Design of offshore structures
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Lecture - 03
Loads on Offshore structures 3

So, today what we are going to see is various forms of loading, that actually applied on the offshore structures.

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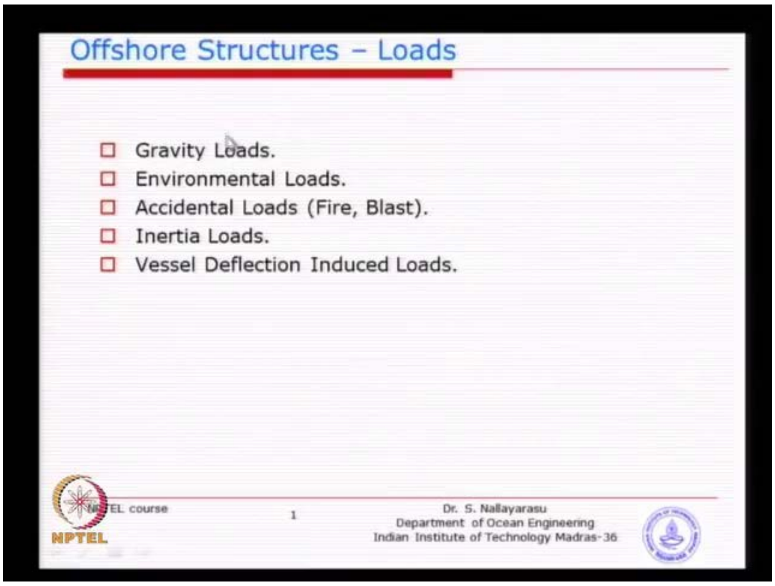

Then how do we calculate them the magnitude and the direction. So, if you look at the gravity loads it is the predominant form in onshore structures. I think most of you will be familiar is the weight of the structure weight of the facility. So, gravity load comprises fixed loads and then variable loads. You know fixture loads is predominantly you are super structure or sub structure self weight of the structure itself, mostly not varying with time. Whereas, the variable loads like live loads or other facility loads sometime vary, depending on the situation from time to time, during the design life.

Environmental loads primarily consists of wind wave and current and other loads if arise we will see one by one. Then the accidental loads especially for oil and gas facility the loads arising from fire and blast. You might have seen in several cases, where you know accidental fire occurs and the material of the construction gets degraded. It is not that the

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load is increasing the structure gets you know the deviation of the properties, because of change in characteristics of material.

So, that is causing the structure to fail, whereas the blast actually is the over pressure when you have a contained room something like this. When the blast occurs what happens there is no way to dissipate the pressure contained in this the build up of the pressure will cause huge overloading. So, that type of loading may also occur in case, where the offshore platforms are subjected to such accidents primarily. That is why it is called accidental loads.

The next one is the inertial loads due to motion response. For example, when you are transporting a structure from one place to other, it is subjected to motion loads, which will cause you know inertia loads on the structure itself, but after the installation of the structure at the final location. These may not be there, because they are fixed structure they are not floating structures, but of course if it is a floating structure.

Then it will be throughout the design life it will be subjected to motion responses. Then sometimes we have this vessel deflection induced loads, where the floating structures have a action of waves. They bend upwards and downwards due to the hull deflection. It is subjected to additional deflection induced loads, which we will see sometimes cause for concern, but I think that will come little later.

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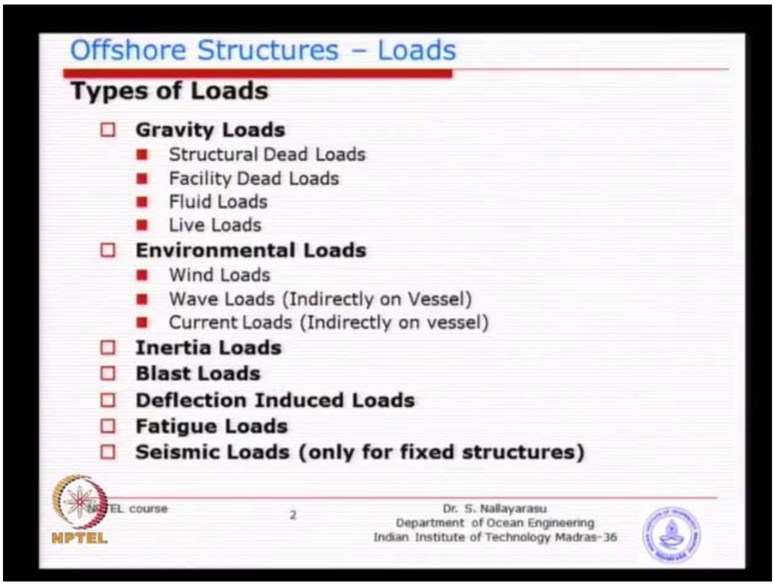

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So, among the gravity loads basically several things needs to be discussed. So, the first one is arising from structure dead loads is easy to calculate, as long as you know the geometry of the structure. Then density of the material of construction I think everyone can easily calculate the weight self weight. So, basically cross section if it is a tubular section you can calculate the cross sectional area. Then multiply by the length and you can find out the total weight. Now, when it comes to analysis you normally distribute the load. Like I think in your mechanics you might have studied basic mechanics, where you know the bending moment diagram for various forms of loading, on a simple beam structure or column. So, basically mostly the dead loads are distributed on the member.

Facility dead loads is basically, if you might have seen yesterday or day before yesterday. I have shown you several pictures of offshore platform, you saw that equipments cables pipes other facilities. That form part of the structure to produce oil and gas. You know those facilities will be considerable weight, in fact compared to the dead weight that could be higher. They are all part of this load conditions.

The next one is the fluid loads basically you are pumping oil and gas, from ground it comes to the surface and it gets processed. So, when you see this fluid loads they could be substantially larger magnitude because, so much of volume is coming from ground. It will get filled with all the equipments wherever processing is going on. That needs to be included and that could be heavier. So, that is why we will see that gravity loads one is the dry loads, which are either the structure weight or facility weight. Plus, the fluid weight the weight of oil and gas coming from ground.

The last one is the live loads. basically the variable loads both are variable loads fluid loads. Live loads both are varying, because fluid loads for example production rate higher or smaller will vary the fluid loads. Similarly, the live loads the live load is nothing but supply from external sources. For example, one of the platform is designed for living facility. So, when people are living there you will get supply from store like food items or other you know the supplies required for people to live there. So, they are all going to be variable loads. Sometime it will be heavier when the supply is reduced or the storage is reduced the loads will come down.

So, basically the live loads are non fixed loads or could vary with time, but then you can actually ask how much variation. It is actually very small, when you look at the

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magnitude of other loads. For example dead loads and fluid loads these live loads normally magnitude wise is quite small. So, calculation of gravity loads I think is just as most of you are engineers, I do not think we need to elaborate. So, simple there is no scientific idea involved, except that you need to just know the size density. Then calculate it, if it is a structure. If it is a facility again similar idea, if it is a pressure vessel I think most of you might have seen a pressure vessel. It is just a large diameter cylinder closed at both ends.

So, it will be like a big tank instead of vertical tank, it is a horizontal tank most of the pressure vessel will be horizontal. So, you know the size you know the the cell thickness and you can calculate. Normally, we do not calculate this kind of special items will be calculated by the manufacturer of the facility. They will give you what is the weight of the facility or the equipment. So, you can take into account in your design calculations. So, calculation of gravity loads I think is quite simple. So, just we will see what are the idea behind.

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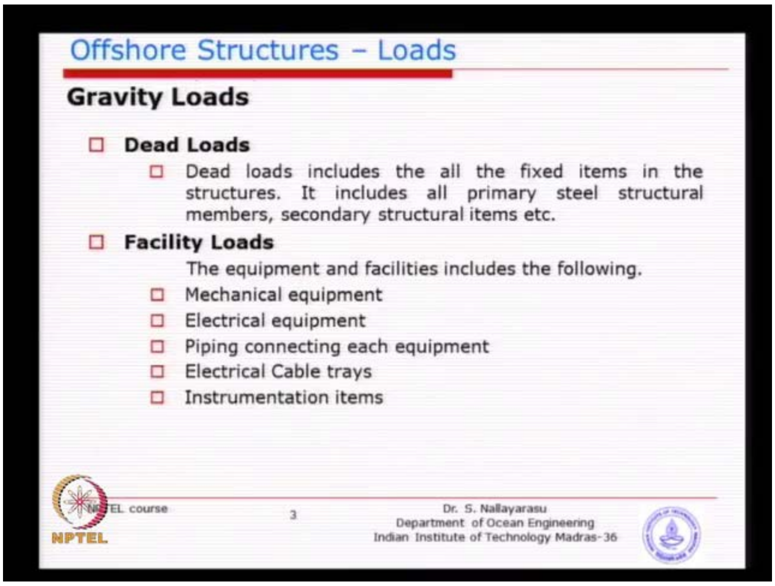

So, dead loads as I have explained there you could easily calculate without any problem, facility loads includes mechanical equipment. They are the predominant form in the any offshore platforms. Then you get electrical equipment as I mentioned every facility requires power generation power to operate, isn't it? So, you will have a power generating equipment like turbine generator and the fuel supply equipment.

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Then piping connecting each of this equipment is basically production then cables and other instruments, which are very much essential. You know most of this are hydrocarbon equipments many locations, you will see lot of instruments and valves for control and manipulation. You know sometimes you want to shut down you will operate from the control room. So, all those items will form part of the facility loads, which as structural engineer, we do not have to worry. It will be supplied to you this will be the weight at this location.

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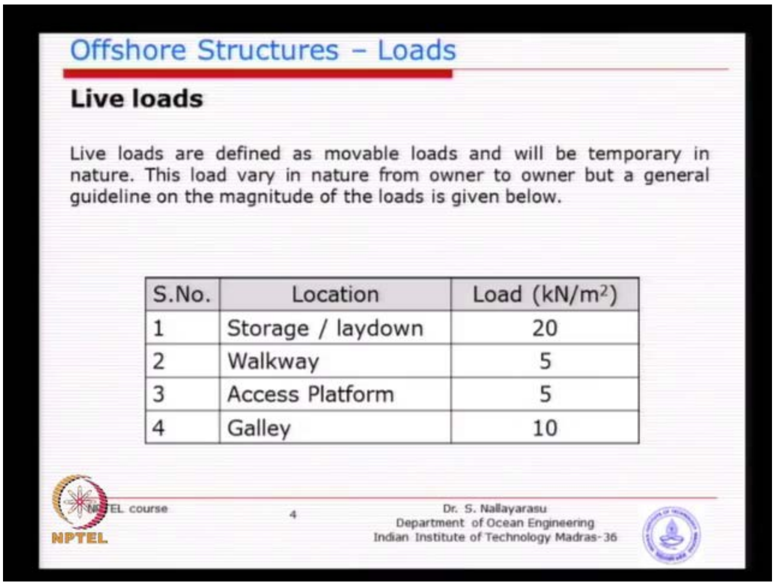

Live loads typically if you remember if you have studied in the national building code. Those who are civil engineers you will see that there are recommendations for various design of various types of structures on land residential building or industrial building or educational building, public amenities, each one category. Normally, you will be given a specific live load. If you remember for example design a residential building 200 kilogram per square meter distributor load is sufficient, but if it is a industrial building, because you are handling heavy equipments. Probably, you require the higher loads. Sometimes, you design for 500 kilogram per square meter as a distributor load.

So, you see here in this all this four categories identified as loading areas. It is not that the whole platform is going to be live loads, because most of the area is occupied by equipments. Facilities only the open area wherever designated as variable loading area. There only you are going to use that most of the time the storage area will be very essential, because when you are getting supply from shore not only for food. Other items sometimes you have storage of chemicals. For example, the process platform may require substantial amount of chemical for feeding into the process systems. So, you will store lot of containers or other types of tanks where you will keep the chemicals. So, basically the storage area that means we need to have designed for larger live load.

So, storage or lay down lay down is nothing but you bring the weight and then place it on the structure and that is the kind of number. Sometimes, you even design for more than 20, but typical number is about 20 kilo Newton per meter square. So, what is the number in terms of kilogram per square meter? It is 2000 kilogram. So, that means two ton per, so it is a large loading you could see that. Whereas, the walkway access areas or galley dining mess. So, you could see that slightly reduced loading and this is a type of typical numbers that you will remember. Whenever, you are talking about live load it is not going to be few hundred tonnes per square meter.

It is a very small number, so you just the idea why I am giving. This number is to keep in memory the magnitude the order of magnitude. You should know how much in relation to what is being done in the land based structures most of the structures on land multi-storey or single storey building not designed more than 500 kilogram per square meter. Mostly the heaviest loading that you design a industrial building about 500 kilogram. Maybe 750, but not more than that.

Except if you go to highways and roadways you design for the multi axial wave loading. Where, you could end up probably somewhere around 2000 k g per square meter like a heavy bridge heavy vehicle bridge could design for two tonne per square meter, but most of the other light structures. The design loading is considerably around less than 5 kilo Newton per square meter. All of you are familiar with this k g and kilo Newton and this business, because, I keeping going back and forth. If you do not understand you better, so what I would like to highlight here is the design loading itself, comparing on land based versus offshore. There is a considerable difference in terms of live loads. So, that you need to get into your mind that we are designing for higher load.

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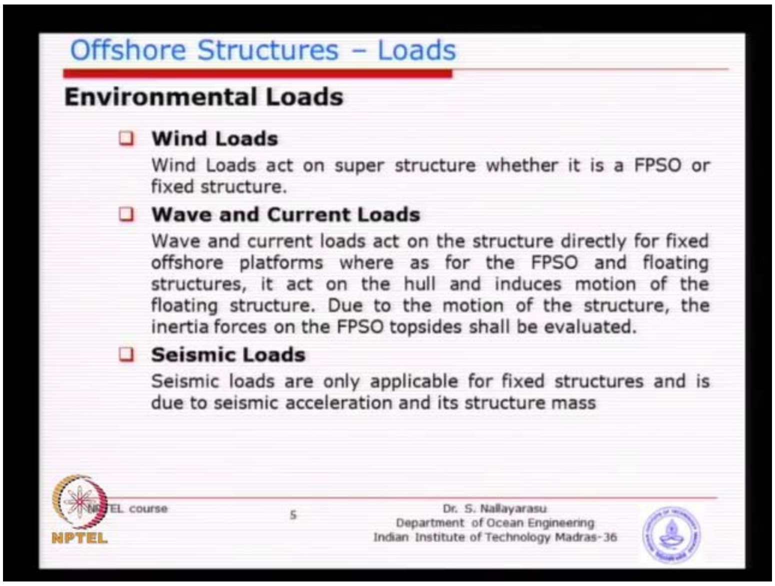

So, basically then we will move on to environmental loads. We will try to see how much we can cover without having to trouble, because you have a little bit of idea about wave and current. If requires I will open up a little bit of introduction. Here, I have slides if required. So, that the flow will be we can look at the wind loads first, which will be basically not a problem. Most of you have already got some idea about the drag force introduced by wind. During your mechanics or some stage of your this engineering during your graduate study.

Then the wave and current loads if you look at the magnitude wind loads and wave and current loads. It could potentially be a large difference, because of the way the structures are subjected to smaller portion of the structure is subjected to wind load. Because, above water, but the larger portion below water subjected to wave and current loads. That is not the only reason why the magnitude is larger, because of the fluid density and the magnitude of you know the forces generated is higher.

So, we will see that one of the days we will see how is the distribution, how many percentage is wind, how many percentage is wave and current. So, where should we give focus to accurately calculate the force, because that could change the way that the structure is designed. Typically, seismic loads may not be coming under the environmental loads, but actually it is due to natural disaster. It is again an accidental load.

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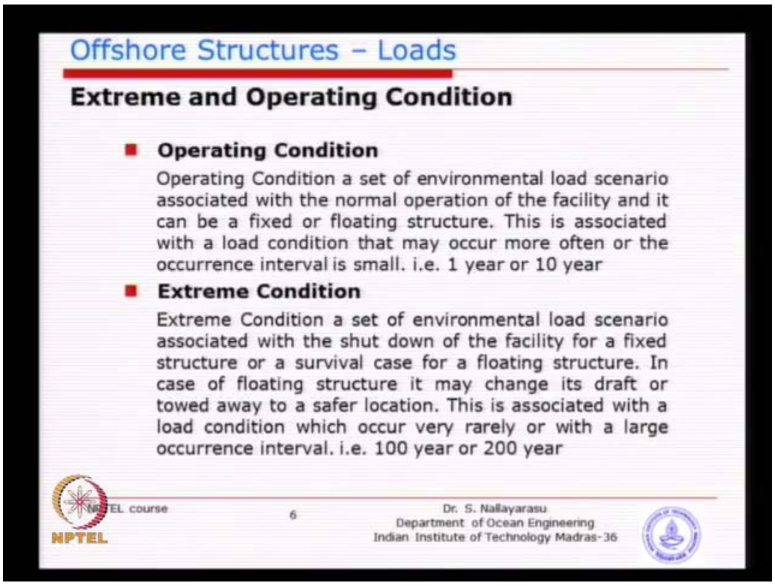

So, in this we have to get a clear idea for offshore structures. Normally, when you design an onshore structure we do not differentiate between an operating condition and extreme condition. Except that some classes of structures onshore we do classify abnormal condition like these the structure may not be able to perform its function. Whereas, in offshore always we divide the situation into two categories normal operation and extreme condition. Where, operation of the platform could be hindered, because of it is unable to perform or purposefully designed. If we sometime we designed the platform in such a way that, when a extreme condition occurs. We shut down the platform reduce the production or stop the production or the living facilities people could be evacuated knowing, that there is a cyclone coming.

Let us not you know create a situation, where we could not save the people. So, we shut down and evacuate the people to safe areas. So, that is exactly when do we decide at what situation we decide, that the platform could not operate or the situation is becoming dangerous, so that we can evacuate. So, basically the demarcation between a situation, where normal operation or normal function could be performed to non performance situation. We divide them into two categories. That is why we call it operating condition and an extreme condition. We need to design for it, but how it makes difference? For example, when you design a building you do not way to think of this situation, because the building has to be occupied all the type.

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For example, it is a residential building you do not think that anytime we want to evacuate this house. Because, this becomes dangerous but, then it actually not serving the purpose for which the house was built. I do not think anybody want to evacuate unless a different situation like a flooding or damages happening. Because, of some other sources of event, but normally you want to occupy the house hundred percent. All the time, because that is the purpose for which it is built.

Whereas, in offshore structures we just slightly deviate, because the extreme condition could potentially prove to be. So, high that the design becomes so uneconomical. So, that is where we just find a difference and the occurrence of such an event is so remote that means once in several hundred years. So, when you encounter such a situation we try do something slightly different. We want to take a higher risk that is exactly the idea we do not want to take a risk here. Whereas, we want to take a higher risk for the extreme condition. So, what it means? For example, if you go to a beach or some days you will see sea condition is normal. Probably, you will see a sea wave height of 1 meter 2 meters 3 meters, but if you go on as a day as where a cyclone is coming. You will see that wave heights are too large.

So, basically what we see is it is not that everyday big wave heights are or big waves are approaching or coming into the location. Where, the structures are designed once in a while, we do not know when it is going to come. So, if you look at the history of last say few hundred years you will see that sometimes cyclones have come in every 20 years 30 years. Then there is no periodical repeatance, you do not know you will never know when it is going to come.

For example, last this year few months back I think there was a cyclone crossing a location at Kandalur. You remember reading newspaper the previous cyclone hitting at the same location was 1973. So, you see the large difference between the previous cyclone. Now, before 1973 there was a cyclone in nineteen fifties, which we do not even have a good record, but if you come to some other location the previous cyclone. The current cyclone could actually be narrow. So, we do not know when which location the cyclones will come and create situation like, the one that we are trying to describe.

So, what we want to find out take the history and just look at the number of cyclones. The magnitude of the cyclone and find out once in so many years a larger wave height. I am just giving a typical example for a cyclone, but does not mean that we are only looking at cyclone extreme sea condition could arise from non cyclonic situation. Also, you could see that a particular day you can see a wave height is very large does not necessary to be a cyclone. It could be a local storm or local depression it could lead to a larger wave height, isn’t it? So, what we are looking at is the wave height or a sea wave condition that exceeds a particular elevation. So, basically that is the difference.

So, you see here this operating condition and the extreme condition the difference is sea conditions are very common, when in operating condition. Basically, a lower magnitude smaller magnitude occurrence of them is very often could be a return period of less than an year or a year. Sometimes, we go for ten year. So, the return period is nothing but how often it occurs in a particular period. So, that is called return period. For example, the extreme condition, we normally take one in hundred year or one in two hundred year. That means at least one time within the hundred year period it will occur that is called hundred year wave condition or if it is one year. Then at least that particular wave height will exceed will be exceeded within that one year period of timing.

So, you can see that the smaller the period one year means the design wave height will be smaller you could expect the larger the period that you cover. For example, you take last hundred years from 1912 to 2012, you look back. Just collect the data you will see that at some stage during the last hundred years, a highest wave could have come at that particular location, but if you look at just last one year. Only then you will not be able to have such a larger sea state.

Probably, sea state conditions could be smaller. So, this return period is very important, you should understand. I think at some stage you will learn this in hydrodynamics course, how to calculate the return period versus a wave height. You have to look for mathematical formulation based on distribution, which I think you will be able to get it. Otherwise, at the end of this course you will also be able to look at it at one of the days.

So, basically the extreme and operating condition is very important, because for example normally during operation of a offshore platform producing oil and gas. You do not want to disturb the function at any cost. So, that we design for their wave flights designated and all the functions of the platform as normal. So, that sometime we call it normal operating condition that means uninterrupted production.

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Now, when it comes to extreme condition for example a extreme cyclone or a extreme storm is predicted. For example, in few days time it is going to cross this particular location most of the time. Nowadays the prediction is possible and the tools are available the projections are available the mathematical modelling is available. So, you will be able to find out this particular location storm is going to come. So, we could do three four activities we could shut down the platform, because during an operation. If a cyclone hits or a storm hits. There it could be a potential damage to the equipment number one. If a damage to a equipment occurs what happens? It is not we are worried about the damage to the equipment.

We are worried about the spillage of hydrocarbons, because the first consideration is given to human life. Then the environmental conditions or environmental impact you have a spillage of oil. It could prove to be potentially damaging to the marine ecology. So, that is why first thing human life you evacuate the people second try to make sure that the equipments are not damaged. So, if you shut down the platform the potential disaster of pumping too much of oil into sea is avoided. Because, by closing the valves even if the damage to the equipment occurs. What happens only a small amount of oil could spill over, because we have closed the valves which was flowing the oil and gas.

So, extreme condition we could save human life by evacuating them from the platform number one number two. Reduce the environmental impact by spillage and damage to equipment. What else can be done remove some of the loads from the platform. For example, you have designed a platform so tightly. That slight exitance of load could make it to fail. So, you can actually remove some of the loads, but that is the last thing we normally do. Because, removal of load involves again a different types of equipment required. So, normally we do not do it.

So, now you see these three conditions you think about it when we try to design we actually consider in the design consideration remove the loads. Now, the third thing what we can do is we can take a higher risk, because this particular condition is going to arise once in a hundred year. So, can we allow the stresses to be higher than the normal. Maybe, because if you look at the design for normal condition you do not allow this. You actually design for the stresses as per the codes.

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Whereas, in the extreme condition, maybe we could allow higher stresses, because the chances of this occurring is very small. The probability of occurrence of this extreme condition is quite small. So, basically by this, I think you could have understood what is the difference between two conditions of design this goes to both for wind wave and current the extreme condition.

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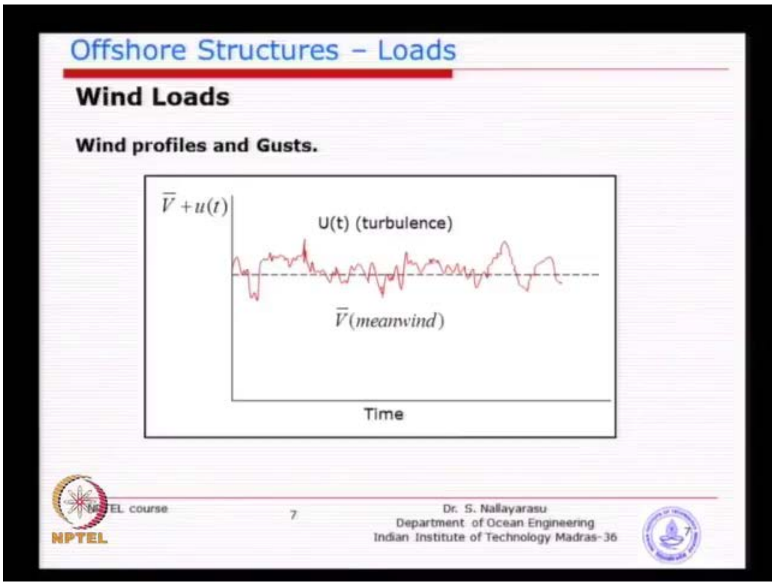

The operating condition is to be defined for all the cases. Now, let us just quickly look at loads arising from wind I think this is also essential for onshore based structures. So, you could see a histogram showing a variation of wind velocity. If you go on put a velocity measurement device I think you might see in most of the places they do this. In metallurgical department they have put the meters. If you go to our sac not sac building somewhere nearby they have got a station, where it measures wind speed temperature. So, you could see the meter there.

So, basic idea is it is not a constant velocity as many of us normally think the wind is also varying with time, but only the fluctuation is very much like a random signal. You might see that it is not so regular nicely. So, you see there the fluctuating component is very small, but the steady component is quite. If you see the dotted line in that it is basically a steady component on which the fluctuating component is changing. So, if you go to a roof of a building. Sometime, you could see that suddenly the gust wind applied

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on your body could you could feel the variation quickly and disappears suddenly. There will be a gusting a large wind speeds and then reduces.

So, basic idea is for design purposes you could draw a line, something like what I have drawn in a dotted line, can take an average velocity. Instead of taking a design activity for all this variations. For example, if I take the lowest and if I take the highest in this whole stretch of data. Then design for its lowest you do not have to design, because anyway you know very well that the wind speed lower means. do not have to worry.

So, you normally take a highest something like, this peak value and make a calculation for the loading. Complete the design that is what everybody normally think, but that occurs only one time in the record that you see, which is not very good. Because, once in so much of time is going to occur maybe not a very critical, but then we have to decide how many times repeated could be considered, as you know reasonable loading. So, that is why we need to understand how it varies.

If we do an average for example, the varies from certain values 20 meters per second goes to 30, 25, 5 something like this. Look at the record for a longer duration take one year record, if you have. Mostly we normally do not have this record for longer duration sometimes you might have. So, you take one year record and average it? You might find average is smaller or higher. You will find it quite smaller, because many times wind may not be there quite period. You know it could be ten meter per second or even less.

So, if you take longer the duration of average you will find that the values of average could comes down. For example, if I take a average over a very short duration. For example, if I go here say I take 3 seconds or 5 seconds 10 seconds 1 minute take the values. Do an average the values could be higher depending on where I do the average. For example, if I do the average down here I find all the values are higher than the steady component. If I do the average somewhere here I will find that it could be equal to the steady component.

So, it depends on where I do the average is very important. That is why we do a calculation called moving average. You might have studied in your mathematics you have studied. So, normally we will do a moving average and find out during, which period is the maximum value. So, we call the wind profiling. Basically, the gusting we need to determine, which period of averaging will represent the real situation. You take

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an average over a longer period it is going to be very small average, that going to take a smaller averaging period, you are going to get. So, there are several techniques available.

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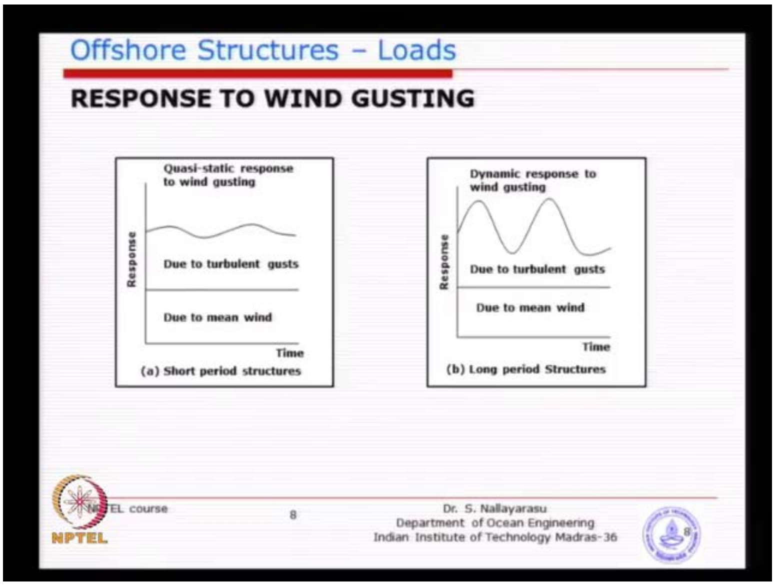

So, the mean wind speed, which is going to cause the drag on the structures basically needs to be determined first. Then the turbulent effect or the variation components could cause different response to the structures. Because, the mean wind we can calculate the steady or static forces. Whereas, the fluctuating component we just need to see whether it is going to be causing any other trouble. Other than the conversion of the gust wind to static loading.

Now, you see here short period structures long period structures, what I have just classified this again goes back to your dynamics. If you have a slender structure what happens the period is larger. If you have a rigid structure the period is smaller, you could easily compare you take a small stick. You can just pull it from one side and just release it could come to its neutral position the period of oscillation could easily be calculated, depending on the stiffness of the structure.

So, that is exactly we are talking about short period structures and long period structures, the longer the duration of oscillation. It is going to interact with the gusting wind. Whereas, the short period structures typically like our jacket may not have such dynamic excitation. Because, you can convert the wind loads, which are really dynamic can be converted to static loading.

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So, the idea behind this particular picture is to say that most of that structures what we are designing based on the framed arrangement. We could convert the wind loading to static loading instead of dynamic loading. The other hand if you go to a for example, you might see, so many places in land also chimney tall chimneys. You might see they are slender structures and subjected to wind gusting, could potentially create a dynamic interaction could fail, also sometimes. So, that is why such type of structures we need to see dynamic response instead of static response.

So, that is exactly the idea behind you need to get a demarcation, what is a slender structure, what is a short period structure or rigid structure. Or structures that is not responding to dynamic loading. It is not that it is not responding the response is so small. Whereas, when you look at the tall structure even the magnitude of loads are small the response could be larger. Because, there is a resonance characteristics near resonance characteristics and that is what we are going to see.

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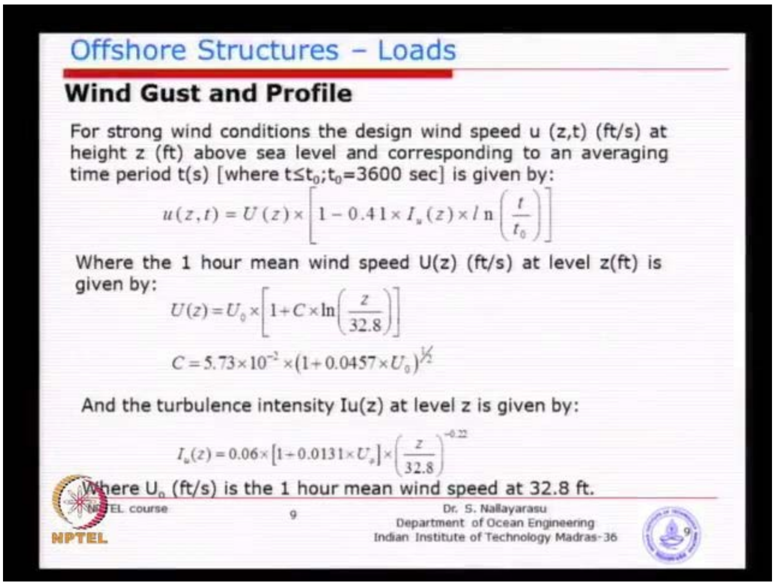

Now, the wind gusting and the profile let me just see, whether I have a picture supposed to be not here the variation of the wind speed with height. I think that is most important in so how the wind is blowing. When you go higher and higher I do not know whether any of you have gone in a tower. If you have just go up a tower slender tower like transmission tower or water tank. You will see that the wind speed as you go higher and higher wind speed wind speed increases or decreases, it increases. So, basically what is

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the profile of the variation is very important. So, you will see that suppose to be having a profile. I think it is missing in this particular anyway we will see I will draw a picture, so typically if you see there.

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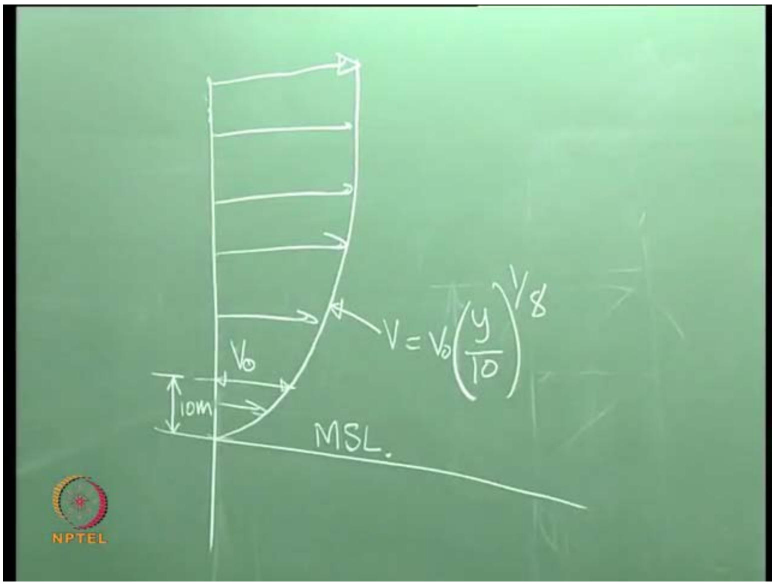

Something like this normally, so if you see this wind speed variation with respect to height. If you look at this picture something like this and in this particular picture I have put V naught, which is given at 10 meter. Most of the wind records given by the metallurgical department they give the velocity measured at 30 feet above mean sea level. So, this is mean sea level the reason behind is typically a everybody follows the same idea of measurement. Even, if they measure at a different place they recalibrate and give you the values at 10 meter. So, any time when you see the records from a measuring agency or a reporting agency or ports or some reports. You see that the most of the velocity or the wind speed given is at 10 meter from mean sea level.

The variation is taken as how the here v naught multiplied by y by 10, because 10 is your the velocity measured and to the power 1 by 8. So, if you plot this function like this it goes almost like a increasing trend with a exponential function. So, you could see that the height is increasing. You will find that the velocity change is quite high, but after a certain height it becomes almost no change. This is what the formula normally we use for quite some time. You know this is given by a typical variation in many of the textbooks as well many of the government agencies.

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For the last so many years we have been using this simple form to estimate if you look at some of the design codes. For example, if you go to I S codes I think 875 you know you they will be giving you a different formula to calculate. So, how you will find you will see that velocity is a function of k 1 something like this you may also have k 2 k 3, so many other functions.

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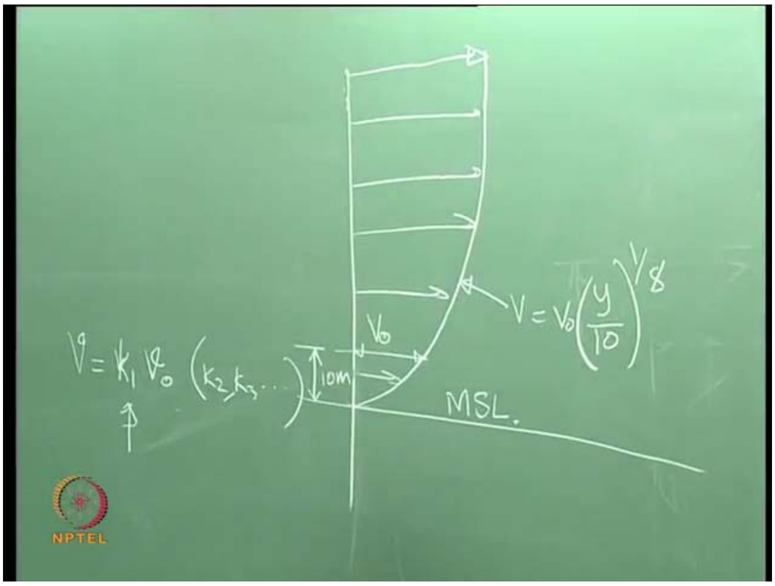

So, this k 1 or k 2 could be a function to describe the variation. We call it terrain or height effect function. So, it is exactly the same this here this y by 10 to the power 1 by 8 or 1 by 9, 1 by 10 again it depends on which recommendation. Whereas, A P I this I have taken this from A P I. It is giving a slightly different formula little bit complicated, but again the result will be similar, what we are seeing is almost same. So, you see here the velocity or the wind speed at certain height and time, which is very important. This one what we here can only calculate with respect to height.

Whereas, the formula given by A P I could calculate with respect to height as well as with respect to averaging time. Just earlier we were talking about three second average five second average one hour average two hour average. So, that is the idea behind we could calculate if we know only one particular wind speed. If you want to find out the extrapolated value for averaging time different averaging time. Then you can use the A P I formula, that is why we use this.

So, it is a little bit complex, because this is an empirical formula. It is not a derived from first principle, so empirical formula. So, you have to be a little bit careful using this because, since it is an empirical formula. You have to follow the units correctly according to the recommends recommendations given by the A P I. We understand the difference between empirical and the formulas derived no in empirical formula. There are constants you see here. There is a constant 1 minus 0.41 this is not derived from somewhere.

It is a correlation fitting based on the measured data and analysis done by the researchers come up with. This could be potentially projecting for the for the particular area or location unfortunately this is given for U S A continent, but we simply follow. Because, it fits very well I think many of them have been tested. So, we still follow in elsewhere. Even though this whole equation is only relevant for the Gulf of Mexico area.

So, basically if you are given a particular averaging period t naught is equal to 3600, which is nothing but the averaging is one hour. So, if you are given one hour averaging period. Then you can calculate any other averaging period. You are given only the wind velocity u naught at 10 meter from sea level. So, you can calculate height elsewhere. So, this formula is very generic, very general, because height variation as well as time averaging can be calculated. So, you see here in this particular function. There is a function called turbulence intensity function to take care of the averaging. This i of z is and highly empirical, what is the function here? It is basically u naught is the wind speed at 10 meter and z is the elevation. In terms of feet you have to be very careful, because this formula is written in terms of feet and feet per second.

So, if you want to use it for your project you have to convert your wind speed to feet per second elevation to feet come here calculate it go back. Then convert back to your units, so do not just put it anyhow any number. Then it will become a bigger problem and C is a constant, which is given in this kind of form. Then the elevation variation is given in terms of U z all of them are substituted here. Finally, you get any conversion from particular, so this is basically an idea that is used for calculation of wind speed.

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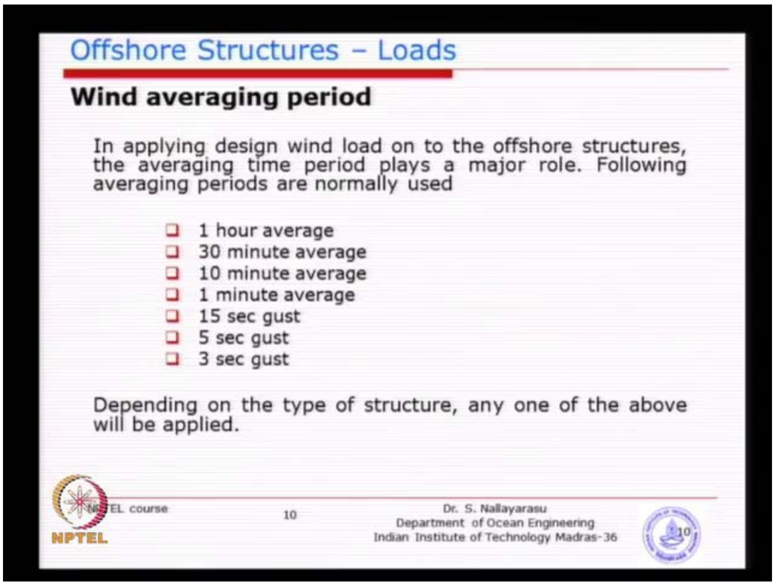

Now, normally you see here wind averaging all of you understand wind is not a steady state business. You understand the idea that you have to get it and why we are trying to do a conversion from a gusting wind a dynamic. Wave a dynamic variation to a steady state, because we see two class of structures one is short period structures. Then long period structures long period structures. Anyway we are not designing for short period structures conversion from dynamic loading to static. It is very much essential, because it simplify the design procedure. That is why we are trying to do, but when you are doing research. Maybe, you do not need to all that you can do a dynamic simulation. Whereas, design always remember simplification, so that you could design it, well within the time period as well economically.

So, in here you see the wind averaging period in industry several averaging is used for different class of structures. Starting from one hour average 30 minute average 10 minute average 1 minute average, ultimately 5 second to 3 second gust. So, the 3 second gust is the highest wind speed that ever recorded. You will see that if you go into a national building code of India. You will see a wind distribution chart what is given there is actually a three second gust. Because, that is the highest magnitude you will find three second is quite a small one and like the one hour average. So, the three second gust will be recorded and given to you from there, you have to calculate back or convert them.

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So, the exactly opposite is coming here that is why we have got a problem. If you are given a three second gust using the A P I formula, you cannot convert to other averages, you understand the idea? So, that is why we have to go and ask the people who are recording and giving the wind speed give us the wind speed in one hour average. We could calculate the others and that is the practice in U S. They normally give a one hour average then you calculate the others. Whereas, in India we have three second gust how do you get back to others. So, we cannot convert and we have to ask the agencies giving this data to calculate and give us so most of the agencies. They give at least one hour average and then at least ten minute and one minute average, which will normally be required for design purposes.

So, all of you understand the method called what we are trying to do for averaging. Averaging is nothing but taking a history time history of wind speeds and cumulative summation divided by the number of sample points. So, at least you get a averaging for that particular period, but then again scientific method of moving average has to be done. Because, you cannot take a sample on a particular location. I will do average then I will get. So, you have to do a blocks of say for example, if I want to a 10 minute average it is not that I only look at that 10 minute. I got to look at 10 minute average of several blocks and then get the highest value. So, then that will be the 10 minute average.

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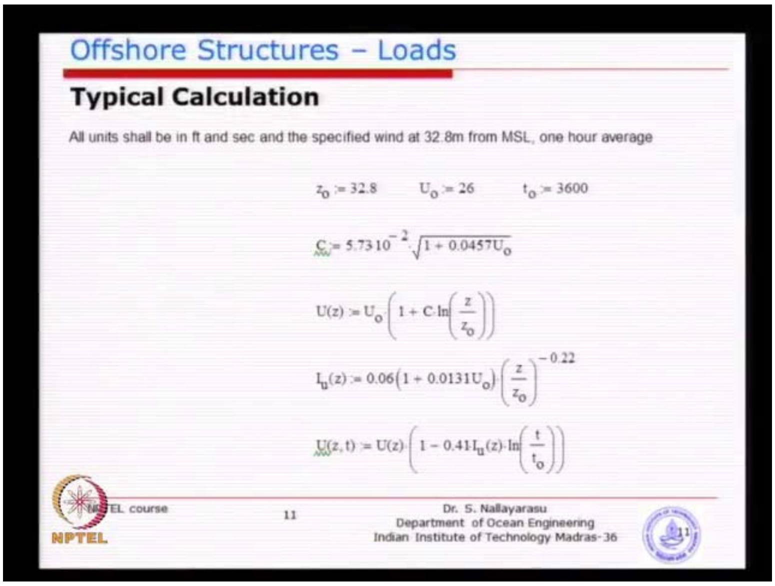

A typical example I have just given you here for calculation how it is done. So, calculation of sea value and given for u naught is given as 26 feet per second in this particular example and just substitution of values. I will show you how the variation is 153 three second gust versus 150 feet 30 minute average.

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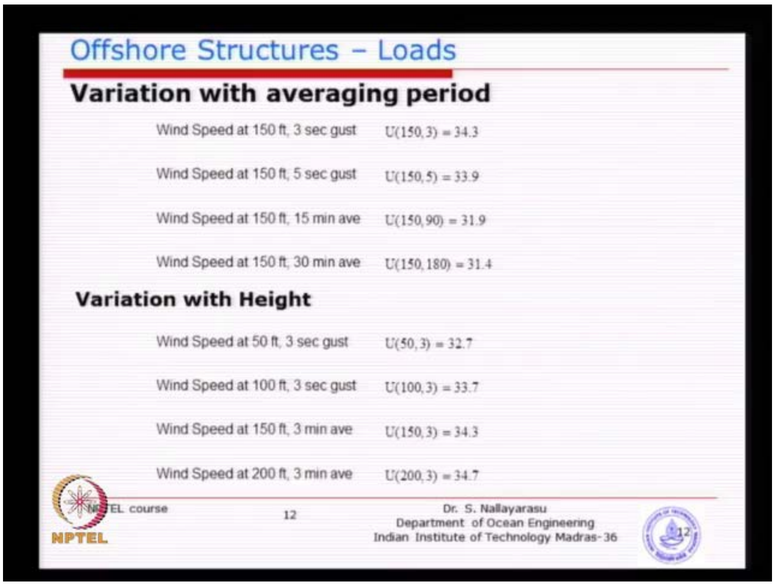

So, you can see here 3 second versus 30 minute the values become 34.3 down to 31.4 using see the same formula. What I was just explaining just to demonstrate how the averaging period affects or reduces or increases the wind speed. So, basically you see here 3 second gust 5 second gust 15 minutes average 30 minute average. Gradually the values come down just, because of the reason I explained in the first slide, where the variation. When you try do an average smaller the period of average you get a higher the magnitude of the wind speed

Similarly, the variation with respect to height. If you see same I am just do using the 3 second gust as an example and 3 minute average as an example 50 feet 100 feet. You see the values increasing from 32.7 to 33.7 approximately about 5 to probably about 5 percent, but if you go higher that could prove to be slightly increasing. As much as if you go from say 10 meters to 300 meters. You could see that twenty percent increase 30 percent increase in the velocity. Once you see such kind of variation or increase. Later, we will find that, when you calculate the wind force the drag force is proportional to

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square of the velocity. I think most of you remember the drag formula. So, basically that means the force will be even higher, that is one.

So, that is why the calculation of the velocity has to be correct and accurately to be predicted. Of course, fortunately in the offshore structures, we do not have to too much height. Maximum height could be say hundred meters. Whereas, if you come to land based structures the towers and buildings, nowadays goes as much as hundreds of meters. So, you could see that the velocity could be considerably important in that kind of cases.

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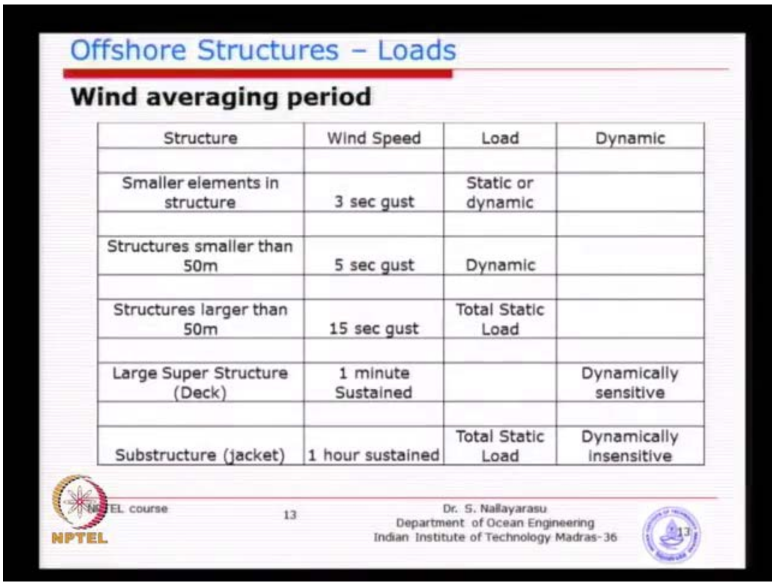

Structure	Wind Speed	Load	Dynamic
Smaller elements in structure	3 sec gust	Static or dynamic	
Structures smaller than 50m	5 sec gust	Dynamic	
Structures larger than 50m	15 sec gust	Total Static Load	
Large Super Structure (Deck)	1 minute Sustained		Dynamically sensitive
Substructure (jacket)	1 hour sustained	Total Static Load	Dynamically insensitive

This I think we have already discussed, but in specific case we will just take the recommendation of A P I. What A P I says how do we approach this problem. Now, we know that the wind gusting is varying and you see here smaller elements in structure. For example, we saw structures containing, so many elements. So, you want particular element in the structure.

For example, the structural member designed for three second gust individual member local design. That means that members supposed to be susceptible to three second gust. You must design for three second gust wind as a single element in the structure, but when you design the whole structure does not necessary. That you have to design for that particular three second gust, because it is a global loading number one number two. The

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chances of all the elements subjected to the three second gust is very small. So, that is why we can go for a slightly increased averaging.

So, when you have a structure smaller than 50 meter. That means smaller sized structure designed for 5 second gust structure larger than 50 meter, bigger size 15 second gust deck structure one minute sustained or one minute average. Sometimes, you will see a word called sustained it is nothing but averaging period. Then the jacket structure designed for one hour sustained or one hour averaging. One hour mean all three words are same sustained averaging mean all are sometimes people use a different terminology.

So, you could see that for a sub structure and super structure there is a designed wind speed different. Basically, one minute sustained for super structure versus one hour sustained for substructure. The idea is we would like to take a slightly less conservative. Because, if you take one minute sustained for substructure design. You could actually make the structure very big. Whereas, it is not going to happen not all the elements in the structure is subjected to similar wind speed. These are all recommendations after a thorough study over a long period of time. In fact the previous revision of A P I did not give such recommendation. In fact it was left to the designer to decide, but now after a thorough investigation, they have come up with this recommendation.

So, that to avoid either under design or overdesign many times codes give you such kinds of ideas. So, you could see there is a last column on the right side dynamically sensitive dynamically insensitive, basically that is again. So, that is why on day one I was talking about design of offshore structures two things are very important. You need to understand clearly the dynamics of the system and the foundations of the structure.

Where, it is fixed these two together form very important aspects, because the dynamics ultimately will depend on the how the fixity conditions in the ground. If it is rigidly fixed you will see that structure behaviour is different. So, you must actually go through those two courses. Then you can appreciate how dynamic play a vital role in changing the characteristics.

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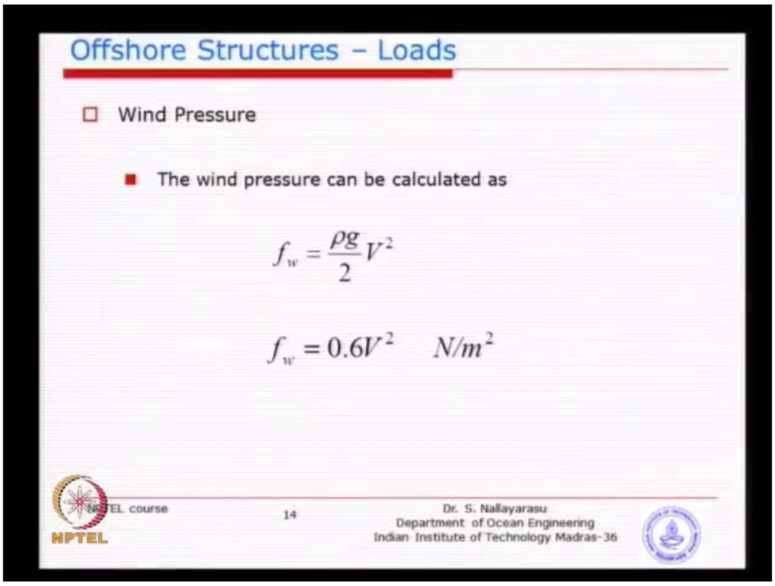

I think most of you could remember or if you do not remember also it does not matter. It is basically a simple formula. It is a drag formula 1 by 2 rho g and v square rho is the density of air, g is the gravitational acceleration. Have you seen this formula before in other forms? It is very similar to kinetic energy. You know basically the energy of the wind half m V square, you know it is very similar. So, if you substitute the density of air and gravitational acceleration. You get a such a simple formula 0.6 V square you have to remember all the time in your life.

Because, this will be used very often whether it is offshore structure or onshore structure or whatever you design you will get this formula. So, 0.6 v square the unit is Newton per meter square do not make a confusion there. If you remember this is if you f w is the wind pressure, basically unit wind pressure. Basically, if you know the area of projection of the structure you could apply area times this pressure and find out total force. I think we can stop here.

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