Dynamics Ocean Structures

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Lecture – 1

So, now, will open up the lecture 7 module 2 the module 1 we discussed about the dynamic analysis in general the basic fundamentals of single degree and multi degree freedom system models and we found and bought the natural frequencies motions of different kinds of idealized mathematical model systems used different methods numerical analytical techniques. So, solve the equations of motion for a single degree and multi degree and we understood the necessity of finding out the this to dynamic characteristics of the systems as well as you also understood what are the features of introducing damping in a given system why damping is essential for success of the because we are damping inherently present in the system therefore, is essential that the understand the response behaviour.

Of an damp and un damp system for multi degree and essentially we must know the what is the range of the expedition frequency happening or exciting the structure what is the natural frequency band of the structural system and whether the structure is going to (Refer Time: 01:15) for a given loading and resonates, what would be the response. So, we understood all the analytically and numerically try to find out them. Now, in this module will try to apply them for different kinds of problem which is mathematically idealized problems on different types of structures

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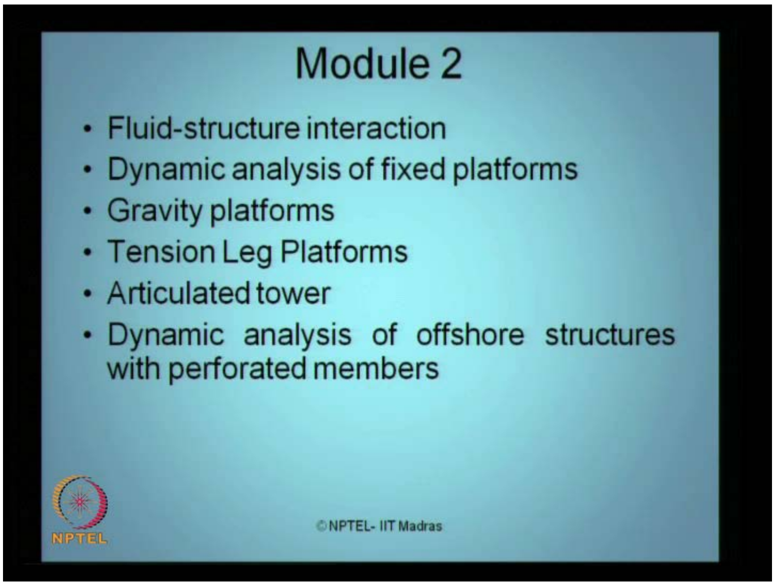

So, the Module 2 will focus on Fluid-structure interaction will also speak about Dynamic analysis of different kinds of offshore structures starting with fixed structures, Gravity platforms, Tension Leg Platforms, Articulated tower and dynamic analysis of offshore structures with perforated members. So, in this module will take you round that what are the different kinds of mathematically idealization we follow to do dynamic analysis of real mathematical model structures in terms of experiments

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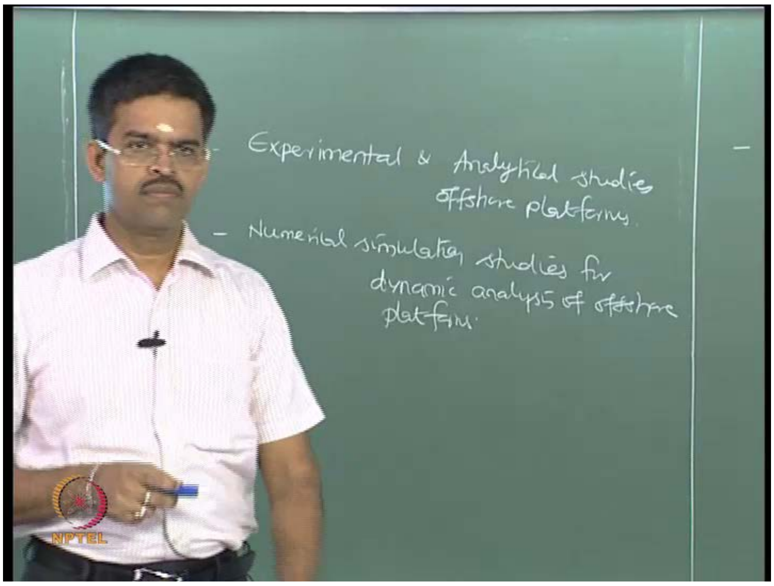

So, in this module will talk about some techniques where we have used for Experimental and Analytical studies as applied to offshore structures will also talk about some Numerical simulation studies carried out for dynamic analysis of a platform in addition we also talk about.

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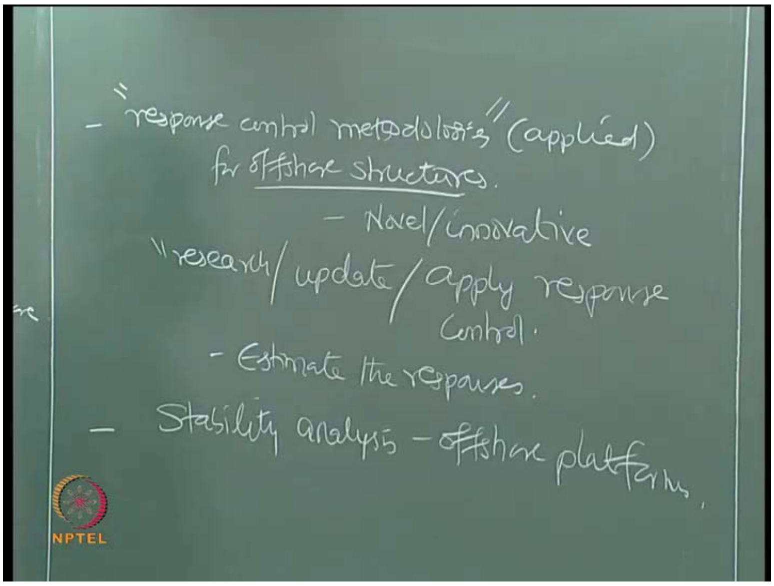

The response control methodologies that can be applied for offshore structures so, will talk about response control methodologies as applied to offshore structures. So, one can see that there are many methods by which response control algorithms are applied to language structures but this kind of application is completely Novel and innovative one by one by that why response control algorithms are not applied to offshore structures because, in overall research as on today people did not bother to actually apply response control people only applied their mind set to estimate the response.

So, in this module we talk about some interesting research carried out by researchers available in the literature there they attempted some response control mechanism for offshore structures we will also take you round some important Stability analysis can you round for offshore platforms in all the studies.

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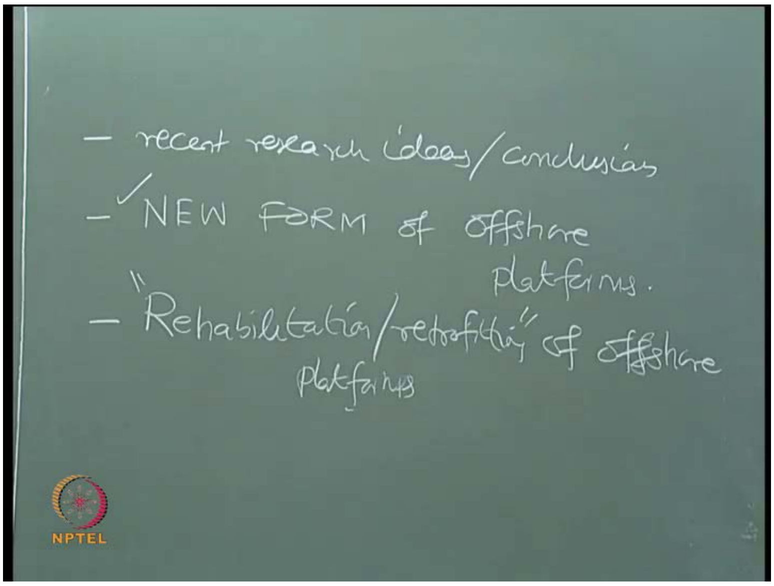

When we discussed we will also highlight some important recent research ideas and conclusions through various research papers. So, will apply this for NEW FORM of offshore structures and more interestingly will talk about something called retrofitting of offshore structures again is a new segment where people apply this technique for language structure, but why retrofitting is essential for offshore platforms what is the necessity what are the different approaches did by people we will also talk about this.

So, this module will be very interesting because will start applying the dynamic analysis principles and concepts for various kinds of offshore platforms as listed in the slides will talk about fixed offshore structures, Gravity platforms, Tension Leg Platforms, Articulated towers and Dynamic analysis offshore structures with perforated members.

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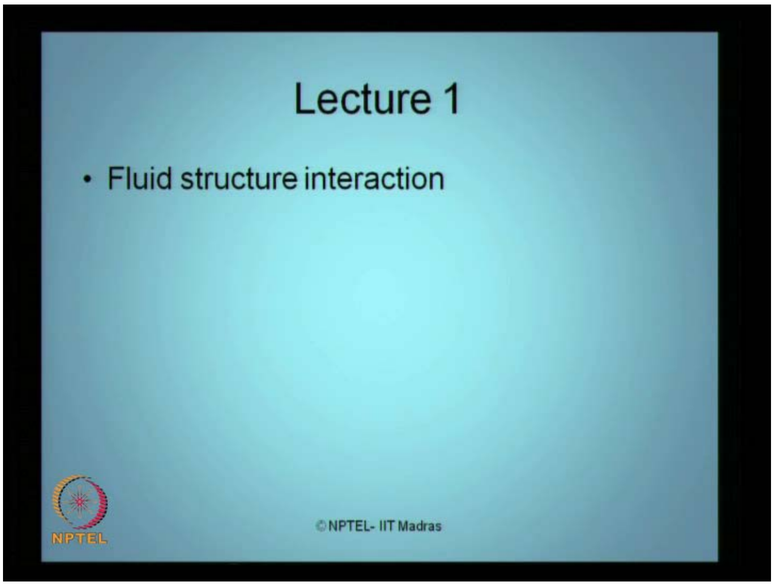

So, in this lecture will focus on Fluid structure interaction may be in the next lecture as well will focus on FSI just to take a brief round what we discussed in the last module very quickly on off shore structures applicable to FSI focus.

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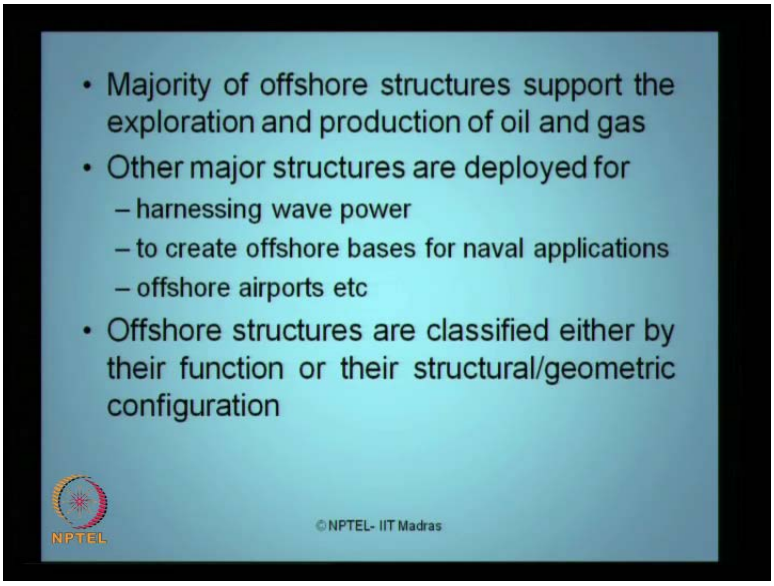

The majority of offshore structures support the exploration and production of oil and gas platforms the other major structures are generally deployed other than for oil exploration or essentially for harnessing wave power because we have got floating devices where people start installing it on the floor on the sea wave to harness wave energy.

Also to create temporary bases for naval applications people also design putting platforms there are of course, offshore airports etc for tourism development also some of the structures are designed also therefore, offshore structures can be very briefly classified either by their function or by the geometry we discussed about this earlier. So, the phenomenon classification of offshore structure will start from the geometric point of view as per the dynamic analysis concern.

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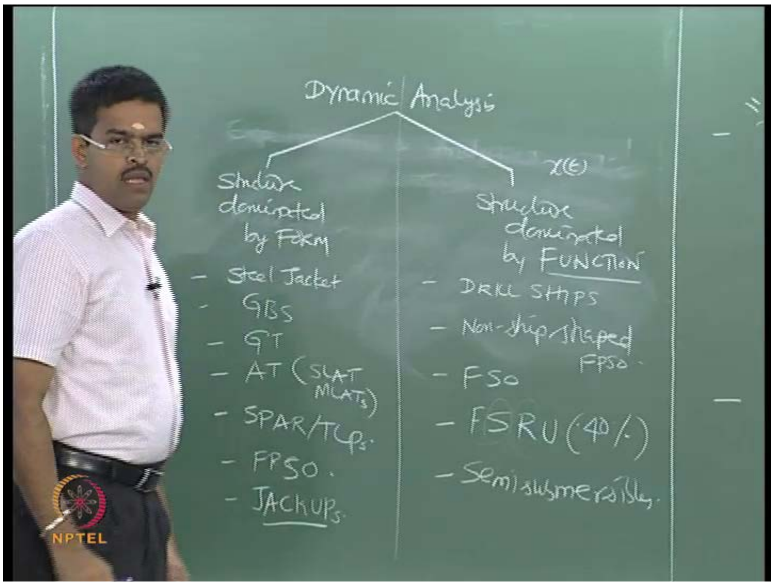

So, will talk about its a Dynamic Analysis concern it talks about two kinds of structure one is Structure dominated by FORM other is Structure dominated by FUNCTION essentially offshore performance a form driven I can give very classical examples again this head starting from let say Steel Jacket platform GBS which are essentially concrete then moved on to GT moved on to AT SLAT and MLATs then we moved on to SPAR and TLPs then moved on to FPSO and so on talk about structures related function we can say DRKL ships.

Non ship shaped FPSO of course, FSO and of course, now floating FSRU Floating Storage Regasification units because Regasification has become an very important aspects in offshore on production. So, instead of transporting the crude oil from offshore to onshore and then this thing the residual material and the processing people started doing the Regasification in the offshore platform itself then transport only the gaseous part of it. So, the remaining residue may not be transported because transportation costs from offshore to onshore because the longer length of the pipelines becomes very expensive.

So, these studies conducted in Indonesia very clearly show that FSRU say more than above 40 percent cost of post processing a fire. So, people started moving the idea of post processing from onshore to offshore itself. So, people need a very large kind of floating putting storage and regasification units which are now coming up in the later stage and of course, Semi susmersils they are not mention about jack up these are also important concept fine formed.

So, the Dynamic Analysis both of them categorically divide because here in this cases where function is important we work with Dynamic Analysis with the focus on displacements whereas the structures where it is dominated form we will focus on size so obviously, structures which are dominated form talked about size I want make them visit therefore, I do the following I want to make them flexible therefore, I will do the following.

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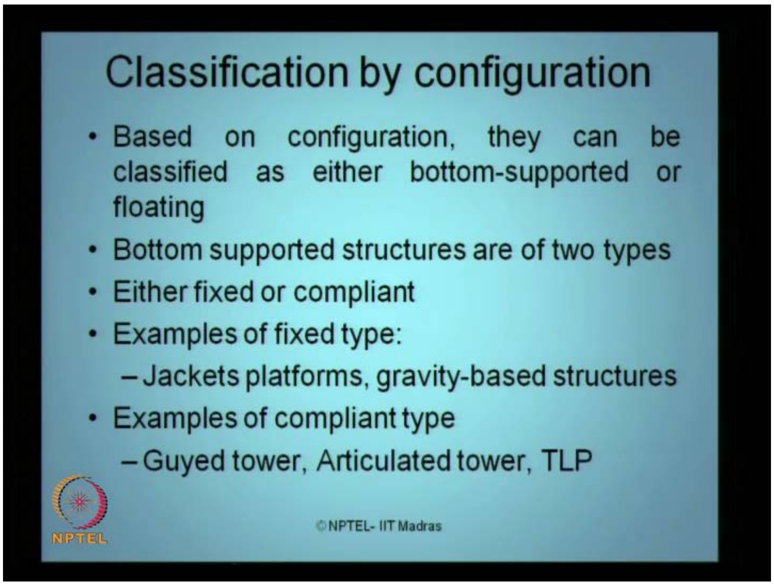

So, will talk about Classification by configuration which we already saw in the last module based on the configuration they can classified either. Bottom supported or floating from can easily see which are supposed to be bottom supported which are floating. So, just for understanding bottom supported structures can be again classified into two forms which are either fixed or complain because I am talking about the flexibility and visibility in post on the structural form. So, when you start fixing the base of the structure to see that I will get enormous rigidity because of the fixed to offer to the platform on the sea where in will talk about floating or complained system then will talk about flexibility introduced in the form itself. So, bottom supported structures can be the two ways one is highly rigid are very highly flexible or on the other hand fixed and complianed structures fixed structures are examples the Jackets platforms gravity base structures for example, whereas compliant type can have Guyed towers Articulated towers TLPS and spars etc.

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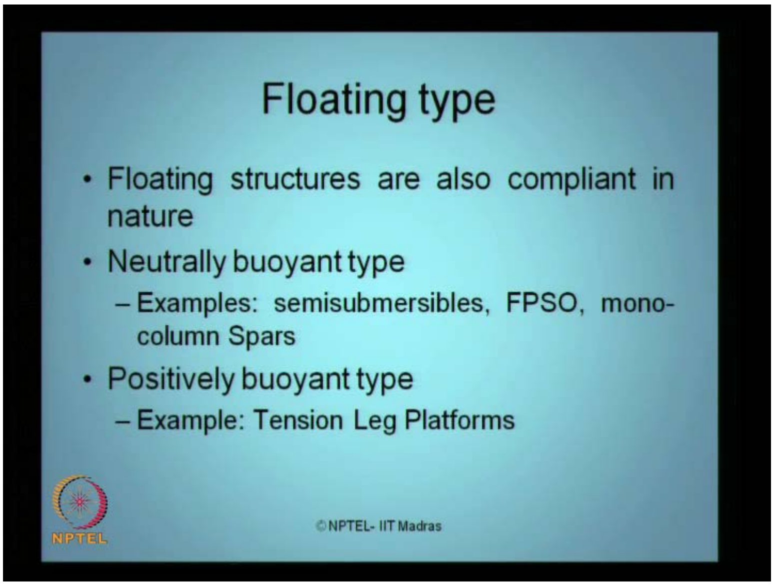

When we talk about the next type of configuration which is the floating type we already said floating type are also compliant in nature then in this case we can neutrally buoyant type structures like semisubmersibles, FPSO, and mono column Spars where as in also have Positively buoyant type where TLP understand the form is very interesting because the buoyant enormously exceeds the weight of the platform.

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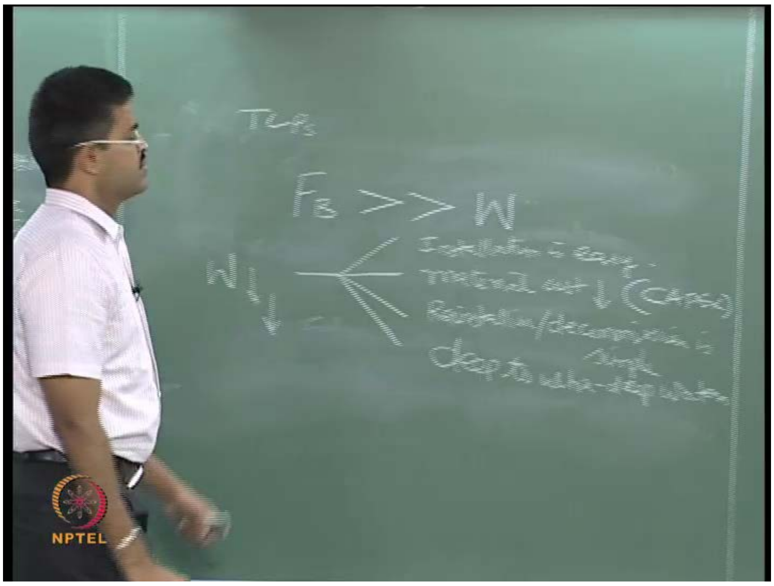

There is the fundamental catchier in the design as per as TLPS are concern (Refer Time: 14:36) enormously exceeds the weight of the platform on the other hand if the weight of the platform is enormously low this has many advantages it the installation becomes economical. Material cost is low what we call as CAPEX capital investment towards initial form is low Reinstallation or decommission becomes simple and because of these advantages it can go for deep to alter what. So, that innovative as TLPS concern which is positively buoyant type structure whereas, neutrally buoyant type and semisubmersibles which depends upon the draft at which is being installed of course, FPSOS mono column spars.

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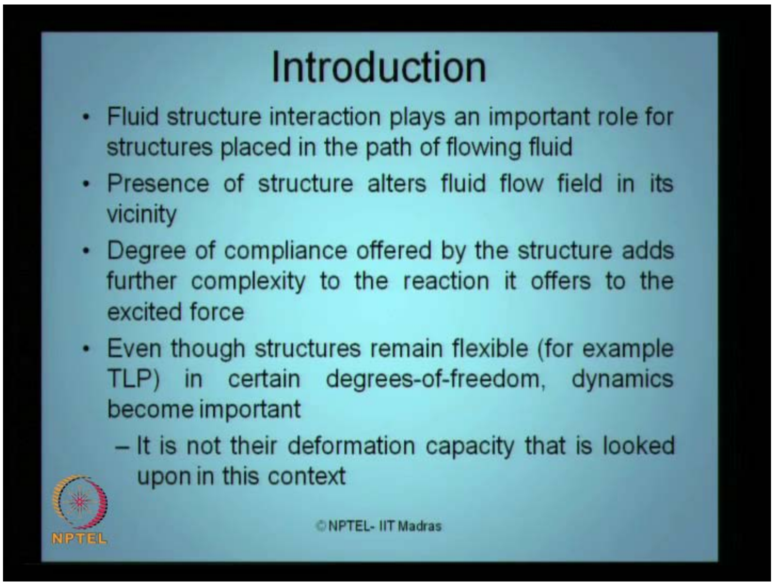

So, will speak about fluid structure interaction now do you any questions what we have in the discussions just now before we starting in to this review to the fluid structure interaction problem any questions will talk about FSI Fluid structure interaction place a very important role for structures placed in the flowing fluid for example, we have a fluid where we place a structure do you remember in the path of the flowing fluid structure interaction with that of the fluid flow is a very important role see what are the factors which will affect this the presence of structure essentially alters the fluid flow field in the vicinity of the member that is very important. So, one may wonder how the influence of fluid flow field in the vicinity will affect my dynamic analysis to understand very briefly

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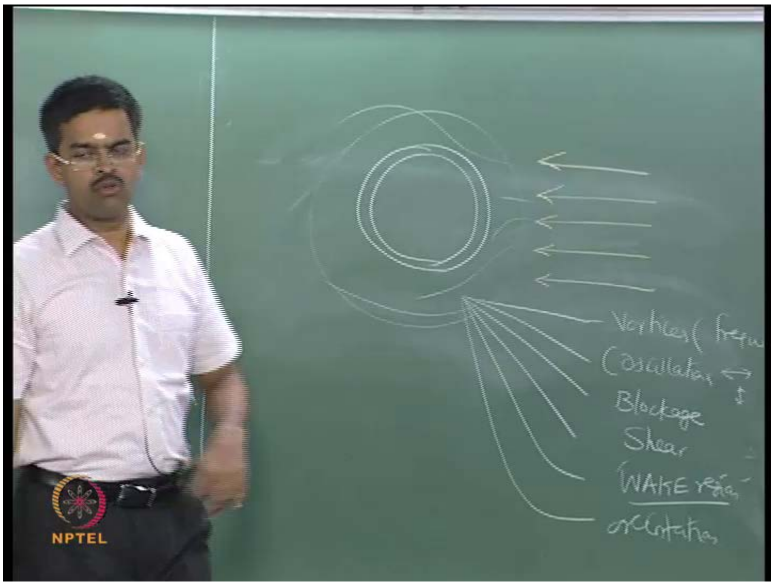

(Refer Time: 17:20) I am drawing the plan usually offshore structures are circular and diameter and are hallow and this may fluid flow field so, it alters characteristic of the field in the vicinity of this. So, it influences many factors it can create vertices. Vertices are nothing, but forces associated with different frequency contents it can create of course, oscillations parallel to the flow and normal to the flow can also create Blockage can also create Shear it introduce the new region this is called WAKE region. So, the interference in the single cylindrical member and of course, orientation of the member whether you place the number parallel to the flow or normal to the flow and of course, a flow field whether the flow filed is uniform or shear type depending upon the variety of factors influencing the flow field on the member do such interaction becomes interesting and important and therefore, how we suffix Dynamic Analysis and this is very simple in the left hand side of the equation if you see let say MX double dot plus cX dot plus kx is F of t that is where classification theoretical dynamic let say equations the motion for a given member single degree or multi degree here quickly understand which are the parameters here influenced by the field flow vicinity in the member as I say blockage is one aspect which can affect the force acting which depends upon the diameter member and series of members in the row.

So, it will affect the mass and blockage are frequency sometimes also submersibles effect which will again affect the mass because of the varying the submersibles and the shear of the regime or the shear flow will affect direction of forces acting member. So, F of t will affect the orientation of the member can create vibrations along an across which will offer again forces in two dimensional state what does in this frequency will cost secondary vibration which is affect omega which is again function of k by m of the whole system.

So, fluid flow with an interference to a structural member which is called as fluid structure interaction can influence many parameters in your equations almost in addition to that the structure is compliant the form k will be affected because of the FSI then of course, because of the submersibles affect because, variance of k and m instantaneously c will also be affected.

So, all parameters especially will get affected if you have any structure member interfering with the fluid flow region in any uniform field or any terminal field as well. So, FSI becomes a very important parameter because we should understand how fluid such interaction will influence the dynamic behaviour response behaviour given structural member in the given regime of fluid flow that is what we are trying to look at it how this is taken care of will talk about that because I said all these parameters will get transformed directly or indirectly in the dynamic analysis how the element transformed is what we will see slowly will as we look into different kinds of platforms, but let us try to understand what are these and how are what do you mean by them and how do we conclude them approximately we must know this that is what we are looking at here.

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So, therefore, the degree of compliance offered by the structure adds further complexity for example, if the member is fixed to the bottom if the member is infinitely long if the boundary conditions are no effect on the fluid flow then the behaviour of the member is different or the interference of fluid on the structure in the vicinity is different the member is a finite length with the member ends close and the member is closed to the submerge region or closed to the presurface then a boundary effects will play a role on this and therefore, if the member is also not fix, but floating as in the case of TLPS etc then in that situation then the compliants offer by the member will again introduce further complexity to the fluid regime or the fluid for regime in the vicinity of the member.

So, not only the member dimension not only the member orientation, but the member location in the member fixety will also affect the characteristic or influence the characteristic behaviour of the member in the given fluid flow regime which we called as Fluid structure interaction. So, even though structure remain flexible for example, TLP as the members move when the force acting on the member the structure is construct to be or the members are construct to be flexible in certain degrees of freedom because 6 degrees of freedom whereas all the 6 degrees are not complian only few degrees for example, search SWA and yarn motions of complianed where as key role and pitch motions are not complained they are stiff degrees of freedom. So, in few degrees of freedom it is complained however, even the stiff degrees also (Refer Time: 23:43) has become important because in complained degrees response will become important in stiff degrees forces will become important that how we all when we have stiff structure fixed member or member fixed to the support force are becoming important because then response should be very minimum for example, gravity based structure or fixed jacket structure.

So, when you have got a structure system or a member whose dimensions are related to the flow field and the boundary conditions impose fixity on the member then forces on the member stresses on the member becomes very important therefore, fitting plays a very important role when we talk about complain structures then response becomes important. So, for example, a complain system like TLP where certain degrees are fixed certain degrees complained both are important.

So, we are not looking at the deformation capacity it is very important to understand what is difference between the response and deformation capacity lets quickly look at this now to understand a difference between these two suppose I am a structure as member which is complained may be a buoyant like structure BLS

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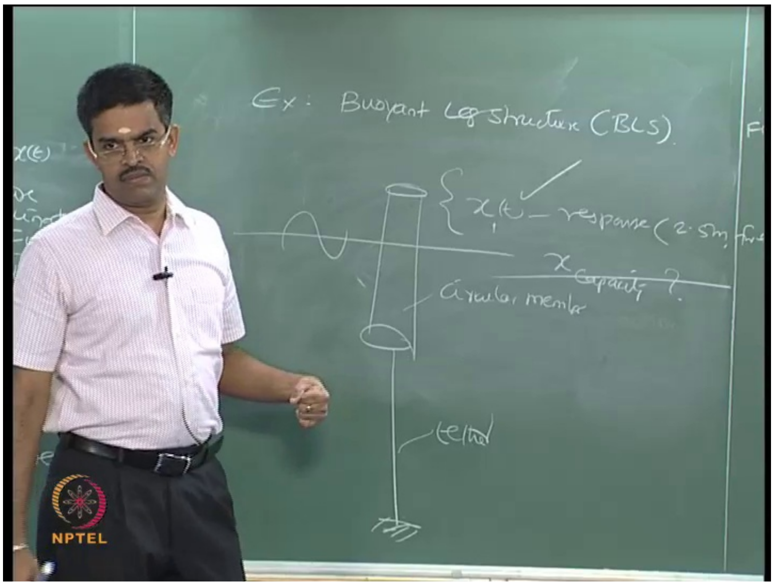

Let us say for example, lets us consider a Buoyant Leg Structure which is BLS is nothing, but a cylinder which is anchor to the either circular member for different purpose they are being use for example, it is a simply floating point obsorbous point buoyant. So, under the wave action the structure or the member keeps on oscillating. So, x of t in a specific degree of freedom let say X1 of is a surge motion this is the response of (Refer Time: 25:49) now for example, the maximum response of a given wave height and weight period at one instance goes to let us say 2.5 litres for example.

Whether the member or the fitting attach the members can sustain this response whether these members can sustain this response is a capacity of the member in the Dynamic Analysis we are not looking at this that is design in dynamic analysis we looking only at this that is what I am saying here it is not the deformation capacity of the member we are not looking at the deformation capacity of the member we are looking the response of the member they are different of course, if the deformation capacity exceeds the response of the member if the member is safe otherwise the member is member will get in to post that kind of behaviour even depending upon the material characteristics etc that is a design part we are not looking at all in Dynamic Analysis remember this we are not combining these two; we are looking only at the response feature of this we are not looking at the capacity of this.

So, it is very clear deformation capacity is not look therefore, material characteristics will not play a major role in dynamic analysis primitively then one can say how can include the material characteristics also on the Dynamic Analysis I can say you do non-linear dynamic analysis where nonlinearity can come from many sources one of the sources what we have in offshore structure system is F of t the forcing function itself can be a non-linear function the remaining nonlinearities can come from large deformations large displacements and of course a material characteristics etc.

So, if you want include this behaviour in the dynamic analysis then I should do non-linear dynamic analysis if you do not want to include them I simply said Dynamic Analysis where I am looking only at the response nor the capacity that is what this last point in the slide means that cannot looking at the deformation capacity, but we are looking into response.

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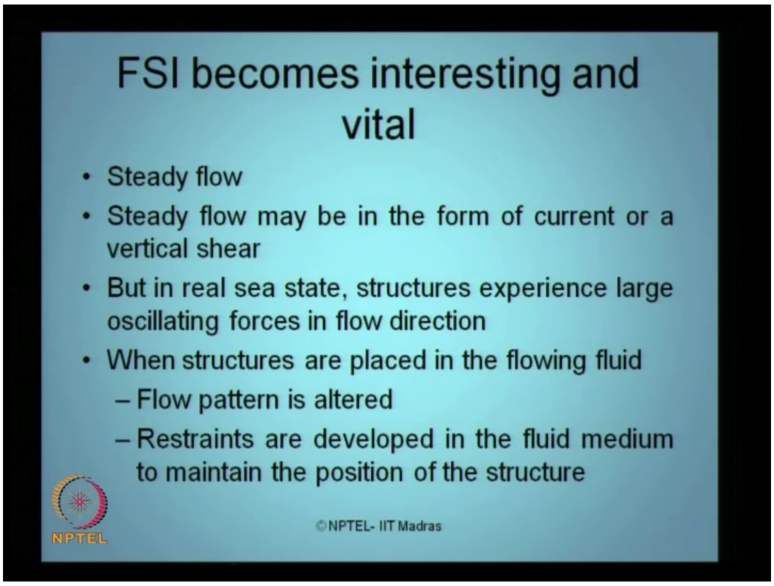

So, FSI becomes interesting because will talk about steady flow when Steady flow may be in the form of current or a vertical shear, but in the real sea state structures experience large oscillating forces in the flow direction as I just now showed you what are the factors affecting the members in the vicinity of a fluid region when the structures are placed in the flowing fluid then the Flow pattern of the fluid itself is altered that is very interesting as I showed here the uniform flow can get altered and diversify. So, the flow fluid itself the flow pattern itself will get diverted or change because of the presence of the member depending upon how large is the member how many member of members are kept in series is in parallel and so on what is the spacing of the member etc.

So, the flow direction or the flow pattern itself will get change and of course, whenever a member is subjected to a action given by the base for example, lateral forces the member will always invoke reaction to it what we called Restraint forces is an excitation force given by the external agency in this case a wave train. So, the member will develop an opposing force to it what we called Restraint force which will depending upon what we called the material characteristic of the member the dimension of the member the boundary condition where the member is fixed or floating etc. So, these restraints developed in the fluid medium will be actually essential responsible for maintaining the position of the member if the Restraint force are much less then that the excitation force the member will start moving the Restraint forces are much higher than that of the excitation force the member which construct to be stiff you will not move the response will become very low.

So, the Restraints are developed in the fluid medium to maintain the position of the structure is nothing to do with the reaction to the forces is actually invoking the position fixity of the member in a given fluid regime why when the fluid attacks or let say acts on a given structural member the fluid feel around the member try to disturb the position of the member. So, the Restraint force of the member are developed only the contract this that is what we say indirectly in to a fluid structure interaction on the other hand structure is not exposing any force back on the fluid regime it is only developing Restraint forces which is essentially responsible to keep the member in geometric location position is that clear. So, on the other hand the simple terms waves try to push the member members do not want to move they oppose the generate Restraint forces. So, this is actually in actual happening in a FSI concept in a given vicinity of the member now the question is before the member and after the member vicinity the train is as normal as it is. So, only around the vicinity we are bothering.

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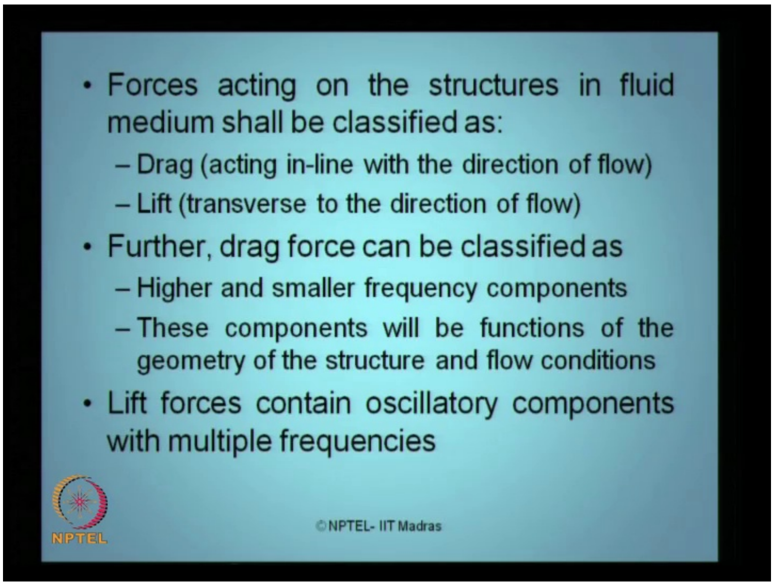

So, the Forces acting in the structure in the fluid medium can be further classified interestingly into two parts one is what we called as the Drag force which acting in line with the direction of flow the other is what we called a Lift force which transverse to the direction of flow (Refer Time: 31:26) variation of two parts we all know this.

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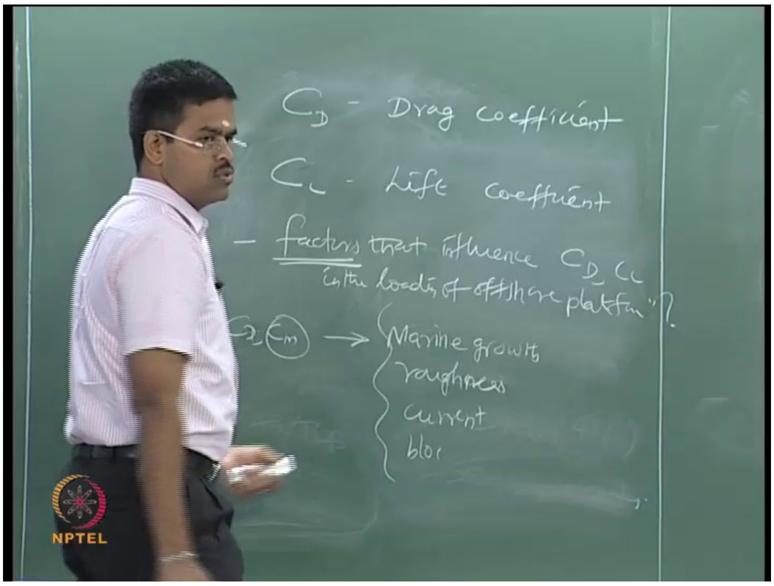

So, the coefficients which are responsible to estimate this forces or nothing, but CD and CL which is referred in the literature and we all understand this. So, interestingly I have a question for you list the factors that influence we already spoke about this in the 1^{st}first module that influence CD and CL in the loop of offshore platform.

So, this is an exercise for you to just find out what are the factors which will contribute to the variation of CD and CL I can just give a clue for you CD and CM is affected essentially by Marine growth roughness presence of current blockage I mean there are many buoyant I want you to just look in to this and see what are the factors which influence these coefficients which are essentially force coefficients because when the member is interacting with the environment in case of fluid regime as I initially said that the members develop Restraint forces just looking the members in position these forces are generated in two formats one is in line with the fluid flow other is transverse the fluid flow what we call as Drag and Lift forces.

So, remember Drag and Lift forces are essentially the restraints develop by the member to contract the action of the wave or the horizontal forces on the member essentially to keep the member in position. So, Drag force can further be classified as components having Higher and smaller frequencies because Drag forces will have components of difference frequency band it can have higher and smaller frequency components why we interested in dynamic analysis and frequencies because we are talking about the frequency content of the force which is generated because of the excitation phenomena and the frequency because of natural characteristics of the dynamic characteristics of system itself.

So, drag of both the components which is having Higher and smaller frequencies these components of course, will be a function of geometry we already saw that and the flow conditions which we are seeing now. So, these are two ways it depends on the geometry of the structural system as well as the flow conditions of course, we will talk about Lift forces, Lift forces contain oscillatory components with multiple frequency so, very interestingly when we talk about these two kinds of forces and transient in steady state response there are two kinds of response we have seen in dynamic analysis or a given member or a given structural system initially it can be a.

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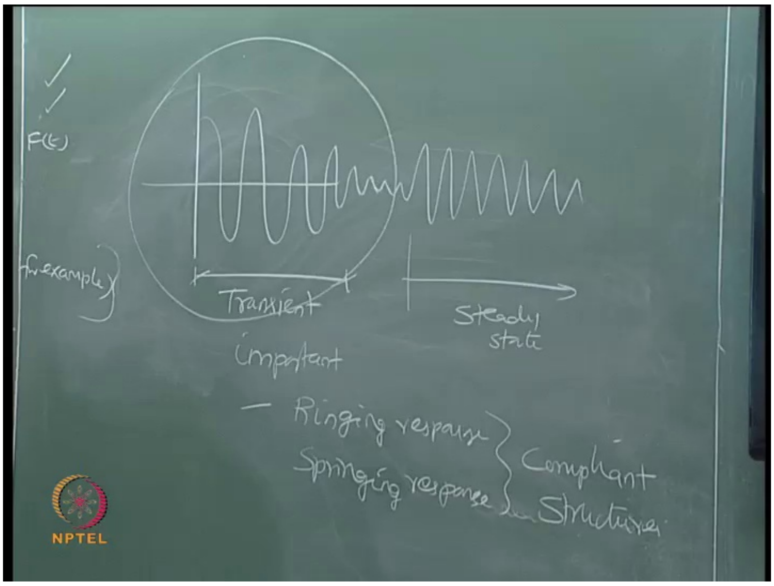

It can be a Transient response and then of course, it can be a Steady state response we already seen the categorically difference between the Transient response and Steady state response single degree freedom analysis in the last module. So, sometimes interestingly even the Transient response sector can also become important this can cost what we call Ringing response and Springing response essentially on complain structures.

Therefore, intensively if you have a Lift force which is having multiple frequency bands it is important for me to understand the frequency band and amplitude of this forces. So, not necessarily that material frequency may have a lower content, but since a frequency content is phenomenon representing my response function I can always have resonance in the transistor itself. So, will talk about this later about the Ringing and springing responses in complain structures like TLPS and spars. So, even the Transient response become sometimes very important or phenomenon important in certain cases where we talk about the responses and there large band of frequencies with lower amplitude or small band of frequencies with higher amplitude which can be otherwise not important in dynamic analysis, but sometimes even this can excite the platform to a dangerous level or x of TS.

So, lift forces can also contain oscillatory components which are also important for us. So, Drag contain higher and smaller frequency components which is essentially function of geometry and the fluid flow conditions whereas lift force contains variety of oscillatory

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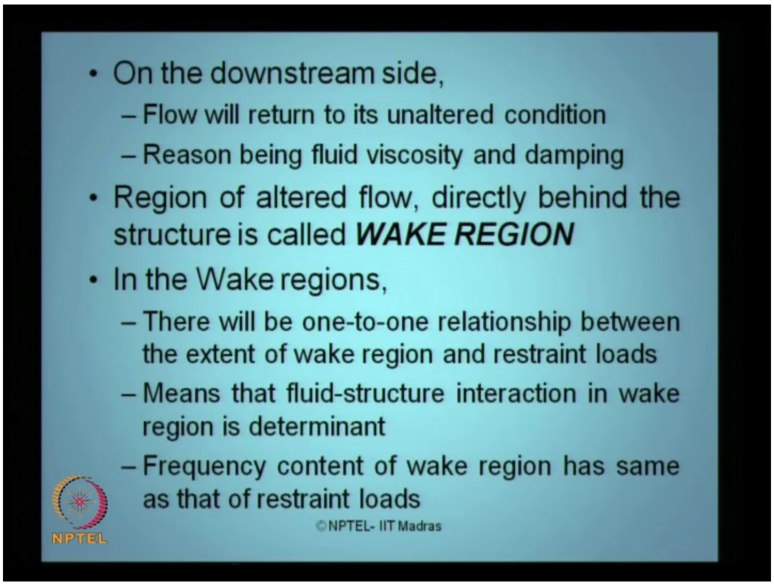

Frequency components I will talk about the fluid structure interaction when the wave train is skipping a member on the downstream side on the downstream side Flow will return to its unaltered condition after it interacts with the member after the flow pass the member.

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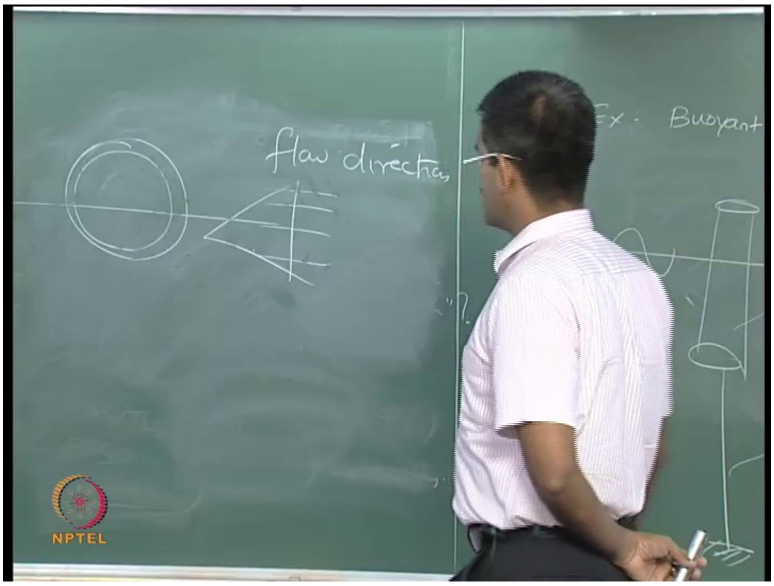

So, on the downstream side the flow returns to it normal you know unaltered state after pass the member there are reasons for this why this flow which has been disturbed or the flow field which has been disturbed because of interference of the member returns to its normal there is a reason for this the reasons are it has got it is depending on the viscosity of the fluid and of course, the damping present in the system not the structure the system is hyrodynamic damping present in the water bird.

So, because of these two reasons even though the fluid flow is disturbed turbulently in the vicinity of the member after it pass the member on the downstream side it becomes again normal the reason is viscosity of the fluid as well as damping present in the system. Now, let us look at this region where my fluid flow is significantly altered or disturbed. So, the region just behind the member this may forward member this is backward direction the region just behind the member is what is called is WAKE REGION. Interestingly the Wake region have a very special characteristic will see that quickly the next line in the Wake regions interestingly there is one to one relationship between the extent of wake region in the restraint loads depending upon the restraint loads generated by the member what is the extent beyond which the wake region will not be present is dominantly controlled by the forces generated by the member here is one to one correspondence of this and interestingly the fluid structure interaction in the wake region therefore, becomes deterministic it is not very complicated it is very simple because it depends purely on one is to one relationship of the restraint force generated by the member or the cylinder.

So, the frequency content of Wake region has same as the that of restraint loads if the restraint loads have a frequency band for example, from 15 to 25 Hertz Wake region will develop the frequency on the same exactly on the same range it means Wake region is actually a response reflection of the disturbance cost with the member on the fluid flow it is on the downstream side now, the Wake region alters the fluid flow significantly let us see how does it do we look at the flow regions or Flow regimes in uniform flow.

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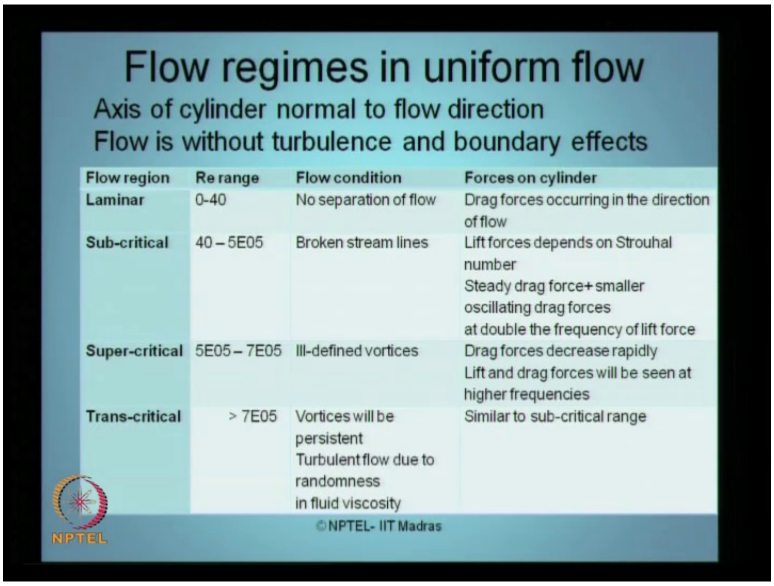

If you keep the axis the member normal to the flow direction and the flow is assume to be no turbulence and boundary effects are neglected then in that case there are four kinds of flow regions which we can identify one is what we called Laminar flow when there Reynolds number lies between 0 to 40. The flow is called as Sub- critical, Super- critical and Trans- critical depending upon the value of Reynolds number varying 40 to 510 power 5 this 5E 05 is nothing, but 5 10 power 5 Reynolds number varying from 40 to let say 5 10 power 5 is what we called Sub- critical and Super- critical varies from 5 10 power 5 till 7 and then Reynolds number is more than 7 10 power 5 we called the flow regime as of flow region as Trans- critical region depending upon the soldely. And Reynolds number we can say then the flow conditions can be again the define for the different regions as we see in this table for example, if the flow is Laminar there is no separation of flow which will result only on Drag forces on the member in the direction of flow it means your Reynolds number lying between the 0 to 40 the flow will remain Laminar.

And no separation will occur and dominantly Drag forces only will be present or Drag forces are the restraint forces generated by the member because of the FSI acting on the member is that clear if the Reynolds number varies from 4 to 40 to 5 10 power 5 if the flow region is sub critical then we generate are what we called Broken stream lines therefore, Lift forces present in this region will depends upon the Strouhals number and it will have the Steady drag force component plus smaller oscillating drag forces which will oscillate at the double frequency of lift force.

So, there will be two components distinctly seen in your response or in the four generation one will be a of course, a Steady drag force the other will be a Drag force which will be oscillating at a frequency as at double of the lift force itself. So, will look at the Super- critical region we have got ill define what is that generated in this region Drag forces decrease rapidly in this region of course, Lift forces and drag forces will be seen at very high frequencies in this region if the flow region moves to Trans- critical what is its present dominantly and the flow will become turbulent and then the forces on the cylinder generated will be as similar to sub critical regions where the lift force again depends on the Stroughal number and the drag force will have two components one will be a Steady drag force and other will be a drag force occurring or double the frequency approximately as that of the lift forces.

So, depending upon the member interfering the flow region depending upon the location or the orientation of the member the axis the member or axis of the cylinder is now kept normal to the flow direction and of course, you ignore or you do not consider the turbulence in the flow field and you do not consider the boundary effects at all its a free boundary. In that situation the flow region can be divide into four components depending upon purely a Reynolds number I can easily estimate the Forces on cylinder as either a Drag force or a Lift force or a drag plus lift at different frequency bands depending upon how the member interference with the flow field looking forward further.

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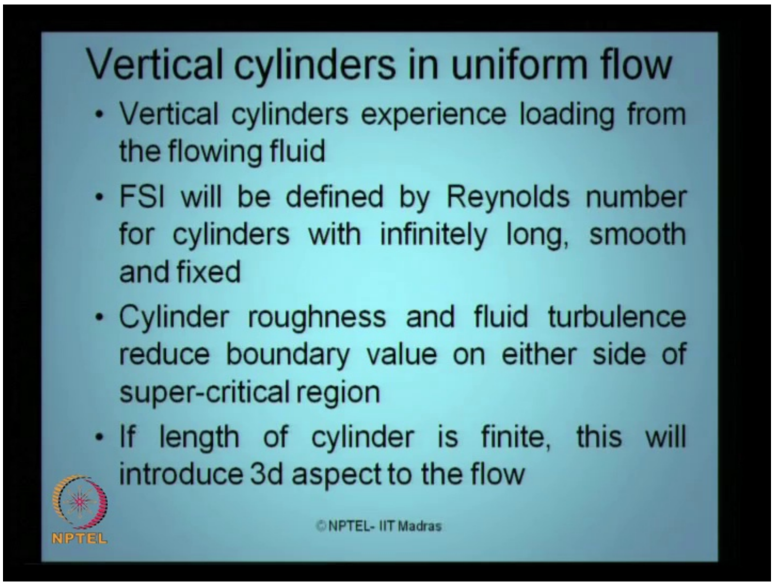

We look at the Vertical cylinders at uniform flow the Vertical cylinders experience loading from the flowing fluid again the fluid structure will again define Reynolds number for the cylinders provided the cylinders are consider to be infinitely long smooth and fixed. So, if you have got infinitely long smooth and fixed cylinders then you can always estimate the response of these members in a FSI region purely based on Reynolds number only the cylinder roughness and fluid turbulence.

Reduce the boundary value of course, in either side of the super- critical region if the length of the cylinder is become finite then the problem will translate to 3d aspect of the fluid flow if you got the finite length of the member then the fluid flow aspect or the fluid structure interaction problem will get in to the 3d mode.

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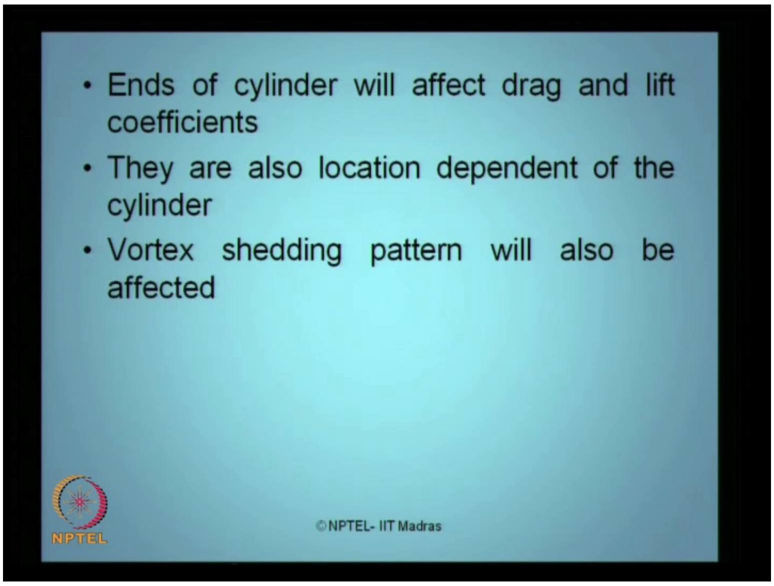

So, the Ends of the cylinder will affect the drag or lift coefficients as we just now saw CD and CL therefore, we can always say the factors influence on CD and CL can also depend on whether the ends of the cylinder is finite and it is closed and of course, most importantly they are location dependent on the cylinder where the cylinder is lying the cylinder is closed to the boundary the close in to the free surface etc location dependent and Vortex shedding pattern will also be affected by the presence of cylinder in the fluid flow region. So, let us look at this figure or the table then consider to this figure.

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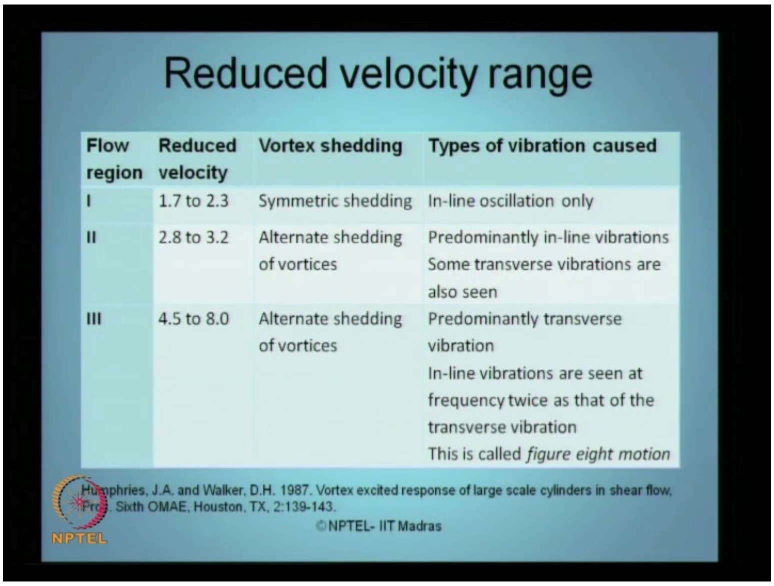

Flow region	Reduced velocity	Vortex shedding	Types of vibration caused
I	1.7 to 2.3	Symmetric shedding	In-line oscillation only
II	2.8 to 3.2	Alternate shedding of vortices	Predominantly in-line vibrations Some transverse vibrations are also seen
III	4.5 to 8.0	Alternate shedding of vortices	Predominantly transverse vibration In-line vibrations are seen at frequency twice as that of the transverse vibration This is called *figure eight motion*

If you look at the reduction in velocity occurring because of the interface of the member on the fluid region can divide this region in- to three as one two and three the reduction of velocity takes place from 1.7 and 2.3 where as it can vary from 2.8 3.2 and further adjustment 4.5 and 8.0 depending upon the regions of one two and three in the region one when the reduce velocity takes from 1.7 to 2.3 there is what we called Symmetric shedding and therefore, only in line oscillation (Refer Time: 46:29) look at the vibration problem of the cylinder the cylinder is expected to oscillate only in line direction that is on the flow direction only if the reduction of velocity takes place 1.7 to 2.3 where as if the velocity reduces very high as 8 then predominantly will be in transverse direction that is very important.

So, if you start reducing a velocity of fluid flow because of interference of the member because of its smoothness because of its fixity because of its location because of its length because of the boundary conditions etc as higher the velocity keeps on reducing the characteristic of vibration will transform from the in line to transverse. So, interestingly this in line vibration which is happening at reduced velocity at 4.8 8.0 is what we called figure eight motion the structure will start oscillating in a characteristic of eight geometric shape this called figure eight motion. So, inline vibration will also be present at a frequency twice as that of the transient vibration. So, the frequency content of the trans transverse as well as inline both will be appearing incase when a reduced velocity of 4.5 to 8.0 and this occurs essentially because of vortices shedding.

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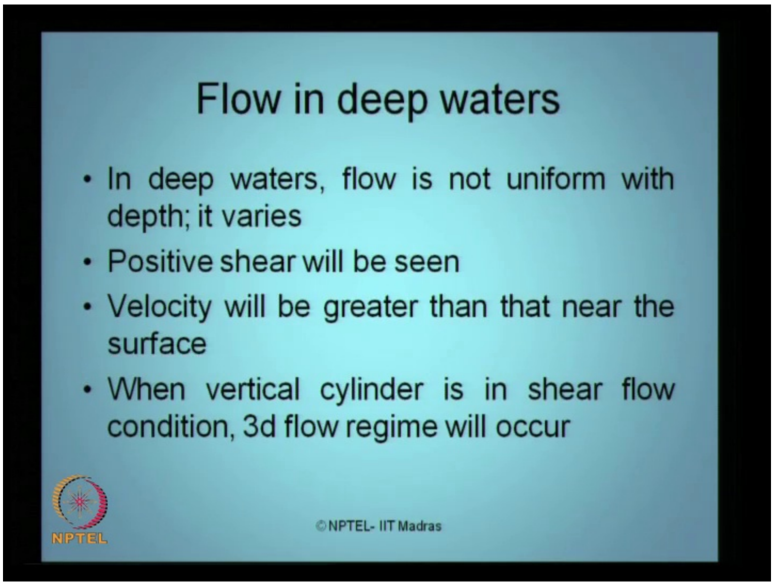

So, look at flow in deep waters the flow is not uniform with the depth it varies Positive shear will be mostly seen Velocity will be greater than that near the surface as you go deeper and deeper where vertical cylinders in shear flow condition then generate what we called 3d regime in the flow field.

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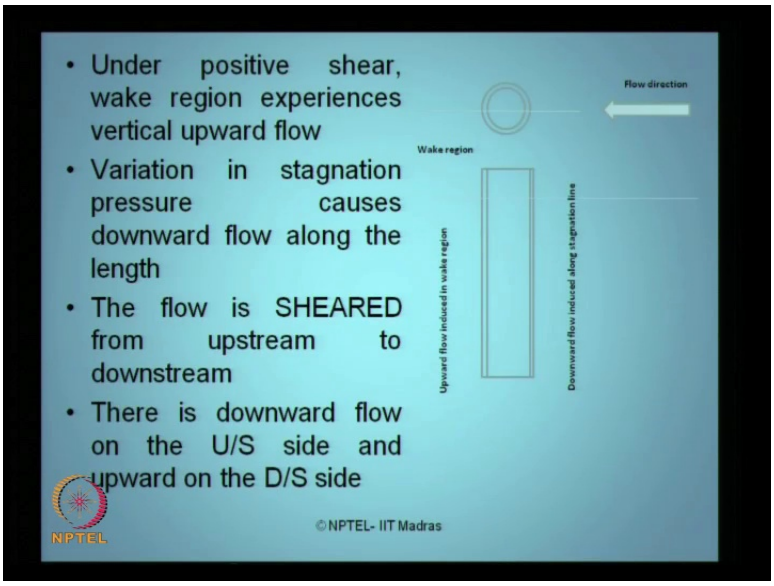

So, if you look at the wake region interestingly this may cylindrical member this may flow direction which is may flow direction if this may flow direction on the upstream side the flow is downward where as in the downstream side the flow is upward. So, the presence of member alters the flow field in the wake region like this I say just now said the again the member is what we call as a wake region. So, on the upstream side the flow is downward where as in the downstream side the flow is upward.

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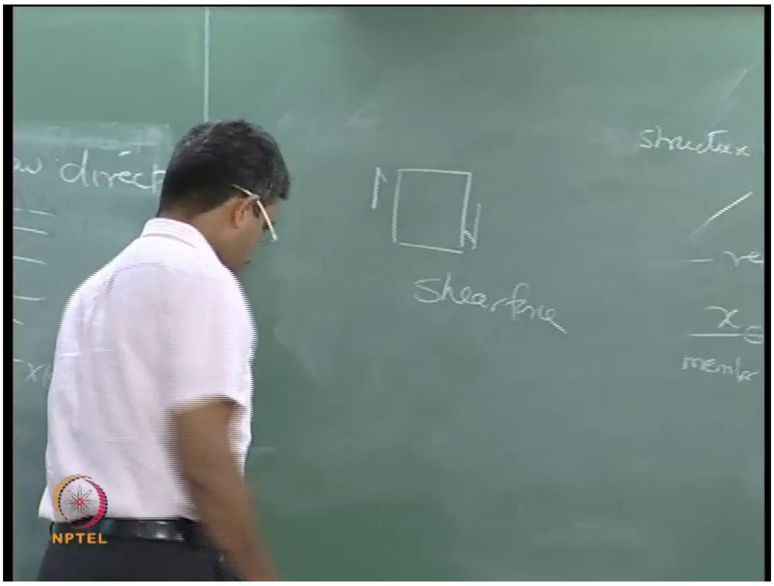

So, if we look at the whole problem like this what is doing the member actually shears of the flow field shear is nothing, but if you have member or structural member where the forces acting like this we called this as Shear force is it or not. So, the presence of member in this case actually shear is the flow field you can see that. So, one way it is downward other way it is upward. So, this is what we call as the force sheared of in the upstream and downstream side. So, the Shear flow effect reduces the pressure coefficient at the top of the cylinder whereas at the bottom it increases the coefficient.

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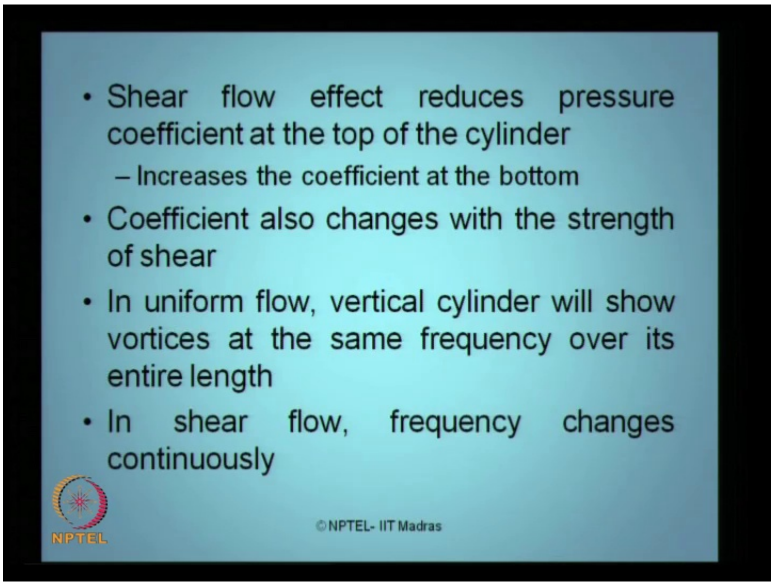

So, in the cylinder itself at the top the pressure coefficient decreases whereas the bottom it is increasing. So, there is a differential pressure set to the cylinder link itself the coefficient of course, changes with the strength of shear present in the fluid flow when the uniform flow cylinder will show vortices of the same frequency over the entire length of the cylinder keep the flow is very uniform of course, if the shear flow the frequency changes continuously.