that rings are provided at 2 meter, and we have design to the tubular section which will be very safe. But what we now need to see is whether the 2 meter what stiffener is required, if you stop here is only half answer is, there the reminder has not been done.

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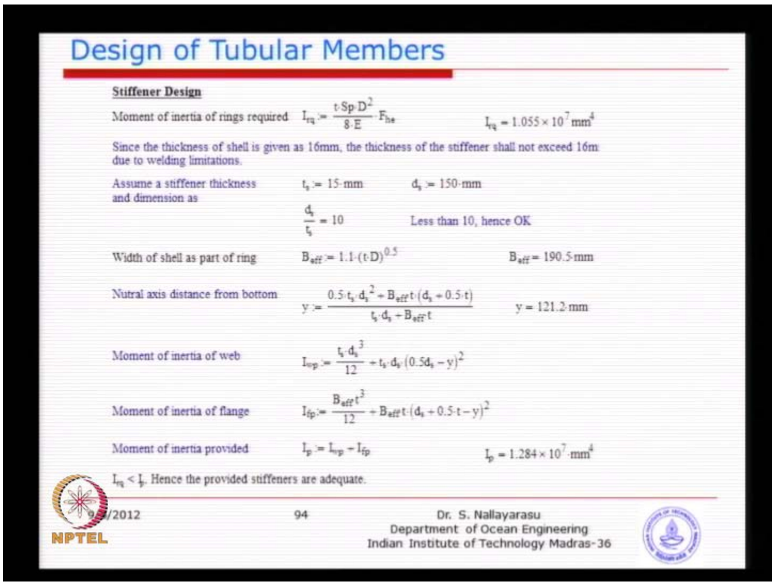

So, for that 2 meter, you have to go and look at the stiffener design, because we have assumed that every 2 meter, the cylinder is stiffened by rings which are capable of taking the buckling loads. So, that is what we are now just going to do find out what is the moment of energy required and then start assuming and this is where if you are assume 10 mm. For example typically, I have taken 15 mm and I have just come up with 150 mm out standard which typically any un stiffened element move the plate thickness to width ratios will be somewhere around 10. We will talk about this when we are talking about another code called a American institute of steel constructions AIC code.

So, typically if you have a 100 mm, 10 mm minimum thickness; if it is 150 mm, you should have a minimum also 10 mm. So, in this particular case, I have just taken 15 mm and basically out stand or so called the web height as 150 mm and I calculated the moment of inertia using the neutral axis and stuff. So, I find that the moment of inertia provided is 1.287 whereas, the moment of inertia required is above 1.05. So, provided is higher, so I am satisfying the requirement. So, basically the stiffener design is nothing but providing sufficient inertia to take the bending loads coming from the hoop.