Dynamics of Ocean Structures
Prof. Dr. Srinivasan Chandrasekaran
Department of Ocean Engineering
Indian Institute of Technology, Madras

Module - 1
Lecture - 7
Wave Forces, Current

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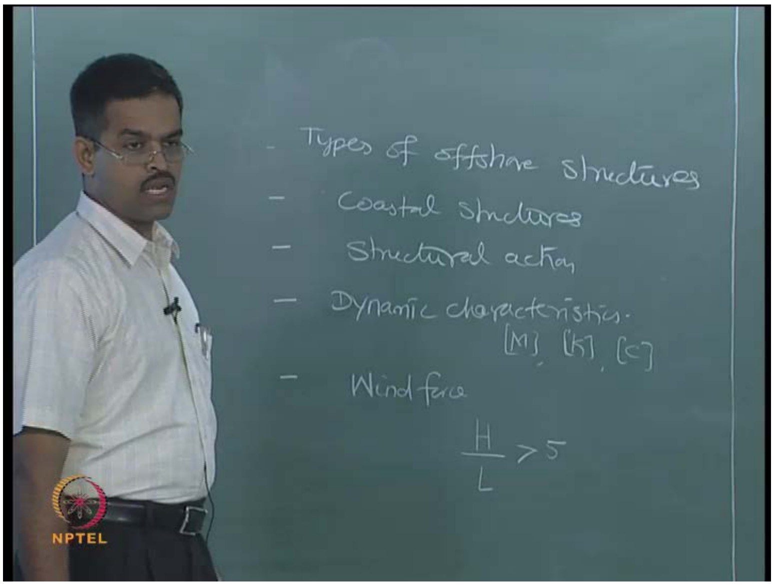

We will have the seventh lecture on dynamics of ocean structures. Let us quickly see what we have discussed in the last lecture. We discussed about different types of offshore structures. We also discussed about different types of coastal structures. We also discussed about the structural action of these kinds of structures under the given environmental loads. We very briefly discussed about the dynamic characteristics, which are important of these kinds of structures. For example, the mass of the structural system may be a matrix, it may be single value, the stiffness then the damping, which can arise from material as well as from the hydrodynamic loading, etcetera.

Then in the last lecture we discussed about different kinds of forces. We started with the wind force and we said that if we want to estimate wind force or the effect of wind force on a given structural system, the system should behave in a cylinder manner. That is the height of the structural system or the member with respect to the least lateral dimension of the structure should exceed 5. So, the dynamic action will be invoked in the structural system. Therefore, we must do dynamic analysis.

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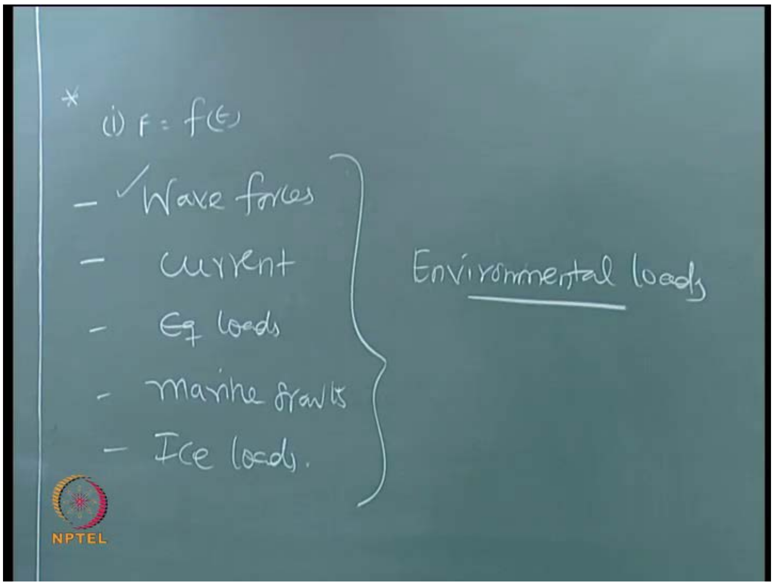

Now, essentially dynamic analysis need not be done, even though the force may be a function of time. Even though F can be a function of time, still you may not do a dynamic analysis, you can do a quasi static analysis or simply a statistical response. It is important that the structural system, where the load is applied should also invoke the dynamic characteristic in the behavior. So, we discussed about the wind force. Today, we will talk about wave forces. We will talk about forces from current. We will talk about forces from earthquake loads. We talk about forces from marine growth, etcetera. Of course, ice loads.

So, all these comprise, including the wind force, as what we call the environmental loads, which act on the offshore structure. So, interestingly we have understood that, even though the force can be a function of time, depending upon the structural system characteristic, you may do dynamic analysis or you may not do a dynamic analysis. That was the brief summary what we had till the last lecture. In the present lecture, we will talk about now the wave forces.

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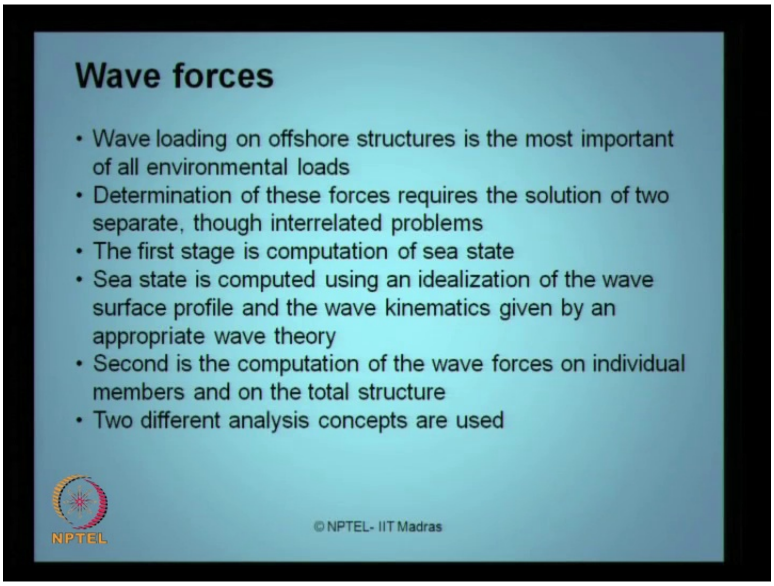

Wave forces on offshore structures or wave loading on offshore structure is one of the most important of all the environmental loads. Determining these forces require the solution of two separate, but interrelated problems. Let see what are they. The first stage is computation of sea state.

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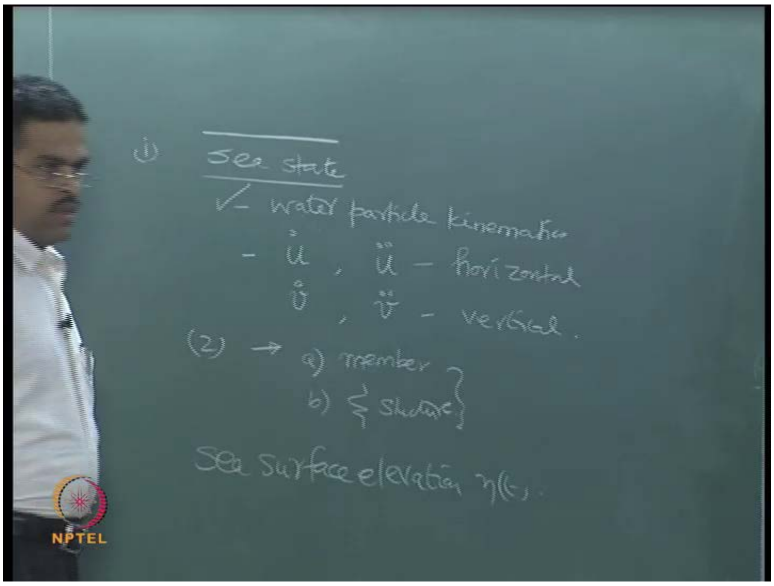

So, wave force estimate has got two important stages. One, you must identify the sea state. The stage is to identify the sea state. You must use a specific profile of the sea state or you must use a specific theory to simulate the sea state and based on that, you must derive the water particle kinematics. The moment I say water particle kinematics, I am interested in knowing the horizontal water particle velocity, the vertical water particle velocity, the horizontal water particle acceleration, the vertical water particle acceleration.

Once I know this, I must then be able to estimate the forces on the member. The second stage is to estimate the wave forces on individual members and then on the total structure. So, it has got two components. I want to know their forces on individual member and subsequently, I also want to know the total force on the entire structure. So, if you identically compare this with the same algorithm what we had in the wind force, there also we first estimated the velocity. From the wind velocity, we estimated the pressure acting at a specific point; found out the coefficients responses for the terrain quantifications etcetera; estimated the force at every specific point and based on that, we either found out the effect of the forces moment on the member or the force acting on the member as such, if I know the projected area of the member. Similarly, here the same algorithm, I will talk about the water particle kinematics first and then I will talk about the force estimation on these members. So, there are two approaches to quantify the sea state, which are very important level of estimating the wave forces.

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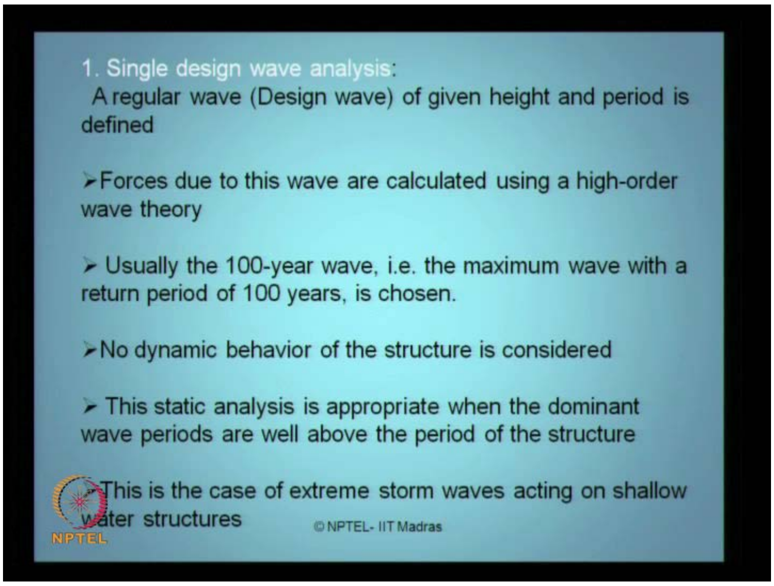

So, the sea state can arrive from two stages. One is what we call as single design wave analysis, where a regular wave what we identify as a design wave of a specific wave height and the wave period is defined. So, you define a specific wave, whose wave height and wave period are given to you. Forces due to this wave will be calculated using higher order wave theory. You will use a higher wave theory and estimate the forces based on this given wave height and wave period. That is, for the given sea state, estimate the forces using higher order wave theory. Usually, we consider 100 year wave, that is, a maximum wave with return period of 100 years. So, that could be your design wave or single design wave, which we will consider for the analysis.

Now, when you do that kind of analysis, where you are talking for the maximum wave within a span of 100 years, then dynamic response is not considered. You do not look at the dynamic behavior of the structure, whereas in wind, you are talking about the dynamic behavioral structure. But in this case, since you are estimating a single design wave whose wave height and wave period was considered to be the maximum in the past 100 years, do not look for the dynamic behavior.

So, this becomes a static analysis and it is appropriately equivalent to the dominant wave period for all period of the structure and the structure will be designed, so that, the period of the structure will be well above or well below depending upon what kind of structure is that, depending upon the wave period. So, this is the case of extreme strong wave acting on a shallow water structure. This is one approach what people have to qualify the given sea state based on which you will estimate the water particle kinematics. The second approach what people have in the literature is random wave analysis.

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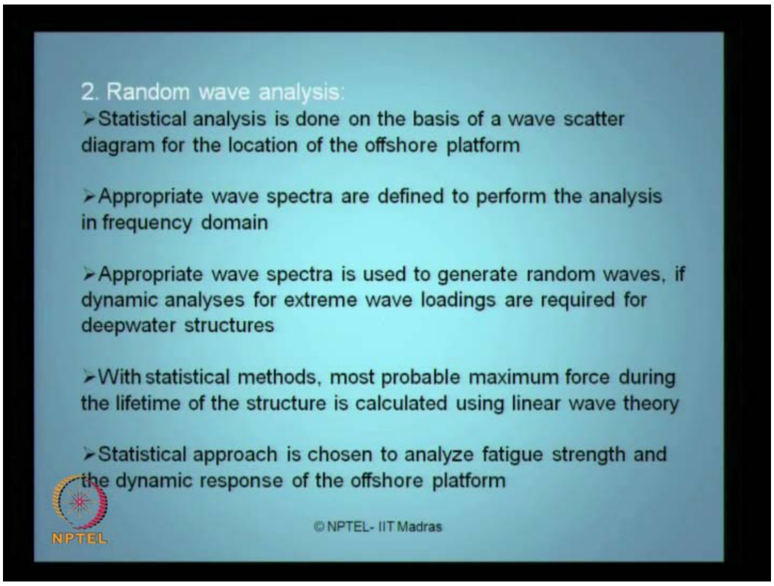

So, here what they do is, they talk about the statistical analysis on the base of wave scattered diagram and the wave scattered diagram is obtained for a specific sea state, where the platform will be installed. So, what we call, location specific wave scattered diagram. You pick up this diagram and do a statistical analysis on the data from the wave scattered diagram.

So, you pick up an approximate wave spectra to define the performance of the analysis in frequency domain. Then appropriate wave spectra is used to generate what we call random waves, if we are looking for dynamic analysis of extreme wave loading in deep water structures, which is one of the important criteria. So, it is very essential that we look for a random wave analysis. Then you have to do a dynamic analysis when you are talking about compliant structures. Why I say as compliant because the moment I go to deep water structures, my structure will have relative motion with respect to the water particle or visible to the wave which is approaching the structure.

So, with statistical methods, most probable wave force, maximum, occurring at that life time will be calculated. Now, it is very interesting that to calculate the maximum wave force, which is going to happen in the given life time of the structure, you use a linear wave theory. Now, there is a diversion here. Either use a linear wave theory to estimate the water particle kinematics or you can use higher order wave theories also. We will quickly see what are these theories. Very quickly because we are not going to focus on how to estimate the force and the structure. My worry is how to do a dynamic analysis, provided if f of t is known to me. If I know the forcing function, then I must know how to do a dynamic analysis. But to understand how to estimate forces, we must have an idea that where are we facing the source to obtain the forces. As I just now said, when we talk about either single design wave or a random wave analysis, in both the cases, it is interesting that I must identify what I call a sea surface elevation, which we discussed in the last lecture as well. We just call it as eta. So, I must design or I must define the sea surface elevation eta, based on which, I will then compute the water particle accelerations in velocities, both in horizontal and vertical. Of course, this is horizontal and this is vertical.

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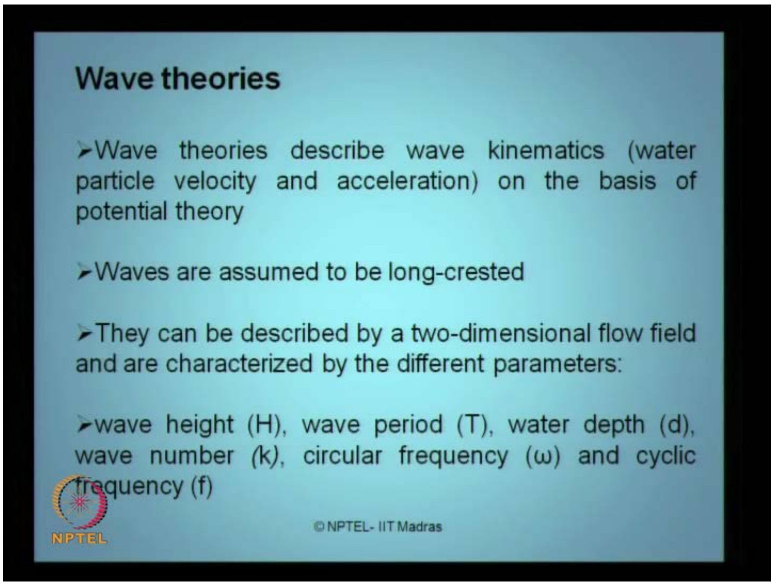

So, there are some assumptions based on these theories. Wave theories describe the wave kinematics, that is, water particle velocity in acceleration on the basis of potential theory. Waves are assumed to be long crested waves. They can be described a two dimensional flow and characterized by the following parameters; wave height, wave period, water depth, which is small d, capital D denotes the dimension or the diameter of the member, wave number, circular frequency omega and cyclic frequency f. So, these are some of the parameters, based on which I characterize the sea surface elevation or my sea state.

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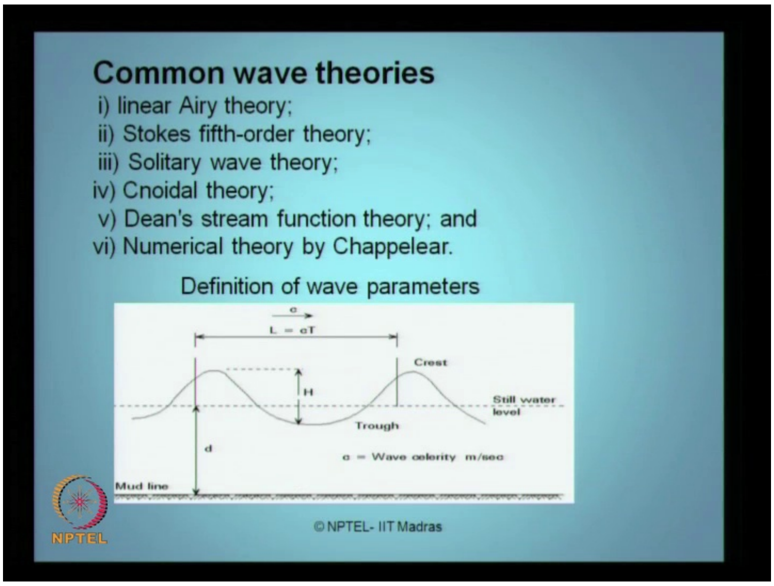

Once I know this, I have got different common theories which we all aware when talk about wave hydro dynamic course; linear airy theory, Stokes fifth order, solitary wave theory, Cnoidal theory, Dean's stream function theory and numerical theory by Chappelear. So, we are not going to discuss all these theories. But for understanding, I will just quickly discuss linear wave theory and Stokes fifth order theory. Very briefly give you some tutorial, so to make you to understand how to estimate wave forces on the members based these on theories. So, the wave parameters are given here. Water depth is small d, wave height is capital H and we know what is a crest and what is trough and we also talk about wave celerity in meter per second.

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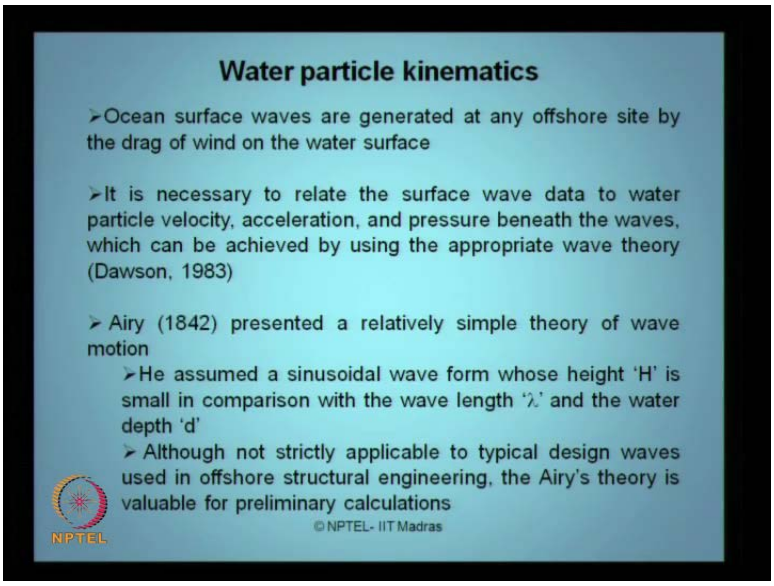

So, if you look at the water particle kinematics, as I just now said, Airy in 1842 relatively gave a very simple theory, what we call as Airy's linear wave theory. They assumed or he assumed a sinusoidal wave, whose wave form is having a height H and small in comparison to wave length lambda and the water depth d.

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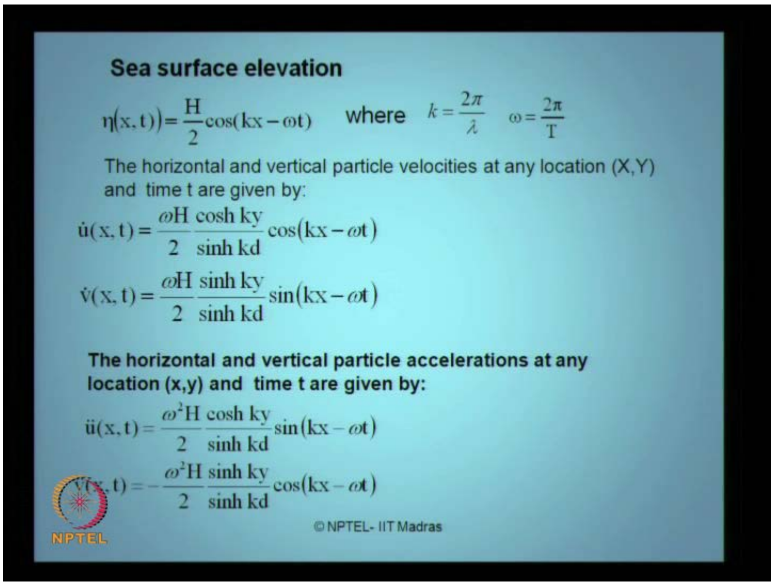

So, Airy's wave theory is very popular. Airy's wave theory gives you the sea surface elevation eta x of t, which is function of time as well as any spatial point x, which is given by the equation, where k is a wave number and omega is a frequency. If we know eta x of t, from this you can easily estimate u dot and v dot, which are horizontal water particle velocity and vertical water particle velocity available in the literature. You need not have to copy this. These are all standard literature. Any hydrodynamics text book will help you to estimate what are these equations. You may not have to worry about the equations of this. Once I know, I can differentiate this and get the accelerations also. So, I have got u double dot and v double dot n.

Now here, the only important thing is, what we must realize is, it is a function of x, which is spatial point. So, function of t, which is the time as well as function of y, which is a dimension measured along the water depth. So, it is a three dimensional function. A time is a variant, x and y are the points of your interest, where you want to. I can give a very quick example how this can be estimated.

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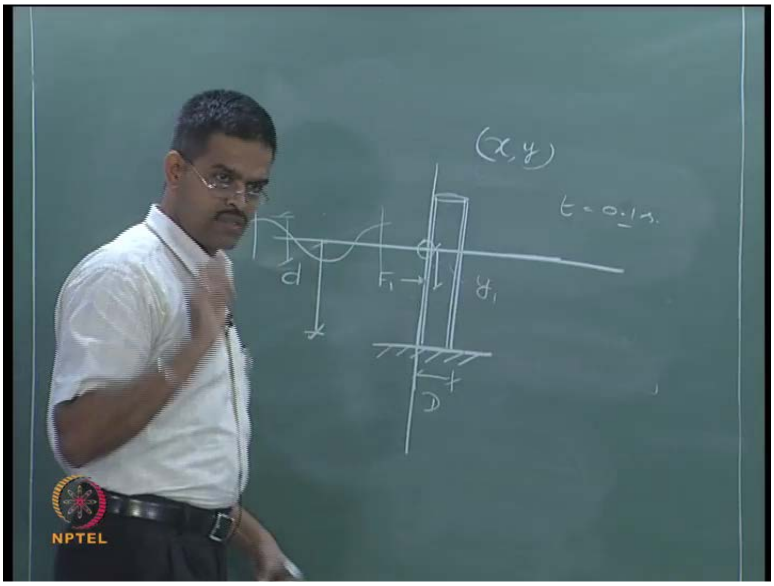

For example, let me say I have a cylinder. I have a cylindrical member, a single member. The cylindrical member is hypothetically fixed to the sea floor. This is my mean sea level and of course, I will indicate this as my water depth d. This member may be hollow having some thickness t, but I am bothered about the outer diameter, which is d and the wave is specified with a specific height and the specific wave length etcetera. So, if I take anywhere as my origin, let say for example, I take this outer end as my origin. So, I will define x comma y based on the point here and let t can be any instantaneous value 0 or may be 0.1 seconds, any value you want. So, you can find the variation of the force at any given time t, for any specific point x and y.

For example, I want to know the force here. So, I must know the value of y, which I call as y 1. I must know the value of x, which will remain as 0 because this is the origin on the same line and again pick up any t of any instant or you can get a time history of the velocity and acceleration variation on this point on the cylinder using this theory. So, I will able to estimate F 1 F 2 F 3 F n etcetera, at any point of x y at any time t, using this eta x of t u dot u double dot v dot and v double dot. Is that clear, right?

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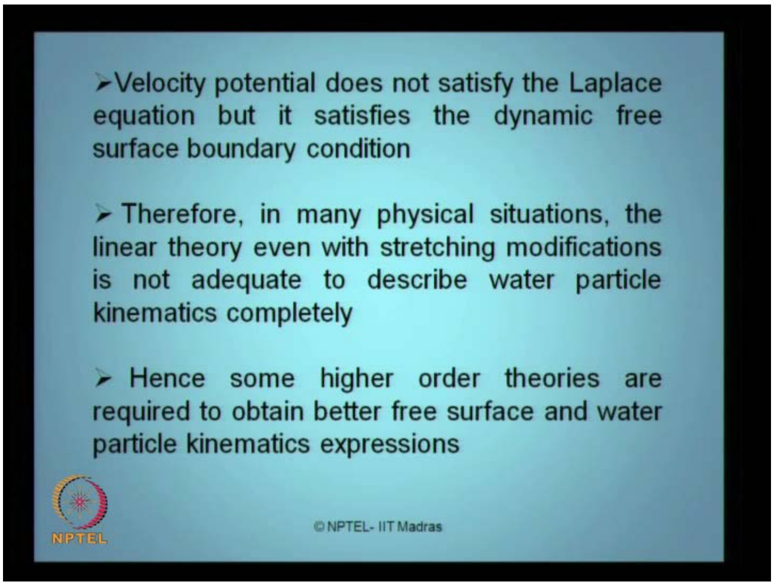

So, there are hitch backs with this theory. Velocity potential described by this does not satisfy the Laplace equation, but it satisfies the dynamic free surface boundary condition. Therefore, in many physical situations, linear theory, even by stretching modifications, there are many modifications given by this theory by Hogben, Wheeler and Chakravarti. These three researchers subsequently modified linear theory, Airy's theory.

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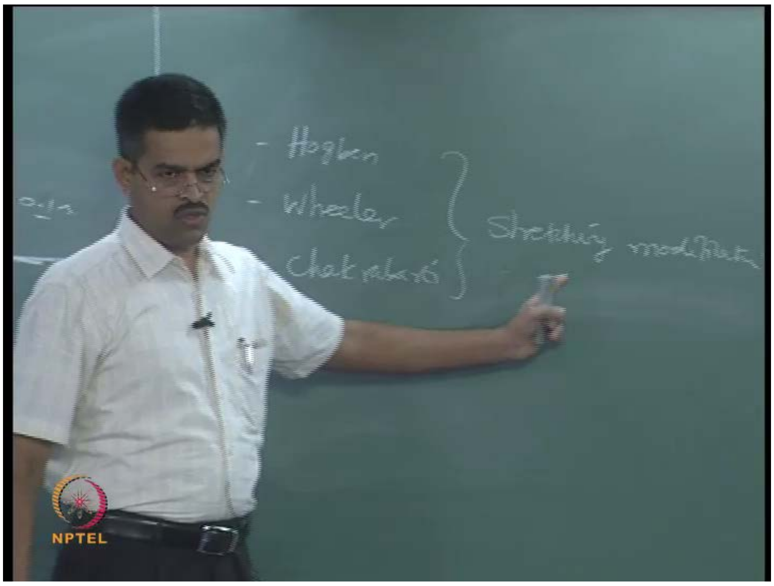

Hogben, Wheeler and Chakravarti, three individual researchers at different times modified this theory. These modifications are addressed in the literature as stretching modifications. We should agree that Airy's theory speaks about the force only till the m s r. It has talk about how to estimate the forces beyond the m s r. So, Hogben and Wheeler stretched this above till H by 2 as well. So, what we call as stretching modification. So, they have modified the eta surface elevation given by Airy's and of course, they have given suggestions for u, u double dot and v dot and v double dot. So, there is a small modification, which you will get in terms of its force estimate, when you use Airy's theory or when you use stretching modification. But the difficulty in the literature is, even after the stretching modification, it is found that the theory is not adequate to describe the water particle kinematics completely. So, then why Airy's theory is being used? It is good for estimating preliminary values of the forces on the member. Then what was the solution? Solution said, people, you should move on to higher order wave theories.

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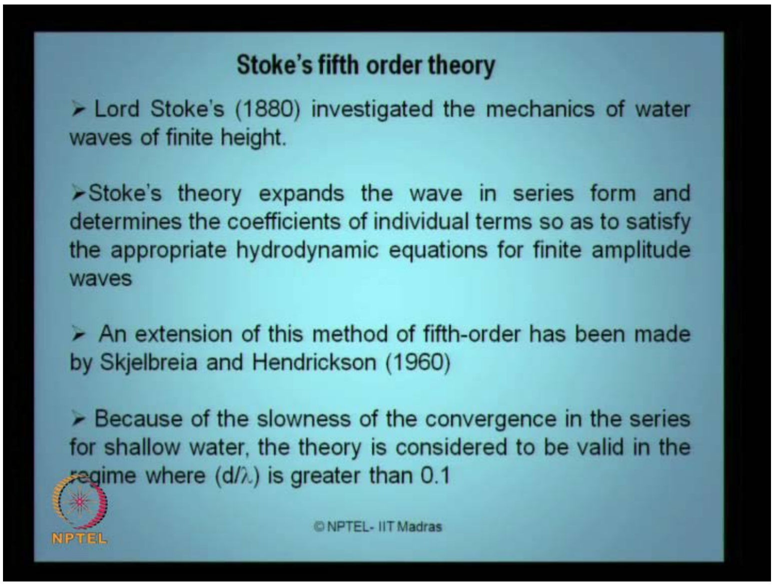

One such higher order wave theory is given by Stokes. Lord Stokes gave it in 1880, which is called third order; subsequently fifth order wave theory. So, Stokes theory expanded the wave in a series form and determines the coefficients of individual terms to satisfy the appropriate hydrodynamic behavior for finite amplitude waves. Then the extension on this theory was suggested in 1960 by Skjelbreia and Hendrickson, which is available in the literature. Now, there is a problem here. Because of the slowness of convergence in the series for shallow water, these theories considered to be valid only in the regime, where d by lambda; lambda is a wave length should be greater than 0.1. So, you must check that your d is the water depth and lambda is the wave length for a given wave. If this function is greater than 0.1, this theory will work better. So, if we look at how Stokes fifth order deviated Airy's theory quickly in terms of water particle kinematics, I will come to that slide here.

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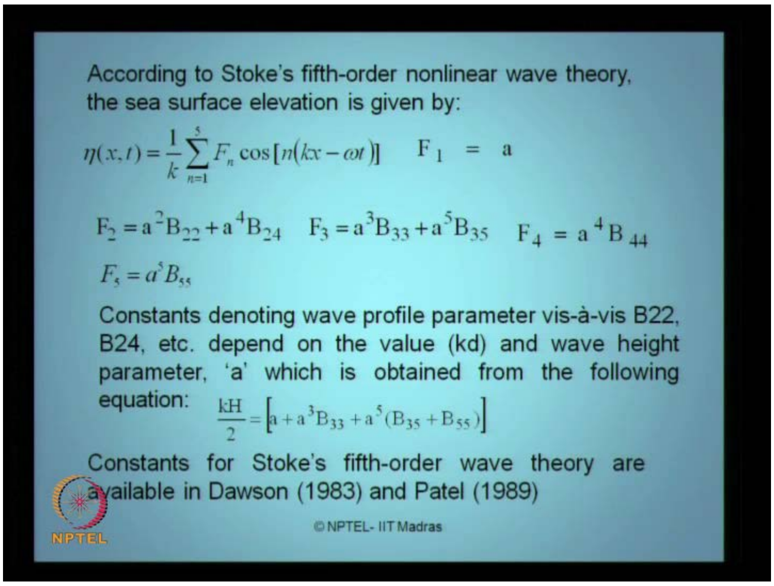

The e tags of p, using Stokes fifth order theory, why it is fifth order because you will see that the series here starts from 1 to 5. So, I am adding 5 terms in the series. That is why this theory is called fifth order wave theory. So, it is nothing but summation of this, where you have constants F n F 1 F 2 F 3 F 4 and F 5, because n runs from 1 to 5. All these values are available in the literature. You can refer Dawson 1983 and H Patel 1989 to have all these coefficients. Also, my own paper on ocean engineering journal also gives you all these coefficients in single shot. The references are only available in the website of NPTEL under this course. So, you can look at Dawson's paper or book or you can look at Patel's book. All these, both the books as well as papers will give you coefficients of all these values in detail. So, what we are interested here is not to discuss those coefficients.

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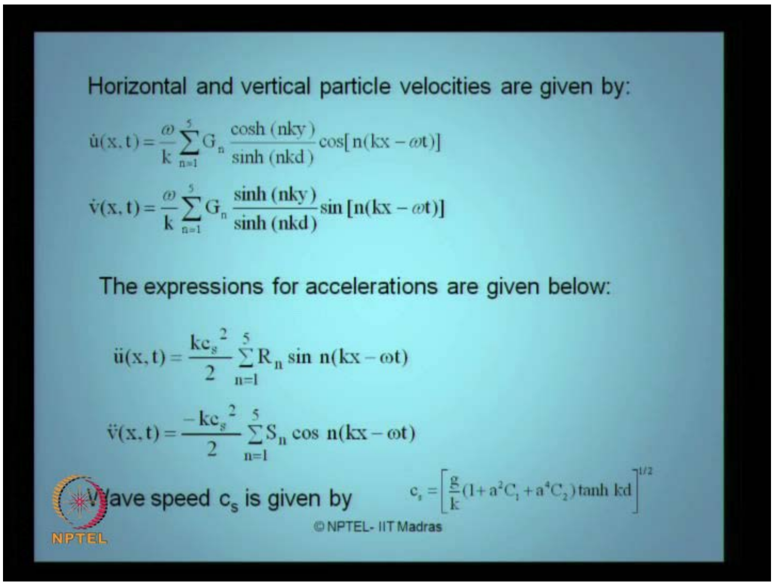

Once I get my sea surface elevation in x of t, then I can find again u dot and v dot, again as a series of 5 terms, n sums from 1 to 5. Similarly, accelerations again summed up from 1 to 5, where R n’s, S n’s n etcetera G n’s are all available as constants given in the literature. I am not talking about them here, whereas, c s in this equation is the wave speed, which is given by an expression as you see here, where again the constants c 1 c 2 etcetera are there. So therefore, Stokes fifth order wave theory is essentially an empirical base device relationship, which is applicable for deep waters, where d y lambda is more than 0.1.

So, we quickly saw two theories. One is a simple simplified linear theory, which can be applied to estimate the water particle kinematics and the corresponding accelerations and velocities. Subsequently, you can also use high order wave theory to estimate again u dot v dot u double dot v double dot, if you are interested in going for more accuracy in the calculations. So, with the example of these two theories, we already know how to estimate the first concept in the wave force, which is defining the sea state and estimating the kinematics.

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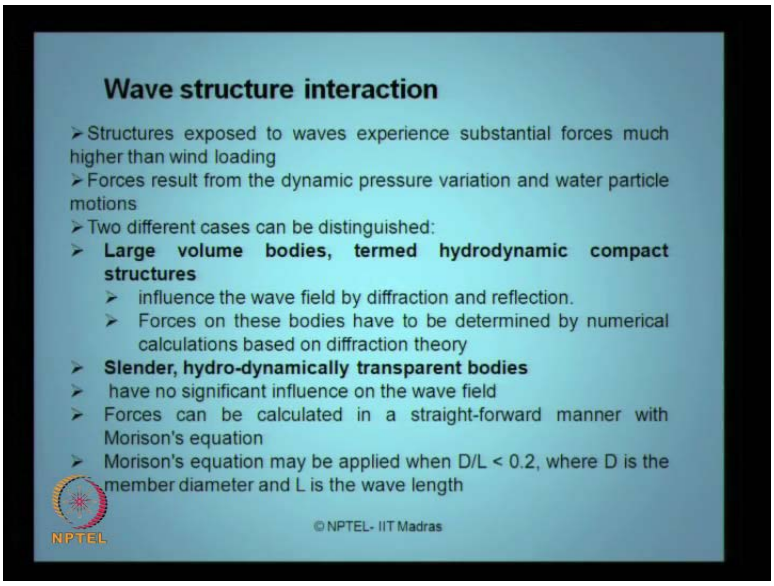

Coming back to how to estimate the forces in the member or in the structure, we study quickly about wave structure interaction, structures which are exposed to waves experience substantial forces, which will be subsequently higher than that of the wind loading. It has been seen in the literature that we compare the magnitude of forces caused by wind against waves, wave action is more severe than wind action on structures, right. So, forces result from dynamic pressure variation and the water particle motion, two different cases are available in the literature, which are distinctly different. One is large volume body and other is slender hydro dynamically transparent body.

If we talk about large volume body, then they are called hydrodynamic compact structures. The influence of wave field on the structure will be by diffraction and reflection. When the wave hits the structure to diffract as well as part of the wave particles will reflect from the body. Forces on these bodies have to be determined by numerical calculation, based on what we call diffraction theory. If you talk about slender hydro dynamic transparent bodies, they have no significant influence on the wave field, because they are transparent to hydrodynamic wave field. Forces to be calculated in a straight forward manner given by Morison equation. Morison equation has only one limitation. The D by L value should lie within a limit of 0.2, where d, the diameter of the member, it is a capital D here, where L of course, is the wave length.

So, if a member satisfies this criterion, whether diameter by the wave length is within 0.2, I can use Morison equation to estimate the forces. So, I am moving to the second part here. The first part said how to identify the sea state. We have discussed two theories. Simple linear Airy's wave theory given by stretching modifications. There are some limitations in this theory. People never accepted this theory for higher order perfect calculations. But for preliminary values, this theory is still valid. People went further down the step and saying, I am going to use higher order theories. Stokes fifth order theory is recommended. So, using both the theories, I can estimate the kinematics of water particle in horizontal and vertical axis.

Once I know this, I can quick up a member, which is hydro dynamically transparent and I can find out the wave forces on the member. You may be worried that, why we are not talking about large volume bodies in the course. As I said, if it is a gravity based structure, it can be a large volume body, where we estimate forces based on diffraction theory. But mostly, all our structures, which are ocean structures on offshore platforms, are slender in nature. So, they are hydro dynamically transparent systems. We will talk about using Morison equation in these kinds of systems.

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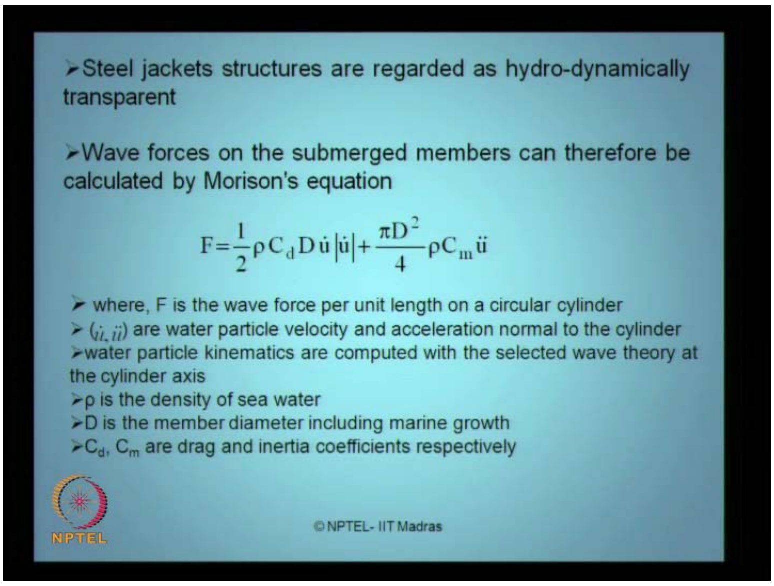

So, for example, look at steel jacket structure. They are hydro dynamically transparent. So, the steel jacket structure has the members fixed at the bottom. So, there is no relative movement of the structural member with respect to that of the waves. So, it is fixed at the bottom. Therefore, I can easily find out the forces from this expression, where f is the wave force per unit length on the cylinder, whereas u u dot, I mean, u dot, u double dot, C d C m are all standard functions, which are available in the literature. Where one is called drag coefficient C d and other is called inertia coefficient C m. rho of course, density of sea water, D, capital D is a diameter of the member and of course, u dot and u double dots are velocities and accelerations in horizontal axis of the member. So, you can easily find out the force, if it is fixed like in case of steel jackets structures.

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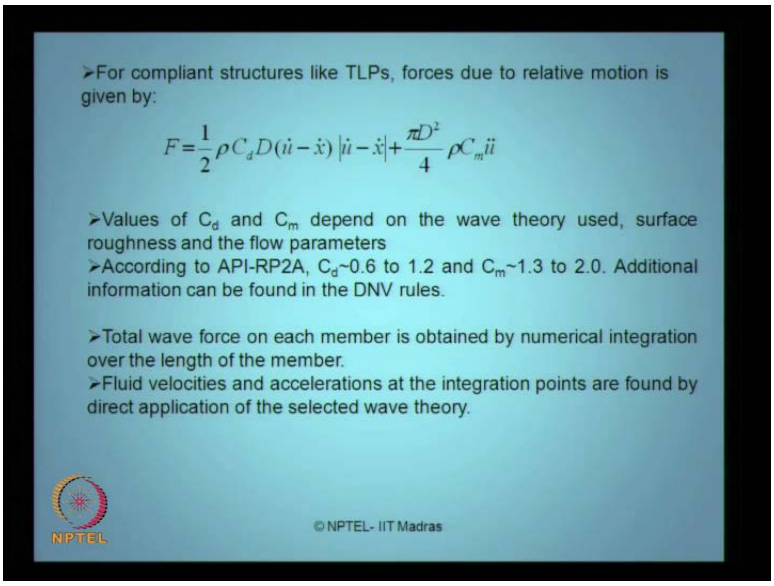

In case of compliant structures, for example, like TLP's, we already know compliance stands for the word movement is a relative motion. Therefore, the structure also moves either in the wave direction or the direction opposite to the wave propagation. So, x dot here is a structural velocity. So, I will try to find out the relative motion between the structure or the member and the wave, therefore the velocity terms are modified as u dot minus x dot. And there is a product here, u dot minus x dot and there is an absolute value of u dot minus x dot. There are two reasons why this term, which is drag associated term is important. This force has got two terms. One is called the drag term, because C d term is appearing there. C d stands for drag coefficient. Other term is C m is called inertia coefficient or inertia force.

So, if you look at the drag term, there is a product of u dot minus x dot multiply by u dot minus x absolute value. This product makes the drag term non-linear. That is why we call non-linear drag. This term makes the drag term non-linear number one. Number two, the absolute sign of u dot minus x dot preserves the direction of the force.

For example, if I do not have this absolute value, you will see this product, if x dot is more than u dot or x dot is an opposite direction of u dot, the multiply will make it always positive. But then I will not be able to prevent or let say preserve the directionality of the force. So, I am putting absolute value in one of them, so that, the directionality of the force is also protected in the calculation. So, this term is very important for us because of two aspects. This introduces non-linearity in the force. Two, this gives me a relative understanding of, in what direction net forces apply. Is it in positive x or negative x? Is that clear?

So, I can easily estimate the force in the member, at any point I want on a given member, because to estimate the force, I need two things. I want the velocity horizontal or vertical and I also want the acceleration horizontal or vertical because you see, here in this force term, two things are required. One is u dot and other u double dot also. I want both, velocity and acceleration.

So, I qualify this from specific theory, may be Airy's theory or may be Stoke's fifth order theory. Once I get this, I find the force in a member at any point of my interest as F 1 F 2 F 3 etcetera. I can sum them up all to get the member force in the entire structure, as I did for wind forces also. So, this is how I estimate the forces in the member counteracted, because of wave actions. Any doubt? Any difficulty here? This is one of the important environmental loading, which will come on the offshore structure. There is a tutorial based on this at the end of this lecture. I will give you that. So, you should be able to solve them.

So, anyway, in this lecture, we are not focusing or the course itself, we are not focusing on how to estimate these forces in detail. But when I move on to the second module on this lecture, I will show you some examples using coding, how the forces have been estimated. I can even pass on the mat lab coding to you. You can work out the forces yourself. But I will not be able to solve the problem explaining you how to work out force on every point of y 1 y 2 y 3. That is not required. You can do the exercise at your own level. Yeah, that is interesting part. I will come to that, when I have to do what we call modify Morison equation. That will come as an added mass term. It is a very interesting question. Why we are not considering the relative acceleration? That is fine. That is called added mass term. We will talk about, because I am talking about the added mass term because m x double dot will be the inertia force exerted by the structure. m x double dot will be the inertia force exerted by the structure. I will handle the term separately in my analysis. It is there. It is very much valid. It is there, but I will handle it separately.

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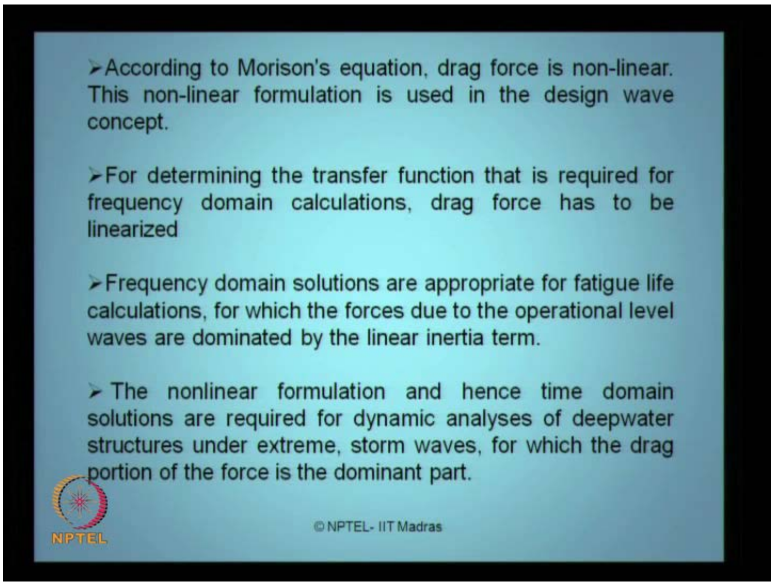

I think, I can skip this because most of this is important only in theoretical point of view. We have already said Morison's equation force is non-linear etcetera.

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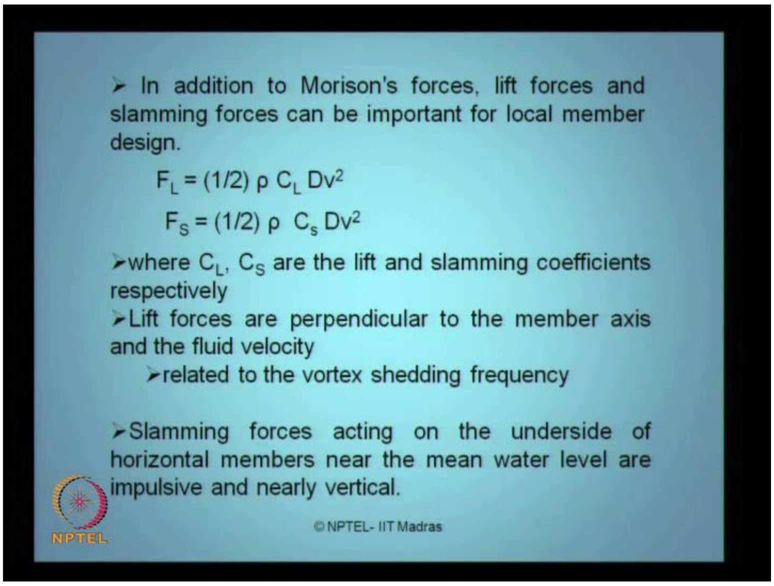

In addition, we have got also called lift force and slamming forces, F L and F S, whereas, C L and C S are called lift and slamming coefficients. The lift force is generally perpendicular to the member axis and it is related to the vortex shedding frequency, whereas, slamming force acts on the underside of horizontal member near the mean water level and are impulsive and more or less vertical. Not necessarily vertical, nearly vertical. So, that is about the lift forces and slamming forces. So, we talked about the wave forces. Wave force on horizontal vertical direction from the water body plus lift and slamming forces as well, if you know the equations here.

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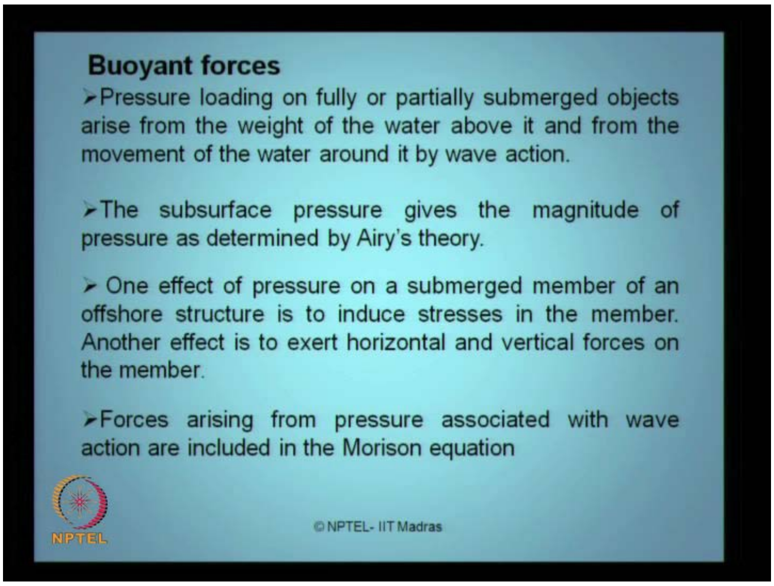

We will talk about buoyant force. We already know when the body is partially submerged, because of the displaced volume of the body, I get a buoyancy force. We all understand this buoyant force. It is very simple to compute. A buoyant force acting around the structure, it acts at a point which is called centra buoyancy for a given whole structure or a single cylinder, depends upon the submerged volume or the displaced volume of the member in water.

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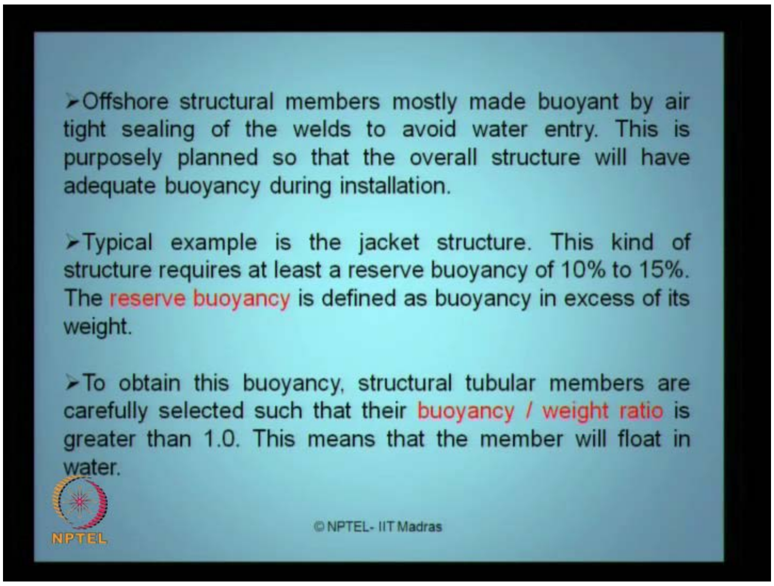

Offshore structures have a very specific concept called reserve buoyancy. Reserve buoyancy is generally about 15 percent. What is reserve buoyancy? It is actually defined as buoyancy in excess of its weight. Specifically, weight and buoyancy if they match each other, then there is a complete hydro dynamic balance. But I used to have reserve buoyancy, where the buoyancy will always be in excess of its weight. That is what we call reserve buoyancy, because I need this for installation, decommissioning, floating etcetera. So, generally steel tubule members are carefully selected, so that, the buoyancy weight ratio is always greater than 1. That is, the weight compared to the buoyancy is always lesser. So, buoyancy force is higher, so that, I have reserve buoyancy in my given structural system to make it a floating, when I want to install, commission, decommission etcetera. That is a general concept what we do in case of offshore structures. Talking about current forces, we spoke about wave forces; we spoke about wind forces.

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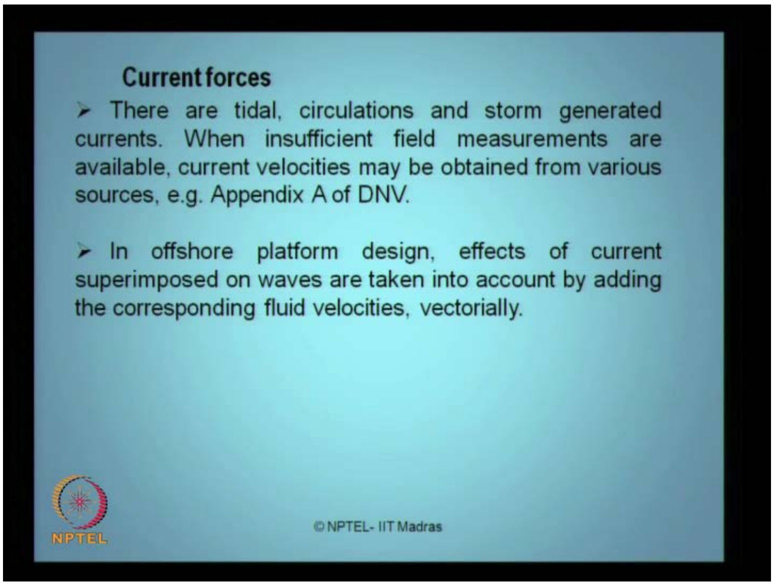

We also saw slamming and lift forces. We did talk about the current forces, the tidal, circulation and storm generated currents exert additional forces on the member. When insufficient field measurements are available, then current velocities may be directly taken from international course. One example is, appendix A of DNV code. In offshore platform design, general effects of current are superimposed on waves. That is a very important concept.

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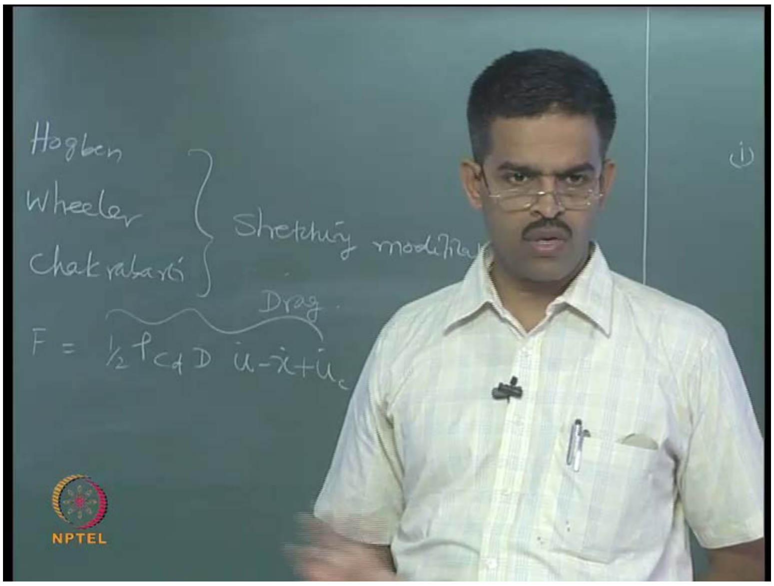

What I do here is, if we look at the Morison equation force, let say half rho C d dia u dot minus x dot plus u dot of c. I will just superimpose the current on the water body velocity itself. That is why I modify this. So, in offshore structures, this is only a drag component. Similarly, we have the inertia component also. So, I superimpose the current velocity directly on waves and find out additional force. I add them vectorially. That is how I will take the influence of current on my structural system.

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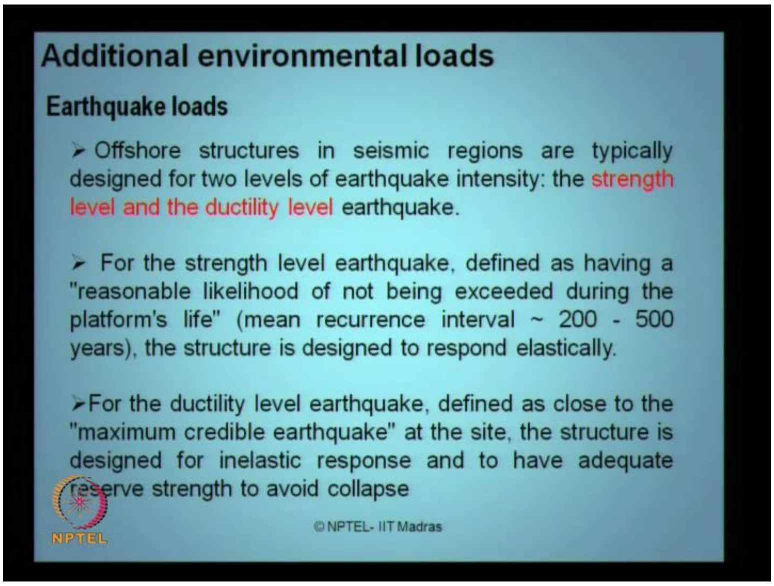

Look at the additional forces acting on the structure, one important additional force coming on the structure in offshore structure is earthquake load. Offshore structures in seismic regions are typically designed for two levels of earthquakes. One is called strength level and other is called ductility level. For strength level earthquakes, they are defined as reasonably likelihood of not being exceeded during the platform life. The mean recurrence interval of these earthquakes is about 500 years. The structure is expected to design elastically for this kind of force.

For ductility level earthquakes, is defined as close to the maximum credible earthquake. What m c e in the analysis, the structure is designed for inelastic response and have adequate reserve strength to avoid collapse. It means, one methodology of estimating earthquake force talks about elastic response, which is nothing but the strength level. The other method talks about the inelastic response, which talks about the ductility level and I think we can quickly understand, if we look at the stress stain curve.

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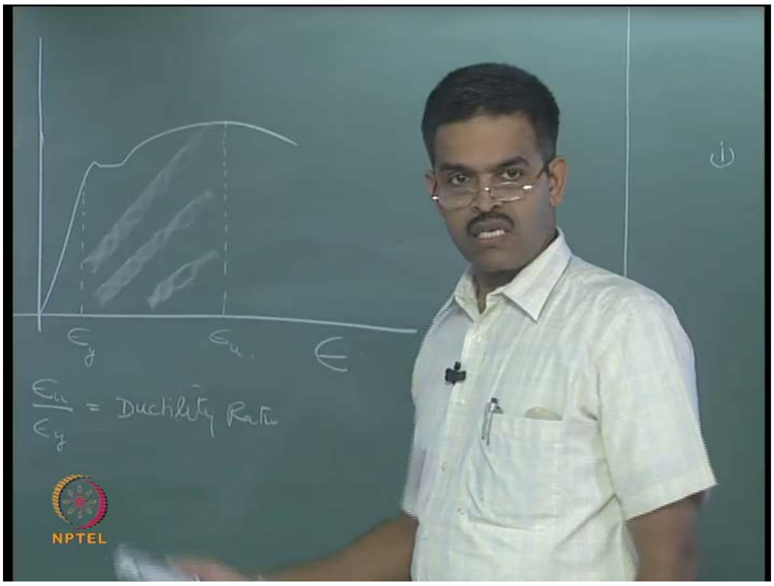

The stress strain curve of steel, which is one of the favorite materials for construction of offshore structures is a strain axis. This is stress axis is a typically stress strain curve of steel, which is being used for offshore construction purposes. Look at my strain value at ultimate. To strain value at yield, I call this strain at yield value. The strain at ultimate. The strain at ultimate; the strain at yield is what we call ductility ratio. For steel, can be as high as 6.

So, steel has got an enormous capacity of strain at ultimate, compared to strain at yield, 6 times. So, this area is very large. So, one can look for Ducticle level design also in earthquake loading for offshore structures. This is what we use in case of plastic design of structures. We are not going to talk about in detail now. So, we are interested in how to estimate the forces, not the design.

Now I wonder, that when we talk about analysis, why we are talking about design? Is there any relationship between analysis and design? First of all, what is analysis and what is design. Quickly. What is analysis and what is design? I mean, it is a very fundamental question. That is, in case of analysis or design? So, when you talk about analysis, as you said, analysis is a part which explains me how to estimate forces coming on the structural system. Not only the forces, but also the responses. For example, what is a deflection, what is a bending moment? All these are analysis; what is the stress level, what are stain level. Then what is design?

Based on these calculated values for a given force, based on the given response of a structural system, based on the material characteristic of the member, we also find out the cross section dimensions of the member. Now interestingly, if we do not know the cross section dimension of the member, you cannot do the analysis. Because, to find stress, you need area. To find area, you note the diameter. Now, diameter obtaining is a design part. So, analysis and design are inherently coupled to each other. You cannot separate them. Is that clear?

So, what we generally do is, we preliminarily assume a dimension of the member; do the analysis; always check the analysis and design for the safety of the member. So, analysis and design are together. We cannot separate them because if you do not know the design concepts or design criteria of the member, you cannot analyze it at all. So, that is why in case of design and analysis. In case of dynamic analysis, we talk about design also partly, but anyway the ductility level and strength level are leading forward to a plastic design of structures like this. So, we will not talk about that in this course. But still there is a clue that this will help us to talk about plastic design of structures in case of offshore structural systems.

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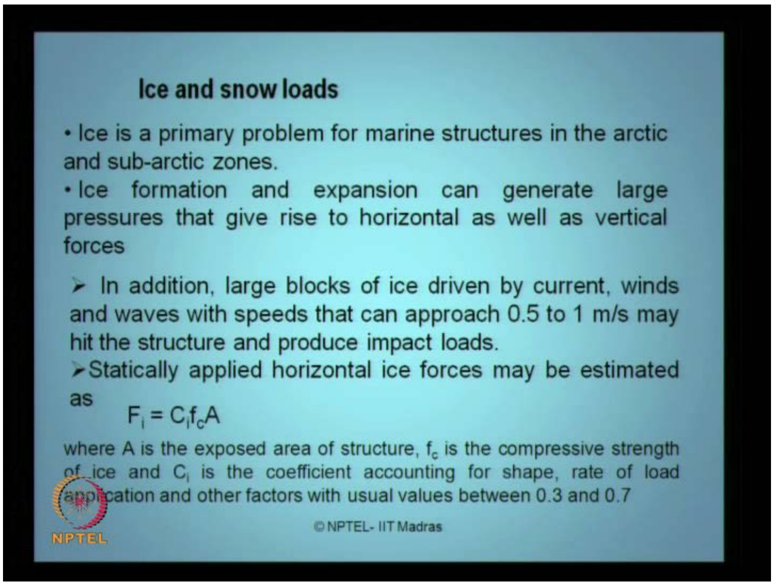

Look at the Ice and snow loads. It is very simple. Ice is the primary problem in arctic region, because ice of huge blocks can come and hit the structure. They can cause impact loads. So, the impact loads caused by large block of ice, can be easily obtained from an equation F i C i f c n A, where a is exposed area of the structure, whereas f c is a compressive strength of ice and C i is the coefficient accounting for shape, rate of load application and other factors. Generally, the value lies between 0.3 to 0.7. So, I can find out force at any point i, which is f i caused because of impact load coming from the ice formation on a given offshore platform.

So, this can be statistically estimated as a horizontal ice force, F i from the simple expression, which is very much valid in case of arctic regions. So, it is very interesting for us to know that, ice can approach the platforms at a very velocity equal to about 1 meter per second also. It has very high velocity, right. It can come and hit the structure. Therefore, ice loads are substantially high. So, we must account for them.

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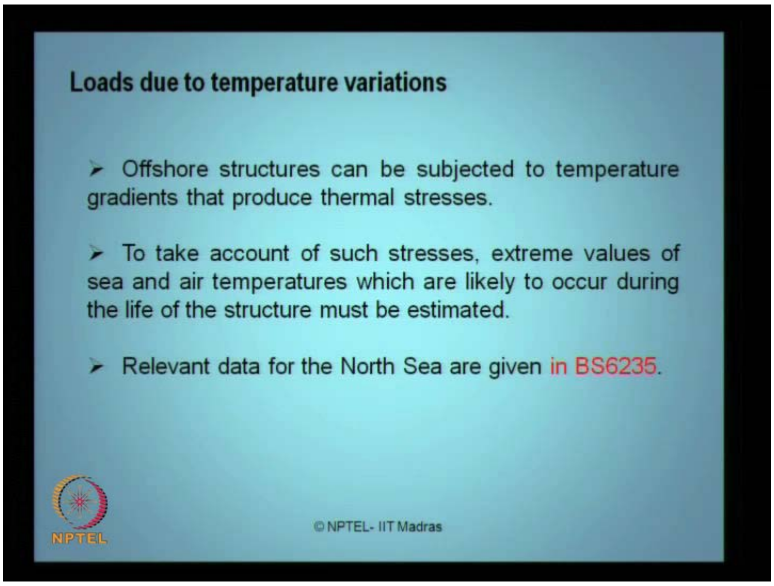

Interestingly, there can be loads caused because of delta t, that is temperature or thermal variation. As we understand along the depth of an offshore structural system or in a sea, there is a tremendous variation of temperature. This will influence, because the member is common. The member is running from the m s l till the depth of the structure r of ocean. But the temperature here and temperature here are different. So, the member can be subjected to additional loads passed by this thermal variation. So, they are ultimately given for a specific data available in North Sea in BS6235 for example. One can calculate the additional stresses caused by this thermal variation on the members.

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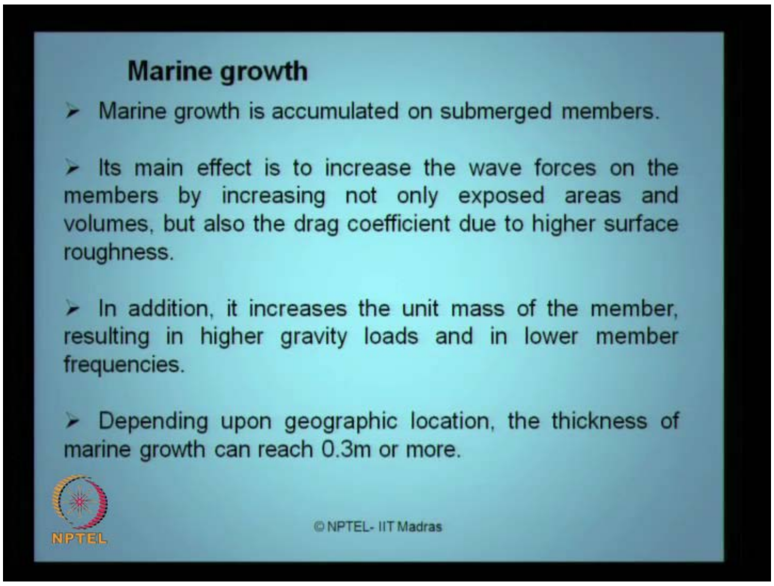

Interestingly, marine growth is a very important problem as far as offshore structure is concerned. Marine growth is nothing but accumulation of biological organism around the surface of the member. To increase the diameter of the member, there are very severe problems related to marine growth. The diameter of the member is increased. So, marine growth has problems.

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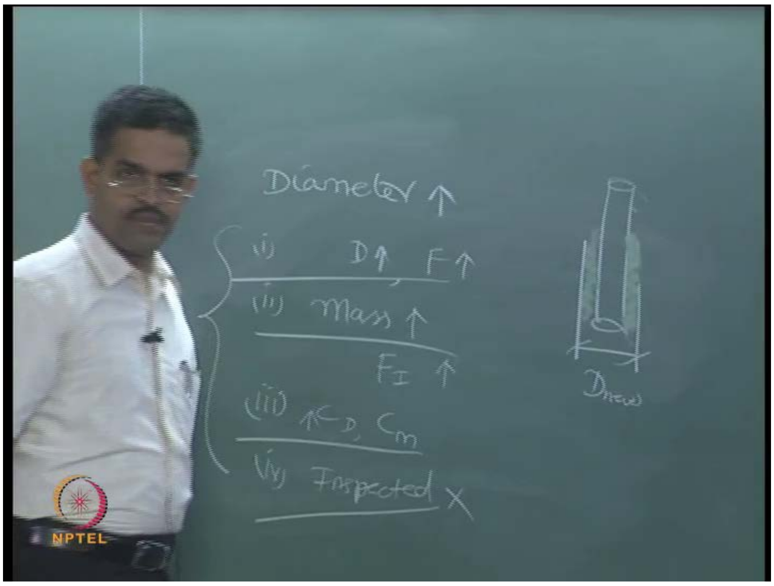

It increases the diameter of the member, because around the member, there can be substantial growth of marine. So, the diameter of the member is now increased, D mu.

So, diameter has gone high. The moment the diameter goes high, force due to Morison equation goes high because force is a function of dia, half rho C D dia. There is a function of diameter here.

The diameter increases, force will increase. That is first problem. Second problem, as the diameter goes high, it adds the mass to the structure and my inertia forces will increase. The third problem with marine growth, it also changes C D and C M values, which are the coefficients used in equation because if the surface becomes smooth, C D is different. The surface becomes rough, C D is different. Here, the roughness on the surface increases, the C D. We have just now saw C D. If C D is increased, force on the member automatically increases.

The fourth problem, it will not allow the structure to be inspected. You cannot inspect the region of the structural system for any failure because marine growth will cover the structure; cannot inspect it. So, these are couple of very serious problems associated in terms of its maintenance as well as in terms of its design and analysis, as far as marine growth is concerned. How it is actually done? It is done by equating the compensation in terms of increasing the thickness of the member, the design itself. That is how it is compensated in the design. The marine growth can increase the diameter up to about 0.3 meters also. It can be 300 mm. So, as thick as that.

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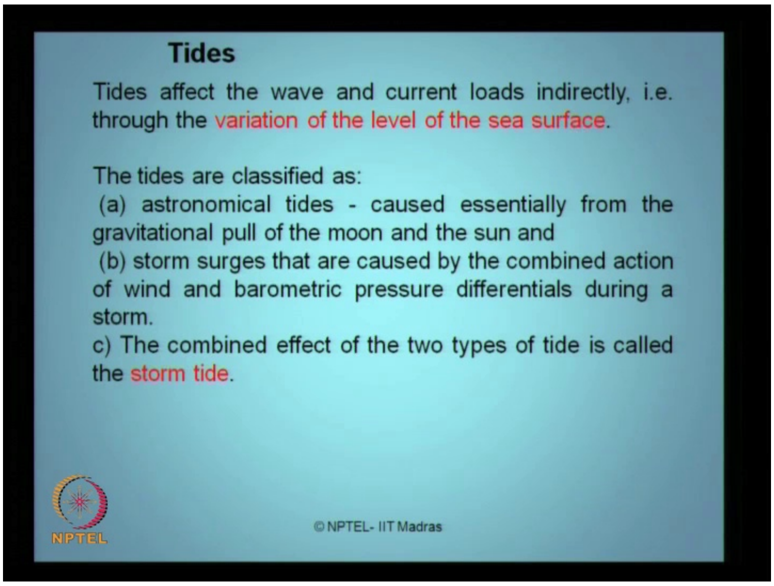

There can be also additional loads because of tides. Tide affects the wave and current loads very seriously, through the variation of the level in the sea surface. Tides can be of two types, astronomical and storm surges. Astronomical tides caused essentially from the gravitation pull of moon, whereas, storm surges are caused by combined action of wind and barometric pressure. The combination of these two is what we called storm tide.

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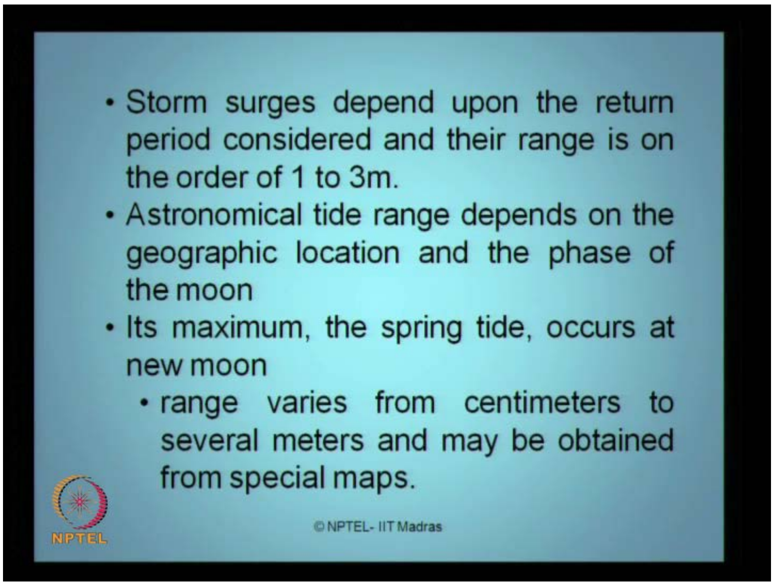

Now interestingly, this leaves, storm surges can be as high as 3 meters even. It is very high. Astronomical tides depend on the geographical location and the phase value of the moon actually.

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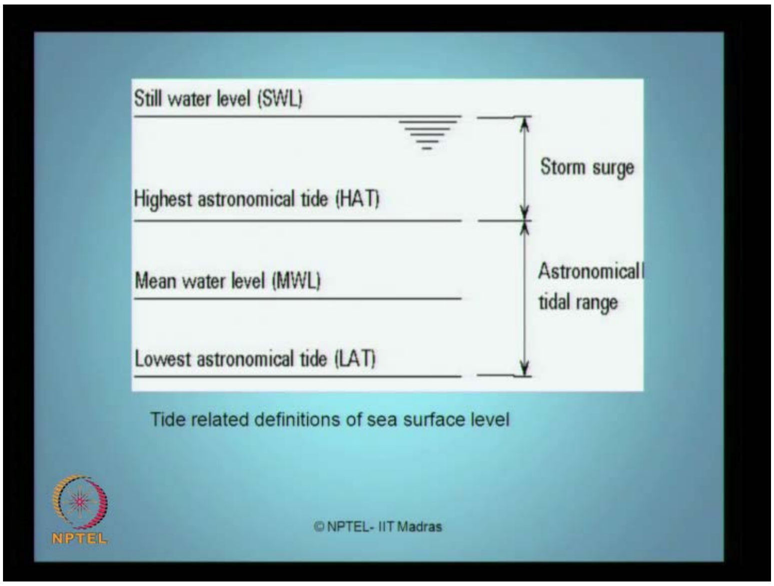

So, this is a very interesting part. Depending upon the storm surge and astronomical tides, the mean water level, the mean water level as you see here, gets redefined. So, what is the problem when this mean water level gets redefined to still water level R to HAT, that is high astronomical tide. The problem is, as this mean water level, which is to be considered in the analysis, goes higher, the immersed volume of the cylinder gets increased. The immersed volume changes buoyancy of the material or the member. The buoyancy force is increased. When the buoyancy force increases structures like TLP SPA, where they are moved to the sea bed, then the force on the teeth was gets changed. It means, astronomical and storm surges include additional forces on the members like this.

So, actually they redefine the mean water level. Just now, we saw Airy's theory cannot be applied, if you want to extend this or stress this beyond the mean water level. Of course, there are stretching modifications suggested by different researchers. But still, it is not accurate. So, the mean water level added to storm surge and astronomical tide ranges will vary and will alter the force on the members indirectly by improving the submerged volume of the member.

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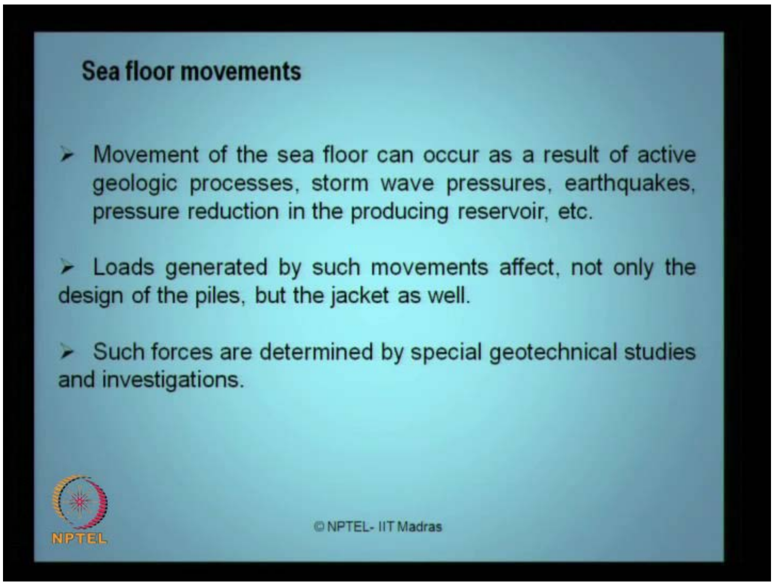

So, that is the effect of tidal forces on the members. Interestingly, sea floor movement can also happen. That also causes displaced type of forces on the member. This is very serious when you talk about fixed platforms or gravity based structures. Now, why this is not important for floating structures or structures which are compliant in nature? Because, the structure of compliant in nature does not rest on the sea bed. They are only anchored to the sea bed. Therefore, influence of sea floor movements on this kind of structures will be less influential. It will be very less, whereas in jacket structures, whereas in the case of a pile supported or pile rested structures, they will be severe.

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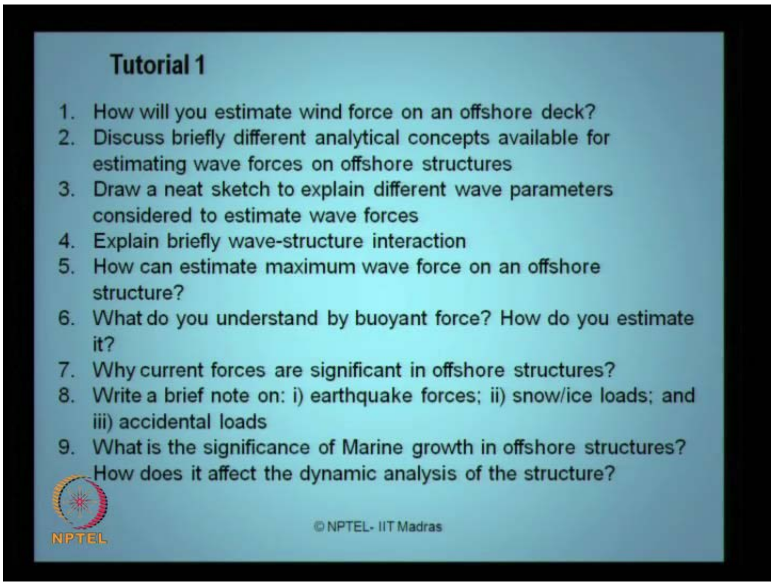

So, these are the different kinds of forces what we saw. In the next lecture, we will talk about the characterization in dynamic analysis. We will move to single degree of freedoms. I have got tutorial sheets for you. So, quickly copy down these questions and these are self-answered. You should be able to answer them on your own. How will you estimate wind force on offshore deck? Discuss briefly different analytical concepts available for estimating wave forces on offshore structures. Draw a neat sketch to explain different wave parameters considered to estimate the wave forces on members. Explain briefly what you understand by wave structure interaction. How can you estimate the maximum force on a given offshore structure?

What you understand by a maximum force on a given offshore structure? You have got a member, may be fixed or compliant. The direction of movement of the member may not be in the same alignment as that of the wave. Wave may not approach the member always at the access of the member. It can be even directional also. Therefore, the component, the phase component phi plays a very important role and we know, the sin and cosine components, which are u dot and v dot on a given member may not occur simultaneously. They are out of phase by 90 degrees. So, at a given point of time, one must have an idea, what is a maximum wave force coming on the member. Is that clear? How will you estimate that? That is what I want to know from you.

There is a empirical equation given for this. It is available in one of my books, which I wrote, which I gave you as a reference; myself and Bhattacharyya. So, look at that book. We have an equation. It is a closed form for estimating the maximum wave force on the member. What do you understand by the buoyancy force? How will you estimate it? Why current forces are important in offshore structures? Write a brief note on earthquake forces, snow or ice loads and accidental loads which are caused on offshore structures. What is significance of marine growth and how it is important for dynamic analysis in offshore structures?

So, the clue here is, as far as the diameter is increased, force increases; in my dynamic analysis, f of t enhances. The diameter increases, mass increases. In dynamic analysis, inertia component of the force increases. So, it is important for me, why marine growth is necessary to be accounted in the dynamic analysis of offshore structures. That is the first tutorial in this lecture, which you like to answer for self-assessment.

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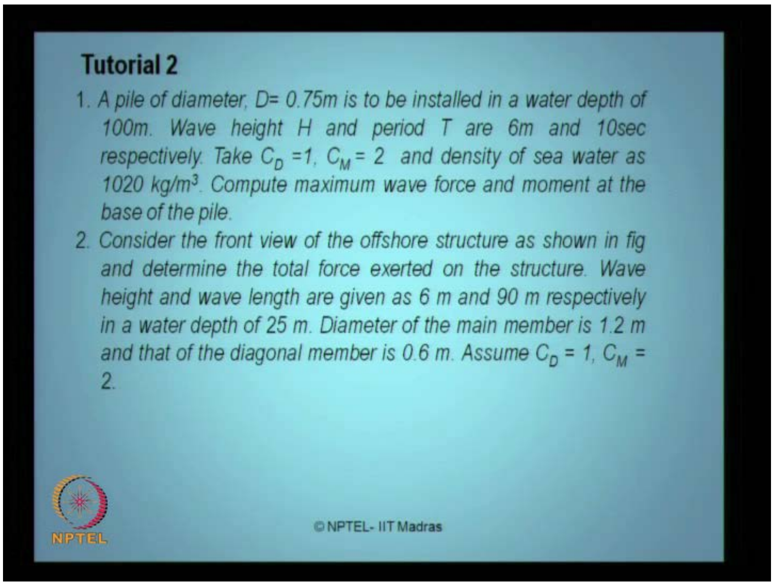

The second tutorial will be on problems. So, I have a pile diameter D. What I will do is, I will take a print out of this and pass on to all of you. So, you need not have to write them. You can try it to solve them. Remember very clearly, none of the questions in the examination will be based on this. Do not try to think that you will answer them and try to bring it here; copy it. Not going to help you at all. I will not ask you even a single question what I have given in the tutorial at all to you. I will ask questions based on this, but it is slightly in different perspective.

I will print this and give it you, because I see lot of faces which are getting worried, because they are not able to write faster. I will copy this and give it you. So, I have got three problems. A pile diameter D of 0.75; C D C M are given; C water density is given; wave height and wave period, 6 minute, 10 seconds are given. I want to compute the maximum wave force in the movement on a base of the pile.

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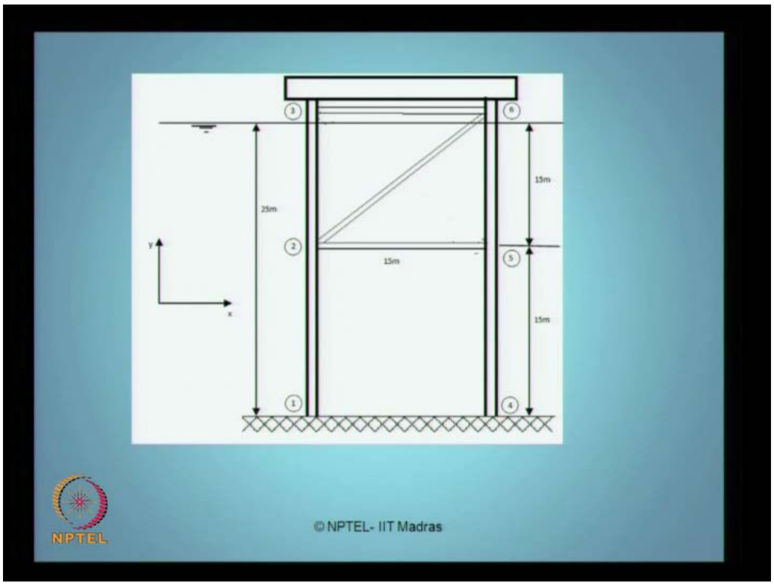

The second example is, depending up on the figure here, I have a problem. Members 1 2 3 4; notes 1 2 3 4 5 6; 30 meter depth. It is to be 30 meters because it is 25 written there. It is 30 meters, 15 and 15 and the length of the member is 15 meter. I want you to estimate force on all the members.

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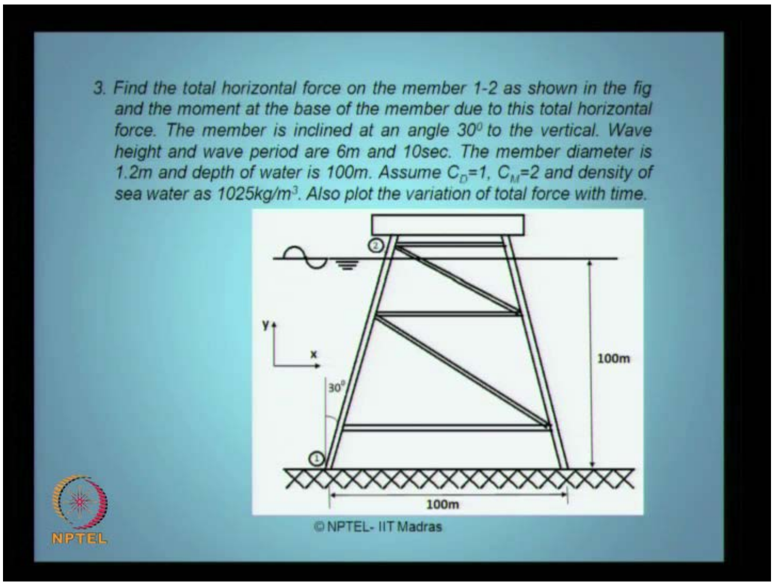

The third problem is again same as jacket structure. I want to estimate the force on the member 1 2, which is inclined using Stokes fifth order, as well as Airy's theory. That is the estimate which is given to you. You must be able to solve this tutorial with the help of the lecture support what I have. Reference materials are available in the website of NPTEL under this course. So, if you have any difficulty, we will have few minutes to answer, otherwise we will close the lecture.

So, we have discussed in detail about the types of offshore platforms, their structural action, the coastal structures, their structural action, the necessity, the requirement of constructing these structures, and the water depths where they are constructed, basically the historical development of offshore structures, right from shallow waters to super deeper ultra-deep waters. We also saw something about new generation offshore structural systems. Why they are constructed and how they evolved etcetera. We also briefly understood what are the different types of environmental loads coming on offshore structures. We have enough tutorials for self-learning. You should be able to accommodate yourself on understanding these concepts thoroughly before you come for the next lecture, where we will talk about dynamic characterization of structures and we will talk about single degree of freedom in another 10 more lectures.

So, any doubts you have here? Otherwise we will stop. So, examination for quiz 1, the date is fixed. But I want to slightly alter it. I do not want to miss the class for the quiz 1 on Monday, because it is going to fall on Monday, 27th February, if I am not wrong. It is Monday. It is not morning. So, I do not want to have the quiz at morning here. I will run the class. So, you can give me a date parallel to that on a Saturday. We will have a quiz on a Saturday, parallel to the date. Either prior to that or just after that. We will have an exam on Saturday. So, we do the exam in the department itself. But as far as the class is concerned, I do not want to waste the time slot of the class. We will have the class.

So, you can decide and tell me when do you want to have the quiz 1. It is tentatively 27th of February, if I am not wrong. I will check up. That is on a Monday. But I want to either have it on 25th or following Saturday. It is no problem for us. 27 is Wednesday. Then may be, so it is on a Monday, a slot. So, you can check up that. I do not have the calendar right now with me. You can check up that. So, there are no more questions? Then I have the attendance sheet back.

Thank you.