Ocean Structures and Material

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Module - 2
Lecture - 2
Introduction to design

Ocean structures and material under the braces of NPTEL IIT, Madras. In this specific lecture, we will talk about introduction to design of ocean structures. Some of the important features and some of the methods and principles, which are generally employed for designing offshore structures. Kindly note that this course does not address the detail design procedures of offshore structures. We are only going to talk about introduction to design of offshore structures.

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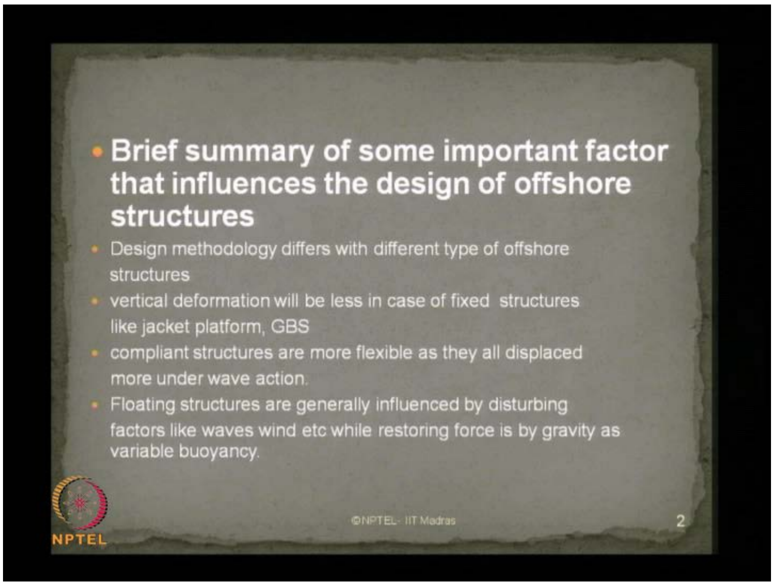

If we look that some of the brief summary of few important factors, which influence the design of offshore structures, they can be sequentially and preferentially in order are given below. The design methodology essentially differs with different types of offshore structures. The vertical deformation will be lesser in the case of fixed structures like jacket platforms, gravity base structures etcetera. Complaint structures on the other hand are more flexible as they are displaced more under wave action. Floating structures are generally influenced by disturbing factors like waves, wind etcetera while restoring force is by gravity as variable buoyancy.

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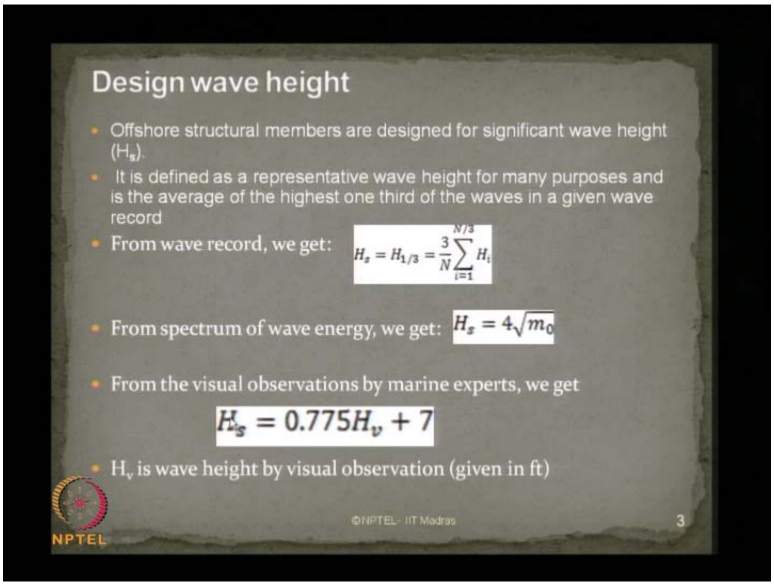

The primary concept which comes into play when we talk about design of offshore structure is one of the important environmental loads, which is the wave load. For estimating the wave forces on members of offshore structures, we first would like to know, what is the design wave height, which will consider in my design calculations? Offshore structural members are generally designed for significant wave height referred as H s in the literature. Significant wave height is defined as a representative value of the wave height for many purposes. It is defined as the average of the highest of one third of the wave record given in a wave record.

So, if you have a wave record which gives you the wave heights arrange them in descending order, pick up one third of the highest of this, take an average of that value as significant wave height which is defined as H s in the literature. So, H s is also defined as H suffix one third, it is because of the reason that H s is average of highest one third of the waves in the given record. Therefore, H one third is an alternative symbol which is used for H s is given by a simple equation of what you have here. In the absence of this we can also find if we have the wave spectrum or spectrum of the wave energy, we can also find seen your wave height from the spectrum of the wave energy using this equation where m o is the first order moment of the spectrum. Also if you have a visual observation records of wave height measured in feet then approximately from visual observation also marine experts calculate significant wave height using this expression where H v in this expression is nothing, but the wave height made by visual observation and that value given is generally given in the feet. Therefore, conversion of feet into meters will be taken care of this multiplier and this constant. Therefore, if there able to visually observe the wave heights in feet then simply use this expression to find significant wave height in meters.

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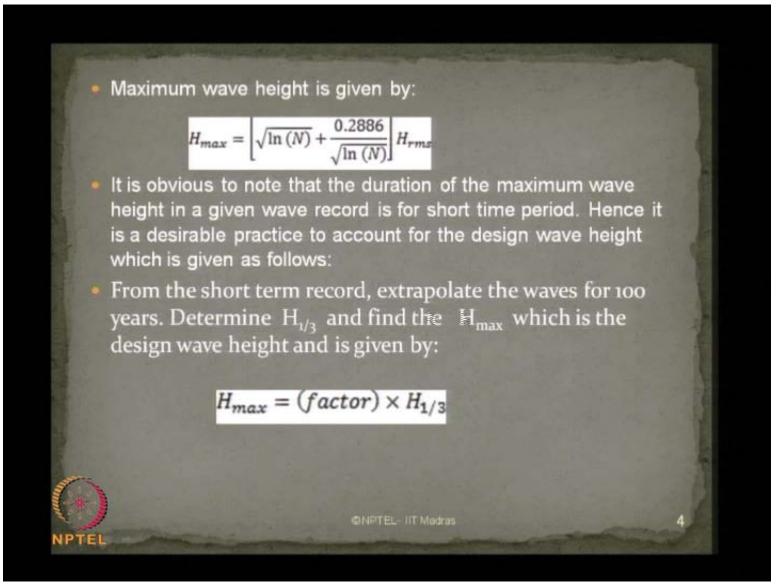

Now, once the significant wave length is known one can estimate the maximum wave height by the given equation as see in the slide. Now, it is obvious to note that the duration of the maximum wave height in a specific wave record is only for very short period of the time. Therefore, in the design it is desirable practice to account for the design wave height which is given as follows. One we ask a question why I cannot take the maximum wave height. It is very interesting to know ladies and gentlemen, the maximum wave height generally prevails only for very short period of time. Since it is only for a short period of a time, it is not advisable and it is not preferential design practice to compute the calculation based on the maximum wave height, but people use the following equations for finding out the desirable wave height can be used in design calculation. For example, if we have a short term record then extrapolates the waves for 100 years.

For example, if you do not have hundred year record, we have a very short term record then extrapolate that record using statistical principles for hundred years then determine its one third and then find H max based on this as given by this equation which can multiply by a specific factor has advise in the literature. After understanding one of the important sources of lateral load coming on those structures which is waves. Structural form of members also plays a very important role in preliminary design of offshore structures.

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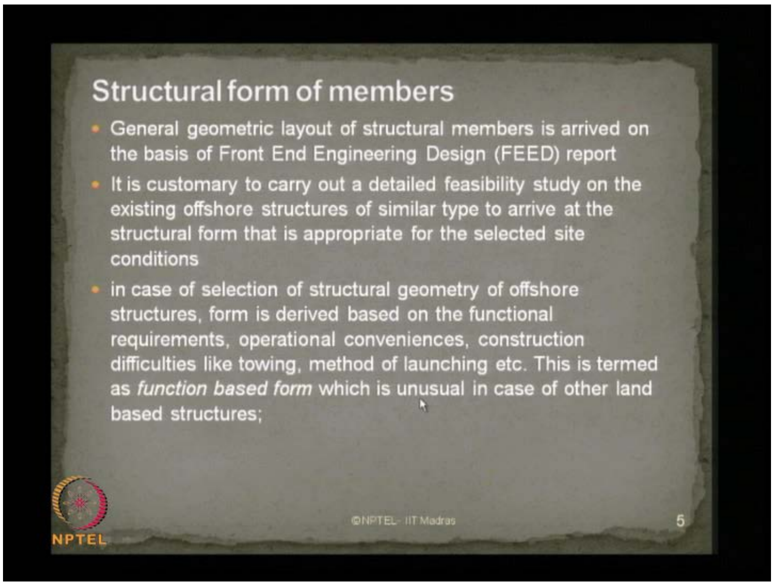

Generally, the geometric layout of the structural members is arrived on the basis of a preliminary analysis and designed report which we called as front end engineering design report; which is briefly said as FEED report. It is always customary to calculate or to carry out a design detailed feasibility study on the existing structures of similar type. For example, we want to design a complaint offshore structure it also to advisable that you conduct a detailed feasibility study on the existing complaint structures for similar type to fix or to arrive at the basic structural form which will be appropriate for the selected site conditions. We have seen ladies and gentlemen, in the lectures, in the first module, that the structural forms vary depending upon their site installation conditions. In case of structural geometry offshore structures, form is essentially derived and designed based on the functional requirements, operational conveniences and construction difficulties like towing method of launching etcetera.

So, the geometric form of an offshore structure is not only guided and design are governed by the water depth. It is governed by many factors which are essentially functionally dominated factors and operational conveniences. People also look at what are the conveniences in terms of construction difficulties and installation problems. That is why we called this as function based form which is unusual in the case of other land based structures.

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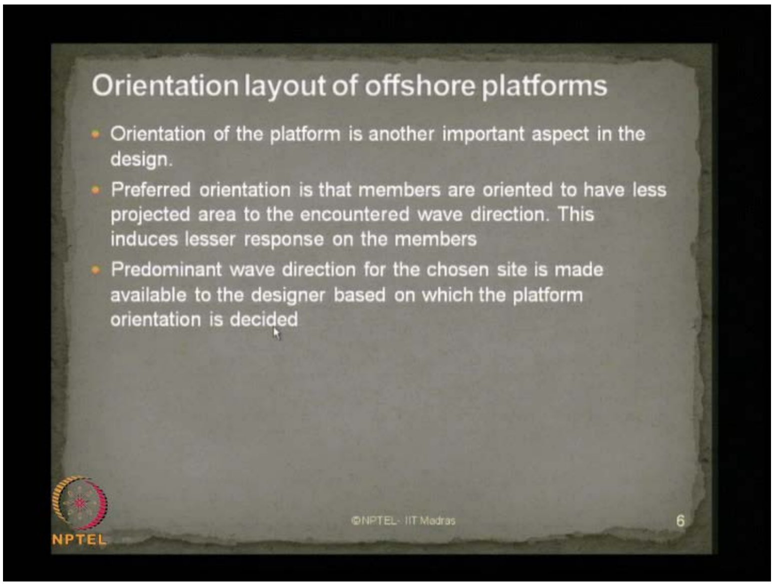

Then one can think about how to orient may of a platform, because wave direction can come in any angle of attack as for offshore structure is concern. So, therefore, orientation layout of an offshore platform also plays one of the deciding roles in preliminary design of offshore structures. Orientation is an important aspect in design of offshore structures. Preferred orientation is that members are generally oriented to have less projected area to the encountered wave direction; that is a general key rule you should orient the structure in such a way that the member should have lesser projected area for the predominant wave direction we just attacking the structure. Therefore, induces lesser response on the members. Predominant wave direction for chosen site is available generally to the designer; it is based on which the platform orientation is finally decided.

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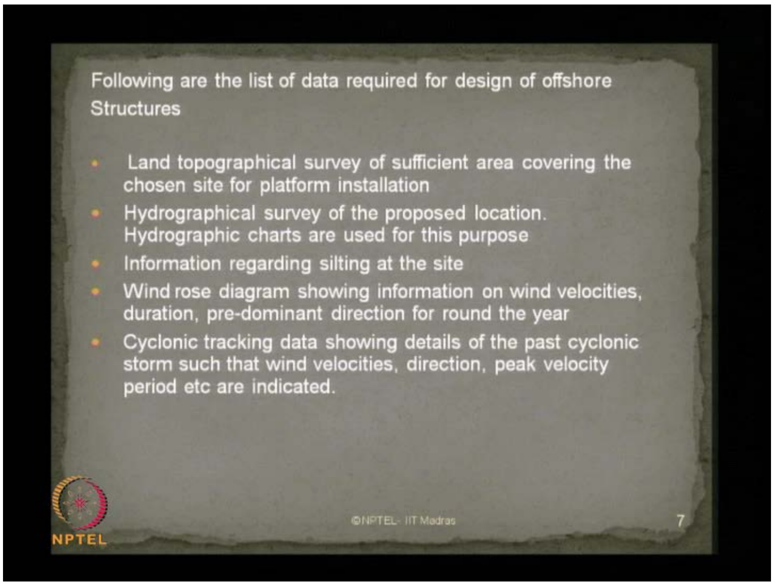

If you ask me a question, what are those important lists of data that are required to prepare or to start with the design of offshore structures? Interestingly, there are many data which are important which you must you have before we start designing offshore structures. The first and foremost is that the land topographical survey of sufficient area covering the chosen site for the platform installation should be available to the designer followed by which hydrographical survey details of the proposed location. Hydrographic charts are generally used for this purpose and this detail should be available with the designer. This can give me information regarding silting at the site. Then wind rose diagram can show me information on wind velocities, wind duration, predominant wind direction for round the year which can be used in the design. Cyclonic tracking data should also be important because this show details of the past cyclonic storm such that the wind velocities, direction, peak velocities period etcetera can be included in your design calculations.

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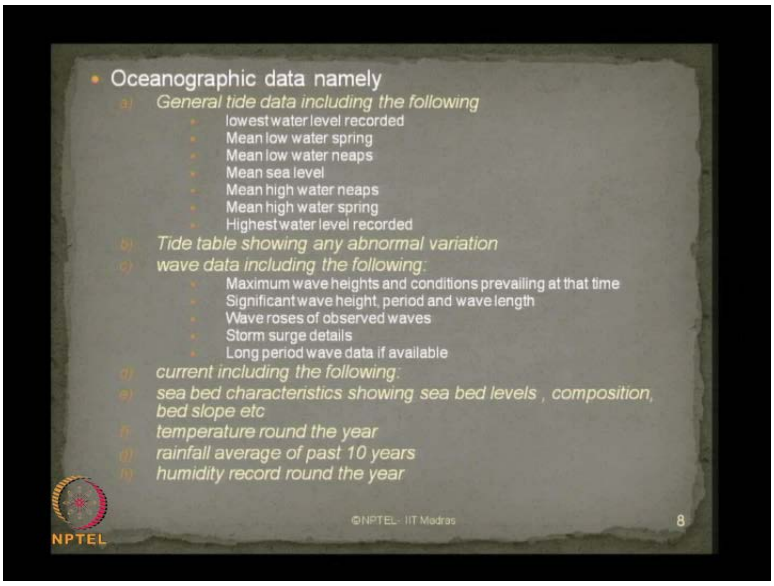

Oceanographic data generally has the following contents. General tide data includes the lowest water level recorded, the mean low water spring, the mean low water neaps, the mean sea level values, the mean high water neaps, the mean high water spring and the highest water level recorded at the specific site. Followed by which the tide table will also show if there is any abnormal variation in tide levels in the specific site. Wave data is an important category of data which is necessary for designing offshore structures on a specific site. Wave data include the maximum wave height and conditions prevailing at that time significant wave height, period and wave length which can be considered for the design calculations; wave roses of observed waves, storm surge details long period wave data if it is available in a specific site. Followed by which information regarding current is also equally important, because current data includes the following like sea bed characteristics showing sea bed levels, compositions, bed slope etcetera.

You should also have the data of temperature variation round the clock, round the year; the rain fall average for the past 10 year record is mandatory for planning and designing offshore structure in any chosen site specific location. Of course, you should have a record based on humidity round the year.

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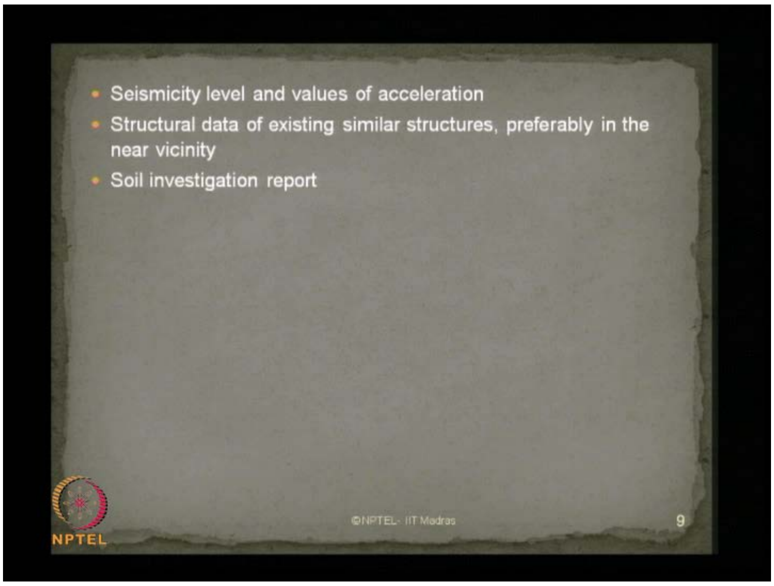

Followed by which most importantly, ladies and gentlemen, because of the tectonic movement happening in the reason past, seismicity level and values of acceleration are also becoming important; piece of information which required for design offshore structures. Structural data of existing similar structures in the nearby vicinity is preferably important, because they can be also parallel used as a basic dimension for computing the member sizes for the offshore structures. To fix up the foundation type, the foundation depth etcetera one should require detailed soil investigation report of a specific site.

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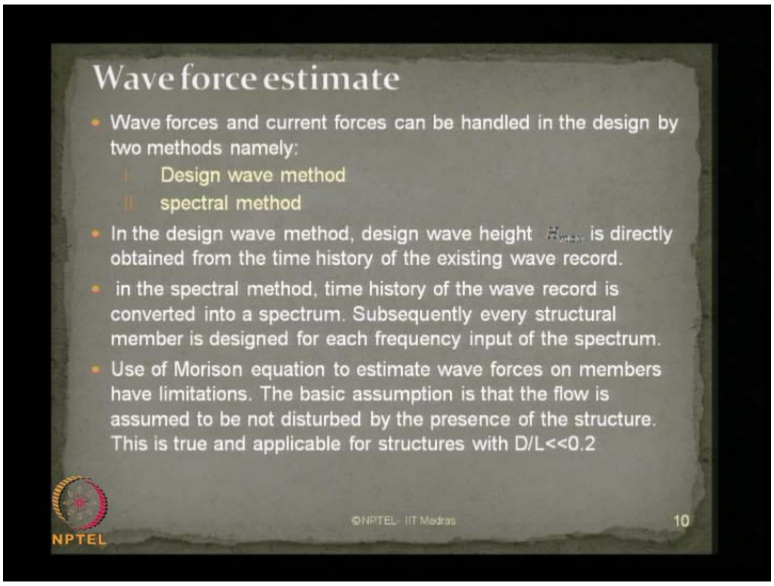

Once I have defined the form for a specific offshore structure, once I have chosen a site, once they are the oceanographic hydrographic data specific site, then I am interested to find out what are the wave forces coming on the members in the offshore structure design and located at the specific site. The wave forces and current forces generally handled in the design by two methods, namely design wave method and spectral method.

In the design wave method, design wave height H max is directly obtained from the time history of the existing wave record. Ladies and gentlemen, in the previous slides we showed you different expressions for working out H max or design wave height from a given wave record. Any one of them can be used to fix design wave height for the current problem. Of course, alternatively in the spectral method the time history of the wave record is converted into a spectrum; you can always do conversion of time history into a frequency domain using Fourier transform relationship. Subsequently, every structural member is then designed for each frequency content input of the spectrum. Use of Morison equation to estimate wave forces on members have of course their own limitations the basic assumption in using Morison equation is that the flow is assumed to be not disturbed by the presence of the structure. This is true and applicable only when D by L ratio is for less than 0.2, where D stands for the diameter of the member and L stands for the wave length.

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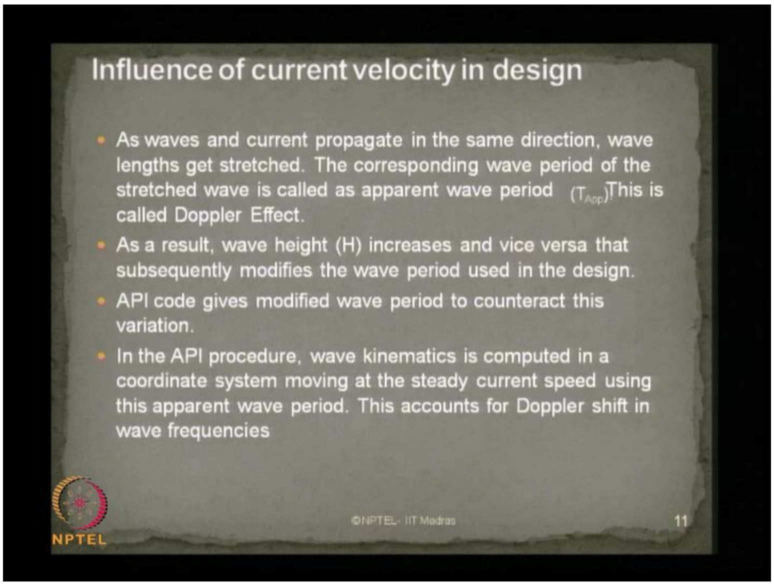

Current velocity present in the sea surface also dominant influences the design parameters as waves and current propagate in the same direction, wave lengths actually get stretched. There is a significant change in the wave length when current is also acting along with the wave in the same direction. The corresponding wave period of stretched wave, it is generally addressed as apparent wave period which is indicated as T suffix apparent in the literature. This is explained and examine as Doppler's effect in the literature.

So, Doppler Effect is nothing, but accounting for stretching of the wave period because of the influence of current on the wind or on the wave in the direction of propagation. As the result, the wave height increases and vice versa that subsequently modifies the wave period and this is used in the design calculations. American petroleum institute API code gives a modified wave period which can counteract this variation due the presence of current on wave stretching. In the API procedure, wave kinematics is computed in a single coordinate system moving at the steady current speed using this apparent wave period. This accounts for Doppler's shift in wave frequencies. So, API procedures indirectly recommend a shift in a wave frequency because of stretching of waves whose wave length is increased in the presence of current.

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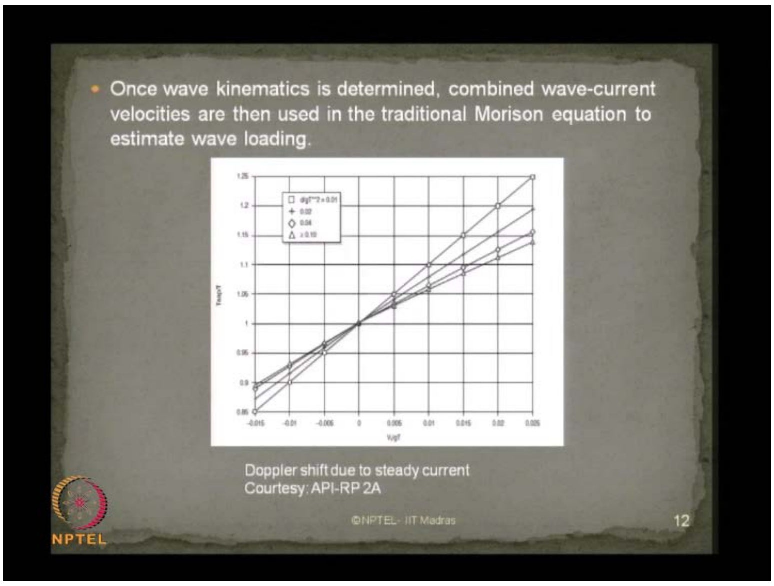

Ladies and gentlemen, in this figure shows what is the variation which can be having or it occurs from the Doppler shift due to steady current which is taken from API RP2A as a courtesy. So, once wave kinematics is determined combined wave current velocities are then used in the traditional Morison equation to estimate the wave loading.

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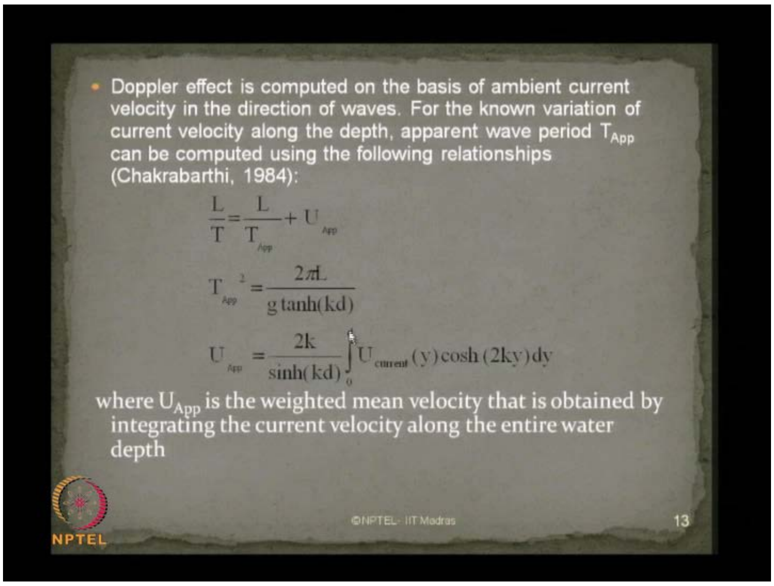

In the absence of the detailed effect of Doppler's effect on stretching of waves because of presence of current; Doppler Effect is computed on the basis of ambient current velocity in the direction of waves as you saw in the last slide. For the known variation of current velocity along the depth apparent wave period can be computed using analytical relationship is given by chakrabarthi in 1984.

So, apparent wave period can also be computed based on this expression where L by T is given by L by T apparent plus U apparent where U apparent is given by this equation where the current velocity is included in the discussion somewhere here in U apparent. In the whole discussion, U apparent is the weighted mean velocity that is obtained by integrating the current velocity over the entire water depth, because the integration in this equation is if we see is for the domain of entire water depth where small d stands for water depth.

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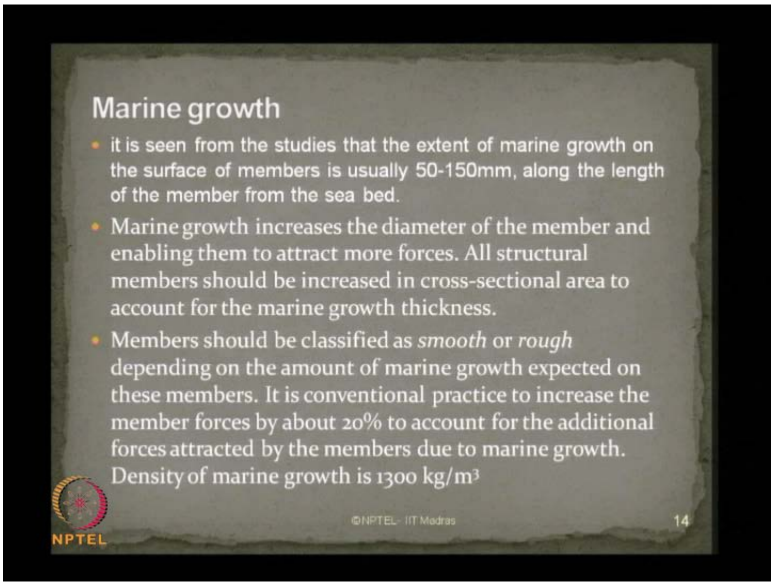

The other alternate parameter and which is a very parallel influential parameter that significantly contributes to the preliminary design of the offshore structures is marine growth. When the members are installed in the sea because of its presence of external agencies in the sea water as well as presence of the marine aqua culture in the vicinity of the members; there is always expected that the marine growth may get form and deposited along circumference of the cylindrical members. Marine growth is seen as an evident study that the extent of marine growth on the surface of members is usually about 50 mille meters can be as thick as 150 mille meter which gets deposited along the periphery of the member. The marine growth increases; obviously, with increasing diameter of the member because it enable more contact for them.

And when the marine growth gets deposited along the circumference of the member, it starts attracting more forces. All structural members therefore, should be designed for increased in cross sectional area which is effectively occurs because of the formation of the marine growth along the surface or along with the periphery of the member.

So, one should account for what is called as marine growth thickness in the design of offshore structural members? On the addition member should be also classified either as smooth or rough, because the dragon inertia coefficient for the surface roughness of member are different which are generally advised by different international course.

So, the smooth or roughness depending on the amount of marine growth expected on these members becomes a very vital parameter to fixed the Morison coefficient that is drag coefficient and inner coefficient which are otherwise used in the force estimate of the member; however, it is a conventional practice to increase the member force by about 20 percent which can account for this additional forces attracted by the members because of the marine growth. Ladies and gentlemen, it is very interesting for you know the density of marine growth is about 1300 k g per cubic meter.

So, this is significant when the volume or when the deposition thickness of the marine growth is phenomenally high around the surface of the member which is generally high near the sea bed. Whenever, series of the members which are arranged in the row or group of members which are placed in the location then they also called or they cause basically what is called a blockage factor.

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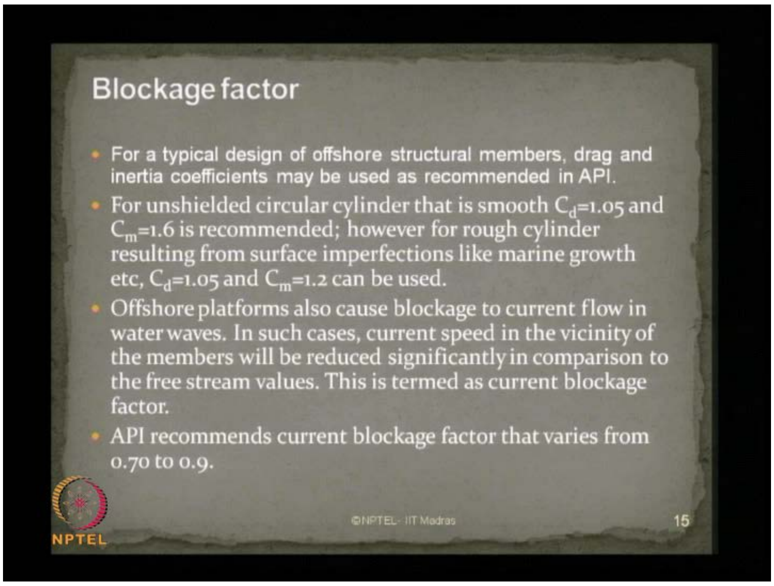

Now, what is the blockage factor? For a typical design of offshore structural members, drag and inertia coefficients are generally recommended from the American petroleum institute coral provisions for unshielded; for example, there is a circular cylinder which has got no members in near vicinity, we called this as unshielded circular member.

And if the member is smooth, it means the member does not have any marine growth sticking out surface of the member we take the drag coefficient as 1.5 and inner coefficient as 1.6 as recommended by API; however, the surface of the cylinder becomes rough because of the deposit marine growth along the periphery of the member, it result in some imperfections surface of the members and therefore, C d remains same, but C m is reduced drastically from 1.6 to 1.2.

Alternatively, offshore platforms also cause blockage to current flow in water waves, because they abstract the flow of free surface of the water from flowing from one direction to other. This creates an additional effect on the members which is otherwise called as blockage factor. In such cases, the current speed in the vicinity of the member is reduced significantly in comparison to the free stream values. This is what we termed as current blockage factor. This should be accounted in the design API recommends current blockage factor varies from 0.7 from 0.9. Having understood how to calculate the water bodicalciramatic using aris wave theory; having understood how to calculate the forces using Morison equation; having learned how to modified the inertia and drag coefficients which are used Morison equation because of presence of current which causes blockage factor as well as stretching of wave length which is called Doppler's effect; then one is interested to know what are the different methods of force estimates which can be applied to compute forces on the members of offshore structures.

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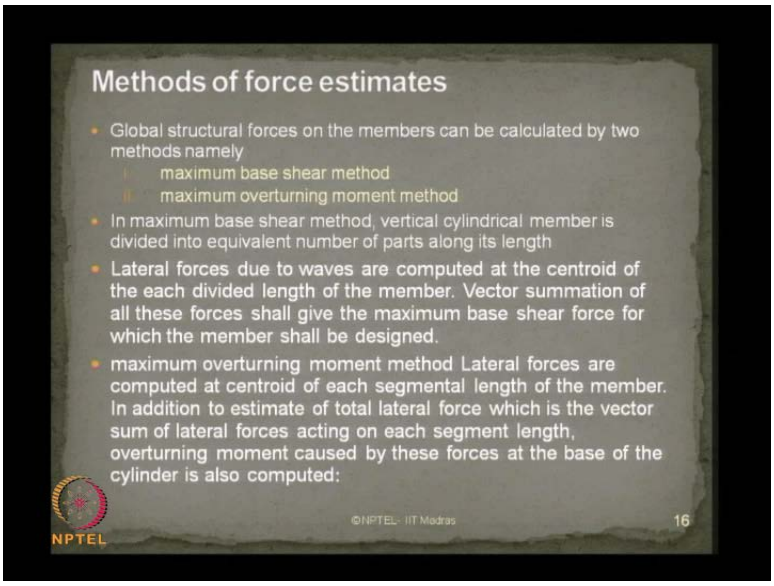

The global structural forces in the members can be calculated by two different methods, namely like maximum base shear method and maximum overturning moment method. In the maximum base shear method, the vertical cylindrical member is divided into equivalent number of parts along its length; the lateral forces which are caused by the waves are computed at the centroid of the each divided length of the member. Then we do a vectorial summation of all these forces which will give me what is called maximum base shear for which the member shall be designed.

So, this method since is accounts for summation lateral forces which is acting as centroid of every segment of the member along the length which becomes the base summation of all the forces at the bottom we called this method as base shear force method. Maximum overturning moment method is also used the lateral forces are computed at centroid of segment of the member causes the moment about the bottom of the member. In addition to estimate of total lateral force which is the vector sum of lateral forces acting on each segment length overturning moment caused by these forces at the base of the member is also parallel computed.

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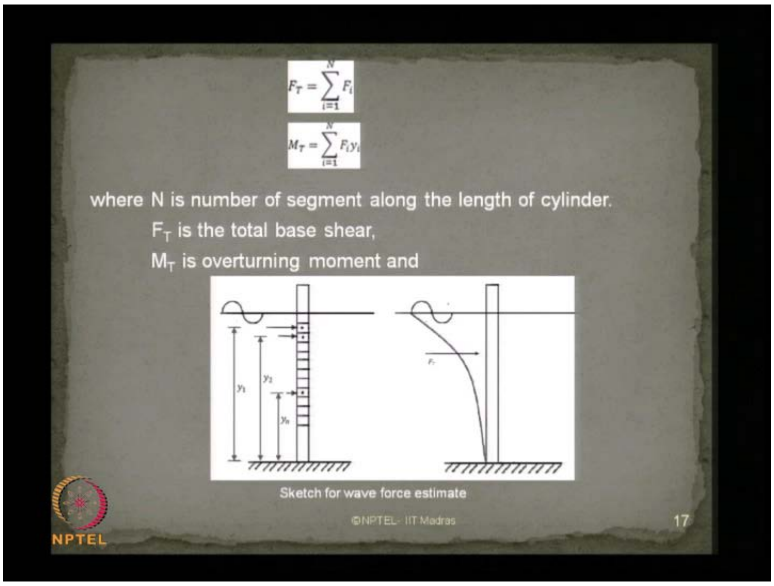

Ladies and gentlemen, let us look at two equations which is force total and the moment total; the force total as we see, if we divide the members in the N number of parts equal or unequal vary from the bottom whereas, y becomes 0 at the sea bed and y keeps on increasing as move towards to the mean sea level. To divide a member into N member of segment, each segment try to fix centroid of the segment because you know the geometric dimension of the segment is always to find the geometric center of this segment, measure the distance of that from the fixed end I call that as y i; i is the i th member which can be computed.

Now, once I get the forces in each segment some all of them as see in this equation find the total force acting at the bottom which we called as base shear method. Also at every point as see here you know the forces because you know the segment length and force acting on the segment sum up all of them find the sources, find the moment of each one of them about the bottom, find the moment because moment is the force in to the distance of that particular centroid from the sea bed which is y i which is shown here as y 1 y 2 y n etcetera.

So, you will also find that the total force will act at the specific location from the sea bed and total moment of course, in this example will be at the bottom because the bottom is fixed end of this member.

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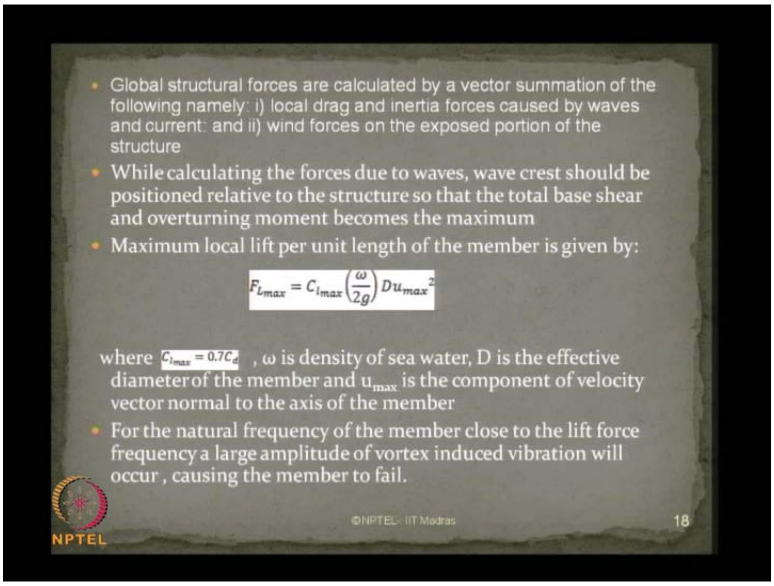

After knowing this, the global structural forces are then calculated by a vectorial summation of the following. One is compute local drag and inertia forces caused by waves and current in a segment; compute the wind forces on the exposed portion of the structure; while calculating the forces due to waves, wave crest should be positioned relative to the structure.

So, that the total base shears and overturning moment becomes the maximum. Remember this, we are not trying to work out forces at instantaneous position of the structure; we are hypothetical saying that the wave crest should be positioned relatively to the structure. In such a manner that the total base shear and the total moment produced by these force should become obviously, the maximum because then the design will be called highly conservation design.

So, the maximum local lift per unit length of the member is given by this equation where

L max stands for maximum lift force and C l max stands for the lift coefficient. Generally, which is taken as 0.7 of the drag coefficient; of course this equation omega is the density of the sea water D is the effective diameter of the member and u max is the component of the velocity vector normal to the axis of the member. D is the effective diameter which includes the effect of the deposit of the marine growth along the member. Therefore, your member diameter D is not as the same as the member diameter we use while installation and design. In due course of the time, the D can be changed because this D is effective diameter of the member.

Now, for the natural frequency of the member closed to the lift force frequency, a very large amplitude of vortex induced vibration will occur which causes the member to fail. So, you will get an idea at what frequency ray you get critical loads acting on the offshore member.

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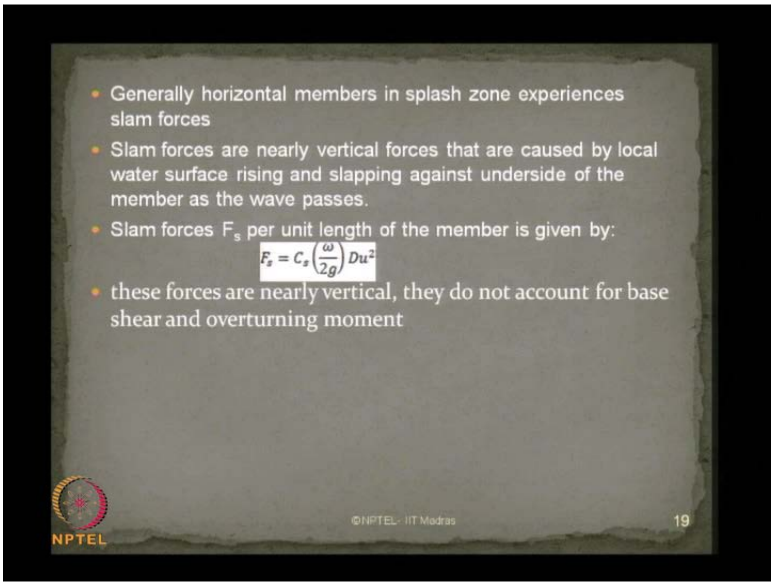

If we look at horizontal members in splash zone, they experience very high slam forces. Slam forces are nearly vertical forces that are caused by local water body or water rising surface slapping against underside of the member as the wave passes. The slam force per unit length indicated as F suffix s is given by the following equation now, you see on your screen; these forces are nearly vertical they do not account for base shear and overturning moment.

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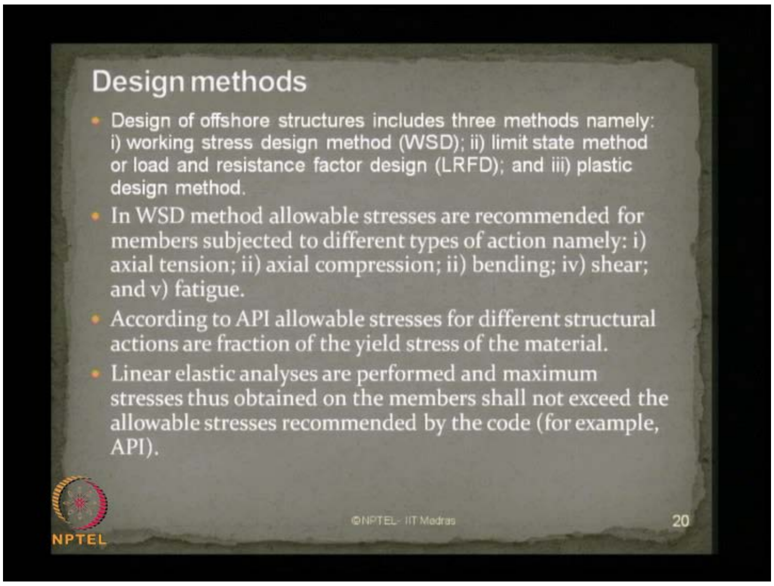

So, very importantly slam force are almost vertical. Having said what will be computed or what methods are generally there for estimating forces or members of offshore structures, we now talk about the design methods. Design of offshore structures includes three methods practice namely, working stress design method called as WSD limit state method or load and resistance factor design which is called as LRFD and of course the third method which is innovative and practice of modern design officers is the plastic design method. In working stress design method, the allowable stresses are generally recommended for members subjected to different combination of forces acting on the members namely tension, compression, bending, shear and fatigue. According to American petroleum institute coral provision, allowable stresses for different structural actions are fraction of the yield stress of the material. For example, if we take F y as the yield stress of the material then obviously, for different structural action the acceptable allowable stress is nothing, but a fraction of the yield stress; it is not same as yield stress. Linear elastic analyses are also generally performed and maximum stresses thus obtained on the members shall not exceed the allowable stresses recommended by the code; for example, API.

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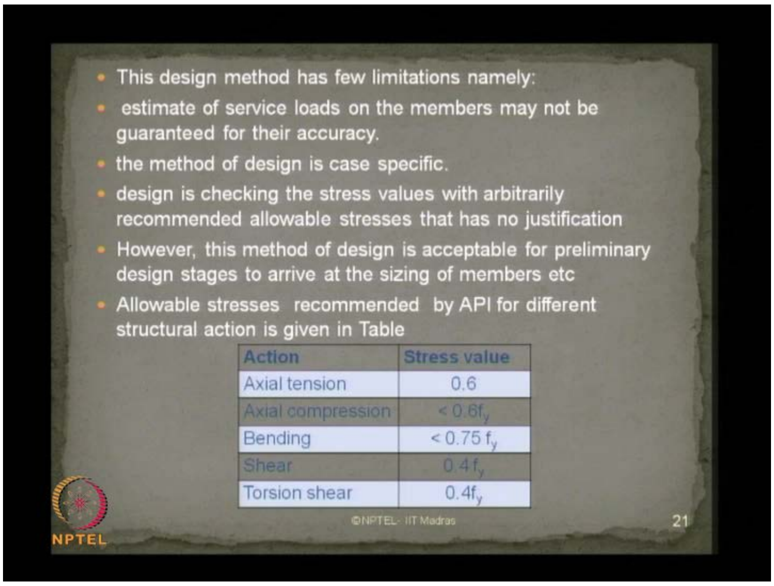

Let us quickly see what are the factors which are considered for different load combinations or independent actions on the members. So, if you look at this table for axial tension, the maximum stress value is permitted in the code is 0.6 whereas axial compression which will less than 0.6 f y, for bending which will be less than 0.75 f y, for shear it should be equal to 0.4 f y whereas, torsion shear there should be less than equal to 0.4 f y again. Once we are where estimating of service loads on the members it may not guaranteed any accuracy, because these load keep on varying depending upon the sea state and the environmental critics happening at the sea state. The method of design is actually case specific; one should know how I am doing the method of design, because design is nothing, but checking the safe stress limits with arbitrarily recommended allowable stresses which have no justification. Because I have to compare the generated stresses with that are recommended allowable stresses which are given in the code and what are these stress they are seeing in the table given below; if the subjecting the member the pure axial tension only then the permissible stress value is only 0.6 of f y and so on so four. Talking about axial compression, talking about torsion shear, then the combination are the factors are the permissible stress value which are acceptable in the design vary as per the table seeing jus now.

So, this method of design is acceptable only for preliminary design stages, it can be carried forward for instrumental or for implemented stages because they are generally used only to arrive at the sizing of members; allowable stresses recommended by API for different structural action s are given in the table below.

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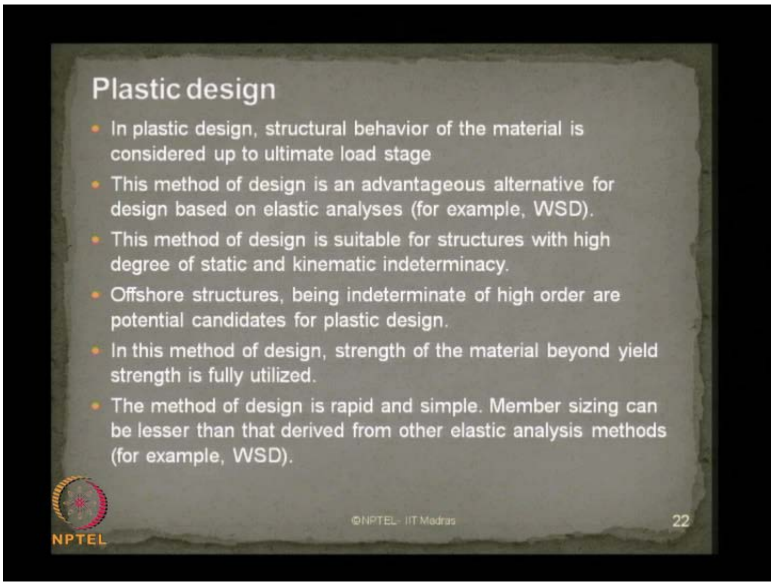

Once I get the allowable stress value can always design the member or I can get the permissible value get the dimension of the member which is otherwise called as design of the structural members of offshore structures. Now, alternatively in the recent pass the searches of started practicing what is called plastic design in offshore structure.

Let us see what is the plastic design very quickly? In plastic design, structural behavior of the material is considered up to ultimate load stage where as in LRFD it was not true. This method of design is an advantageous because it is very good alternative for the design based procedures as suggested by working just design because working just design uses elastic analyses whereas, plastic design uses plastic analyses. This method of design is very highly recommended for structures with high degree of indeterminacy; the moment of indeterminacy, it includes both kinematic and static indeterminacy.

So, if you got offshore platform with very high degree of indeterminacy both static and kinematic indeterminacy then you can go for plastic design as recommended for this type of structures. Offshore structure therefore, being indeterminate of very high order are potential candidates for plastic design. In this method of design, the strength of material is not stretched beyond the yield strength of the material. There is always the wrong convection with designer seeing that in plastic design the stress value will exceed f y; the stress value never exceed f y. The method of design is rapid and simple; member sizing can be always lesser than that derived from conversional elastic analysis like working stress design. So, plastic design leaves an economical sizing of the member; the yield is never increased or never touch the point to be its optimum value in the design etcetera.

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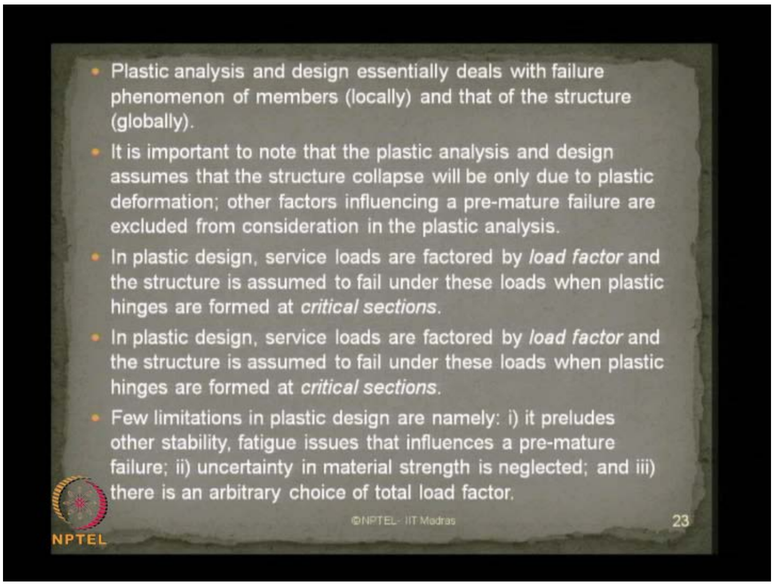

Plastic analysis and design therefore, essentially deals with failure phenomenon of members. The failure phenomenon can be local because the member can fail, it can be global because the structure whole can fail. It is important to know that the plastic analysis and design assumes that the structures collapse will be only due to plastic deformation. No free included collapse mechanism are there considered in the plastic analysis. Plastic analysis and design purely assumes the structures collapse only due to plastic deformation other factor can influence a pre mature failure, but generally these factor which are contribute pre mature failure are generally excluded from the consideration in the plastic analysis. I can give an example how do you say pre mature failure can occur then offshore member?

Now, let us take as cylindrical member subject to toxcial compression, when the cylindrical member is very large and length compared to least literal dimension of the member; before the member fails in an axial compression there is a possibility that the member may buckle. Therefore, buckling effect on the member can cause the pre mature failure. Of course in plastic design these kinds of pre mature failure are not accommodated. In plastic design, service loads which are acting on the member or factor basically which are multiplied by a load factor which is assumed to fails under these loads when plastic hinges are formed at critical sections. Ladies and gentlemen, in a plastic analysis you must understand what we talk about critical sections. Critical sections are not the locations where the bedding moments are maximum, these are the location where a combination of good amount of plastic ingers can be formed because of the geometric variation, because of the load concentration, because of the variation of the moment all inertia, because of the sway mechanism impose on the structural configuration of the platform. In plastic design, service loads are generally factored by load factor and they act at very specific critical sections. Few limitations in plastic design are very important to be considered; one it preludes other stability fatigue issues that influences a pre mature failure. Uncertainty in material strength is completely neglected in plastic design. There is an arbitrary choice of the total load factor which can be a subject of question.

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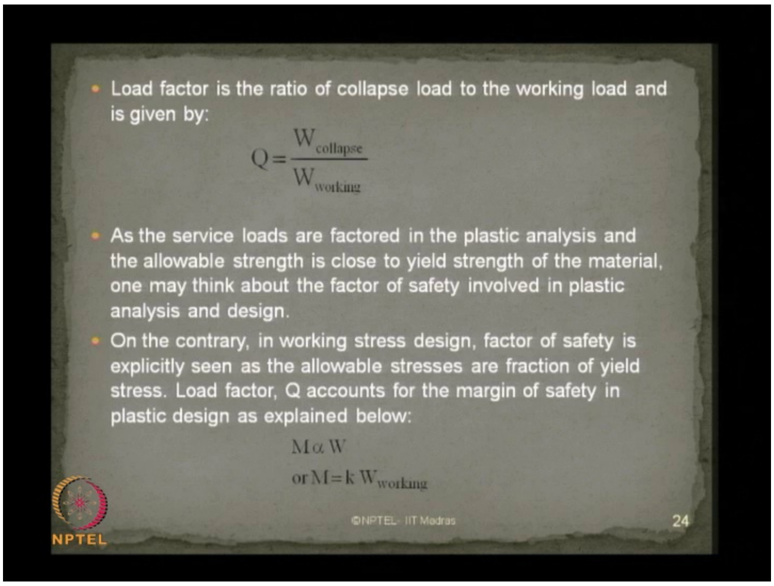

So, the load factor which an arbitrary value selected, which is the subject of interest is defined us the ratio of the collapse load to the working load, which is given by simple expression as you see on the screen now. As the service loads are factored in the plastic analysis and the allowable strength is close to yield strength of the material, one may think about the factor of safety involved in plastic analysis and design. Ladies and gentlemen, very importantly please understand the service loads are increased by the factor, whereas, the yield strength of the material or allowable strength is closer to the yield strength of the material.

Now one may wonder really a factor of safety involved in plastic design methodology. On the contrary in the working stress design factor of safety is explicitly seen because factor of safety is nothing, but the allowable stress fraction of yield stress. So, only the fractional of yield stresses will be recommended as an allowable stress. Therefore, you explicitly see the factor safety in working stress design. The load factor Q which accounts for the margin of safety in plastic design is therefore, explain below let say the M is proportional to W or M can be the multiplier constant with the working load W.

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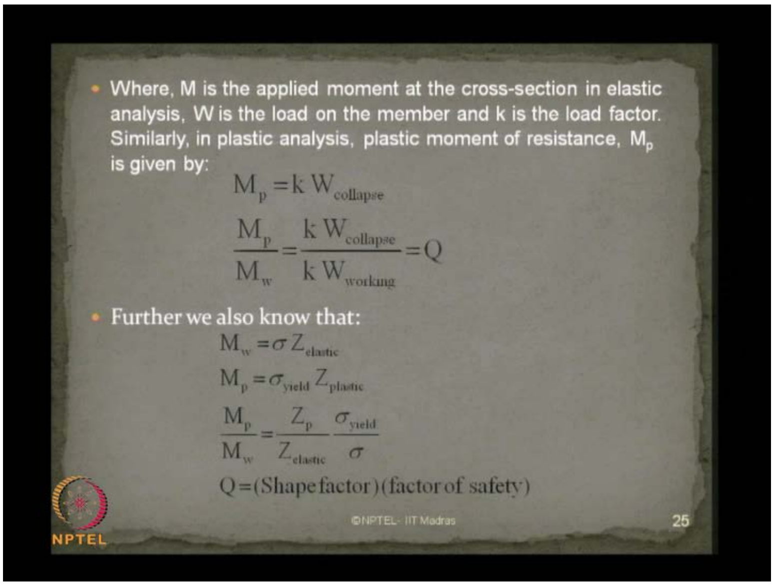

Where M is the applied moment at the cross section in elastic analysis and W is the load on the member and K of course is what we called as load factor. Similarly, in plastic analysis the plastic moment of resistance M P is given by a simple equation as see here. When we follow the equation you will notice that Q which is nothing, but ratio of the plastic moment is the product of the shape factor to factor of safety because the ratio of plastic moment of modulus to the elastic module of the sectional modulus is nothing, but the shape factor. And this is what we generally used as the factor of safety even in our working stress design. Therefore, in plastic analysis and design methodology there exists very interestingly the factor of safety which is again comparable to the factor of safety available in working stress design methodology.

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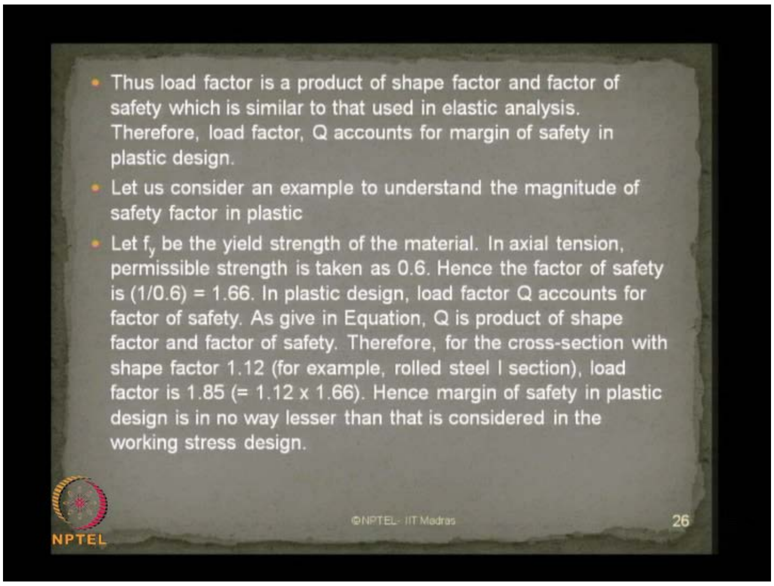

Thus the load factor is nothing, but the product of shape factor and factor of safety which is similar to that used in the elastic analysis. Therefore, a load factor Q which accounts for margin of safety in plastic design can be considered the margin of safety which is seen here in the other design factors.

Now, let us consider an example to understand the magnitude factor of safety in plastic design. Let us say for an example, f y be the yield strength of the material in axial tension the permissible strength is generally taken as 0.6 as the yield strength. Therefore, one can see that the factor of safety is 1.66 which is nothing, but 1 over 0.6; however, interestingly in plastic design the load factor Q accounts for factor of safety as discussed in the previous slide. As given the equation earlier Q becomes product of shape factor and factor of safety. Therefore, for the given cross section with shape factor 1 by 1.2, you may wonder what is that cross section which can have the factor of 1 by 1.12 for example, this can be rolled steel I section.

So, let us say the shape factor for the rolled steel I section is commonly used in offshore structures has the shape factor of 1.12. Therefore, rolled factor which is 1.12 is multiplied by 1.66 which gives as 1.85 which is comparable good with that of the working stress design. Hence, margin of the safety in plastic design is in no way lesser than that is considered in the working stress design.

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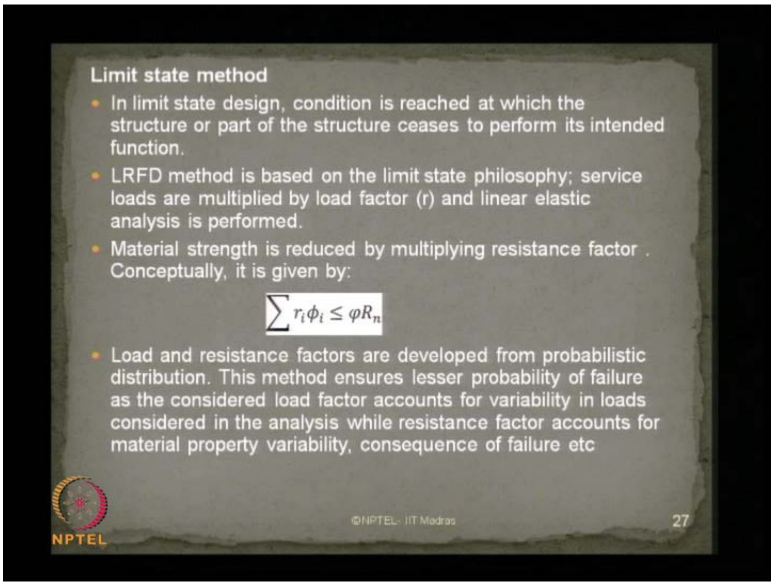

Alternatively, people also followed the other design methodology which is called as limit state design methodology. In limit state design methodology, the condition is that reached at which the structure or part of the structure ceases to perform its intended function; that is why we say the function is reached its limit state. LRFD method is basically an extended technique of limit state design where load resistance factor design method which is expanding LRFD; LRFD is based on limit state philosophy. Service loads are generally multiplied by a load factor r and linear elastic analysis is performed to compute the values.

So, the material strength is of course reduced by multiplying the resistance factor; conceptually it is given by the following equation as we see on the slide now. Load and resistance factors are therefore, developed from probabilistic distribution. This method of course ensures lesser probability of failure are compared to load factor which accounts for variability in loads considered in the analysis; while the resistance factor accounts for material property variability and consequence of failure etcetera. So, there are various parameters considered inherently in the design methodology in limit state technique as see on the slide now.

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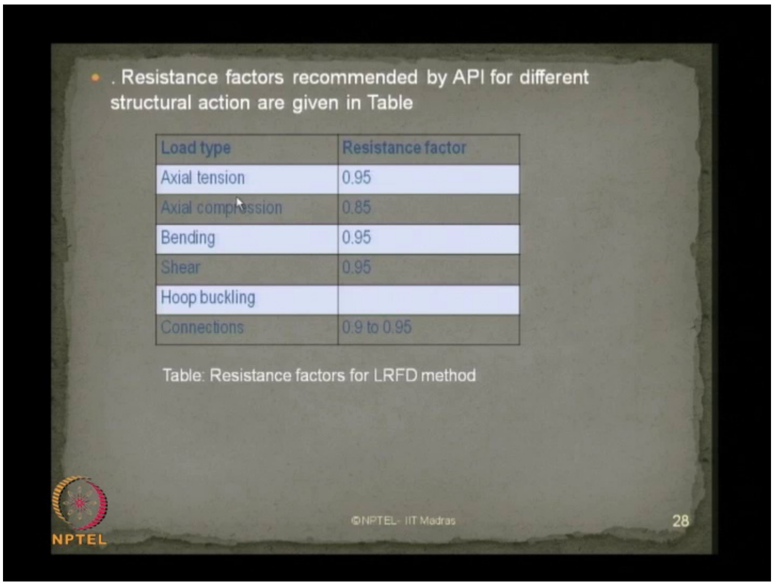

Therefore, you can always summarize these resistance factors which are used for LRFD as given by the international codes; for different kinds of load types like axial tension, axial compression, bending, shear, buckling connections etcetera you have got different distance factor suggested by international codes. The summary of the table shows you what are all those distance factors which are depending on what kind of load is acting on the member.

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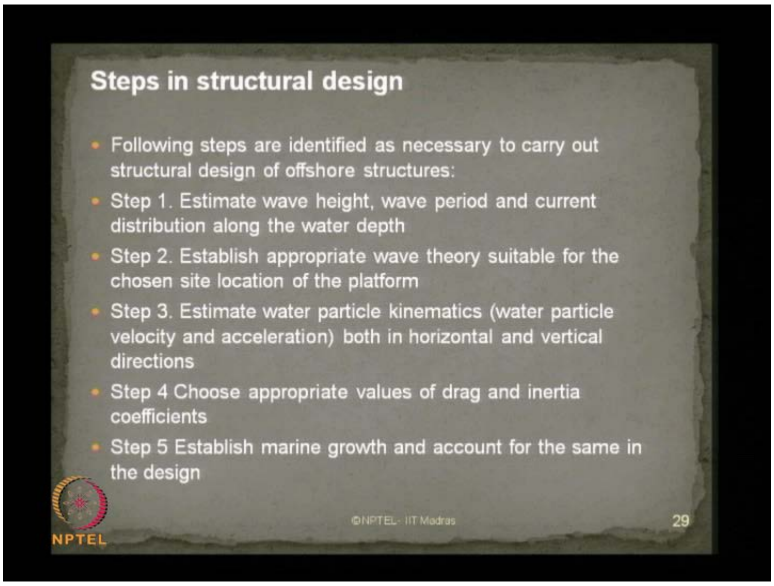

Now, let us quickly summarized what are the steps involved in structural design of offshore structures. Following steps are identified as necessary to carry out structural design of offshore structures. In step number 1 is: estimate the wave height wave period and current distribution along the water depth; in step number 2 is: establish wave theory that is suitable for the chosen site location of the platform; in step number 3 you will estimate the water particle kinematics that is water particle velocity and acceleration both in horizontal and vertical direction; in step number 4 choose appropriate values of drag and inertia coefficients. Ladies and gentlemen, in this lecture we understood how to select C d and C m values based on Doppler's effect and correction effect as given by API. In step number 5, we establishing marine growth thickness and account for this thickness and in the design.

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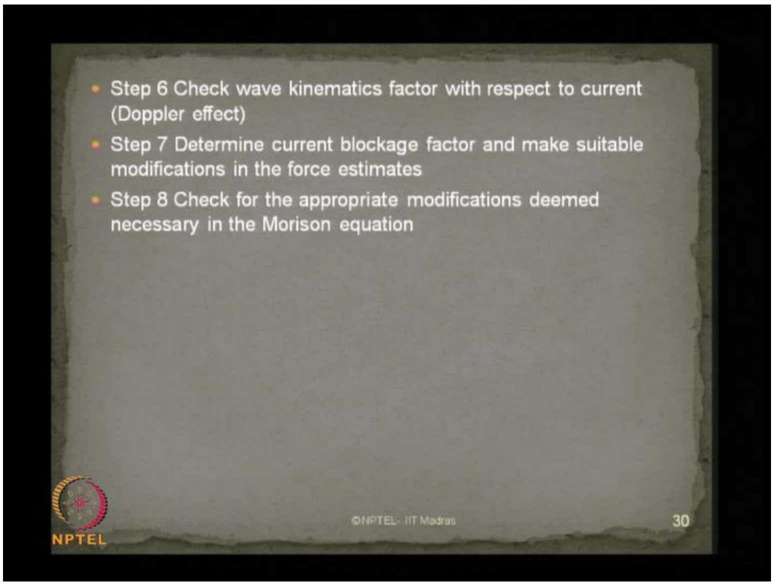

In step number 6, you check wave kinematics factor with respect to the current is called as Doppler's effect; in step number 7, determine the current blockage factor and make suitable modifications in the force estimates; in step number 8 check for the appropriate modifications deemed necessary for the Morison equation and ultimately design the members.

So, ladies and gentlemen, in this lecture we have learnt the preliminary methods and steps involved in design of offshore structures. Of course this course does not address the design methodology on detail. We have seen in this lecture how to design preliminary the offshore structural member design.In the next lecture we will talk about the construction methodology and installation technique of offshore structures.

Thank you.