**Dynamics of Ocean Structures**
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**Module - 2**
**Lecture - 15**
# TLPs under seismic excitation

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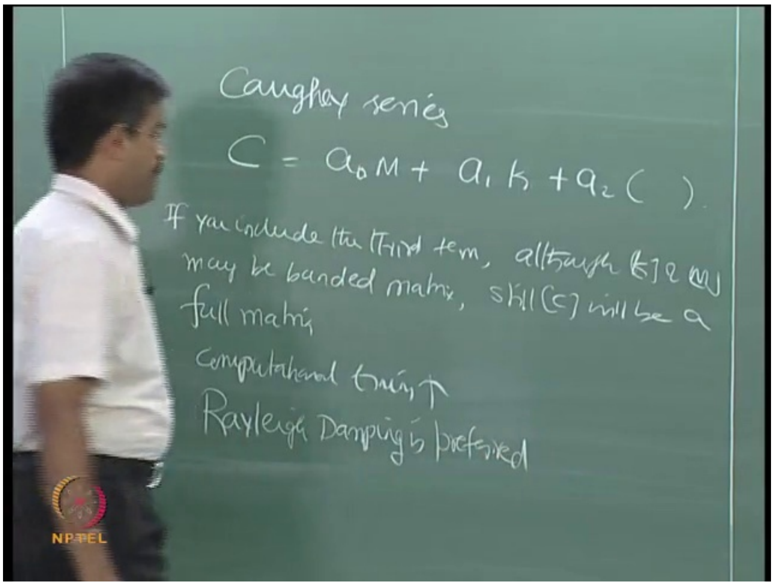


So, in the last lecture we discussed about the Caughey series which has the component of matrix plus components of k matrix plus components of combination of these, but the specific problem with the Caughey series is if you are including the third term. If you include the third term, then although k and m will be banded matrix, but still C will be a full matrix, so this includes the computational timing is this in this case, and therefore Rayleigh damping is preferred with respect of Caughey series.

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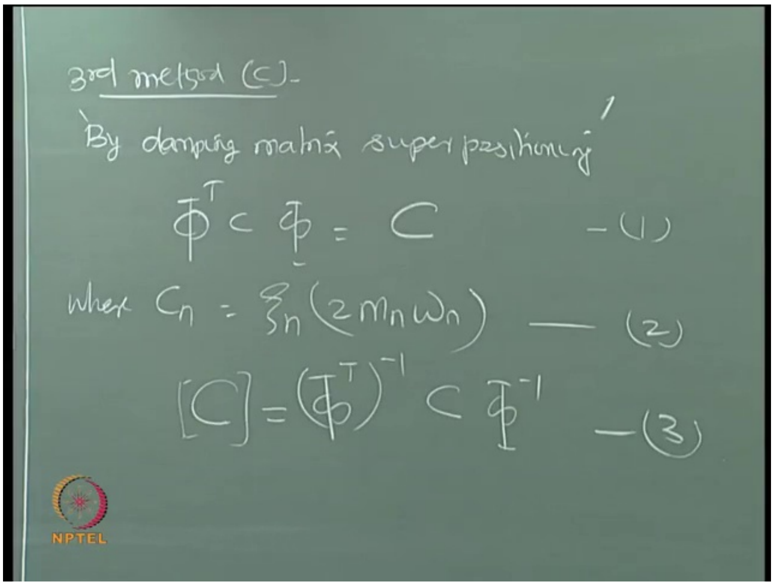


There is the third method we can do damping, this is by damping matrix super positioning, so I will do the super portioning with damping matrix and try to find the semantics of different matrix. So, we already know that phi transpose C phi is C where if you want to find C damping at the nth degree of or damping and we already know this is equal to zeta 2 m n w n for a classical damping. So, we know from this equation we can find C further as phi transpose inverse C phi inverse.

This is the mathematical multiplication, we apply pre multiplication, and post multiply there we can see this equation now equation three will give you the C matrix completely. Since there are two inverse matrix involved this is again computationally complex, so again you can simplify this further, let us see how we remove this.

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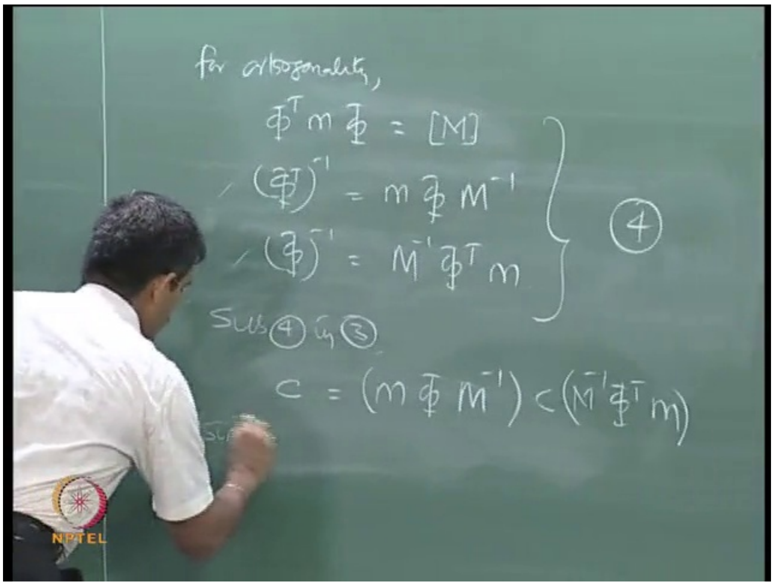


So, for orthogonality phi transpose m phi is a weighted mass matrix we already know this therefore, pre multiplying post multiplying I can find always phi transpose inverse is m phi m inverse and phi inverse has m inverse phi transpose m. So, I call this equation number four, I can pre multiply and post multiply these two, so what we wanted in equation three is phi times inverse and phi inverse which are the model matrix. For the given problem I have them here and the wonder is what is  the advantage of doing it here.

With respect to doing it here only simple because the mass matrix is diagonal phi transpose inverse to the mass matrix is pre multiplying post multiplying it the inverse is simple compared to the overall inverse of the phi transpose. I can easily do these steps here and find C, so we can substitute here in equation three so substitute four in three and substituting phi transpose and phi here and get C. If you do that, my C matrix will now become m phi of m inverse of C of m inverse phi transpose m, now m and C are diagonal matrix I can write C as like this.

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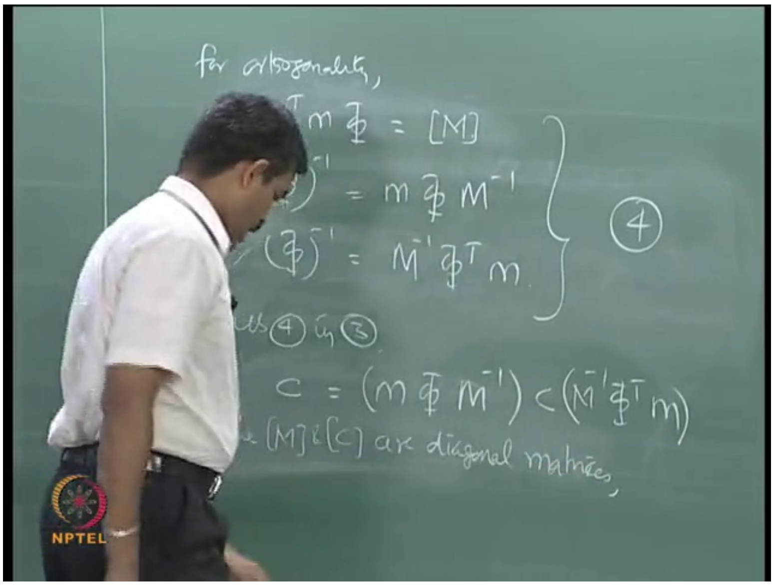


Rewriting C can be, now instead of putting that as the inverse I have n d freedom.

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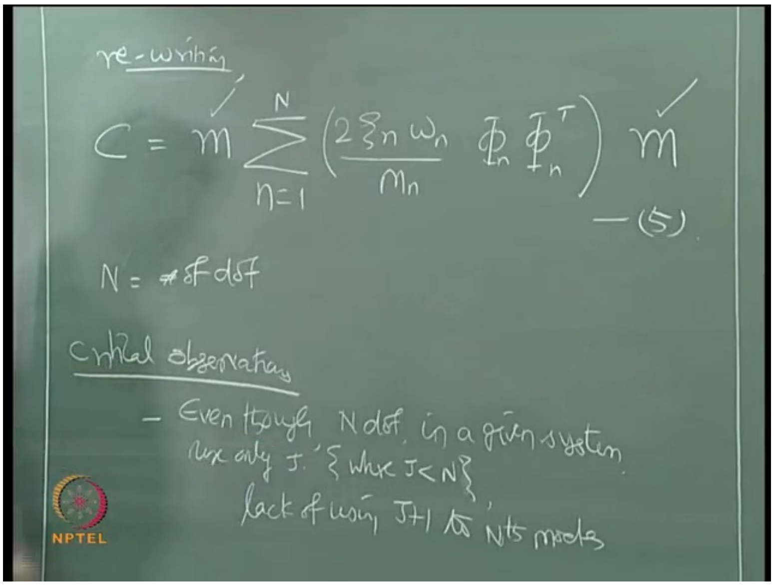


I want to do the summation of n degree m n varies from 1 to n where n is the number of degrees of freedom substituting for C as 2 zeta omega m, but m square. So, I can rewrite this as two zeta n omega n by m n of phi transpose and n degree of freedom and multiply this with m further, so the m here I have and m here I have is what I have here and here C I said zeta omega m there is m square in denominator. So, put that m n here 2 zeta n omega n by m n, so I have everything here, so I can easily C matrix for all the n th degrees this is what I call for damping super positioning for every ratio that frequency for the n th degree.

What are the critical advantages of this particular method, I call this equation number phi, so the critical observation I am not saying advantages critical observation of this method. So, even though there are n degrees of freedom In a given system use only j where j is less than n use only j degrees may be phi or 10 degree problem using only the first three degree. Even though you do that the lack of using j plus 1 th to n th modes, the remaining modes you are using only j I got n, so from j plus 1 till n you are deleting that modes.

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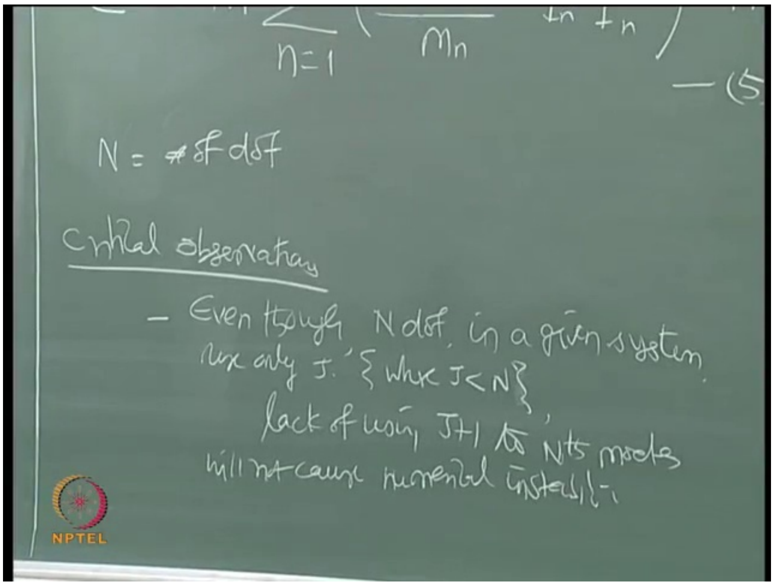


So, the lack of using these modes will not cause numerical integration that is the advantage, but there is the condition here.

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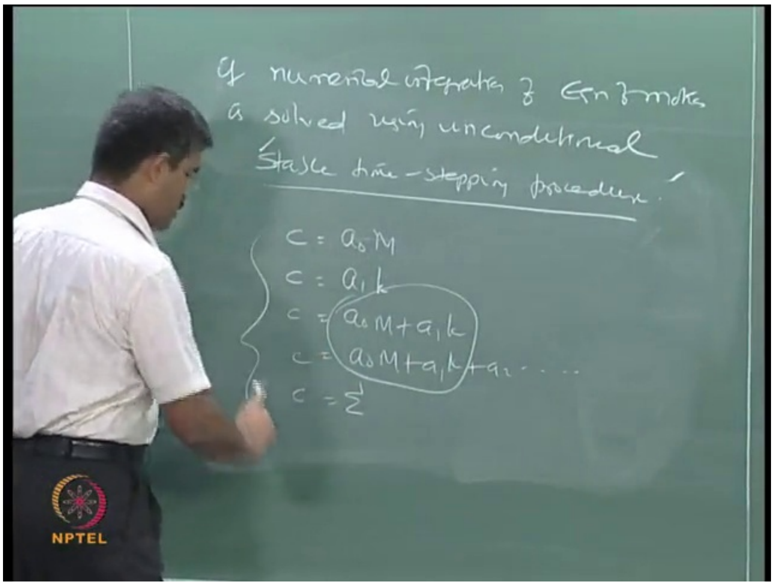


If you want to do this, then conditionally if the numerical integration of equation of motion is solved using unconditional stable time stepping procedure, so if you are using this technique and delete the higher modes it will not cost any numerical instability. So, the solution process is also advised by the literature I will give the references in the presentation here. So, let us quickly do a problem to understand how we do this application.

So, you have got three methods by which you can compute t 1 is simply or other five methods, one is simply C as ratio of m you can take C as ratio of k. You can take C as ratio of m and ratio of k you can take C as ratio of m plus ratio of k plus higher ratio of this. You can take C as summation of the model proportions, we got several methods where you can estimate C matrix, these are the part of relay both are relay this is Caughey. This is relay, this is classical or this is smaller classical damping we have different applicability, so we cannot compare of them there is no question that I will get the C matrix by employing the different techniques.

Remember, these are not different methods of finding or comparing C you will never get the C always never these are different procedure to get C. Most practically, relay damping is employed for our structures where called because the values they get is by damping or applying relay procedure is closely related to the what we get from this. That is what plus C there are references given in the literature, I will project that later in the second half of the lecture here.

So, there are references people say, let us use Rayleigh damping which is most probably used in most of the structure problems. People use Rayleigh damping. If you see intelligently, they have used model super-positioning in many papers. Usually, there are many varieties of applications and preferences given by the researchers. First, we solve the different kinds of problems before we solve the demo state of example problem on this do you have any question regarding this symmetric of damping.

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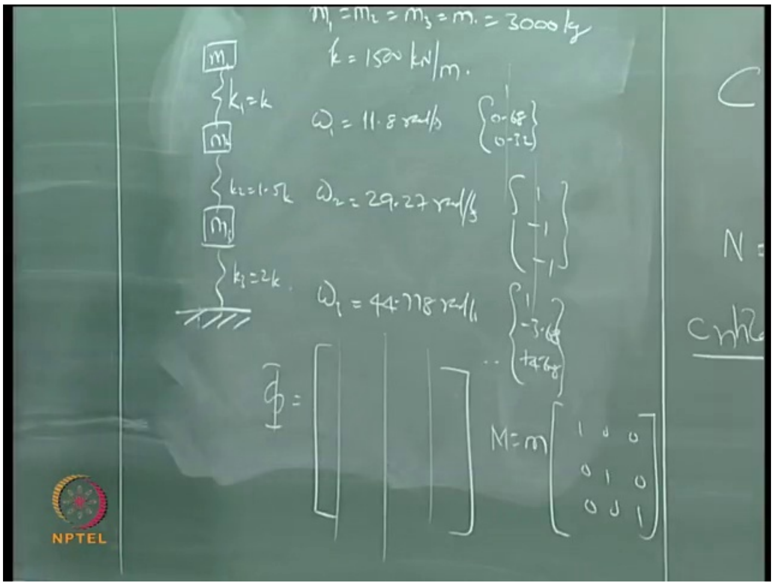


We will move this, we will take up the same problem as we are doing in the earlier examples we can compare the C matrix. So, I have the problem which is all are m and m, this is m one m two m three so m one m two m three is m this is k one k two and k three this is k this is 3000 k g and this is 1500 kilo ton. So, for this we already know omega one is 1.8 radius per sec and phi 1 was 1.68 and 1.32, omega 2 is 29.27 radius per second and phi 2 was 1 minus 1 minus 1 and omega 3 is 44.78 radius per sec and phi 3 is 1 minus 3, 0.68 minus 4.68 single crossing double crossing 0 crossing.

Second model and third model of course I need m matrix for solving this I have m, I have phi capital phi is nothing but the assemblies of these we understand this. If you want to write capital phi in this problem the first row will be the first column second is second and third will be the third I think this we understand and m a matrix for this problem. I will write it here m matrix is m of 1, 0, 0, 0 1, 0, 0, 0, 1 half diagonals are not there in this problem, so what I wanted you to do is zeta as phi percent, I will remove this equation take zeta as five percent and determine The damping matrix by super imposing the damping matrix five percent for each mode take five percent for each mode.

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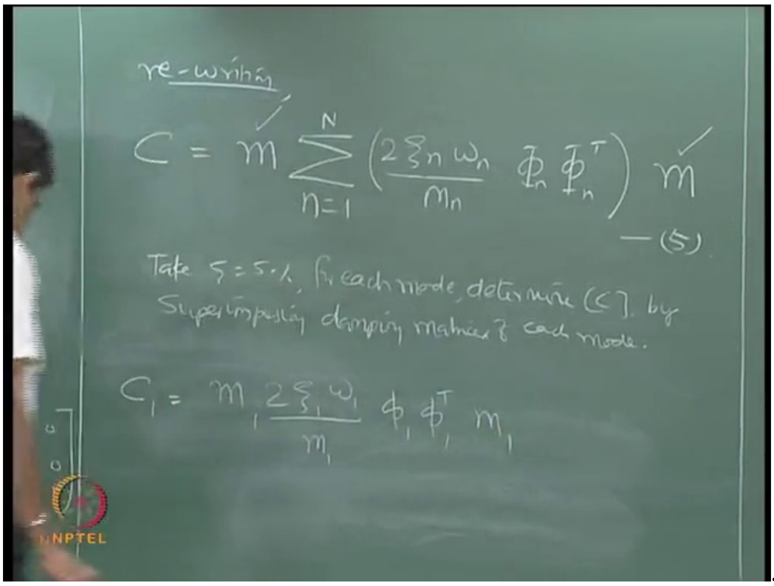


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Determine C that is the damping matrix by super imposing damping matrixes of each mode. So, let us do this problem, so let us compute C 1 first because I need to find the damping method of each mode. So, let us take C one first here n is 1, so this becomes m times of 2 zeta 1 omega 1 by m 1 of phi one, phi on transpose of m 1. So, pre multiply and post multiply of zeta 1 percent and tell me what is C quick, so just for starting with the initiation we can say like this 2 times of 0.05 of 11.8 by 1 of m phi 1 phi 1 transpose.

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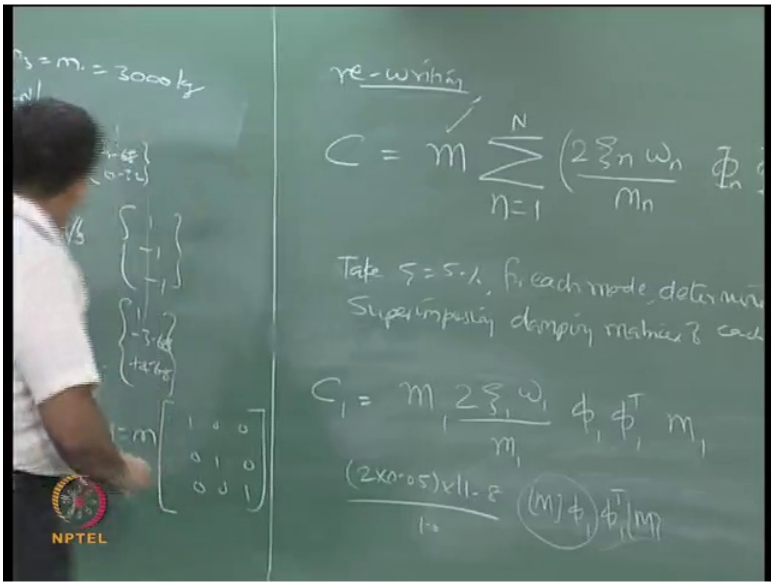


So, first pre multiply and post multiply and get me C 1, C 1 would look like this C 1 will you work it out I will give the C 1 here.

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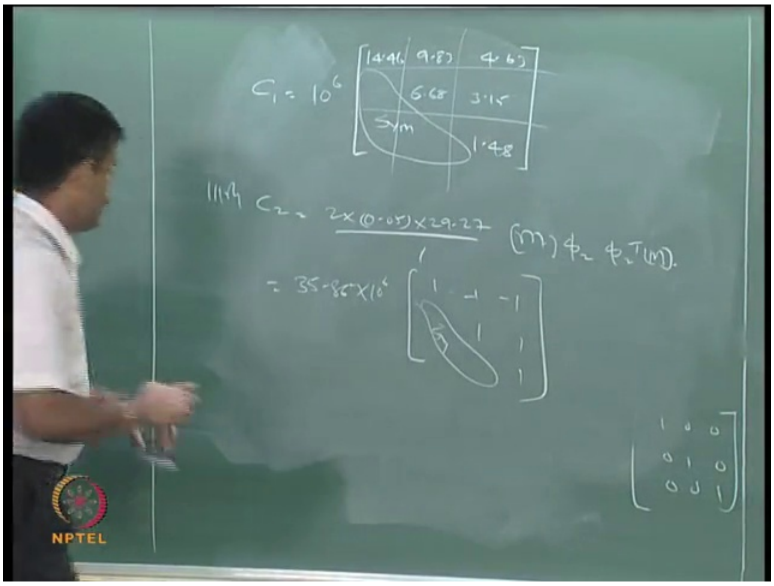


C 1 is given by 10 power 6 of 3 by 3 matrix 14.6, 0.83 and 4.63, 6.63, 3.15 and 1.48 similar this means same. So, now you want to get C 2, similarly C 2 substitute back here two into 0.05 that is what I am saying to use, I should use 5 percent in each mode that is any argument given here into 29.07 of omega m phi transpose m. So, pre multiply post multiply with phi and phi transposes and try to get C 2 and C 2 is 35.65 into 10 to the power 6 of this is 35.861 minus 1 minus 1 1 1 and 1. Similarly, what you want to the C matrix is the summation of this for all modes, we can also do for C 3 just say for an example I have C 1 and C 2, I would not take only two modes as we already said. You can to need not take n modes, you can always put j modes and j plus n th modes will not cause any numerical incident to the problem.

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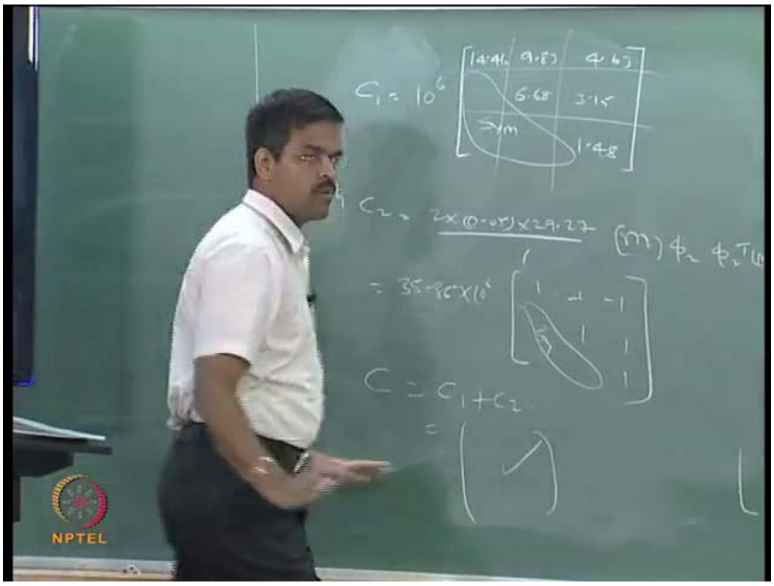


So, any time you can trunk it modes you want so let us say I take C 1 and C 2 C matrix is the sum of C 1 and C 2 I get something this is how we obtained C matrix for this problem by this method any doubt here any doubt here. If C 3 is not present, what does it mean is the third mode and start contribute for damping that is the meaning third mode is contributing for damping. So, any doubt you have, to find the model participation factor and note, that will come in the third module; what he is asking is an intelligent question; how do we know trunked by number of modes practically?

Ideally speaking, you should take all n number of modes in our problem we need six degrees of we need to take 6, but you have got infinity way let us say multi storing building etc very high large side dynamic problem. How do you truncate the modes truncation of mode depends on what is the model participation factor coming on to the prevail talk about the third model then you will get an idea where to start.

So, let us believe that ideally speaking I can include all the models here Caughey had this problem when we talked about C at zeta it is skipping on omega 135 they are skipping in between certain frequencies is it not, but here you may not have to skip. You can continuously add the entire continuous ratio in all the modes and find the C matrix, so that is the can say different way of C matrix compared to Caughey. Of course we understand Caughey series improve mental under damping relay dumping is the reference what we have here. So, this is being practiced commonly and many of the international courses advise to see based on this there are limitations whether the modes are whether the frequencies are widely placed closely placed, there are many arguments.

Let us speak about all the modules if you got omega 1 omega 2 very close to each other how do you handle them if you have got all omegas successively for different points 0, 1 radius per second how do you handle them. So, we will talk about, now we understand that mathematically you can compute C n degrees of it anything you can you can trunk it this just says when you trunk it at j j plus 1 th onwards there will be no facility cause to the problem. That is what the literature says; this is an example application for the problem using this technique. Now, we have all the same problem using three methods you can also solve using fourth and fifth method of C 0 I mean a 0 m and k because we have the m and k always find all the three matrixes.

Then we could compare and see how they are happening- one common in all of them is C will always remain as symmetric matrix in this example not necessary matrix it depends upon the k and n matrixes. So, in this example all the symmetric matrix all the square all are full size matrix it is not banded computation is some are expensive some are difficult. For example, this problem is computationally expensive because you have got to pre multiply and post multiply it for phi and do it compared to Rayleigh, Rayleigh was simple because you simply know a 1, 0 is simply multiply with m and k and get C. So, that was faster, so there are advantages and disadvantages, how they compared practically problems etcetera.

These are all given in literature, we are not exposing much more, this voluntarily how damping matrix is estimated for hydro dynamic involvement in structure etc. Damping comprises two structures we have seen one is from the material degradation another one is from the geometric degradation lots of differences lots of compensation of energy loss which is again the material degradation is also damping source in general. In addition in hydro dynamic we got radiation dumping etc we discussed this in previous lectures in the same model any question.

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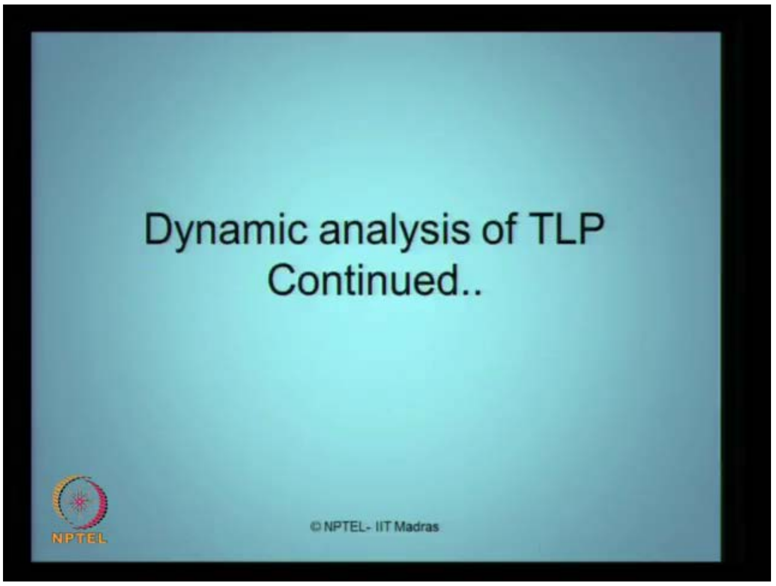


Move on to the computation here, so what we stopped was the TLP problem where we had a TLP where derived the mass matrix we derived the matrix. Now, we can derive the damping matrix I will show that.

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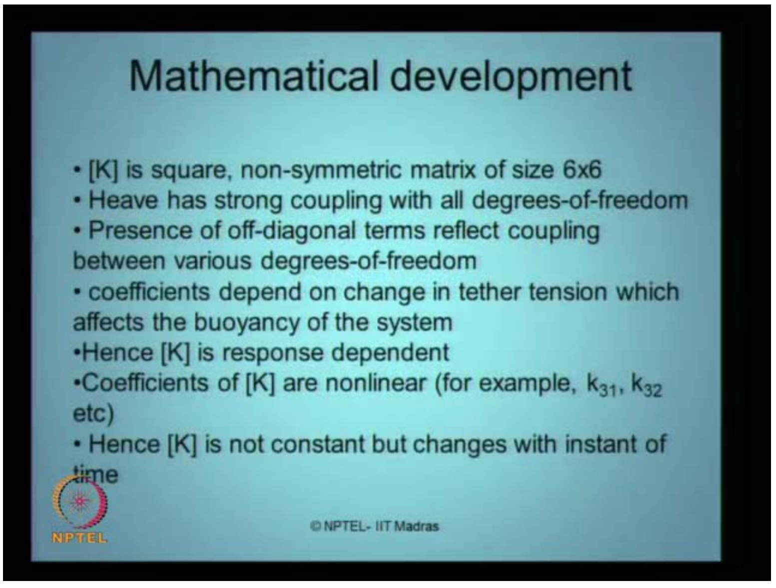


Now, let us quickly recollect what we have studied k matrix which has been discussed is a square non symmetric. It has got strong coupling with al degrees of freedom off diagonal present in the k reflects the coupling freedom with other degrees of freedom coefficient of k matrix depends on change in tether tension. So, it is not constant it varies with time, therefore k becomes response dependant in this problem and coefficient of k of course is non-linear. We have studied in detail how are they non-linear, therefore k is not constant, but keeps on changing in respect of time while you solve the problem. Now, coming back to the mass matrix structural mass is assumed to be lumped at every degree freedom, therefore mass matrix supposed to be diagonal, but the off diagonal is also present it indicates the contribution of added.

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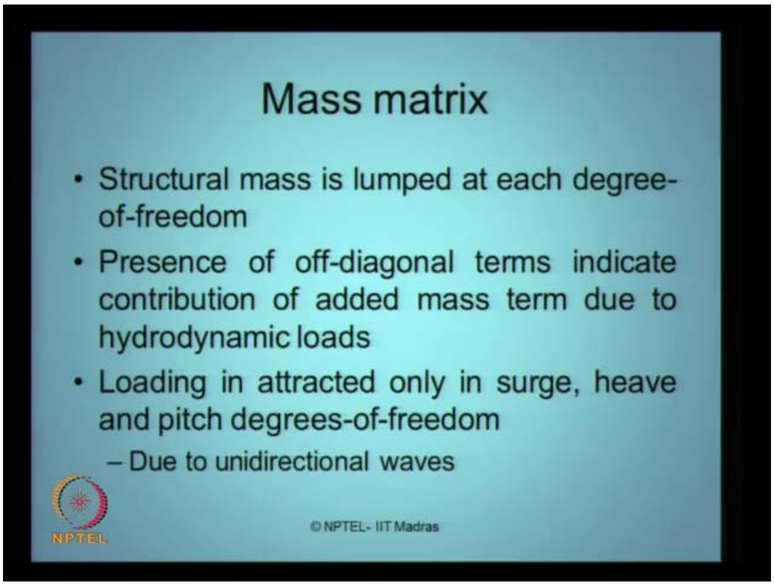


Mass term due to hydrodynamic loading the loading is attracted in this problem only in three degrees of freedom that is surge heave and pitch degree of freedom due to unidirectional waves structure.

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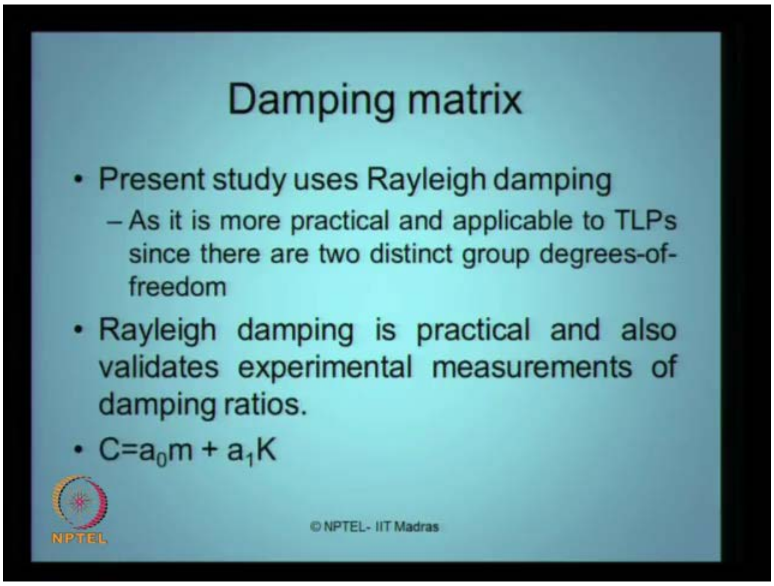


So, coming to the damping matrix present study uses the Rayleigh damping because it is more applicable top TLP because we have an advantage TLP has got two distinct group of degrees of freedom one is fixed and flexible. We can select two ratios and do Rayleigh damping, so this model applies Rayleigh damping, so what we have studied is a 0 m plus a 1 k and C will also be updated because k is getting updated. So, we will pick up an example problem which has been discussed in this particular paper being Taylor and Francis ship and off shore, but still we present the exerts of this directly, so this is the very interesting part.

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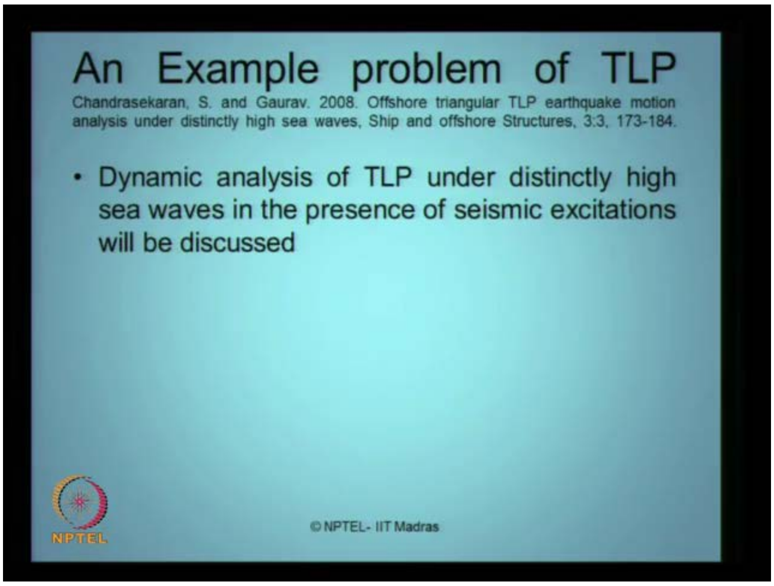

I will tell you what this is, why you are not taken away by convention of solving the problem of simple p with regular way because that is available in the papers. I will show you the long data there is the very interesting problem what we are attempted through this particular study. Let us see in gala of Mexico in specific gannian way specific geometric location geographic location, sorry we got Mars TLP located is located, so there has been observation in this specific C say that there is distinctly high series.

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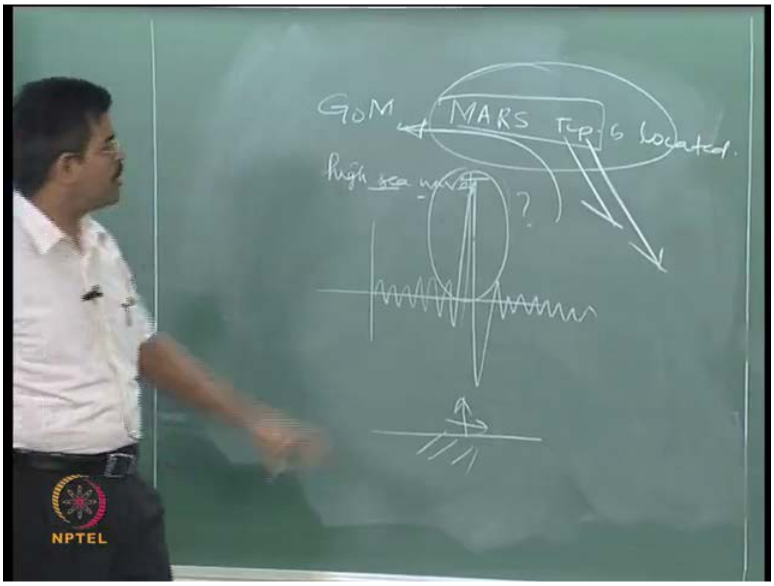


This come in this location wave is very high what does it mean is you look at the times tic record of the wave distinctly, there is the shot up. Then it is this kind of phenomena is noticed in this by experimental measurements by king mansurein will show you are the literature of this reference. I will show you later, now how to handle this kind of exclusive impulse height either axis because this has not been done so far. The reason they have found out is with this specific location whenever there is sequent movement in x and y direction there is the excitation in this wave so this study.

So, in process sanctification on distinctly this wave and analyses TLP of thus order, but if you wonder that why the paper analyses the existing TLP is safe. So, this paper does not study last TLP this paper an economic geometry from last TLP which is triangular oriental. There is geometric optimistic done on TLP and checked that has got new derivative form existing TLP from an existing TLP.

Examine the worst TLP observed by the researchers observed practically experimentally for which this TLP is not been designed to understand the point the problem completely different it is not a conventional problem. I picked up this problem for demonstration of problem its easy and it will be interesting for us to understand. How would it be different problem analyses on a distantly on a high sea waves the seismic excitations high sea waves is critical for given sea state.

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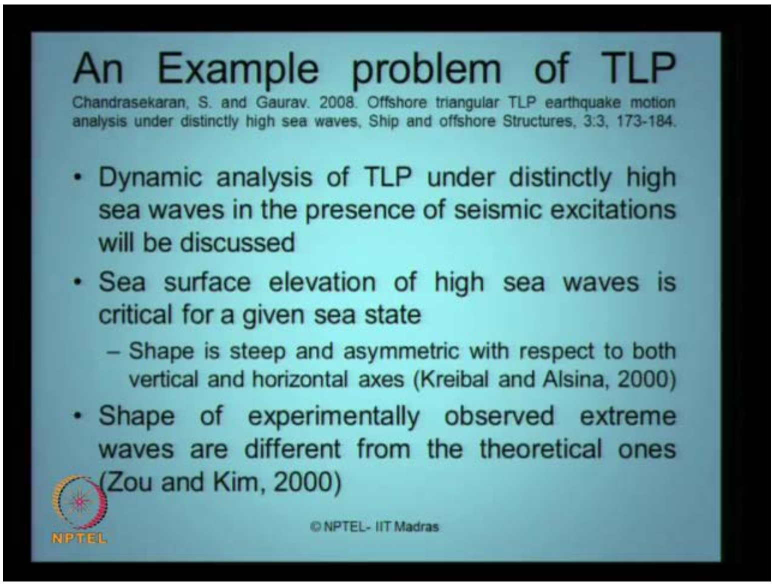


The Shape is steep and are symmetric that is very important I will show you the wave I s asymmetric with respect to both the axes vertical and horizontal because this is what we told as distinctly high sea wave by Kreibal and Alsina. If the way they remain asymmetric and steep in shape in both the axes, then we call it as distinctly high sea wave the shape of this is experimentally observed extreme waves are also available. They should compare to the critical ones for generic because theoretically people did not generated this wave, but explanatory they have measured this wave Zou and Kim done this.

If you generate a wave numerically or analytically, investigation for this problem this wave should match with that of what you have in the experimental observation. So, there is the limitation within which you have to develop the model update the generating of the loading first. Then update the problem loading itself is updated to the experimental observation in this particular case.

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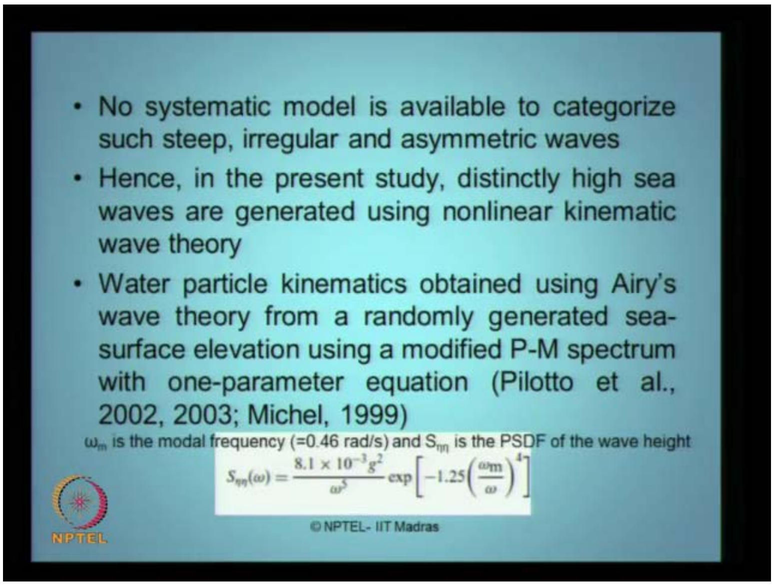


So, no systematic Model is available for the analysis because people are analyzed the mars TLP for cyclic explanation the mars TLP for distinctly high sea waves for the experimental methods by different researchers. So, a new innovation was done by changing the shape for different configuration in terms of geometry and then this analysis is done. First of all, it is verified in this problem we will see how it is done quickly, so in the present study we talked about distinctly high sea waves which generates through non-linear kinematic theory.

I am not talking about the generation of the wave; I will give any hint about it the water particle kinematics can be obtained by Airy's theory with randomly generated sea surface elevation. Using this, we can always modify the spectrum to obtain non-linear kinematic theory application using one parameter which has been given by Pilotto. Pilotto, has said you can modify this one parameter deviation which can fit for a non-linear kinematic theory which has been done in this problem.

So, that is the equation we have in economics that is the spectrum that is only one parameter which is omega variation omega m is taken or is the modal frequency and specific mode. There four its 0.46 radius per second, there is the reason for this why and s eta, eta has a power spectral density function of the wave height we can see about the wave height in this problem.

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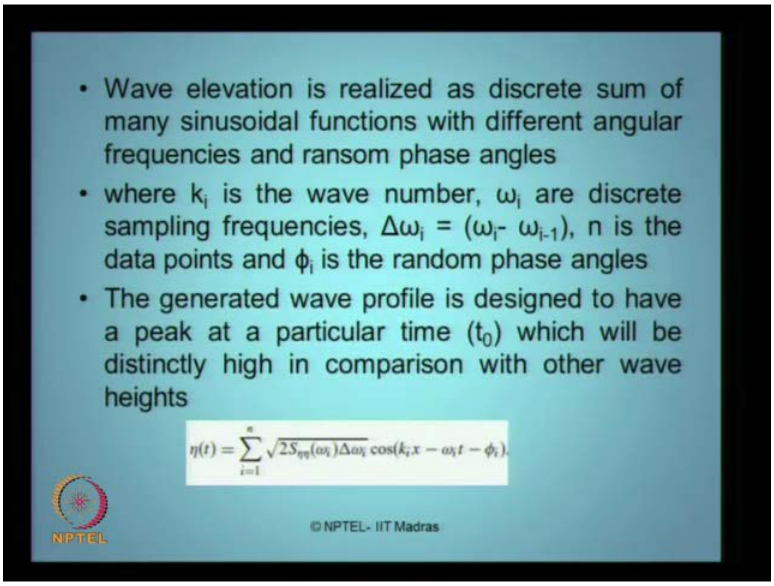


Once I do this I generated a wave and took the sea surface generation of the wave because I am plotting the times tic from the spectrum. We can do the analysis, you remember I am using the relay dumping relay dumping is that I must use the unconditional conversion your times tic relay procedure. I want to convert this into times tic domain for two reasons one is for this and two, I want to be sure that the wave generated should be deep an d asymmetric. So, I must generate a wave of this specific order the wave height on the specific and convening height multi times larger than the convening height. This I can see only from the times tic generation and I also want to know what time this is occurring on what frequency is that frequency matching with my frequency of the structure that is the reason.

So, wave elevation is realized as the discrete sum as see here of many sinusoidal function given send the functions as explained. Here, k I is the wave number, here and omega is the discrete sampling frequency where omega is omega I minus omega I minus 1 and n is the at the point. Considering for this reason and phi is the random phase angles, the generated wave profile is designed to have a peak and a specific particular time p naught and peeks I want to have this peak at the specific freedom TLP which can mere designate loading.

So, I can always check what the TLP generated will be stable for this specific kind of the wave if it occurs there is the freedom here the p naught is not where I want this peak what I want. I have picked up the p naught in this case to be as same as the period of heave let us see what happens here these are spectrum sample time history.

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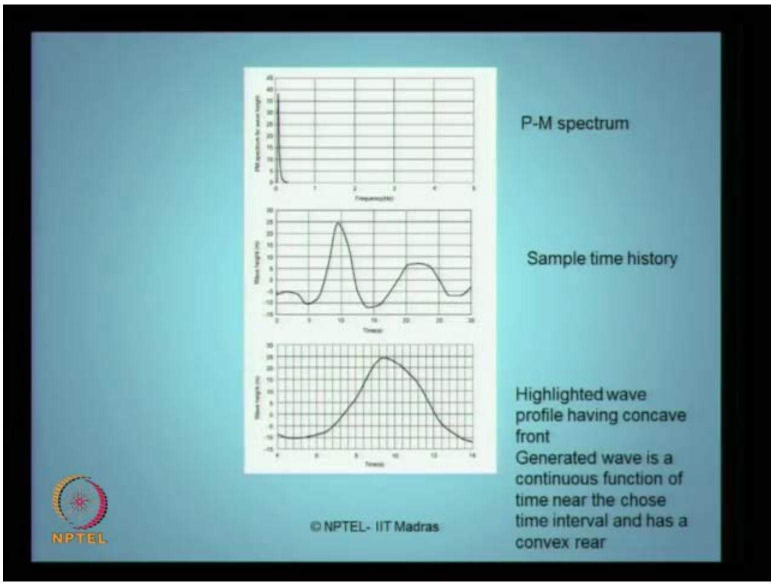


When peak goes to 25, the successive peak around is phi minus 5, then and the highlight wave shows a very specific window between 6 and 14 where window being generated. So, the studies show that generated wave should be continuous and should have a concave front which should is accepted as the asymmetric wave. We just shown the specific frequency or the it is having the frequency symmetric vertical and horizontal axes.

You can see from here horizontal axes is asymmetric its having the specific p naught peak which is multi times larger than the successive peaks what we call as distinctly high series. Let us say this has been completely say map with the times tic Zowan Kim in 2000 and they were experimental values. This analytical value this is the TLP which forms the geometric form of triangular in shape this has been derived from exactly Mars TLP which is four legged which is square in shape.

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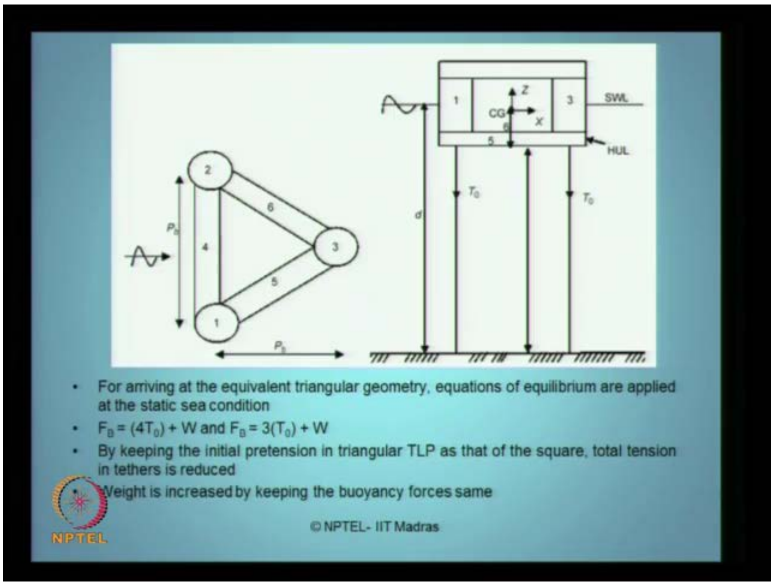


What is the basis for comparison is given here to arrive at a equivalent triangular geometry that of the square geometry there are two cases can be compared here by using the equations of equilibrium. In this problem, I can say the buoyancy can be 4 T plus W that is for square TLP because T naught is dimensional in each because the triangular TLP will be 2 T naught plus w where w is the weight of the platform by keeping the initial pretension same.

In triangular, p naught square are kept the same because the square what happens is three t zero will be much lower than 4, T 0, say now one point 3 times lower than 0. Therefore, the total tension is reduced this has been adjusted by increase in the weight this is the basis on which the people geometry has been evolved. So without doing much alteration in the size of the TLP from the top side of triangular which exists in now even now so the triangular geometry is attempted, now at that geometry the periods are different see here.

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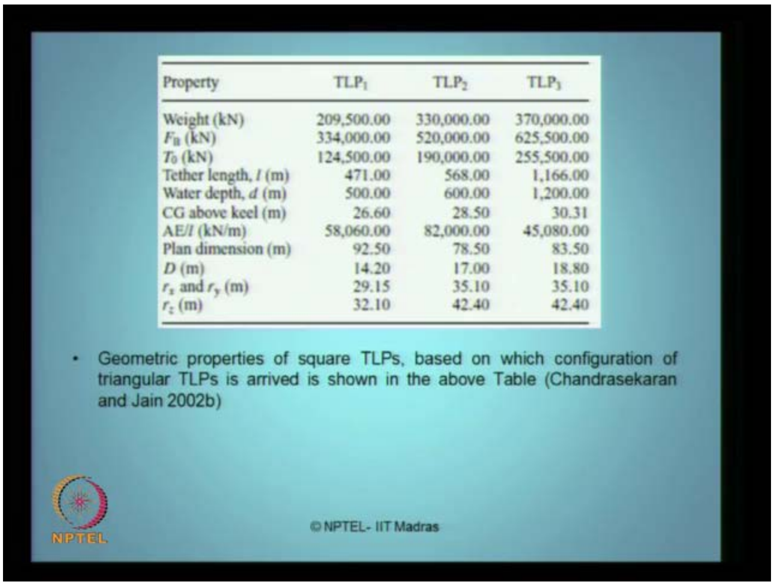

| Property | $TLP_1$ | $TLP_2$ | $TLP_3$ |
|---|---|---|---|
| Weight (kN) | 209,500.00 | 330,000.00 | 370,000.00 |
| $F_B$ (kN) | 334,000.00 | 520,000.00 | 625,500.00 |
| $T_0$ (kN) | 124,500.00 | 190,000.00 | 255,500.00 |
| Tether length, $l$ (m) | 471.00 | 568.00 | 1,166.00 |
| Water depth, $d$ (m) | 500.00 | 600.00 | 1,200.00 |
| CG above keel (m) | 26.60 | 28.50 | 30.31 |
| AE/$l$ (kN/m) | 58,060.00 | 82,000.00 | 45,080.00 |
| Plan dimension (m) | 92.50 | 78.50 | 83.50 |
| $D$ (m) | 14.20 | 17.00 | 18.80 |
| $r_x$ and $r_y$ (m) | 29.15 | 35.10 | 35.10 |
| $r_z$ (m) | 32.10 | 42.40 | 42.40 |



These are the properties of 1, 2 and 3, these are three different TLP's which are available in literature existing TLP's literature says that these are existing properties, so p equivalent triangular shape has been for TLP 1, TLP 2, TLP 3 is based.

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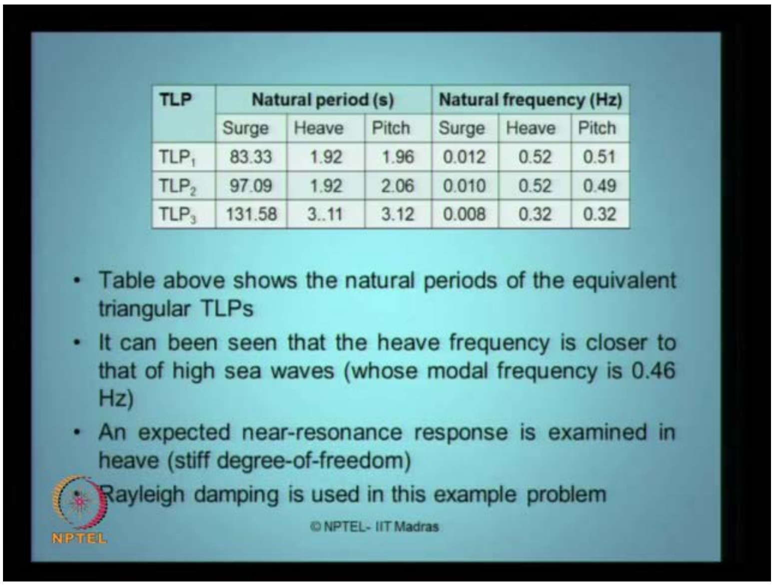

| TLP | Natural period (s) | | | Natural frequency (Hz) | | |
|---|---|---|---|---|---|---|
| | Surge | Heave | Pitch | Surge | Heave | Pitch |
| $TLP_1$ | 83.33 | 1.92 | 1.96 | 0.012 | 0.52 | 0.51 |
| $TLP_2$ | 97.09 | 1.92 | 2.06 | 0.010 | 0.52 | 0.49 |
| $TLP_3$ | 131.58 | 3..11 | 3.12 | 0.008 | 0.32 | 0.32 |



On the basis what we shown in the slide, so these are the natural periods and frequency in hertz this is 1 by T naught radian's per seconds. So, TLP 1 equivalent triangular TLP 2 equivalent triangular TLP 3 equivalent triangular the periods are around varies from 8 to 130 in surge, whereas in heave varies from 1 to 3 or 2 to 3 in pitch. Here, they are pitch, so look at the frequencies in hertz for have degrees 0.52, that is 0.3 to 0.5 surge is very low very large time periods pitch and heave re relatively same pitch degrees. So, we have this geometric electric of this problem, now interestingly see that frequency what you see in this particular case is closer to the modal frequency of 0.46 which you have used in the P L structure.

So, I am trying to look at the near resonance case the strip degree of form in the stiff degree of platform and look whether the platform gets completely uprooted in case of such waves coming and attacking the platforms. The uprooting is happens only when the heave motion is phenomenally high 0.46 is the modal frequency used in my P spectrum. The last stage we showed that and 0.52 is my heave frequency and he expected the near resonance scale happen in this case Rayleigh example.

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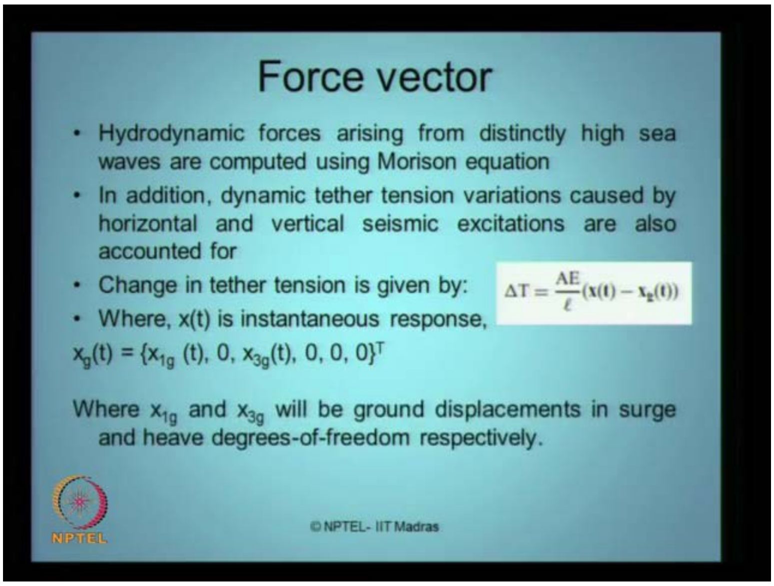


So the force vector equation of motion which arise from distinctly sea wave is computed using simple morison, because d a are valued here. In addition, the dynamic tether tension variations it is said one of the module I am super imposing delta t values of theta on to the super structure add that to my appropriate problem. So, delta t is what I get from this equation which is x of t minus x g of t where x of t of my extra function of my platform where x g x t is having is having x 1 of g and x 1 of t. Both horizontal and vertical motion of is accounted for times tic both in surge axes and heave axes has been accounted for my x g of t motion.

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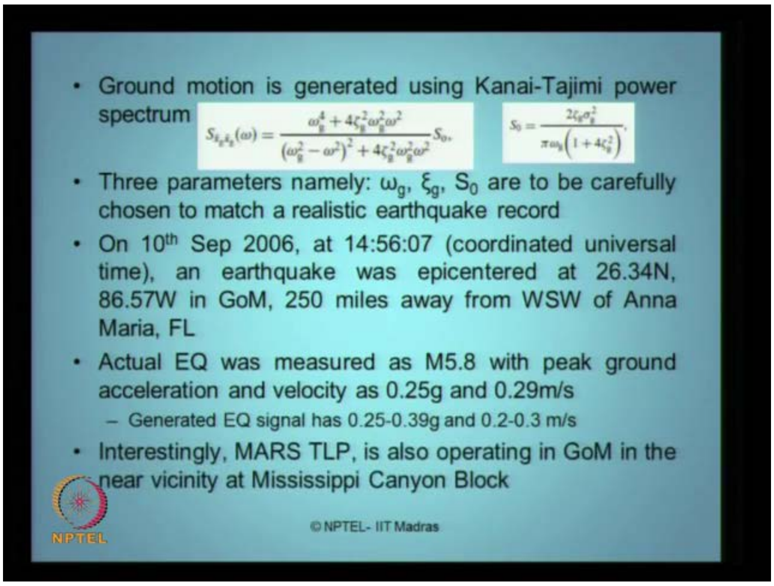


So, this is my Kanai Tajimi spectrum, we already had it it is an artificial using k p power spectrum there is the other one equation. There are three parameters of omega g zeta g s naught is the ground damping which is not the structural damping omega g is the ground structural damping and s naught is the spectral coordinator which is the problem which is available here.

So, they should be carefully selected to match a realistic earthquake, there had been earthquake occurred in gulf of Mexico on September 10, 2006 at fourteen fifty six seven seconds IST. The specific epicentered at 26.34 north 86.57 west where nearby 250 miles away in Florida where in gulf of Mexico a mars TLP is located. So, the specific spectrum of this m 5.8 with peak ground is picked up and the 0.25 g and 0.29 meter per second and this has been used to generate a signal for work like this here this is my thing.

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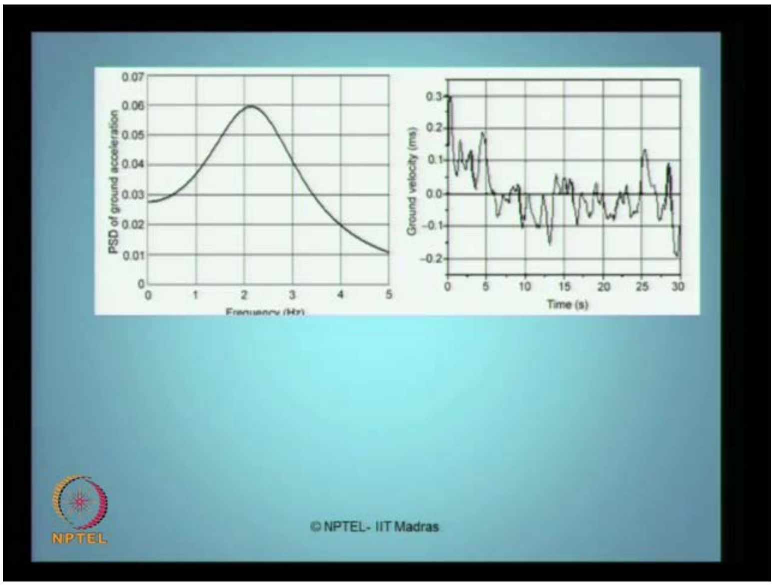


This is my power spectrum density which matches is exactly what we had geographic specification occurred the course specification of TLP in Mexico. The right side is the times tic this has been used because I need the times tic density to compute my relative because of the delta t will change in a t. Thus, once delta t changes, of course k and m get updated and C also get updated in addition to buoyancy change. The FFT also changes FFT equation vector sum of distinctly high sea generated artificially using the modified Pso Moscow etc plus delta t arising from Kanai Tajimi spectrum etc. In horizontal vertical axes both we get super portion of both this equation of motion.

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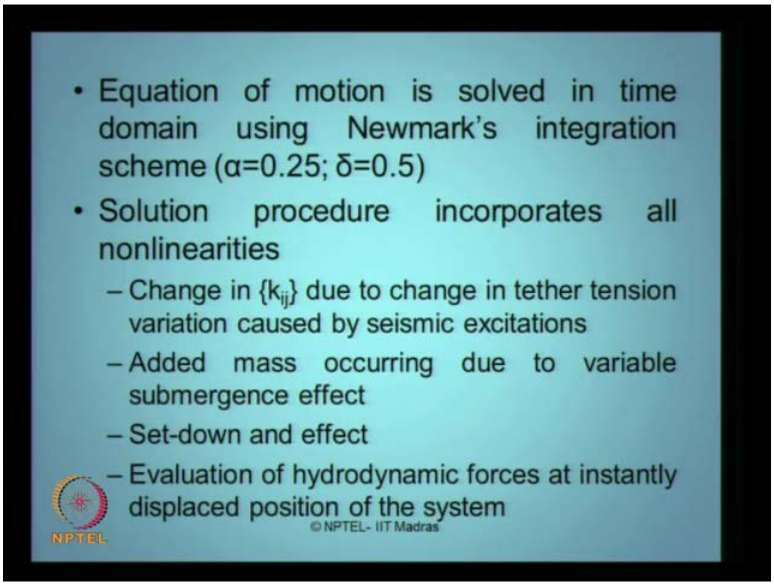

This is solved in Newmarks integration scheme with alpha 0.25 and delta 0.5, so I have the explanation for newmarks deta key which we will discuss in tomorrow's lecture. We will work out an example and show how this can be done, so let us believe here that I know how to put Newmarks integration scheme. So, going ahead solution procedure is here will incorporate all non-linear matrices of k i j mass this is going to be function of tether tension cos by extra tension my k i j will get updated population procedure. Added mass will also be updated because of the variable submergence effect or the emergency effect set down and its effect will also effect accounted for the analysis plus the hydro dynamic forces are instantly displaced position of the system. So, all these non linearities are accounted in my analysis and the solution process takes place and these are mirrors.

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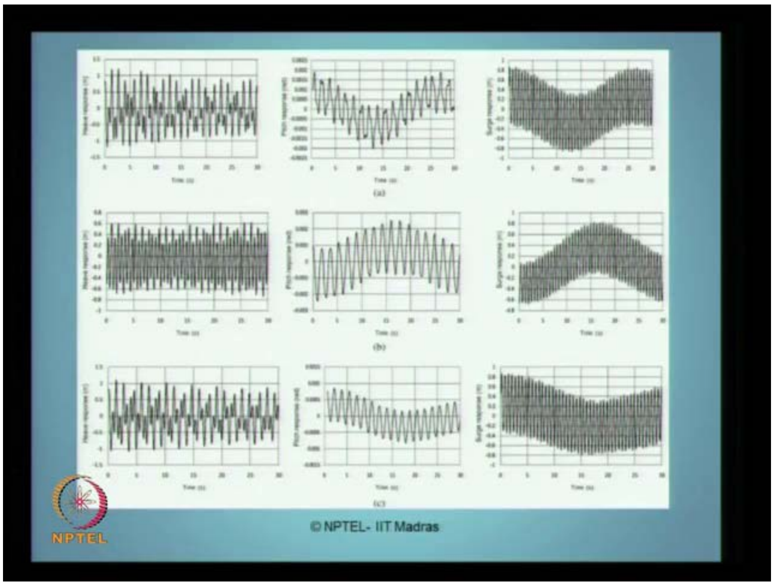


The left hand side curves shows heave response meters this is pitch response in radians and this surge response in meters, you will see in moreover this cases the heave response is never varying here. We can have the specific order heave response getting low exercised in a specific example because of 0.46 radians per second, sorry 0.46 hertz which is matching with frequency of heave we looked at the values of TLP 1, 2 and 3 what you wanted to show.

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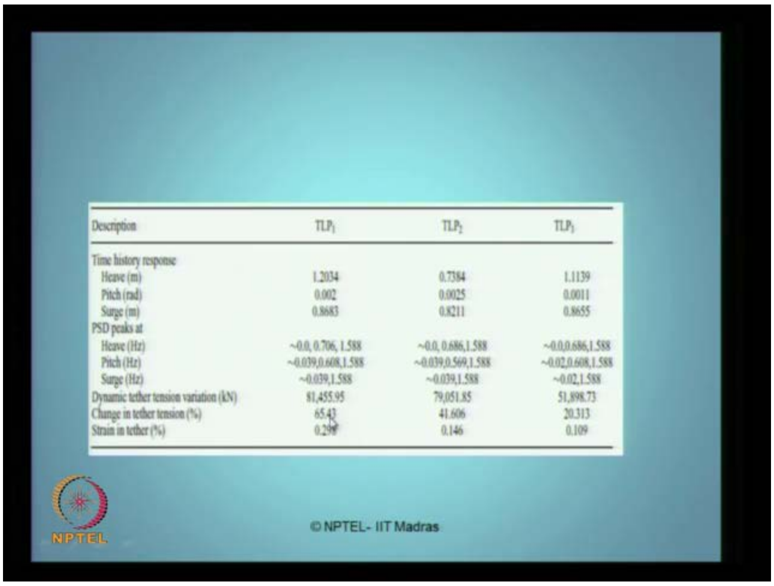

| Description | $TLP_1$ | $TLP_2$ | $TLP_3$ |
|---|---|---|---|
| Time history response | | | |
| Heave (m) | 1.2034 | 0.7384 | 1.1139 |
| Pitch (rad) | 0.002 | 0.0025 | 0.0011 |
| Surge (m) | 0.8683 | 0.8211 | 0.8655 |
| PSD peaks at | | | |
| Heave (Hz) | ~0.0, 0.706, 1.588 | ~0.0, 0.686,1.588 | ~0.0,0.686,1.588 |
| Pitch (Hz) | ~0.039,0.608,1.588 | ~0.039,0.569,1.588 | ~0.02,0.608,1.588 |
| Surge (Hz) | ~0.039,1.588 | ~0.039,1.588 | ~0.02,1.588 |
| Dynamic tether tension variation (kN) | 81,455.95 | 79,051.85 | 51,898.73 |
| Change in tether tension (%) | 65.43 | 41.606 | 20.313 |
| Strain in tether (%) | 0.29[illegible] | 0.146 | 0.109 |



Here, is tether tension variation, tether tension variation is about 65 percent increased because of cyclic expectation. So, if you do not consider this 65 percent exemption will not be accounted in the analysis, so this has happened because of present distinctly high waves and cyclic expectations and time is about 0.29 percent. So, there is no pull out in tether, but the change in tension varies in practically developed or more or less 60 percent. So, there is increase, so we all understand that change in tension increases the bio volt from 60 to 70 percent think about k n and omegas.

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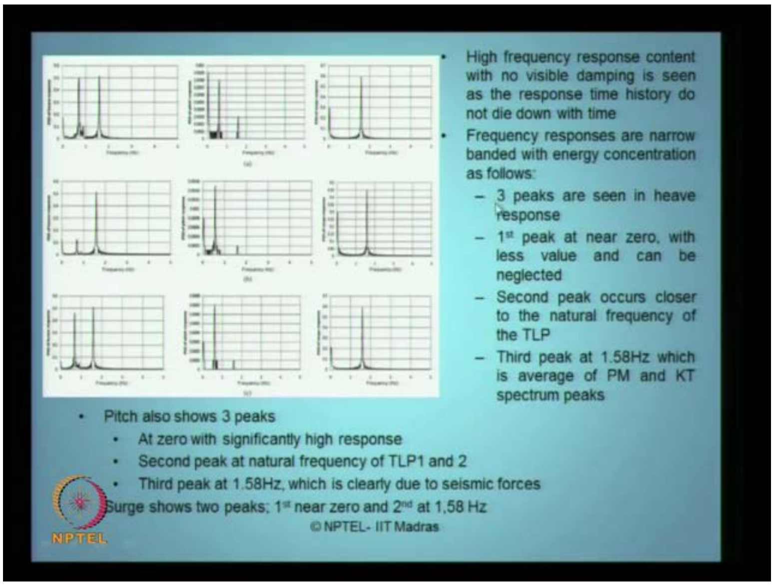

So, these are my power spectrum density of functions of heave pitch and sorry heave pitch and surge of course you can see this responses in the paper in detail. So, we will quickly look at the observations heave frequency response is no show visible damping. So, here it is not dying it is continuing here, there is no question of dying down heave response not dying down at all there is no visible damping present in this system which is computing for decay of response.

Further, you will see that the heave response shows three peaks, one is course able 0 and a very low magnitude which can be neglected. The other two are phenomenally high which happens closer to and the frequency of the heave affidavit cell, so there is resonance happening here which is quiet dangerous. The third peak is about one point five meter height is very interesting which happens in pitch also this happens in pitch also you may see that the value may be lower happening in pitch.

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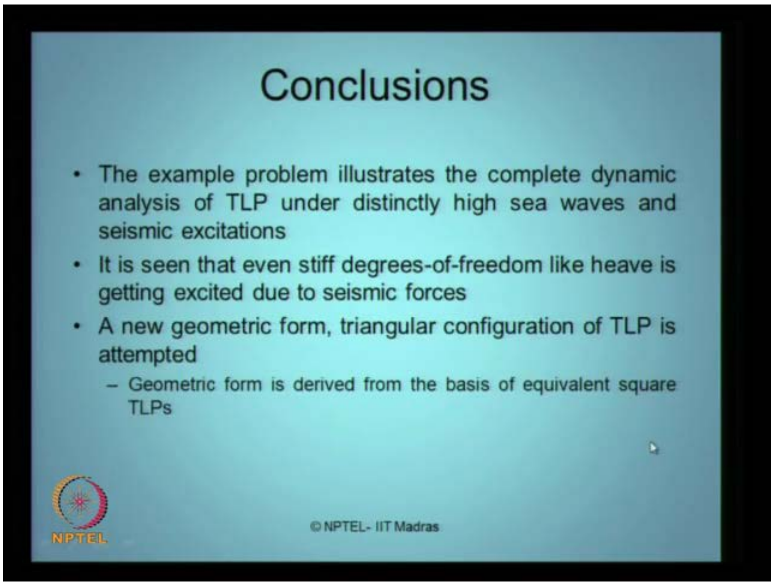


It happens in surge also what is this 1.58 number the 1.58 number is interestingly is an average of the loading spectrum frequency and Kanai Taijam spectrum frequency. It is happening in between these two, so it is neither happening in Kanai Taijam spectrum frequency of earth quake nor at loading frequency average of these two. If you look at the average of these two is 1.58, so this 1.58 is phenomenal is seen in all degrees of freedom pitch and surge are phenomenally high. Subsequently, to understand the phase plotted for these to understand whether this is in nature, they are stable they are of course of long period.

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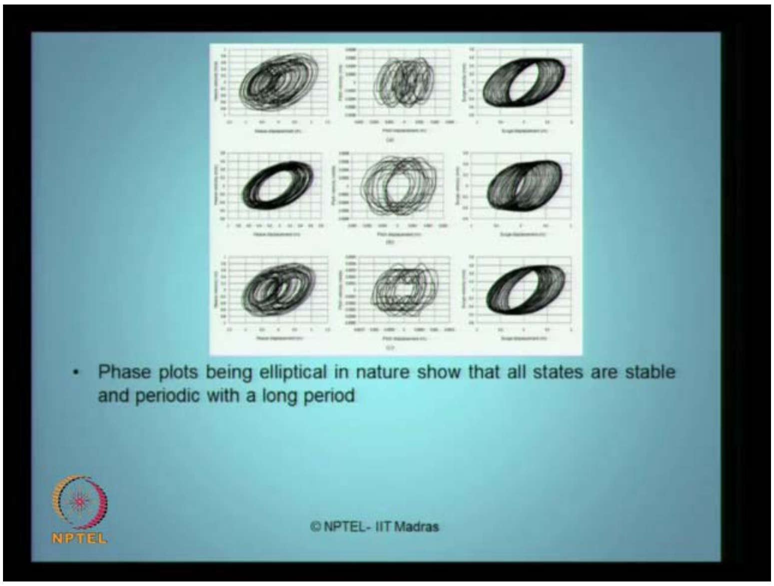


This is not secular electrical, so quick conclusions of these studies.

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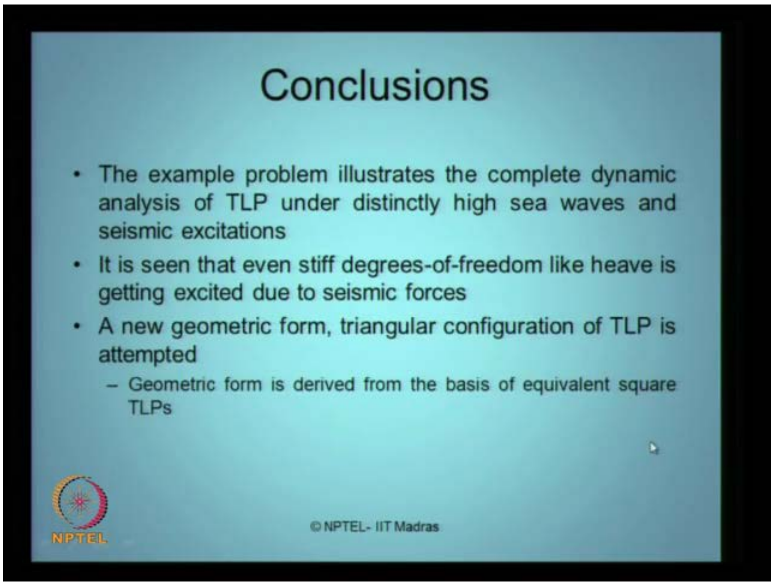


The example problem illustrates the complete dynamic analysis of TLP under distinctly high sea wave seismic excitations. We can see this from the example even the stiff degrees like heave is getting excited because of siesmic forces. Distinctly, a loop geometric configuration has been attempted the geometric form of is derived from the equivalent form existing from the TLP side.

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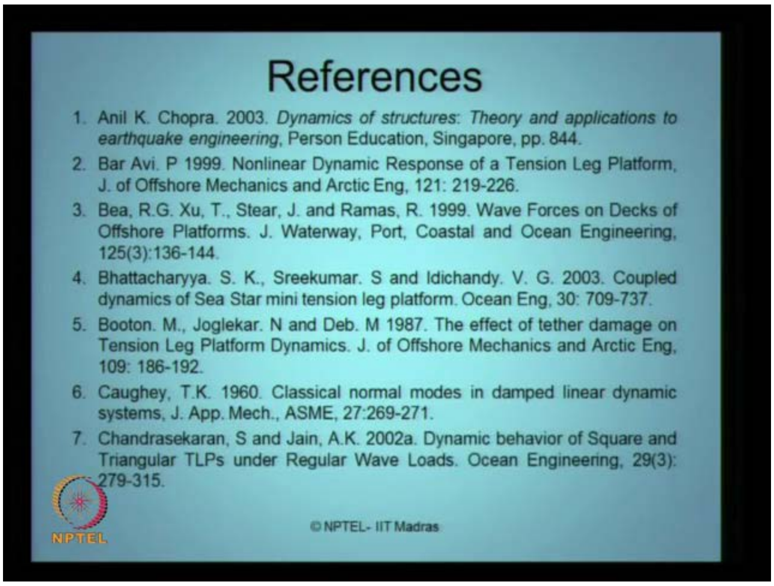


So, there are many references for the whole lecture non-linear response bar avi, wave force on decks coupled dynamics of sea star, boot on for the effect of tethal damage Caughey classical normal notes my paper on dynamic behavior.

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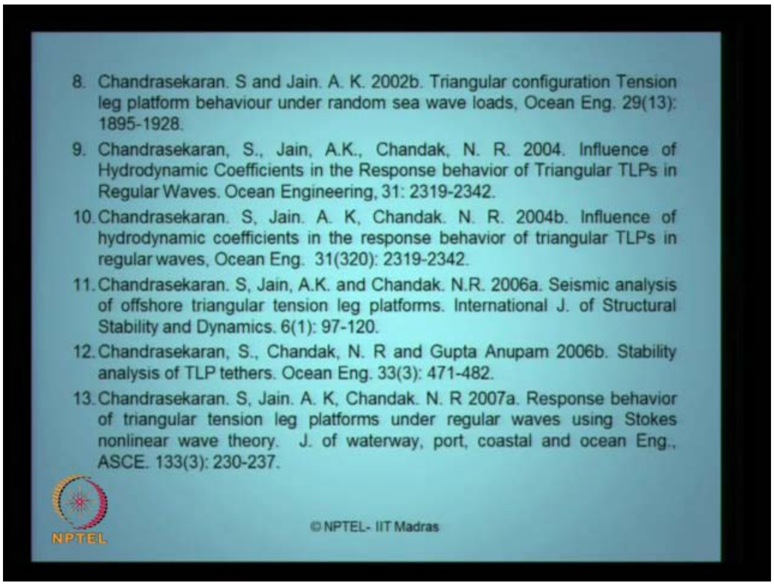

My paper again on dynamic behavior triangular, TLP influence of ocean engineering influence on triangular TLP's, then seismic analysis stabilities of tethers, response behavior of triangular tension.

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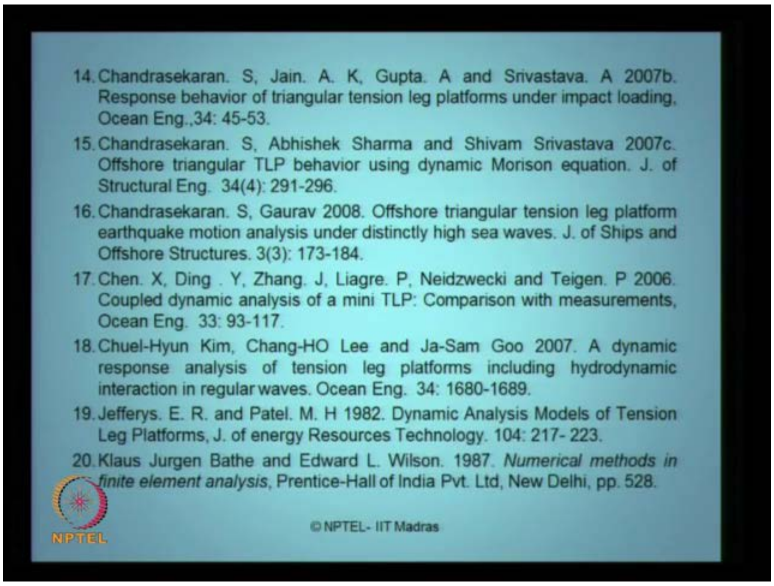


Then, impact loading, then dynamic Morison equation, then distinctly high sea wave, then Chen on comparison on dynamic response, Kim Metle on dynamic response including hydro dynamic interaction of waves Jafferys and Patel model analysis bathe and Wilson numerical methods.

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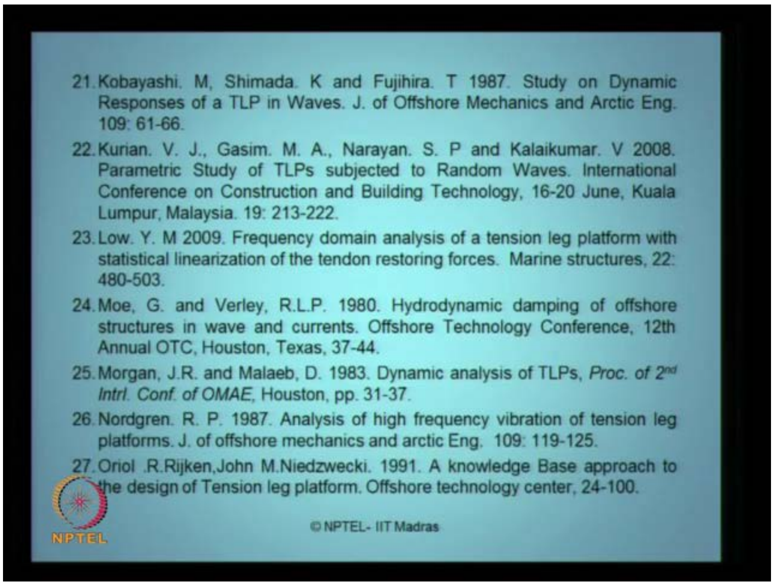

Finite elements Kobayashi dynamic response of TLP in waves, Kurian paramatic study on random waves, low frequency analysis of TLP, Moe and Verley damping offshore structure in current and waves, Morgan and Maleeb dynamic analysis of TLP, Nodrian analysis of high frequency vibration Orior Niedzwecki knowledge base design to TLP's.

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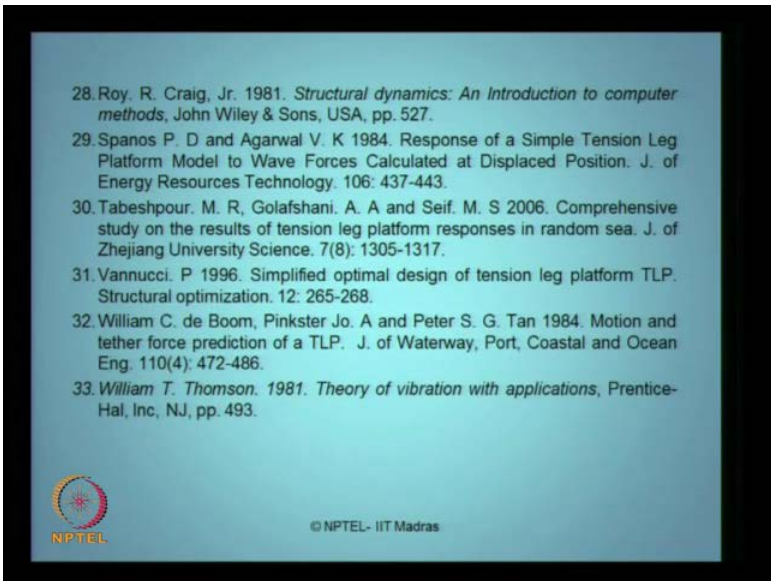


Roy and Craig structural dynamic introduction, Spanos and Agarvai response of TLP Tabeshlpur comprehensive study on TLP results of tension Vanuuci simplified optimal design. So, I want you should refer these papers to understand further. so try to look at the literature of this and try to understand them because what we are seeing here is in this in the couple of lecture are how to estimate a damping k and m.

From the factors of principles how a new geometry can form attempted for a dynamic analysis and how the equation motion can be solved using time stepping procedure. This we will discuss in the next lecture tomorrow using Newmarks tether method, so we will solve the problem and how this could be done and not for this case because the utilities was 6 degrees of freedom. I will pick up a simple problem two diagonal to do a same procedure so that atleast conversions can be done in the classics so this will help us to understand how I do a dynamic structure for a company structure like TLP.