Advanced Marine Structures
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Lecture - 5
Environmental loads -01

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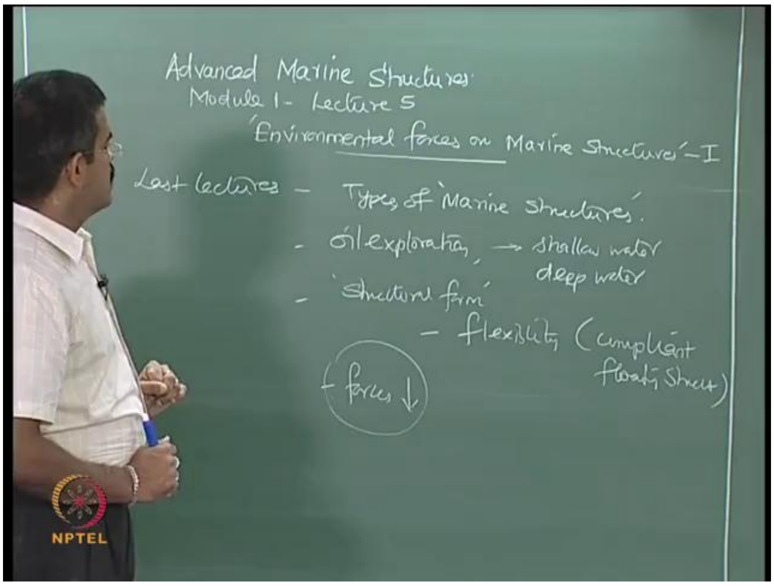

So now, we are continuing to discuss the lectures on course title advanced marine structures. This is lecture five on this course, where we will talk about it today, different environmental forces acting on marine structures; this will have two lectures or possibly three we will do some numerical examples. We will explain you in detail how to compute the environmental forces variety of forces acting on marine structures. Let us, quickly see in the last lectures, we discussed about various types of marine structures. The moment I said marine structures they have got a specific purpose for which they have been designed. The fundamental purpose is exploration of oil in deep sea. So once I said that oil exploration becomes a primary objective of this kind of structural systems.

Oil exploration started moving from shallow waters to deep waters therefore, it was very obvious for us to understand that the structural form or the system, which has been used to deploy achieve shallow waters cannot be used, exactly the same format with the tough deep waters. So there has been a phenomenal change in the structural geometry what I say, a structural form, which is meant for the same function but at greater water deep. So the movement I say movement structural form, then people thought about introducing flexibility in the motion of the structures, which we call as compliant or floating statistics.

So the movement I introduce flexibility then the question comes, the forces attracted by these kinds of structures are becoming lesser but these structures have other difficulties related to the frequency or the time period at which they have the fundamental mood of vibration. So when you gain one advantage, when you gain another advantage of deploying them in deep waters you are parallel another difficulty of adding complexity, because of its structural behavior. So, in this lecture we will talk about what are those environmental forces, which act on any type of marine structure in general.

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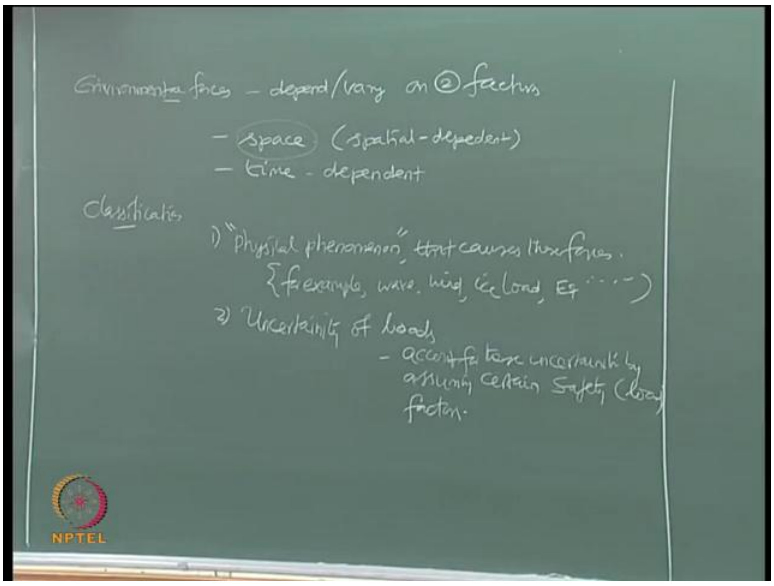

So now the environmental forces can be broadly classified before we study about the classification of these forces they depend essentially or lets say they vary essentially on two factors. So they vary with respect to space and they vary with respect to time. So the environmental forces acting on marine structures has got two implicit variables present in the system depending upon a special location, where you estimating this forces and also depending upon the time at which this forces are estimated. So they are time dependent and spatial dependent. Now I want to classify them. So when we talk about classification of these forces, I can classify them broadly by two ways. One could be based on a physical phenomenon, which causes that the physical process, which causes these forces can classify them for example, wave forces, wind forces, ice loads, earth quake and etcetera.

The second classification can be depending upon the level of uncertainty of loads. So one can quickly understand how uncertainties are addressed in such analysis procedures we account for these uncertainties by assuming certain, I should say safety but in the bracket I should say load factors. So one can classify them depending upon the group of uncertainty of the loads, one can also classify them depending upon the originating physical phenomenon based on, which these forces are generated, having said this that the classification can be based on the physical phenomenon or the group of uncertainty.

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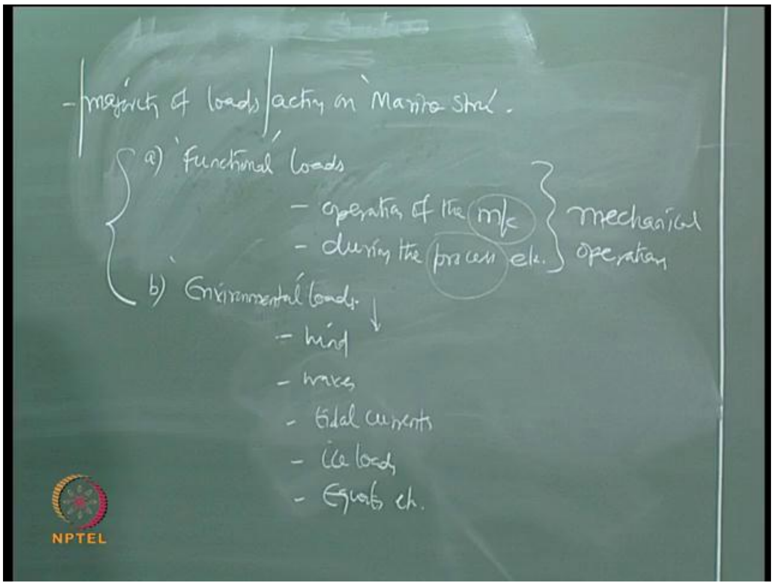

Then, let us see what will be the major majority of the loads acting on marine structures. What would be the majority? the bigger class of loads, which generally act on marine structures. a there can be functional loads, functional loads or those forces, which essentially arise from operation of the machinery, during the process etcetera. So they are related to mechanical operations. The second of course, will be from the environmental, which now gets classified as forces, which comes from wind, which comes from waves, which comes from tidal currents, which comes from ice loads, which comes from earth quakes etcetera. So again there are two major areas or major divisions of forces or loads, which act on marine structures. One essentially come from the functionality part of the platform, the other essentially comes from the environmental part, where the site is located.

So as you understand depending upon the structural form what to select for a specific type of marine structure to operate at a specific sea state to operate at a specific water depth, one can try to manipulate the arrangement of members, so that the environmental loads coming on the structural form chosen can be reduced. So we have this liberty as designer to select or to choose the structural form, which can eliminate these kinds of loads in a very efficient, intelligent and acceptable manner. On the other hand when the platform has got to perform intended function depending upon what kind of machinery the platform should have, what kind of operation the platform should perform therefore, the forces coming from the functional aspects cannot be compromised.

So there is always a balance between these two, if we select a form only to reduce the forces coming from environment, so that you think there is the structure has been chosen intelligently, then the chosen form of the structure cannot be performing the intended function or if you give the focus only on the intended function, then the environmental loads affecting on such a large platform can become higher for example, gravity based platforms, which are essentially having lot of caissons, where you got large storage capacity, in that case they attract lot of environmental forces.

So one may seen interestingly understand in the selection or in the origin of thought of marine structures, people made very intelligent balance between the functional performance and the forces coming at the specific location, where the platform will be commission. So is before understanding how to compute these forces independently on a member or/and a group of members what we call as marine structural system. Let us try to understand this first that before you encounter or calculate these kinds of forces be thorough in understanding the concept of choosing a structural form for a given marine structure. So the form alone is not important because the chosen form should perform the intended function but function alone is not important, because then they will start attracting more forces I have given example.

So there is, there is have to be a balance between this particular aspect and this particular aspect, which combined together form a single capsule of majority of loads coming on the marine structure. In addition to this you got accidental loads impact and short loads, which also come from the structure because of unforcing consequences, which can apply or which can exert on the given structural form, this can be common to any type of any chosen form of marine structure because they are unforcing and unpredictable loads. So we have now classified the forces based on the physical phenomenon and based on uncertainties.

Why I am classifying them based on uncertainty also because I am going to talk about different methodology finalizing design in the same module later, there I will talk about different kind of load factors or combination of loads for example, all loads need not be combined together to act simultaneously on a marine structural system. There is always independent and intelligent guess which load should be combined in what format with what weightage therefore, uncertainty plays very important role because all forces as you see here may not have the same level or degree of uncertainty as they can be predicted.

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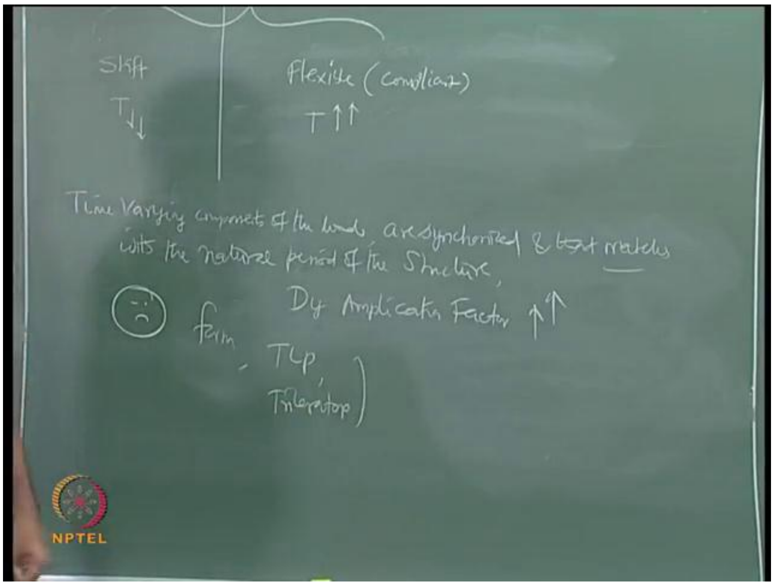

Some of them can be predicted to very high accuracy, some of them cannot be therefore, you cannot simply combined all of them and say I am going to design an marine structural system for the worst combination that all forces are acting simultaneously that rather becomes very hypothetical situation. Is that clear? So we are seeing that functional aspect and the form both are important to estimate the forces or loads coming on the marine structural system. Now have been said this as I see the structural system can be have two different forms, one can be very stiff system whose time periods, I am talking about time periods of the structure, which is very low.

So we call this is very stiff because we understand that time periods being very low giving high level of stiffness to a member or to the structural system. The other verity can be flexible system or what we call as compliant system because the structures start moving or getting displaced under the exerted forces. They have the natural periods as vary, now there is a very clear bifurcation in the structural form itself obviously when time varying components of the loads, please understand this statement very clearly, I already told you that the loads has got two components, one is the spatial dependence other is time dependence, for one second let us forget about the special dependence part of the load. We will talk about the time dependence part, if the time varying components of the loads are synchronized unfortunately or synchronized put together and that matches with the natural period of the structure.

Then as you will understand this land up is a very problem what technically we call as dynamic amplification factor will become very large; it means the structure will get excited dynamically. So this is another implicit aspect of choosing a form on the load combination, which unfortunately synchronizes whose period or the dominant period matches with a natural period of the structure. So therefore, one has got to be very careful in estimating the environmental forces or the loads coming on marine structures, because it is not a mathematical computation of finding out forces in the member as we talk about in land way structures.

In marine structural systems, the form itself is not under the governance of the designer because my functional operational governance me the form as we saw in the previous lecture. So if I am bound or compel to select the specific form because of salient advantages of this form on an applied function, then this inherently develop some problems related to dynamic amplification as well, so the combinations become more and more complex as we start looking at the force computation on any structural form divided distinctly under this heading, which are classical examples of marine structures. Now to add more confusion to this, you will see that when I have got the structural form, which is an hybrid combination of stiff and flexible both for example, let us take a case of TLP, let us take a case of triceratop.

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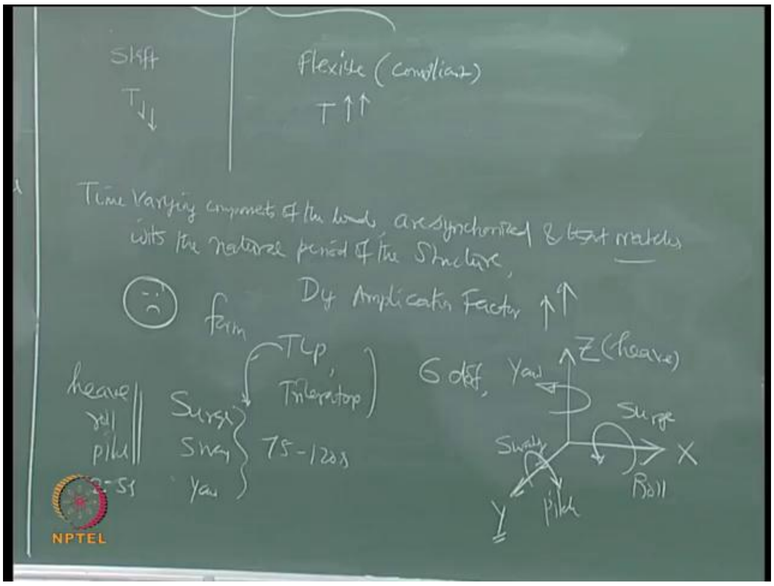

In this case, if there are six degrees of freedom, which I show you here, let us say this is my x axis; this is my y axis; this becomes my z axis and we all understand that the structural system has essentially six degrees of freedom three displacements each along each axis and three rotations one about each axis, so I call the displacement along x axis as surge, the displacement along y as sway you can easily remember this because this y matches with this y and displacement above z axis sorry along z axis is what we call as heave. So there are three distinct displacement degrees of freedom, which happens on along each axis and off course, if you hold your four finger point to your thumb towards arrow direction the remaining four fingers show you, the direction of rotation I marking it this way.

So, if I show it here they will mark me the rotation, so rotation about x axis, which I call as roll similarly, rotation about y axis, which I call as pitch similarly, rotation about z axis, which I call as yaw. So there are three displacement degrees and three rotational degrees making it as six, whereas in structure like triceratops when the decks or isolated from the (( )) structure of the bottom by placing the boil join in between, then there is no transformation of rational degrees of freedom from the sub structure to the super structure therefore, the rotational degrees of freedom on the sub structure are different and the super structure does not get this transfer. So they are independent motion on the deck as well as the BLS as well.

So they got nine degrees freedom six on the DLS and three additional on the deck, which will only the translational degrees of freedom or rational degrees of freedom depending upon what they considering as analysis, there is no mutual transfer of rational degrees from the deck to the DLS or vice versa. Now, if you gather the information what we discussed in the last lecture, we already said TLP is a classical example of an hybrid system, where the surge, sway and yaw two displacement and one rotation. We have periods close to 75 to 120 seconds, which are very very high and these degrees are called as flexible degrees, whereas heave, roll and pitch they have time periods varying from 2 to 5 seconds.

The time periods are very low therefore, they are stiff degrees of freedom so TLP has got an hybrid combination of two distinct degrees of freedom on the same geometry. So just now we saw depending upon the chosen geometry how forces can cause complexities, now here is another inbuilt complexity, where the form itself is combined. So marine structures are classical examples, where force estimation on the members are not simple numerical examples. There are many inbuilt implicit effects and consequences happening within the system, which one must understand very clearly before we attempt estimate the environmental forces or any loads coming on such marine structural systems. Is that clear?

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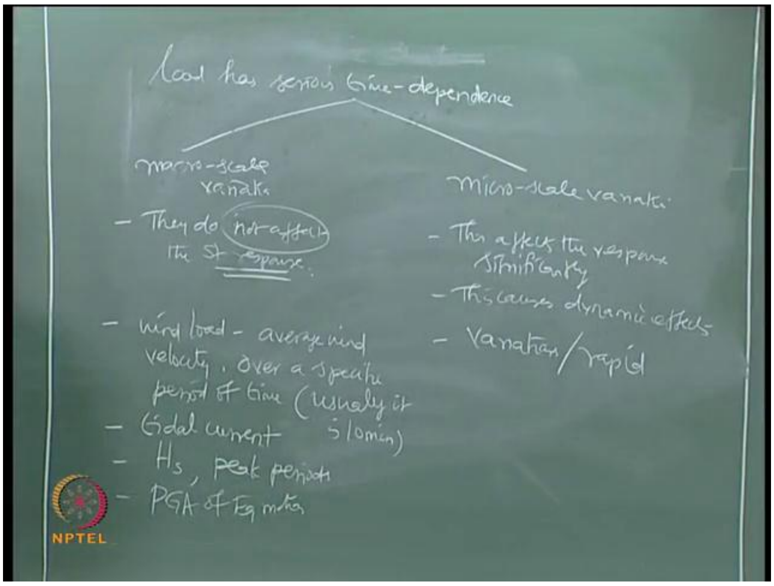

Now having said this we already said that load has very serious time dependence. Now picking this specific sentence of dependency of the environmental load, I can classify loads in two different forms; one is what we call macro scale variation. Off course, other is called micro scale variation. In macro scale variation they actually do not affect this structural response. When you have got the load on the macro scale variation, I will give an example later they do not affect the structural response, whereas when you have got an load which varies on a micro scale on time dependence then this affects the response of the structure significantly now one may ask a question so what is that influence which makes the response significant the influences this causes dynamic effects.

Now one may wonder and ask me sir its micro scale variation whereas here is macro scale variation but it is expected that the dynamic effect should be more and pronouncing in this format rather than this format, your thinking is right but I want to simply add one more clarity to this when I say micro scale variation the variations magnitude may be small but they are very rapid that is very important. So they vary instantaneously within a short period of time and that causes dynamic effects on structures. Now examples of macro scale variation for example, wind load, which is worked out from average wind velocity over a specific period of time. So one may work out sir wind is continuously blowing in the off flour sea state what would be that specific period of time over which a wind velocity is averaged.

The average can be 24 hours it can be 1 minute, it can 20 seconds, it can be 60 seconds etcetera. Usually, it is 10 minutes, so what we understand by this is, if we take a record of wind velocity variation keep on computing this variation for a period of 10 minutes average it that is a classical example of macro scale variation, because it not affect the natural response that is why in most of the cases wind is consider as two components; one is the static part of the wind other is the gust factor of the dynamic factor. We will talk about this slightly later in the next lecture. So this one classical example, the second could be the tidal current, significant wave high and peak periods, these all are macro scale variations.

The next could be peak ground acceleration of earth quake motion, all are random process; all are time varying; all are time independent there off course, spatial dependent as well but we have ignored the spatial dependency for the time being for the time dependence part, now this is macro scale variation, so they will not cause or they will not affect the structural response significantly. So one we start working of the forces on marine structures, let us try to understand very clearly, which component of them will affect the response which component of them will cause dynamic affects. So we should know where to focus on what kind of loads combinations depending upon, what is the physical process, which is causing this force, wind, wave etcetera. What is the spatial effect of this force? Whether the spatial affect is along the length and breadth or along the height for example, length and breadth could be wave, height could be wind etcetera. So all these component should be independently understood thoroughly before we start estimating the environmental loads on simple marine structural members.

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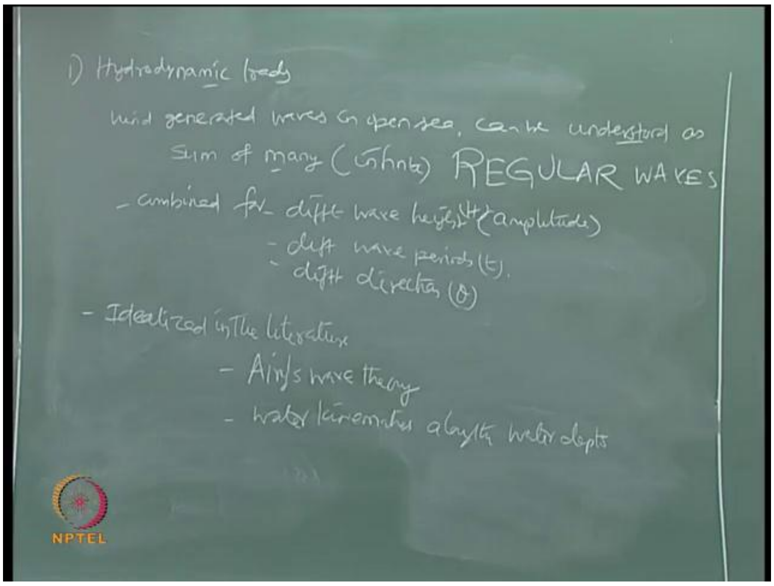

Now have been said this, let us talk about one classic type of loading, which is hydrodynamic. The movement we talk about hydrodynamic loading, we say that wind generated waves in open sea can be understood us. I am saying understood people idealize it; people assume it etcetera. Can be understood as sum of many the movement I say many people some time say infinite some time people say finite etcetera, so many REGULAR waves. They are combined for different wave heights, which we call as amplitudes different wave periods and the third aspect of this, what is that aspect? Different directions theta, t, H.

So pick up waves of different amplitude, different time periods or wave periods and different directions, assemble all of them by mechanical method or by simulation technique all are regular waves then you will able to modify or model the wind generator open waves for an open sea state. Now this has been idealized in the literature very well, people classically use what we call Airy's wave theory theories wave theory is very interesting fundamental and thought provoking theory, which will help you to estimate forces on members will give you the water particle kinematical variation along the water depth in a given sea state. Airy's wave theory is used always for preliminary analysis there is a fundamental difficulty with this theory we will not get into hydrodynamic of this theory or different theories nevertheless will give you basic equations based on which water particle kinematics of this can be computed.

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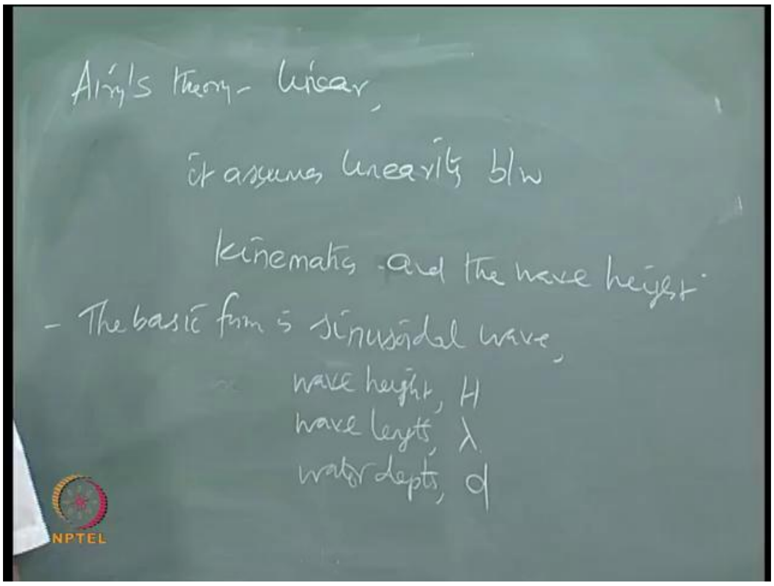

Now Airy's theory is called as a linear wave theory because it assumes linearity between that kinematics and the wave height. The fundamental are the basic form of the wave is a sinusoidal form of wave height H, wave length lambda and water depth d, the moment I say water particle kinematics what exactly this gives me.

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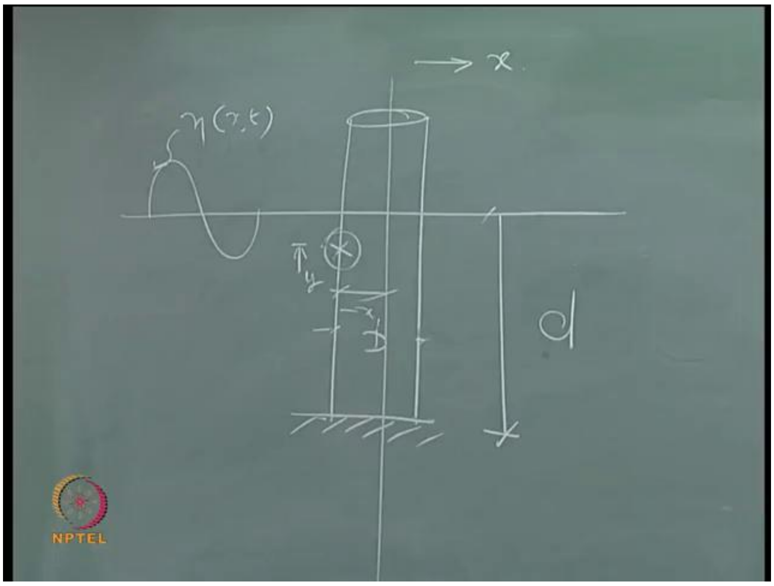

Suppose if we have a cylindrical member may be fixed at the bottom there is not bothered the boundary condition now located or deployed at a specific water depth d by the external diameter of this member is D can be even hollow cylinder of certain thickness t we are bothered about the external diameter now, subjected to a fundamental basic form, which is sinusoidal. Then Airy's theory essentially gives you the sea surface elevation, which is expressed as theta, if the wave height and the wavelength and wave periods and water depth are known to you at any point of interest at variation y at any point of space variation with x.

If this is my x direction, which is called propagation of wave then I must have the sea surface elevation, which is space dependent and time dependent. The movement I know the sea surface elevation, which is space dependent and time dependent at any point on space and time I must get the water particle velocity and acceleration both in horizontal and vertical directions. The movement I get the water particle velocity and acceleration in both horizontal and vertical directions at any point of my choice, then I can compute the force exerted by this way at this point using mooring equation or using classical diffraction theory, we will talk about it slightly later.

So the water particle kinematics nothing but addressing the computation of the sea surface profile and velocity and acceleration at any desired point horizontally and vertically. So I should have five equations; equation number one should give me the sea surface profile or I say wave elevation profile and two, three, four and five should give me successively the equations for velocity and acceleration in horizontal and vertical directions. These equations are generally available in all classical standard literature, which addresses wave forces on any given member for completion sake for the interest of the viewers. I will give you these equations here; so that you can use them understand them directly. This has very strong references many literature, which already referred you in the NPTEL website.

Can see those and try to understand more elaborately how these kinematics are been computed but I am giving only the equations here because I am not getting into the hydro dynamic evaluation of this water particle kinematics based on the theory, which is proposed by Airy's in 1850's.

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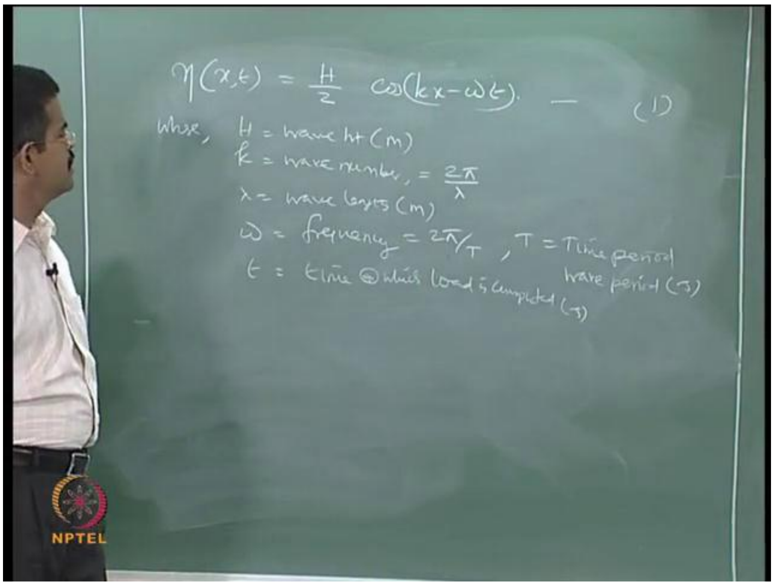

Sea surface elevation is given by H by 2 cos k x minus omega t, where I should say h we all know it is the wave height; k is called as wave number, which is equal to 2 pi by lambda, where lambda is called wavelength, omega is the frequency and t is instantaneous time at which you are computing the load of course, omega is given by 2 pi by T, where T is the time period or to be very specific we will say wave period. So this will be in meters, this is a number, this will be in meters, this will be in radians per second, this will be in seconds and of course, this will also be in seconds. I call this equation number 1 is at any special point at any time instant you will be able to find out the sea surface elevation using this theory or using this equation.

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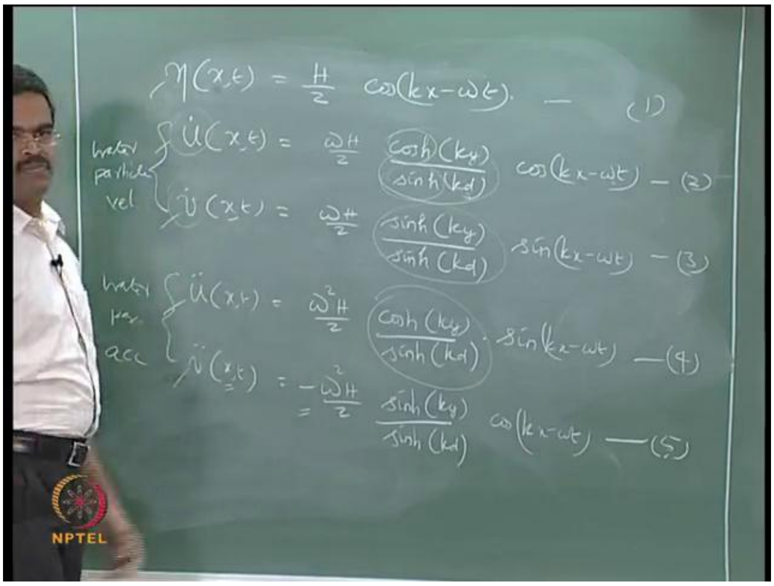

The horizontal water particle velocity u dot and the vertical water particle velocity v dot can be now given by these two equations. I call this equation number 2 this is equation number 3; these are hyperbolic functions we already know sin hyperbolic x and cos hyperbolic x standard mathematical expression, remaining all are explained the new variable here is y, which is the point of our interest. So this gives as spatial dependence on two axis; one is along x which is directional wave propagation; other is along the water depth, which is y. Is that clear? So it has got two it is addressing two spatial components; one is along the wave direction propagation, which is x which is already available here.

Of course time dependence already denoted here and the point of our choice is denoted here and of course, d is nothing but the water depth. I have got this as horizontal and vertical water particle velocities, these are all velocities. The movement, I differentiate it once I will get my acceleration let me write that. So as we understand the variable only t with respect to time therefore, these terms do not change they remain as it is, most interestingly when we look at the vertical water particle acceleration, which is v double dot here this is got the sign to be preserved in their force because this can be even create a cancellation effect in your calculations.

So as I said all these five equations in sequence will give me the water particle kinematics. So this is water particle acceleration; this is water particle velocity; this is horizontal; this is vertical so I can call this for example, as vertical water particle acceleration. So this address two components the spatial component not only along the wave propagation but also along the water depth and of course, the time dependence, so very simplified fundamental form of equations, which gives you the water particle kinematics at any point of your choice on any offshore member. Once I know these values using them at a specific point of my choice can always compute the lateral force exerted by this which we call as hydro dynamic load or force. Now interestingly there are some more thought provoking ideas given by researches followed by Airy's theory which came out to lightly subsequently later.

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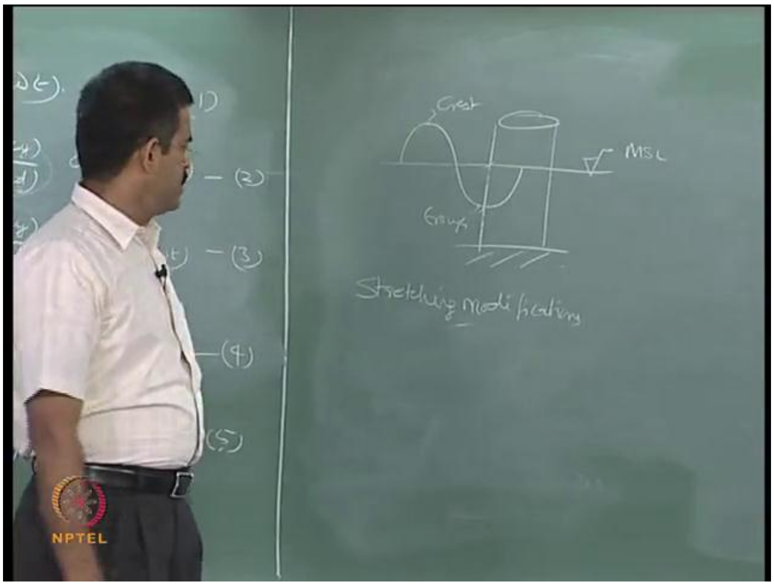

Let us pick up the same member fixed at the bottom for instance I let say this is my wave profile look at this path of the member of course, this is called as the crest of the wave this is called as trough of the wave. If the crest of the wave touches the member, then the force is different. If the crest trough of the wave touches the member then the force is different. Now Airy's wave theory computes forces only till this level, which is called the mean sea level or mean water level, any effect caused by the submergence is not accounted in Airy's theory. These are what we call as stretching modifications; these are given by many researches subsequently, once Airy's theory was accepted for calculating forces on marine structures. Let us quickly see the modifications in the lecture we will stop here.

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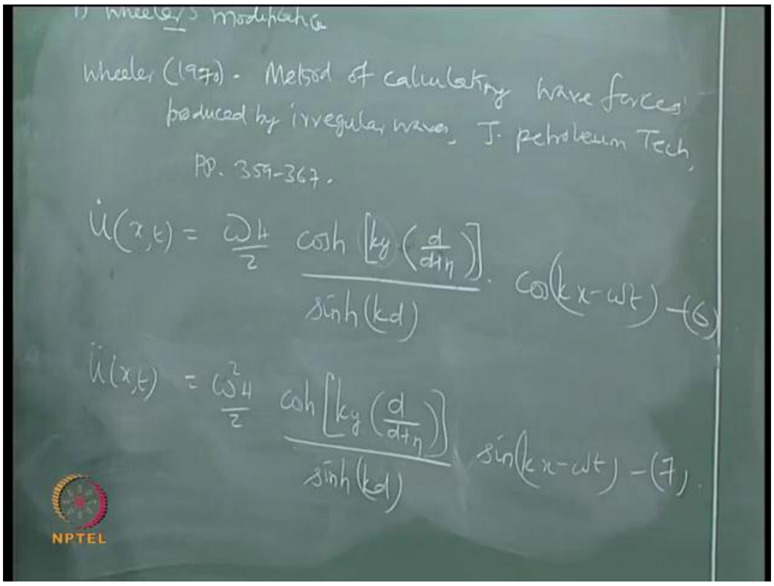

The first modification what I want to address is wheeler's modification, which has given by wheeler in 1990 sorry 1970. Method of calculating wave forces reduced by irregular waves, Journal of petroleum technology PP 359-367. He has suggested modification on the horizontal water particle velocity and vertical water particle velocity so according to wheeler's modification,

So there has been a modification in numerator in the earlier equation it is only k y but the stretching modification suggested by wheeler's gives you k y multiply by factor which d by d plus eta, where eta is as same as what we get from equation number 1, which is nothing but the sea surface elevation or wave elevation. Similarly, the horizontal water particle acceleration, which is nothing but the differential of this or the suggestions made by wheeler, so that this will account for the stretching modification caused by the variable submergence effect from that of MSL the actual point of submergence, because here eta is accounted, where eta nothing but the surface profile of the wave equation.

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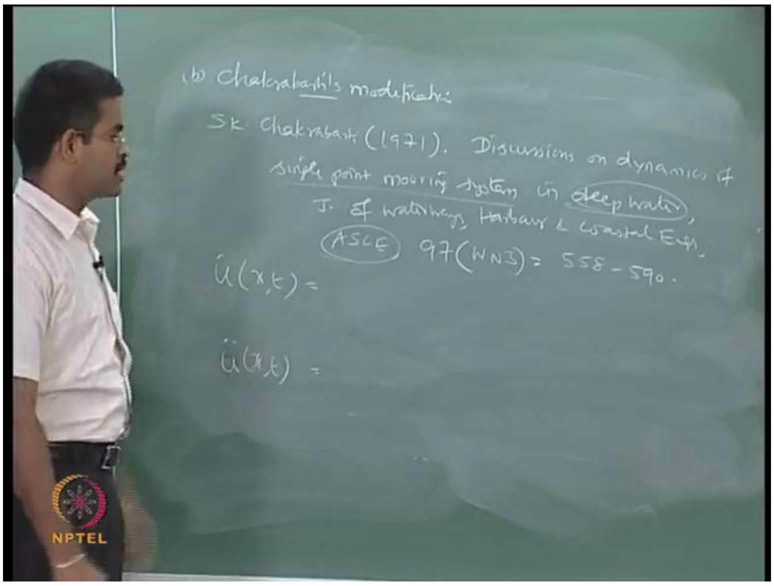

The second modification suggested by Chakrabarthi's, which is given by S.K. Chakrabarthi, which has suggested by Chakrabarthi 1971 in ASCE journal on single point mouring systems for deep waters. According to him will be given by the equations, which we discussed in the following lecture. So in this lecture, we are attempting to find out the environmental forces coming on marine structures. We understood how the forces can create complexities on given structural form of marine structures, what are the implicit complexities involve in estimating the forces on members. We started with hydro dynamic force we started with wave loading we explained you about the Airy's wave theory very briefly; we were talking about the stretching modification. We will continue in the next lecture on environmental loads on marine structures.

Thank you.