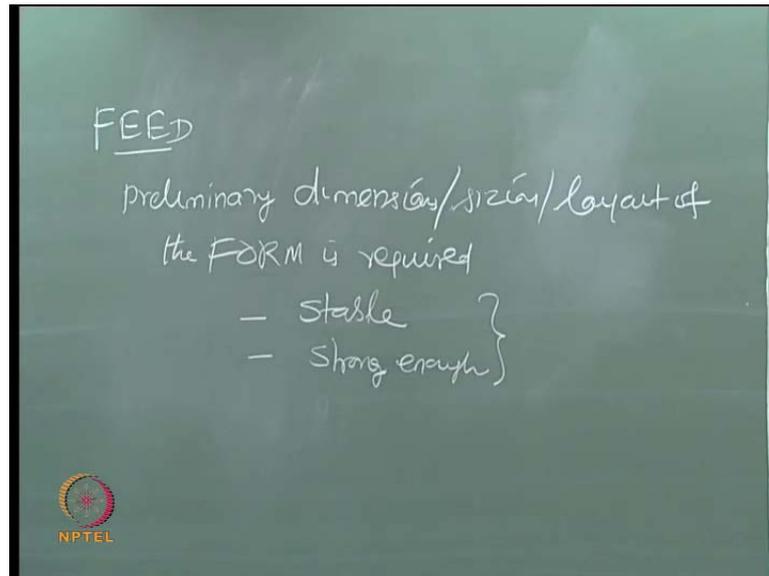


Dynamics of Ocean Structures
Dr. Srinivasan Chandrasekaran
Department of Ocean Engineering
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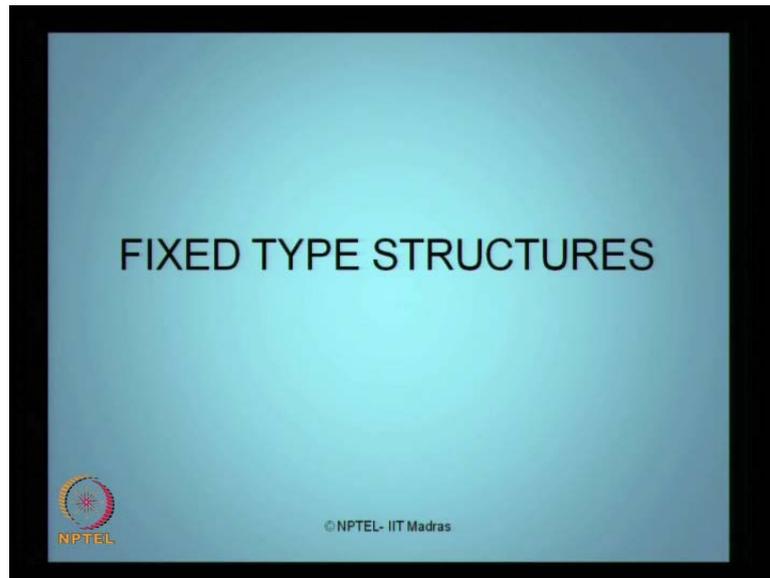
Lecture - 4
Steps of analysis using software

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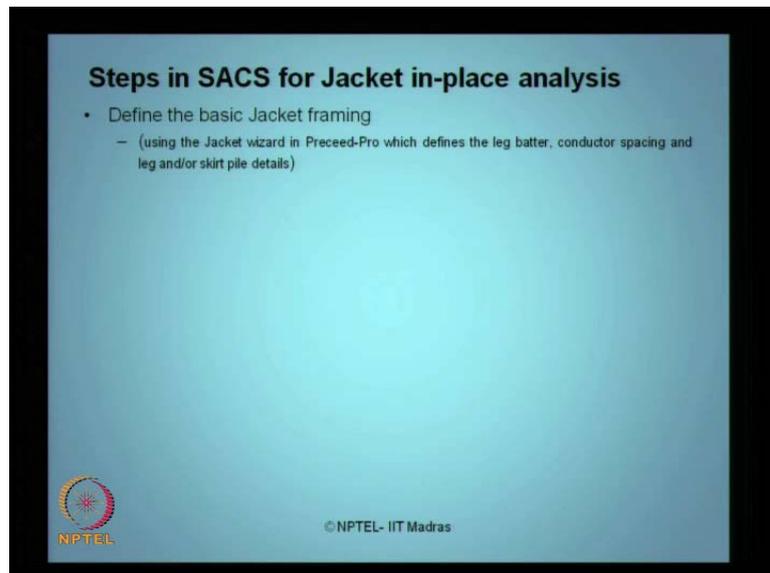
In the last lecture, we discussed about the (()) engineering design concept, where we introduced some preliminary dimensions or member sizing or layout of the form is required to ascertain that the chosen form is stable, and the chosen form is strong enough. So, there are many international codes which will govern you to check all these aspects, which we saw in the last lecture.

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So essentially, before we do a detailed dynamic analysis, one must do, basically in-place analysis using a software. We will quickly see how and what are the steps involved in picking of any one software of this nature, and see how you can model it for a fixed type of structure in this lecture.

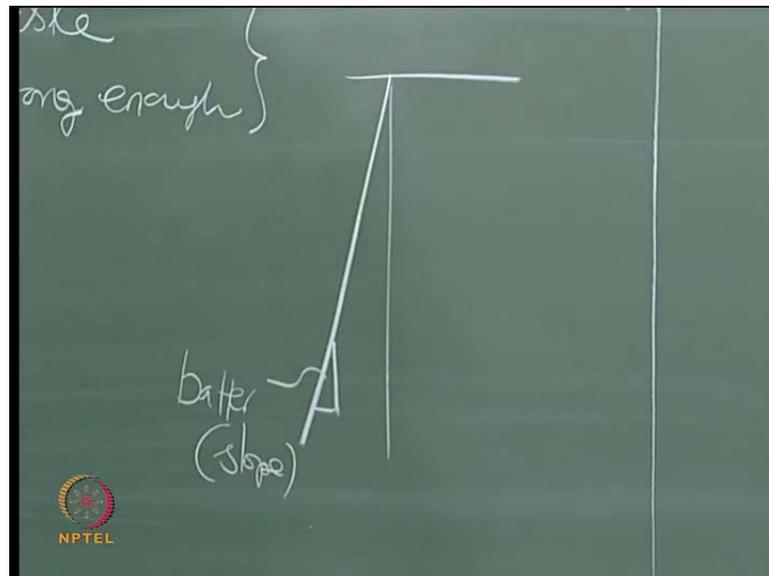
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So, let us take up the software SACS, which is useful for doing in-place analysis of jacket structures. So, you have to first define the basic jacket framing, which will talk about the layout in terms of its elevation and plan for the member sizing available. This can be

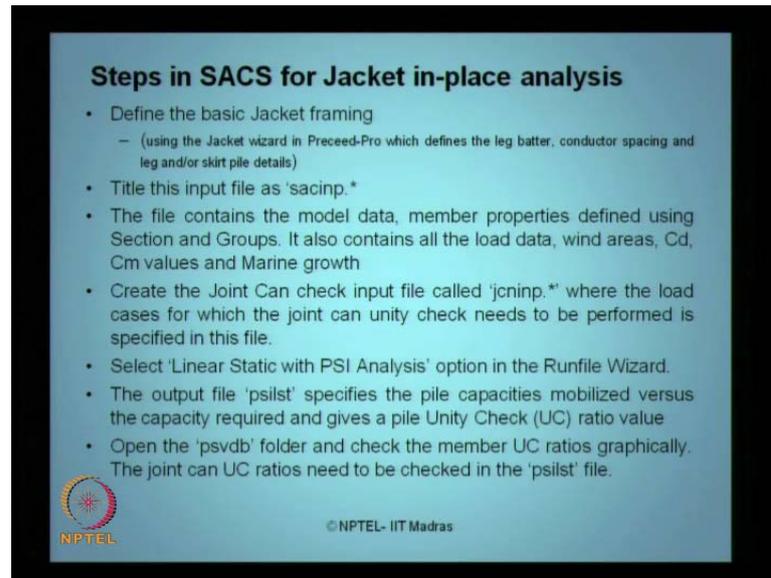
done using the jacket wizard in Precede-Pro in the menu, which defines the leg batter. Batter is nothing but the slope of the leg. Because in jackets you will see, the leg is not vertical.

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The leg is not vertical. If this is your top hall, the leg is not vertical. The leg is inclined and we call this as actually a batter. It is nothing but the slope. So, what should be the slope? This is the initial line. That is your original leg. So, you have to specify the batter and then the spacing and of course of the leg and the skirt pile details, if you have anything of that nature.

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Steps in SACS for Jacket in-place analysis

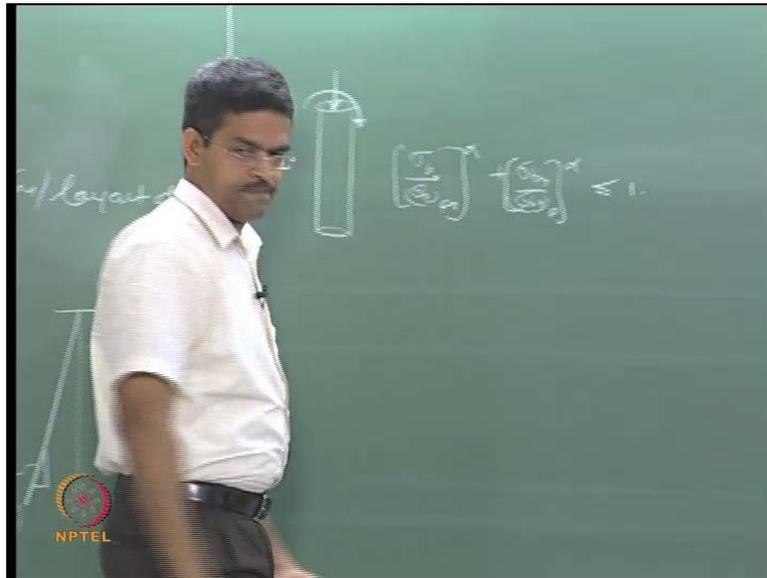
- Define the basic Jacket framing
 - (using the Jacket wizard in Preceed-Pro which defines the leg batter, conductor spacing and leg and/or skirt pile details)
- Title this input file as 'sacinp.*'
- The file contains the model data, member properties defined using Section and Groups. It also contains all the load data, wind areas, Cd, Cm values and Marine growth
- Create the Joint Can check input file called 'jcninp.*' where the load cases for which the joint can unity check needs to be performed is specified in this file.
- Select 'Linear Static with PSI Analysis' option in the Runfile Wizard.
- The output file 'psilst' specifies the pile capacities mobilized versus the capacity required and gives a pile Unity Check (UC) ratio value
- Open the 'psvdb' folder and check the member UC ratios graphically. The joint can UC ratios need to be checked in the 'psilst' file.

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Then, give title to this input file as “sacinp dot star”. May be the extension is generated automatically. Then, the file contains basically the model data for your problem, the member characteristics and properties defined using the sections and groups. You can even group them and you can give them separate sections for each leg as well. It also contains the all load data, the wind areas, the Cd Cm values and marine growth details, all along the length of the member. Then, you have to create the Joint Can check input file called “jcninp.*”, where the load cases for which the joint can unity check needs to be performed is specified in the specific file, by name “jcninp dot star”.

Then, select “Linear Static with PSI Analysis” option in the Runfile Wizard of the software. The output file “psilst” specifies the pile capacities mobilized versus the capacity required and gives a check for unity check ratio. What we call as UC. So, it will check the file capacity ratio and the available capacity which is been imposed on the pile and we will check whether it is exceeding 1 or lower than 1. So, once open the “psvdb” folder, which is the name of the folder automatically generated and then, check the member or the members for the unit check ratios graphically, because graphically it will show whether the member has exceeded the unit check ratio exactly.

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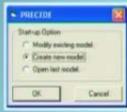


Unit check is nothing but if you are having a combined action of axial force and bending, for example, let say I have a cylindrical member, which is subjected to an axial force and of course, bending as well, then stress bending by stress bending is permissible in x axis rise to the power alpha plus the stress bending by stress bending permissible in y axis raise to the power of alpha should be less than or equal to 1. What we called as unity check. So, if it is biaxial bending scheme. If it is an axial plus bending, again this kind of similar check of combined ratio of UC will be checked graphically in the file. Then, the joint can UC ratios need to be check in the “psilst” file, which you have created in the previous step.

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Jacket Modeling for In-place analysis

- Click Modeling>Precede
- Select "Create new model" then OK

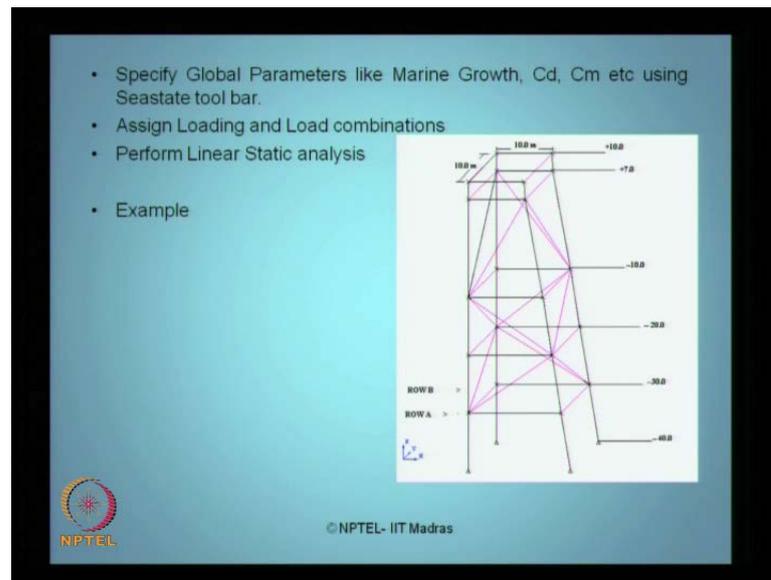


- Select Alphanumeric jacket joint names with tags > OK
- Assign all elevations, jacket leg batter, spacing, conductor details and skirt pile details
- Legs will appear
- Assign brace members as follows
- Select Member > Add > select relevant joint and give group label > Apply.
- Specify Member properties by selecting Property > Member Group.

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So, once you do this, then the jacket modeling can be done for in-place analysis using this particular pull down menu, which is called Precede. Precede is a pull down menu. So, click Modeling Precede as you see in the screen here. Create a new model and then, say OK. Then, select alpha numeric jacket joint names. For example, a 1, a 3, the joint names has to be generated. Select them with tags. Then, press OK. Assign all elevations, jacket leg battering, spacing, conductor details and skirt pile details now in this model. The legs will appear now and assign the braces members as follows. Select the members, add, select relevant joint and give group label to them and apply. So, keep on adding the bracing members to your jacket. Specific member properties of each one of the added braces and now we are selecting property and member group. You can always group them in a single one. So, give property to the any one member. It will be assigned to all the members automatically.

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This is the model we generated in SACS after giving the details for the bracing. So, the cyan colors what you see here is all the bracings which we generated. These are all the bracings. These are the legs, which I are having the batter and of course, different elevations of minus 10 7, sorry, plus 10 7 10 minus 20 30 and minus 50 have been generated for a plan size of 10 meter by 10 meter. So, it can generate a graphical model like this.

Then, specify the global parameters like marine growth, Cd Cm values etcetera. You see the sea state tool bar available in the software. Then, assign loading and load combinations. Perform linear static analysis. This is very important. We are not doing a dynamic analysis here. So, the example structure what you see on the right is what you will see on the screen, once you follow all the above steps to do the linear static analysis.

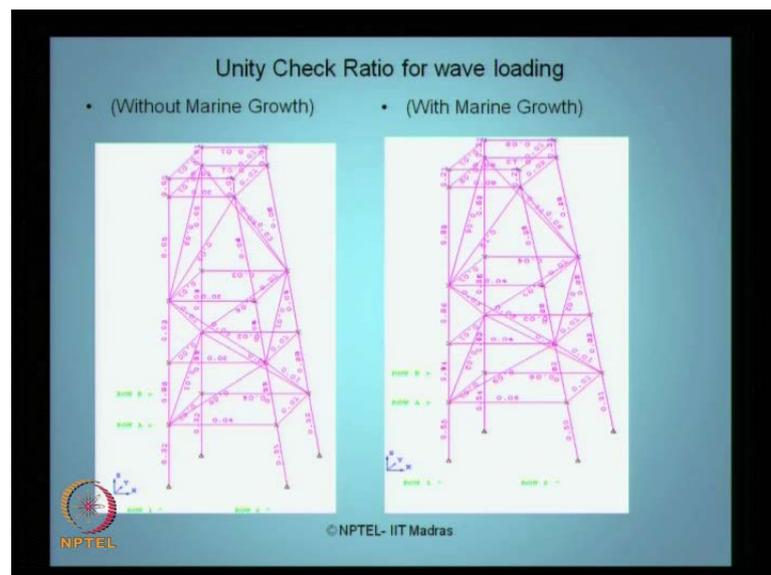
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- Two Different analyses need to be performed with and without marine growth
- Load Data
 - Wave Data
 - Wave Height 8m
 - Wave Period 12s
 - Wave direction 0 deg

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Subsequently, two different analysis need to be carried out or performed for this kind of structures. One is without marine growth and one is with the marine growth. The load data what we generally use or what has been used in this specific example is a wave height of 8 meter, wave period of 12 seconds and of course, you should check it for different approach angles. We start up with 0 degree here.

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So, this how you will see when both the figures are generated with and without marine growth. The left one what you see is without marine growth and right one what you see

is with marine growth. File data has been checked and unit check ratio for the wave loading has been carried out and all the numbers what you see here is giving me the values of unit check ratio. For example, let us check this member. This member is giving 0.68, this member is giving 0.06, this member is giving (()). So, all unity checks have been approved, so that it does not exit 1. So, this will give you graphical information about whether any specific member has failed the unity check or not for given loading condition what you have assumed. If it fails, you have got to change the section group or dimension or the characteristics of the member or the entire group once again. Redo the analysis, run the analysis once again and see whether unit check has been approved.

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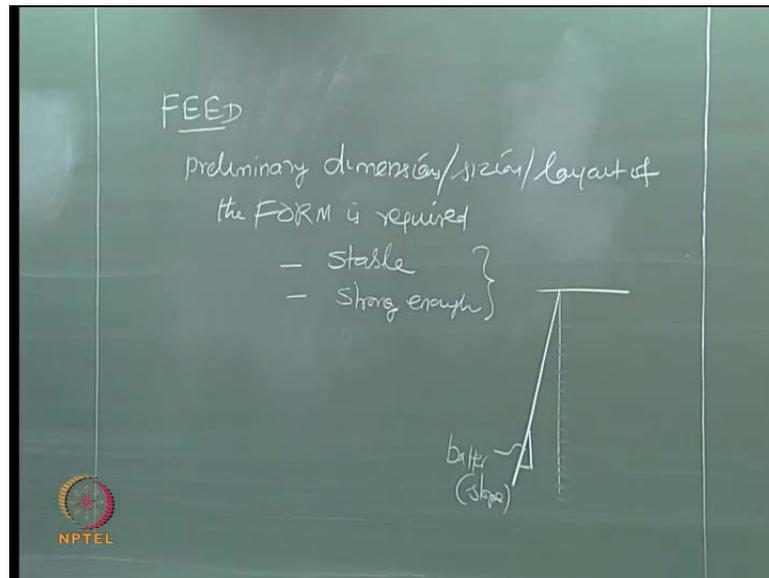
Dynamic analysis

$$[M + M_a]\{\ddot{X}\} + [C]\{\dot{X}\} + [K]\{X\} = \{f(t)\}$$

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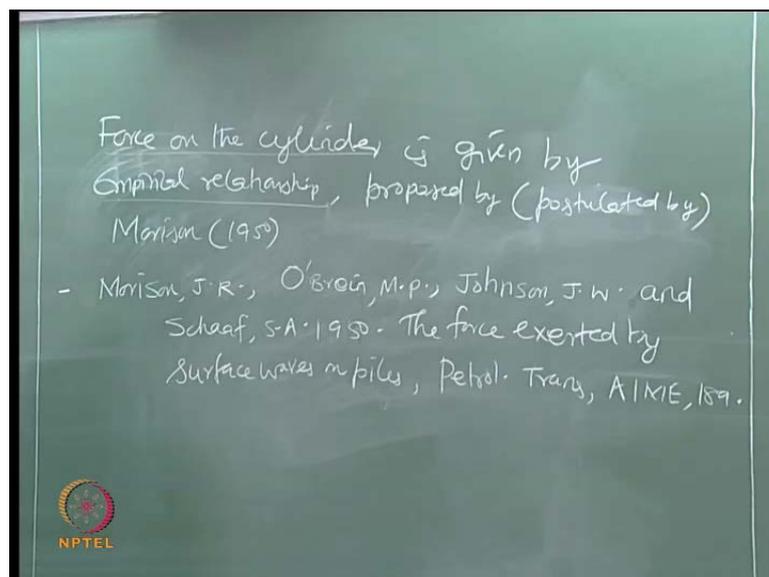
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So, unit check is where we are saying that the structures have become stable. To understand that the configuration and the members are strong enough to withstand the bending or axial stress supplied on the member. So, once you do this, I have a classical equation of motion here, which we already know for multi degree freedom system, which we intend to solve. Once you come to this state, then we will talk about f of t here.

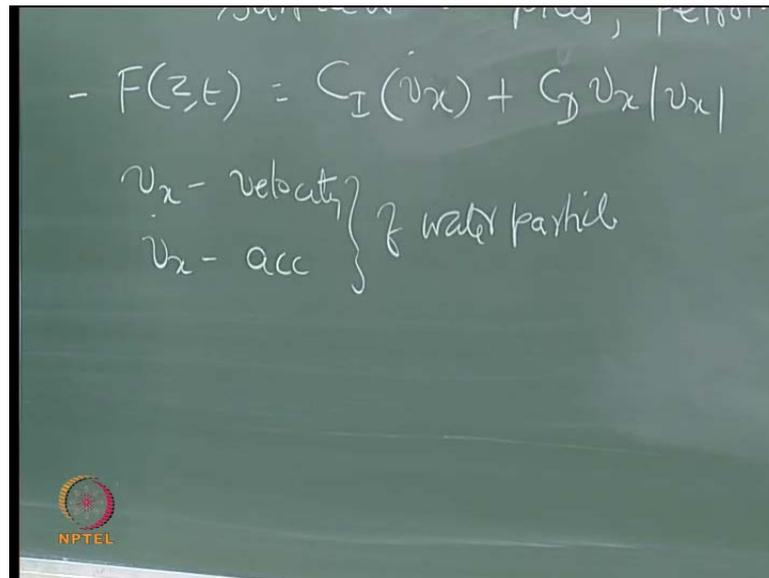
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So, we already know the force on the cylinder, this is essentially given by an empirical relationship, proposed by or I should say postulated by Morison in the year 1950. The

references, so the researchers Morison et al proposed in 1950 an empirical relationship based on which the force on cylinder can be computed, which is f of t , which we are talking in the right hand side of the equation. There are some idealizations on this particular f of t , which we want describe here before we do a detailed dynamic analysis for this by solving some examples.

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The image shows a chalkboard with the following content:

$$- F(z,t) = C_I(\dot{v}_x) + C_D v_x |v_x|$$

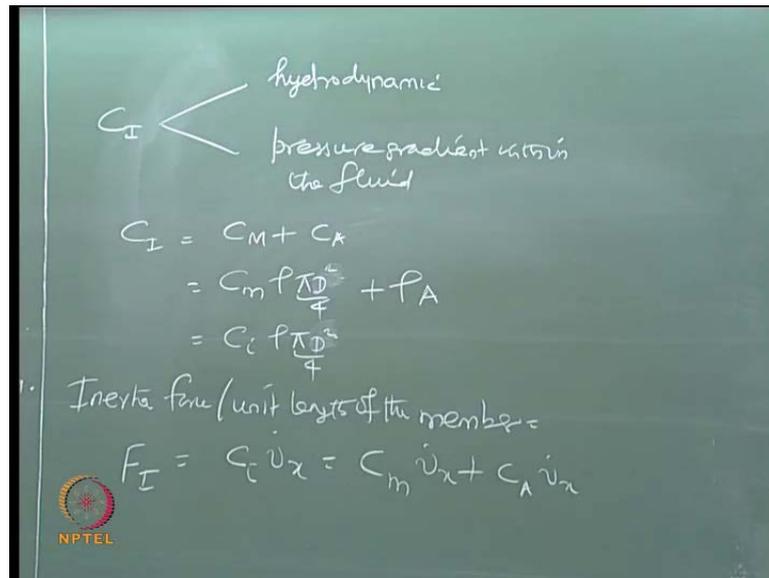
Below the equation, there is a handwritten note:

v_x - velocity }
 \dot{v}_x - acc } } water particle

In the bottom left corner of the chalkboard, there is a small logo for NPTEL (National Programme on Technology Enhanced Learning).

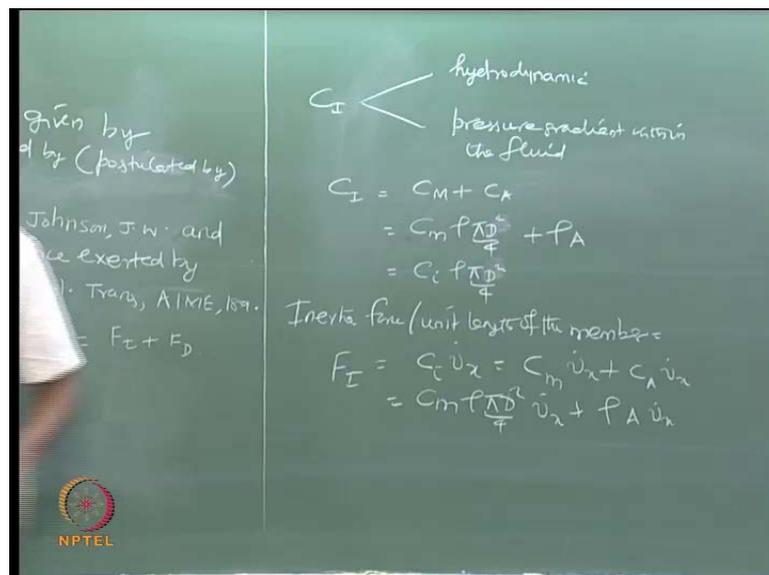
So, this f of t , which is a function of z and t , where z is along the height of the member is a combination of inertia, which is multiplier of acceleration plus drag, which multiplier of velocity and so on, where v_x stands for acceleration of the water particle, which in short we can say, initial force plus drag force.

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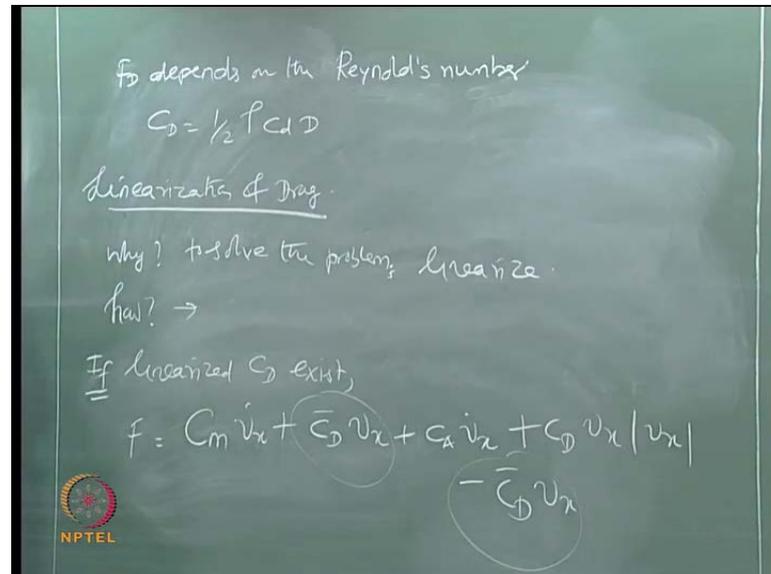
The inertia force has got two components again further here. It has two components. One form is the hydrodynamics and one form is the pressure gradient within the fluid. So, which I can separate as C_i is now C_m plus C_a , where this is C_m plus ρA . This can be simplified as $C_i \rho d^2$ by 4. Let us use capital D here and D is the outer diameter of the member and C_i is the inertia coefficient of the section. Hence, the inertia force per unit length of the member can be given by C_i inertia force alone, which is C_m plus C_a and so on.

(Refer Slide Time: 13:49)



It can be further expanded with this. It can be $C_m \pi d^2 \rho a$. You look at the drag coefficient. There is a problem here.

(Refer Slide Time: 14:22)



The drag coefficient or the drag force depends on the Reynolds number. What we can say simply is, half rho C d D. Now, if you look at the force vector completely, here I am talking about linearization of drag. Why it is required because I need to solve the problem and I can linearize it. How it is done is what we will see now. Where it is non-linear, there is term here in the original equation where we wrote, $v \cdot x$ and $v \cdot x$ getting multiplied within absolute sign to prevent the nature of the force acting on the member. So, let say for example, if a linearized drag coefficient exists, if it exists, then the force vector now can be given as $C_m \dot{V} \cdot x$ plus $C_d \bar{V} \cdot x$ plus $C_a \dot{V} \cdot x$; this is acceleration, plus $C_d \bar{V} \cdot x$ absolute $C \cdot x$ minus $C_d \bar{C} \cdot x$. This is the same equation which we wrote earlier. I now added and subtracted a new term, these steps. So, from these two, I will pick up the error function.

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rewriting

$$F = C_m \dot{v}_x + \bar{C}_d v_x + C_A \dot{v}_x + E$$

Where E is the error function, Using least square approximation, minimize the error function.

$$\frac{\partial E^2}{\partial \bar{C}_d} = -2 \langle (C_d \dot{v}_x^2 | v_x) - C_d v_x^2 \rangle = 0$$

Where $\langle \rangle$ is the time average



So, I can rewrite the equation as, f can be now rewritten as, $C_m \dot{v}_x + \bar{C}_d v_x + C_A \dot{v}_x + E$, where E is the error function. Now, I can minimize this using least square approximation. Using least square approximation, I can minimize this error function as below. So, the second derivative of this error function with respect to the \bar{C}_d is simply given by, minus 2 of; where the symbol is time average and that should be set to 0. I am minimizing it. So, there is a C_d here. That is the C_d here. I will rewrite it again; minus 2, there is a C_d here anyway. There is a C_d here. So, I am doing a least square approximation. So, $C_d^2 \dot{v}_x^2 | v_x - C_d v_x^2$ within time average is set to 0. So, from this equation, I can easily find \bar{C}_d . This is going to be \bar{C}_d , right? \dot{v}_x is \bar{C}_d .

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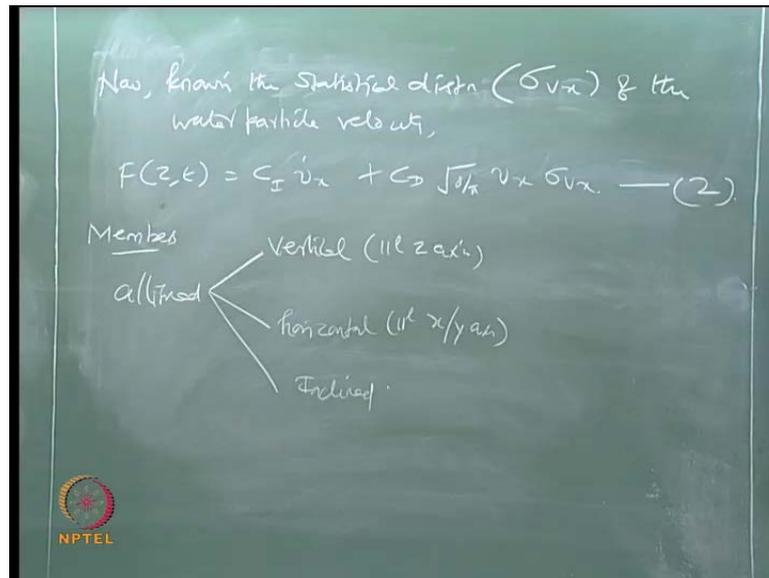
$$\bar{C}_D = C_D' \frac{\langle v_x^2 / |v_x| \rangle}{\langle v_x^2 \rangle}$$

for a Gaussian non-zero mean process,

$$|v_x| = \sigma_{v_x}$$
$$\langle |v_x| \rangle = \sqrt{8/\pi} \sigma_{v_x}$$
$$\langle v_x^2 / |v_x| \rangle = \sqrt{8/\pi} \sigma_{v_x}^3$$
$$\bar{C}_D = C_D' \sqrt{8/\pi} \sigma_{v_x}$$

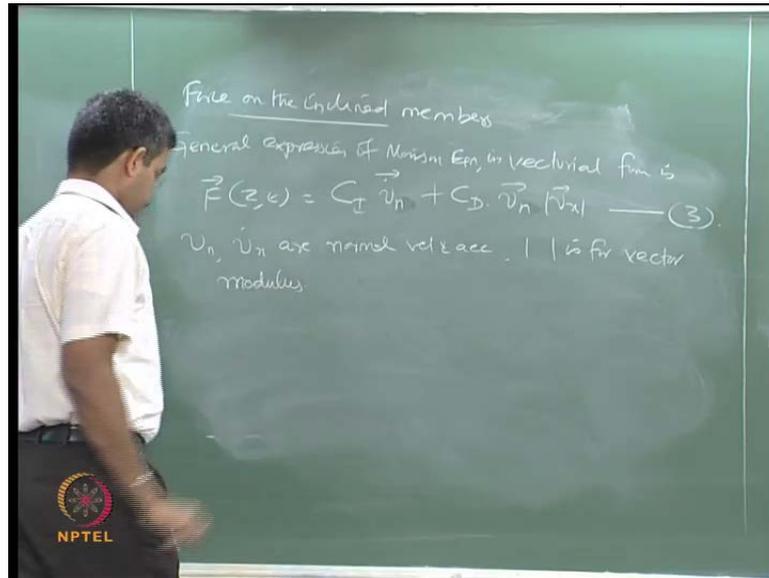
So, this C_D bar can be which I want. So, linear is drag coefficient, which is C_D times of, because I am setting it to 0, V_x square absolute V_x by, of course, the time average of this and of course, the time average of this. Now, for a Gaussian non zero mean process, we can simply say, V_x square absolute will give me the sigma V_x square, that is the variance and v_x alone, the time variant will give me, this is sigma V_x , approximately root 8 by pi of sigma V_x , if it is a Gaussian process. The numerator time variant of V_x square V_x will now be root 8 by pi sigma V_x q. So, substitute that in this equation, I get C_D bar as C_D times of C_D . C_D is already here. V_x cube and V_x square, so I will get root 8 by pi sigma V_x . That is my linearized drag coefficient. So, I can use this instead of having a non-linear drag term in my f of t .

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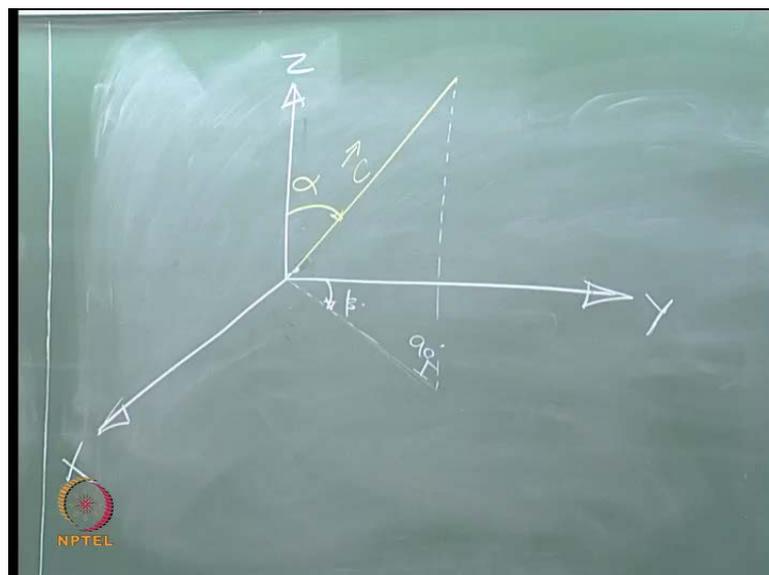
But, the only difficulty in this equation is, I must know the statistical distribution of the velocity of the water particle. Hence, now knowing the statistical distribution, that is σ_{v_x} of the water particle velocity, you can now say, my f of z of t is simply $C_I \dot{v}_x$, that is the acceleration, which is the inertia coefficient plus $C_D \sqrt{8/\pi} v_x \sigma_{v_x}$. I just replaced the linear term the square term with this equivalency of $8/\pi$. I will call this equation number 2. Now, the question is, in an offshore structure, what you just now saw an example, I have members which are vertical. So, members can be aligned in many ways. One it can be vertical, that is parallel to the z axis. It can be horizontal, parallel to x or y axis. Most importantly, it can be inclined. If it is inclined, how do I do my force? So, f of t for an inclined member.

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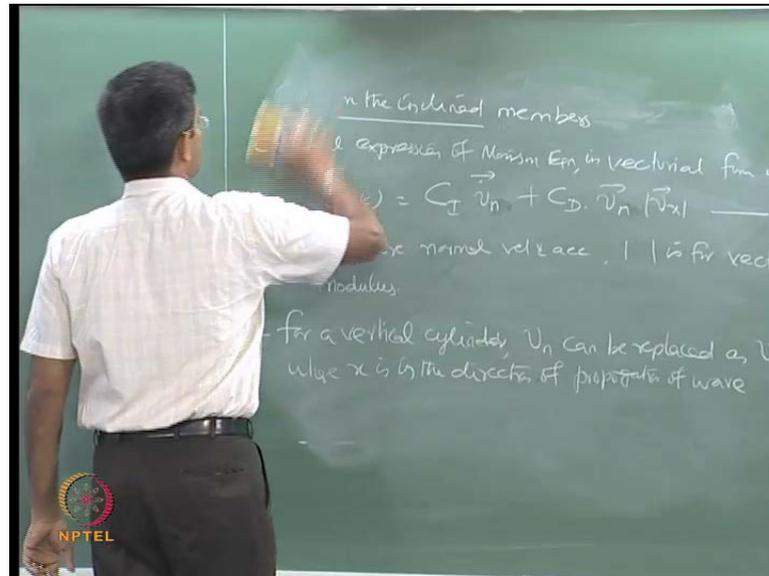
So as first step what we generally do in such analysis is, we can linearize the drag term by this approximation, which is given by, so force on inclined member, so the general expression of Morison equation in vectorial form is given by, let us say n . We are talking about an arbitrary orientation plus C_D of $(|\vec{v}_n|)$. So, it is a general equation without linearizing it. Let me call this as equation number 3. Now, I have a member. In this case, \vec{v}_n and $\dot{\vec{v}}_n$ are normal velocity and acceleration and $|\vec{v}_n|$ stands for, let say the vector modulus.

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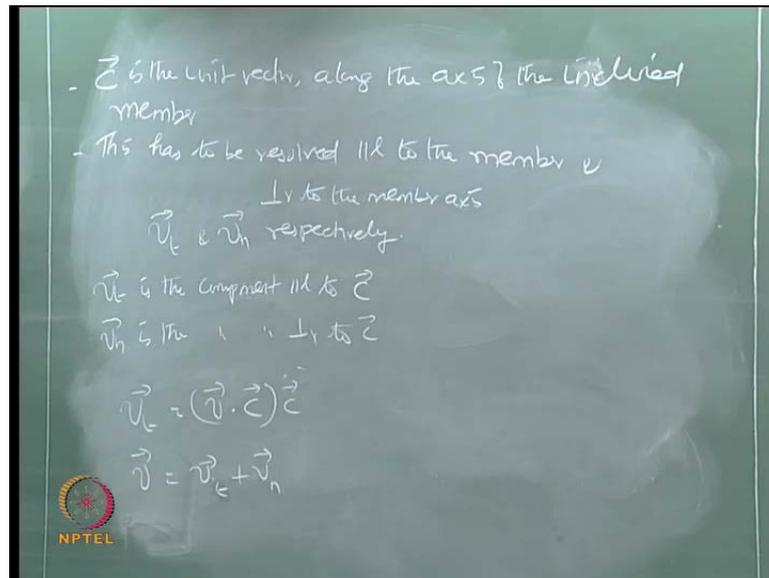
Now, I have a cylinder or I have a member, which is arbitrarily oriented like this. C be the component along the member and the angle with which this member axis makes with z is α . Let this be (()).

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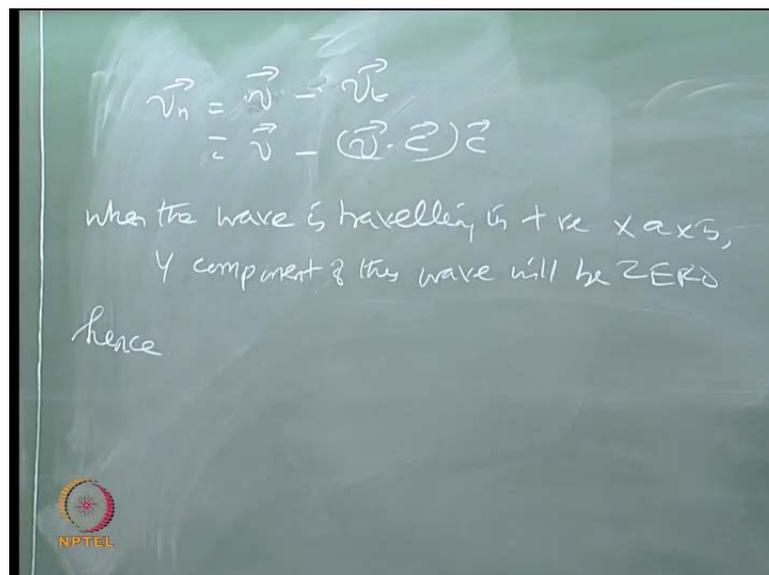
So, for a vertical cylinder, V_n can be replaced as V_x , because force is normal. We are talking about V_n is nothing but the normal velocity of acceleration. If the cylinder is vertical, I can always use V_n as V_x in my calculation, where x is in the direction of propagation of wave. So, use this equation again number 3 and try to expand this vectorially.

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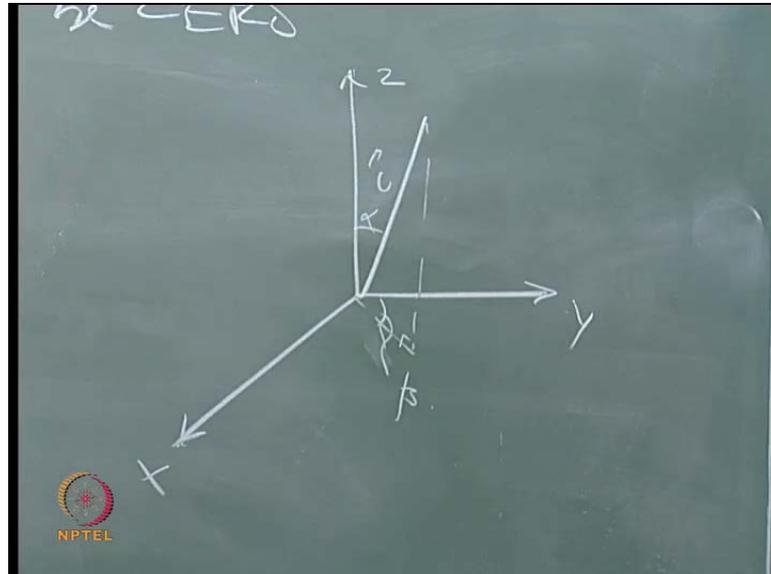
So now, C is the unit vector along the axis of the inclined member, of course, as shown in the figure. Now, this has got to be resolved parallel to the member and normal to the member axis. When I try to do that, I call these two components as V_t and V_n respectively. It is tangential at normal comments respectively. That is, V_t is the component parallel to C vector and V_n is the component normal to C . Therefore, I can write V_t as $V \cdot C$ and V_n as, no, we say V is V_t plus V_n .

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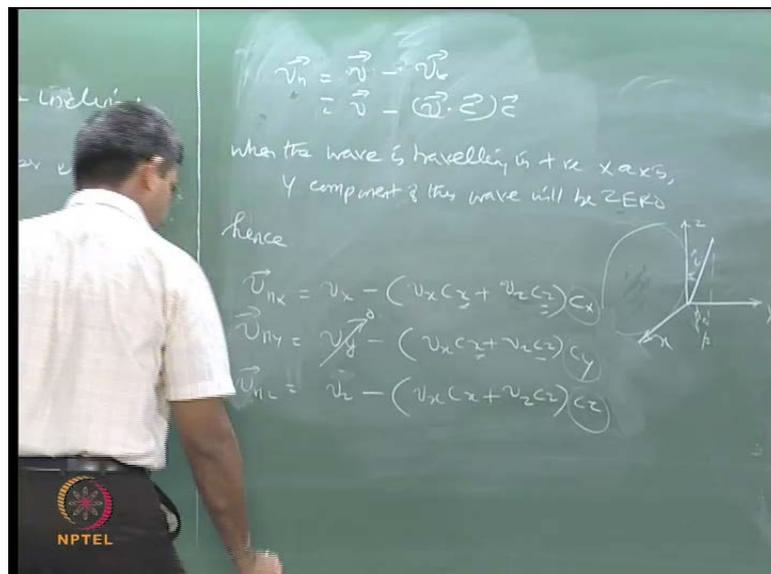
Therefore, now I have V_n as; I will remove this, that is, V minus $V \cdot C$ of C . Now, when the wave is travelling only in the positive x axis, the y component of this wave will be 0.

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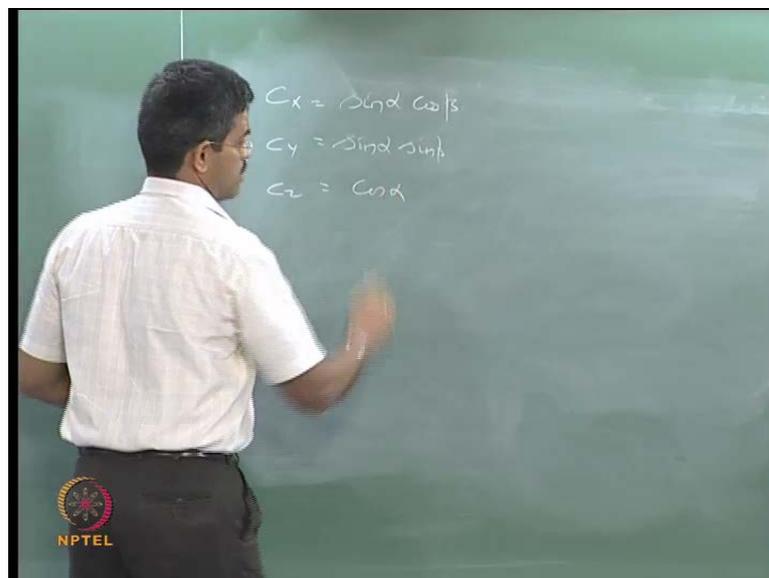
Hence, I will draw the figure once again here. This is my x y z . This is my member, which is C , this is α and this is β . So, the projectile on this plane will be 0. So, there are two planes normal to this. z y plane has got two planes normal. One is x y and other is z x . This will be 0, because the y component is 0 here. Therefore, I will get back to this plane.

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I can write simply, $V_n x$. I am looking here. $V_n x$ as V_x , looking here, minus of $V_x C_x$ plus $V_z C_z$ of C_x . Similarly, if you want to do the normal component $V_n x$ in terms of y , I should say V_y minus $V_x C_x$ plus $V_z C_z$ of C_y . But, we already know V_y is 0. Similarly, $V_n z$ is V_z minus $V_x C_x$ plus $V_z C_z$ of C_z . You can see all these products are happening only on the xz plane. Now, this multiplies what you see here; I will remove this figure. There is small confusing here. I will just erase this and write this as x . The direction cosines what we see here, can be expanded as the corresponding projections of this vector on the respective planes.

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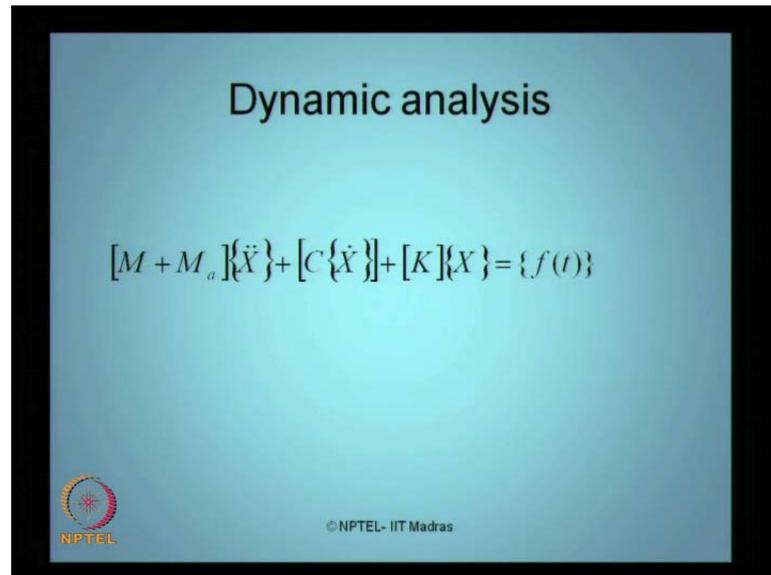


Therefore, I can say C_x , C_y and C_z are given by, the direction cosines are, sine alpha cos beta, sin alpha sin beta and in C_z , in my argument is, cos alpha. That is what I am having here. So, it is very interesting for any member, which is arbitrarily oriented, whose angle of inclination is known to me with respect to the z axis as well as the projectile on the xy plane can easily find the force vectors for this member with the same algorithm. I will now substitute these values on my respective Morison equation to get the force on this member for unit length of the member. So, f of t can be linearized. The drag non-linearity can be taken away by an approximation as we just now shown.

Similarly, any member which is arbitrarily oriented other than vertical or horizontal can be also handled in the same fashion. So, the conclusion for the unit length of the member for a wave force, which is the right hand side equation of motion of this, can be sorted

out like this. Of course, for the left hand side of the equation of this motion, we already know m and k. We will talk about c slightly later, when we talk about the next model because c can be always approximated based upon the first values of m and k, where there are different models advised by researchers to identify the proportionate the damping matters.

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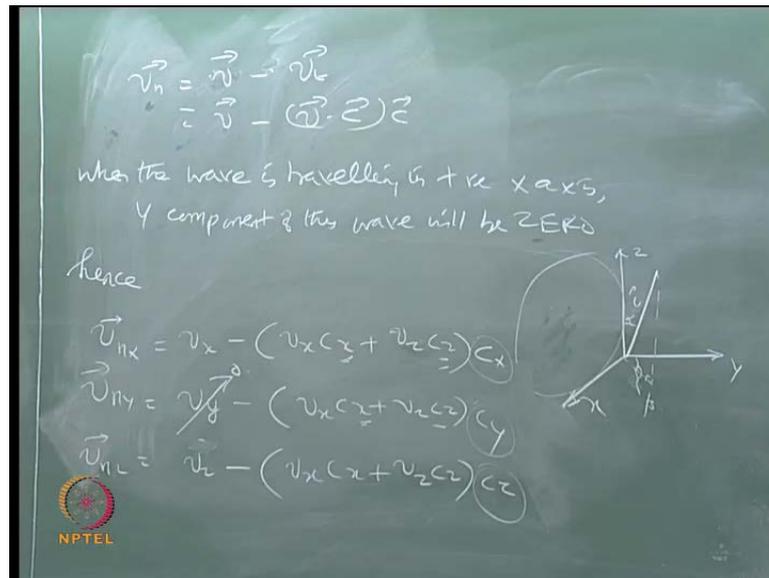
Dynamic analysis

$$[M + M_a]\{\ddot{X}\} + [C]\{\dot{X}\} + [K]\{X\} = \{f(t)\}$$

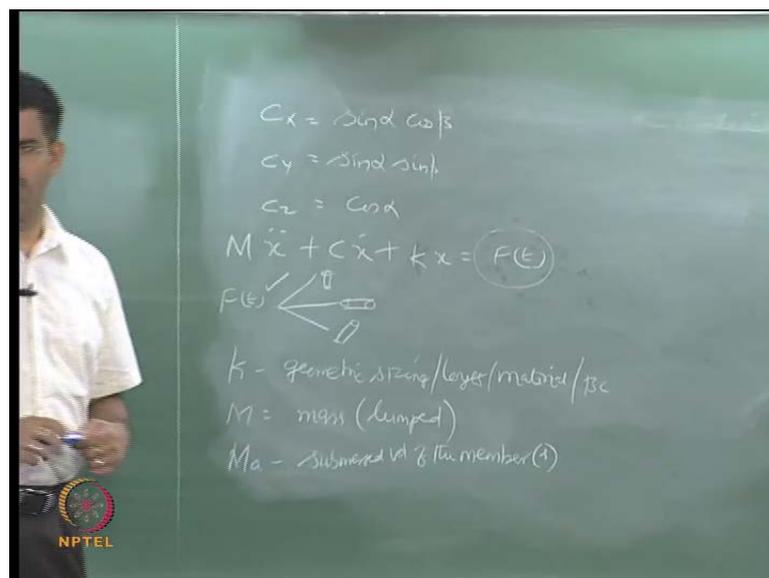
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So, in my argument, depending upon the added mass values, that is depending upon the submerged volume of every member, I can always estimate the mass matrix and k matrix. k matrix depends upon strength in my equation of motion.

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We have discussed f of t on different members, which is vertical, which is horizontal and which is inclined per unit length of the member and of course, k depends on the geometric sizing, length, material and boundary conditions or support conditions of the member. I can estimate k and of course, m depends on the mass, which is lumped as per your choice and of course, M a depends on the submerged volume of the member or members in this system. So, my whole equation of motion is now know. I can solve this equation of motion to get my response value, which are x of t's. What I will be getting from the solutions. Any questions here?

So, I can handle vertical members, horizontal members, inclined members and I can also linearize the drag term, which is one of the non-linearity present in the system, because of the multiplication component of the velocity vector at the force in Morison equation. So, if the Morison equation is not applicable, for example, the diameter of the members are very large, they are not slender, we have to account for the diffraction equations, which I will discuss in the next lecture, how I will handle large volume or large diameter member using diffraction theory, which again approximation given by different researchers, which we will discuss in the next lecture. Then, we will take up an example and solve and show how f of t can be computed in simple terms for both of these models, using either linearized drag or using diffraction coefficients.

So now, I have a closed form answer for me, that I will be able to estimate my right hand side of this equation of motion and left hand side is of course a problem formulation for me, which I already know. I can solve this using different algorithms available to me, which I will show you or discuss with you in the subsequent lectures. I can solve this in time domain or frequency domain and get my x of t , either in time history variant or frequency variant. Ok?

So, precluding the dynamic analysis, we are required to do a static analysis, which will tell me whether the form assumed by you is stable and strong. So, SACS can be an interesting software, which can do this and which can be applied as we have shown here. You have got to practice this for making in model and do it. Now, arguments comes here as we explained in the previous lecture that, if an earthquake force also acts on a given system, how do I model this? How do we account for the earthquake or the ground acceleration onto the system? There are two cases here. As far as the fixed jacket structures are concerned, these structures rest on the sea bed, rest on piles etcetera. So, the direct force of ground acceleration can be implied on this as to how to handle this. If they are floating, if they are anchored to the sea bed by teethers or some other system, then how are they transferred and both cases we will handle.

So, in the next lecture, we will talk about how to handle in f of t the ground acceleration to which this system is subjected to and also, we will take an example of diffraction problem and see how we can find out f of t for that as a empirical relationship, which is again approximated given by different researchers, because diffraction theory is again

more complicated in its numerical algorithm compared to linear velocity potential as we just now saw in Morison equation.

But, not necessarily every problem has a suitability of Morison equation getting applied. There can be large diameter members as in case of the gravity based structures. So, how to handle them? We will discuss that. So, once it is understood, I should now tell you an algorithm how to solve the equation of motion in a time domain or frequency domain. If I know that, I can pick up any problem of a different form, model that, check for stability and strength and get FEED approval. Then, go back to dynamic analysis and find out the member force in each unit length of the member for any orientation of the member, form the problem, iterate it or write an algorithm to solve the problem in time domain or in frequency domain and get the response history in frequency domain or time domain respectively. So, my problem will be computed.

Now, the catch lies in different problems or different forms. How do I actually form the problem? How do I get my k matrix? How do I get my c matrix? As I just now said, how do I get my mass matrix? So, if I understand this then I will very well understand how to lump these masses at different locations, where x of t is being measured in terms of multi degree as a rigid body motion, which we normally approximate or idealize in ocean structures. I must concentrate to get f of t at those points and do the solution for this equation of motion. Sometimes, there is possibility that this equation of motion can be decoupled and in some cases, it is not possible. Depends upon, whether you can really normalize this motion.

So, this is where you are going to take away in couple of lectures from down the line as far as dynamic analysis of offshore structures are concerned in this module. So, next class, we will be focusing on how to get the f of t , if there is a ground excitation. Because, now, we spoke only about the horizontal loading or lateral loading that comes from the waves. Of course, we gave you an introduction as to how to get this force from, because of wind in the first module. This talks about wave because Morison equation deals only with the wave. Of course, the Morison equation can be modified, when there is a current velocity also. So, you can use wave and current and you can handle here. But, aerodynamic superstructures (()) can be handled separately with different methodology as we discussed very briefly in the last module. So, we are taking about the hydrodynamic analysis of the platform. When we talk about aerodynamic, I will tell you

how this has been arrived at. So, we will do a couple of examples to understand this and give you inferences on that. Any question here?