Design of Offshore Structures
Prof. Dr. S. Nallayarasu
Department of Ocean Engineering
Indian Institute of Technology, Madras

Lecture - 06
Tubuler Joint Design for Static and Cyclic Loads VI

So, yesterday we were trying to understand the concept of fatigue tabular joins. I think in the previous few classes we have already understood, how the joint is designed for static loads. There are several methods I think deliberated for the design of tubular joints. For cyclic loads one of the simplest and a methodology, which has become obsolete now, but of course still recommended for preliminary studies is a simplified fatigue evaluation, without looking into the cyclic the loads are repeated. So, basically it is very similar to the punching shear check or the capacity check, which we are making for joint design for static loads. Only thing is we are just looking at slightly modified method. That means here the number of cyclic will not come into picture.

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So, in this method you will do a design sea state, instead of taking this the various sea conditions exist for the design like. For example, if you take twenty-five years you will different sea state going to exist for different period time. Number of cycles for each of this will be different. Instead of going and looking at those data a p t. Initially, nineteen sixties early-stage have recommended pick up a sea state, which will be representative of

the overall behavior of the a sea state conditions are the particular site. Analyze this structure very similar to the in service analyses, like storm condition. Calculate the applied actual stress pending stress and the in plane out of plane conditions.

Calculate the stress concentration factor, which will be dealing with it, in more detail later on stress concentration factor is the ratio of the local stress to the nominal stress. Then find out the combined effect of actual plus bending including the concentration factors. Basically, this is the is S R S S value of your in plane out of plane. Because, this is the surplus same. Before you do the S R S S you multiply the corresponding stress concentration factor.

That means in planes multiplied by in plane stress concentration factor square. Basically, the same thing to the out of plane. Then you take the value of actual stress. Just like a nominal normal combination, what we use to make actual stress, plus the bending in plane and bending out of plane. Because, all these stresses are acting in the same direction.

So, basically combined them find out the combined peak or the combined highest hot spot stresses. Once you have this, this is the applied stress due to a representative sea state, which represents the fatigue ways. During the lifetime it could be twenty years thirty year fifty years. Then compare this with a allowable hot spot stresses. Very similar to what we are doing for a static design, what we did there is a applied actual load applied bending moment. Then we had a allowable actual load and allowable bending moment. As long as the allowable is higher, we decided the that the joint is safe against static load. So, the whole procedure here is the catch is the first one, which is a design representative sea state.

The last one, how do we get the allowable hot spot stresses? Otherwise a procedure is as usual as computing the stresses in the member. Instead of that we are doing the stresses is the member multiplied by the local increase due to the stress concentration, then you combined them. So, procedure is exactly same, we need to find out what is the design sea state and what is the allowable. So, A P I have initially recommended, you take hundred-year storm condition, which will be the maximum wave height for that particular site, take as a representative value. Basically, use that to study their member stresses and local hot spot stresses.

So, when we are doing the in-service condition you do exactly the same. Except that we will not multiply the stresses by stress concentration factor, will be taking only the nominal stress to check the members. Whereas, we are going to take the local hot spot stress to check the joints. Then the allowable peak hot spot stresses is just a comparison. That means this needs to be provided by somehow either by empirical formulas or by some recommendations. A P I has given a initial charts like this we could see here, we horizontal axis is the water death and the vertical axis is the allowable hot spot stresses, incase I think.

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Figure C5.1-1—Allowable Peak Hot Spot Stress, S_p (AWS Level I)
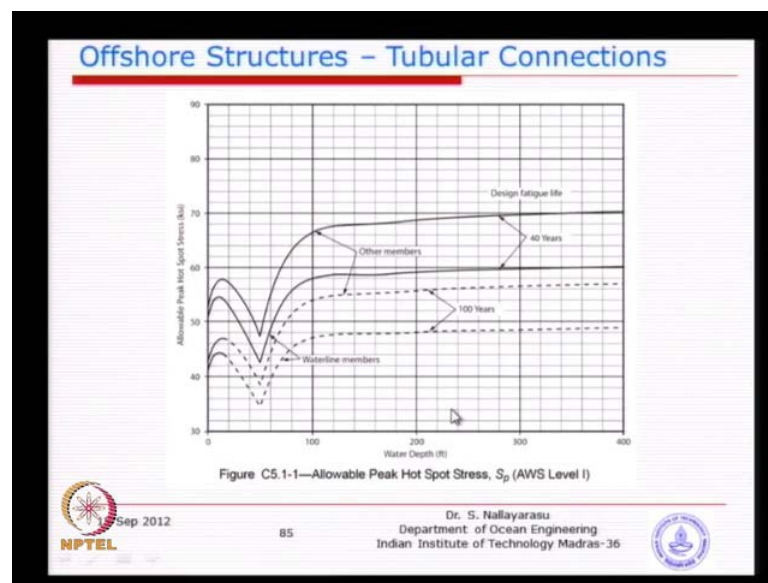
So, basically you see most of them are larger than thirty forty K S I. That means it is nearly higher than the field, high strength steel is fifty case. I think most of you remember. So, you could see here for hundred years and slightly reduced design life A P I. As recommended this is again based on Gulf of Mexico studies, all these recommendations given in A P I. Remember, all of them are only, I would say 100 percent applicable to Gulf of Mexico. You could apply if you look, if you read the A P I or prefers, they will say you should apply your local conditions, before applying A P I requirements to anywhere else. Because, the codes are developed only for their reason of the interest.

Whereas, when you apply to Indian water are elsewhere, you need to make sure that the parameters that you are looking at or similar or at least aware of the things, that they

have done. So, this particular chart is basically applicable to Gulf of Mexico area. So, the water depth is given in terms of so many feet. So, as long as you see here you are within this 400 meters water depth, 400 feet water depth, you could apply this idea, but you put is larger. Then you cannot apply this particular graph. Basically, for hundred-year the doted line, nothing as all of to you can see if it is.

For example, 100 meters water depth your allowable peak hot spot stresses is around 48 case, which is very close to yield 50 K S I material, basically for reduced life time period. So, you can see here the design static life is forty years. Then the allowable high stresses going slightly higher. So, these two graph there are level 1 and level 2, what is level 1, level 2? Basically, the risk level like we were trying to learn earlier time the L R F D the different risk level you take. Earlier, A W S as recommended instead of giving the probability of non-failure or probability of failure.

They have just defined as level 1, level 2 and you could apply, because of the uncertainties involved in this method. Basically, sign to use the hundred-year storm condition representative of the fatigue. This hot spot stress allowable is not representative of the actual joint, but it is coming from some empirical formula. Because, none of the designed parameters are involved here. You can see here is basically the water death and your allowable stresses, straightaway coming from this type of graph. It is not recommended to use this method for detailed design.

You know basically means for implementation purpose, but this can be used for screening purpose. For example, when you start to look at a jacket or a structure. That is in the very initial stage, you do not have enough time. May be you could use this as a just starting point, but then in the previous revision of A P I, this was actually there, but in the region A P I. They have removed from the mandatory section, but put as a guidance section in the later part.

So, that means you can still use it at your own risk, but not recommended as a even for preliminary studies. So, you go to be little bit careful, now it is know. It is becoming as just the guidance notes at the tail end of the code. So, you have to little bit careful, because this method is little bit crude, I would say. So, in association with this they also have recommended stress concentration formula, which is very simple.

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You will see this is one page covering almost all joints. Basically, all possible load types. So, you have T K Y and x joints as well as actual load in plane and out of plane, bending all cases are given there. This also is very much coming from very early worth like, nineteen seventies preliminary worth under stress concentration. Thus, why the formulas looks so very simple and can be use very quickly. Whereas, when we are going to do a real design.

This is another formula we are going to use it. Because, the recommendations later like nineteen nineties and the recent studies have done lot of work and the empirical formulas for S C F is slightly different. Now, you look at here for example, axial load lambda times is defined as a parameter relating your gamma and tau. I think gamma is what is what is the ratio gamma, gamma is d by 20 tau, is a ratio of the stiffness of the brace to stiffness of chord. Basically, lambda is defined as the value given here. So, as long as you have the values of gamma and tau, you can calculate the stress concentration in the actual direction and is lambda time alpha.

Then for bending in plane and out of plane you have got 2 by 3 and 3 by 2 multiplied by a, as long as you can calculate the. So, this is for the chord, that means on the peripheral points on the bigger member. For the brace side you can see here similar formula except, that the braces S C F is dependent on chord S C F you can see here. So, unless you calculate the chord S C F, you cannot come and calculate the brace S C F. Brace S C F is

basically one plus something coming from the second term. Must be greater than 1.8, that is the the idea behind earlier studies on S C F.

So, this is called a simplified or basically the early studies of stress concentration. We will see later this equations have been modified substantially. So, you will see that this processor is quite simple, you do not really need to look at number of cycles. You do not need to look at the stress history over a period of time. What you are looking at as a design sea state. Calculate the stresses calculate the simple stress concentration factors using this simplified formulas. Obtain the peak hot spot stresses and then compare that, with the allowable hot spot stresses, as proposed in the A P I for level 1 level 2, for different water depth 40 and 100.

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Then for the detailed design method there are two methods. Distinctively, we can identify, which is what is going to be used in the real practice. Of course, the left side one we have discussed enough on the cumulate on the fracture mechanics method, which I think we have derived the formula, which is relating number of cycles to the initial crack growth for A I to A F. So, this two has been related and we got a relationship, which is defining cycles stress range with some constant. So, n times s to the power m is equal to some constant. That means you have a various combination of cycles and stresses for a same answer. So, that why you get a graph something like this.

So, we are going to see this fracture mechanics was as a static point, where the relationship between the number of cycles and the stresses where related, but unfortunately, because of the complexity this method of fracture mechanics was unable to proceed, for the detail design or the initial design. Basically, because of the informations not available. So, using the same method we try to do a alternates scheme, where in we will use the relationship between, this stresses and the number of cycles to failure, but we will not actually go and investigate the crack growth, but you look this safety of the joint, in a slightly different manner. So, what exactly is the idea is based on?

So, called the stress a number of cycles to failure relationship for each of the material each of the type of joint, that somebody has generated. So, what has been done again, we have gone back to from theoretical background. We are unable to proceed, we go back to experimental studies fabricate a joint go to the testing machine. Make it to fail note down the number of cycles at which it is failing. Find out what was the applied stress range. So, repeat these for several times, until you get a reasonable data that represent various ranges of cycles, various ranges of. That means you will fabricate shape may be 10 or 20 models.

If you have time, if you have money, but the problem is such statistic long time cyclic test, does not mean that you can finish the testing in half day. Because, you need to apply the number of cycles as per the reality. So, that means if you take a longer time. So, doings too many test is not a feasible idea. So, what people have done in the earlier time, they do few test celebrate with the numerical models. Then use those data to extra polite. So, it's not that every time they do 20 and several tests, because is involving time and money. So, this S N curve is a methodology to establish that relationship between the number of cycles to failure, for a particular given stress range.

So, if you establish this then, basically next time you can go and find out for a given stress range, what will be the number of cycles that we can allowed, because that is the idea behind. So, this S N is a relationship derived experimentally, incorporating few things, one is the geometric material and some geometric effect. For example, when you fabricate a welded. I will show you some photographs, I just picked up from yesterday lets behind something like this. I think the other day hope you are able to see, you could see here the surface of the welded is not that smooth.

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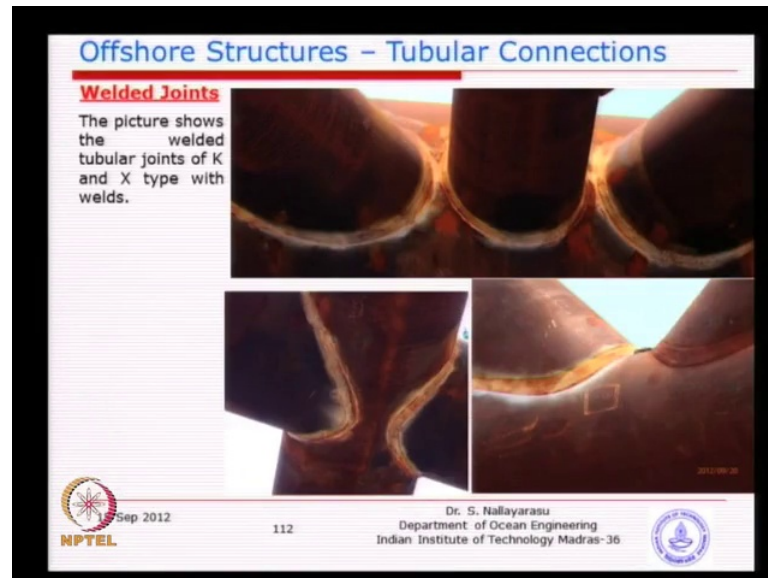
You will see that kind of profiles whenever the last weld bit is joining the material. You will see a sudden jump some slope will be there. So, basically incorporating these effects, because then you are fabricate in this when you are fabricating, this joint for model testing. You will include this weld effects any undercuts, basically are the location of the junction between the parad material and the weld. You may see that some kind of undercut or may be defect. All those things will be incorporated in the assent. Because, incorporating these three in this stress concentration factors will be very difficult, even by experiment or by numerical models.

So, the S N curve includes geometry material and the defect due to fabrication. That means either can be undercut or profiling of the weld and any imperfections. So, that means this S N method is obviously very good. Because, it represents the reality you fabricate typical joint of that type, it can be a plated joint. Then you go will have a different relationship, but only problem is limit bit of hypothetical idea. Because, they are unable to link this failure number of cycles, through the actual crack. Because, we are not estimating that, we leave that crack growth on one side. We will just decide based on number of cycles, that we can allow a number of cycles, that is actually applied from the sea state.

So, you compare like allowable stress versus applied stress, what we are going to look at here is so many number of cycles of stress is applied. We know that the joint will fail, if

you apply n number of cycles. So, the ratio will tell you the allowable cycles versus applied cycles. iI the ratio is less than one, then always designed is safe, but unfortunately what happened either of them. Either the allowable cycles or the applied cycles, does not reveal what will be the the crack and the joint. So, that is why we have a little bit of confusion. There will be a hypothetical idea, but representatively we decide that joint is safe. This method is in fact has been successfully use to for so many decades.

In fact this is the only method that has been implied for a last thirty forty years in the design of either fixed structure or floating structures or mobile units. Still we believe that this method is representating actual situation. Basically, no other choice, because of this idea is little bithypothetical uncertainty is involved in the relations between, allowable cycles to the crack is very high. So, that means we may have to apply a larger set of safety.

So, in this method we apply reasonable factors safety to be decided by the designer of course. Now, the A P I recommends some numbers. For example, when you divide the applied cycles to allowable cycles, you get a ratio is less than 1. If the ratio is equal to 1, then it is almost near failure. Now, you divide by the factor safety, if you have factor safety 2, then the ratio must be less than 0.5. So, as long as your ratio of fraction is less than 0.5 you have a factor safety of 2, you have a factor safety of 10. Then the ratio must be less than 0.1, so thus the idea behind. So, this cumulative fatigue damage method is nothing but you take each sea state. For example, you have three wave height in the field just forget about so many numbers.

Take the first wave height find out the stresses, find out the number of cycles that particular wave height is applied. Because, you can go and measure this this information from this site. Correspondingly find out what is the number of allowable cycles for that sea state, then find out the ratio. So, n 1 divided by n 1 and second sea state. Do the exactly the same thing and then add it, the idea behind is the effect is cumulative. That is why we call it cumulative damage method nothing but the effect is added as much the information, like the wave is coming the next day, the next day.

So, every time the damage is cumulatively added very similar to what we will learned a last few classes. The crack is initially few millimeter and start to propagate, it is not closing up. Its adding the effect together, so is exactly similar idea. Only thing is the

representatively given by not the crack width or crack length is given by the number of cycles of load applied. Of course, having said the disadvantages method the advantages are very good.

The method is very simple, really you no need to spent too much of your computational time. Because, it is basically a arithmetic I would say the whole method is arithmetic, as long as you have the stresses calculated on the structure. Simply take the number of cycles applied over allowable cycles will see this method in more detail. Basically, what we really require in order for this method to work is the wave climate.

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So, wave climate is nothing but the relationship between the wave height and wave period and wave direction for a particular site, at the for the duration of design life of the structure. So, if you design life of the structure is 25 years, you need information relating this three parameters for a reasonable period of time. Because, we are going to design the structure for future, not for past.

You might have collected the data for the last several years. Then you need to extra polite or predict, what could be the potential distribution over the design life. So, this is where little bit of difficulty comes. Because, you have to actually get this prediction correct. Otherwise, all you are calculations are not going to be correct. So, the wave climate is basically that description of your sea state conditions. Either short term or long term the next one is a structural response, which is very easy. Because, all of you are

civil engineers. You can calculate the stress applied on a structure by means of static for dynamic analysis, which is very easy.

As long as you know, what is the sea state. You apply the loads to the structure ,you get the response. Now, this the structural response you could include or neglect the dynamic effects. Depending on whether the structure is close to the the natural period close to the waves periods. That I think is a secondary method, but most of the jacket structures are away from the natural periods, close to the sea state conditions.

Now, the waves scatter data can be described in several ways one of the particular. The easier way is describing by the individual wave height, which I think in the early days of this course, we were talking about design method. So, either the spectral method or the descript wave height method, we were talking about. the descript wave height method, we take the individual maximum wave heights. Basically, that means when you look at a sis to gram of sea condition. You look at each wave height and take that as the representatives or you could represent that sea state by means of a spectra of any type.

That you could specify for the particular site, but described by a significant wave height and a peak period. I think this is got you might have studied in your hydrodynamic, the spectral distribution is normally represented by significant wave height and peak period. Whereas, the time list is different by wave height and associated zero crossing period. All of you know what is zero crossing period. If you draw the time history the the period between the zero crossing to the next one. Whereas, the peak period is basically relationship between the hutch max t max and the t z.

You will be able to calculate this is the spectral distribution. So, there are two ways of doing it, the normally use the first one for simplified fatigue. Basically, using the deterministic Analysis. Whereas, the spectral response will use the the significant way height and the corresponding peak period. Let us learn how much easy is to do this method first. Then will go to the response by spectral. In doing, so there are several things you need to work out first, the structural response in terms of nominal stress.

That means a simple static analysis of the structure for a given wave height and stress concentration fact is basically we saw some simple formulas earlier, but you will see a little bit complex formula. Then hot spot stress range is the multiplication of the local stress multiplied by the stress concentration factor. The S N curve is the relationship between the stress that can be applied to a structure. Until, failure with number of cycles being N. Then cumulative fatigue damage is nothing but the added effect of the ratios of applied cycles to the allowable cycles. The factor safety is basically defined as how much additional safety margin, you want to keep on the fatigue damage.

So, you want to have a safety margin of 10 the fatigue damage must be restricted to 0.1. If the safety margin is 1 then the damage can be as much as 1, so that is the idea behind. So, these are some of the definition, you must keep it nominal stress range is nothing but the stress applied to the structure slightly away from the joint. For example, if you have a T joint that the joint is here the member is subjected to a stress of some magnitude, but the range is nothing but the positive and negative or the maximum, minimum. The difference between the values of these two will give you the stress range. You must remember is not only the amplitude is to go, look for the positive negative amplitude or minimax amplitudes.

Then the difference could give you the stress range stress concentration factor is basically the local or localized increase at the junction between the brace and chorded.

So, you need to calculate this of course, this is the ratio of the local hot spot stress to the nominal stress applied l square slightly away. Then when you multiply these two this with this you will get the hot spot. Hot spot is nothing but the localized increased stress, which we have by indirect means. Because, we know how to calculate this. We know how to calculate this by empirical methods. Then we try to get this, but of course there is a easy way.

You do not want to do both of them, if you want to this one straight away. Of course, is it can be done you can do a finite limit analysis can find out, but not every time you have the time and resources to do the finite element in this. That is why you try to this and we do this by empirical means and try to obtain this indirectly. So, that is the idea behind you could ask, why should we do this. We have the computers, we can do this hot spot stresses our self without relying on either the stress concentration factor, given by some people in the empirical formula. The nominal stress, which could be done in some cases if you have a problem, which is so complicated. You could actually carrier A P I studies yourself find out the stress concentration.

As long as A P I studies are correct the several time what happens A P I studies are done incorrectly. Then you will not be able to get the information correctly. Of course, the S N curve is not something that you want to generate, which is time consuming involves lot of money. So, basically we have to rely on the S N curve generated by the agencies like codes and standards are institution governing the country. They have already done that exercise every country have got. So, basically you could use that information without much worry. So, once you have this, then you can want calculate the fatigues damage. So, waves scatter data we have two parameters.

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Basically, the wave height under wave period, which can be described by the maximum wave height for individual wave and the corresponding zero crossing period. Basically, if the data will look something like this. You look at this and the left side you see here, vertical axis defining the wave height, the horizontal axis defining zero crossing period each of the bin is describing.

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For example, this is basically this vertical line is 2, this vertical line is 3. That means between the period of 2 and 3 for a wave height of 0.5 meter, we have number of

ocranses 307. The idea is each one is given a range is not a specific or a descript item is just the bin covering certain range of wave height certain range of wave period. So, how do we get this? So, if you have a time history recorded at a site. For example, we will have to go an analyze the data to find out individual wave height typically. Account it inside this bin, as long as you satisfy the condition. As long as the period is within 213 and the height is less than 0.5. That means 0 to 0.5, then you will count them inside the this bin and if it is say.

For example, to going to 0.5 to 1 meter you will come down count them in the second bin. So, you have to do this for the whole range of data that you have. So, every time when the wave come inside you will do this. So, this data how do we get it the only way to get this is to have a site specific measurement. That means you will deply a wave measuring device at the site. Then record the that the variation of sea state the variation of surface elevation and analyze that data. Basically, you will get this information and this is where the most difficult part. Now, you want to plan to build a platform in a particular site, that is future. So, what we are actually measuring is the past.

Now, we need to make sure that the measurement that we are going for the last one year is going to be representative of the next 25 years. Because, you may not actually have twenty years measurement. Nobody is going to plan for a twenty five year measurement thinking that after twenty five years, there is a going to be a platform there. So, normally when you identify a field, which is potentially having oil and gas. Probably you will be planning to do a survey for a shorter duration three months, six months. Maybe one year, but not more than that. So, you have a measure data for one year, but then you are going to rely this for the next twenty five years, next fifty years.

This is where the difficulty of course, number of mathematical models have been gavel up over the long period of time, which is going to describe, based on the information that you have collected that, what could be used for next few years. So, there will be a correction required for this data, which is only one year measurement, but then you are you are going to use for so many years of your design.

So, this is where you will see there is a uncertainty. Whatever the mathematical model we are trying to do is impossible to predict, what could be the number of occurrences, that will occur the next year. The year after, but typically living behind the uncertainty,

particular sea condition at a location can be described by a simple two parameter, wave height an one site and the wave period and other site and numbers indicating number of times be occur. Now, if you look at the wholes sea state has been covered here each time of wave height and a wave period is associated with number of cycles. Basically, the energy industry sea condition and the larger the number.

For example, if you go around you look at it 6000, 6000 is the biggest number. So, what you see from here 2 meter wave height with wave period ranging from 4 to 5 is predominantly occurring at that site, 6000 out of probably few hundred thousand. So, basically that is the largest number, that you can see. that means if you go to the site every time, you will see very often the wave height is around 2 meters. So, that is the idea behind it. For example, if you do not have any of this number. If you just only one number in the whole scatter data. That means that site is very good, you do not need to do measurement. Because, basically only one wave height one wave period.

All the time it occurs, you would not find a place like this. So, basically that is the idea behind this. Waves scatter data is the scattering of the energy, from lower sea state to a higher sea state with a mean value or the center of the highest occurrence is somewhere. So, from here what we can understand, if you do a wide average calculation, most of you might have studied in mechanics to find out the central gravity. You can find out very easily by multiplying the area times the central gravity of individual area. Similar thing you can do it can find out, where will be the maximum energy content. Basically, multiplying the wave height and the number of occurrences. You will see that typically will come around 4 to 5, somewhere here.

If I just look at it my myself without even do calculation, I can say the the effective wave height could be somewhere between 2 to 3 meter. Basically, the wave period could be 5 to 6 seconds somewhere there. Because, I know the numbers look in that order, even if you do calculation you will be able to come to conclusions. Basically, somewhere here what it means, 5 to 6 seconds. So, imagine you take one year, which is 365 times 24 times 60 by 60 divided by say divided by 5 seconds, how many cycles you will get? Nearly, four million cycles three and half to four million cycles.

So, you can see if you have a sea state condition and a particular place for one year with every time somewhere is crossing. You will see that few million cycles are going to

occur, but you may not have the hundred percent every times. Sea is rough some time, may be come you can distance may be there. So, basically will be around two and half three million cycles. So, for one year you are going to face three million cycles of some sea state, it could be smaller bigger, but in the nominal somewhere around 2 meter wave height. So, you could actually do that simple calculations. So, how do we do this?

Basically, this two parameter one information is missing wave direction is missing. Because, now you have a structure, which is constructed at the site, but that we do not know is which direction wave is coming. Because, our structure is sensitive to the direction from, where the wave is going to come. So, what we normally do is we need to actually measure the information, at the site predominant direction of wave every particular duration, but most of the modem wave measuring devices, actually can get this information.

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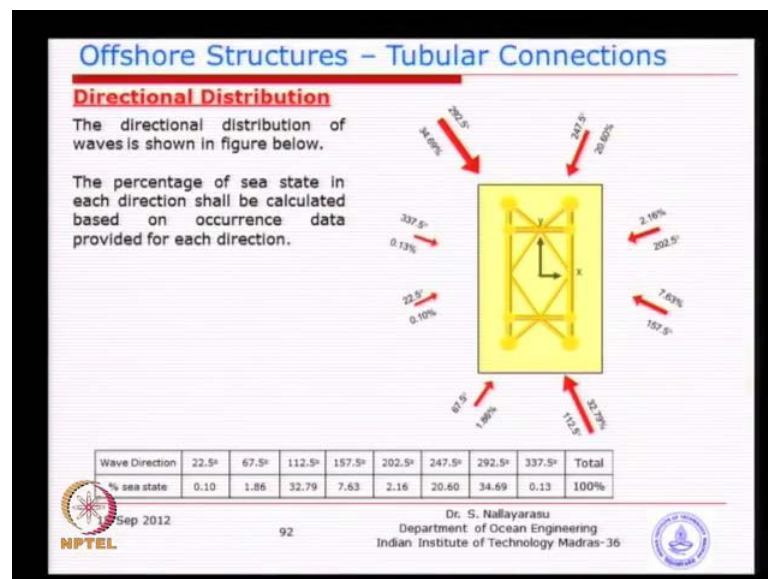
As a second parameter doing the recording itself, but if you do not have normally, what we do is we collect the information with regards to win data at the site, you have a windrows diagram. I think most of you might have seen the windows diagram. I think most of the might have seen in the windrows diagram the diagram indicating the periodical or the seasonal variation of the wind, with respect to the horizontal direction. So, you could get that information, because mostly these ways what we are looking at is the locally generated or wind generated waves. What we are looking at? Basically, you

could use the information from the windrows diagram to reload to the waves, that may occur.

Sometime we do use this, because the earlier like say ten fifteen years back measurements devices for wave heights. They do not give you the that direction use to have lot of difficulties. Basically, you have the wave data and we have the wind data and with the wind data. You just decide to do certain ranges. For example, the waves are going to not only just come only on the direction, but I have drawn here. You may have any direction, but what we have decided is the band of arial. For example, 0 to 30 degrees you put occurs. I will assign to one direction, because theoretically speaking you should do the analysis of the structure for all possible wave directions. Theoretically, that means you may have thousands and thousands of directions.

You may not actually practically possible. That is why we actually cumulatively find out. For example, any wave direction between this point to this point added to this direction that is means its represented by one particular direction. Rather than I will do analysis for every direction that I would encounter at site. Because, this is to simplify the design calculation. Otherwise you will end up you know too many number of variables and two many number of wave directions, we cannot actually do it. So, basically in the earlier days I think we have studied for a typical jacket structure. How many directions we require minimum? Eight directions to represent the weak or the maximum stress producing direction, which is going to be a important parameter.

So, normally for typical rectangular structures A P I recommends minimum eight, I think is a commonsense, but if you have a tubular structure. For example, single column does not matter to, you need only one direction, because any direction you apply. For example, circular tube any direction, you apply will be same stresses. Whereas, for rectangular or square structures with the structural frame arranged. In this way you need to have to identify them. The weakest direction by which the stresses will be maximum. So, by inspection most of the rectangular frame structures. If you apply eight directions will be covering most of the cases.

So, typical distribution is see here on the bottom. There is a table you can see here we have picked up these type of directions, which as the designer we know this is the direction going to cause maximum stresses. To get this for example, 22.5 degrees, let me
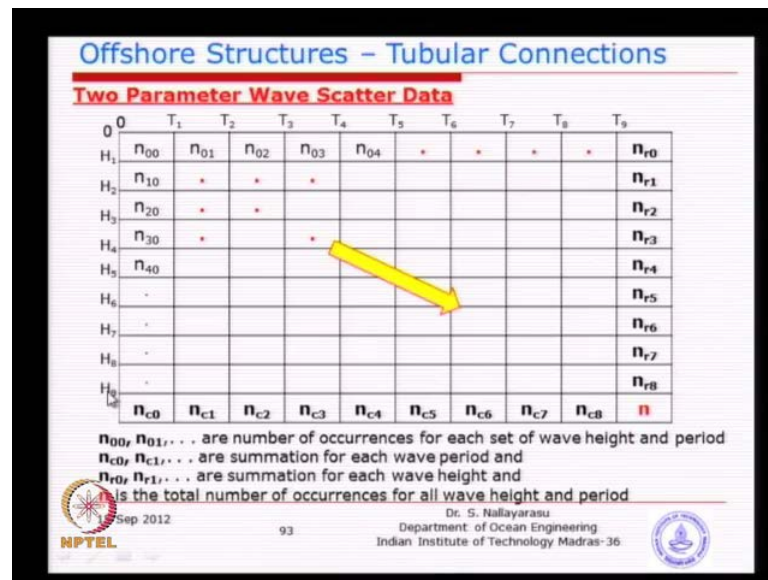
go to 22.5 degrees somewhere here. Either only 0.1 percent of the total waves approaching from there. That means this is any wave approaching from zero degrees up to 30 or 40 degrees has been lumped into here. You understand the idea know, how the directions, where arrived any waves approaching from 0 to 40 is assigned as a 22 degrees very similar like this. Any waves approach any waves having 3 and 4 second in between is assigned, as that particular number of occurrences.

So, what we are looking at is the a kind of approximation just to reduce the amount of work that we need to do strictly speaking. You actually have to do analysis for each one of the wave. If you do not want to do any of this approximation. You can pick up one wave analysis results and go to second wave. That means you will able to the analysis for millions of waves, which we do not have the resources and time. That is why we are condensing our data that any wave coming between 3 and 4 seconds, as the period we just put it. So, that we do not need to do as many analyses has we require, but we can do simplified.

So, basically this method is an approximation to the real sea condition. We are just trying to condense the information to our easy and way of doing calculations. Actually the method is highly susceptible to error depending on who is doing the analysis. For example, I have come up with 2 to 3 second as my band or my division. If I go to another version we decides to do 2 to 4 seconds as the band. So, what happens the approximation becomes more, if you got another version. We can do between two and two and half as the band, so the accuracy increases. So, that is where the problem here there is no mandatory information avail from the course.

That what should be the division that you should look. Strictly speaking, you should not divide you just take each wave and then gone do it, which is not feasible highly depends on the particular designer, that we doing this analysis. That is why we have to be careful that, this method may need to conservative results are may can lead to un conservative result, depending on the particular designer. So, the same data can be described in generic form instead of information like this. Basically, the wave heights are divided into bands from zero to whatever, the maximum wave height at that particular site.

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Two Parameter Wave Scatter Data

0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	
H_1	n_{00}	n_{01}	n_{02}	n_{03}	n_{04}	·	·	·	·	n_{r0}
H_2	n_{10}	·	·	·						n_{r1}
H_3	n_{20}	·	·							n_{r2}
H_4	n_{30}	·		·						n_{r3}
H_5	n_{40}									n_{r4}
H_6	·									n_{r5}
H_7	·									n_{r6}
H_8	·									n_{r7}
H_9	·									n_{r8}
	n_{c0}	n_{c1}	n_{c2}	n_{c3}	n_{c4}	n_{c5}	n_{c6}	n_{c7}	n_{c8}	n

$n_{00}, n_{01}, \dots$ are number of occurrences for each set of wave height and period
$n_{c0}, n_{c1}, \dots$ are summation for each wave period and
$n_{r0}, n_{r1}, \dots$ are summation for each wave height and
n is the total number of occurrences for all wave height and period

Similarly, the wave periods can be divided into zero to highest period possible there and to be filled with information. That is corresponding to each of that band and the total numbers occurring at the site could be either added vertically or horizontally, we should get the same information. So, typically two parameter waves category data is nothing but the occurrence data for each of the sea conditions. That is existing at the site some of the areas could be empty, does not mean that everyone of them will have some numbers. Like, if you see this table, what is the meaning of this, that there is no information there, that means that the state does not occur or arise at the location.

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Two Parameter Wave Scatter Diagram (Wave height, period and occurrences)

Wave height (m)	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	Totals
Totals	631	6855	14500	12802	6227	1235	151	11	1		42413
8.0								1			1
7.5							1				1
7.0						4	2				6
6.5					5	18	1				24
6.0					31	69	2				102
5.5				2	159	41					202
5.0				65	437	3					505
4.5			3	679	391						1073
4.0			53	2250	54	1					2358
3.5			1352	2171	24						3547
3.0		27	4810	386	58	1					5282
2.5		2204	4283	374	44	8	2				6915
2.0	20	6418	1594	216	19	4	1				8272
1.5		3042	4950	622	72	7	1				8694
1.0	324	3492	870	77	10	3	1	1			4778
0.5	307	301	31	8	2	3	1				653

Mean zero-crossing period (seconds)

The above data does not show any directional distribution and hence same needs to be obtained using the relationship between wave height, period and direction

Basically, for example, we go to 5 meter wave height with the wave period between 2 and 3 does not exist and cannot exist. You can go back to your wave theory some of the combinations of wave periods and wave heights cannot exist. Because, either they cannot be generated or they cannot be propagated to the site. Because, it my doubt already broken. So, basically you see wherever the data is not available. That means they does not exist you cannot go and assign the number. Basically, this is the genetic table that you would like to generate the reason. Why I wanted show this is basically, the next will be the important information. In the information containing the directions with respect to wave height.

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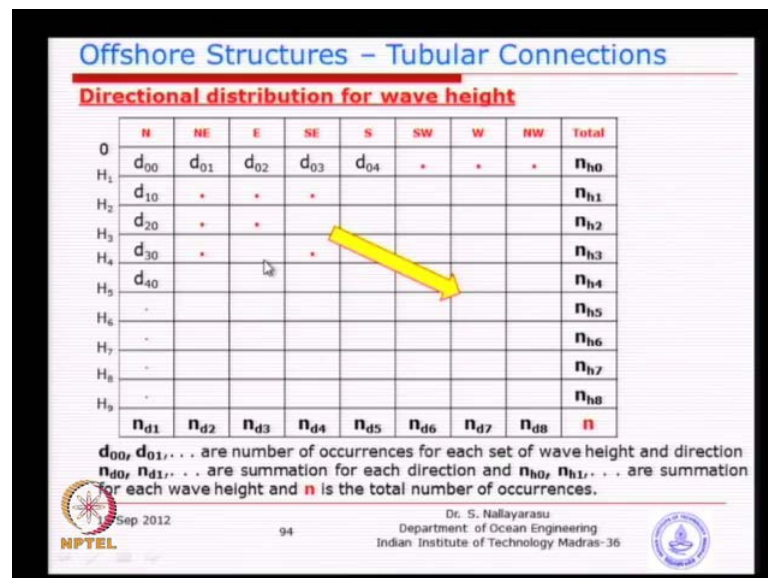
Sometimes you get this information from the we measured data, you have two three parameters to parameters are already linked the third parameter, which is wave height with the direction is linked by again the number of occurrences. That means when you have a time history measured, you can get this information from the measured data. So, from here the number of occurrences also shame the relationship between, the wave period and the wave height is n number of occurrences with a division, something like this the same waves. Because, you are looking at the same wave in a different combination you have the wave heights and the wave directions. Also, when you some up you should get, because you cannot have two different numbers.

Now, using this data you can actually link the direction with the wave period. Because, you got a two linkages just multiplications. Most of the projects, we get this two tables provided by the previously measured data from wave height measuring devices. Basically, the reason why we need is you can multiply this with the ratio of this to this to get the corresponding directional distribution. So, basically that is the reason why we need this two table.
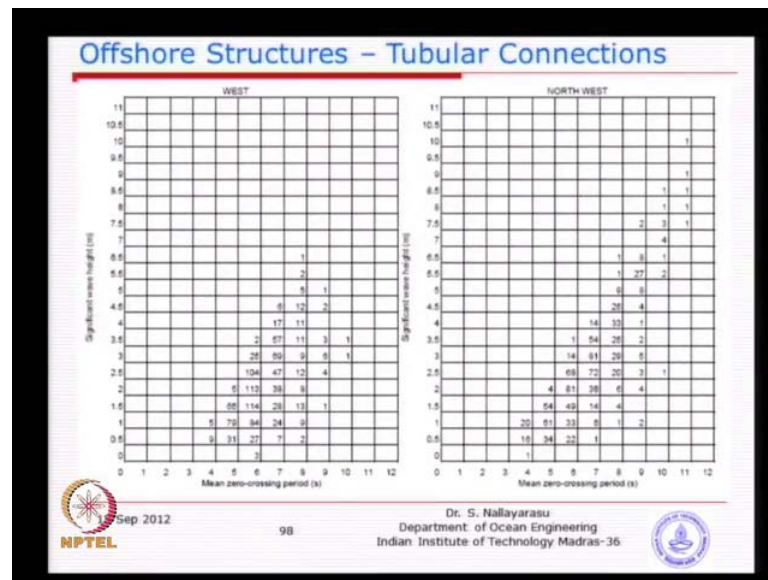
(Refer Slide Time: 44:12)
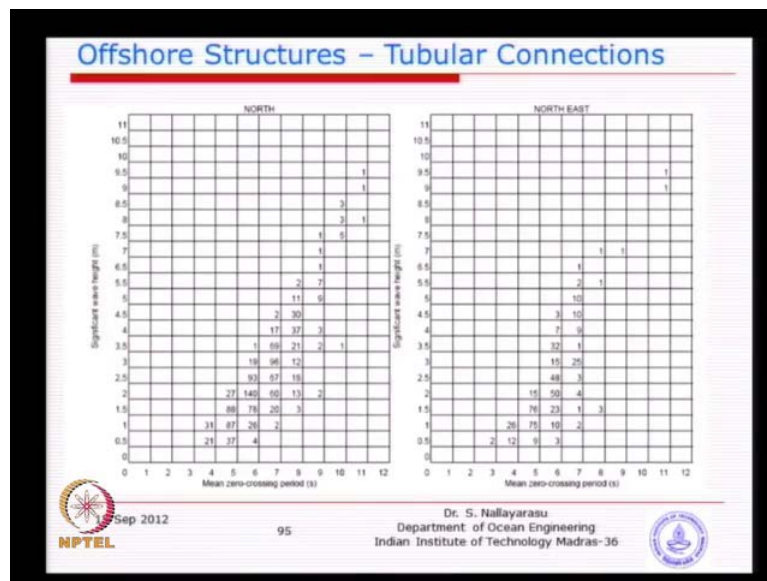
Sometimes the owner themselves generate these data for each direction. For example, this particular project, they have already done that exercise. What we wanted to do describing the wave height versus the period, with each direction the numbers are provided.

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So, once you get this type of data, then we do not have much to bother to generate, because far each of the directions.

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They have already given, like eight tables each direction is provided with the wave number of, number of occurrences wave period and wave height.