Offshore structures under special loads including Fire resistance
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Lecture – 11
Wind Loads

Friends, today in the 11th Lecture under the NPTEL course on offshore structures under special loads including fire resistance, we will continue our discussion about some details and complexities related to Wind Loads.

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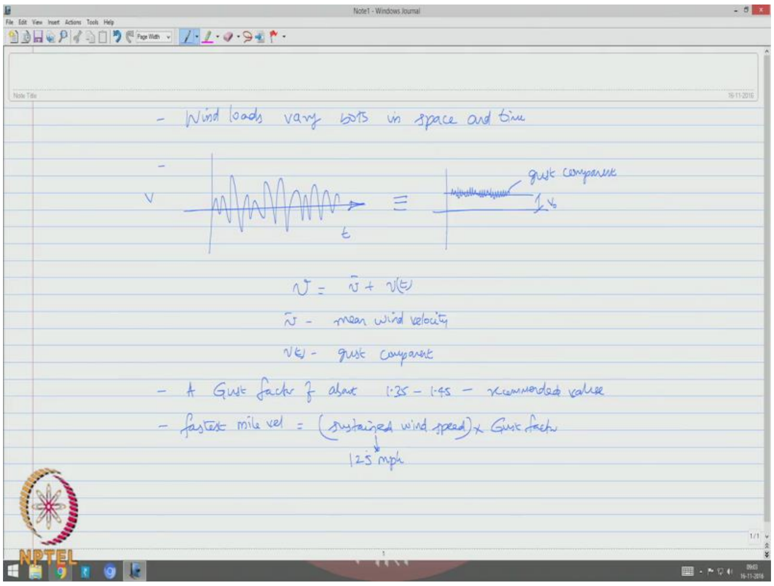

As we discussed in the last lecture wind loads vary both in space and time. We also said that if I have a wind load which is measured as a variation in time and I call this is total wind velocity. And if it varies along the time as we see here this can be equivalently said as a wind velocity with a static component what we call V 0 and the dynamic component which varies with time which we call as the gust component.

Therefore, V can be said as V bar plus V of t; where V bar is the mean wind velocity and V of t is the gust component. We also said in the last lecture the gust factor can be used to account for the variations which can be considered equivalent to compute the gust flow. A gust factor of about 1.35 to 1.45 is a normal recommended value for design of offshore structures. So, one can always estimate the fastest mile velocity which is actually equal to the sustain wind speed multiplied by the gust factor. A sustain wind speed for a 100 year written period is taken as 125 miles per hour.

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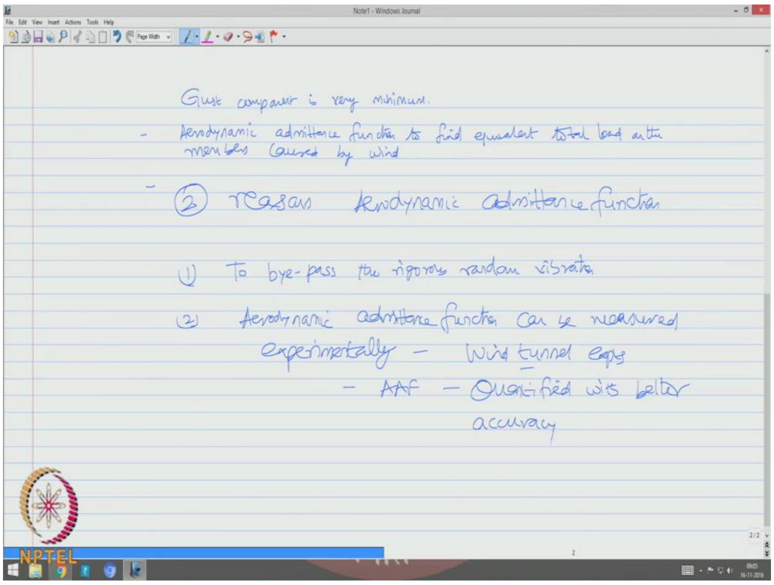

So, to account for the spatial variation and time we also said that the gust component variation is very minimum. Hence, people use what we called aerodynamic admittance function to find the equivalent total load on the structural members caused by wind. We clearly understand the wind has got two components: one is the steady wind or the mean wind velocity component, and other is the time varying component which is the gust factor or the gust component. To account of both of these at one given point of time people used aerodynamic admittance function.

There are essentially two reasons. Why do we use aerodynamic admittance function? One, we use to bypass the rigorous random vibration concept. Secondly, aerodynamic admittance function can be measured experimentally one can conduct wind tunnel experiment to measure aerodynamic admittance functions. It means aerodynamic admittance function can be quantified with better accuracy.

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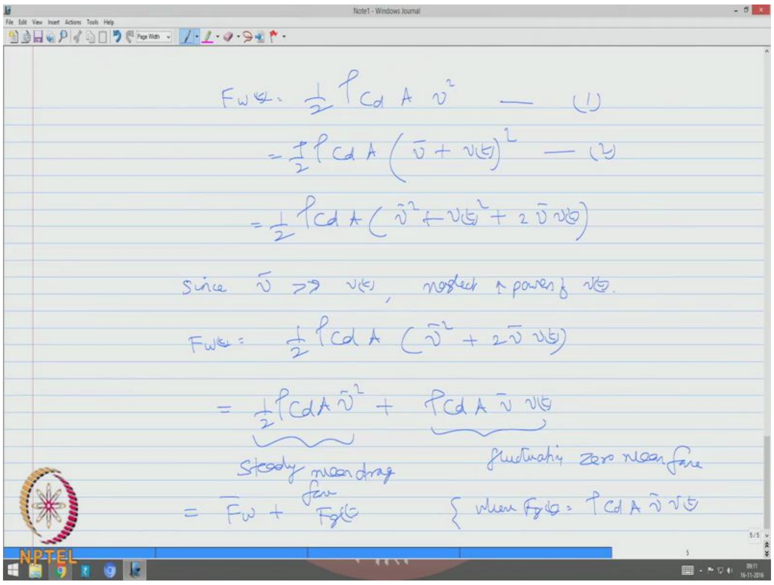

Force and wind is actually half rho Cd A V square, equation 1; which is half rho Cd A V square is actually V bar plus V of t the whole square. Expanding this let say half rho Cd V bar square V of t square plus 2 V bar V of t. Since, V bar is much higher than V of t we can neglect higher powers of V of t. Therefore, F t can be said as half rho Cd A V bar square plus 2 V bar V of t. Expanding half rho Cd A V bar square plus rho Cd A V bar V of t. So, this component is called steady mean drag force, this component is the fluctuating zero mean force. So, now, I can say this as F bar omega plus Fg where in the gust component is rho Cd A V bar V of t.

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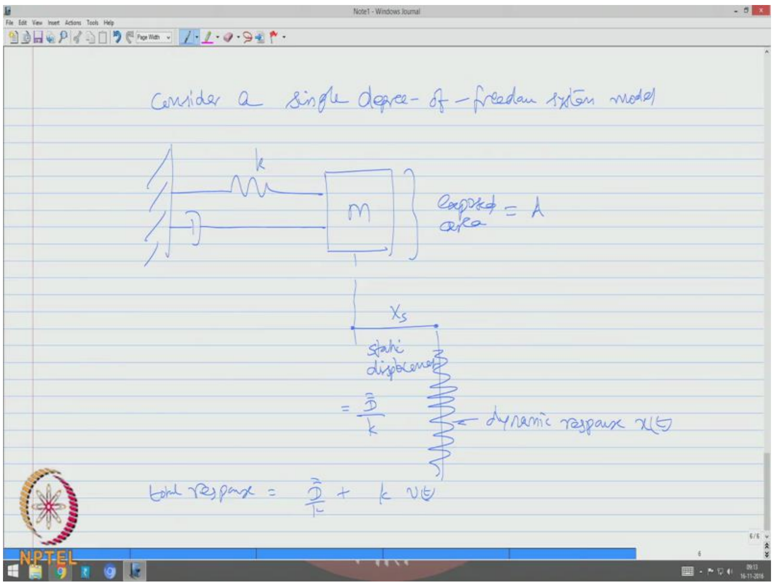

So let us say, consider a six single degree freedom system of it. Let say I have a model attached with some stiffness sprink k and the some damp perceive, and there is a mass attach to this, the mass as an exposed area A. Now the mass undergoes a static displacement x s which is called static displacement, and from this point it undergoes a dynamic response. So, this is the dynamic response which is x of t. So, static displacement we know it is actually d bar by k, so I can now say the total response could be static response plus k of V of t which is actually a dynamic response.

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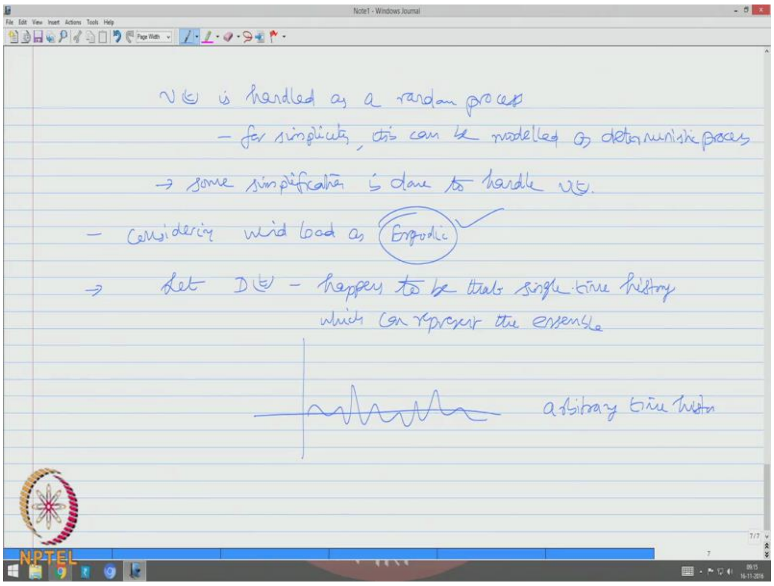

Interestingly V of t is handled as a random process; strictly speaking it should be handled as a random process, but for simplicity this can be modeled as deterministic process. So, some simplification is done to handle the gust part. We also know that we are considering wind load as Ergodic, we already said in the lecture what do we understand by Ergodic.

Therefore, once we say it is Ergodic and acceptable let D of t happens to be single time history, that single time history which can represent the ensemble, let say typical time history is this wave this is an arbitrary time history.

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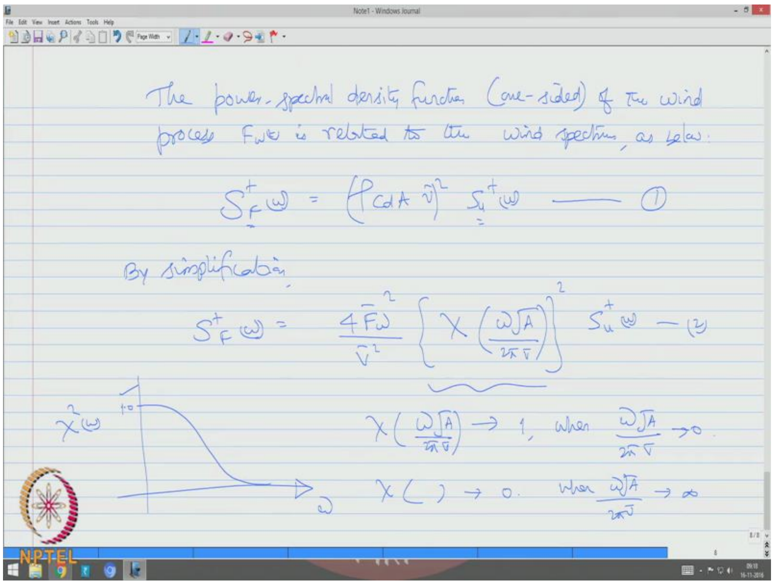

Therefore, the power spectral density function which is one sided of the wind process F t is related to the wind spectrum as below S F plus omega is rho Cd A V bar square of S u plus omega, this is actually u; this is a force, this is a response. By simplification S F omega can be now said as 4 F bar omega square I am taking the mean wind component by V bar square of a chi function of omega root a by 2 pi V bar the whole square of S u omega.

Interestingly, let us look at the property of this particular function. The particular function looks like, this for omega I want to plot chi square omega. So that is how the plot looks like this is unity. So it means chi of omega root a by 2 pi V bar tends to 1, then omega root a by 2 pi V bar tends to 0; that is what we see here. When omega root a by 2 pi V bar tends to infinity the chi function tends to 0. So, that is the characteristic of this function.

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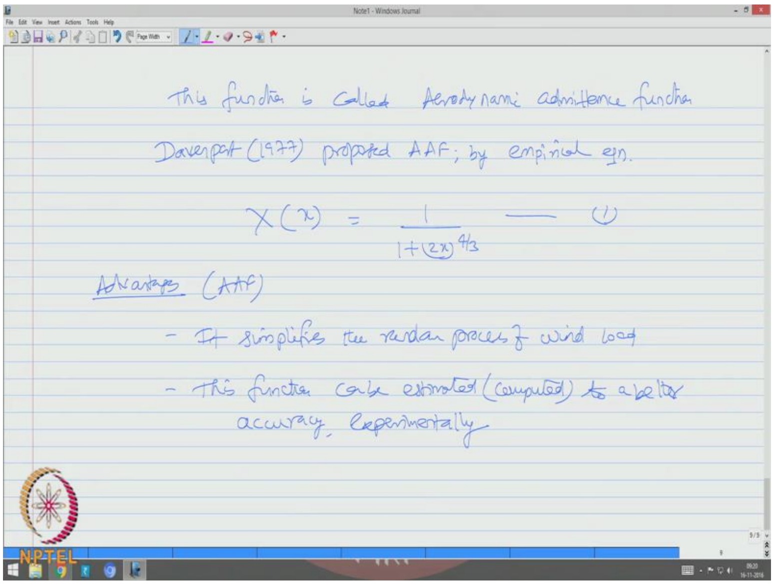

This function is called the Aerodynamic admittance function. Davenport in 1997 proposed an aerodynamic admittance function by an empirical equation. He says chi of the variable can be simply 1 by 1 plus 2 x to the power 4 by 3. So the advantage or let say the advantages with aerodynamic admittance function is; it actually simplifies the random process of wind load, because we are using the aerodynamic admittance function you are not involve in the gust component and the complexity is estimating wind forces. Two, this function can be estimated, I should say rather compute; significantly to a better accuracy experimentally.

So, use of aerodynamic admittance function converts the complexities and random cause of wind loading to somewhat more or less simple problem of deterministically.

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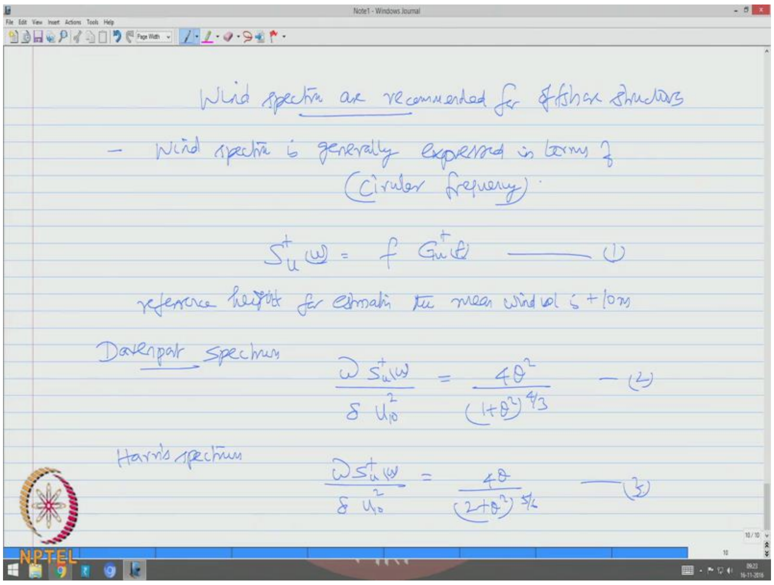

So, based on this wind spectra are recommended for offshore structures, like we saw wave spectra wind spectra also recommended for design of offshore structures. This is the fundamental understanding of wind spectra compare to wave spectrum. Wind spectra is generally expressed in terms of circular frequency further S u omega is f of let say G u f. The reference height for estimating the wind force, let say the mean wind velocity is 10 meters.

So, Davenport as given a spectrum which is Davenport spectrum it says, that omega s omega by del u 10 square is actually equal 4 theta square by 1 plus theta square 4 by 3. Harries also given also spectrum it says; omega S u omega by del u 10 square is 4 theta by 2 plus theta square 5 by 6.

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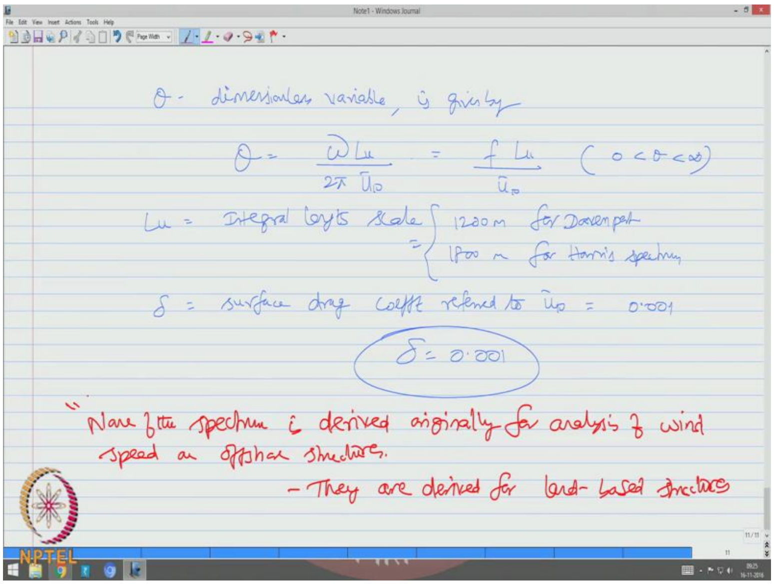

Whereas, theta is a dimensionless variable which is given by theta is equal to omega L u by 2 pi u bar 10. Which otherwise 2 pi wave omega you know it is actually f which is L u by u bar 10, where 0 less than theta less than infinity. In this case L u is called integral length scale which is actually 1200 meters for Davenport spectrum, and it is 1800 meters for Harries spectrum. Delta is called the surface drag coefficient referred at u 10, usually this value is taken as 0.001, so del is usually 0.001.

One fundamental complexity what we have in all these spectra design and recommended for offshore structures is that- none of the above spectrum is derived originally for analysis of wind speed on offshore structures. Then one may ask me a question, they are derived for what kind of structures. They are derived for land base structures. So, this can be seen as one of the important complexities which may arrives in accurate estimates of wind forces on offshore structures.

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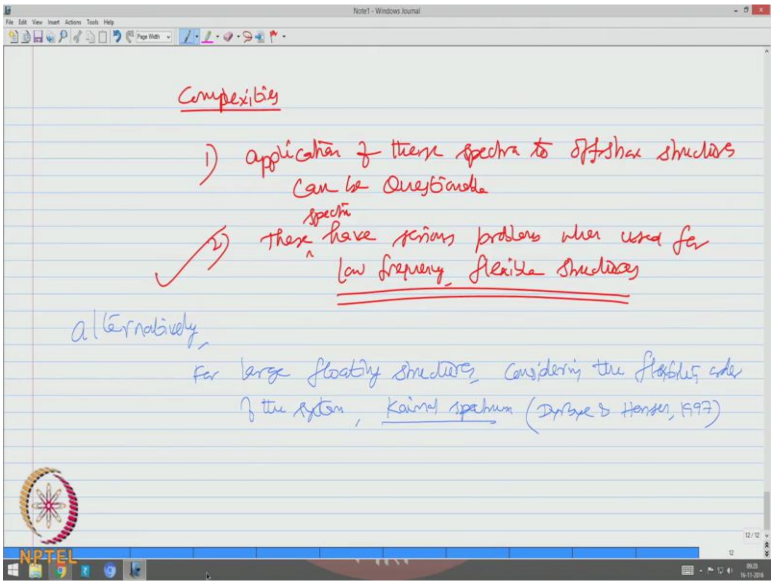

So this can be lead to further complexities, what are those complexities: application of these spectra to offshore structures can be questionable, that is the first thing we have. The second issue we have is something structurally related, these spectra have serious problems when used for low frequency flexible structures. This is the catch, because we are discussing about hybrid structures where there are two set of frequencies; one is extremely low with a very high period, other is extremely high with a very low period. So, when you have a structure which is flexible what we say is compliant, with a low frequency dominance in it is response vibration characteristics using these spectra will (Refer Time: 23:09).

Alternatively, other researchers have given alternate spectra for computing wave wind forces on offshore structures. For large floating structures considering the flexibility order of the structural system Kaimal spectrum was proposed. So, Kaimal spectrum as recommended by Debye and Hansen in 1997 is an alternate spectrum used for large offshore structures.

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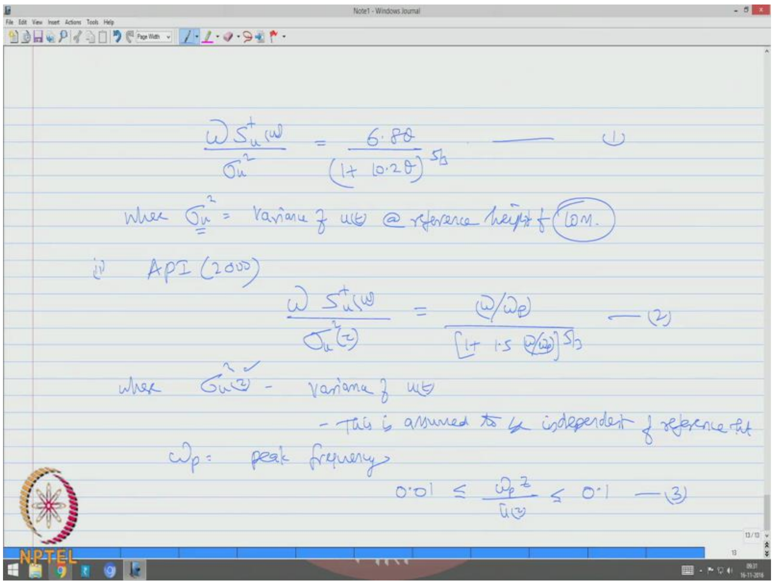

This says that omega S omega by sigma u square will be 6.8 theta by 1 plus 10.2 theta raise to the power 5 by 3; hence, call this equation number 1. Where, sigma u square is the variance of u of t at reference height of 10 meters. The second spectrum comes in line for large floating structures is given by American petroleum institute in 2000 omega S u omega, but I should say sigma u z square. This is actually a equal to omega by omega p that is the ratio 1 plus 1.5 omega by omega p the whole raise to the power 5 by 3. Where, sigma square u is a variance of the gust component. The only interesting part is this is assumed to be independent of reference side.

In the earlier case if we see this is actually measured with reference to 10 meter height, whereas in this case it is the functional z itself. Omega p is called peak frequency, which can be estimated by the relationship 0.01 less than or equal to omega p z by u bar z less than 0.1.

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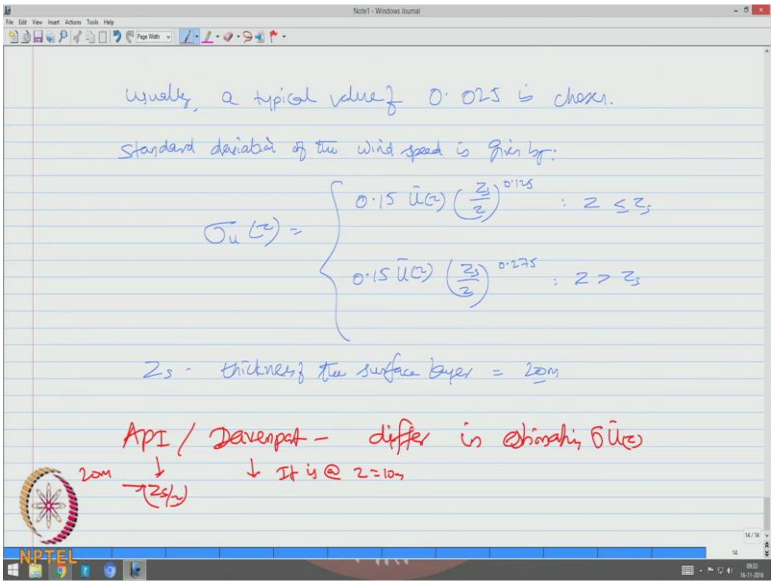

Usually a typical value of 0.025 is chosen for the design. In that case standard deviation of the wind speed is given by actually equal to 0.15 u bar z z s by z to the power 0.125 for z less than z s. Otherwise, this is equal to 0.15 u bar z z s by z to the power 0.275 for z greater than z s. Where, z s is called thickness of the surface layer usually taken as 20 meters.

So, one can be clearly see here API and Davenport fundamentally differ by estimating or fundamental differ in estimating u bar z of sigma. So, Davenport says it is at z equal to 10 meter, whereas API says this ratio of z s by z where z s is 20 meter and z s the height where you are considered your calculation.

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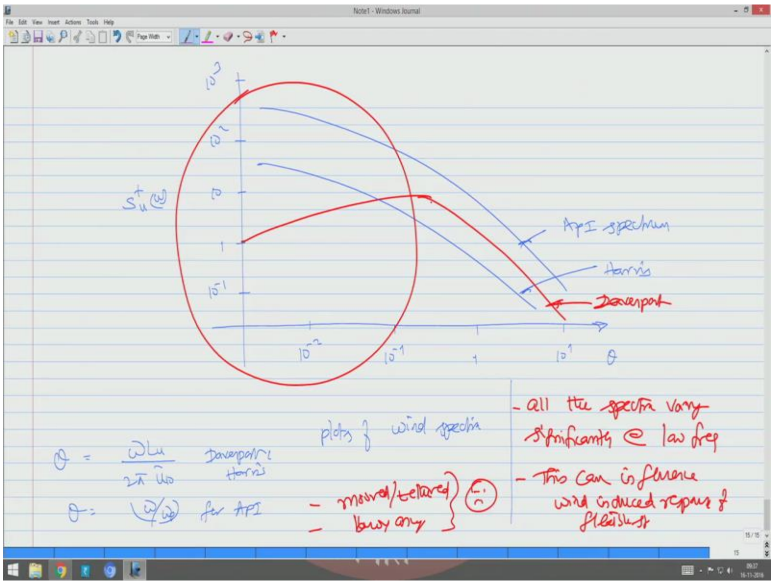

So typically if I try to plot these spectra, let say 10 power minus 2 10 power minus 1 let say 1 and 10 power 1, I am trying to plot theta. Whereas, in this case let say 10 power minus 1 let say 1 let say 10 10 square that is it 10 cube. This I am plotting S u omega versus theta, this is the plot or I should say plots of wind spectra. Typically APIs spectrum starts from here and goes this way this may APIs spectrum. Whereas, the Harries spectrum starts from here and follows similarly the same path as API, this can be Harries spectrum.

But Davenport has a small variation; this starts from 1 takes the peaks somewhere here in between and then it goes it in between this two, so I should say this is Davenport. Please note in the above theta actually is omega L u by 2 pi of u bar 10 for Davenport and Harries, whereas this is equal to omega by omega p for API. Because API, actually it does not calculate the variance based upon u 10, but depends upon surface wave thickness which we saw in the last slide.

So, there is a very important observation we can make by looking at this spectra. All the three spectra or all the spectra vary significantly at low frequency. We can see when the frequency is lower a variation is significant. So, this can influence wind induced response of flexible structures essentially when the structure is moved or tethered which derives strength from buoyancy, those structures can be very critically affected.

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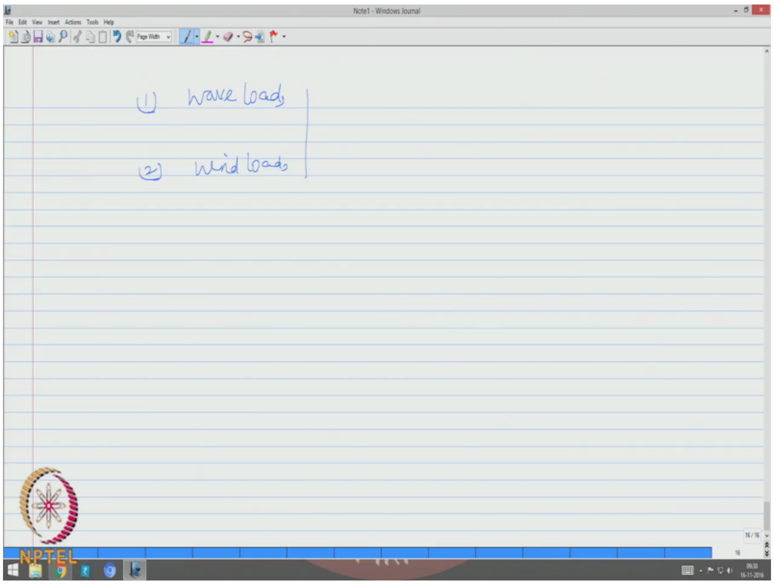

So friends, we have discussed conventional loads, like wave loads, we have also discussed wind loads; we have also said they are randomly varying, but they can be idealized as a Gaussian process. Therefore, one can make some significations to convert them to equivalent quasi static loads as in the case of wind loads by using aerodynamic admittance function. And one can estimate more or less the influence of the gust factor or the gust component on the overall response of the structural system by adding it indirectly which includes the spatial and the time variation in the loading to get the response or platform under wind loads.

However, in the last lecture we saw the complexity that arise because of the wave loads which essentially come from three factors, the spatial variation, the time, and the wave directionality, essentially the wave height or the amplitude the period and the wave direction. So, one is interest to know what is that phase leg or angle of attack of the wave where the drag and inertia components both or maximum at any given time. We also showed you how interestingly the phase leg can be used to cancel to the forces on the offshore members which depend upon to decide what should be the spacing of the legs of the members; essentially the form dominated geometric design of complaint.