Computer Methods of Analysis of Offshore Structures
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Module - 02
Lecture - 17
Damping Estimate - 2 (Part - 2)

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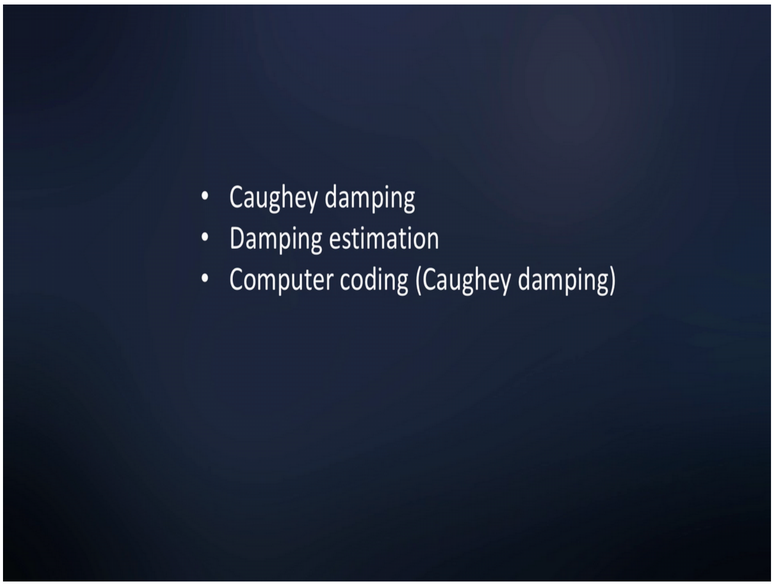

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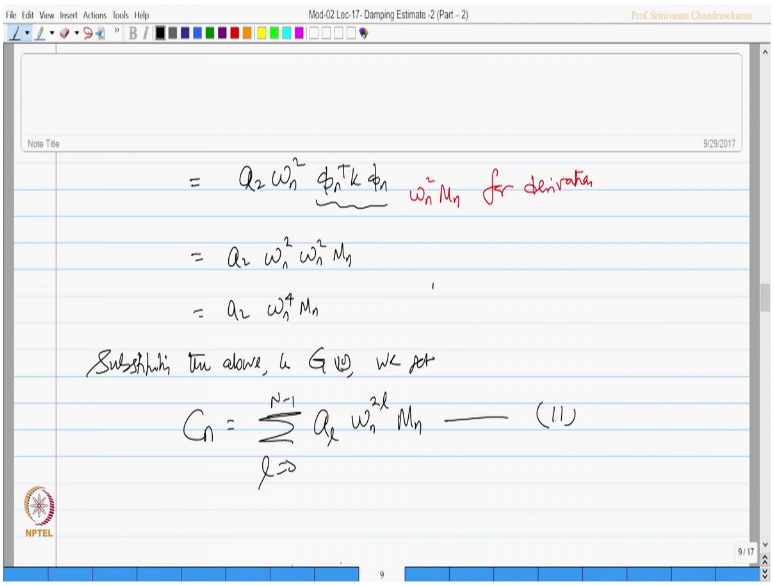

Which can be said as a 2 omega n square phi n transpose k phi n can be actually said as omega n square m n by standard derivation; hence, a 2 omega n square omega n square m n which is a 2 omega n 4 m n.

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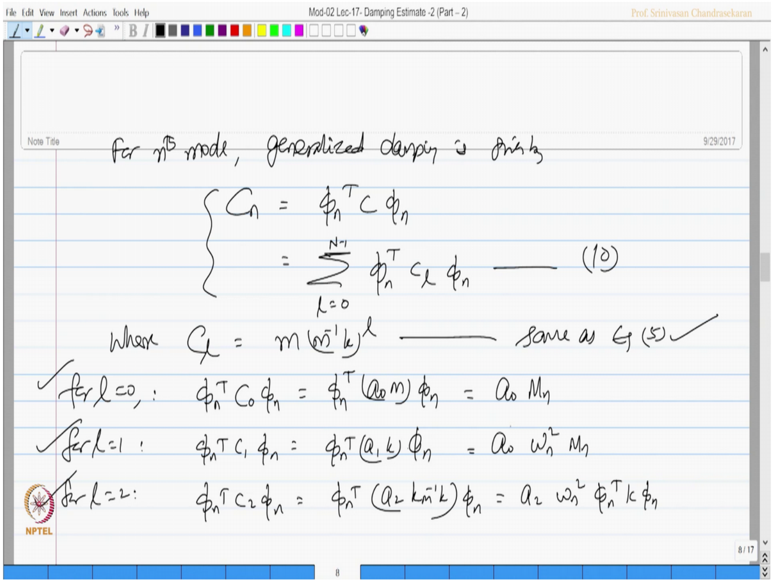

So, substituting for l equal to 0 1 and 2 in equation 10: substituting the above in equation 10 we get C n will be summation of l equal 0, n minus 1. We can see the equation 10 C n l equal to 0 n minus 1 phi n. So, we have worked out phi n transpose c 0 c 1 c 2 that will be the summation, right. So, it is going to be a, a l omega n 2 l of m n equation 11.

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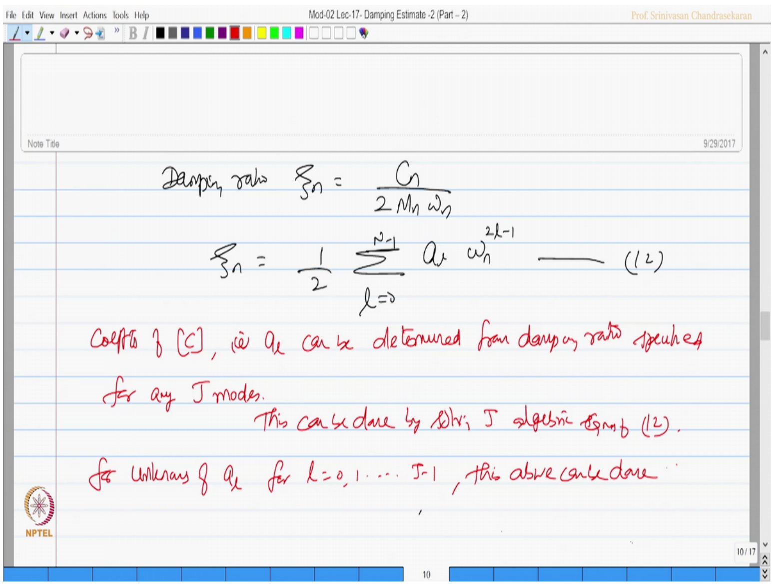

Now damping ratio zeta n is given by C n by 2 n omega n. So, zeta n is now going to be half of summation of l equal to 0 to N minus 1, a l omega n 2 l minus 1 equation 12. So, it is interesting to know that the coefficients of damping matrix that is a l can be determined from various damping ratios specify for any J modes.

This can be done by solving J algebraic equations of equation 12. So, for unknowns of a l for l equal 0 1 etcetera till J minus 1 this can be done the above can be done I do not think there is any confusion in this.

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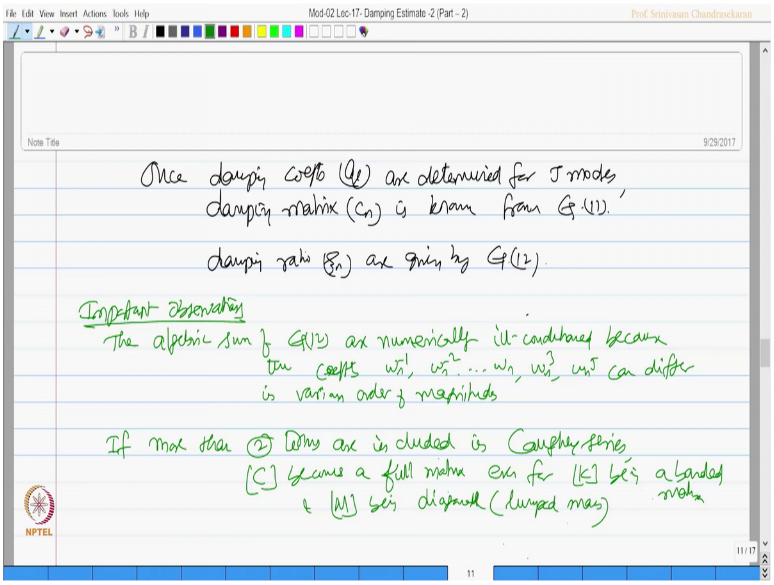

Once the damping coefficients a l are determined for J modes, then the damping matrix C n is known from equation 11. And damping ratios zeta n are given by equation 12; there are some important observations of Caughey series, the algebraic sum of the equation that is equation 12, algebraic sum of equation 12 are numerically ill conditioned because the coefficients omega n minus 1 omega n minus 2 etcetera omega n omega n three omega n 5 can defer in various order of n magnitudes.

Now, how to address this issue? If more than 2 terms are included in Caughey series, C becomes a full matrix even for K being a banded matrix and m being diagonal because masses dumped.

So, what is the consequence of this?

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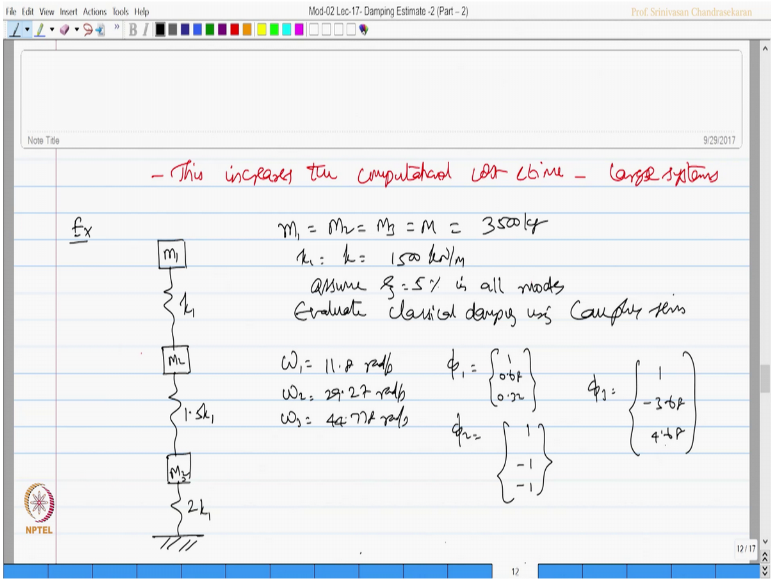

The consequence is this increases the computational cost and time where then matrix now becomes a full matrix, especially when applied to large systems.

Let us take an example problem the same case what we did, let say this is m 1 m 2 m 3; m 1 m 2 and m three are m let us say it is 2500 kg. This is k 1, this is 1.5 k 1, this is 2; k 1 and k 1 is simply k which is 1500 kilo Newton per meter and let us say assume zeta 5 percent in all modes. So, using Caughey series let us evaluate. So, evaluate classical damping using Caughey series, that is the question asked.

We all know that omega 1 for this problem is 11.8 radians per second, omega 2 is 29.27 and omega 3 is 44.778 and the corresponding mode shapes also were known to us phi 1 is 1.68 and 0.32 phi 2 is 1 minus 1 and minus 1, and phi 3 is1 minus 3.68 and plus 4.68 that is we already know.

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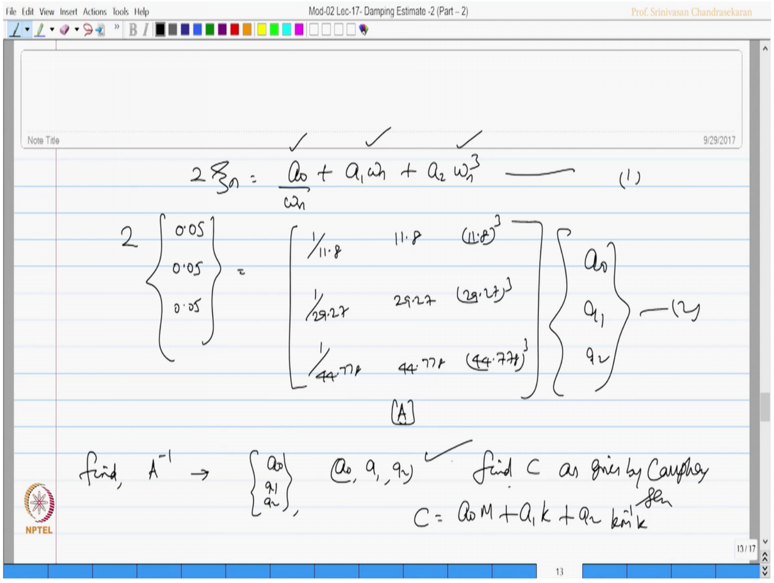

So, we know that 2 zeta n is equal to a 0 by omega n plus a 1 omega n, plus a 2 omega n cube this is actually the value what we have from this equation ok.

So, 2 zeta n is we are taking three series 0 1 and 2; so a 0 a 1and a 2. So, if it is 0, l is 0 this becomes one by omega n that is the term what we are getting here similarly if this is one. So, zeta 1 a 1 this becomes omega 1 that is what I getting here. The second term and similarly if this is 2; so 1 by 2 a 2 and this is going to be omega n cube that is what we are getting here. So, 3 terms, ok.

So, very interesting to I am assuming damping ratio same in all the modes classical damping which is expressed as in matrix form 1 by 11.8 that is my omega 1, 1 by 29.27 omega 2, 1 by 44.778 then omega 1 omega 2 and omega 3, then omega 1 cube, omega 2 cube and omega 3 cube of a 0, a 1, a 2 I can convert the above equation into a matrix form as given below.

Now, I call this matrix as A find A inverse. So, that will give you the coefficient matrix a 0 a 1 and a 2 once you know a 0 a 1 and a 2, one can find C as given by Caughey series. So, which actually equal to a 0 m plus a 1 k plus a 2 of k m inverse k this can be easily solved and found.

Let us take a computer program of this.

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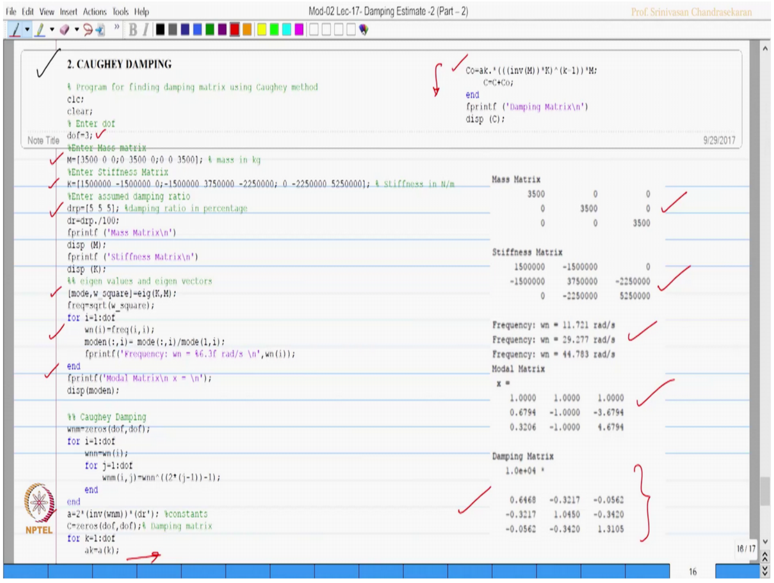

So, this is the program which is showing you the Caughey damping. We have to enter the degrees of freedom and enter the degrees of freedom give the mass matrix, give the stiffness matrix, assume damping same in all modes classical damping then of course, eigen values and eigen vectors are determined we already have the answers with us, get the modal matrix then find out the damping constants and then find the c matrix the program is actually continuing from here and to here. So, it is continuing here and then print. So, mass matrix is input stiffness frequencies corresponding mode shape and the damping matrix.

You will notice that the damping matrix obtained for all the three degrees including mode 1 2 and 3 is marginally different from what you obtain from Rayleigh damping in the last lecture.

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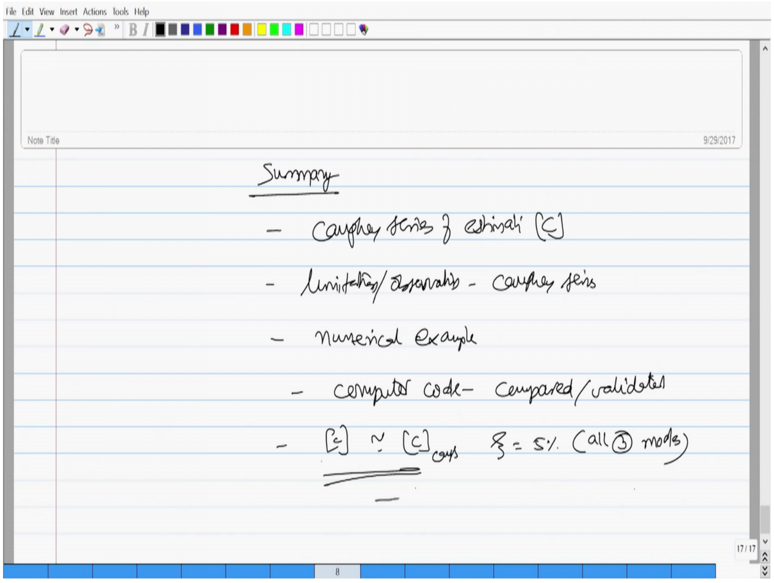

So, friends let us quick at the summary of this lecture, in this lecture we have learned the Caughey series of estimating classical damping matrix, we have also seen the limitations or observations of using the Caughey series. We have done a numerical example we have also given the computer coding to solve the problem and we compare the answers and validated.

You have also seen a damping matrix obtained by Rayleigh and damping matrix obtained by Caughey or more or less similar for zeta equals 5 percent in all 3 modes. I hope you have followed this lecture. You will attempt to solve this problem completely using a computer program, compare the answers for other application problems and let me know if you have any difficulties.

Thank you very much.