Dynamics of Ocean Structures
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Lecture – 04
Structural action of ocean structures

Today we will discuss about the Lecture 4, is on Dynamics of Ocean Structures is in Module 1. Of course, the whole course will be run in 3 modules.

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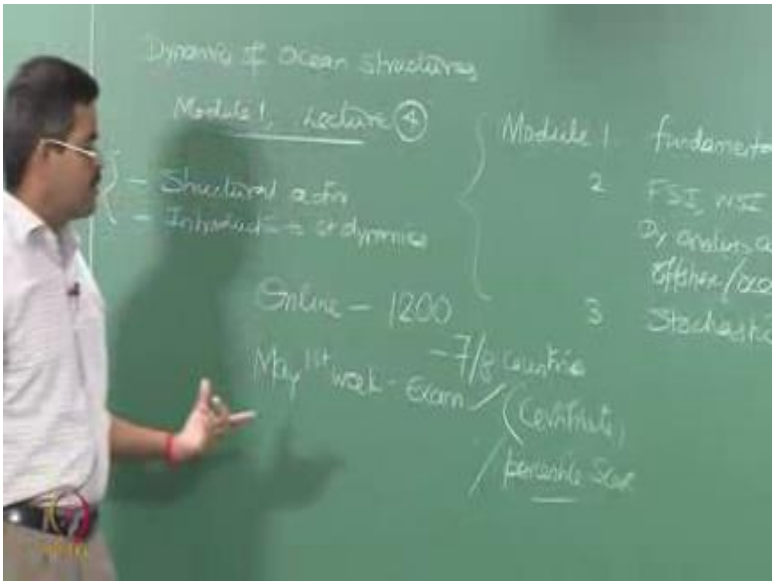

Module 1 will talk about we will talk about Fundamentals of Dynamics. On Module 2 we will talk about Fluid Structure Interaction, Wave Structure Interaction and Dynamic Analysis applied to Offshore and Ocean Structures. Of course, in Module 3 we will talk about the interesting area of research which is on Stochastic Dynamics. Interestingly you must understand that this course is actually a online course, we just currently registered by more than about 1200 students from at least I think 7 to 6 countries. At the end of the course may be possibly in first week of May there will be an exam which you got to pass, then you will be given a certificate duly signed by IIT Madras. The certificate will have a unique ID and your photograph, and most importantly your percentile score on the subject.

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Now, you may ask me what is interesting about this. So far I think an IIT system you would have obtain the certificate or a grade to a maximum sample size for PG class of order not exceeding 100. There is a maximum sample size of PG class in a IIT at least in IIT Madras. Now here you have a denominator of 1200 and this 1200 will include many faculties, I mean engineers practicing professionals. Many graduates how have already graduated who have already studied dynamics. Now when we compute with them you really know where you stand actually.

So, if you are only within a class of let us say 25 who all does not know anything about the subject standing top amongst 25 who does not know anything about the subject is not great. If you stand on top 10 amongst 1200 who already knows the subject it matter something actually, is very important. It is a golden opportunities. Of course, this lecture is free, online lecture for all this 1200 is totally free. There is only a payment of fees for taking the examination if you want to get a certificate. And of course, there is a marginal price I think it is only 1000 Rupees something.

This kind fortunately with God's grace we have got a very interesting book on Dynamic Analysis and Design of offshore structures which is authored by me. This is the Springer release. The price of the book is 103.99 Euro, this book is available. Now if you miss out

any lectures or if you are not able to understand anything in the classroom here I thing you can closely this follows this book, this book has got lot of details explained with the examples. We also do the examples here. It is not that you have to purchase the book for necessity. But this will have lot of tutorials and assignment which you have got to answer.

In addition to this those who are taking this classes as a regular credit you have got to undergo quiz 1, quiz 2 and quiz 3; quiz 1 and 2 and major exam at the end of the semester as schedule of IIT where will be given a great separately. So, there are dual purpose here; one of course you will get a relative grade within your class you can also get the global grading with the certificate which is valid in all developed and developing university and countries in the world. So, this is a very great opportunities what IIT NPTEL has extended to all the people. This is the first time IIT is doing this on the NPTEL schedule I thing you should use this.

In the previous Lecture 1, 2 and 3 we discussed about different verities of offshore platforms. Let us quickly see, what are those varieties of platform.

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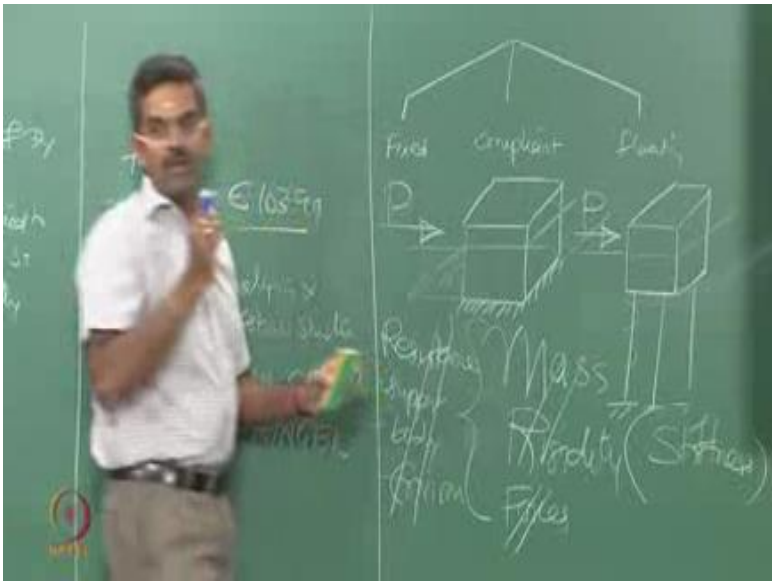

Of course if you have missed this lecture they are available in online, you can see them and before coming to the next class please understand that. There are 3 verities of structures which we generally have in ocean structural system. When you talk about the ocean structural system let us quickly now focuses only are structures which are meant for oil exploration production. Now you may ask a question; what is the difference between an off shore structure and then ocean structure? The fundamental difference only in the function, there is no difference in the form.

The function is ocean structures are generally design for variety of purposes. Maybe sea walls covering, coastal protection, jetties for birthing etcetera, whereas offshore structures are more complex in nature because they are designed and develop only for a specific function which is either oil exploration and drilling or production and processing. These structures are of the coast they are into waters at greater depths. Therefore, the complexity of the dynamic analysis of these structures are much more higher compared to structures on the coast, because compared to structures on the coast they are more or less on the land.

So, the dynamic analyses on land base structures are generally philosophically well known in the literature. The one which is follows is the one when the structure moves towards water. And if the structure remains floating it becomes more interesting. So, there is 3 categorizes is here; one is fixed type, other is compliant type, other is purely floating. Now let quickly see the structural action, the difference in the structural action between them. You may ask me why we are interested in knowing the structural action differences before we talk about dynamic analysis. Dynamic analysis will come into play only when you have the structure ready to visualize.

If you have a structure ready to visualized for example, I have a bluff body maybe a cube which is resting on the floor, which is comes here to be fixed and a cube which is resting on rollers when both the cubes are pulled by some forces or pushed by some forces of some magnitude may be static in nature. You will immediately recollect from the fundamental mechanic that the response behavior of this cube is difference from that of cube. So, you need to know the support conditions, the body dimensions, the mass of the system, the rigidity of the system which we call as stiffness, the forces on the system and

most importantly the resistance offer to the system maybe from the supports, maybe by the body itself, maybe by the environment; what we all call as damping.

So, we must have the system in visualization first. So, when we agree the system in visualization becomes important to understand the dynamic analysis let us get back to the system first. Offshore structures are classically broadly into 3 category; fixed type, compliant type and floating type. Fixed type is simulated to this, where the bottom of the structure is rigidly fixed to the sea floor. Compliant type is different from this, where the bottom of the structure is anchor to the sea floor. Now quickly the difference between this and this is that the structure has some freedom to move, but the structure is positions restrain, so the freedom is not infinite. There is a boundary; there is some limit there is a restrain imposed on the system by the supporting condition.

The third one of course, is fully floating totally free. Now obviously, if the put the same my waterline here, because the structure is floating you may say how this is floating that cables or the members can slacks can get tighten. When they float the structure invokes additional force from the free surface, where structure does not flow. More or less the force on the free surface is fixed. So, the additional forces coming on the member depends on the geometric conditions how the structure is supported.

So, if you do not understand this variation between the types of platforms we will not be able to do dynamic analysis, because we really do not know what the forces are coming on the structure. You may ask me I am worried about the analysis where the force coming to play. Force is important components in dynamical analysis. So, 1 and 2 come from the system, 3 comes from the environment, 4 comes from the system and environment. So, there is the combination between the environment and the structure which makes dynamic analysis very very complicated, and to add to this complication the forces acting on the structure or a multi dimensional.

You may ask me a question what are those complex forces we generally act on a structural system which will challenge the structural action of the system. Let us quickly see what are those forces; which have been explained in the lecture 3, but for understanding purpose let us say.

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So, I will put in general the environmental forces. Some people address this as environmental loads. To start with from the super structure one may ask sir what is the difference between super structure and substructure. Super structure is one which is the above water; sub structure is one which is below or in water. Whereas, in land base structures super structure is one which is above soil and sub structure is in foundation.

Whereas, an offshore structures the one is above water is super structure the one which is in water inside water is sub structure. We start from the top, we know wind loads which we are discus in the last lecture, following by which wave loads. Waves also will have current action. They will also have marine growth. There can be dead loads. There can be live loads. There can be an accident load which has called collision loads. There can be seismic forces. Let us put earthquake forces etcetera. We have anyway discussed all these things with the respective equations, with respective spectrum. Ice loads, acting on offshore structures.

Interestingly, most commonly many text books do not touch upon the effect of earthquake loads and ice loads on offshore structures, they are very rare. In fact, they are very scare in the literature itself. And many books and many research papers will idealize wind loads as non dynamic in nature. They make it as equivalence static or quasi static.

There are reasons for this why it is so. We will talk about that let us move on to the dynamic analysis. So, we must know that how the structural actions of these three are different when the forces are acting. We will take one examples, let us say earthquake loads will take an example to demonstrate how earthquake load can cause significance difference between the types of structures as a structural action. We are talking about only structural in prospective. These forces are not focused in this literature on these lectures like a hydrodynamic engineer. If you really ask me can you give me the equation of Arise theory or ISSE spectrum to calculate the wave forces possibly you have entered the wrong class you have go to the some other class to find out this.

As a design engineer, as a structural dynamic analysis I must be given these loads readily available either in the software or in the code. So, I must know these codes. In the previous lecture of lecture 3 all the spectrum related to all of them are available and given in a close form equation to you. So, how this equation been derive, what are the conditions, what are the space perimeters based on which the conditions are effecting this equations, where are they applying; we just ignore all of them, we are not bother about them because that part we are away from this we are entering the different domain now. For me forces are one component in the analysis. Of course dead loads and live loads will contribute to mass. Where the rigidity will come from, where the damping comes from, I will explain that.

So, now the question is very easy to ask what would be the difference in structural action of these varieties of platforms where typical forces say earthquake loads is applied. Once I have a capture of this idea then you can without these apply anyone of them in your mind set and see how the behavior will be different. So, please understand our focus area is not calculating the forces on the structure. Then what is the focus? The focus is what the response of the structure for these forces is. So, very important we are talking about dynamic analysis, whereas in every analysis problem we will always compute the forces and the displacement. Here the forces are given to you; you should be able to estimate the forces from the standard spectrum.

What you do not know is the response. So, that is why categorically many research papers say dynamic response analysis. The term response is interfered between the

dynamic and analysis. Many people said it is dynamic response analysis. When people say hydrodynamic response they do not touch about the structural response at all, they talk about the variation in the loading not on the structural form. We are talk about structural response purely on structural dynamic perspective. Therefore, we will not focus on load so much this is also an important area of research I agree, but we are not touching upon in this lectures or modules because there are some other space where we can study them. Many text books are available. You must have learnt or you will be learning or you may not be bothering we are not concern about them.

Let us answer the question back again I have a force, a typical earthquake load I want to apply. First question comes is a standard spectrum available for defining earthquake loads for offshore structures. The answer is big no; people have not given any standard spectrum to calculate earthquake loads on offshore structures at all even today. Whereas, for wind, wave, current, dead, live, accident and snow loads spectra are available. For earthquake loads spectra is not it means in a scientific analysis of offshore structures is very very weak in the literature domain as on today.

What is reason for this? There are two reasons for this let us talk about these reasons very quickly. Reason number 1, people initially thought earthquake loads will not cause significance response on the platforms.

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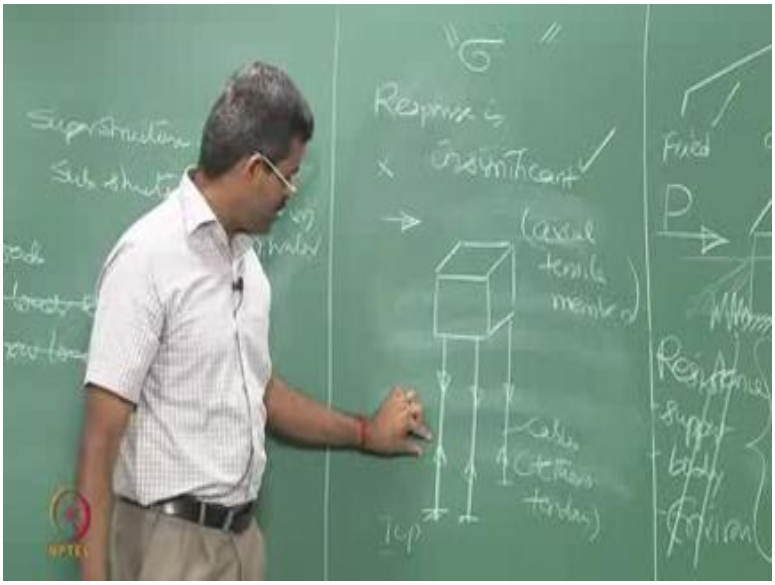

So, response is in significant is not people thoughts. Now there must be a reason for this why people have thought like this. The people thought like this because they apply their actual force only for one variety of platforms which is bottom supported. Obviously, any model or any platform or any bluff body which is bottom supported when subjected to excitation in all the three axis x y and z the platform or the body will respond. But then why people said it is insignificant, because the mass of the body is so heavy the response initiated by this forces where dammed by water body. So, people thoughts it is not effective at all, because all the time they thought the response is indirectly related to the stress levels on the members. When complaint platform emerge in late 80's where the platforms is not resting on sea belt, but anchor to the sea belt using tethers and cables or tendons when the platforms starting floating then this response statement became invalid.

Now, let us see what is structural action which is evoked by complaint platforms when you apply a seismic force? Let us see this is my complaint system which is held down in position by I would say cables. Technical speaking they are called as tethers, they are called as tendons, etcetera. So, we must agree that these are axial tensile members. The example what I am showing here is a tension leg platform TLP. So, these cables or tendons will be in axial tension, I do not know how many of you really know that how to

mark a tension arrow and a compression arrow in a given cable member, because this always a great confusion what people generally have.

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Let us quickly answer that because; let us say I have a member I have 2 nodes maybe node a and node b. If the member is pulling the node it is tensile. If the member is pushing the node it is compression. Remember it is action of the member on the geometry it is not the support on the member. If the member is pulling the node it is tension, if the member is pushing node is compression. And I do not know you will definitely not mark like this, this is meaningless. It has to either pull both sides or push both sides this cannot happen this is wrong. So, here these members are in axial tension.

Now I have earthquake signal applied here. Now I will take signal in the vertical axis a random signals whose peak ground velocity and acceleration known to me, history is known to me is given to me by a spectrum I will come to the spectrum later. Spectrum gives me PGA or PGB; P ground velocity or P ground accession time history is known to me I applied time history here. The water level is here, this is my mean sea level mean water level. And I am talking about depth of above let us say 1000 meters great depth water cushion is there.

Let us apply the signal of earthquake force here. The question asked is will the structure response. I am all the time bothered about what is the response of structures. Here the term response re defined as the displacement not the forces. Now, otherwise the structure is moving it is free (Refer Time: 23:36) to floats. So, there is a lot of a freedom given to the structure in terms of the displacement, but what is that happening to the structural displacement one such forces do apply at the bottom is a kilometer down from the point of water level.

Interestingly when the sea belts moves up and down the cables are either pulled or slacked. When the cables are pulled or slacked the stiffness of the system changes, because there is change in bouncy of the system. When the bouncy of the system is changed the response system is significantly alter. This causes dynamic tether tension variations. So, this is dynamic tether tension variations or imposed on the tendon which causes response to the super structure automatically. Now, one can ask me a question what will happens when this anchors or this cables or tendons are removed that is the third case which is freely floating.

If you have them freely floating you will not able to do any operation because it is kept on floating. You got to portion (Refer Time: 25:00) this using either a geometric portioning system or a mooring line which is generally done in the case of a (Refer Time: 25:15) or a drill ship. Now, in such cases also when the system is moved down for portion keeping when earthquake signals are apply will have some impact on the motion of the bodies which will affect the production capacity of the (Refer Time: 25:32). But, if you have a drilling rises connected for production in the rises or effected this will effect pull down of the riser completely that will loss in production of the system. In all the three cases earthquake force apply to a variety of a platform imposes variety of structural reaction which is not common.

So, what you try to understand here is not the force alone, but the effect of force on the system which we call dynamic response analysis. The variety does not come from the force the variety essential comes from how do the structure behaves for this process. If there are 10 variety three platforms you have thirty combinations. I have taken a specific example how they behave. Similarly, one can apply any one of these in mindset and see

how this structures will behave if you know the structural geometry. So, the most important component now come to mind is what is the geometry which is important, is it the sides, is it the member arrangement, is it the cross section dimensions of the member or is it the water depth, is it the wave height, is it the tidal variation, is it the bouncy or the variation submergence, is it the wind force, what is that causing the difference in the action.

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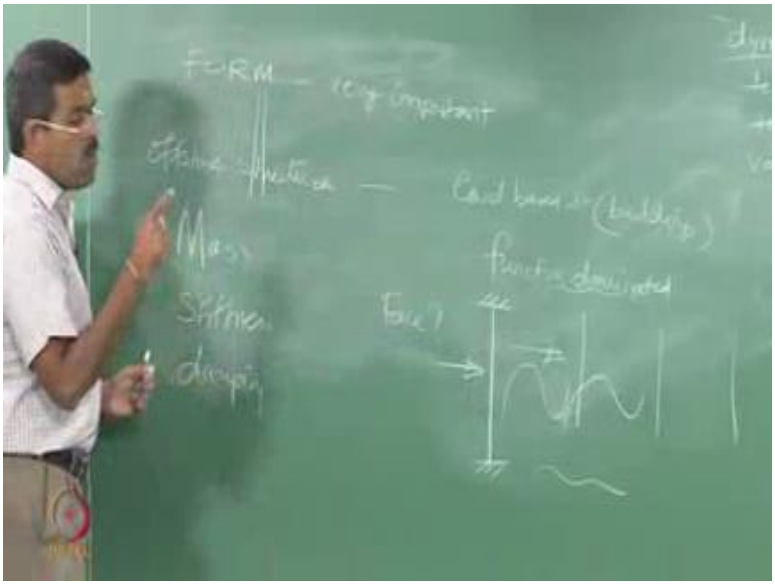

So, it becomes very important that the structural form; so the structural form becomes very important. Say, you must agree compare to offshore structures. Compare this to any land base structures, for examples builders. Most of these structures are function dominated. I can give an example, an airport, a theater, a multiplex, hospitals, a school, a library and institution, an OAT, an ICSR. They are function dominated so they will tell you what should be the size of the space available, what should be the arrangement of the rooms available; all these are architectural designed.

Whereas, an offshore structures function nomination is not important it is the form. So, they are form governed systems because, form is the one which either make it complaint or floating or fixed it is not the function. Remember functions of all the three are exactly same. All the three platforms are meant for oil exploration production, so function is

same form is different. So, form domination will influence three characteristics; the mass of the system, the stickiness of the system, and of course the damping of the system.

One can say, what is about the force? That is the interesting question because, the force attracted based on the form is also challenged; I will tell you why. If a pole is fixed maybe even both the edge, it will have a tendency to attract more forces. If the pole is free floating there is no boundary condition, free. The force attracted by this pole will be the least, why because the pole will start moving and give way to the force passed through the pole. It means there is a relative agreement between the structure and force, when the wave hits the pole moves, when the wave hits the pole moves; that are the relative movement between the structure and the wave. So, this relative movement will compromise the force on the member.

Whereas, this structure will not move at all will attract the forces. So, depending upon the form the force also is governed, but however depending on the form mass, stiffness, and damping will very seriously very that is not doubt on that. You may wonder why we are talking about only four elements mass, stiffness, damping, and force. These are called essential characteristics of a dynamic loading. If you do not having any one of them you do not do dynamic analysis. These are called essential characteristics of a dynamic loading or dynamic analysis. If anyone of them is absent the dynamic analysis is not complete, but there are cases where we study undamped systems, there are cases where we study free vibration so force not present. But there is no case were we study mass is not present stiffness is not present.

Now the question comes why amongst this four these two are very important, why these two are not important. Because, if there is no force one can say the structural will not move, but the structure is meant not a move because it is freely floating. This is one of the important characteristic of any offshore platform, because this will save lots of time and money in terms of commissioning the platform. The platform should enable to free float on its own. The day you make the platform float on its own erection and commissioning charges will drastically come down. If you have got to make the platform to float by some means hocking them, craning etcetera or appending or loading out the construction cost is going phenomenally high which was the problem in fixed type.

So, the type of platform will help you to reduce the forces as well as to make it easy for commissioning and decommissioning, I want to remove the platform because I do not find oil in a specific place I want to decommission the platform. You will now understand many of the fixed offshore structures in alpha Mexico the big (Refer Time: 32:10) happening how they are going to remove this platforms, because there is no oil well available there. Oil well maybe there but there is no production. So, they have become fascinated structure that is all once upon a time it was Conoco had a platform, but Conoco does not produce oil at this specific platform now. What to do with that? You cannot create a hotel and you con not own that much of money what the platform was earning few years back, therefore USA please remove this platform or pay a penalty to us because you cannot hold the waters unnecessarily.

So, decommissioning becomes a serious problem. The movement you say decommissioning it results in environmental impact analysis. If you leave the platform there what will happens to the aqua culture, we remove the platform what will happen to the aqua culture, while removing if you blast what will happen to the aqua culture. There are many accepts relating to even decommissioning also. So, people are paying to the nodes to decommission these platforms. They are trying to find mean by which this platform can be put to use by some means so that they do not have to decommission. So, decommission become very very difficult. Whereas, in platforms like this, in platform like the TLP remove the tethers the platform is set to a float like a vessel or a ship. So, drag the vessel using a tug boat move it from a to b you have decommissioning, so no problem.

So, decommission becomes a challenge and this was not thought earlier when people install platforms in 1900s. The first offshore well was explored in 1899; in 1912 we are taken oils elsewhere in the world not in India but elsewhere. So, these industries about hundred years old, the technology is about hundred years old, but we are learning it unfortunately at the hundredth year. That is the unfortunately part that is our mistake, but people having using this technology for many years. So, these four components become important for dynamic analysis. Out of this four these two become predominantly important, why because based on these two only I make a mathematical model for dynamic analyses.

So, the mathematical modeling is focused on these. Now the question comes how and why, why not on this. That is what you are going to answer that is calling the essential characteristics of dynamic analysis. Any questions here, any doubt, any questions here?

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So, the dynamic loading essential has two components; one is the time variant, the time variant part of it. The second is variation in magnitude; this magnitude may be also variation in direction, variation in space, etcetera. So, these two must be inherently present to prescribe a load as a dynamic load. For example, if the load is not time variant the load cannot be called as a dynamic the load, if the load does not vary in magnitude as well as in time in a static rule. So, these two should there.

Now the question comes any load which having a very load magnitude, but varies your time, can it be called as a dynamic loading. The loading can be called as a dynamic loading but you need not have to do dynamic analysis, why this is the answer now. The answer is, if you want to perform a dynamic analysis the most important component to do a dynamic analysis is inertia force. For example, I have a paper the paper has got a lot of degrees of freedom to move the paper is mass less so I do not generate inertial force on that because m x double dot is a inertial force, I do not have mass I do not have to do dynamic analysis on a paper. Alternatively I have a huge box which is very massive, but

the box does not move still I do not have a dynamic analysis. Because, x double dot is very low. You understand the point.

If you look at these kind of structures now as you move from a massive system to a floating system mass has been compromise, but motion as been en largely very height. Therefore, dynamic analysis becomes very important, very important, and least important. It is because of the reason the dynamic analysis in offshore structures was not developed at least for above 20 years when the platforms are constructed. People thought I have a rigid supported bottom supported system I do not have to bother about in dynamic analysis let us do. So, they when all doing most of them quasi static analysis and the platforms are constructed. When the form starting modifying from fixed to complaint and floating people then realized yes the mass is compromised, but the displacement response became very large so I have to do a dynamic. It means form governing the magnitude and the time variation including the mass is important for doing a dynamic analysis.

So, when you talk about this then one can ask what are the two basic approaches we have; one is deterministic approach, the other is non deterministic. These are two approaches we have. Deterministic approach is applied to analysis where you have something called prescribed loading. Then what is the prescribed loading? If the time variation or the time history of the load is completely known I call this load as prescribed load. If I have prescribed load time history I do dynamic analysis I called that as deterministic approach. I derive all results straight forward. So, the answer is close form solution. So, deterministic approach will give me a close form solution to all the problems what I am doing for dynamic analysis.

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When I talk about non deterministic, it is only an approach not a method please understand, there is a different between approach and a method. This is an approach, it is not a method. If the time variant is not known completely I called this as random loading. In case of random loading I generally express the load using spectrum. So, all solutions I do from this analysis will be all based on response spectrum, so no direct solution, whereas this gives me direct solution.

Again there is basic question ask now in my; sir amongst the 11 types of the loads we are discussed just now which are prescribe loading, which are non prescribed loading. For examples dead load, is the fully prescribed load essentially it is not even dynamic in natures more or less time invariant because dead load is more or less static expect you do not include the variable submergence effect on the dead load. Live loads more or less time invariant, so it is a prescribed loading; wave load, wind load, earthquake load more or less random in nature, so they are non deterministic.

Now, you see there is a combination of difference types of forces acting on the structure what analysis should I do; should I do a spectrum analysis, should do time history. Now either way you can convert them into time history and do an analysis, you can convert this spectrum and do analysis. This is what we called time history analysis, this is what

we called frequency domain analysis, both are available for dynamic analysis and offshore structures both domain are alright. Preferably people do time domain analysis for dynamic analysis structures because, you have got lot of merits compare to frequent domain analysis which we talk about slightly later when we really get into the analysis part in a second module.

So, we have learnt couple of things in this class; one how form dominance changes the behavior of the structural action. Why mass, stiffness, forces, and damping are important. Among these four components of dynamic analysis why mass and stiffness are more important? When I approach through dynamic analysis what are the two approaches I have, how are the different where are they applied, where are they applicable. Once you understand this in the next class we should talk about how mathematically idealize the given system and develop the mathematical model, because I have to do a mathematical analysis I must have a model. How to develop the mathematics model based on the so many dialogues what we discussed in 3 or 4 lectures. Any questions, any questions, any doubt.

So, you please go to the lectures 1, 2 and 3 whenever you are free and of course you have to go to the lecture 4 also. All these lectures will be available to you on the same day maybe after laps once it is processed which you available to of viewing you can download them and see them. And there is an announcement pattern available in the website you can also post a question there which will be answer with 24 hours.

Of course, physically also you can ask questions in the class nobody is stopping you, if you have any questions to ask. So there have any doubts, any questions to ask. This will have an examination at the end. I request that all of you should register for the exam, because this exam has got lot of certification at lot of value other than getting a grade in the class, because your competent is 1200 level in the international community, you really know where do you stand. And there is a benefit that this credit of three from the certificate is also transferable for any programs in IIT as well as in aboard. Of course, a great sheet is also transferable. Similar to that because this course will run for the entire semester for 52 lectures so it is as good as a full semester course.

Therefore these credits are transferable for anywhere higher education program. So, that advantage you have you get the certificate. Those who are looking at this course online is better that you register for the exam. And you can always get duel benefits you can anyway get a grade in the course being participating the course physically can also get a certificate if participate in online exam, you can get both the advantages.

There are text books are available, I have given about 140 references papers and research papers and conference papers. All of them are important; you must see all of them and read all of them. I have given about 80 text books, one amongst is authored by me. You have to read all of them. All tutorials are important, you must participate in the class in form of answering tutorials etcetera then only you will now understand the principle focus of this course is make you to understand dynamic analysis not to make you as a master. If you really know sir I have already understood dynamics completely I am looking for high end dynamic analysis I think I am sorry this course will not address that in the beginning.

But, at the end you will see that you have understood high end dynamic automatically that is the promise. To start with you start with white board. You do not know anything about dynamic analysis we start from that level, we take it stochastic dynamics which many of us do not know in an easy manner in the class room, and we will talk about that like this.