Offshore structures under special loads including Fire resistance
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Lecture – 16
Uncertainties

Friends, welcome to the 16th lecture under the NPTEL course on offshore structures and the special loads. In this lecture we are going to talk about some uncertainties involved in the analysis and design very briefly.

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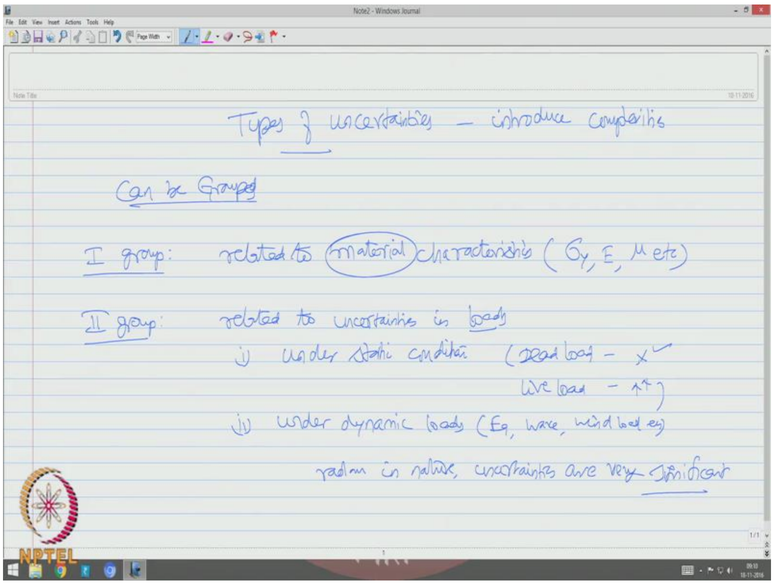

There are different types of uncertainties which actually introduce complexities in analysis and design, these uncertainties can be grouped let us say the first level or the first group these are uncertainties which are related to material characteristics like (Refer Time: 01:28) youngs modulus, poisons ratio etcetera. The second group of uncertainties are related to uncertainties in loads; one is material other is loads. This can be further sub divided in 2 routes, let us say under static conditions where we say for example, dead load, it may not have any major uncertainty so it can be omitted. Live load it may have large extent of uncertainty depending upon the designer choice and so on.

The second sub category under the second group could be under dynamic loads, under dynamic loads such as the earthquake load, wave load, wind loads etcetera, which are random in nature uncertainties are very high or I should say very significant.

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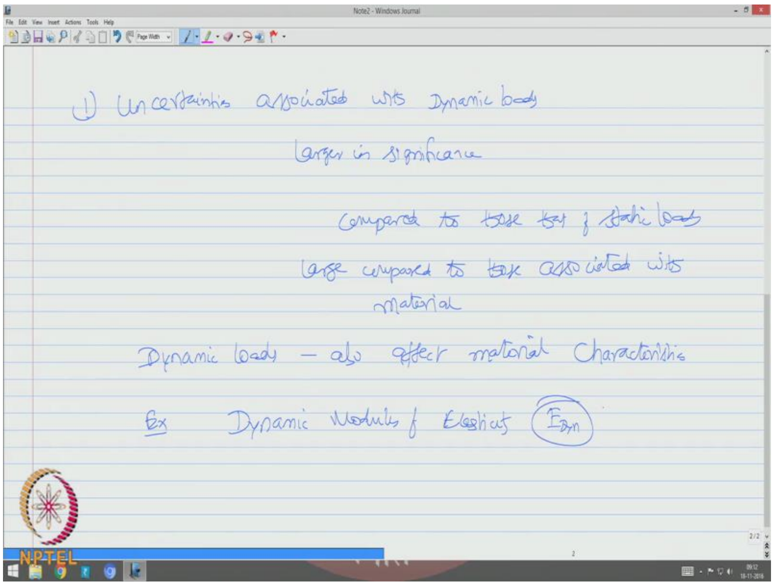

Now, uncertainties associated with dynamic loads or generally larger in significance compared to those that of static loads that is a first observation, they are also larger compared to those associated with material; interestingly dynamic loads also affect material characteristics that is a very interesting statement, let us say for example, will talk about dynamic modulus of elasticity E dynamic.

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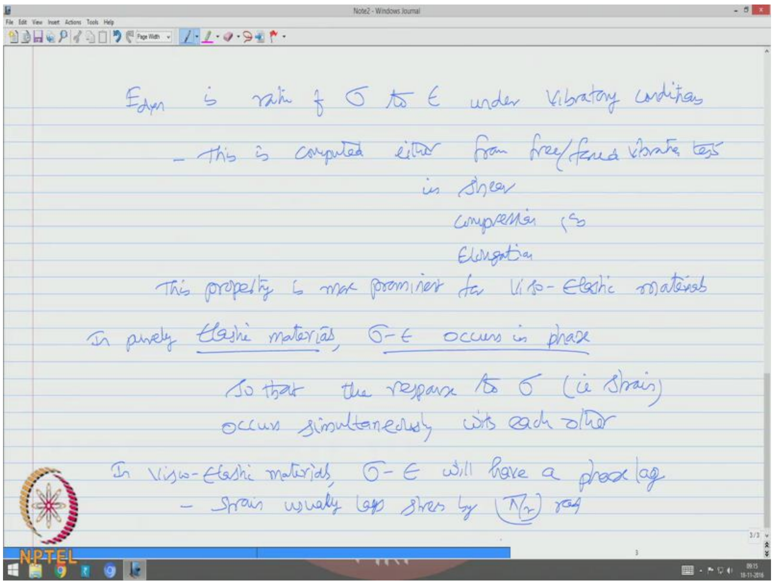

E dynamic is ratio of stress to strain under vibrations or vibratory conditions. How they are computed? This is computed either from free forced vibration test in shear compression or elongation. Generally this property is more prominent for Visco-elastic material. In purely elastic materials, stress and strain occurs in phase, so that the response to stress that is strain occurs simultaneously with each other, but that is true only the material is purely elastic, but in Visco-elastic material, stress and strain will actually have a phase lag, strain usually lags stress by pi by 2 radiance; so phi which is the phase lag is actually pi by 2.

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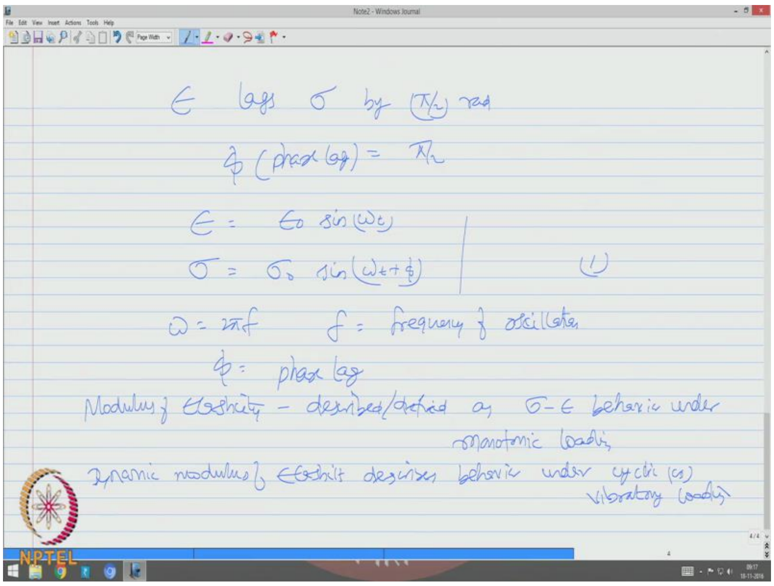

So, strain is E0 sin omega t, where as stress is sin 0 sin omega t plus pi and we know omega is 2 pi f, where f is a frequency of oscillation and phi is called as phase lag. Generally modulus of elasticity is described or let say defined as stress strain behavior under monotonic loading, where as dynamic modulus of elasticity describes behavior under cyclic or vibratory loading.

So, friends in a case where the load process is highly dynamic in natural random, which has got lot of uncertainties, we should have a thorough idea about the dynamic modulus of elasticity of the material we should used in the design.

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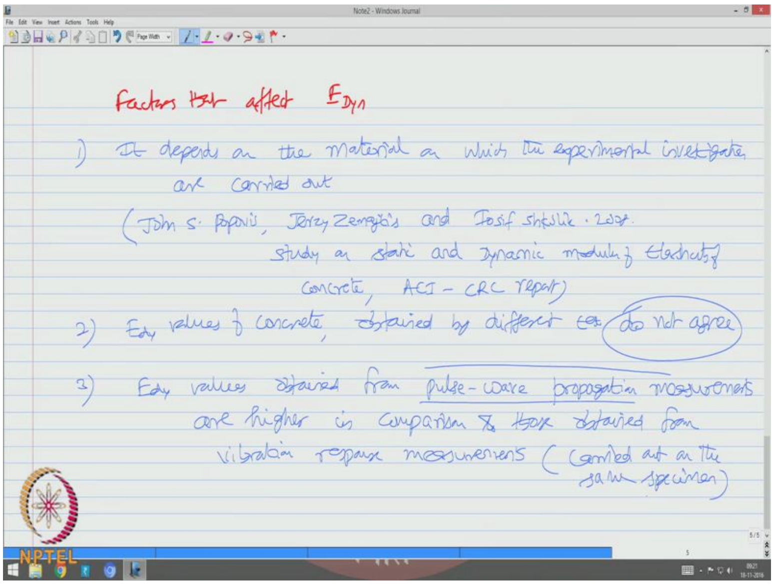

Let us ask a question, what are the factors that affect dynamic modulus of elasticity? One, it actually depends on the material on which the experiment or experimental investigations are carried out, as very clearly stated by John. S. Popovics, Jerzy Zemajtis and Iosif Shkolniku. 2008 study on static and dynamic modulus of elasticity of concrete, which is an ACI - CRC report.

The second factor is that the dynamic modulus of elasticity values of concrete, obtained by different tests do not agree there is a wide variation. The dynamic modulus of elasticity values obtained from pulse-wave propagation measurements are higher in comparison to those obtained from vibration response measurements. In fact, dynamic modulus value also depends on the type of experiment you conduct, when even carry out on the same specimen, the test methods give you different results.

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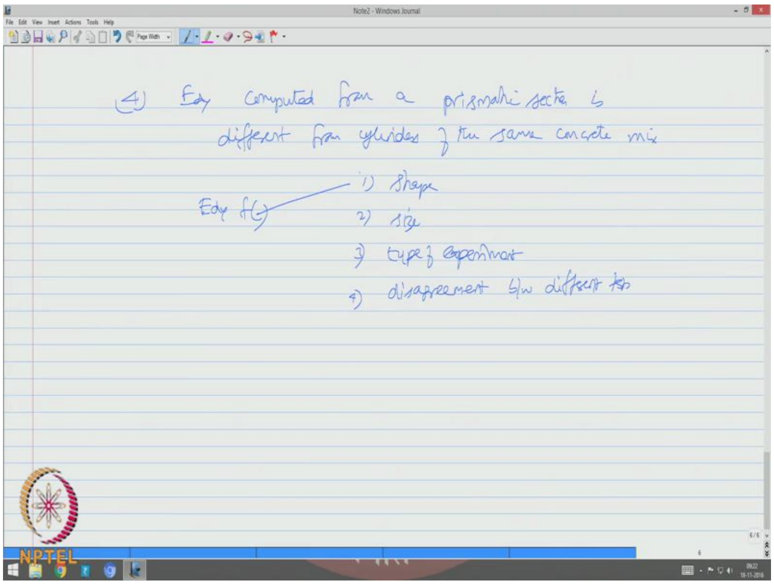

The forth factor dynamic modulus of elasticity computed from a prismatic section is different from cylinders of the same concrete mix. So, E dy is function of 1 shape, 2 size, 3 type of experiment and forth a strong disagreement between different test. So, there is a wide variation. Let us see one by one by different test how E d can be calculated.

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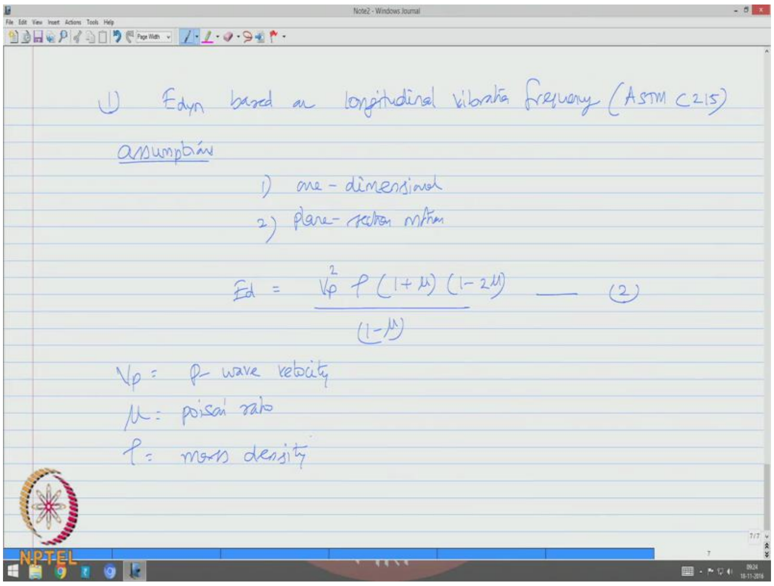

Let us say E dyn based on longitudinal vibration frequency. Please understand dynamic modulus depends on very strongly the type of (Refer Time: 15:06) you perform. This is as per ASTM C215, it has got some basic assumptions, the test is performed on onedimensional specimen; the test shows plane section motion only no bending. So, E dynamic is given by V p square rho, 1 plus mu, 1 minus 2 mu by 1 minus mu. I call this equation number 2, where V p is called the P wave velocity, mu is called poisons ratio and rho is the mass density.

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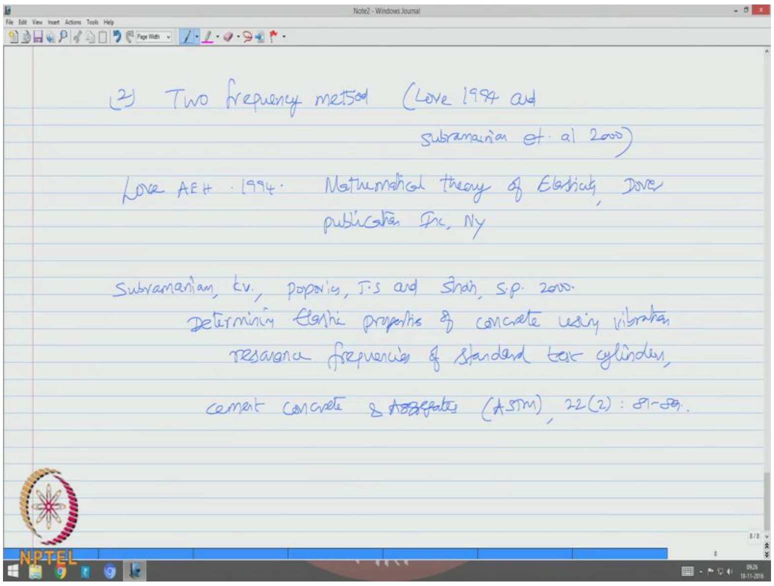

There is another method by which can compute dynamic modulus of elasticity; this is two frequency methods, which is proposed by Love 1994 and Subramanian et al 2000; so Love AEH 1994, Mathematical theory of Elasticity, Dove publication, New York. Subramanian K V, Popovics J.S and S.P shah 2000, determines elastic properties of concrete using vibration resonance frequencies of standard test cylinders, cement concrete and aggregates ASTM, 22 2: 81-89.

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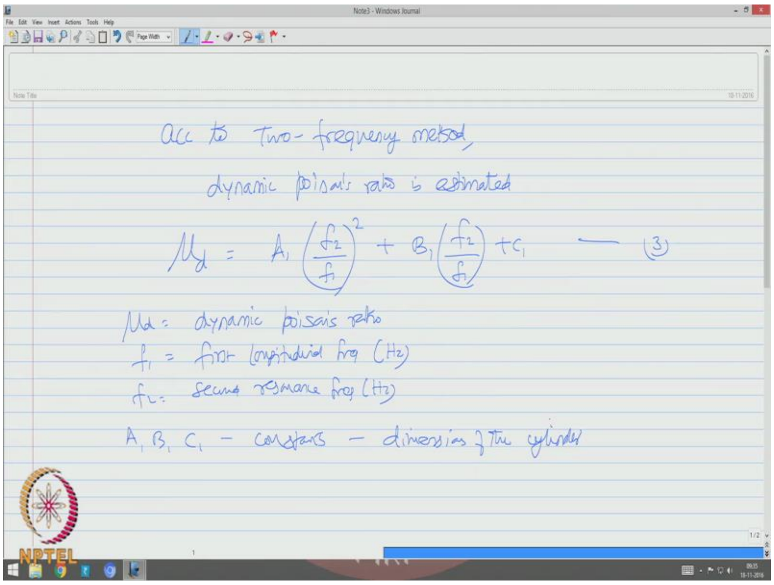

So, according to two-frequency method, dynamic poisons ratio is estimated, which is given by A1, f 2 by f 1 square plus B1, f 2 by f 1 plus C 1 where mu d is called dynamic poisons ratio; f 1 is the first longitudinal frequency in hertz, f 2 is the second resonance frequency in hertz A 1, B 1 and C 1 are actually constants, which depends upon the dimensions of the cylinder.

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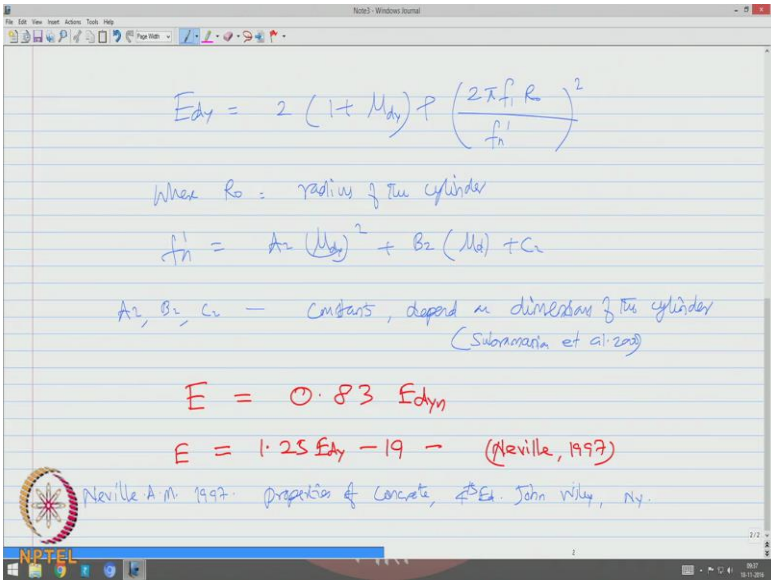

Once I know the dynamic poisons ratio, I can find dynamic modulus of elasticity as twice 1 plus mu dynamic rho, 2 pi f 1 R 0 by f n dash square where, R 0 is the radius of the cylinder and f n dash is given by A 2 mu dynamic square, plus B 2 mu dynamic, plus C 2 where A 2, B 2, C 2 are constants and they depend on dimensions of the cylinder as given by Subramanian et al in 2000. Now interestingly let us have a relationship between the conventional Youngs modulus and the dynamic Youngs modulus which is connected by this relationship or 1.25 E dynamic minus 19 is E as given by Neville 1997; so Neville A.M 1997 properties of concrete, 4th edition John Wiley, Newyork.

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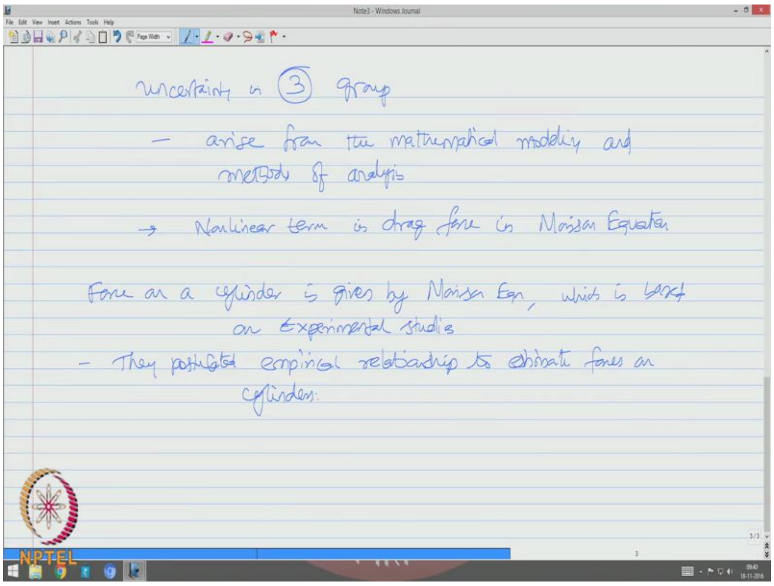

Having said this, let us now understand uncertainty in third group. Third group essentially arise from the mathematical modeling and methods of analysis. So, interestingly let us talk about the non-linearity or non-linear term in drag force in Morison equation. Morison equation is used to determine the hydrodynamic force on offshore members, force on a cylinder is given by Morison equation which is based on experimental studies, they actually postulated an empirical relationship to estimate forces on cylinders given by Morison J.R O' Brain, M.P, Johnson, J.W and Schaaf, S.A in 1950.

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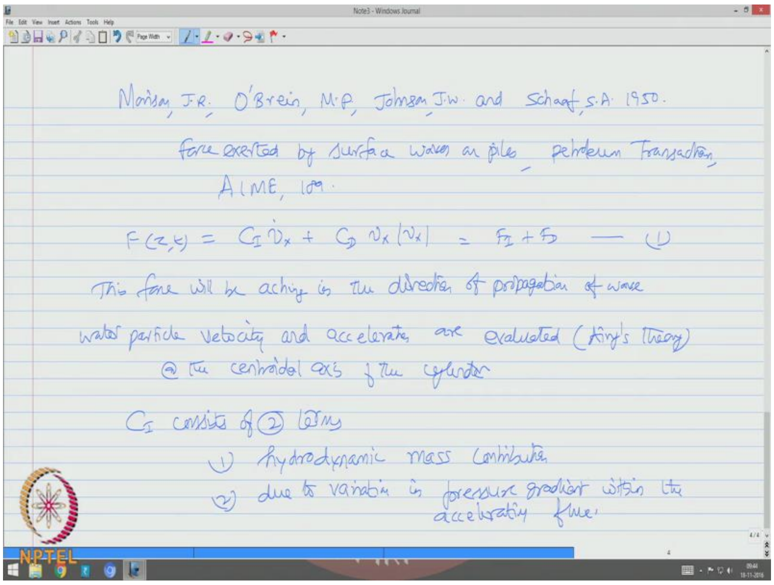

Force exerted by surface waves on pipes petroleum transactions AIME 189. So, according to them F of z t is C I, V dot x plus C D, V x V x which is inertia term plus (Refer Time: 26:52) term. This force will be acting in the direction of propagation of wave that is in the forward direction.

Water particle velocity and acceleration are evaluated may be for example, using Airy's theory at the censorial axis of the cylinder. C I consist of 2 terms; one is the hydrodynamic mass contribution and the other term is arising due to variation in pressure gradient between of let us say within the accelerating fluid. The C I has got 2 terms CA which is C m rho pi D square by 4, plus rho a which can be said.

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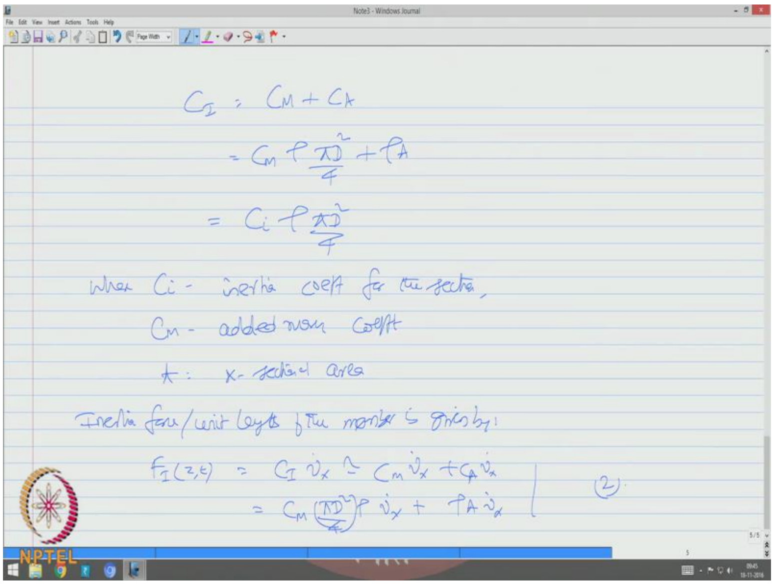

As C i rho pi D square by 4 where, C i is the inertia coefficient for the section, C m is the added mass coefficient, A is the cross sectional area therefore, inertia force per unit length of the member is given by F I, again a specific location z t is C I V x dot is approximately C m V x dot, plus CA V x dot, which can be C m pi D square by 4 rho V x dot, plus rho A V x dot - let us call this as equation number 2.

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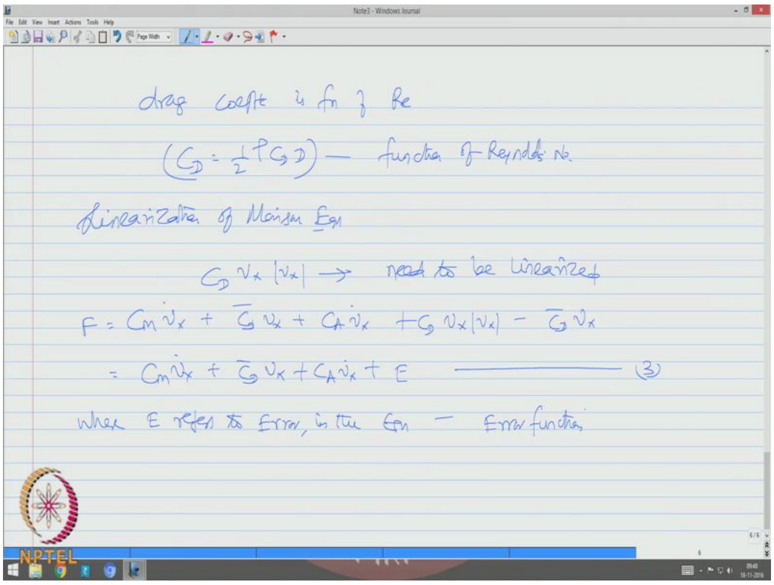

We also know that the drag coefficient is function of Reynolds number. So, C D half rho C D dia is actually also a function of Reynolds number.

When you apply this in Morison equation, it gets squared off. So, let us talk about linearization of the Morison equation itself because Morison equation as a term C D V x V x. So, this need to be linearize, let say F is C m V x dot, plus C D bar V x, plus CA V x dot, plus C D V x minus CD V x, which can be C m V x dot plus C D bar V x, plus C A V x dot plus E where E refers to error in the equation which is nothing but a specific error function.

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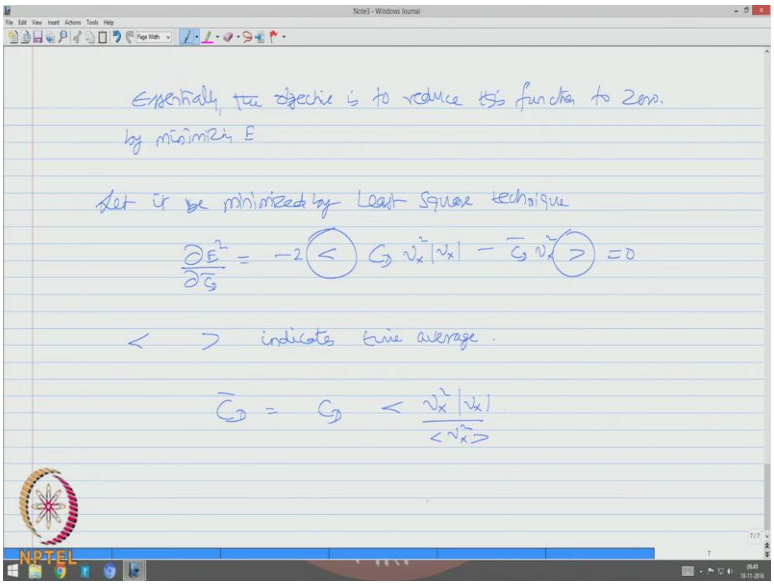

So, essentially the objective is to reduce this function to zero by minimizing E.

Let it be minimize by least square technique E square by dou C D should be minus 2 of less than let say C D V x V x minus, C D V x square. So, the symbol indicates time average, C D bar is C D V x square V x by V x square.

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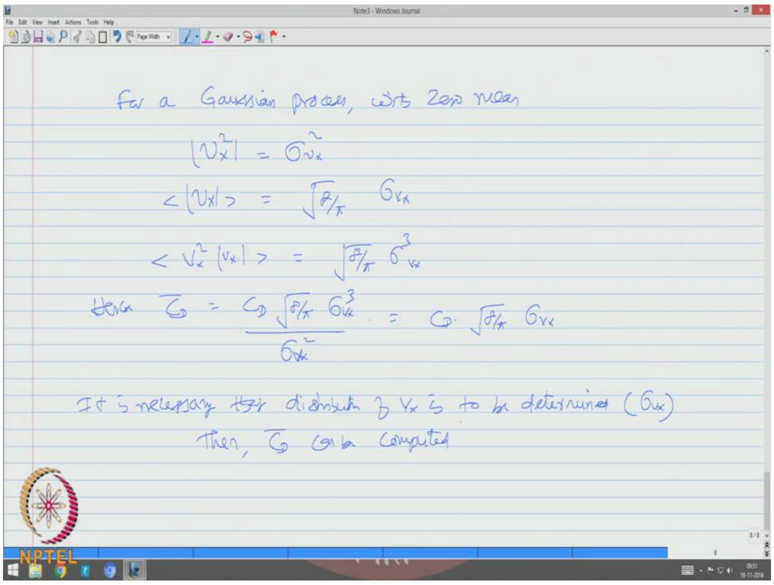

Hence for a Gaussian process is zero mean V x square, is sigma V x square and V x time average will be root 8 by pi sigma V x and time average of V x square V x can be root 8 by pi sigma V x cube. Hence C D bar is C D root 8 by pi, sigma V x cube by sigma V x square which can be C D root 8 by pi sigma V x. So, it is important and necessary that distribution of V x is to be determined because we need sigma V x, then only C D bar can be computed.

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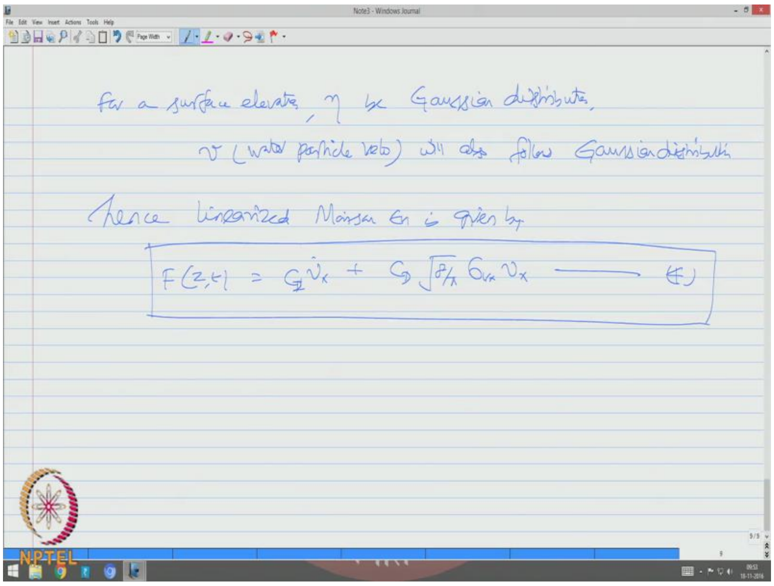

For surface elevation eta be a Gaussian distribution, V that is water particle velocity will also follow Gaussian distribution. Hence linearized Morison equation is given by F z of t, C i V x dot, plus C D root 8 by pi sigma V x, V x equation 4. So, that is the linearized term what we have, which is again an approximation of one important drag non-linearity coming down from the equation.

So, friends in this lecture we discussed about 2 levels of different uncertainties, one from the load side which is the drag non-linear term in the Morison equation. The second one is the dynamic modulus of elasticity, which is actually the relationship between stress and strain under vibratory conditions. So, we have seen how we can estimate them more appropriately by the given empirical relationship of different researchers in this lecture.

Thank you very much.