Dynamics of Ocean Structures
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Module - 1
Lecture - 4
Types of Compliant Towers

So, we will continue with the class coming to the fourth lecture on dynamics of ocean structures.

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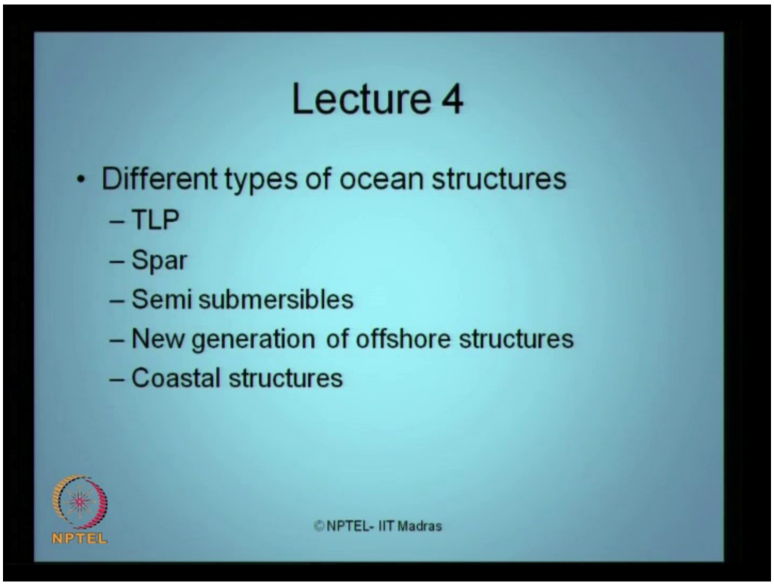

In this lecture, we will talk about more on different kinds of compliant systems. They are tension leg platforms, spar, semi submersibles, new generation of offshore structures and some very brief introduction to coastal structures. In the next lecture we will discuss about some of the different varieties of coastal structures and how are their structural action been defined for different kinds of loads.

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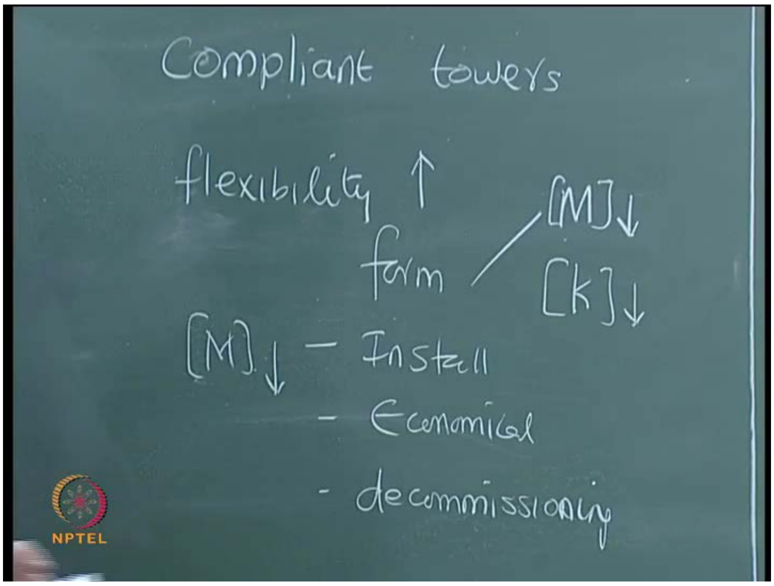

So, for the understanding of what we discussed in the last lecture, we said that complaint towers have high degree of flexibility. Flexibility is high, the advantage of this flexibility, which is introduced from the form is mass is lower, stiffness is also lower. Now, mass getting lower helps me to install; makes it economical, makes decommissioning, simple.

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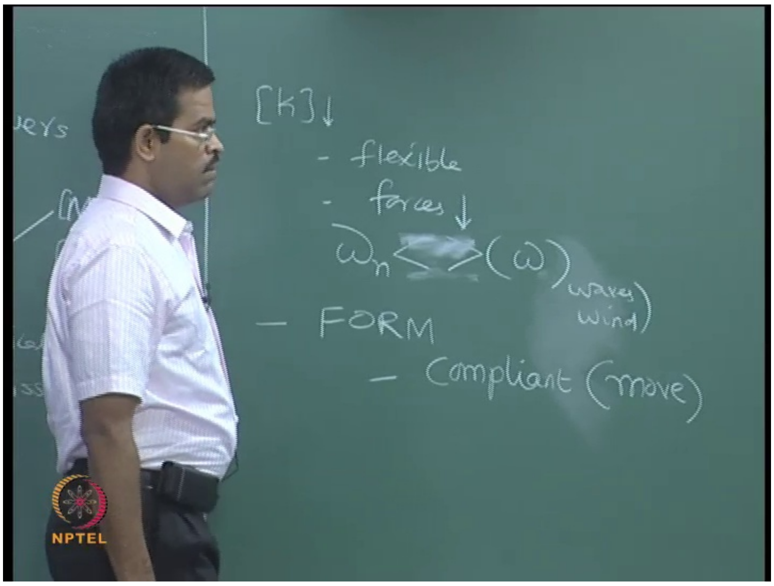

Stiffness getting lower makes the structure flexible by the virtue of which it will attract lesser forces and most importantly the natural frequency of the system is beyond the bandwidth of natural frequency of the waves or frequency of the waves, waves, wind etcetera. It is not in the bandwidth of this.

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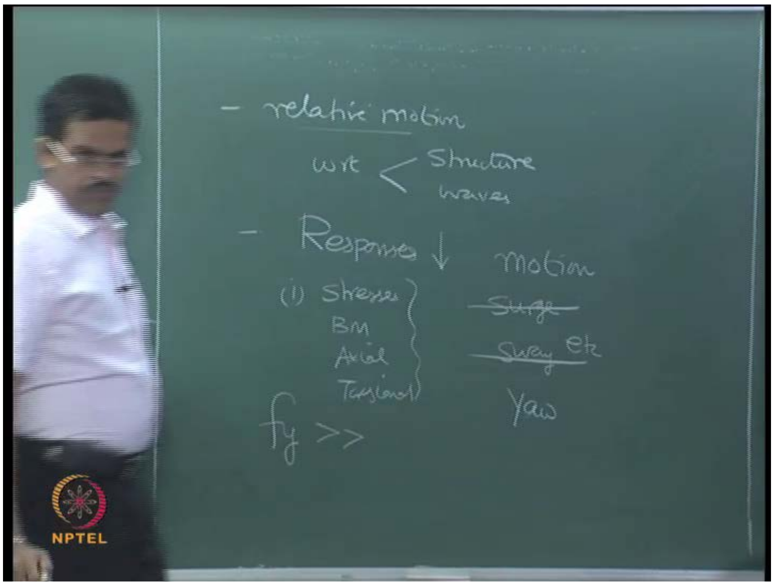

So, these two characteristics have been achieved by selecting a form in the design stage itself, which makes the structure compliant; compliant means the structure moves. When the structure moves, the structure encounters a relative motion. Relative with respect to what? Relative with respect to structure and waves. So, this relative motion reduces the response, because the forces are reduced.

Therefore, ultimately the benefit what I get is structural responses are reduced. Now, what is the great advantage of structural responses getting reduced? What are the structural responses? Classically may be the stresses, bending moments, axial forces, torsional moments etcetera. Now, there is no great advantage, if these are all reduced because any way I am using a steel, which is having a very high value of f_y. So, I do not gain any great benefit by reducing these values on my structural members, but what I am talking about is the responses reduced in terms of motion. That is for example, surge, sway etcetera. To understand the responses, we must know what are the different degrees of freedom, which a floating body may have.

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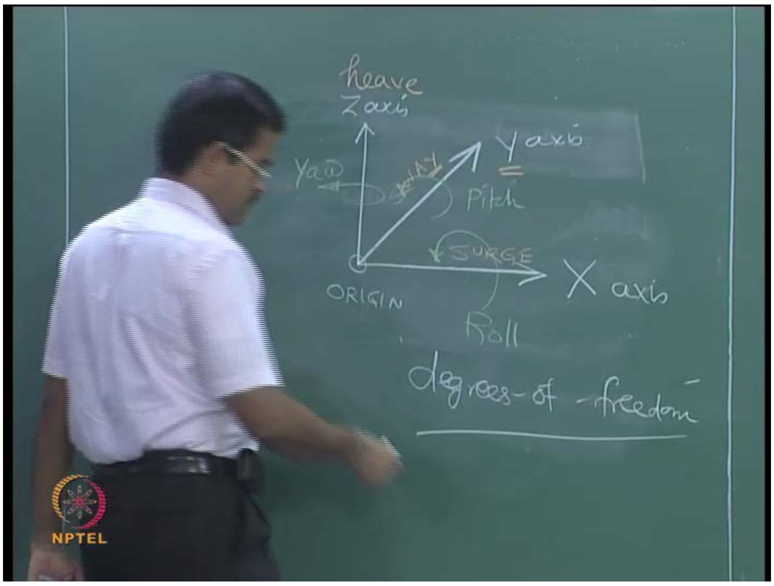

If you look at the three axes, let us say I am drawing all the three axes here, I am putting them as x axis and putting this as y axis and this as z axis. Let us say, this is my origin where I am going to measure my response; where all the responses are practically zero. So, any response, which is along the x axis is termed as surge, which we all know any response along the y axis is termed as sway. So, this y matches with this y, you can easily remember this. Any response, which goes along the z axis is heave. Any rotation? You put your thumb towards the axis; remaining four fingers will shows you a direction of rotation, I am marking it in that fashion, this becomes roll.

Similarly, I show my thumb here this becomes my pitch, I put my thumb here this becomes my yaw. So, all these are specific names given to directional displacements. All these greens are specific names given to rotational displacements. On the other hand surge sway and heave are displacements along x y and z axes, whereas roll pitch and yaw are rotations about x y and z axes respectively. So, it is a specific name given in the lecture. So, what we call them here is the degrees of freedom, we will talk about this in dynamic perspective later. So, these are the degrees of freedom. So, since we talked about the response in terms of the structural motion, we wanted to know under which degrees of freedom a compliant system will have lower responses and why?

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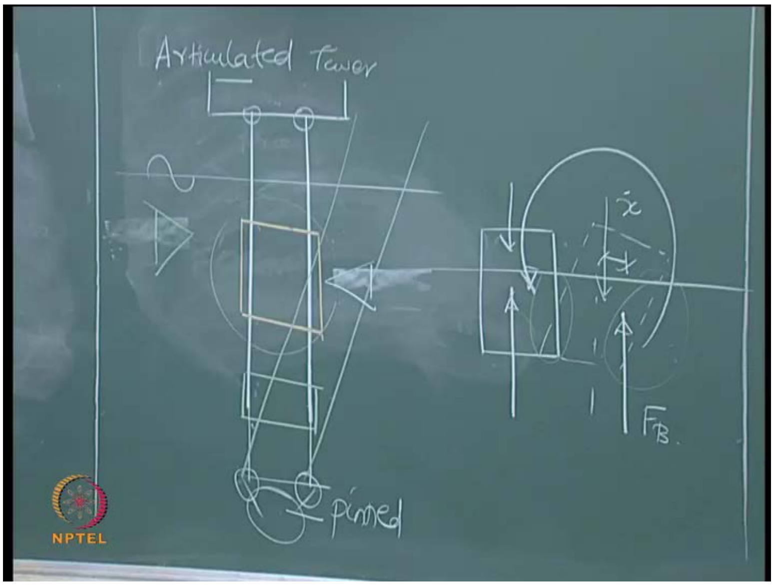

So, You put a floating body, let us take for example, the articulated tower, which is also a compliant system which we discussed in the last lecture. I have a tower, the tower has a top side; we are not drawing the top side detail. the tower has the mean water level where it is installed. The tower has a buoyancy chamber. The tower also has a ballast chamber. Then the tower extends subjected to a pinned connection. Maybe a hinge here, a hinge there or hinges here also; we are not talking about this for the right that the moment here. When I have a here, as we have seen, when the structure is subjected to any wave action, it is a lateral motion.

The structure of the tower has a tendency to swing, which we call as either a surge action or a sway action depending up on whether the wave is acting along x axis or along y axis. So, this will create a pendulum action, because it is a hinge here; the stricture keeps on oscillating as we have quickly seen. What happens to the buoyancy chamber? Look at this portion separately. Now, the force is acting from the left to right, I have a buoyancy chamber, which is initially vertical. Now, I have a buoyancy chamber, which is tilted. It means if I draw an horizontal line, the immersion in this side is more than the immersion originally I have.

Therefore, there is a shift of buoyancy from the center towards the right, agreed? I call this as my buoyancy force. For example, of course, there is no change in my right. So, this is what I call x bar or y bar depending up on is it sway or surge. This produces a lever arm. This gives me anti clockwise moment, which opposes this force action and the structure comes back to normal stage. Similarly, if the wave force is acting towards right to left, same thing reversely happens, is that clear?

But there is a demerit in this kind of platform. It is that the restoration of this happens; it depends on the volume of external submergence or additional submergence given by the buoyancy chamber. So, this action is very fast that causes lot of discomfort to people on board. It means compliant towers do not have control on surge motion, sway motion and sometimes yaw motion. Also, that is rotation about the vertical plane in plan. So, these degrees are of discomfort caused to the people, working on board and this has got to be addressed in the firm. So fait is not been addressed.

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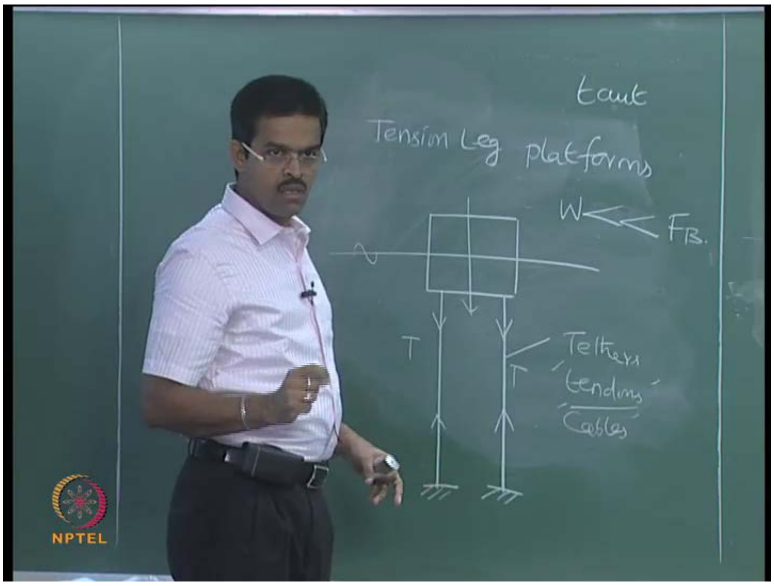

So, people suddenly worked much more on this and derived a new form, which they call tension leg platforms. It is a new form. Let me have a new structural form, a tension leg platform. If you do not understand the block diagram of a TLP, the block diagram of TLP looks like this. I have a floating body, a 3 dimensional body. The original idea of this floating body in this structure was to keep the whole system above the MSL and introduce a separate buoyancy chamber, which will restore the action that has happened in guyed towers in terms of guys in articulated towers in terms of buoyancy chambers. But in TLP what they did is, they immersed the floating body itself in water.

So, the MSL is somewhere here. So, if we want to have a large volume of submerged area, it is proportional to the weight isn't it? Note if we increase the weight, then all those advantages what a T's had in terms of installation commissioning decommissioning cost, all were lost. It is not because if you increase the weight, then you will be imposing some extra penalty towards the increase in weight in terms of these points. So, they have got to be addressed. So, what they said is I will make this system whose 'w' whose weight is much lower than the buoyancy force. So, I will make the structure very very light.

So, when I achieve this in my form I am compensating for those concepts, which I have been earlier derived in a T's because now I have a light structure. I am not increasing the mass, I am making it flexible because it is any way floating. So, I am maintaining that k integrity stiffness integrity. So, whatever advantages I had initially from the design of this form is transferred technically to this form by keeping weight of this form much lower than the buoyancy.

Now, the problem comes how do I install this? Because the buoyancy force will always act in the direction opposite to that of the weight of the structure. When the weight of the structure is balanced to buoyancy exactly, a structure will flow in any draft you want. If the weight is much lower than the buoyancy when you start putting the structure of sea for floating, the buoyancy force will simply push the structure up, is it not? It would not exist there, right? So, there need to have some system by which you want to hold it down.

They introduced tethers, people call this as tendons and non-structural engineers will call this as cables. So, it is up to you, want to name it in what form. So, tethers tendons are the technical name given to this. Nothing but they are axially axial loaded members, which are nothing but a form of taut moored cables. Taut it is not tight, taut moored cables, but they are specifically named as tendons or tethers. Can you recollect?

This name is also given in one of the similar structure on land based design. What is that structure? Tendon. Very good. Pre.stress concrete also has this name. So, if generally, when you evolve a new form, people associate certain terminologies to those members, which are becoming slightly unique and which becomes common in many of the literature. Right?

So, tendon is a term given to pre stressed members. The axial forces transformation members in steel in a pre stress concrete structures here. These vertical members are called as tendons these are nothing but actually cables. So, now, the essential function of this tether or set of tethers is to pull this down. So, they will always have to remain in tension; isn’tit? Now I want to pull this down. So, they should remain, I think we all understand how to mark tension and compression in a given axial member. Many people have this confusion. Let us quickly eradicate this confusion. Many people have this confusion; plus minus confusion will be there, till your death right from the day of entry to civil engineering.

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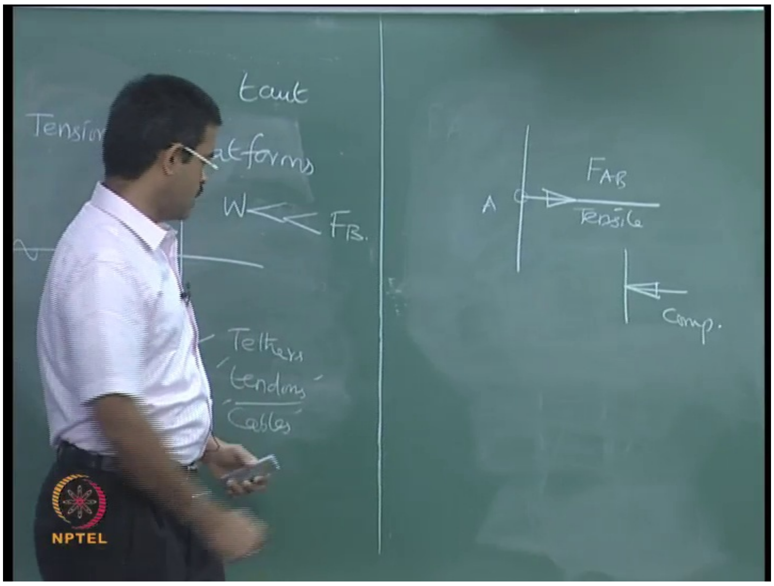

But, any way this confusion will also remain. I have a member, I have another member this is let us say joint A. There is somewhere joint B here. I want to mark the member F AB force, AB in the member, I get an answer as FAB as tension. How, do I mark? You must always associate the arrow from the joint, is it not? Towards the joint if I say this member is tensioned from the joint, put the arrow. If I say the member is compression, put the arrow towards the joint.

So, this is tensile and this is compression, the member who is the joint. Therefore the member is under tension & the member pushes the joint. Therefore, the member is introducing compressive force or compression. So, now, I have, let us understand this.

Let us come back here. So, there will be tention. So, I am putting the joint I mean arrows away and away. So, they are in tension now, their design is very interesting.

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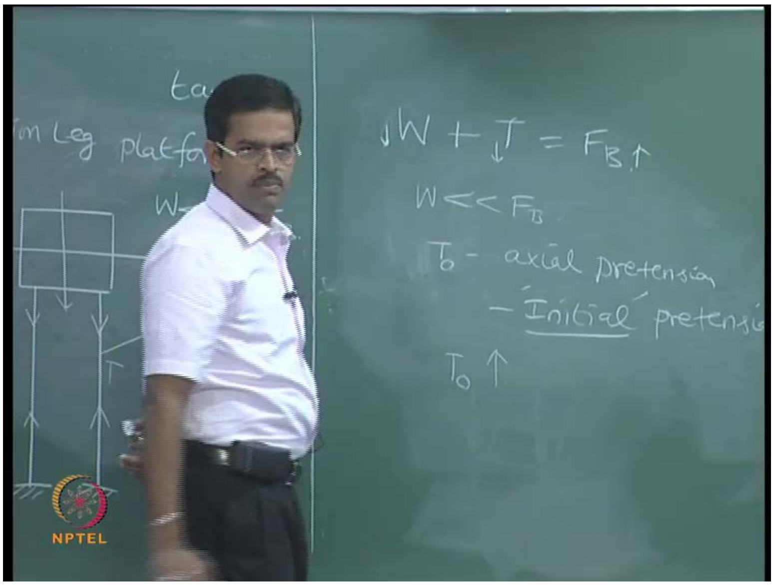

W plus T should be equal to FB. Is that right? Because W is acting down; T is also acting down. In this case, FB Of course, we all know it will not port force right? So, the different between W and F B is compensated by T. Now, interestingly the moment we said W is much lower than F B, you can expect the value of T, which I call as axial pretention in the tether literature, specifically addresses this as T naught, why this naught has come because it is initial pretention.

Now, you may wonder why this term initial has come here? Initial is a pretension set in the cable or the tether to hold the structure down. Now, since the difference is very high this T naught is expected to be a very high magnitude when a very high magnitude of T naught has got to be imposed on a wire or on a cable or on a tendon or a tether in a hostile environment, where you want to install? Install this? How do we install this? I cannot have a big work force which will go down to the sea bed and I keep on pulling the cable. I cannot install a complex machinery at the sea floor at a depth of 2000 meters 2200 meters where the work force or the machinery will be holding, the tether and holding it down, cannot do that, very simple.

What they do is all these members should be made void, hollow inside, keep on filling ballast material in this, keep on increasing the weight. Very high, tow it down, put it at the side, release this water or release this ballast material; that tension will be transferred to the cable automatically. That is the installation process. Any way we are not worried about that in dynamics class but still one should know how this comes out, that is why it is installed. Now, let us quickly see when I have a platform like this, remember very carefully my structural system is only this. These are all nothing but cables and tethers.

There is a similarity of this system in guyed towers also. You would have seen guyed towers also had mooring lines. So, only the system is this is also a structural member of a TLP, no doubt about that. But my form is only this, my mechanism is this. Now, when I apply an act lateral force to this system as we applied it articulated tower, what will happen to a TLP like this, which are those degrees of freedom, which I will now get an advantage that is our focus now, is not it?

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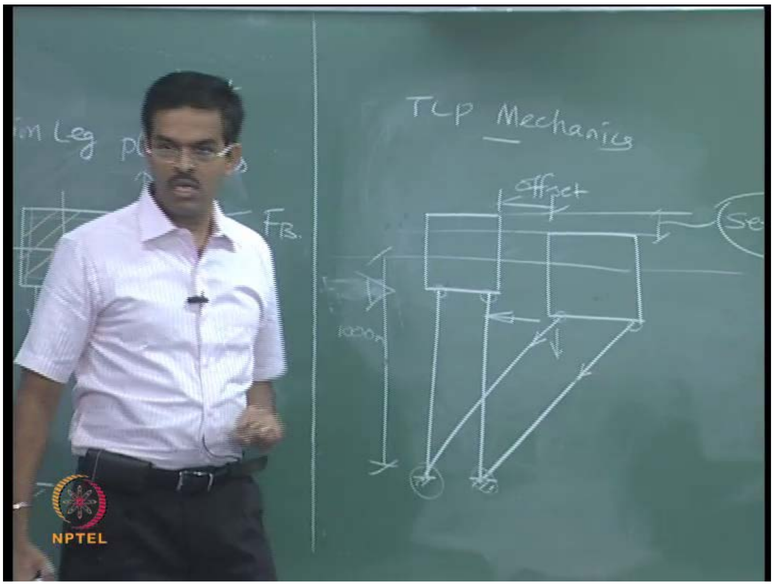

So, let us quickly see that. That is what we call as TLP mechanics. So, I have a TLP the water level is somewhere here, I apply a force or the wave action is applied on to the system. The TLP moves this way. Now, there are two questions, we want to ask you. number one; what is the guarantee that the hull or the form remains horizontal? Because an articulated tower, but for the absence of articulation near the deck, the hull would have been inclined. Also, what is the guarantee that I have the super structure, which is remaining horizontally?

It means these connections should remain pinned connections. Now, I have a question again here, do you want these connections to remain pinned? These connections pinned, is it? Now, what is the axial force imposed on a cable when it is a pinned connection? Infinite magnitude, is it? Infinite magnitude, this is an important point where articulated towered that had towers, had a problem of failure, is it not? We recollect the lecture of last time, we said these are the points where the tower if at all we have, failed. It will fail at these points. So, they have become fixed connections, it is nothing; but it is not a member, it is only a tendon. It is not a member only a cable or a tendon. It is a mooring line.

For example, what was the connection of a mooring line in a guyed tower at a touchdown point? Was it hinge? Was it hinge? It is fixed because you are having a lead anchor drag anchors, etcetera. We are having a weight; also counter weight. It is completely more or less fixed; it should not move at all, is it not? Cable should not get lifted up, right? So, one great demerit of a T is by putting an articulation at the bottom, which was imposing a fatigue failure on the joints and are becoming a critical point in the design was eliminated in this form, by making it fixed the motion.

What the TLP makes in the direction of wave or force is what we call offset and the motion what TLP makes in the direction of heap from the original portion to the final portion is what we call set down. Now, interestingly, everybody will agree to me that when a horizontal or lateral force is acting on to the member the structure moves, I can say the structure is surging or swaying etcetera. So, to restore the structure back I do not need a hinged connection; here the cable is already.

In high tension, the cable will start pulling in back and the horizontal component of this force will counter act the wave direction. Of course, the vertical compound of this force will add to the weight, which will balance the additional buoyancy created by self. So, it is a very interesting mechanics. So, commissioning and decommissioning becomes very very simple only thing. What I have got to do is, I have got to play with this connection and either ballast or deballast it, if you want to install or uninstall, very simple.

Now, interestingly, look at this form this form has no proportion with respect to at what depth this is being installed. This can be even 1, I mean 1000 meters; this can be even 1500 meters. The only difficultly you will have is the tendon length will be keep on increasing, you will be designing it only for buoyancy and we all understand buoyancy depends on the submerged volume and not on the water depth and weight.

Of course, depends up on the plan dimension, which is depending up on the function of the platform. So, I can put this platform in any depth I want. So, it has become depth insensitive is that clear? So, the form has become depth insensitive. Now, by this form it has got a very great structural advantage in dynamics, what is that advantage? It has got a very great structural advantage in dynamics point of view.

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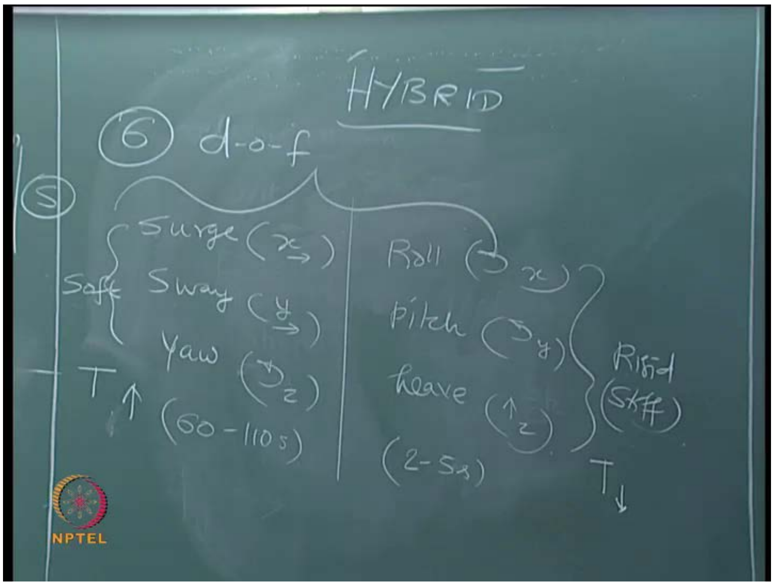

Let us see what is that. There are 6 degrees of freedom, which just now we saw; I will group them in a very interesting way surge sway and yaw. I am grouping them, I amean there is a reason why I am grouping it like this; roll pitch and heave for our recollection of understanding. Because it is a class, after two days and Monday 8’ o clock is always a cursing class, people do not want to come at 8’ o clock. In fact, people do not want to get up at even 10’ o clock also.

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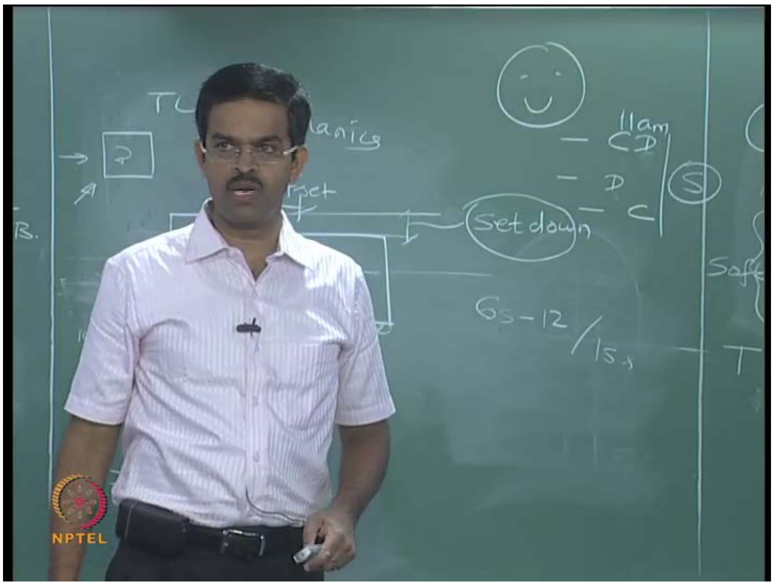

What they want is two things, one, the moment you get up, you should go to CD. CD is coffee day. After that you should go to dating. After that you should go to sinus, that is sleep. So, in between this is missing, that is study. So, getting up in the morning, because coffee day opens only at 11, it is very difficult. We are not suppose to have the class at 8’ o clock because coffee day does not open at 8. So, it is very difficult for people to answer a question quickly. So, surges displacement about x axis, sway is displacement along y axis, yaw is rotation about z axis.

Roll is rotation about x axis, pitch is rotation about y axis, heave is displacement about z axis. I am grouping them, it is not that I grouped it; the form itself demands this grouping, see how? Look at this body, once again. Look at this mechanics once again. When the Tf is subjected to lateral forces, surge is the motion what you have in the direction of wave, sway is the motion which is normal to the direction of wave and yaw is the motion, which can occur when you look at this in plan, when you look at this problem or the form in plan.

This maybe the wave, if the wave comes at an angular direction to the platform, there is a possibility that the platform may even rotate about the z axis. So, these are all what we call soft degrees of freedom, highly flexible, they are very highly flexible and they are soft degrees of freedom. Now, there is a reason why these degrees of freedom I have been kept soft in the form can you tell me this, reply for this question? Why I want to select these 3 degrees of freedom and keep them as soft in dynamics perspective?

What is the necessity? We are talking about advantage and compliant section, compliancy, means movement. Movement means softness. So, these are the ways by which the platform will respond to the wave action, right? Either they will move horizontally in x along y or y z the rotation about z axis, if you oppose this then the platform become rigid is it not?. So, I do not want to do that, I want to make it solve on the other hand the rotations of these about x and y and movement about z axis along z is restricted. So, they would become rigid or stiff.

There are reasons, why I want to make these degrees of freedom stiff because I do not want any vertical movement of the platform along z axis. There are two reasons for this one my cables will be imposed directly on axial tension additional to what is happening in the mechanics. So, this may cause what we call full out up of the tether I do not want that failure to happen, I want to restrict the heave motion. Number two, physically, psychologically, you will understand if you are made to move horizontally in x and y axis, gently you can manage.

If I when asked to move in the z axis constantly even for a small magnitude, you will get tired; any person who is on board when subjected to a vertical motion constantly, you will not be able to work on this. Third reason, any movement on heave will affect my buoyancy force directly, which will again affect my T naught. This kind of dynamic change in T° may cause a fatigue to the tether. So, I want to avoid that. So, I have made this as stiff degree of freedom, now rotation about x and y are kept normal and very less because they are rigid degrees of freedom, because I do not want any discomfort to people when the platform rotates about x and y axis for operational safety.

The movement I say these degrees of freedom are soft. The time period of these degrees of freedom are very high; they range from 60 to even 110 seconds, frequency is inversely proportion to T. They are lower frequencies, that is why they are soft means highly flexible, whereas rigid degrees of freedom we have stiff the time periods of these are very low. They can be anywhere from 2 to 5 seconds, I am talking about the time period. Now what is the common time period at which these waves will hit this structure? Now, just take for example, Indian ocean's conditions or Indian coastal conditions.

It varies anywhere from here, but there are many answers we can start giving numbers from 1 to 100, I think it is do not cross 100, but at least people have studied naval architecture in ocean engineering they will limit this 100 to 20. It can vary anywhere from let us say 6 seconds to 12 very or 15 seconds. Now, there is an advantage my band width of excitation periods are well separated from my structural periods. So, the dynamic response of this kind of system has got to definitely will be out of resonance, because the band periods of my force is separated from the design in terms of its degrees of freedom is not it?

So, there will be no near resonance response. It is activated in the system because of the wave action, but the difficulty is with the wind action this may not be the case. Now, you may wonder sir, how I can design a platform for both wave and wind action any international code? You pick up the international code says, when you consider both of them simultaneously you must always consider only a percentage value of both of them, not 100 percent. For example, considering wave and earthquake, it is wave action plus 30 percent of earthquake only, it is not 100 percent.

So, you design, but it will still remain same. So, any structural system or a form which has two distinct divisions of degrees of freedom, is what we call hybrid system. TLP is a hybrid platform; TLP is the only platform in offshore structural systems, which is hybrid. That is why they are very popular, they have been installed many numbers of platforms in different parts of the country in the world and so on.

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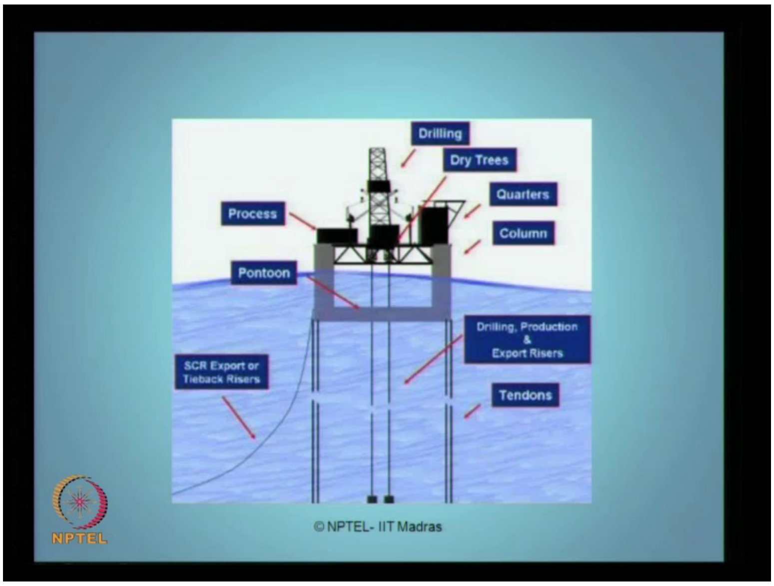

So, these are some of the components of a TLP, the drilling dry trees quarters, columns and pontoons and of course, the tendons.

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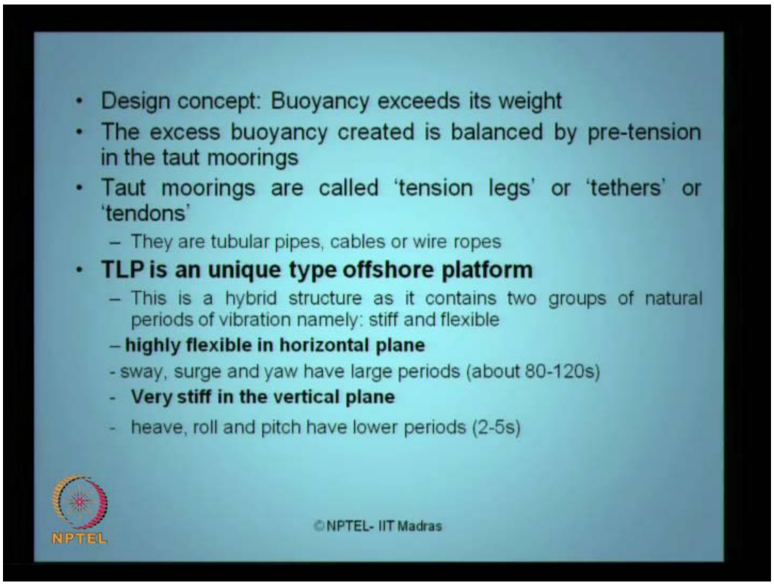

So, we will quickly browse through this design concept that is buoyancy exceeds its weight, we earlier discussed that. Weight is much lower than buoyancy, the excess buoyancy created is balanced by pretension in the taut moored cables, taut mooring or otherwise called as tension legs, because they are always in initial pretension. Generally these are tubular members or wire ropes TLP is any type of platform because it is having horizontal and vertical plane different behavior.

Highly flexible in horizontal plane because you see all these degrees of freedom are related to horizontal plane, I pick up a plane which is horizontal, this is surge from your end, this is sway and this is yaw. All these happen on a horizontal plane. So, it is highly flexible in a horizontal plane, whereas heave motion it is a vertical plane role or pitch all these happens about the vertical plane. So, it is very stiff about the vertical plane. So, such a combination is what we call as hybrid systems.

This is achieved not by the wave action; it is achieved by the form. We are talking aboutthe evolution of different kinds of forms of offshore structures on dynamics perspective. Remember we have never addressed anywhere here the cost or anything related to the action because I want to reduce the forces on the member etcetera. All we are discussing is about the principles of dynamics as applied to the structural system, which is deriving benefit from the form itself. So, it is a dynamics prospective.

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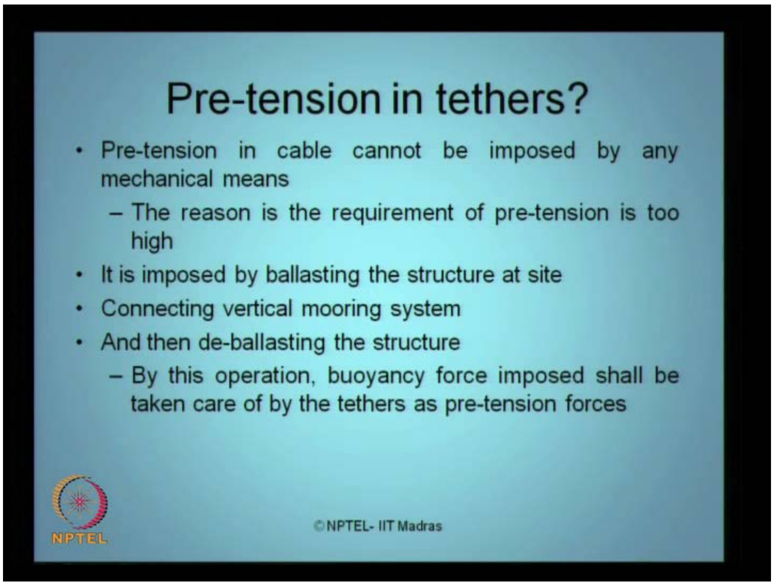

So, how pretension is imposed on the tether as you understand; how it is imposed on a guyed tower? There is a fare lead point; there is a fare lead point through which the cable passes and goes to the hull there are lock lot of rock, rocker mechanic systems kept on the hull on the top, which will keep on winding the cable and keep on imposing pretension to the cable.

Similar way it is done here, we are not anyway talking about this application technique here. As I said very clearly, simply the ballasting and deballasting, I can impose tension to the cable. So, commissioning and decommissioning becomes very easy, not that easy as we are saying here, but it is not as complicated. As we are thinking about, it is comparatively simple with respect to all other forms which you have so far seen.

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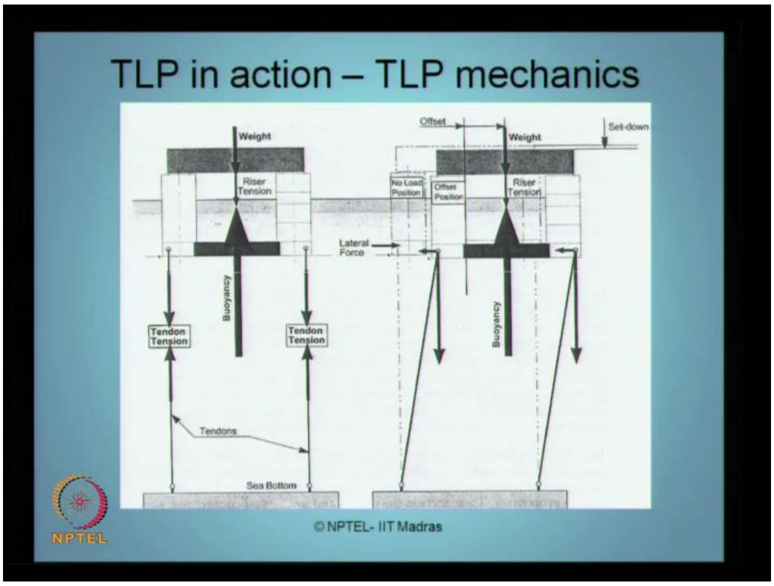

So, that is a TLP mechanics here you can see the offshore and the set down here that is a schematic diagram which has already been explained here. I showed it because that looks better than what I have drawn here.

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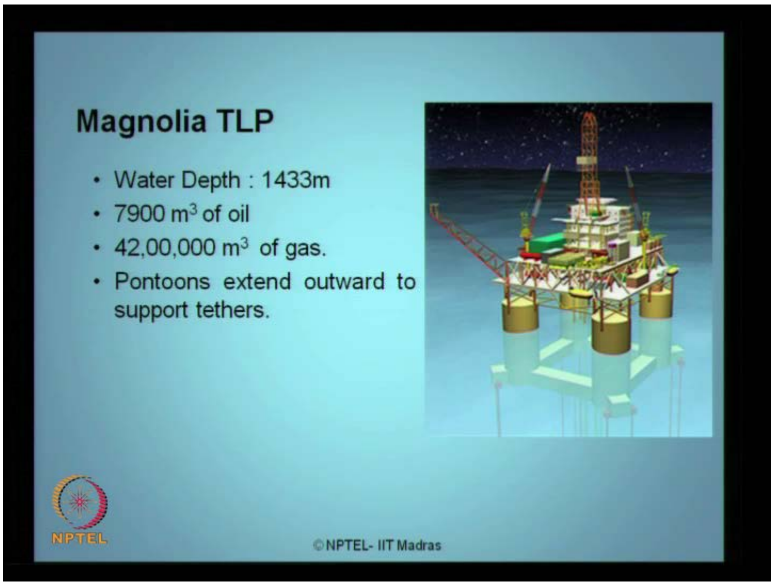

So, these are some of the classical TLP's to be constructed; enough literatures available in open source you must see them, 1400 meters capacity. Already we know, what do you mean by cubic meter of oil, what are the GDP etcetera.

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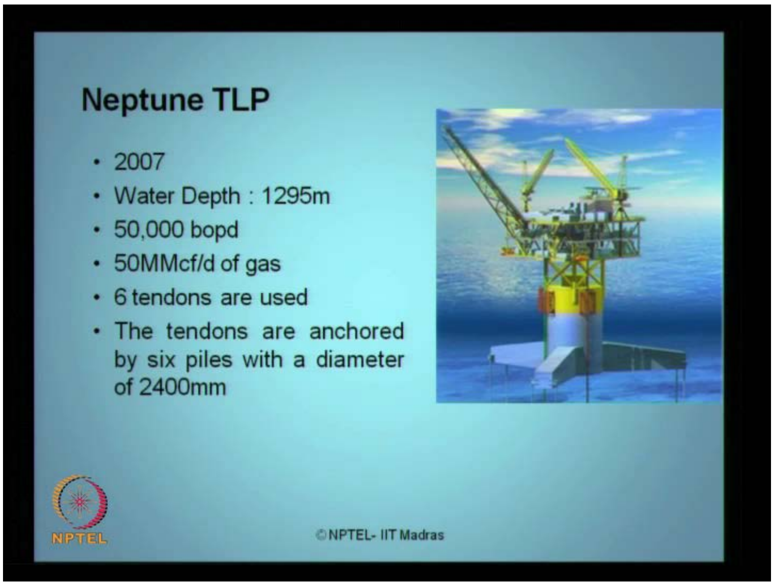

Neptune TLP 2007 constructed at 1300 meters approximately. So, all these are deep water platforms 50000 DOPD etcetera. The other kind of platforms is spar platform which is also having a similar response behavior to that of TLP, but of course, it is not a hybrid system where distinctly two sets of degrees of freedom are separated in the form it is not there. Slightly different, but spar can get into deeper waters compared to TLP.

They are contemporary to each other; this is like two regional languages in a given in the same country, Hindi is a national language as well as regional language in many states of the country. So, we really do not know whether English is better or Hindi is better. So, similarly, spar and TLP spar also has classical advantages in terms of its structural form.

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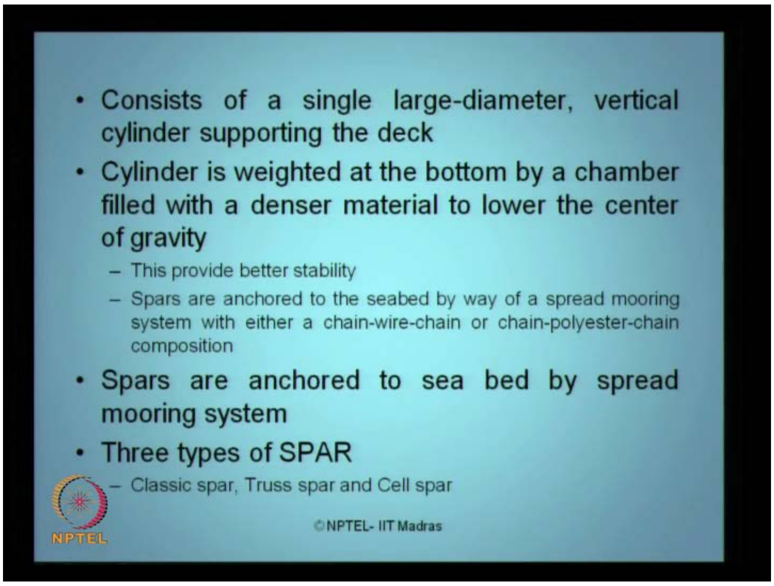

It consists of a single large diameter vertical cylinder which is supporting the deck, I will show you a photograph followed by this. The cylinder is weighed at the bottom by the chamber filled with denser material, that is how the spar is being installed. This provides better stability for the spar platform or the cylinder against lateral action of wind and waves, Spars are actually anchored to the sea bed by the way of spread mooring system.

Either with the chain wire chain or chain polyester chain system; we are anyway not talking about the construction part and part of it. That is anyway we will be discussing in different course, here we focus only on the structural action derived in dynamics perspective. So, generally they are preferred to be anchored by a spread mooring system. There are different kinds of layout of mooring lines. There are three type of spar existing, the classical spar, truss spar and the cell spar.

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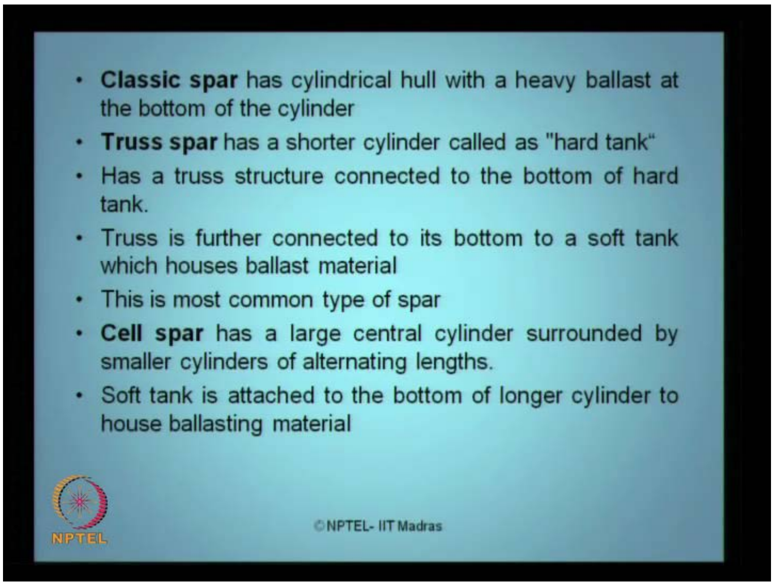

I am in, I am quickly defining them. Classical spar has got a cylindrical hull with a heavy ballast at the bottom of the cylinder, truss spar is a shorter cylinder called as an hot tank. These are all available in the standard literature you must have studied them already in different courses. So, my insistence is not towards you to memorize this, but you must understand the form very importantly, which I will follow after this presentation is done. The most common type of spar is a truss spar and of course, your cell spars also have large central cylinder surrounded by small cylinders of alternative lengths.

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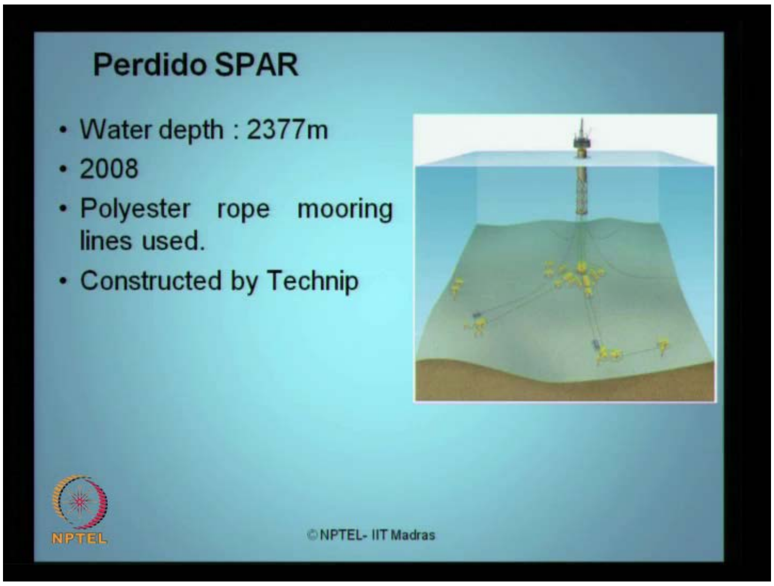

This is another spar platform what we have, Perdido spar. We can see the spread mooring system which can be seen in this photograph here. The advantage of this spar system is it goes deeper than TLP's because the cable or the tether cost is far relatively becoming inner springs in the system. It goes around 2300 meters, constructed in 2008, polyester rope mooring was used, constructed by the company naming Technip.

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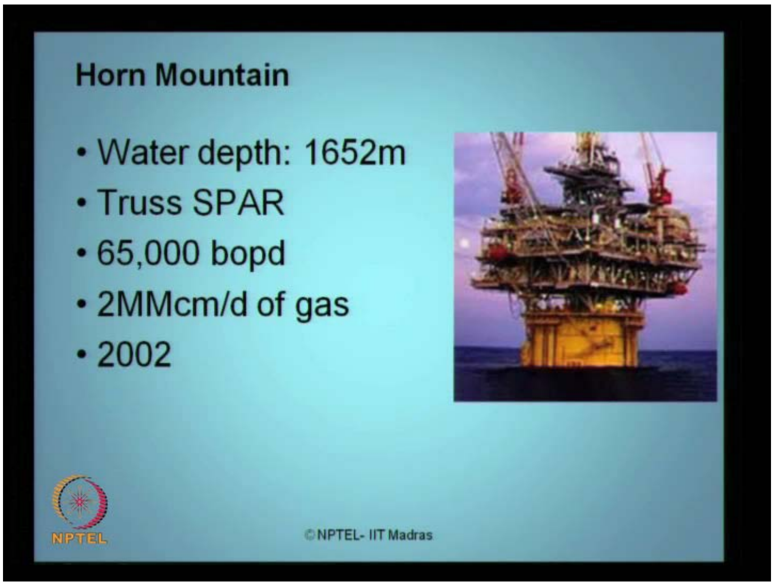

Horn mountain is another spar; you can see the central cell spar here, it is not a truss spar. You can see the top side complication remains as same or as simple as the earlier platforms. The only design alternative here is the cell spar has been the other structure has been replaced by a cell, the center. The advantage what spar claims is with respect to other platforms an operational advantage is that, all the drilling raises and lines will get through the spar they are protected from the wave action, whereas in TLP they are exposed.

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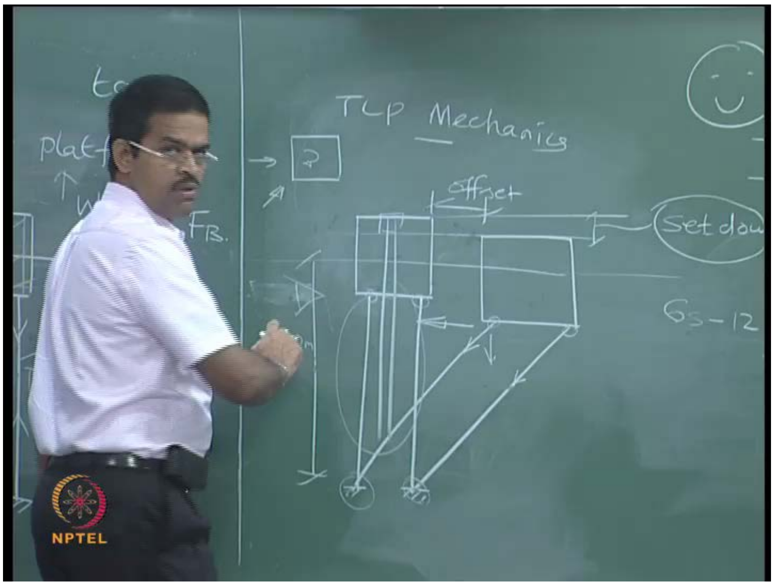

For example I have a moon pool here, the drilling unit is here, the drilling raisers are exposed to wave action, whereas in spar it does not happen. So, that is the advantage operationally what people claim, the spar is better; it is better inspectable because you have a cell spar you can get in through the cell and inspect it, maintain as a spar superior. Therefore, it can go for deeper waters. The other kind of form what we have just discussing it here, a semi submersible. We have talk about the dynamic analysis of floating structures at the next module.

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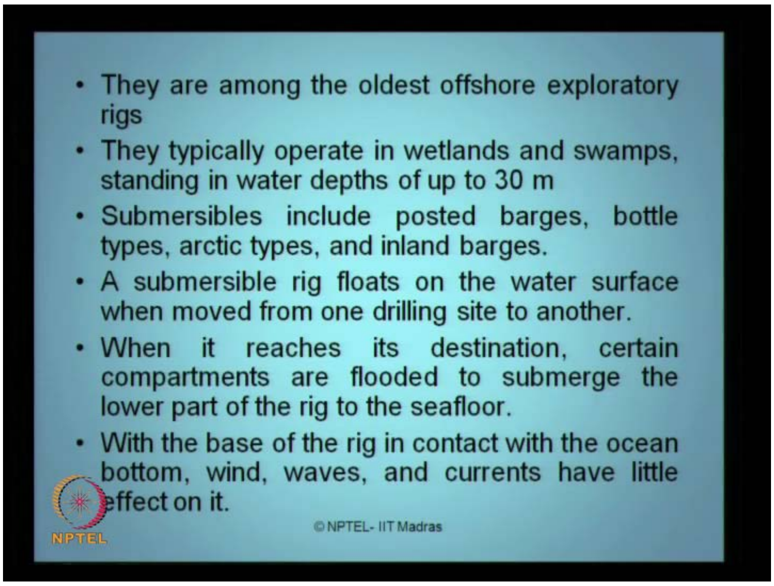

So, we should have an idea about semi submersibles, you must have studied this. Very quickly I will go through this. It is one of the oldest offshore exploratory rigs typically operated in wet lands, but the question is they are meant for exploration? Therefore the water depth is not very seriously high. They include posted barges bottle types, arctic types and inland barges. A semi submersible rig floats on water surface and move from one drilling type to another one.

So, floatation analysis becomes very important in this kind of structures. I will show you a very interesting, let us say, the free floating analysis what we did for a commercial rig in South Africa. So, we have the full design perspective there is a new kind of semi submersible and drill ship which we did. So, we will show you at the next module, where we talk about dynamic rigs of floating systems, how it is done and which software has been used etcetera, we will discuss that.

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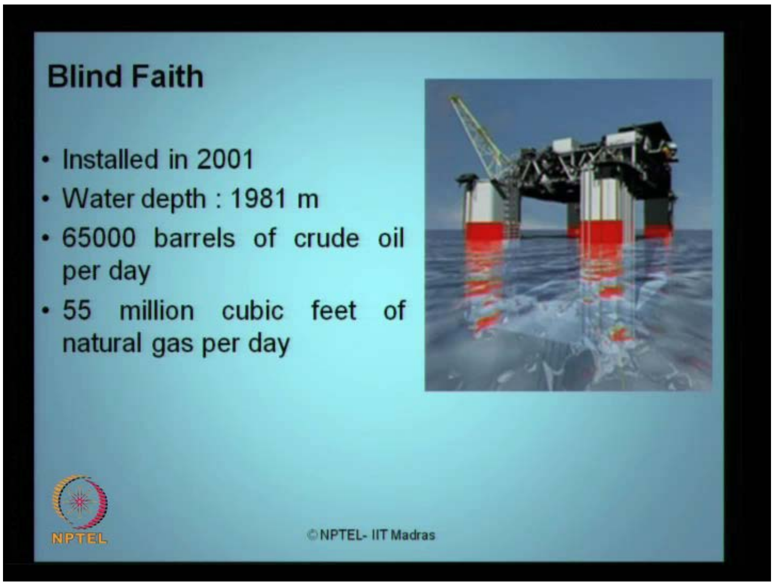

It is another important semi submersible constructed blind faith, installed in 2001 etcetera. It is a production platform. The next one is an FPSO which we all know, floating production storage and offloading.

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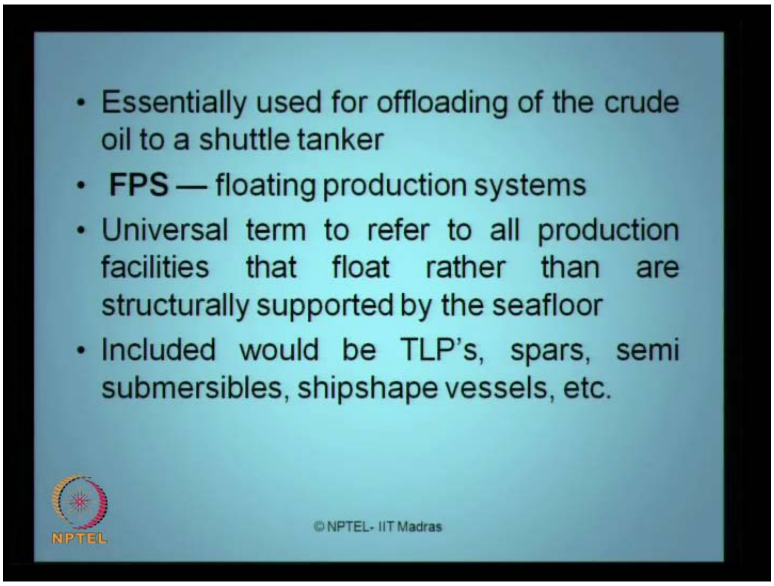

We just quickly go through this slide. It is not of very important to me, but still essentially used for offloading of crude oil to the shuttle tanker, FPS stands for floating production system whereas FPSO stands for floating production storage and offloading as well. So, in universal term being used, to be supported by the sea floor and included will be the TLP spars, semi submerse, all actually offloading production system, as we saw in the classical definition.

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So, we will talk about FSO’s also very briefly, floating storage and offloading. There is no production here production is on a different platform. It is associated with the production unit and FSO is also a kind of platform. They are actually existing tankers; I mean converted as floating structures which is essentially used for storage and offloading only, not for production.

So, production is done by a different platform, they have been associated with these platforms only for storage facilities. So, they are used to store the crude oil, then ship it to another location for processing. So, it is a functional platform; it is not a platform meant for production drilling FSO. So, FPSO’s again these are all floating kinds of systems, which also include what we have as PLP’s and spars etcetera.

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So, they can be as large as it is about 183 meter long 62 meter wide. It is very long FPSO; generally these are all existing vessels being converted for this kind of purposes plutonio is a very famous FPSO being commonly deployed. We will quickly look at the mooring and station keeping, because we were do when orthoflex analysis, later in the next module.

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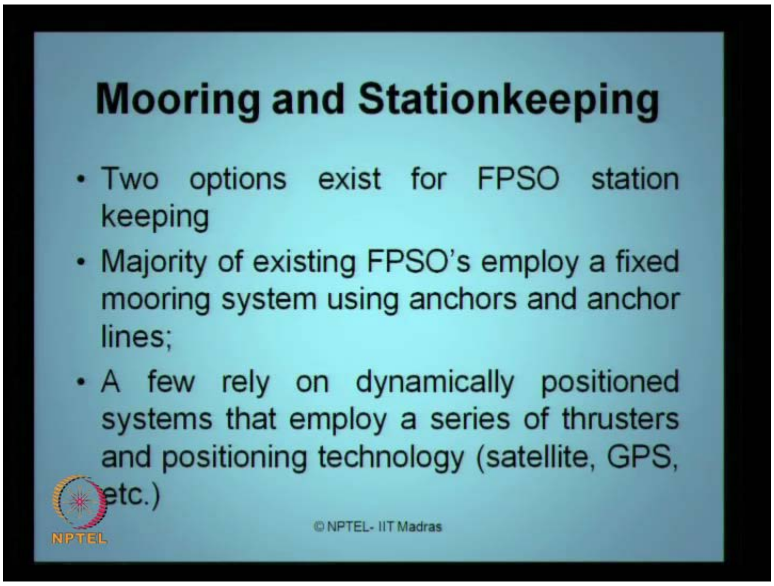

So, one should know, how do we do by a mooring analysis? So, there are two options that exist for an FPSO to hold it down in position, people have studied about dynamic positioning systems. We will not discuss that in detailed here, but I will just give a very brief outlook on DPS when we talk about this kind of installation systems later.

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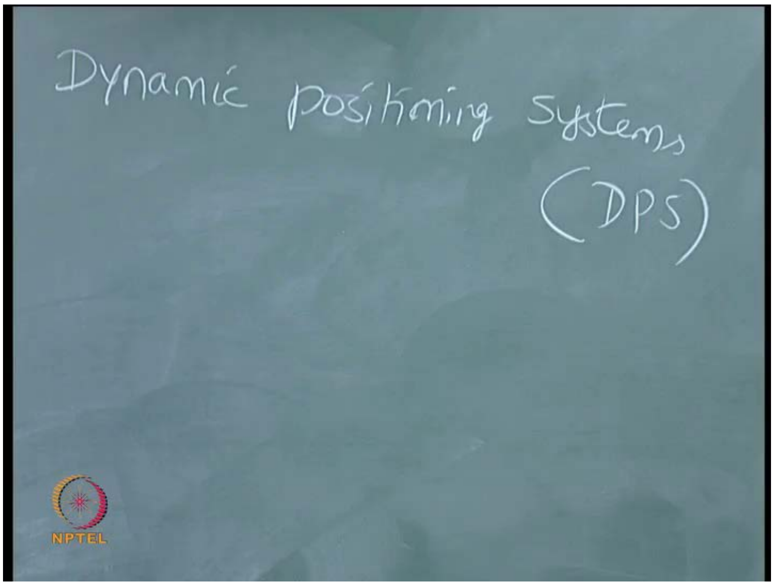

So, generally this is DPS. DPS is a very famous term all over India now. But still we can also use satellite or the thrusters can be positioned to control the ocean using the GPS techniques etcetera. So, this we will mainly use for station keeping which we see here.

So, the mooring lines are essentially used to keep them position restrained when they are under operation. What we are focusing here is the new generation offshore structures and 2 minutes from now, now we have evolved. So, for different kinds of offshore structural systems, we saw how the geometry was taken, as an advantage in the design itself.

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So, let us talk about new generation structures down the line. The first will be the buoyant leg structure. So, essentially I am talking about the buoyancy force. So, BLS are very important new phenomenal structures; they have been meant and designed for offshore production in deep waters trice. There are tops in another new form of structural system we will look at each one of them separately in the next module. We have we have to study dynamic analysis at difference kinds of platforms fixed platform, jacket, etcetera.

We will discuss about this in detail, we will derive the stiffness factors and mass matrix of these structural systems here. We will show you how the dynamic analysis can be done I will show the results here using some stand software what we did. So, these are all research base platforms. We will talk about these forms, how they have been arrived when we move to the next module three legged TLP's T B TLP's that is tension based TLP's non ship shaped FPSO's etcetera. These are all new generation platforms, which are actually derived an advantageous form based on the structural action or the dynamic action under the lateral loads.

So, in the next lecture, we will talk about the coastal structures and their structural action against the lateral loads. Do you have any questions on this lecture? I will be happy to answer you any questions. Here, I have a tutorial. I will show you in the next lecture. We will have questions on all these. All these are self learning exercises. We will not evaluate them, there is no need, but as you will anyway copy either from my notes or from anywhere else.

So, you are self evaluating the questions, which will be given in your examination will be all from a non standard books. So, these are all learning process you must learn. If you have doubt please ask me here; the doubts cannot be put as answers to the questions in examination. Whatever we discussed here only will be asked in the examination that I am sure, but the only difficulty is whatever I discuss, I will certainly ask in the exam that is the problem. So, how you have understood? How you have encrypted and decrypted. I do not know because my handwriting is excellent, it is state of odd handwriting. So, so how you have understood and how much you have understood that too early in the morning or late in the afternoon, I do not know, that is flexibility is very high and so on. So, if there are no questions, we will stop here.