Dynamics of Ocean Structures
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Lecture - 03
Environmental Loads

Dear friends, today we look at the 3rd lecture on the course of Dynamics of Ocean Structures. We will talk about environmental loads. In the previous lectures, we discussed about the structural action of various type of offshore structures, their design, philosophies, their form based designs etcetera. In this lecture, we will talk about what are those forces which will act on ocean structures. Just a glimpse we already said that offshore structures are divided into three categories; fixed type, compliant type and floating type.

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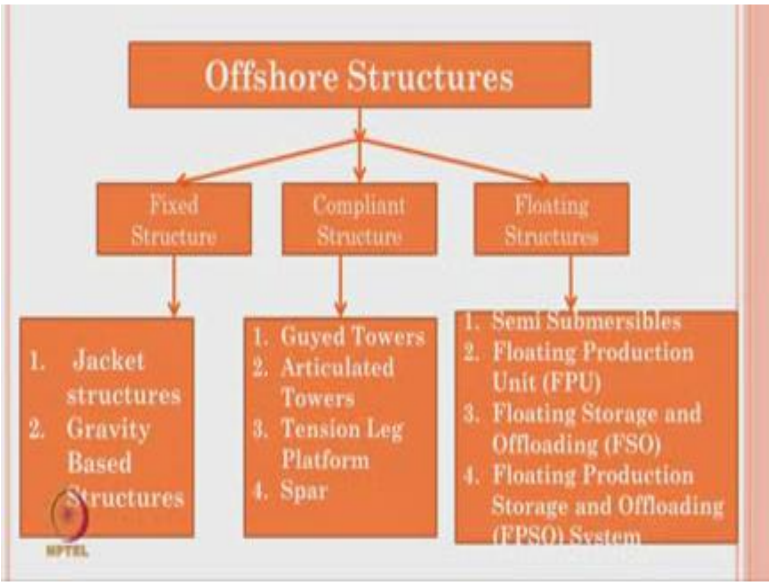

We are already seen in detail what are the functional requirements and form based demands in this type of structures, where do they operate etcetera in the last two lectures.

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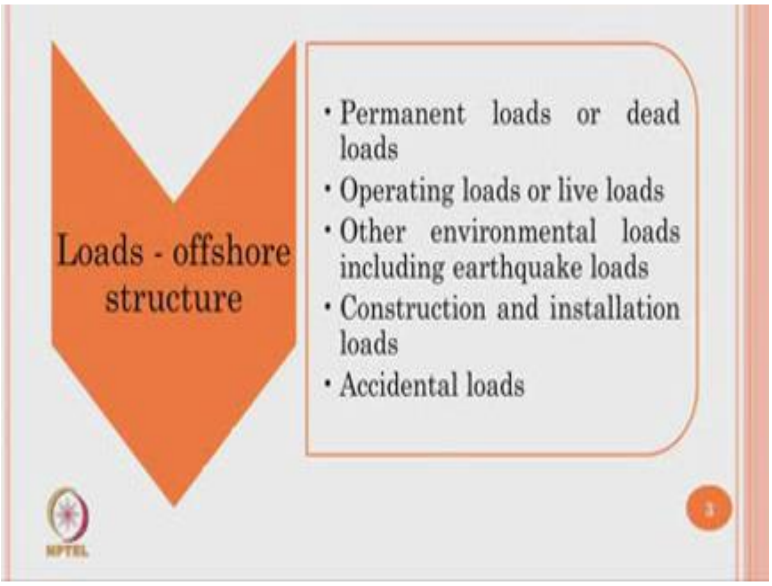

Now, let us talk about different varieties of loads which come on offshore structures. There are essentially five categories of loads; permanent loads or dead loads which are subrogated as Pl, operating loads or live loads which can be called as Ll, other environmental loads like earthquake loads called as Ol, construction and installation loads and finally, the accidental loads. Let us quickly see one by one how they can be estimated, what are the governing equations. We saw the spectrums being respectively used to estimate these forces.

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We start with the wind force. We will start from the top; the expose surface of the platform like drilling derricks, living quarters, helipad, and flare booms etcetera will be those structural systems which generally attract wind forces. We already must understand that offshore structures are designed as such a manner that the super structure is essentially kept transparent for wind forces.

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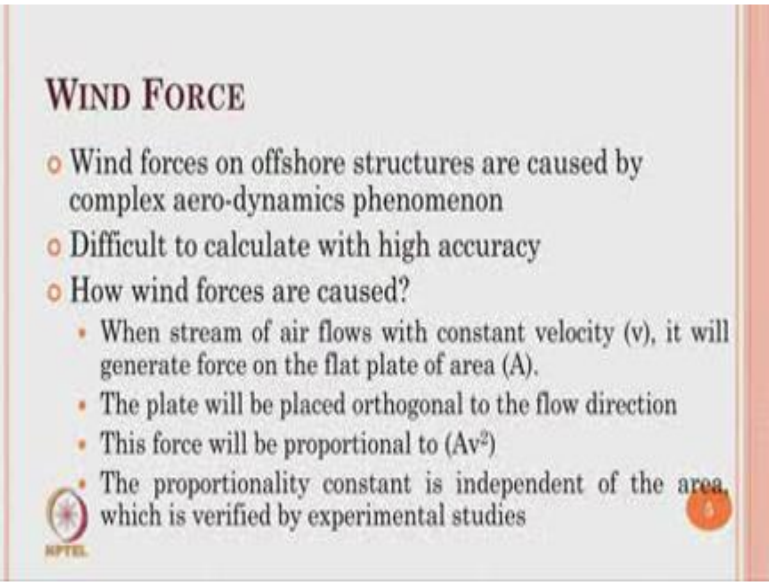

Wind force on offshore structure is essentially caused by complex aero dynamic phenomena. It is rather difficult to calculate them with high accuracy than how wind force is caused. When steam of air flows through the constant velocity v, it will generate the force on the flat plate whose area is A. Remember the area here is not the cross section area, but the area of exposure. Generally the area of exposure is considered normal or orthogonal to the flow direction. Therefore, this force will be now proportional and it is normal to the area of exposure and that value will be proportional to Av square, where A is the exposed area and v is the velocity of wind. The proportionality constant to estimate, this force remember is very important. It is independent of the area which is specified by experimental studies.

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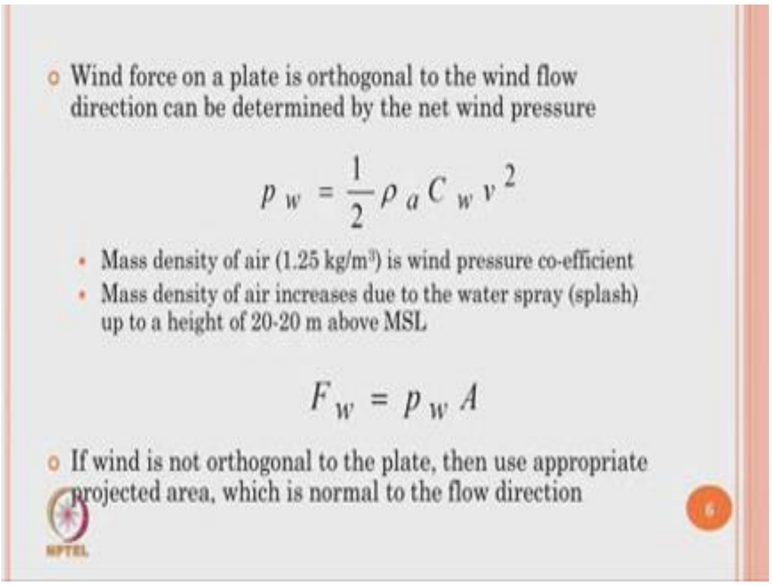

Therefore, the equation given below will tell you to estimate wind force on a plate which is kept orthogonal to the wind flow direction. Obviously, in this equation C w v and rho A can be those estimates which are to be calculated. Mass density is nothing, but the rho A which is taken as 1.25 kg cubic meter. Mass density of air increases due to the water spray because of the splash effect up to the height of 20 meters above the main sea level. Now, once we know the pressure which is a net wind pressure acting normal to the plate area, now I can find out the force which is given by the equation given below which is rho w into the exposed area or P w in the exposed area. So, P w is the one which is calculated from the above equation and area A is what we already calculated. Now, if the wind is not orthogonal to the plate or vice versa, the plate is not normal to the direction of flow direction of wind, then use appropriate projected area which is normal to the flow direction.

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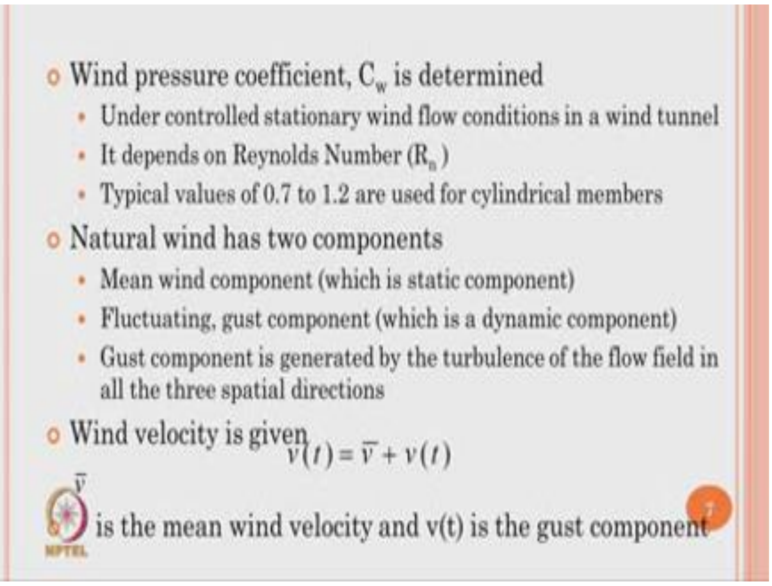

The wind pressure coefficient C w in the previous equation is generally controlled stationary. Wind flow condition in a wind tunnel is computed experimentally. It depends on the Reynolds number r n; the typical value which is being used in offshore design is varying from 0.7 to 1.2 for cylindrical members. Essentially you must appreciate by this time. Now, that most of the offshore structural members are cylindrical in shape, natural wind has got two components. One is the mean wind component which is a Static component and the other one is a fluctuating component. We call this as Gust component and technically speaking this component is a dynamic component.

Now, gust component is generated by turbulence of flow field in all three special directions respectively x, y and z planes. The wind velocity has got two components as we expressed here. One is the mean wind component which is static; the other one is the gust component which is varying the time which is dynamic v bar. In this equation is what we call mean wind velocity and V t is called the gust component.

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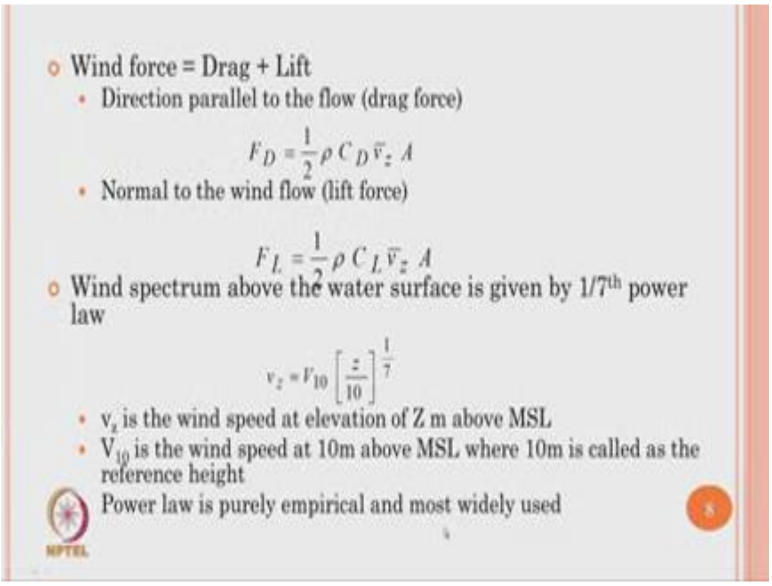

Wind force consists of two parts. One is the drag component; other is the lift component. The direction parallel to the flow is called as the drag force and the one which is normal to the flow is called as the lift force which is given by these two expressions as shown in the slide. Now, we generally use a wind spectrum above water surface which is given by 1 by 7 power law as given by this equation, where in this equation V z is a wind speed at any elevation, z meter above the mean sea level whereas, v 10 is considered as the wind speed at 10 meter above the m s l, where this 10 meter is called as a reference height from the data power law. Remember friends it is purely empirical, however is most widely used.

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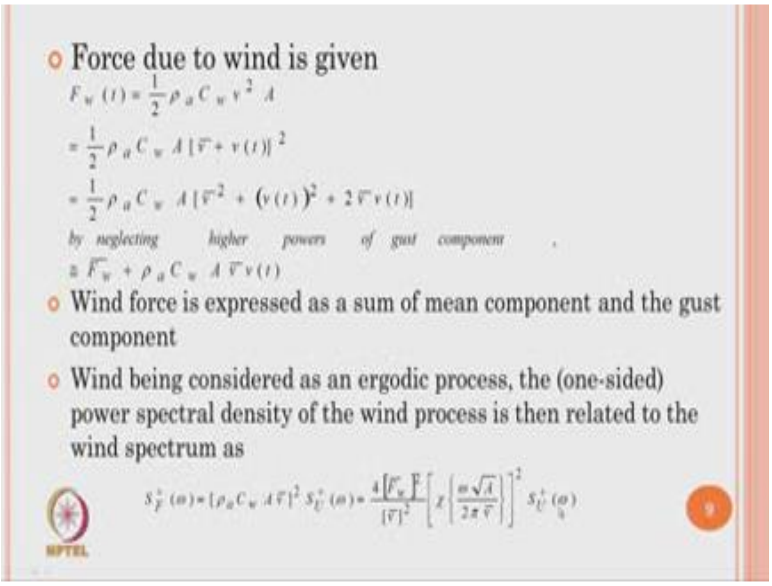

So, force due to wind is given by this equation of summarizing the previous equations together in one half rho a C w V square A. we already know the components of rho a C w V and A etcetera and we already know that v has got two components; the static component and the gust component. You tried to expand this equation and neglecting higher powers of the gust component, we have simply this value like this. Now, the wind force is therefore expressed as a mean component of wind and the gust component the wind being as Ergodic process, the one sided power spectral density function of the wind process is then related to the wind spectrum as given by this equation as you see in the slide now.

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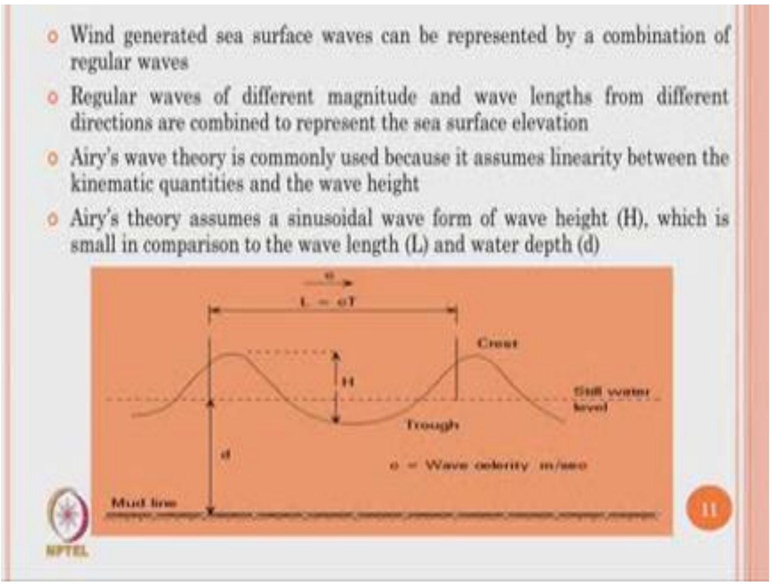

After understanding how to compute the wind forces from the desired spectrum, let us talk about the next major environmental load coming on offshore structure which is wave forces. Wind generated sea surface waves can be represented by a combination of different regular waves as shown in the slide. Regular waves of different magnitude and wave lengths from different directions are combined together to represent the sea surface elevation. That is a general phenomenon. Airy's wave theory is most commonly used as a preliminary theory because it assumes linearity between the kinematic quantities and the wave height. Airy's theory assumes a sinusoidal form as you seen in the figure here, where h is the height from the crest to the trough and that is we call as the wave height which is very small in comparison of the wave line which is varying from one specific point on the wave to the corresponding point on the next wave.

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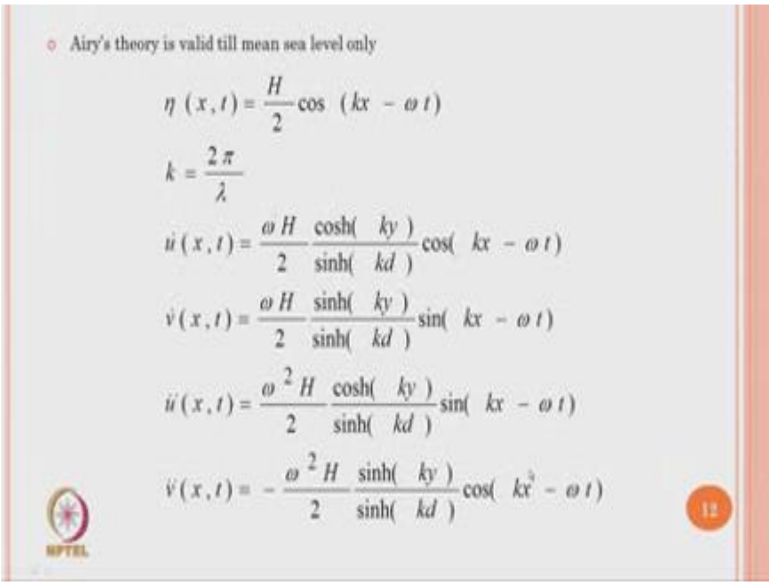

So, this is what we call as wave length and wave height is generally small in comparison to the wave length and of course, d represents water depth and capital D will represent the member diameter. In this equation, c is called wave celerity which is expressed in meter per second. Now, Airy's wave theory is valid only till the mean sea level. So, Airy's wave theory straight away gives you the surface elevation which is eta x of t as given by this equation, where k is called as a wave number and lambda is a wave length as we know and u dot u double dot v dot and v double dot are respectively the horizontal water particle velocity and acceleration and vertical water particle velocity and the acceleration respectively which is derived from as a function of the c surface elevation which is given by Airy's linear wave theory. It is linear because it assumes linearity between the wave height and the wave water particle kinematics.

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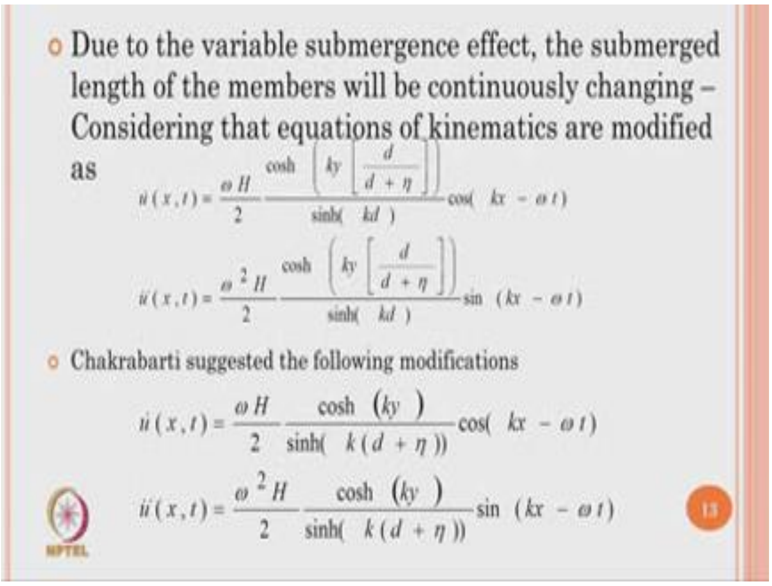

Now, due to the variable submergence effect, one can ask me a question what is variable submergence effect. Please understand here in this picture that this is still water level. In the cylinder of the member remains exactly here and the water level remains static as horizontal. Then, there is no variation of the wave wide with respect to the immerse level of the cylinder, however the wave is not horizontal, but it follows the crest trough as you see here.

Therefore, when the cylinder is static at a specific place as a waves passes through the cylinder, some portion of the cylinder will immerse more and some will immerse less. This is what we call as variable submergence effect. The submerged length of the member will continuously change. Therefore, the kinematics needs to be modified if you really want to include the wave submergence effect which is given by Chakrabarti's modification. Chakrabarti's modification suggests there is a difference in the horizontal water particle velocity and acceleration. As you see in the equation given here in this expression except everything already explained, d here is a water depth measured from the main sea level.

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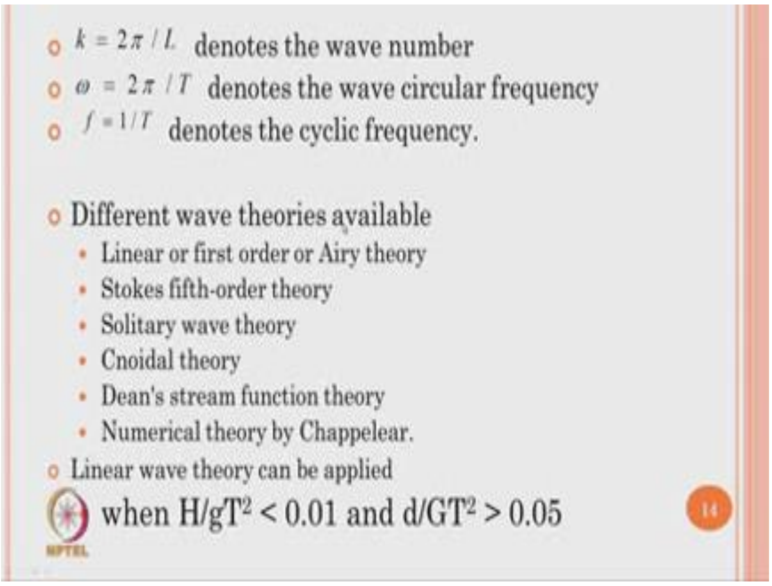

So, k denotes the wave number, omega denotes the wave circular frequency and of course, f denotes the cyclic frequency which is immerse of the period of wave. Now, to estimate the water particle kinematics that is nothing, but the horizontal and vertical water particle velocity in acceleration. There are different wave theories available in the literature linear or first order Airy's theory, Stokes fifth-order theory, Solitary wave theory, Cnoidal wave theory, Dean's stream function theory, Numerical theory given by Chappelear. The linear wave theory can be applied only when the specific condition is satisfied, where H by g T square is less than 0.01 and d by GT square is greater than 0.05.

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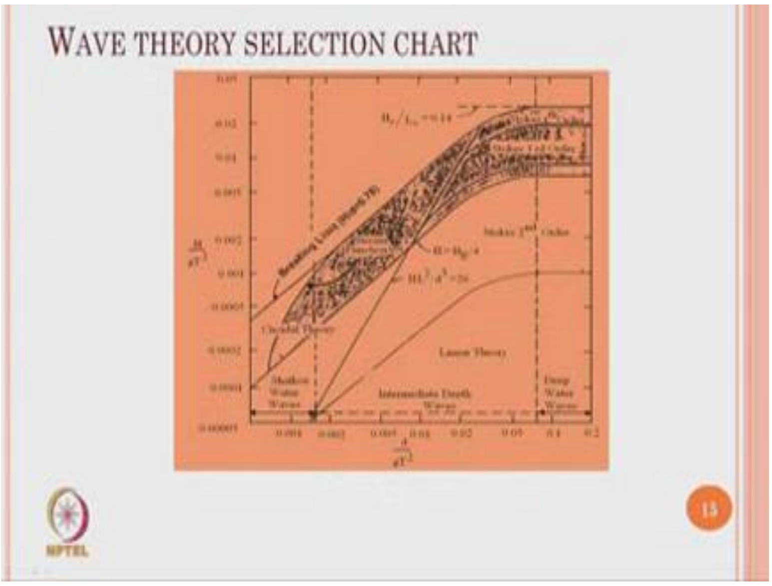

Now, this chart which is shown in the slide now will be a governing chart for selecting the corresponding wave theory. Depending upon the two corresponding ratios H by g T square and D by g T square for a given wave period for a given water depth for a given wave height, you know the vertical and the horizontal axis values. Based on this you will know which theory you want to follow; linear theory, stokes second order, cnoidal theory, shallow water theory etcetera. So, one can select any relevant theory and from the theory, one can estimate the horizontal and vertical water particle velocity and acceleration.

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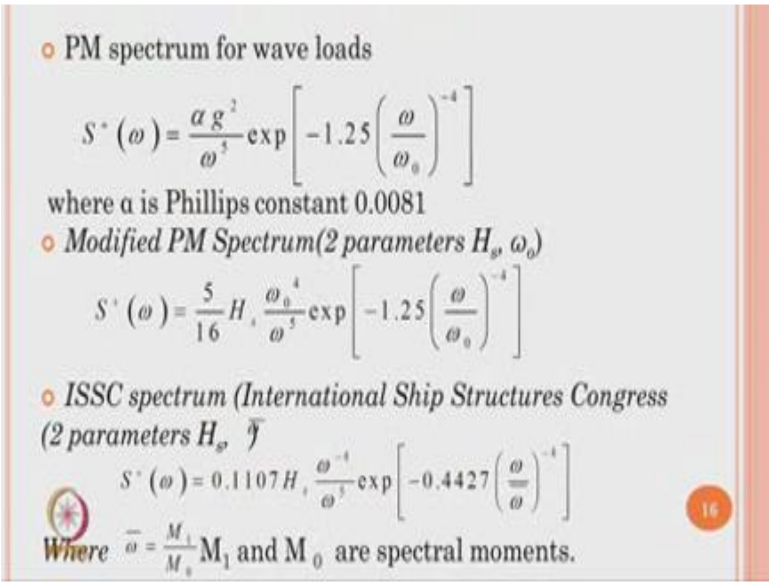

Alternatively you also have spectrums to designate the wave loads. The famous spectrum as you see here is S omega as given by the expression given here, where alpha in this equation is known as Phillips constant which value is 0.081 subsequent to this Moscow weights as proposed, the spectrum which is modified and with two parameters HS and omega naught as you see here, we also use international ship structures congress specified spectrum which is also a two parameter spectrum HS and omega bar which is famously known as ISSC spectrum as given by this equation whereas, in this equation omega bar is the ratio of M1 by M naught, where M1 M naught are called spectral moments of the spectrum.

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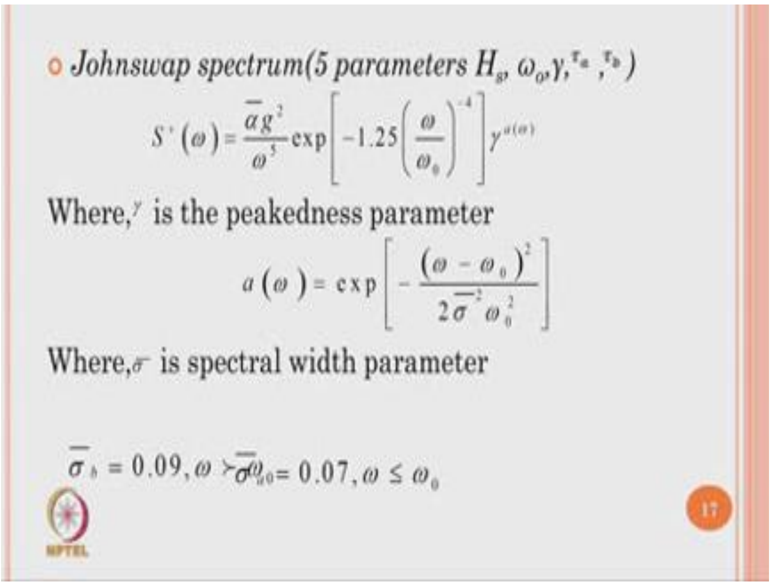

We also have something called Johnswap spectrum which is 5 parameter spectrum H s omega naught gamma tau a and tau b and the equation is available in this screen now, where in this case mu is known as the peakedness parameter and sigma bar is spectral width parameter as used here which can be used to compute.

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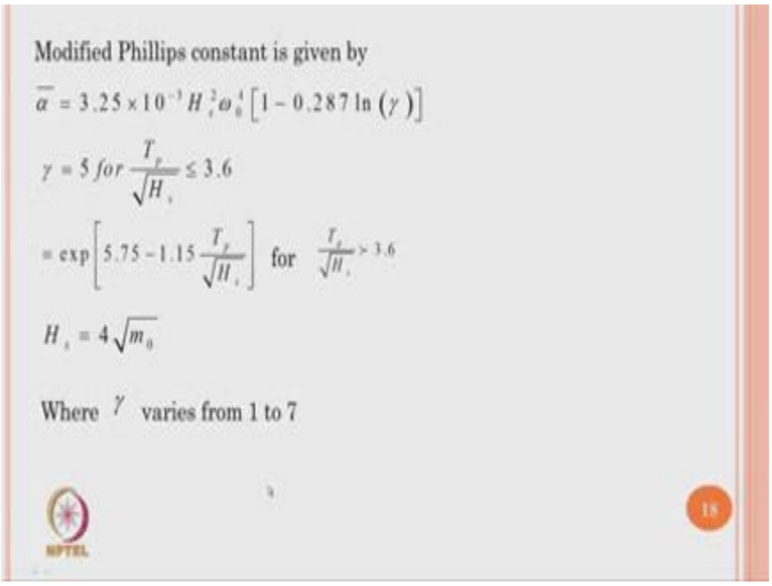

The limit’s between sigma b and sigma a bar, the Phillips constant as you see here earlier is subsequently modified and therefore nu is also modified for a given value and the variation of nu is from 1 to 7. With the help of all these spectrums available in the literature, one can know the forces coming on offshore members.

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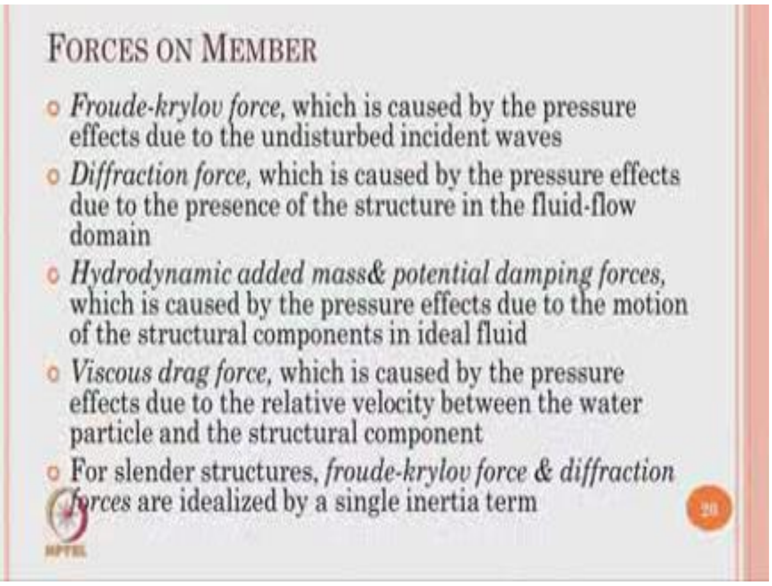

Let us see how these forces can be computed on offshore members. Froude-Krylov force is essentially caused by the pressure effects due to the undisturbed incident waves. Diffraction force is also caused by the pressure effects due to the presence of structure in the fluid flow domain. Hydrodynamic added mass and potential damping forces are caused by the pressure effects due to the motion of the structural components in ideal flow fluid. Viscous drag force is caused by the pressure effects due to relative velocity between the water particle and the structural component for slender structures. Froude-Krylov force and the diffraction force are idealized by single inertia term.

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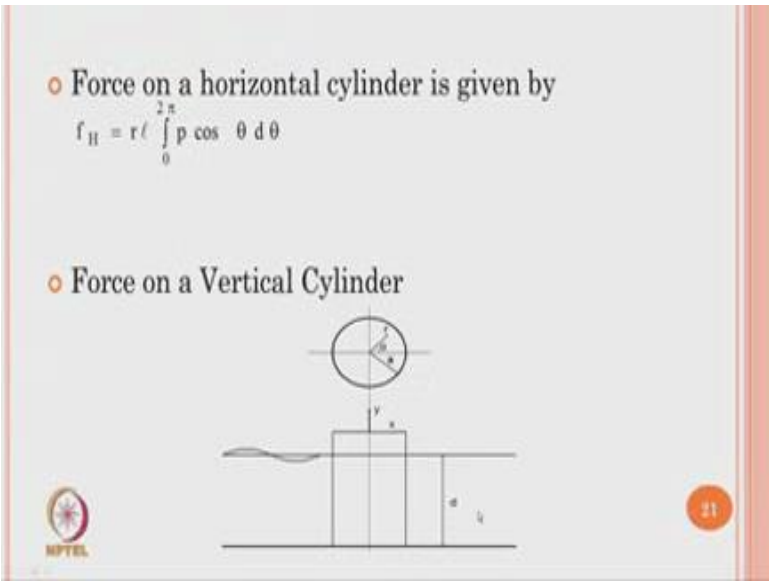

Let us quickly see what governing equation is which tells me to estimate force on a horizontal cylinder which is available in the screen now.

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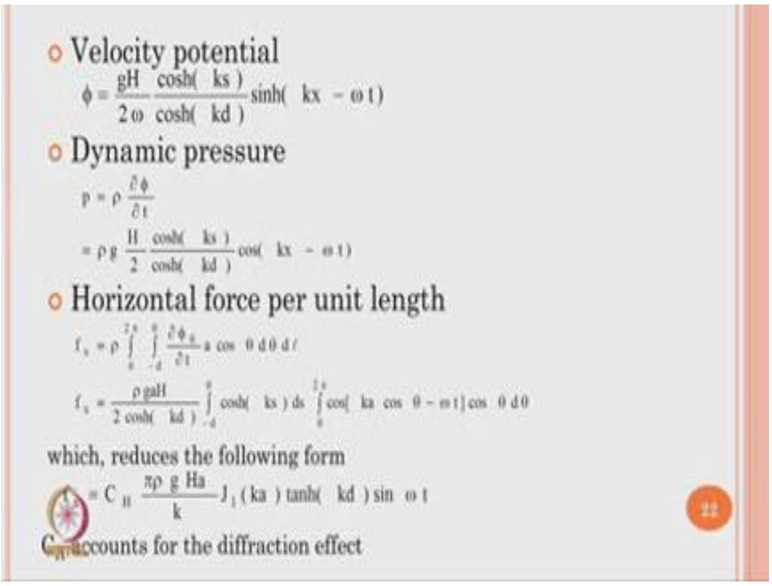

Force on a vertical cylinder will be given by the velocity potential and the dynamic pressure variation as seen in the equations in the slide. Now, the horizontal force per unit length is therefore given by the expression. As you see here, this reduces to the following conventional form where C h accounts for diffraction effects in the region.

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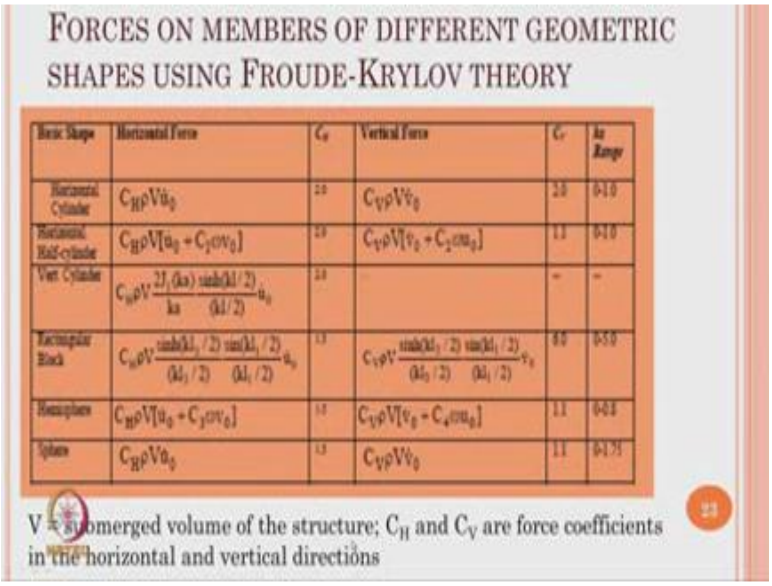

Now, forces on the members of different geometric shapes using Froude-Krylov theory is available and summarized in a tabular form, where the value of C h is also recommended by the theory for different basic shapes as horizontal cylinder, horizontal half cylinder, vertical cylinder, rectangular block hemisphere and sphere. The horizontal force is given by this equation and the vertical force is given by this equation, where the horizontal coefficient and the vertical coefficient are given by these two respective columns whereas, the range applicable to this equation is available in the last column.

In this equation, v stands for the submerged volume of the structure, c h and c v as explained are the force coefficients in the horizontal and vertical directions respectively. Now, we have understood how to compute the wind force acting on the super structure, how to compute the wave force acting on the immerse section of the force body.

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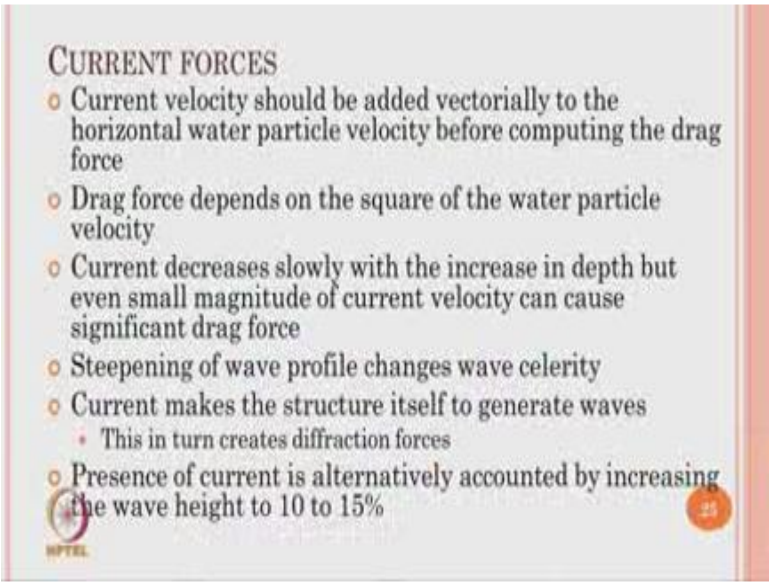

Now, let us talk about the presence of current forces on members. Current velocity is generally added vectorially to the horizontal water particle velocity before computing the drag force. Drag force depends on the square of the water particle velocity. Current decreases slowly with the increase in depth, but even small magnitude of current velocity can cause significant drag force. Therefore, you must add current velocity vectorially before you compute the drag force because drag force is square of the water particle velocity. So, remember that steepening of the wave profile changes. Wave celerity current makes the structure itself to generate waves and this in turn creates additional diffraction forces.

Now, the presence of current is alternatively accounted also by generally increase in the wave height by about 10 to 15 percent. The second kind of force which also acts on the offshore structure member is the earthquake forces. One can ask me a question how earthquake loads become important in offshore structures. Friends, as we all agree and understand by this time that when offshore structure system is bottom supported that is when they rest on the sea bed for example, gravity wave structures for example, jacket or template structures which are held down in position by piles, resting on piles the seaquakes happenings at the sea bed or transfer directly to the that of the members, however when the members are floating or when the structure of the platform is compliant in nature, how earthquake forces to bother the platform is very important. Let us see the successive equations.

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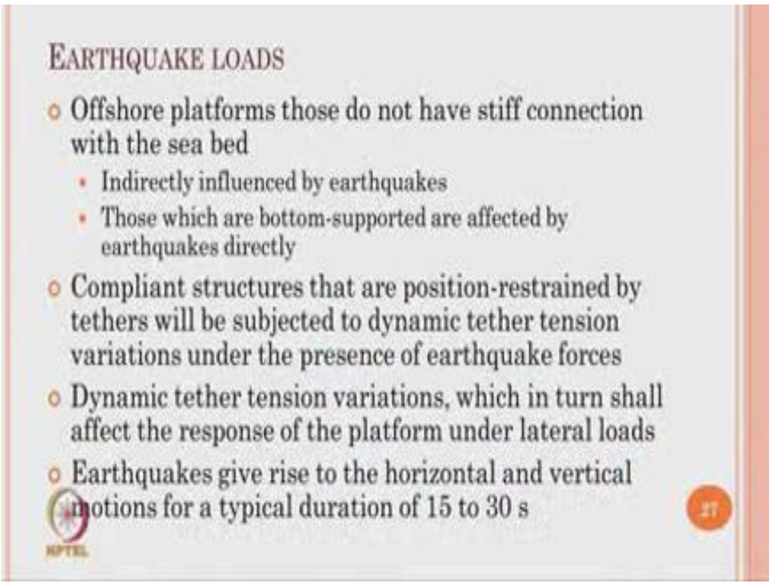

Offshore platforms, those do not have stiff connection with the sea bed are indirectly influenced by earthquakes. However, when they are bottom supported, they are affected directly by the earthquakes, but the compliant structures that are position restrained by tethers for example tension leg platform will result in dynamic tether tension variations because as we all know tethers are used held on the platform on position. When the tethers are affected by the earthquake, loads super imposed on them and tension in the tether changes. We call this as dynamic tether tension variation and this has occurred because of the presence of the earthquake forces.

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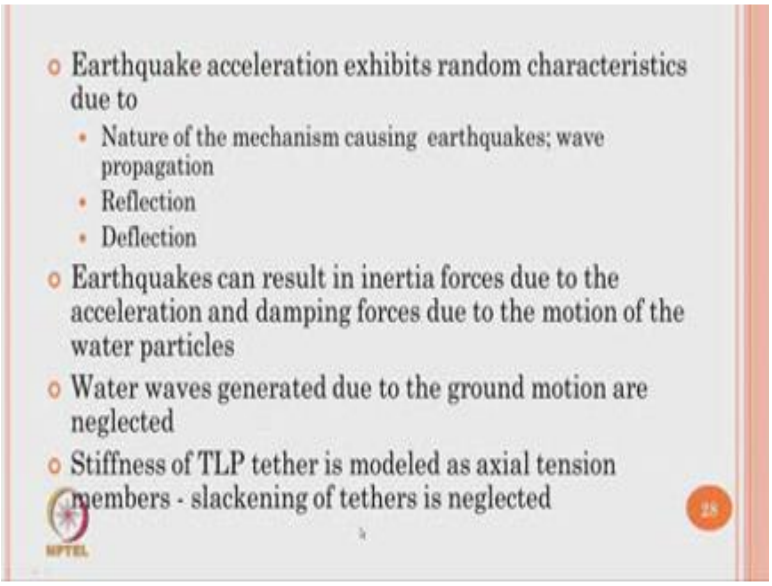

The dynamic tether tension variation in turn will affect the response of the platform under lateral loads. The earthquakes forces therefore give rise to the horizontal and vertical motions of a typical duration varying from 15 to 30 seconds. Earthquake forces accelerate random characteristics due to the nature of mechanism causing earthquakes wave propagation reflection and deflection. Earthquakes can result in inertia forces due to acceleration and damping forces due to motion of the water particle. Water waves generated during the ground motion are generally neglected in the study. Stiffness of the tether is modeled as an axial tension member and slackening of the tether is generally neglected in the dynamic analysis.

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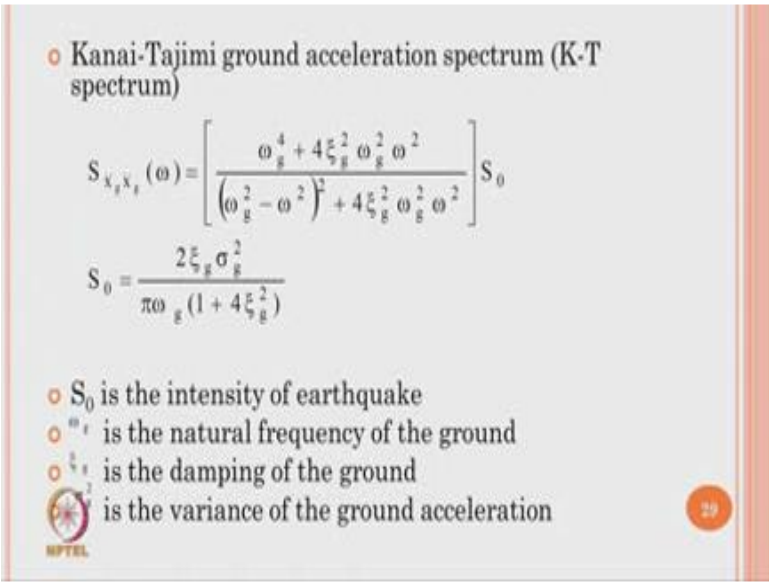

There are two spectrum generally given out of which the famous spectrum which is commonly used for seismic analysis of offshore compliant structure is Kanai Tajimi ground acceleration spectrum which is briefly called as KT spectrum. The equation is available there where s naught is called the intensity of earthquake which is given by this equation, where omega g in this expression is called natural frequency of the ground motion, zeta g is the damping of the ground whereas, sigma g square is the variance, sigma g square is the variance of the ground acceleration.

So, we discussed about the aerodynamic loads or the wind loads acting on the super structure, we talked about wave loads, different wave theories very briefly and we discussed about couple of spectra commonly used in offshore structure, we talked about the current forces, we talked about the earthquake forces. The next is on the line is the ice and snow loads.

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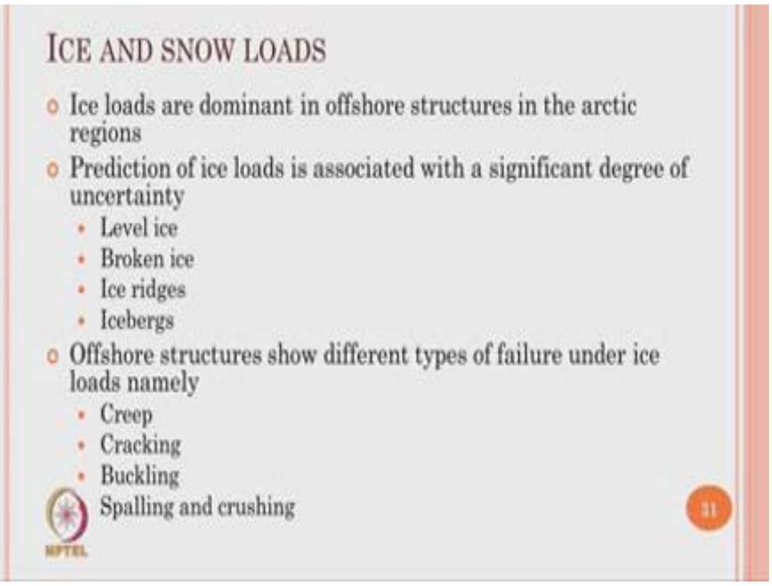

Ice loads are dominant in offshore structures in the arctic regions. Prediction of ice is generally associated with a significant degree of uncertainty because it depends upon whether the ice is a level ice, broken ice, is it ice ridge or iceberg because impact cause by this are entirely different on the structural members. Offshore structures show different modes of failure under ice loads. They may result in creep failure, they may result in cracking, they may cause buckling and they may also result in spalling and crushing of concrete.

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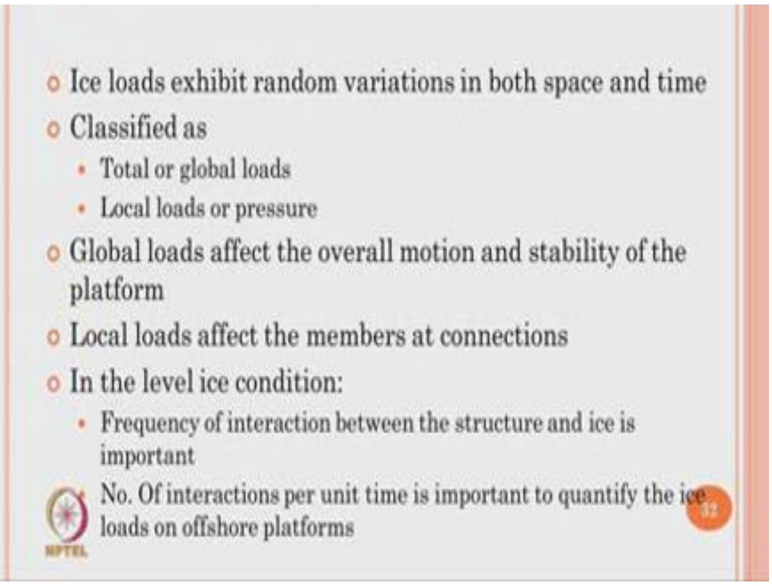

Ice loads exhibit random variations in both space and time and therefore, they are purely dynamic in nature. They are classified as with the total or global loads local or pressure variations. The global load affects cause the overall motion and affects the stability of the given platform whereas, the local loads cause members only at the connections. Now, in the level ice condition, the frequency of interaction between the structure and ice is very important where the number of interactions per unit time is important to quantify the ice loads on offshore structures.

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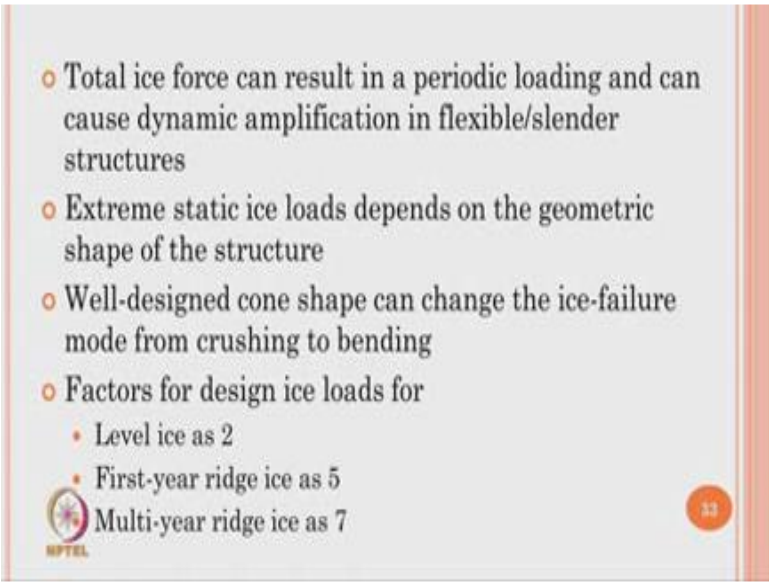

The total ice force can result in a periodic loading and can cause dynamic amplification in flexible and slender structures. Extreme static ice loads depends on geometric shape of the structure. Well-designed cone shape can change the ice failure mode from crushing to that of bending factors which are commonly used for the design loads or for level ice. It is 2, for first year ridge ice it is 5 and multi-year ridge ice it is 7.

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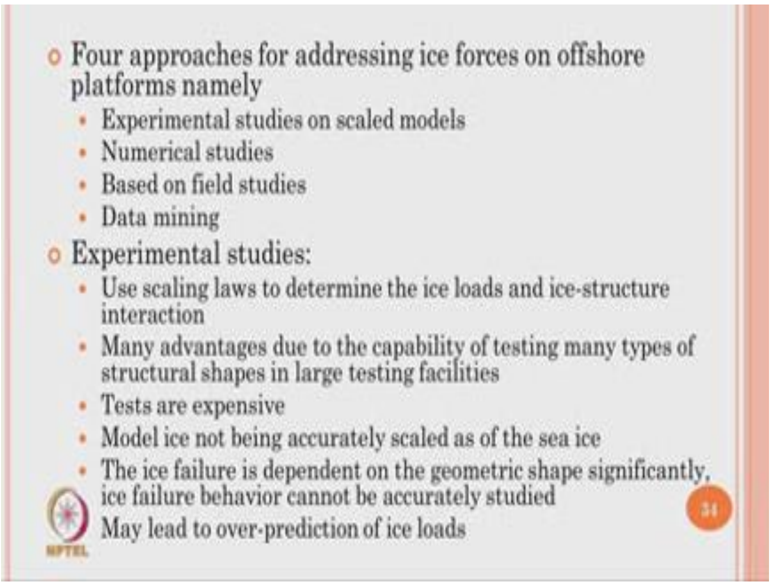

There are four approaches available in the literature for addressing ice forces on offshore platforms. They are namely experimental studies on scaled models, numerical studies, based on field investigations and of course, data mining. If we look into the experimental studies scaling laws used are generally to determine the ice loads and ice structure interaction considerably many advantages due to the capability of testing. Many types of structural shapes in large testing facilities as resulted in evolving this kind of equations. Of course, these tests are very expensive. Model ice not being accurately scaled as of the sea ice; the ice failure is dependent on the geometric shape significantly an ice failure behavior, therefore cannot be accurately studied. It may lead to over prediction of ice loads.

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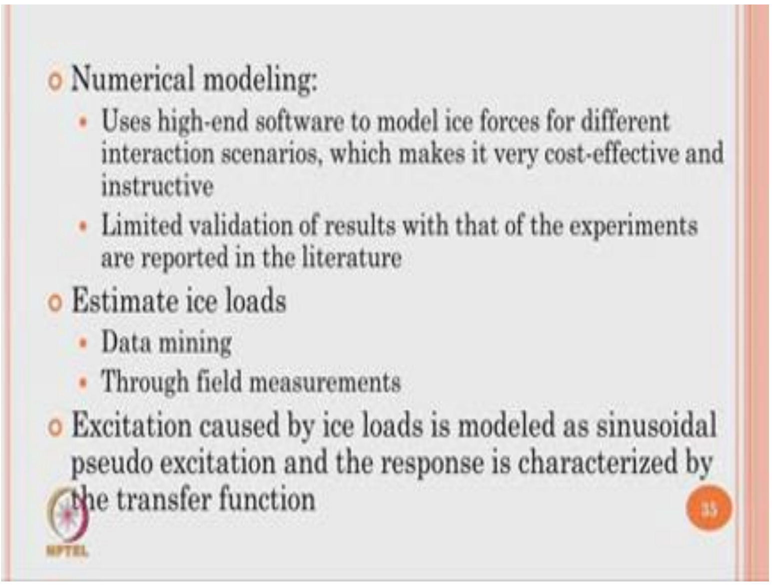

If we look at the numerical modeling of ice loads on offshore structures, this uses high end software to model ice forces for different interaction scenarios. This makes it very cost effective and instructive. Limited validation of result is available and comparable with that of experimental results. Therefore, they are very scarce in the literature. If we look at the estimated ice loads, generally people use data mining or through field measurements. The excitation caused by ice loads is modeled as sinusoidal pseudo excitation and the response is characterized by an appropriate transfer function.

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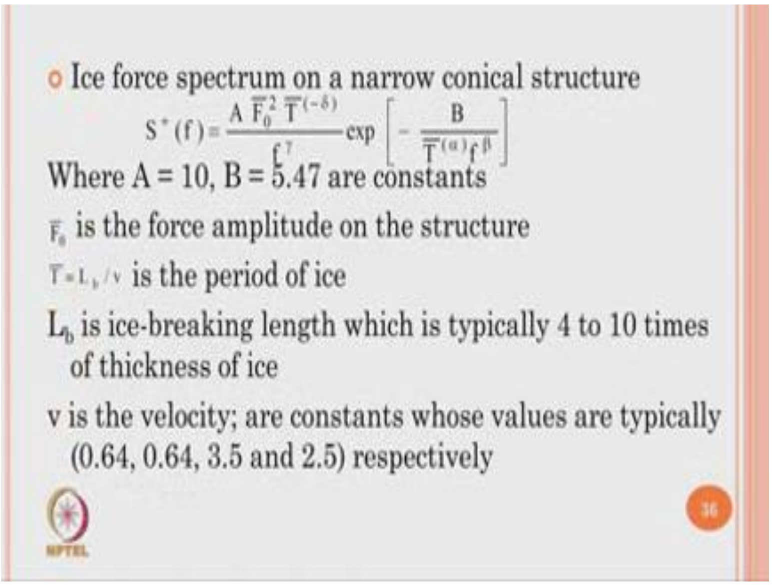

The ice force spectrum on a narrow conical structure is given by the equation available on the screen now, where the constants A and B used in this equation are 10 and 5.47 respectively, f naught is a force amplitude on the structure t bar is called as period of ice which is a ratio of l b over v, where l b is ice breaking length which is typically 4 to 10 times of thickness of the ice, where v is the velocity constants are values which are typically varying from 0.64, 3.5 and 2.5 respectively.

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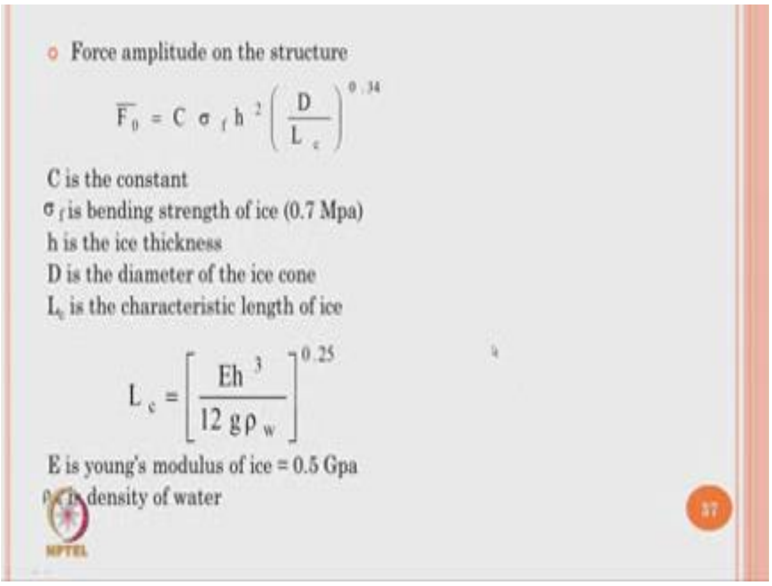

Let us quickly see what is the force amplitude caused on the structure which is given by the equation available on the slide, where C is the constant, sigma f is the bending strength of ice which is taken as 0.7 mega pascal, h in this equation represents the ice thickness, D is the diameter of the ice cone and L c is the characteristic length of ice which is given by the equation below, where in this equation E capital is young's modulus of ice which is 0.5 Giga pascal and rho w, the density of water is 1000 kg per cubic meter. Having said this, another source of important load coming on offshore structure is marine growth. It is an additional deposit which grows along the circumference length of the member which increases the diameter of the member. As the diameter of the member increased start attracting more forces will create added mass to the structure, the structure will become stiff. It also results in corrosion.

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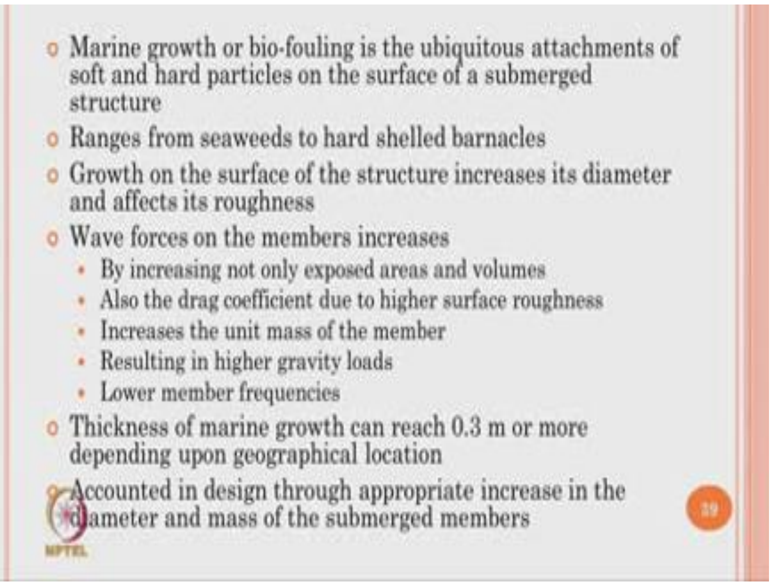

Marine growth or bio fouling is ubiquitous attachments of soft and hard particles on the surface of a submerged member. This ranges from seaweeds to hard shelled barnacles. The growth on the surface of the structure increases its diameter and of course, it affects its roughness. Very significantly wave forces on the members therefore increases because of various reason.

One by increasing not only exposed area and volume, it also increase the drag coefficient because the roughness of the member increases the drag coefficient changes due to higher surface roughness, increases the unit mass of the member results in higher gravity of loads and also, it makes the member frequencies slightly lower. The thickness of the marine growth can reach a maximum over 0.3 meter or 3 in m. Sometimes it can even more depending upon the geographic location, this is generally accounted in the design through appropriate increase in diameter and mass of the submerged members.

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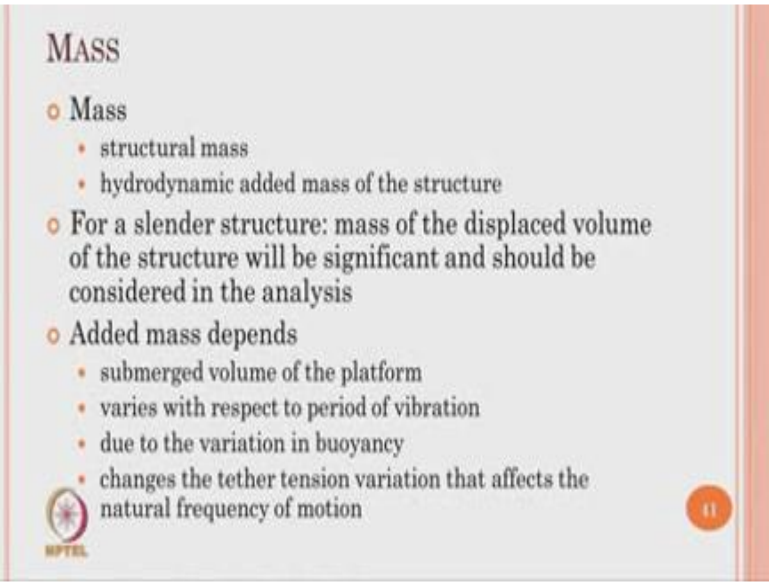

Now, let us come to how to calculate mass in an offshore member. There are two kinds of mass that we will talk about in dynamic analysis. One might be called structural mass and the other one is called hydrodynamic added mass of the structure. For a slender structure, the structural mass is the mass of the displaced volume of the structure which will be significant because it is floating on slender structure and therefore, should be considered in the analysis. The added mass depends on submerged volume of the platform. It varies with respect to the period of the vibration. It is also due to the variation in buoyancy and it is also caused by change in tether tension variation which affects the natural frequency of motion of the platform.

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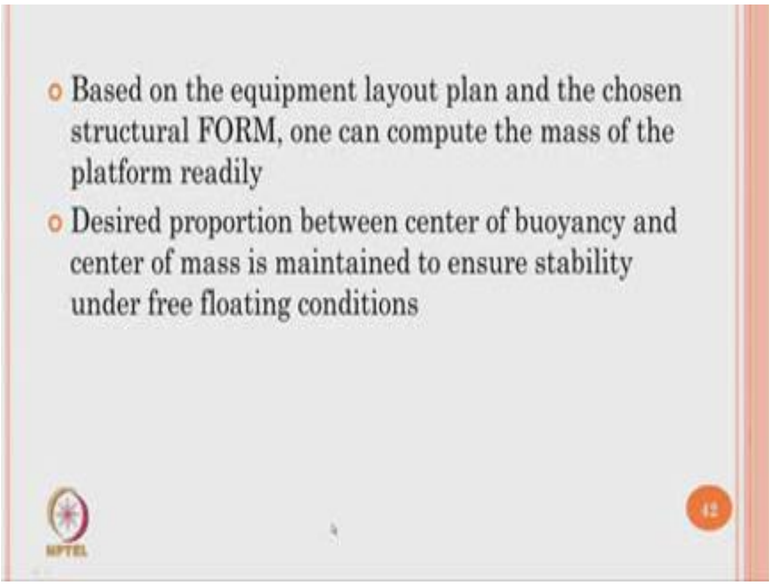

Based on the equipment layout of the plan and chosen structural form, one can easily compute the mass of the members and therefore, the whole platform readily desired proportion between the center of buoyancy and center of mass is maintained to ensure stability even under free floating conditions.

Friends, please understand that form based design is very important governing parameter in offshore structures because whatever maybe a shape and size of the member, you have to maintain a specific desired ratio between the center of buoyancy and center of mass. If you really want to maintain here stability in the given platform even under free floating condition because if a complaint structure like TLP tethers are pulled off, TLP should be able to remain stable in free floating conditions. The next aspect which comes in dynamic analysis is damping.

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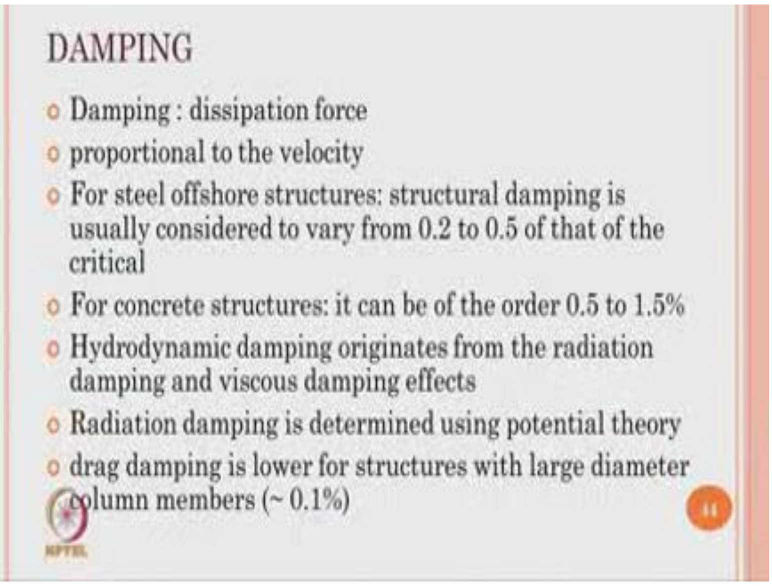

Damping is nothing, but a dissipating force. It is proportional to the velocity. In this case there are varieties of damping which we will talk about slightly later in the same module. For steel in offshore structures, structural damping is generally considered to vary from 0.5 to 0.2 with that of the critical for concrete structure; however this value can be of the order between 0.5 to 1.5 percent.

The hydrodynamic damping generally originates from the radiation damping and the viscous damping effects. Radiation damping is determined using potential theory. The drag damping is lower for structures with large diameter of column members is about 0.1 percent.

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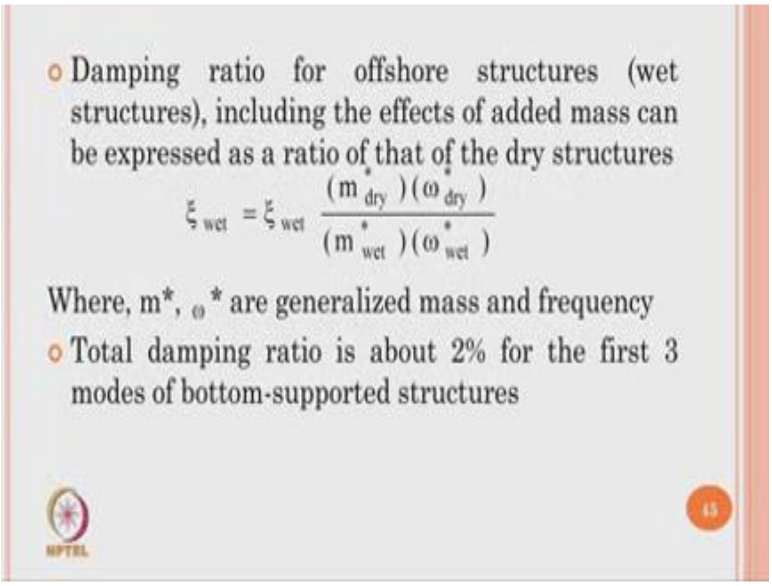

The damping ratio for offshore structures that is wet structures including the effect of added mass can be expressed conveniently as a ratio of dry structures as given in the equation below. So, the damping ratio of the wet structure can be expressed as the proportional of the mass of the dry system and the frequency is dry with respect to the mass of the wet system and the frequency is wet, where m star and the omega star are otherwise called generalized mass and frequency respectively. However, the analysis confirms that the total damping ratio in offshore structure is only about 2 percent for the first three modes of bottom supported structures.

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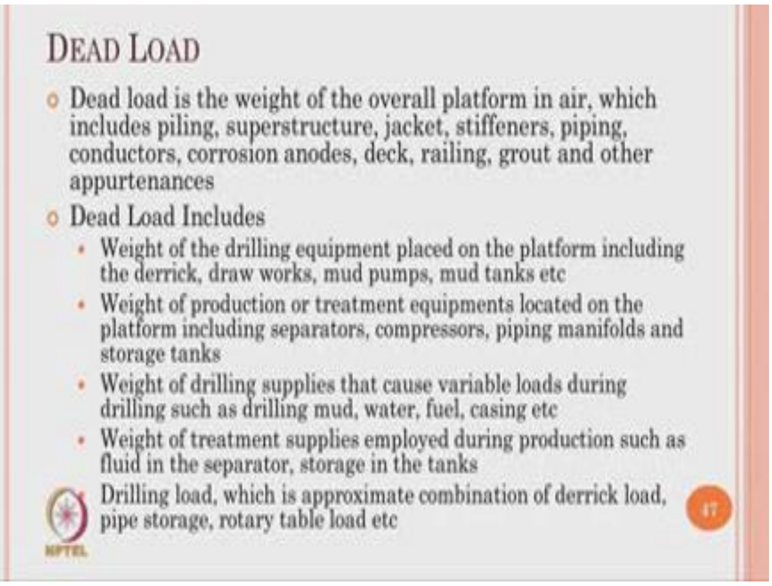

The other important aspect of load which plays a role in offshore structure is the dead load. Dead load is nothing, but the overall weight of the platform in air which includes piling, superstructure, jacket, stiffeners, piping, conductors, corrosion, anodes, deck, railing, grout and similar other appurtenances used for drilling and acceleration. The dead load includes weight of the drilling equipment placed on the platform which includes the derrick, the draw works, the mud pumps, the mud tanks etcetera.

Weight of production or treatment equipment located on platform which includes separators, compressors, piping, manifolds and storage tanks, it also includes the weight of drilling that cause variable loads during drilling such as drilling, mud water fuel and even casing etcetera. Dynamic load, sorry dead load also includes weight of treatment employed during production such as fluid in the separator storage in the tanks etcetera. It also includes the drilling load which is approximately the combination of derrick load, pipe storage, and rotary table load etcetera.

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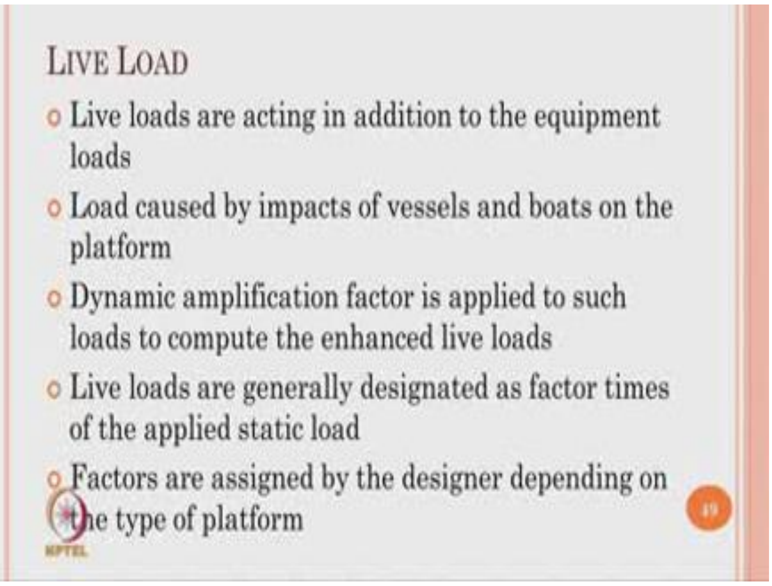

Let us talk about the live load which is acting on offshore platforms. Live loads are acting addition to the equipment loads caused by impact of vessels and boats on the platform. Live loads are generally associated with a factor called dynamic amplification factor which will take care of the effects of impact caused by the vessels on the platform members. So, dynamic amplification factor is applied to such kind of loads to compute the enhanced live loads. Live loads are generally designated as some factor times that applied static load. These factors which are nothing, but multipliers to the static loads are assigned by the designer in charge depending upon the type of the platform.

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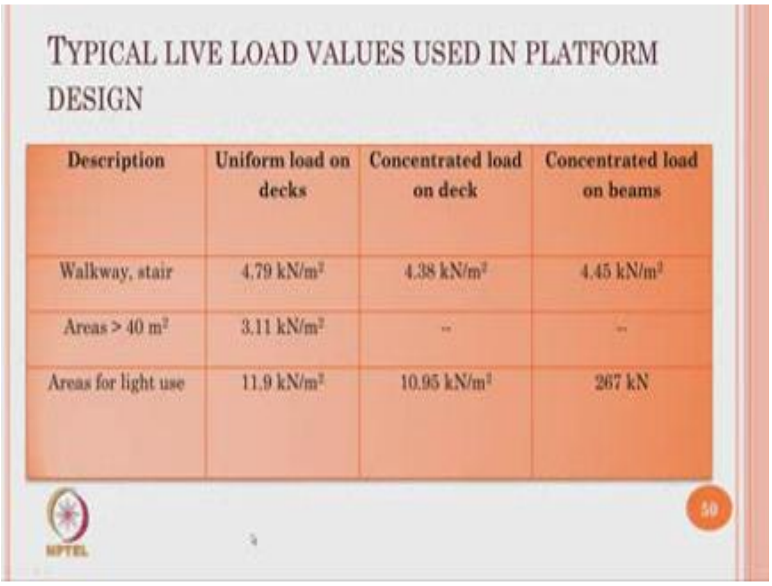

TYPICAL LIVE LOAD VALUES USED IN PLATFORM DESIGN

Description	Uniform load on decks	Concentrated load on deck	Concentrated load on beams
Walkway, stair	4.79 kN/m²	4.38 kN/m²	4.45 kN/m²
Areas > 40 m²	3.11 kN/m²	--	--
Areas for light use	11.9 kN/m²	10.95 kN/m²	267 kN

This table quickly shows the typical live load values used in the platform design. There are varieties of live load which are multiplied uniform deck loads, concentrated deck loads, concentrated loads on the grid beams. There are different areas which are also having different designation of forces as suggested by the international courts for walkway and stair case for areas above 40 square meters. For areas light in use, you have different recommended values given by the international courts.

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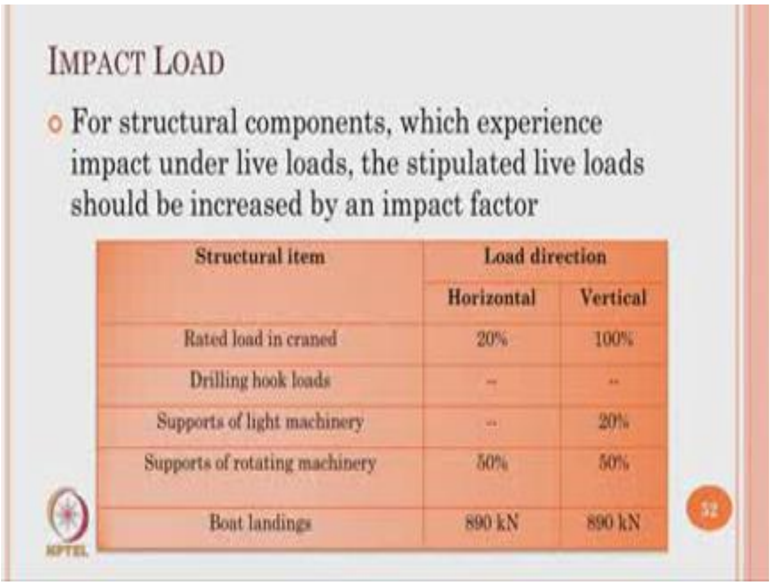

The next one is talking about the impact load for structural components which experience impact under live loads. The stipulated live load should be multiplied by an impact factor as you see here. Now, the impact factor can cause in additional increase in load both in horizontal and vertical directions. The rated load in cranes can be 20 and 100 percent whereas, support light machinery we have got only multiply factor of 1.2 and add it only on the vertical component whereas, if we are talking about supporting of rotating machinery, then you must divide the total additional load equally to the horizontal and vertical components. We have boat landing. There is no percentage given. Straight values are given in the core.

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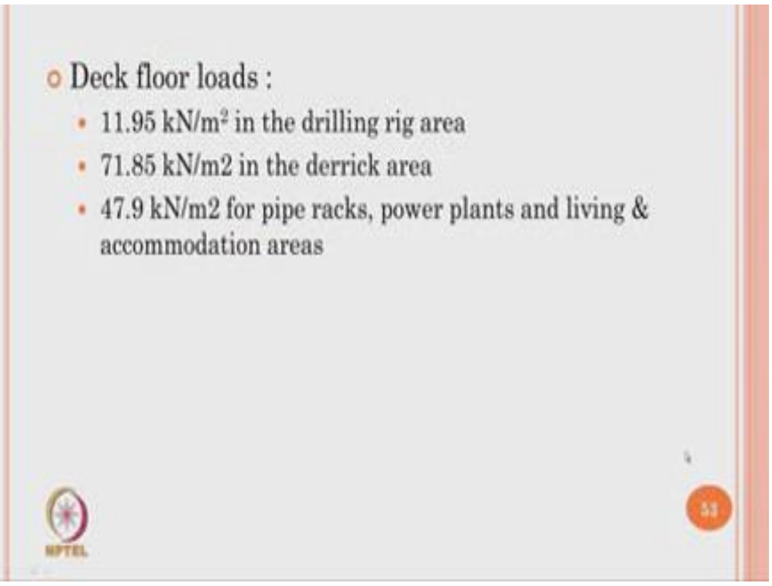

The typical deck floor load where the drilling rig is located varies from 11.95 kilo newton per square meter whereas, the derrick area will have a live load of 71.85 kilo newton per square meter whereas, the pipe racks power plants living and accommodation areas will have a live load of 47.9 kilo newton per square meter.

Friends before we move on the dynamic analysis, let us quickly see a hint on general designed requirements.

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Design methodology of offshore platform differs with different types of offshore structures. For example, in case of fixed structure, the vertical deformation will be lesser because it is bottom supported like jacket platform or GBS. These structures are highly rigid and therefore, they tend to attract more forces. The design criteria share therefore should be to limit the stresses in the members and not the displacement. The displacement of course under the members, under these applied loads will be quite insignificant.

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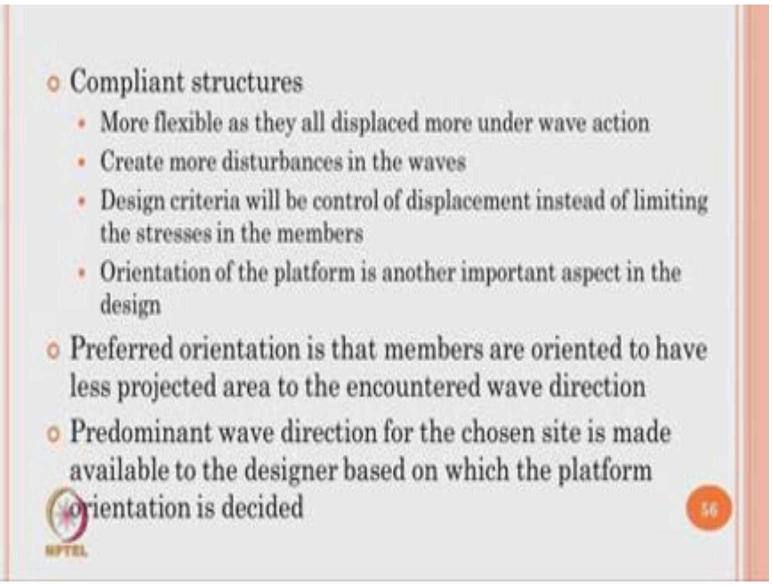

On the other hand, in case of compliant structures as they are more flexible, they are displaced more under wave action. This creates more disturbances in the wave surrounding the platform, the design criteria. Therefore, we will be to control the displacement instead of limit in the stresses in the members. You understand when you won't talk about design of fixed structures. We talk about membrane stresses and member forces and stresses, whereas in compliant structures we focus on displacement. We must control the displacement compared to that of limiting the stresses.

Of course, orientation of platform is another important aspect in the design. The preferred orientation is that members are oriented to have less projected area to the encountered wave direction, but we all agree and understand wave direction is not unique, is not fixed. Wave can vary from any direction. Therefore, the preferred orientation should be symmetric to the wave approach angle.

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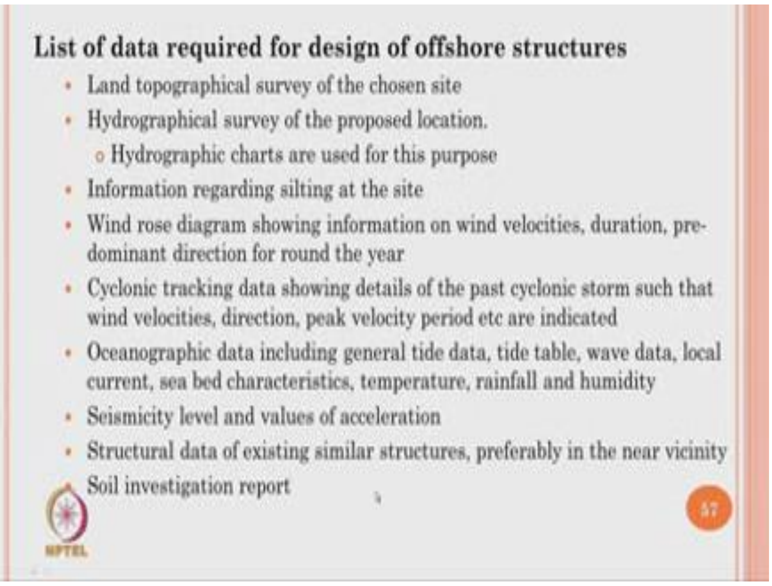

The prominent wave direction for the chosen side is made available to the designer before the platform orientation is decided to do this, there are different data required by the designer land topographic survey of the chosen site. Hydrographic survey of the proposed location hydrographic charts information regarding silting at the site; wind rose diagram which shows information on wind velocity, duration, predominant direction round the clock the year. Cyclonic tracking data which shows detail of past cyclonic storm such that the wind velocity, direction, peak velocity period can be calculated.

Oceanographic data include general tide data, tide table wave data, local current sea bed characteristics, temperature, rainfall and humidity. Seismicity level and values of acceleration also known to be in advance, the structural data of existing similar structures preferably the near vicinity should also be made available most importantly for ground wave structures or gravity based systems. You have to have a detail soil investigation report as well.

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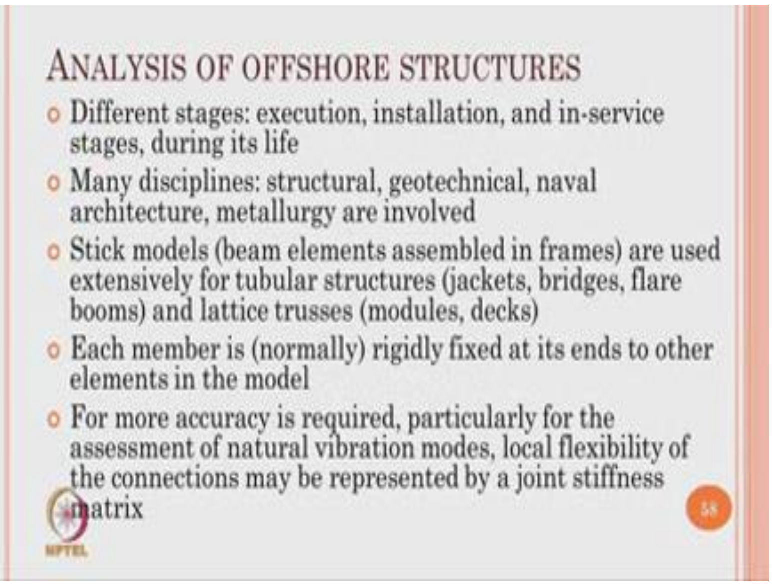

When we talk about analysis of offshore structures, there are different stages like execution, installation, in service stages. During its life time, many disciplines in analysis are involved; structural engineer, geotechnical naval architect and metallurgist are involved in designing or analyzing offshore structures. Generally people prefer stiff models, beam elements assembled in frames extensively for tubular structures like jackets, bridges, barges, flare booms etcetera and lattice trusses structures for modules and decks. Each member of the given form, geometric form of the platform is normally rigidly fixed at its ends to the other element in the model. For more accuracy particularly for assessment of natural vibration modes, local flexibility of the connections may be represented by the equivalent joint stiffness matrix in the analysis. In addition to its geometric and material properties, each member is also characterized by hydrodynamic coefficients relating to drag inertia and marine growth and of course, depends on whether you allow wave forces to be automatically generated or not.

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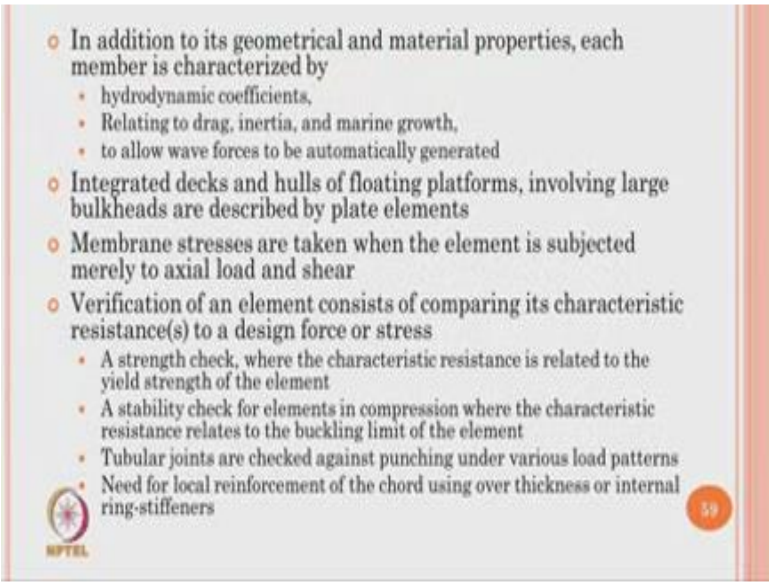

The integrated deck and hull of floating platforms which involve large bulkheads are described by plate elements in the analysis. Membrane stresses are taken when the elements are subjected to member merely axial load and shear verification of an element consist of comparing its characteristic resistance. The design force of stresses is done, a strength check where the characteristic resistance is related to the yield strength of the member, a stability check is then performed for element in compression where the characteristic resistance relates to the buckling limit of the member. Tubular joints are checked against punching under various load patterns. There is excess in need for local reinforcement of the chord using over thickness or internal ring stiffness can also do.

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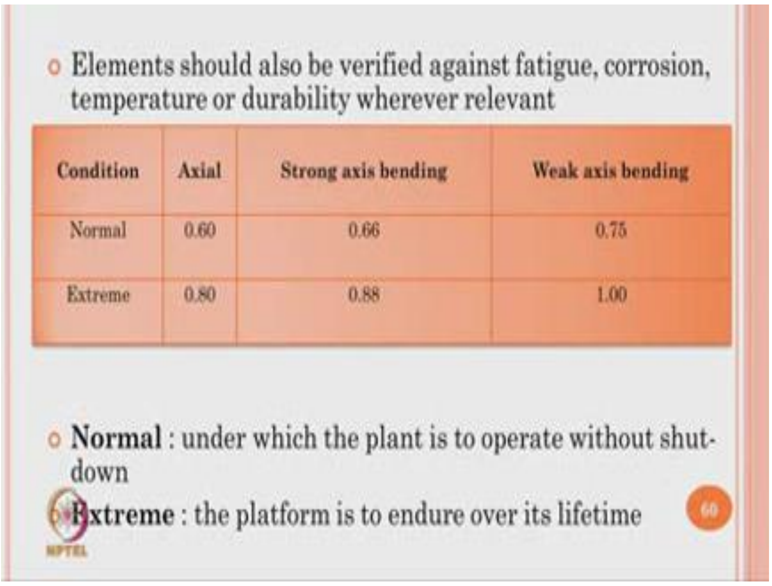

- Elements should also be verified against fatigue, corrosion, temperature or durability wherever relevant

Condition	Axial	Strong axis bending	Weak axis bending
Normal	0.60	0.66	0.75
Extreme	0.80	0.88	1.00

- **Normal** : under which the plant is to operate without shut-down
- **Extreme** : the platform is to endure over its lifetime

Offshore members and elements should be also verified against fatigue, corrosion, temperature and durability wherever it is relevant. If you look at the factors of combination under axial strong axis bending and weak axis bending in normal and extreme sea states, we generally recommend this multiply in factors. Normal in sense under which the plant is to operate without shutdown. An extreme in sense the platform is to endure over its lifetime. So, there is no physical damage or catastrophic damage ensured to the platform in design.

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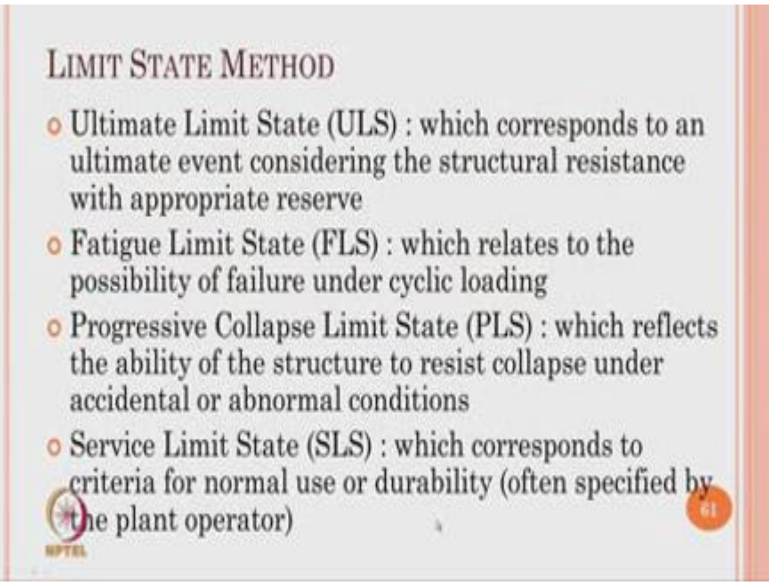

When I talk about design, and then foremost presently in practice is limit state method. There are different limit states, ultimate limit states which correspond to an ultimate event considering the structural resistance with appropriate reserve. Fatigue limit state corresponds to the possibility of failure under cyclical loading. Progressive collapse limit state possibly refers to the ability of the structure to resist collapse loads under accidental or abnormal conditions. Service limit states correspond to the criteria for normal use or durability is often specified by the plant operator.

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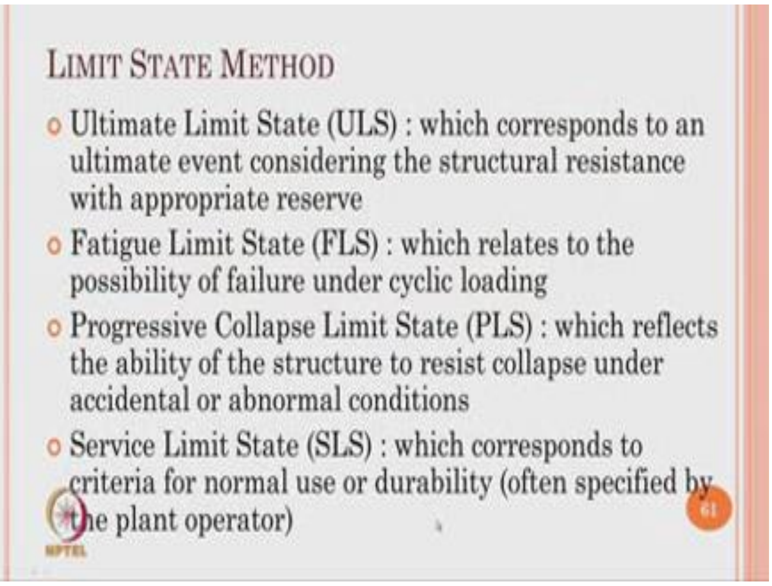

There are different load factors suggested by international courts which I am summarizing here for different kinds of load limit states. As you saw in the previous slide P stands for the permanent loads, L stands for live loads, D stands for deformation loads, E stands for environmental loads and A stands for accidental loads. Possibility is you will see the accidental load combination is practically zero exceed in the case of accidental loads.

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There are different conditions that are also specified for various limit state. For example, in case of construction, load out, transport, tow out, launching, lifting, in place and in place extreme, in place exceptional earthquakes, rare earthquakes, explosions, fire dropped objects, boat collusion and damaged structure. We have different P by L acceptance of loads for different criteria. P category, L category, D and A category, these categories already explained in the last lecture. So, you should go for what kind of designed criteria when you look for construction stage. For example, you should look for ultimate limit state or service ability limit state etcetera. So, what is the design criterion, what are the constructional conditions stages, where is analysis being actually done using various limit states which are explained in the last column? In addition to this, offshore platforms are also attracted to fabrication and installation loads.

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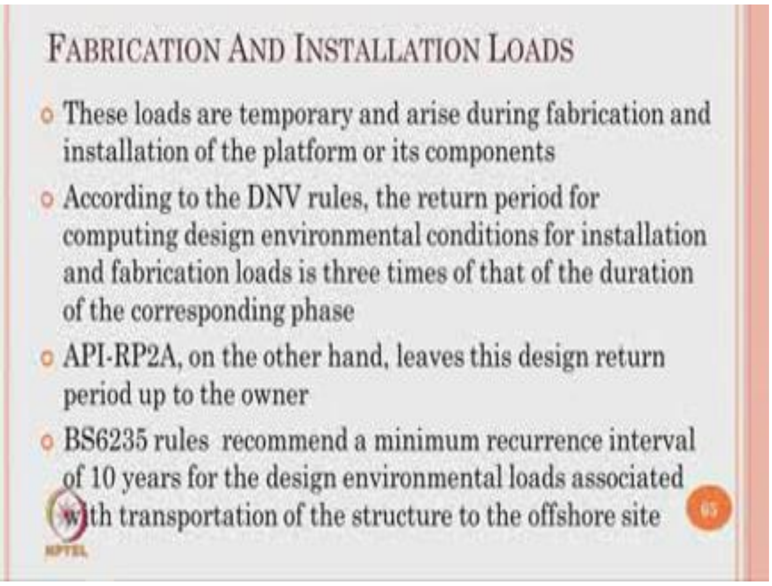

These loads are of course temporary and arise only during fabrication and erection of the platform and their components according to the DNV rules, the return period for computing design environmental conditions for installation and fabrication loads is approximately about three times of that of the duration of the corresponding phase. API-RP2A, on the other hand leaves the design return period up to the owner or the designer. BS6235 recommends a minimum recurrence interval of 10 years for the designed environmental loads associated with transportation of the structure to the offshore site.

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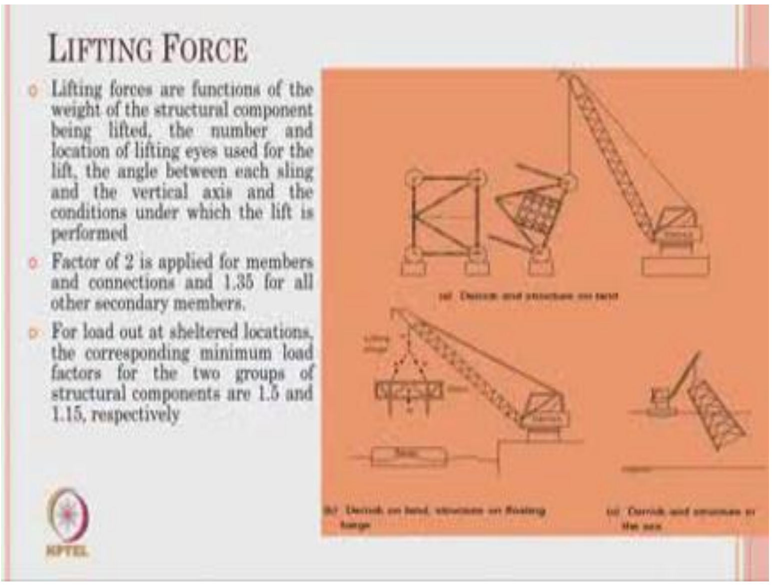

In addition to this as we employee cranes on top side, we also have to bother about the lifting forces. Lifting forces are functions of weight of the structural component being lifted the number of the compress being lifted and the location of the lifting I for where are you lifting it the angle between the each sling and the vertical axis and the conditions under which the lift is performed. Factor of two is generally applied to all the members in connections for designing for lifting forces and 1.35 for all secondary members for load out at sheltered locations. The corresponding minimum load factors for both the group of structural component is respectively 1.5 and 1.15. The figure on the right shows different kinds of drilling operations as well as the lifting forces which are encountered on the platform.

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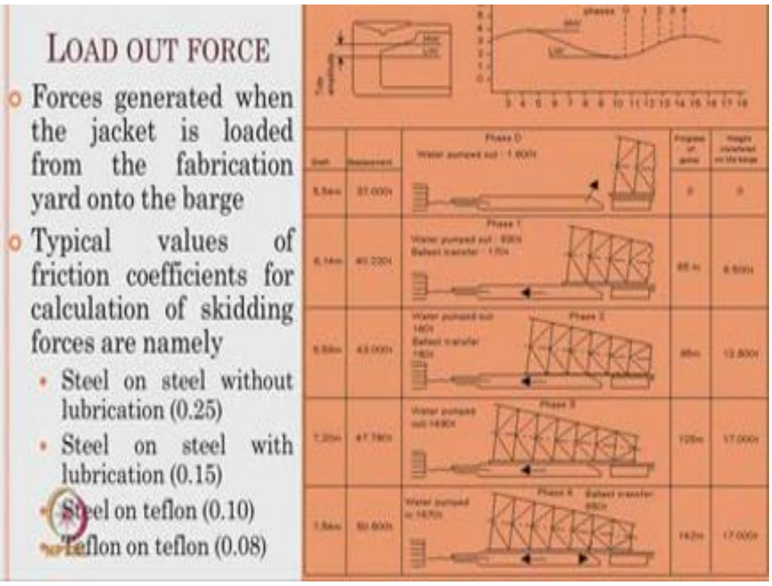

When you load out the platform module for commissioning, the load out forces needs to be calculated. These forces are generally generated when the jacket is loaded from the fabrication yard onto the barge what we call as load out stage. The typical values of friction coefficients for calculation of skidding force are namely steel. On steel without lubrication is 0.25. Steel on steel with lubrication is 0.15. Steel on Teflon is 0.1. Teflon to Teflon is the lowest load out force which is 0.08 because there is no friction between them. The table on the right side will give you what are the different drafts and displacement of the load out and what would be the weight transfer on the barge in terms of tons and the progress of the jacket in terms of load out operation.

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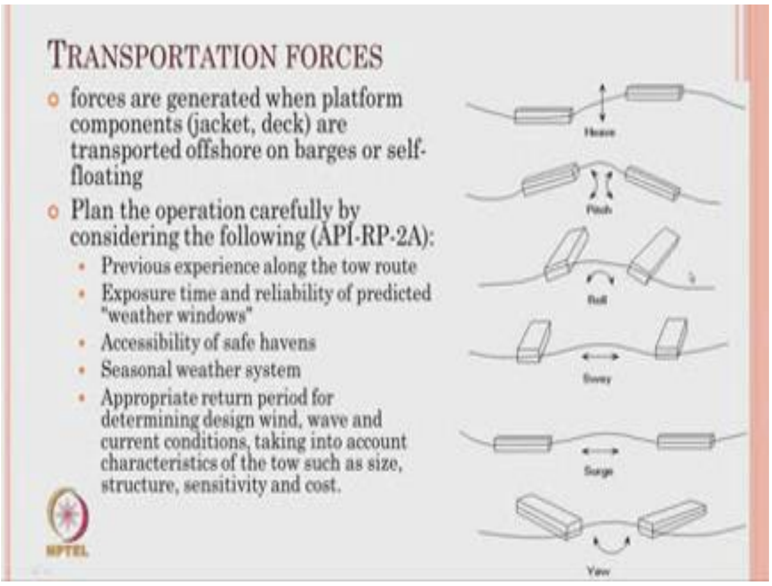

In addition there can be some transportation forces which are generated when the platform components are transported offshore on barges are meant for self-floating. This operation needs to be planned carefully by considering the following requirements. One should know the previous experience along the tow, route the exposure time should be based upon the weather window, the accessibility of safe havens should be always calculated, seasonal weather system should be considered before you plan for transportation forces, appropriate return period for determining the design wind wave and current condition should be calculated. They should take into account the characteristics of the tow such as size, structure, sensitivity and cost.

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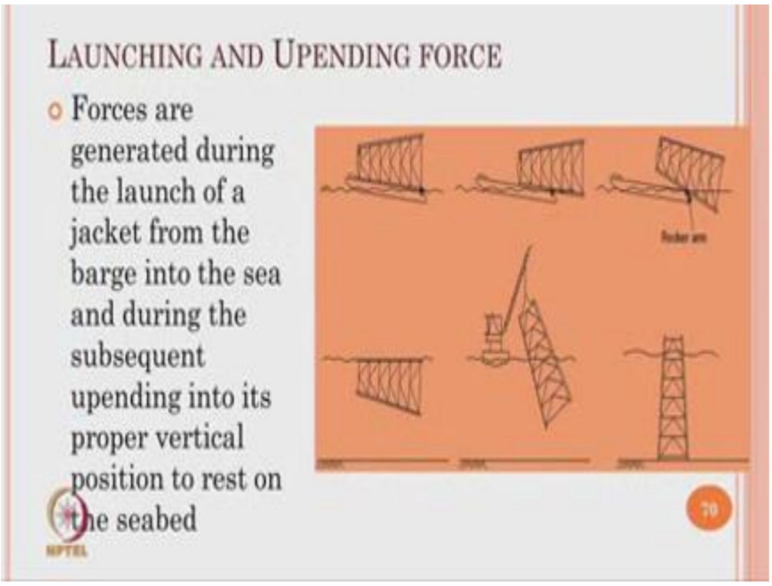

The other kind of force which occurs in offshore platform is launching and upending forces. We already know the upending is the process by which after launching the platform of the jacket is vertically forces are generated during the launch of the platform from the barge into the sea and during the subsequent upending into its proper vertical position to rest on the seabed.

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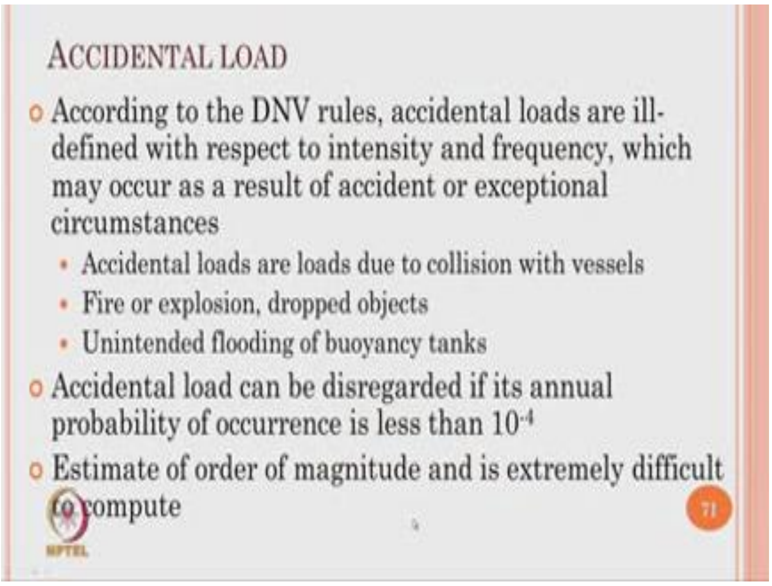

Accidental load is the last category of loads which are acting on the offshore structure. According DNV rules, accidental loads are ill defined with respect to the intensity and frequency which may occur as a result of accident or exceptional circumstances. Accidental loads are loads due to collision with vessels, fire or explosion and cause be dropped objects. Unintended flooding of buoyancy tanks can also result in accidental loads. Accidental loads can be disregarded if its annual probability of occurrence is less than 10 power minus 4. The estimate of order of magnitude and the time period of accidental load are extremely difficult to compute and therefore, only thumb rules have been used to calculate accidental loads on offshore platforms. We have discussed different kinds of load phenomena, different source of loads, different spectra, different governing equations based on which these forces on the offshore members can be calculated.

So, with this background one should be able to understand what are the environmental forces acting on the offshore members, how are they calculated, how are they distributed along the height in the superstructure along the depth in the substructure.

Thank you very much.